NIGHTFALL

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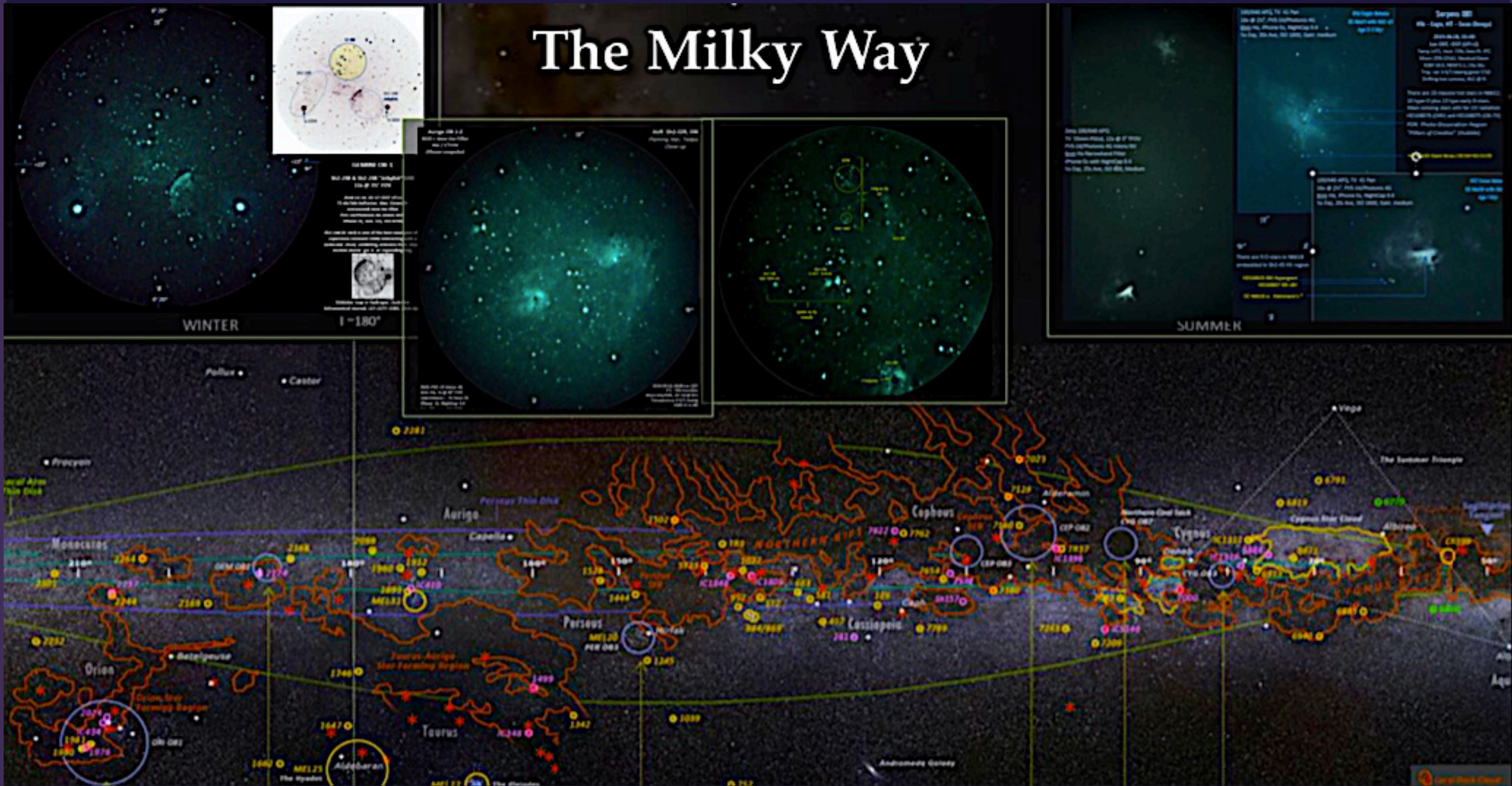
ASTRONOMICAL SOCIETY OF SOUTHERN AFRICA



Special Report # 7

Allan Dystrup, Classic Rich Field

CLASSIC RICH FIELD

A remarkable celestial journey

ALLAN DYSTRUP

NIGHTFALL

Special Report #7 ***July 2020***

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Classic Rich Field

Contents

Introduction

MY LOCATION
Nordic coastal temperate backyard observing site.

I'm located at 56°N 12°E in Denmark, within a humid coastal temperate climate zone on the border between the Arctic and the Mediterranean air cells. Here we have the polar Jetstream meandering overhead, dragging in a steady stream of high and low pressures from the Atlantic Ocean, with their associated warm- and cold fronts; Our weather is thus mostly hazy, partly cloudy or overcast, with only occasional clearing up between front passages, which can be hard to predict and often lasts only ½ an hour to a couple of hours.

Here I live in a suburb just north of Copenhagen, in a Bortle yellow-orange zone with an average NELM of around 5.5 (SQM 19). Given our prevalent partly cloudy and quickly changing weather, I cannot rely on driving to dark skies to observe, so instead I have settled on observing from my suburban backyard using a quick grab & go setup in combination with modern technical aids for counteracting the Nordic "white nights" (nautical and civil twilight from May to August) and the full-year light pollution.

Scandinavia
(Google Earth)

MY EQUIPMENT

From achro- to apochromatic glass, and from visual to electronically augmented observation.

I bought my first telescope at the age of 15 back in 1965: a 3" EQ-mounted achromatic Unitron refractor with synchronous motor drive. My first target was the solar system: The *Moon, Jupiter, Saturn, Mars*, and subsequently -- like many other beginning amateur astronomers -- my first real observing project became a sweep of the *Messier* deep sky objects.

Then followed decades where education, work and establishing a family got the upper hand, until my retirement 8 years ago. When I picked up astronomy as a hobby again in 2012, the observing conditions had degraded significantly due to increasing light pollution in the past half century, -- but the tools of the hobby had also evolved, now offering short focal length fluorite apochromatic refractors, live video, night vision devices and smartphone cameras.

I like the build quality and optical excellence of the best classic refractors, so when I decided to sell my 3" f/16 Unitron achromat, I instead bought a couple of 1990'ies Vixen and Zeiss fluorite APOs. I use these easily handled f/6-f/8 refractors on manually operated vintage equatorial and motor driven Zeiss mounts (TM and IB). I enjoy exploring the night sky by star hopping to my targets, using first binoculars (Zeiss 8x30, 10x56), then pointing the scope with a Z-Bolt laser while using a wide-field eyepiece on my Zeiss astro Amici diagonal as a finder. The correct-image Porro prism binocular and Amici roof diagonal views are consistent with my star maps, which makes navigating the night sky a breeze. Having located the object, I can just activate the equatorial RA drive, then leisurely sit down at the telescope to visually observe, study and register the details, using either my sketching block, a small live video LCD-recorder or a Night Vision device with smartphone attachment, as appropriate.

UNITRON (POLAREX) 3" Refractor
Model 142, D75/F1200
UNITRON Motorized Mount & Tripod

1965

ZEISS (CZJ) 4" Refractor
Model APQ D100/F640
ZEISS Ib Motorized Mount & Tripod

2020

MY PROJECTS
From myopic Messier objects to rich field galactic structures.

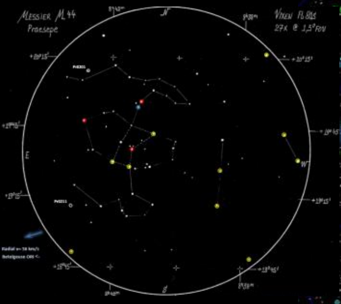
Coming back to astronomy, I decided to boot my DSO observations with a new sweep of the Messier objects, and nearing the completion of that project, I compiled a data-sheet encompassing the *"Best NGC"* objects, including all RASC, SAC, Caldwell, Herschel-400, and O'Meara catalogs; I then initiated another deep sky study based on this comprehensive list, but at some point along the project, the view I got of the universe began to feel increasingly myopic and disjointed, -- so I stopped to reflect.

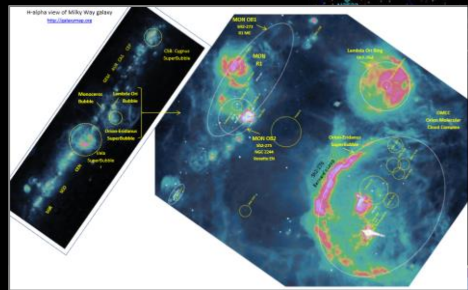
What I missed was an overview of all the Milky Way Messiers and the brightest NGC's for observation with small amateur telescopes, -- not just their individual location, morphology and astrophysics, but a description of these objects in a **broader, coherent structural and evolutionary context** that I could use as a mental map and ideally also go out and directly observe on the night sky, using only my small backyard setup.

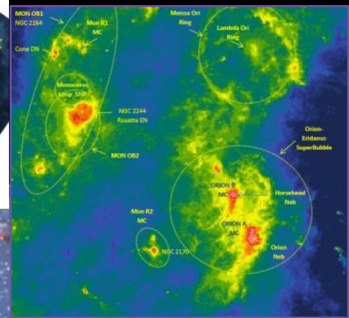
I imagined a presentation of the individual deep sky objects that included their large scale spatial location and distribution, relations and dynamics, origins and evolution, starting from our own solar Ursa Major stellar stream in the *Local Bubble* of the Orion galactic arm, then stepwise widening the view, first to other close by *co-moving star groups* in surrounding Bubbles (stellar streams like the Pleiades, Hyades, Praesepe and α Perseus), then gradually moving further out to ever larger structures of interstellar molecular clouds (Emission, Reflection and Dark nebulae) with their embedded young star-forming regions in our own *local supernova shell* (OB-associations in the Gould's Belt), and finally zooming out to similar shells in the star clouds of the more distant parts of our Orion spiral arm and in the adjacent Sagittarius and Perseus arms, while also seizing the opportunities for peeking through *galactic windows* to remote objects all the way out towards the edge of our Milky Way.

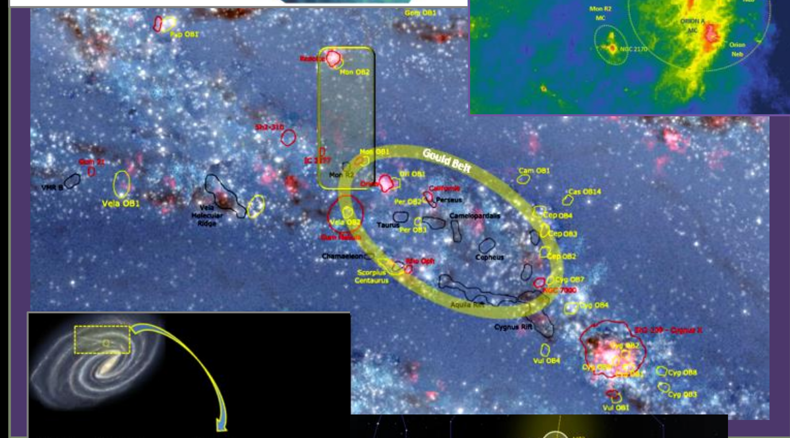
From here I'd like the description to take me further out in steps: first to our *Local Group* of galaxies and satellites, then to the nearby galaxy groups in the *Local Sheet* and filaments (M81-CVn_I-M101, CVn_{II}-Leo_I, Virgo), then out to the Ursa Major, Virgo and surrounding *galaxy superclusters* and all the way to the edge of the observable universe. All along the presentation I'd like the description to outline the 3D-patterns and evolution of these large-scale structures, from galaxy groups to voids and walls, to attractors and streams of galaxies, in a way that I could go out and observe directly on the night sky, from my own backyard with my small 2-4" refractors.

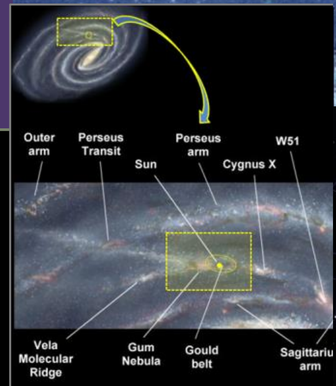
So, this was my grand vision, -- maybe hard to accomplish, but now wouldn't that be marvelous?! I looked for literature that offered this kind of coherent description with wide field maps and context explanations, but I found only a few sources that partly covered my field of interest (cf. SOURCES below). And so, I started to structure my personal observations and notes in this way, in an attempt to build up my own structured mental map of the universe to guide my nightly wide field deep sky observations from my suburban backyard.

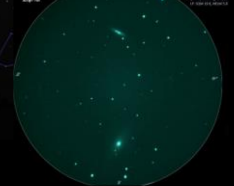












Some Sources

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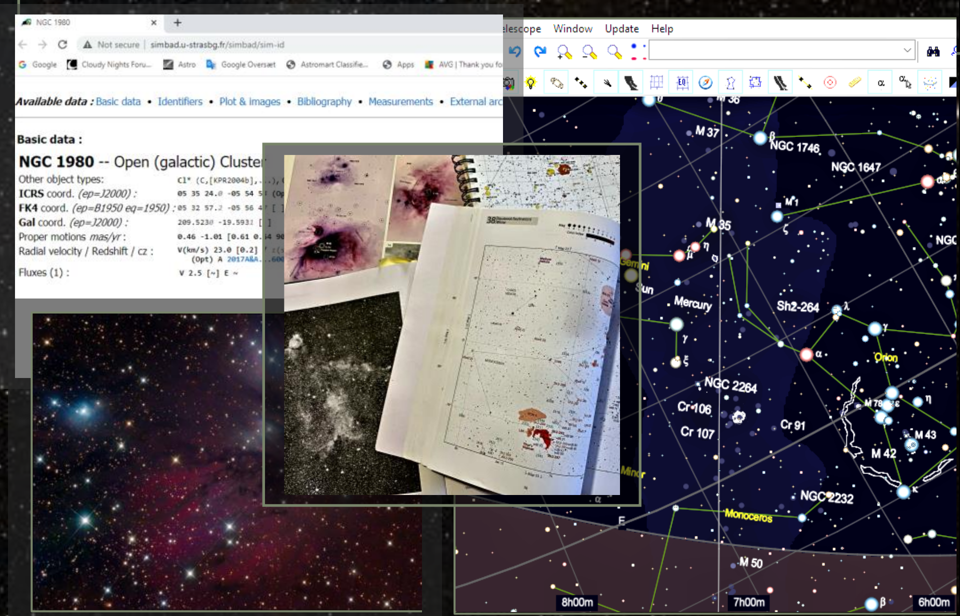
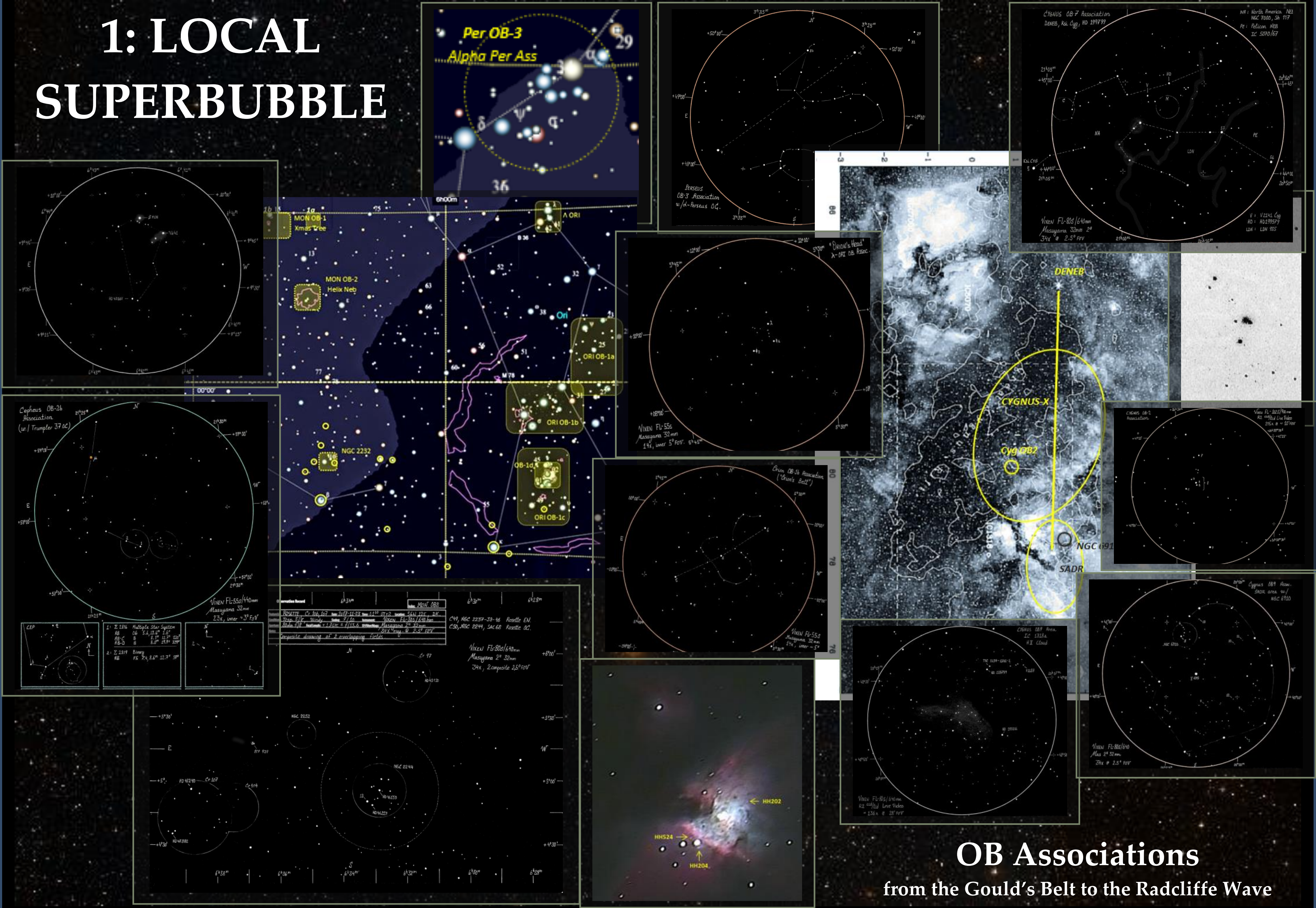


https://aladin.u-strasbg.fr/AladinLite/

1: LOCAL SUPERBUBBLE



OB Associations

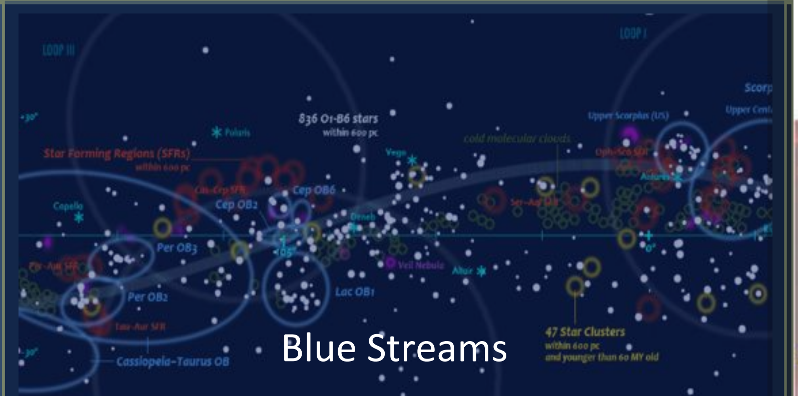
from the Gould's Belt to the Radcliffe Wave

The night sky with OB-associations shown in 2D projection. Map generated using *Cartes du Ciel* (Sky Map) v. 4.0, Patrick Chevalley © 2002-2017 GN .

Gould's Belt

At the start of February 2017, I set out on my rich field observation journey with a survey of the groups of bright blue-white stars (so-called type **OB-associations**) that are found in a band across the night sky: from *Orion-Taurus* up through *Perseus-Cassiopeia-Cepheus-Cygnus*, then down through *Centaurus-Scorpius-Vela-Puppis* and back to *Monoceros-Canis Major.*

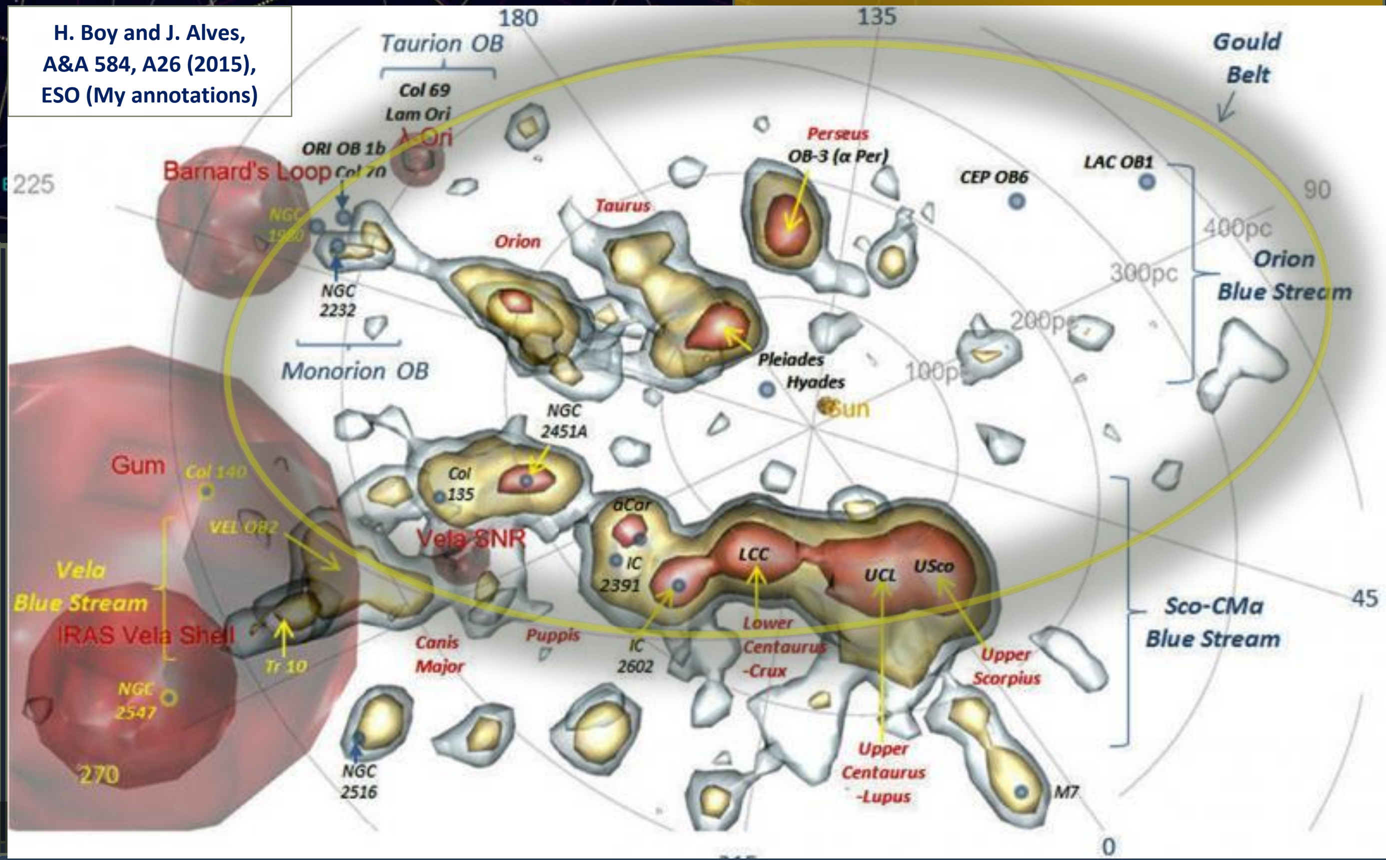
This broad band of young, massive stars are born in **giant interstellar clouds of dust and neutral helium gas,** which have been swept out and compressed by several supernovae that created a large and hot expanding **"Local Superbubble"** in the interstellar medium. The structure was first described in 1879 as a **ring** tilted 20° from the galactic plane when seen projected in 2D on the celestial dome (*Gould's Belt, Lindblad Ring*);

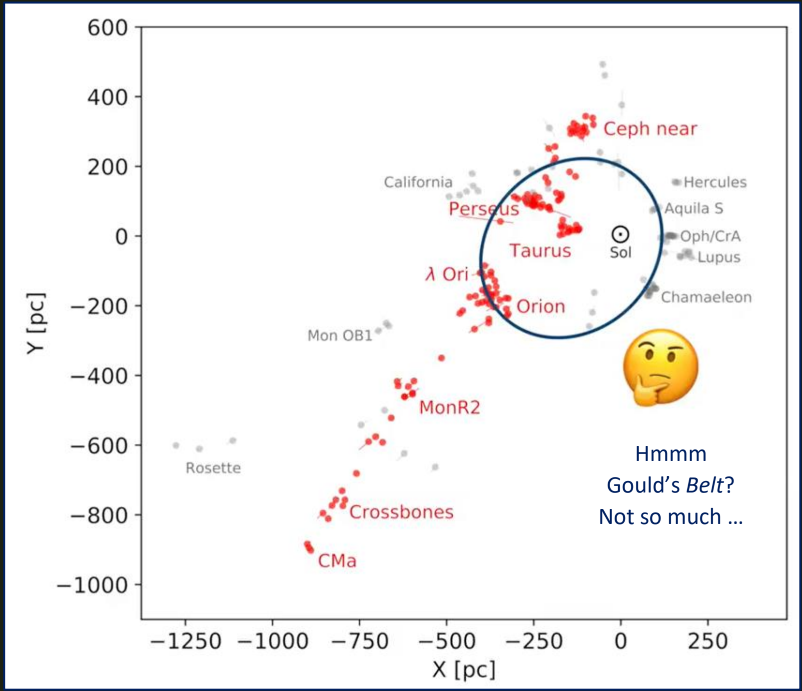


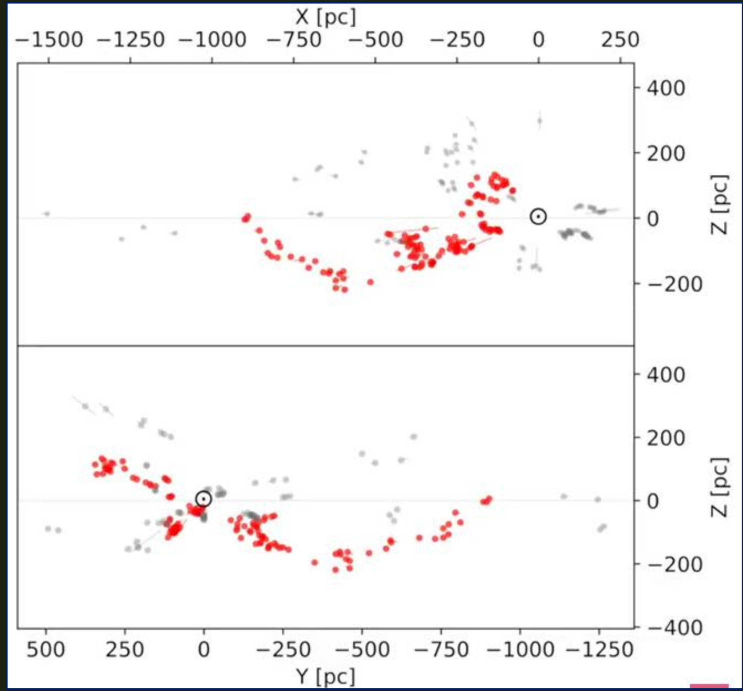
Then, in 2015, the distribution of OB-associations was depicted in more detail in a 3D-map based on Hipparchos satellite data as **separate segments** of OB-star clouds: the large Orion and Scorpius-Canis Major "Blue Streams" plus the smaller Vela Stream:

https://www.handprint.com/ASTRO/IMG/gould.gif

H. Boy and J. Alves, A&A 584, A26 (2015), ESO (My annotations)







Filament Waves

Finally, in January 2020, the Gaia satellite provided precise data for the positions and dynamics of both the OB-stars and their surrounding gas and dust clouds in our solar neighborhood. A 4D simulation based on these data showed that the OB-associations were created - not as a ring structure or in isolated streams - but as two huge (1500 pc ~5000 light years long) waving segments of gas: the **Radcliffe and Sco-CMa Waves**, which 20 Myr ago were lined up together in **one long galactic filament**. The origin of such galactic filaments is very much an active research area as of 2020.

<- João Alves et al., A Galactic-scale gas wave in the solar neighborhood, Nature Vol 578 pp. 237–239(2020)

R (Reflection) Associations

OB associations consists of mainly massive hot blue spectral type O and early B giants, surrounded by H-II ionized emission nebulae. In my rich field stellar project, I also studied two other types of stars that are found in groups connected to the OB-associations, namely:

- R associations (R for "reflection"), type late B-A2 stars, often surrounded by reflection nebulae, gas and dust.
- T associations, mainly low-mass T Tauri variable main sequence dwarf, ca 100x fainter than those found in the R-associations.

R associations contain young stars not sufficiently massive and luminous to disperse the interstellar medium or to ionize the surrounding gas, creating emission nebulae; Their radiation is however strong enough to be scattered by the surrounding dark clouds to a degree where they become visible as reflection nebulae

Table 4.1 The Nearest R Associations

Name	Distance (pc)	B stars
Taurus R1	110	4
Taurus R2	140	2
Scorpius R1	150	9
Perseus R1	330	4
Taurus-Orion R1	360	5
Cepheus R2	400	5
Vela R1	460	3
Cassiopeia R1	530	5
Orion R1/R2	470	6
Cepheus R1	660	3
Canis Major R1	690	8
Monoceros R1	800	4
Monoceros R2	830	7
Vela R2	870	6
Scorpius R5	870	4

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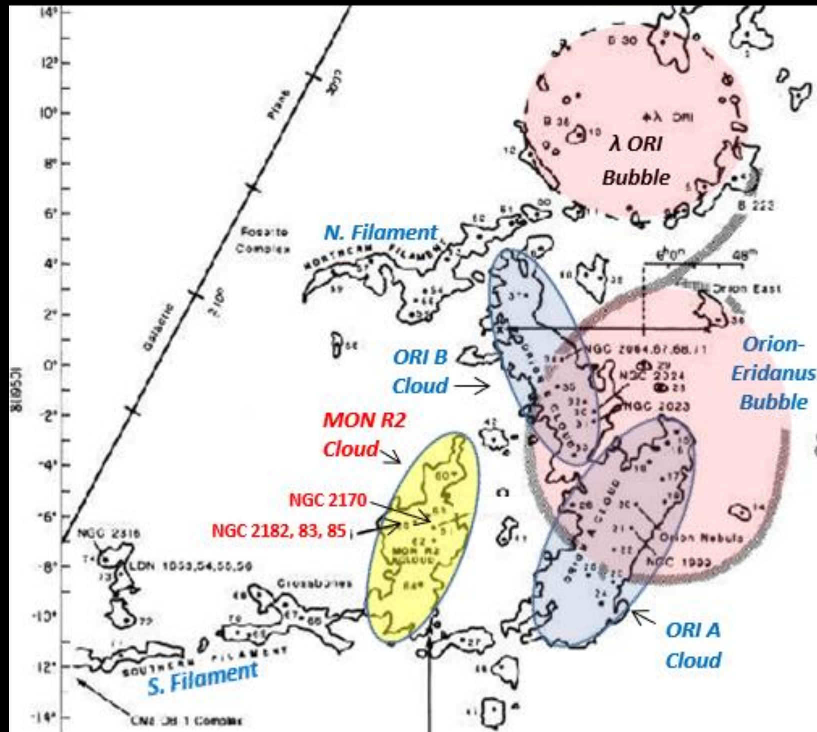
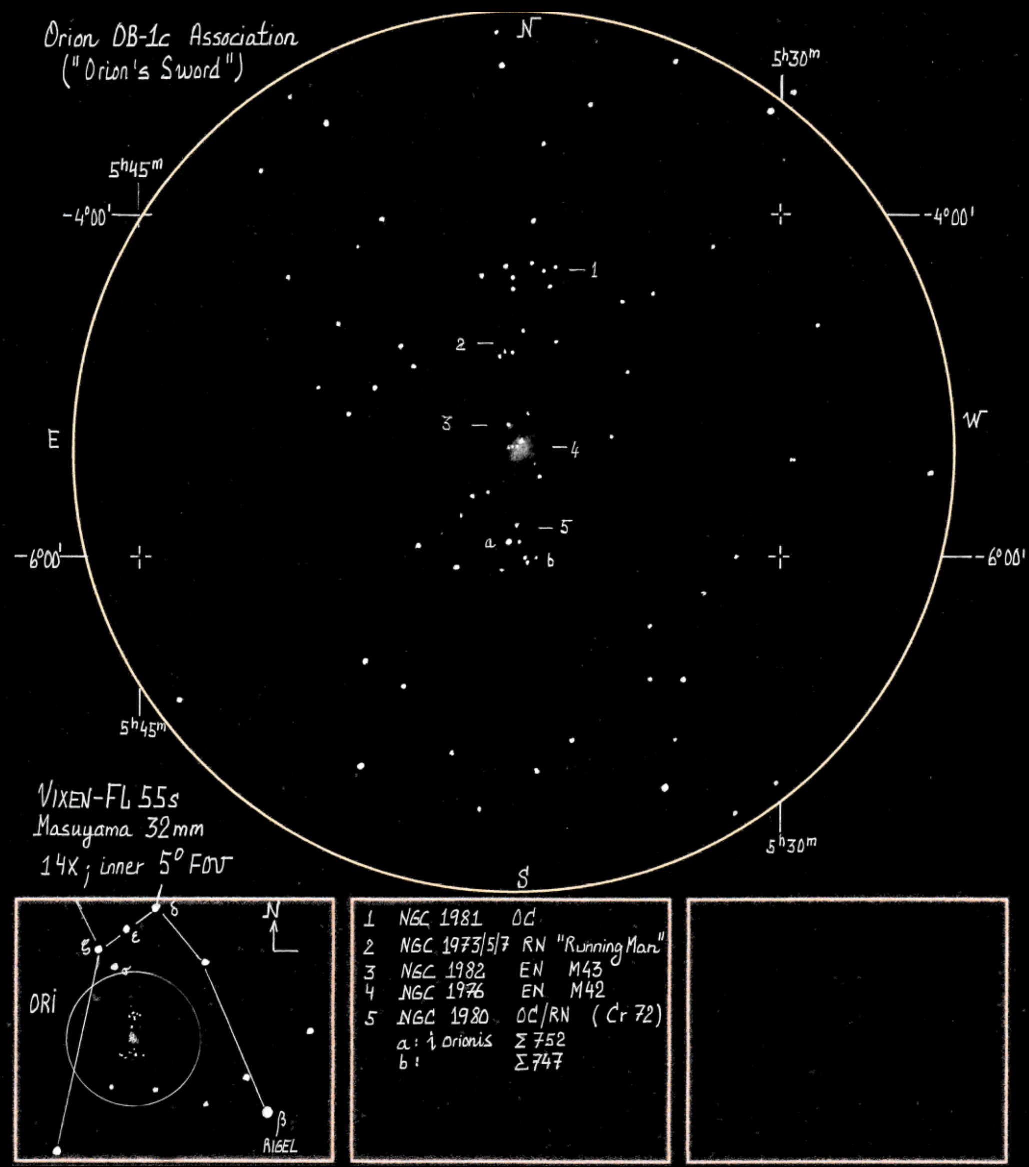


2" Classic Vixen Refractor FL-55S/440 for Rich Field observation

For the rich field OB-association observations, I used primarily my small 55mm f/8 refractor with a 32mm eyepiece yielding 14x magnification in a 6° wide FOV. Here's the instrument setup in my backyard, shown with an example observation of the Orion OB-1c stellar association. My observations in this part of the project were all done sitting down at the telescope and sketching the view, often framing smaller targets by adding a 1.5x GPC barlow for 32x mag. at a medium 3.6° field of view.



Monoceros OB2

The **star hop** to Monoceros OB-2 is easy: from the S foot of Pollux (Ksi Gem) in the Twins, I follow a line along four ~4.5^m stars stretching 10° down SW: from Ksi Gem to S Mon (at the root of the Xmas tree), then via 15 and 13 Mon to Eps Mon. The heart of the Rosette nebula (with the NGC2244 central OC) is located right between 13 and Eps Monocerotis, a small notch to the SE.

NGC2244 is seen already in my **10x56mm bino** (6° field), as a group of five 7-8^m members plus one brighter 6^m star (12 Mon, which is however a foreground star). A nice view!

Switching to my **Mas-32mm EP (34x @ 2½° FOV)**, I now start a wide field drawing of MON OB2; This eyepiece nicely frames NGC2244, but I need to overlap it with another field to the E to include the Collinder OCs that are found in the MON OB2 association, so I decide to make a composite drawing of two eyepiece fields covering a total of ca. 3½°.

The Rosette

I start with the W part of the wide field view: the **NGC2244 OC** central to the Rosette EN. At 34x the cluster shows up as an obvious but loose rectangular congregation in the wide field of open clusters, that all feature several young, bright hot blue stars of type O and early B; The family of MON OB2 clusters were created in a **sequential subgroup formation**, starting with Cr 107 (age 15 Myr), followed by Cr 106 (5 Myr) and then finally and recently (a few hundred Kyr ago): the central NGC2244 OC, right out of the delivery room, and still shrouded in its bed sheets of gas and dust (the Rosette).

The Rosette emission nebula (NGC 2237-38-46) is primarily ionized by two ultra-hot (~50 KK) rare type O3.5 V stars: the 6.7^m star **HD16150** at the center of the rectangle of stars, plus the 7.2^m star **HD46223** just SW of 12 Mon; I've marked these stars on my drawing, but there are several other hot type-O stars in the cluster (as can be seen in a drawing I made of NGC2244 two years ago using my 55/440mm Vixen FL-scope). I now try to catch a glimpse of the **Rosette EN** from my suburban backyard, using OIII and UHC filters; – there is, maybe, a hint of a shadow of… something, around the 2244 cluster as seen with the UHC, but my sighting is a far cry from definitive, and certainly not firm enough that I can fix it on my drawing. Instead I've drawn the circular outline of the area of nebulosity, so I know where to look next time I try to chase down this elusive ghost.

The Collinders

Moving one eyepiece field east, I now have NGC2244 at the W border of the FOV, and the two main Collinder open clusters (106 to the N, 107 to the S) in the E part of the FOV. (Smack in the center of the field I discover a small fuzzy patch, -- I'll return to that in a moment).

Prominent in the oldest, northern cluster **CR106** is the 6.1^m star **HD47129**, also known as *Plaskett's Star* or V640 Mon). This is one of the most massive (spectroscopic) binary star systems known, each star 40-50x solar mass. The two huge, blue class O8 supergiant members orbit each other at about half the Earth-Sun distance in a period of only 14.4 days. Both show strong stellar winds, which collide in the middle and produce a cloud around the stars. I've marked this most interesting object on my drawing. CR106 is a loose open cluster containing ~14 members.

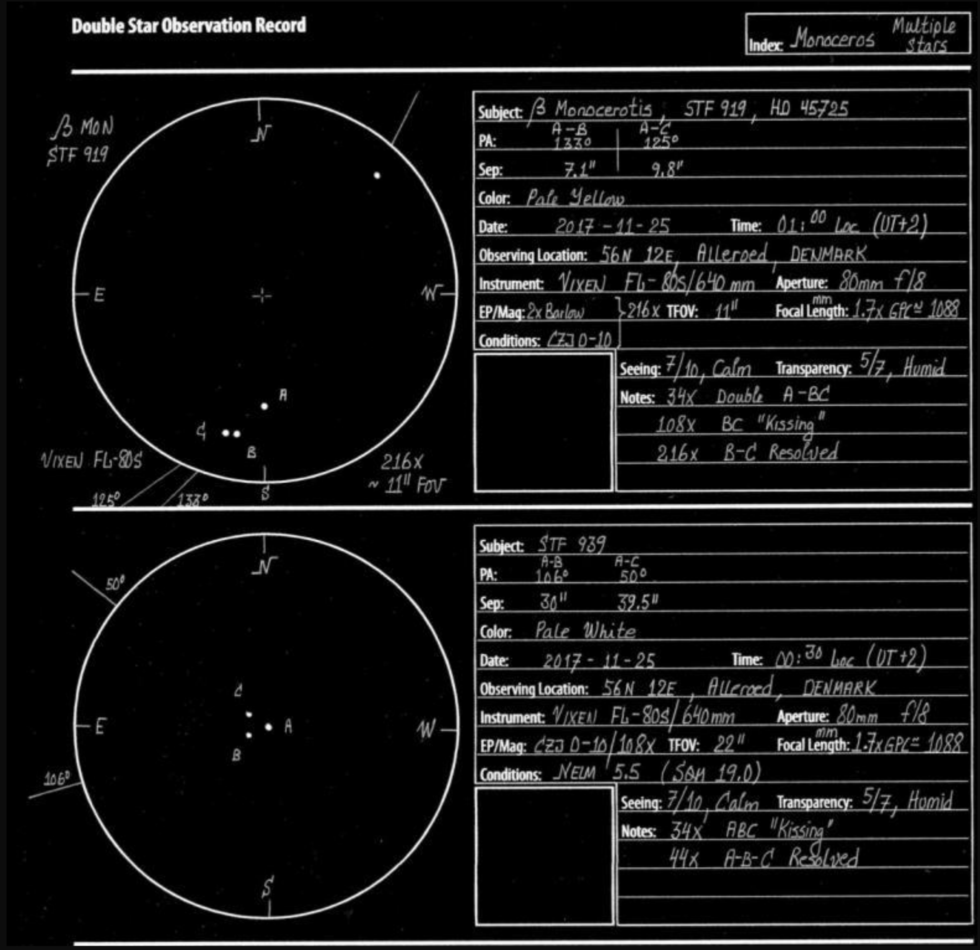
Switching my attention now to the much younger, southern cluster **Cr107**, two brighter stars catch my attention: the 6.1^m B1 Ib supergiant **HD47240** to the N, and the 7.1^m B0 III giant **HD47382** in a "Mickey Mouse" group to the S. Cr107 may not be a true open cluster, but rather part of a larger spiral filament of field stars.

A Tale of Two Triples

As mentioned, central in the eastern field I "discovered" a tiny hazy object (at 34x), which at higher magnifications (from 43x, CZJ O-25mm) turned out to be a spectacular close triple star forming an almost perfect equilateral triangle. Of course, checking my star maps, it turned out that F. G. Wilhelm Struve had already around 1850 cataloged this nice triple of 8^m type B stars as **STF939.** Here's the data: A: type B 0.5 IV, B: type B9 and C: type B8 V; A-B: 8.3m | 9.2m, 30" Sep., 106° PA, and A-C: -- | 9.4m, 39.5" Sep., 50° PA.

My "discovery" of STF939 prompted me to revisit another well-known triple in the neighborhood: the ~4^m **STF919** (Beta Monocerotis or HD45725). This is a tight triple, with the components all being almost identical 6-7x solar mass white type Be stars (i.e. hydrogen fusing main sequence dwarfs with circumstellar disks/shells). W. Herschel, discovered this triple back in 1781, and described it as: *"one of the most beautiful sights in the heavens."* Here's the data for Beta Mon: A-B: 4.6^m | 5.0^m, 7.1" Sep., 133° PA; A-C: -- | 5.4^m, 9.8" Sep., 125° PA.

I enclose my drawings of the two triples.



Observation Record
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Feature(s): ROSETTE Cr 106, 107
Date: 2017-11-23
Time: 01^00 UT+2
Location: 56N 12E, DK.
Conditions: Trsp. 5/7, Windy
Seeing: 7/10
Instrument: VIXEN FL-80S/640 mm
Aperture: 80 mm f/8
Focal Length: + 1.7GPC ≈ f/13.6
EP/Filter/Mags: Masuyama 2" 32 mm
34X mag. @ 2.5° FOV
Notes:
Composite drawing of 2 overlapping fields.
C49, NGC 2237-38-46 Rosette EN.
C50, NGC 2244, SAC 68 Rosette OC.
VIXEN FL-80S/640mm
Masuyama 2" 32mm
34x, 2 composite 2,5° FOV
6h38m
6h34m
6h30m
6h28m
6h36m
6h32m
+6°
+6°00'
+5°30'
+5°00'
+5°
+4°30'
N
S
E
W
Cr 106
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NGC 2252
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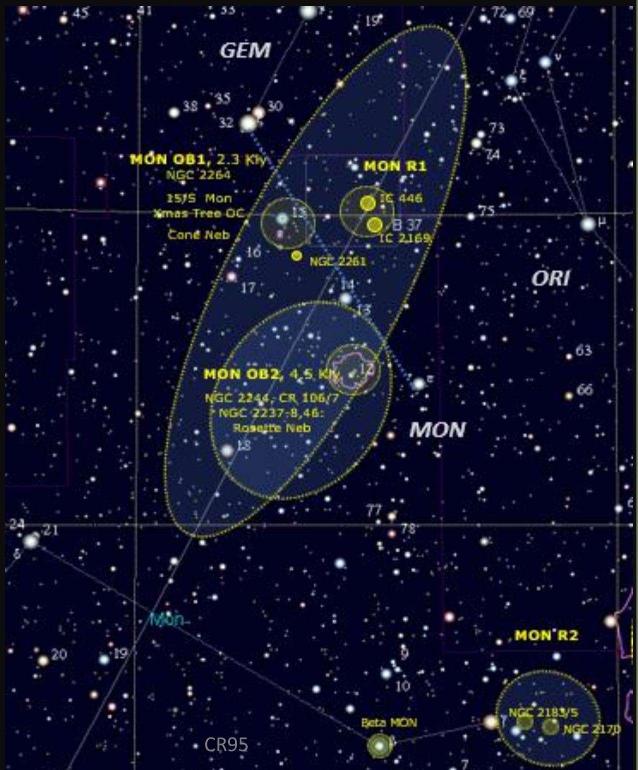
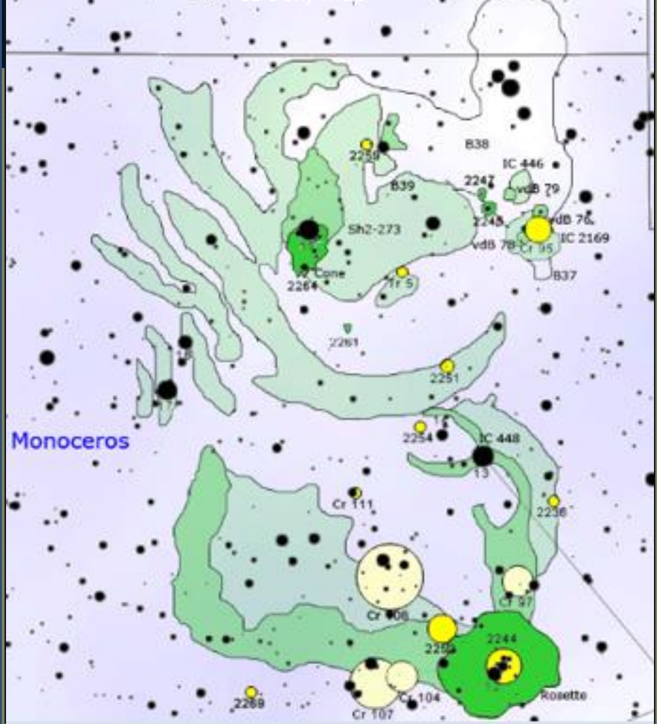
12
HD 46150
HD 46223
HD 47240
Cr 107
Cr 104
HD 47382



CDC Sky Map



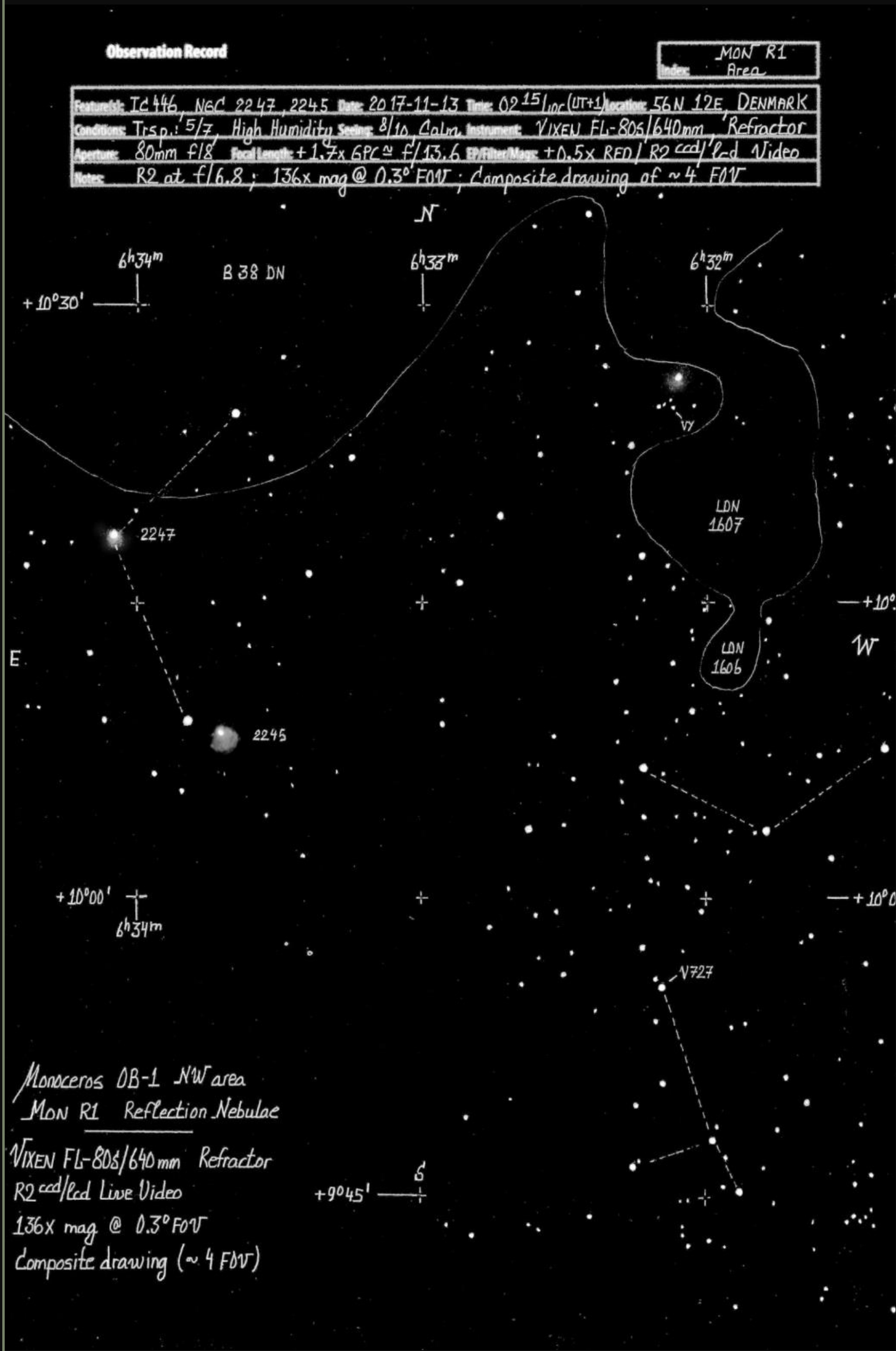
R Associations

As an example of R-associations that I studied in the project, here's my observation of the Monoceros R1, which is part of the giant cloud of interstellar dust and gas in Monoceros OB1, located at the outer edge of the Orion Spur at a distance of 2-3 Kly. This large cloud (Sh2-273) also includes the nebula complex NGC 2264: home to the Fox Fur EN, the Xmas Tree OC and the Cone DN.

Collinder 95 OC (CR95) is a young sparse OC with the brightest member located to the N in the group being the eclipsing beta-lyra variable: **V727 Mon** (HD46005). This B8 V dwarf is the main star illuminating the enclosing IC 447/2169 reflection nebula – but I can see no clear trace of nebulosity in my video session.

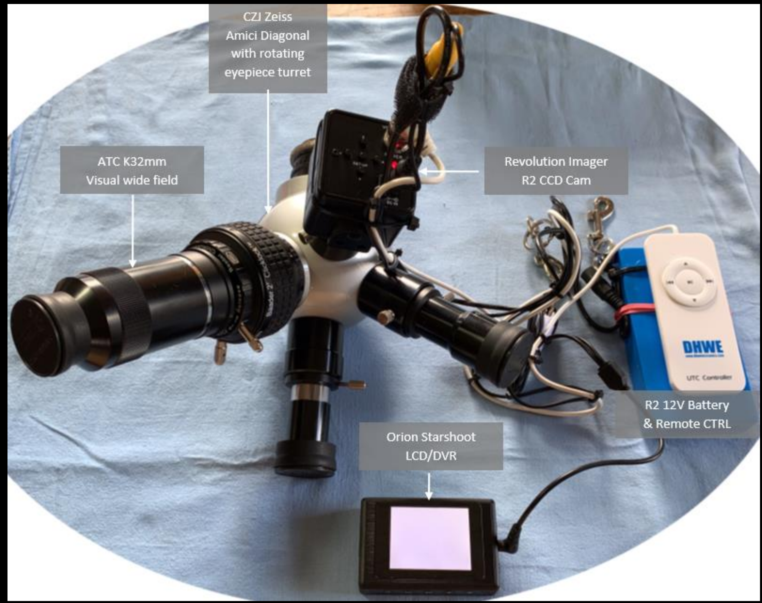
Panning N past a triangle of ~9^m stars I arrive at an area, where the stellar field is divided in two by an N-S patch without any stars: this is a "dark finger" (LDN 1607-1606) that reaches down from the Bernard B3**7** cloud of dark dust and gas. There's a small "peninsula" of stars protruding from the E into the dark area, and this is the position of the IC 446 reflection nebula. The nebula is faintly visible in live video as a hazy halo around the 11.15^m type B2.5 main sequence dwarf **TYC 737-255-1**. Just below IC 446 is another interesting object: VY Mon**,** a type Herbig A5e/Be pre main seq. massive YSO.

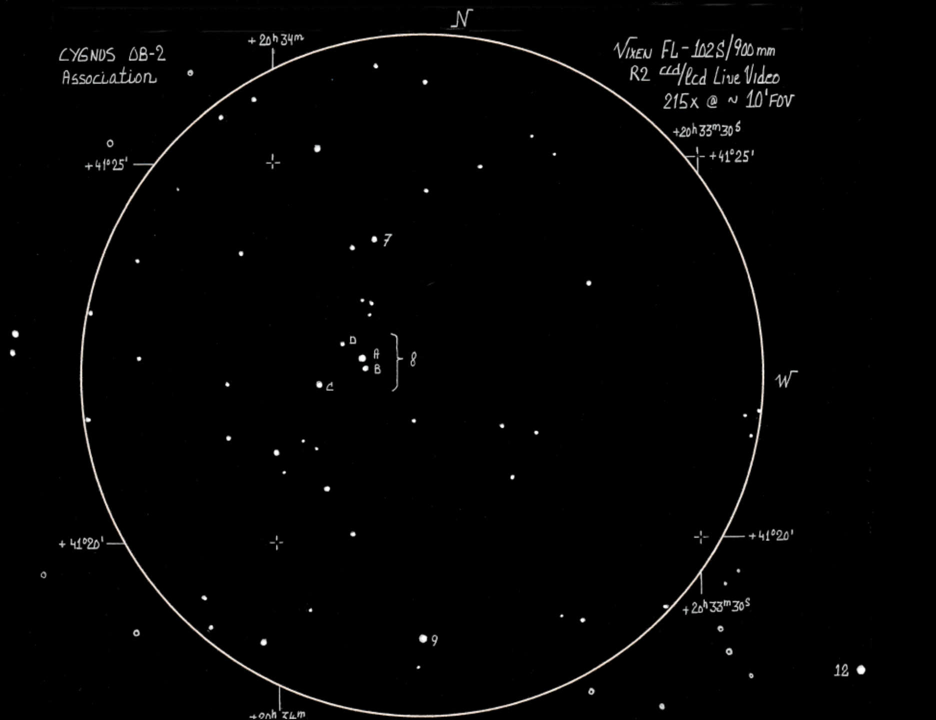
Finally, panning E now from IC 446, I come to a large triangle of 7-8^m stars, which is the home of two small reflection nebulae: the star in the middle is surrounded by NGC 2247, while NGC 2245 is located just W of the star to the S (HD 46265). Both nebulae are visible in live video, 2247 being the faintest (yet still unambiguously detected), while 2245 is outstandingly obvious, looking like a small cometary nebula with a bright nucleus (a ~9^m star?) and a broad fan-shaped "tail" towards the SW.



4” Classic Vixen Refractor FL-102S/900 for Rich Field observation

For small targets such as the *Cygnus OB2* or for close up observations of larger OB-associations (such as MON OB1), I would pull out my larger 4” f/8.8 refractor and use a 2.6x GPC barlow with an ATC K32mm 48° AFOV eyepiece yielding 73x magnification at 0.66° TFOV, or I would ultimately click over to live video using my R2 video camera and a small LCD screen from which I could sketch and record the objects live at 215x in a 0.17° TFOV.





Monoceros OB-1
NGC 2264

It is now 02:[45] early AM local, (UT+1); the clouds have collapsed and the wind has exhausted itself, leaving a relatively calm, cool and clear night sky with a NELM @ 5.1^m (SQM 18.1), a humidity down at 60% and a temp of 5° C; A perfect night for exploring the universe! I click over to the R2 cam for live video at 5s exp (gain 36 db, ave 1); to properly frame the whole extent of NGC 2264 at the cam's image scale of 0.3' FOV in 136x mag., I have to make a composite drawing of three overlapping video fields.

I start my sweep from the north with a view of **S Mon and surroundings**; this is indeed - as W. Smyth has described it - *"a magnificent star field"!* S Mon itself is a luminous (14.500x sun) spectral type O7 class V-IV transitional subgiant, just caught in the act of moving off the main sequence. It belongs to a small cluster of young (~3 Myr) OB stars: **∑ 950**. S Mon has a tight C-component (Aa-C, PA:16 °, 16"), which I can just resolve, and some further components in a multiple group, which I have indicated on my detail drawing as they showed up in my 80mm refractor. In fact S Mon is best described as a quadruple system (Aa-B-C) consisting of mostly early, massive and brilliant blue-white stars of type O7, B7, B8 and A6 (the wide pairs to the south of S Mon are probably *not* gravitationally bound to the AaB-C core system).

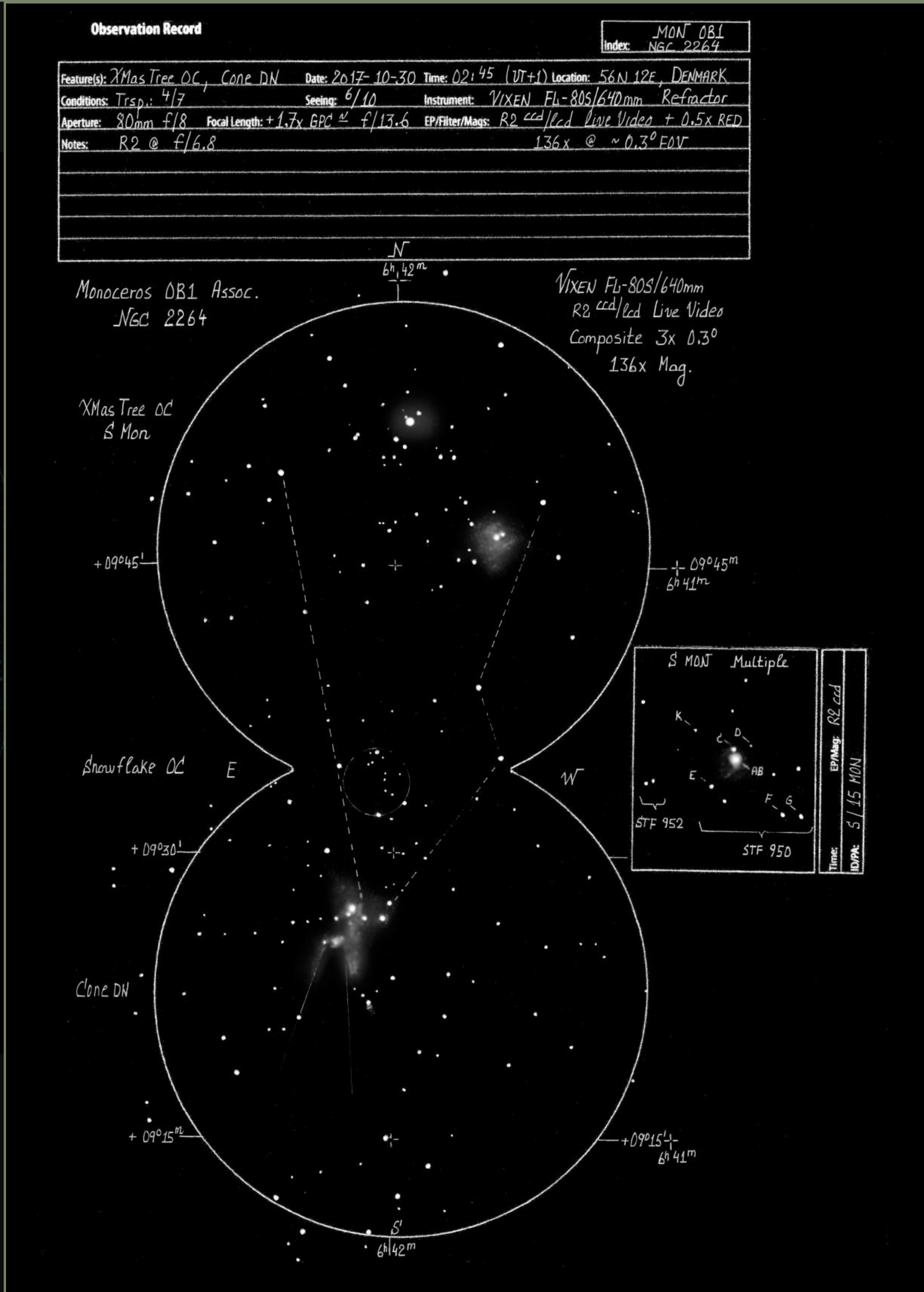
Sweeping south, I now move past the chain of early B-stars (from V641 Mon to HD 261810), that is at the center of the brightest patch of the Sh2-273 HII cloud. I have an Astronomik CLS CCD filter in the nose of my R2 cam. to eliminate the LP in my suburban backyard, and with this setup I can verify the **"Fox Fur"** nebulosity, that I glimpsed in my wide field observation using only glass eyepieces + an OII filter.

Moving further south, I come across a small star-rich area N of **HD47887** at the tip of the Xmas tree. This is the position of the **"Snowflake" OC**, a rich group of young (<0.1-5 Myr) T-Tauri protostars, still in the process of contracting from surrounding accretion discs, and settling in to become core hydrogen burners on the main sequence. The TT protostars have begun warming up, but are currently only visible in near-IR and Hα light. -- But having seen IR photos of the area, I know for sure they are hiding there, in those cool HI gas clouds! (I've marked the area with a faint circle on my drawing).

A final step south takes me to the pre-main sequence B2 III giant: **HD47887,** where the top of the XMas Tree meets the tip of the Cone Dark Nebula. At first, I can't make out the contours of the cone, but the absence of stars in the triangular area below HD47887 is evident. By turning up the gain and averaging of the CCTV cam to max levels, I am however able to clearly see both the ionized top of the cone, as well as the edges of the dark pillar of cold hydrogen and dust, that is being carved out by the strong UV solar wind radiated by the S Mon complex. A fantastic sight!

All-in-all the NGC 2264 areas of ionized glowing gas intermixed with dark nebulae of neutral HI and dust, and with embedded nurseries of TT-stars and hot OB giants sculpturing the ISM – WOW, what a treasure chest for astronomical observation!

But there are more treasures in MON OB1 (*"there is another one!")*.



Monoceros OB-1

NGC 2261: Hubble Variable Nebula

The night will be turning into astronomical dawn in just 1½ hour, so I click straight over to the R2 live video cam to start my close up (136x) observation of the soft star in the central pair. Already at low settings (5s, 36db, 2 dnr) the soft star reveals a small faint fan of nebulosity stretching up N, and as the image stabilizes in ~30sec, the nebulosity gets brighter and starts to look exactly like what O'Meara has described as: *"the head of a match just beginning to ignite".*

What I'm seeing is a **small reflection nebula** discovered by W. Herschel in 1783, and which has spooked astronomers for the following decades due to its irregular fluctuations in brightness (5.5-13^{m}) over a time scale from a few weeks to months. On top of this, the nebula shows rapid displacement of details by up to 1" in just a few days. Fast forward to 1966, when the object was finally described as a "cocoon nebula" – the newborn star R Mon (actually a tight binary type B + T-Tauri) being enveloped in a dense opaque disk of gas that spirals into the star, with two jets being ejected at right angles to the disc. The stellar wind and jets light up and hollow out cones in the surrounding gas clouds, while dragging dark filaments of dust in spirals inside the cone walls. This is what creates the flickering shadows in the N cone, which we see as a variable fan-shaped reflection nebula (the S cone is presumably totally obscured by dust).

For max detail I now push the camera settings to max levels of gain and averaging (44.8db, 6 dnr); the fan now reveals a bright (~12^{m}) core to the S, like a comet head: the position of R Mon. From the core I can see the triangular hollow cone stretching up N. The cone edges are obviously brighter, and especially the W wall shows subtle details in contours and brightness. This is indeed an extraordinary and unique sight, not quite like anything else in the night sky.

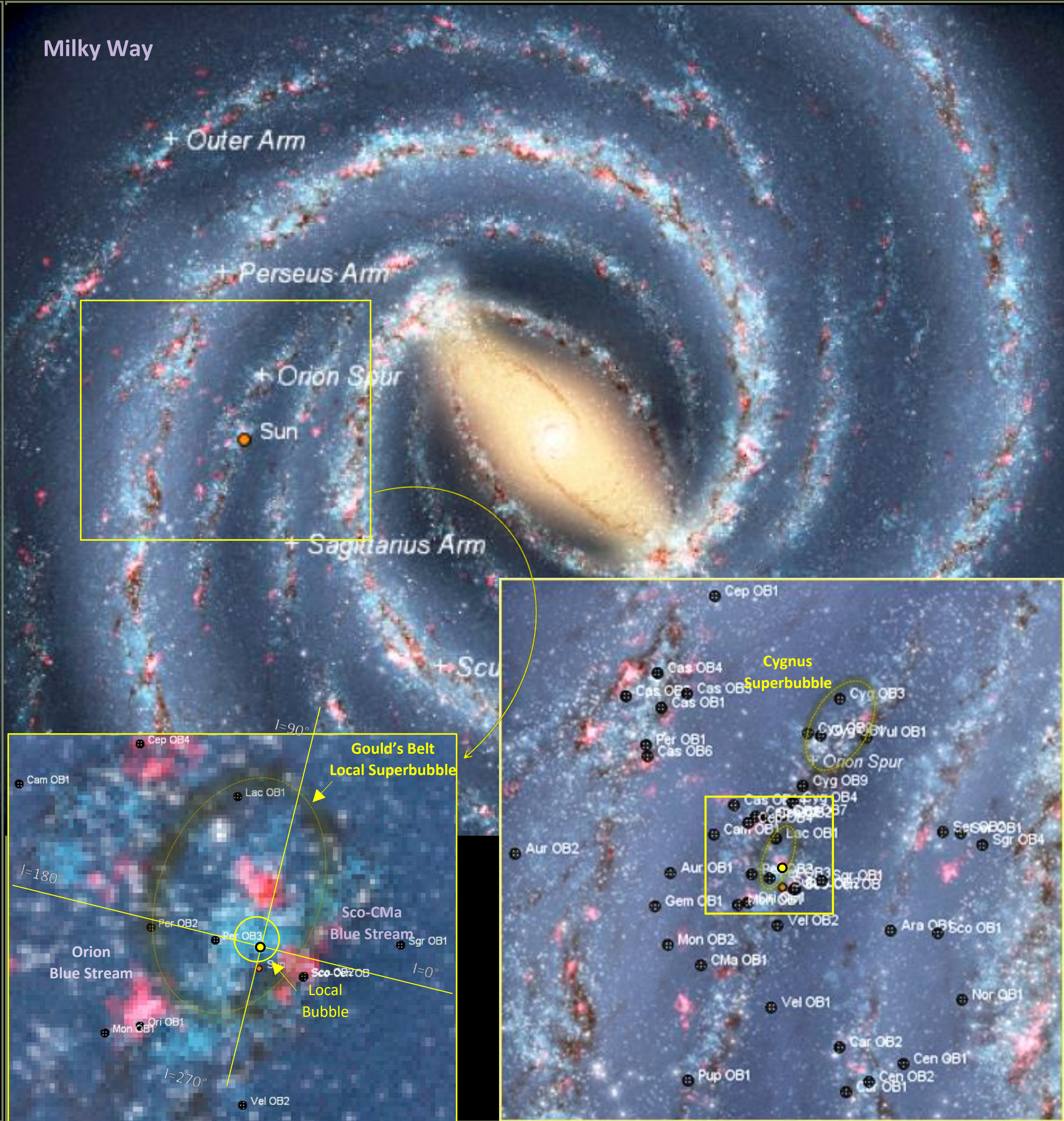
R Mon is one of just a handful of **YSOs (Young Stellar Objects)** bright enough to study in amateur telescopes, the closest other candidate being *NGC 1999 in ORI OB1c* --the *V380-Orionis* cocoon. In R Mon the molecular cloud has gravitationally collapsed into a tight binary protostar, which is still completely buried in its surrounding envelope. The collapse has resulted in a spin-up of the protostar with creation of an accretion disk. This in turn has wound up strong magnetic vortices along the rotational axis, leading to the ejection of bipolar jets, which has carved out cone-shaped voids in the surrounding molecular cloud "cocoon". At the same time the energy from the gravitational collapse and accretion has heated up R Mon so it is now emitting light that is escaping predominantly along the polar axis, illuminating the cones from the inside. R Mon is currently showing bursts in brightness due to the combined effects of contraction and mass accretion, as it moves towards the HR main sequence to become a hydrogen fusing newborn star.

A star being born… how marvelous!!

At the end of this part of my rich field project, I had traced the OB-Associations all along the galactic plane of the ca. 1600 light year diameter Local Superbubble in our Orion spiral arm (seen in 2D projection on the night sky as the *Gould's Belt*: from Orion up to Taurus through Perseus and Cepheus, then down to Monoceros and into Scorpius-Centaurus-Canis Major).

From here I also ventured further up along the inner part of the Orion Arm to more distant OB-associations in the Cygnus Superbubble, and then down the Orion Arm past the Orion-Eridanus Superbubble to the more distant associations in Monoceros and Canis Major. It had been exciting and educational to observe, document and share my own backyard observations of the OB-associations, to compare their appearance in my small telescopes with the published scientific images and data for origin and evolution, and to discuss the latest astronomical research on these objects with highly knowledgeable fellow amateur astronomers at the Cloudy Nights astronomy forum (such as *Glenn LeDrew* and *Doug Bullis*).

I felt that I had now established quite a coherent mental map of the major star forming complexes in our solar neighborhood, and along the way I had also taken the time to stop and observe objects that were cosmologically closely related to the OB-associations, including the surrounding regions of large dark clouds (as the Cygnus Rift) and emission nebulae (as North America, Butterfly, Fox Fur etc.). I had furthermore zoomed in on smaller embedded newborn stellar objects (YSO like Hubble's Variable), open galactic star clusters and supermassive dying stars, including luminous blue variables (LBV as P Cygni), Wolf-Rayet stars (WR as WR136 in the Crescent Nebula) and supernova remnants (such as the Veil).

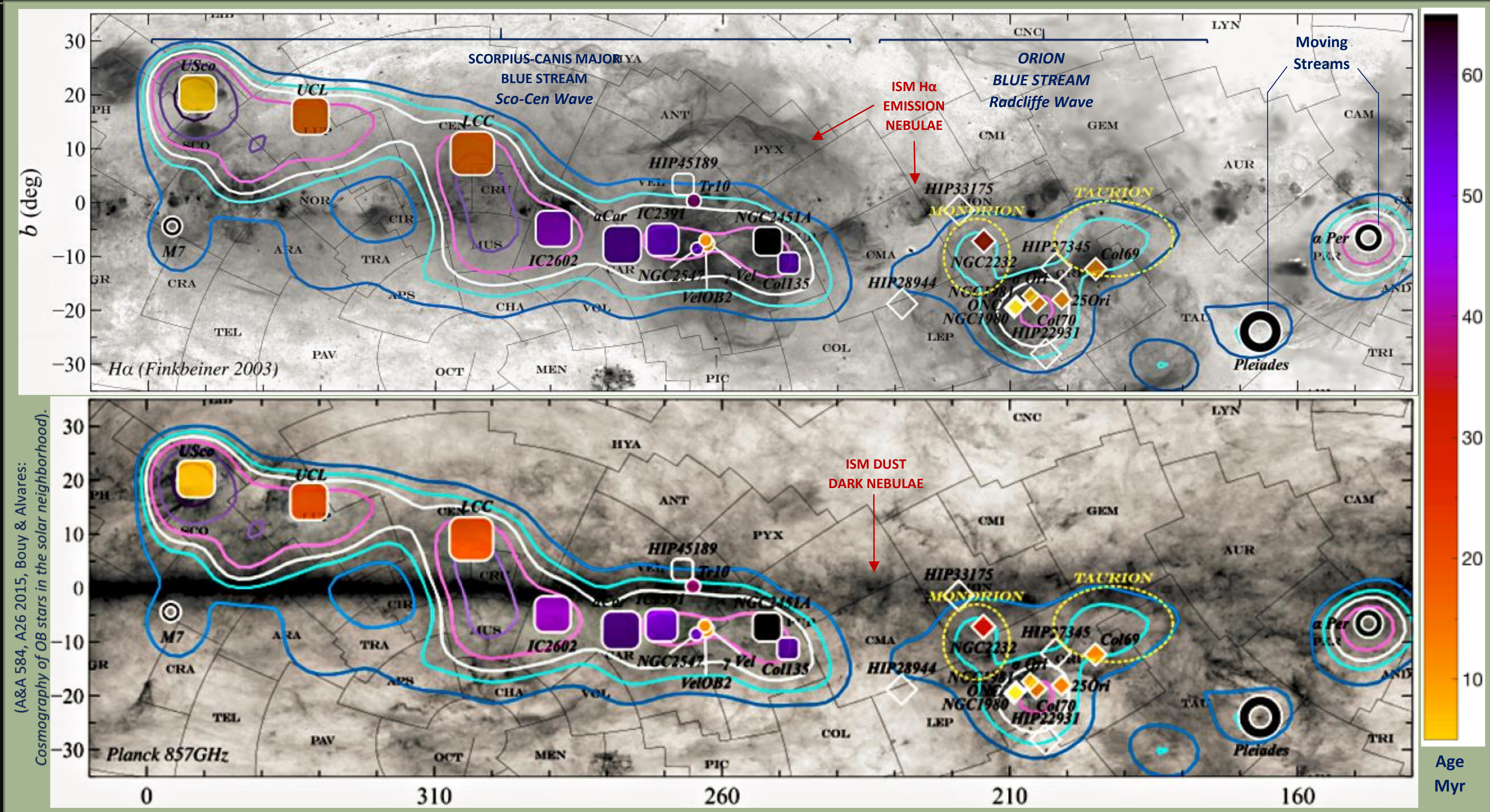


Through my observations and research, I realized that to better understand, not just the spatial distribution but also the creation and dissolution of the OB-associations, I would have to study in more detail ”both ends” of the spectrum of galactic star formation.

ISM Gas and Dust Nebulae

At one end of the spectrum, I would like to have a closer look at the pristine interstellar medium (ISM) with its large molecular clouds of hydrogen and dust, and with its supernova bubbles with compressed gas walls; Of special interest in these star forming walls would be the wealth of large ionized HII-emission patches and dark clumps (HH-globules) with embedded tightly bound newborn clusters of YSOs and PMS T-Tauri stars.

Below is shown the density of type OB-stars, first projected on a Hα ionized gas map of the sky; OB-associations are found along the Milky Way plane in the two “Blue Streams”: the **Orion Blue Stream** groups are indicated by squares and the **Sco-CMa Blue Stream** groups by diamonds. The following image shows the same objects projected on a Planck 857 GHz dust map of the Milky Way.



(A&A 584, A26 2015, Bouy & Alvares: *Cosmography of OB stars in the solar neighborhood*).

Moving Streams

I started my "Classic Rich Field" project by studying the bright star-forming regions (SFR) in the galactic plane of the wall of our Local Superbubble that surrounds the solar system. The bright OB-associations in these SFRs were easily observed with small refractors from my suburban backyard, even during the summer twilight prevailing in May-August at my 56°N latitude in Denmark.

I've shared a few of my SFR observations from Monoceros here in this article, but many more can be found on the Cloudy Nights astronomy web site in the CRF thread, starting here: https://www.cloudynights.com/topic/565226-classic-rich-field/?p=7682123

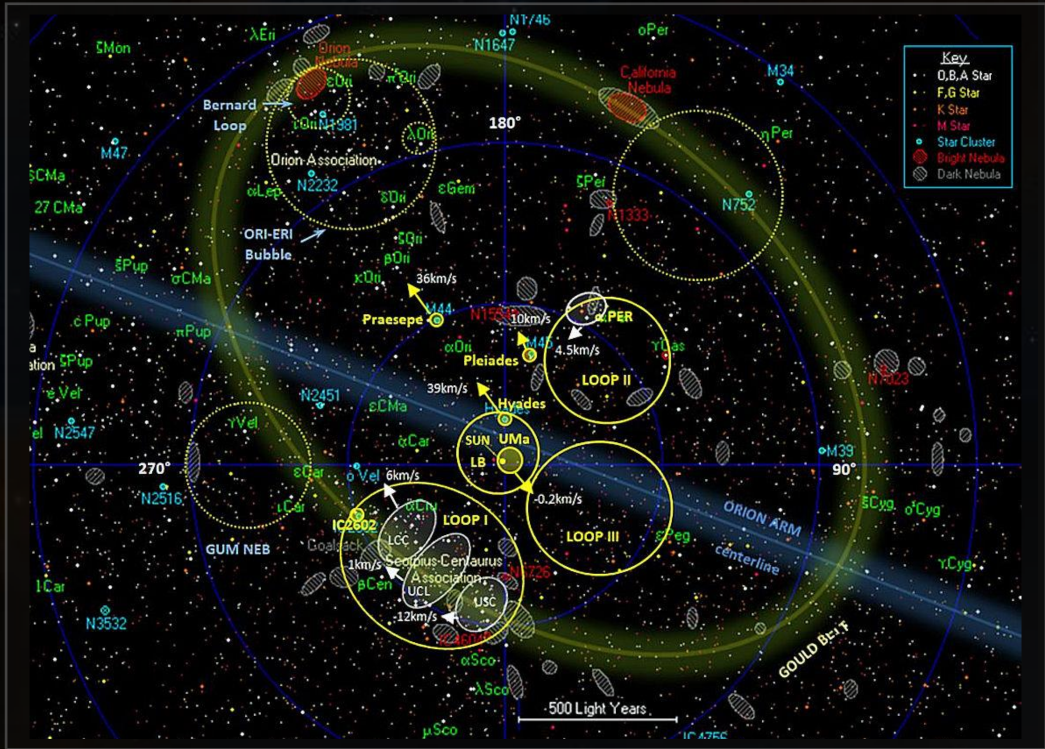
My plan was now to complement my study of the bright massive young star clusters with rich-field observations of the gas- and dust clouds that these stellar associations are born out of and still embedded in, -- but this project would have to await my acquisition of a night vision device to make it feasible for my small grab/go equipment in a NELM 5.5 backyard (see chapter 3 on the Milky Way).

Instead I now first turned my attention to the other end of the stellar evolution age-scale, as I started my project of observing the aging and increasingly unbound star clusters that can be seen in the immediate neighborhood of our solar system, inside the Local Superbubble. These old, co-moving stellar streams are now slowly scattering as galactic disc field stars under the influence of stellar winds, galactic resonances and tidal forces.

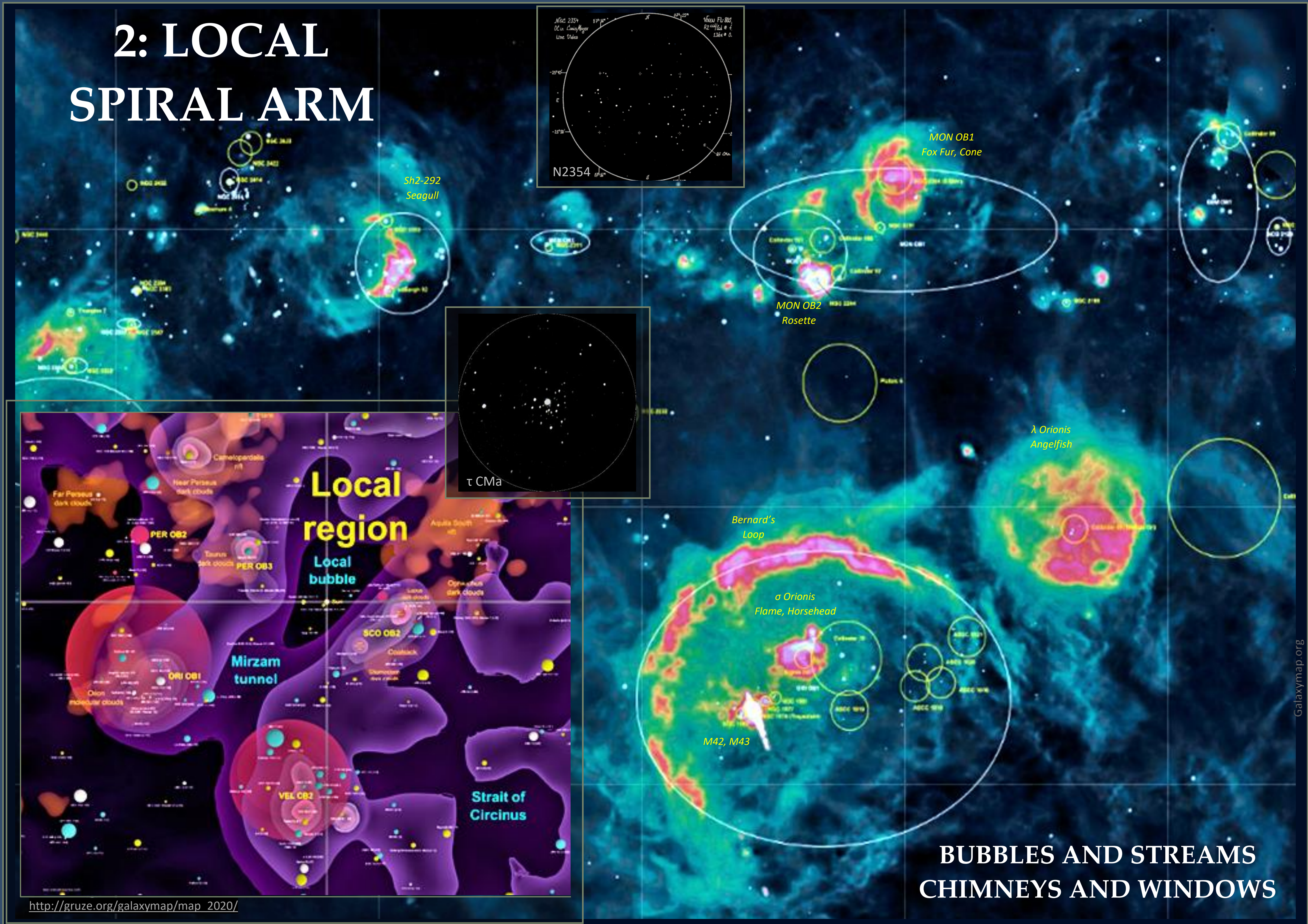
Thus was born the next part of my CRF observation project:

2: Local Spiral Arm
Bubbles and Streams, Chimneys and Windows.

https://aladin.u-strasbg.fr/AladinLite/



2: LOCAL SPIRAL ARM



http://gruze.org/galaxymap/map_2020/

BUBBLES AND STREAMS
CHIMNEYS AND WINDOWS

BUBBLES IN THE ISM

Superbubbles

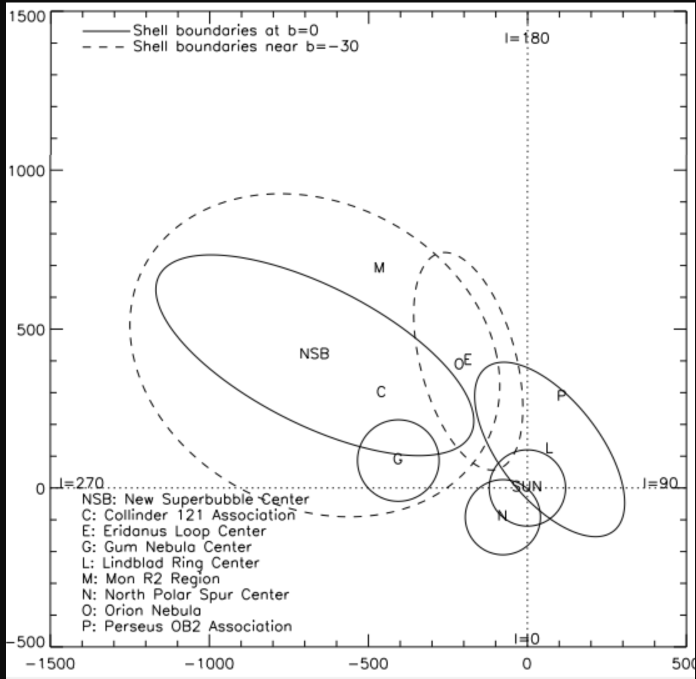
Giant galactic gas bubbles such as our Local Superbubble are created when a series of supernovae in young star clusters explode.

This produces a sequence of heated shock waves that sweep out nested shells of hot expanding gas. The expansion encounters least resistance perpendicular to the Galactic disk, where it blows out so-called chimneys, whereas most of the dense interstellar medium (ISM) in the galactic plane is swept up into filaments of molecular clouds.

As the gas density and pressure rise in the molecular cloud filaments, shock induced gravitational collapses and turbulent filament collisions are initiated, resulting in sequential star formation that creates "blue streams" of OB-associations, as exemplified by the Orion and Sco-CMa streams in our Local Superbubble wall. Other examples further out in our local spiral arm are: the Cygnus, the Orion-Eridanus and the Gum superbubbles.

Smaller Bubbles

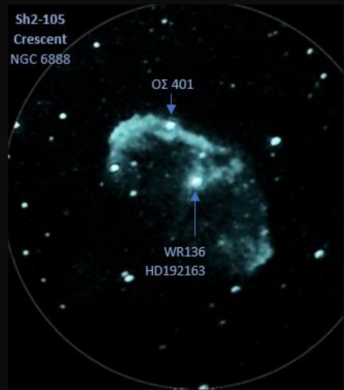
Smaller bubbles in the ISM form, when the earliest to condense and most massive OB-stars in a star forming region through UV stellar wind and/or a couple of supernova explosions push back the remaining uncondensed cloud of interstellar matter. Our solar system is currently passing through one such Local Bubble that is surrounded by similar ISM "Loops" in the Orion Arm: The Scorpius Loop-I with LLC-UCL-USC, the Perseus Loop-II with α Per and the Loop-III SNR bubble.



← LEFT

Nearby blown up cavities in the ISM neutral hydrogen (H-I): Superbubbles (**shells**) and smaller bubbles (**loops**) are shown projected onto the Galactic plane, as viewed from the north Galactic pole, and with the direction towards the galactic center oriented down. Solid circles or ellipses represent shells in the galactic plane (near b=0°), while dashed circles show shells below the plane (near b=-30°). Letters mark centers of the cavities.

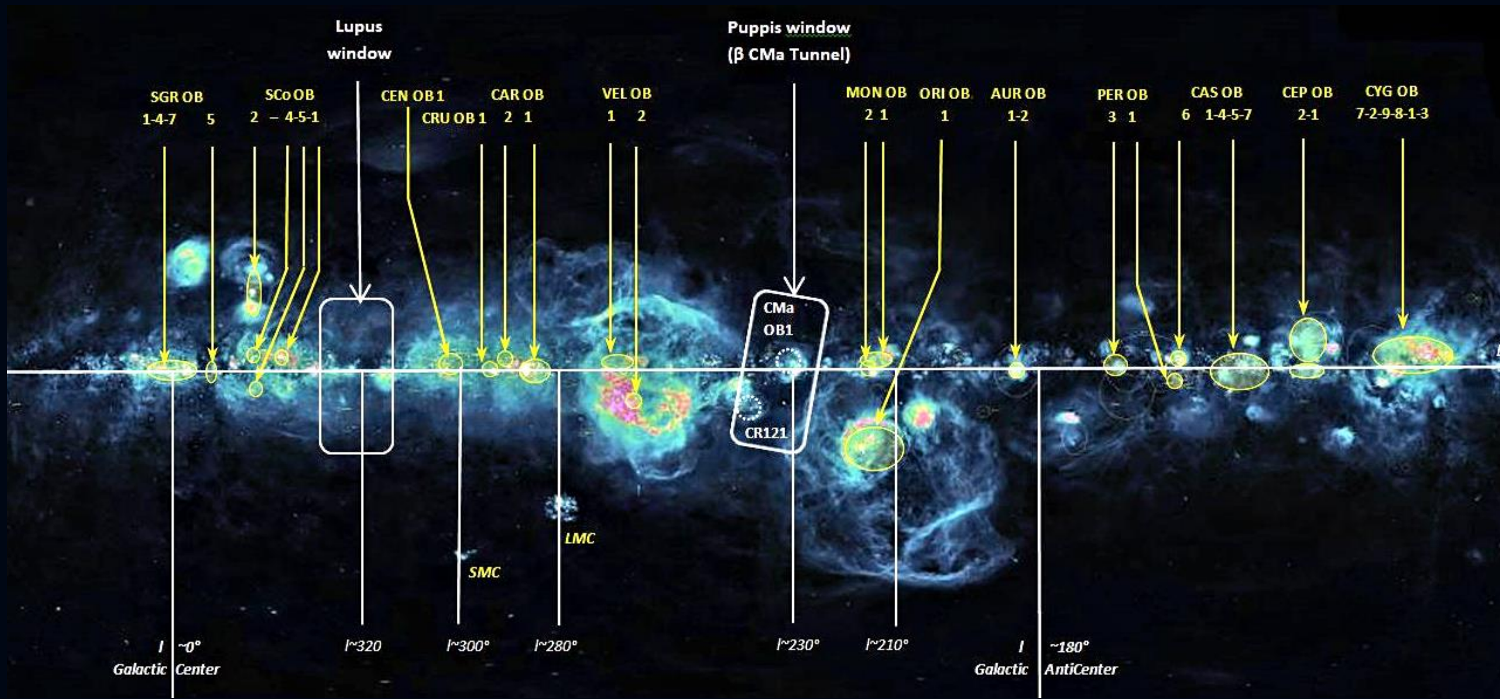
← THE ASTROPHYSICAL JOURNAL, 498:689E703, 1998 May 10. AAS 1998.



BELOW

Map of the Milky Way in H-alpha, showing several large supershells as well as smaller loops of ionized hydrogen.

Our own Local Superbubble has contributed several major emission nebulosities from OB-associations such as in Orion, Scorpius-Centaurus, Auriga and Cepheus. Other superbubbles can be spotted in the regions of Cygnus, Cepheus, Cassiopeia, Vela and others.



LOCAL SUPERBUBBLE

Our **Local Superbubble** with the ORI and Sco-Cen blue streams were formed ~30 Myr ago by a series of supernova explosions in the now old “fossil” *Cas-Tau association* close to the **Per OB3** group. This event pushed out the ISM in the galactic plane into long wavy filaments of neutral gas and dust that under the influence of galactic resonance and co-rotation settled into in a chain of dark molecular clouds, from the outer CMC-RMC over the AQL RIFT and further inwards towards the CYG RIFT (the *“Lindblad Ring”*).

On a still larger scale, the dark molecular clouds (DMC) are all part of a lane of dust that traces out the inner edge of our Local Orion Arm. Note that the DMCs in the Lindblad ring and the Orion spiral arms are noticeably thinner in the direction of CMa and PUP, which open up a window with a view towards the outer Perseus Arm in this direction (the *Puppis Window*).

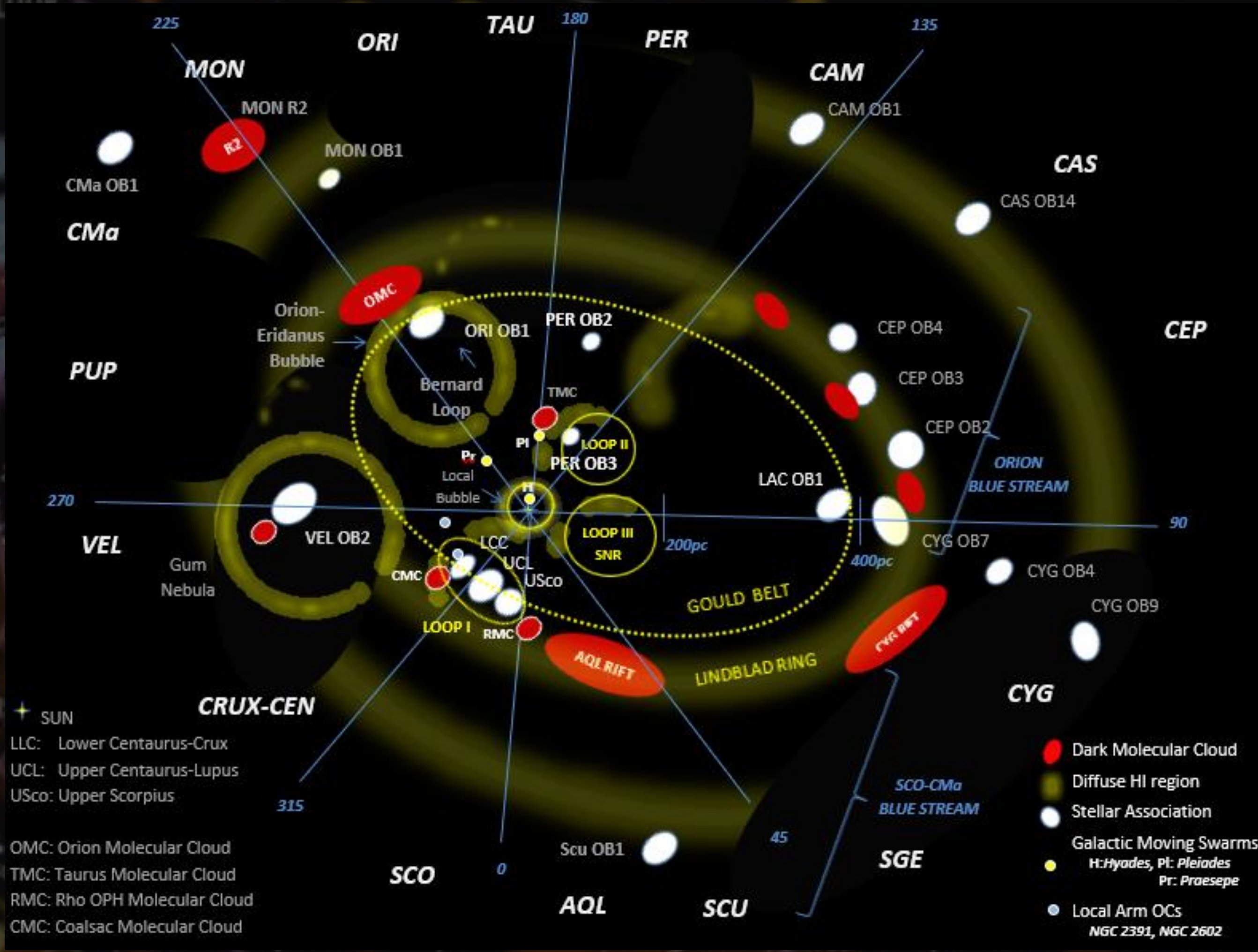
Later, under the further influence of gravity and magnetic flux, parts of the filaments were twisted and folded, and these local compressions and collisions ignited the star forming regions with their OB-associations that we now can trace across the night sky (the “*Gould’s Belt*”).

LOCAL BUBBLE

Inside our Local Superbubble, and close to the center on my schematic drawing of the Local Spiral Arm (aka the *Orion Spur*) , we find the Sun located in its own small (300 ly diameter**)** **Local Bubble** of expanding gas; The sun is surrounded by some nearby, wide moving groups of stars, including the closest *Sirius Swarm* (with the Big Dipper stars), the *Hyades Swarm*, partly inside the Local Bubble, and the more distant *Pleiades Swarm*. The Local Bubble was possibly blown up by an exploding star ~100 Kly away (the collapsed core of this supernova may then be the pulsar *Geminga*, which detonated 370 Kyr ago), -- but more likely our bubble is the remnant of multiple supernovae in the close by 70 Myr young Pleiades moving group.

NEARBY ISM LOOPS

Surrounding our Local Bubble, but still mostly inside the Local Superbubble, we find 3 other interstellar bubbles: Loop I-II-III. A couple of larger ISM Superbubbles are also shown on the map: The *Orion-Eridanus* shell and the *Gum Shell* (around VEL OB2).



Loop I is most interesting: when the shock wave from the *Cas-Tau* supernovae reached the gas clouds in this region, the compression first initiated the star burst in the central UCL association ~15 Myr ago; Supernovae and stellar winds in UCL then blew up the LOOP I bubble, and at the same time initiated a sequential star formation, progressing first up to LLC (12 Myr ago), and then down to USCo (5 Myr ago); the process is even continuing today, where the LOOP I bubble is now compressing the Rho OPH dark Molecular Cloud (RMC) to a point where stars are beginning to light up inside it.

Loop II was blown up also around 15 Myr ago, and it is currently colliding with interstellar matter in the Taurus Dark Cloud (TDC), initiating the nearest starburst region to our sun, with many early sun-like T-Tauri protostars.

Loop III is probably the young expanding shell of a single supernova that went off ca. 1 Myr ago (a SNR), as we see no association of massive young stars or remnants of such, which could have driven the expansion.

Windows and distant OCs

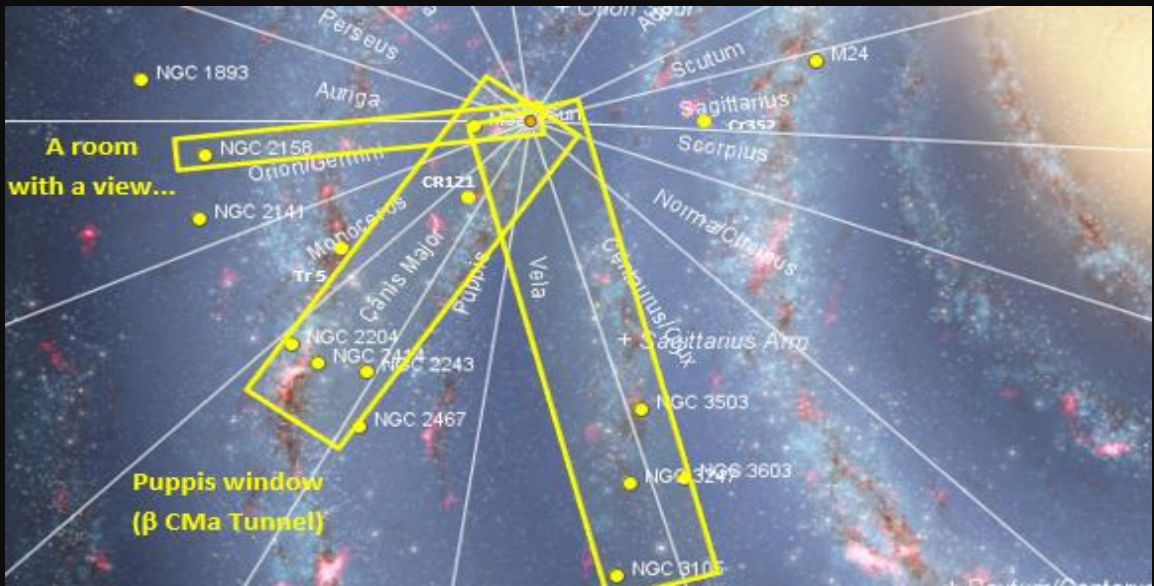
Orion's dog is showing his balancing act, hopping along on his hind legs up at the neighbor's roof ridge while leaning on the TV antenna, but I ignore this and start making my drawing. CMa OB-2 aka **Cr 121** is a distant (3.3 Kly ~1 Kpc) loose group with the type K2Iab red supergiant **Omi-1** at the center. Inside a ~1° circle around Omi-1 I can see a pair of 6^m type A1 giants to the S, the **WN5** Wolf-Rayet star (EZ CMa, HD50896) to the N plus several early B-stars.

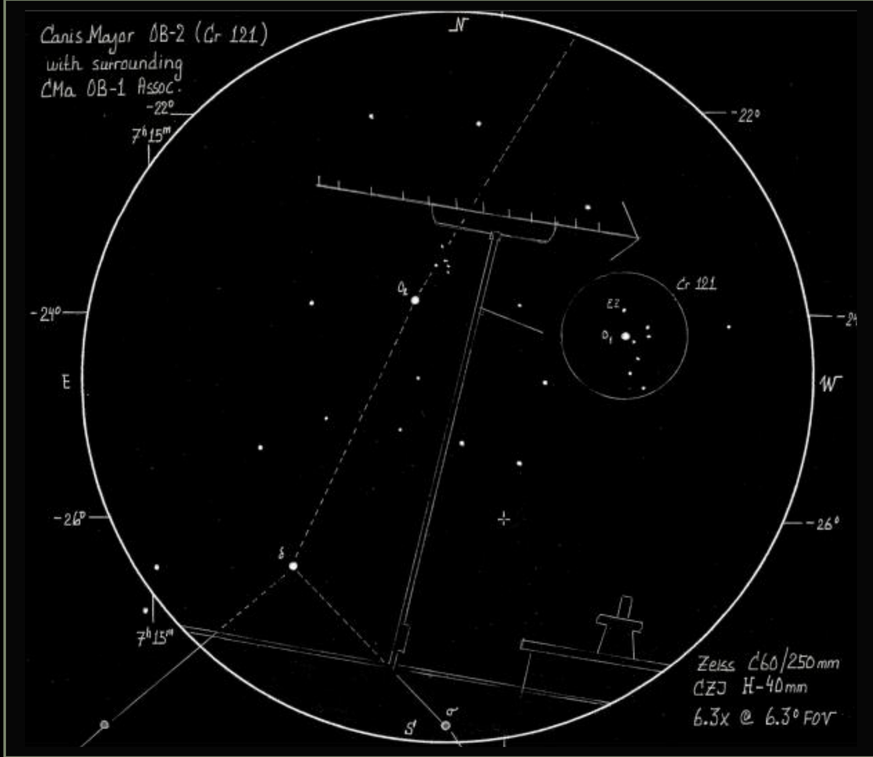
Several bright evolved supergiants sharing the same radial velocity and proper motion are found in a wider ~10° area surrounding the central CR121/OB-2 association in CMa. These include: γ, δ, η, ι, ξ^1, o^1, o^2, and σ CMa. The supergiants in the wider OB-1 association plus the lack of nebulosity suggests an age for Cr121 of ~15-20 Myr. As mentioned previously early supernovae in Cr 121 are likely candidates for blowing up the NSB supershell (GSH238+00), which merged with our Local Bubble creating the β CMa tunnel (the *Puppis Window*).

Trumpler 5 (Tr5) is located on the celestial sphere between the Monoceros OB1 and R1 regions. It is at a whopping distance of ~11 Kly (3 Kpc) towards the anticenter in the galactic plane. We can observe it at the very far edge of the Monoceros molecular cloud, through the *Puppis Window*. Tr5 is a very old open cluster, around 3.5 Gyr (only ~5% of all Milky Way OCs have an age of >2 Gyr). It was born as a large and rich OC, but due to its age most of its brighter members have long since gone supernova, and due to its position, there's a significant absorption from interstellar dust as seen from our place in the Orion Arm (extinction ~0.7^m).

Still, the 0.3° stellar field of Tr5 at 136x magnifications is a nice view: the FOV is strewn with 200+ stars from 10^m and fainter; there's a pair of star chains wrapped around the bright star HD260597 to the N in the field, and the core of the cluster is just to the SW of this group (marked with a circle on my drawing).The core includes the variable carbon star V 493 Mon (indicated by 'V' on my drawing), and indeed the "sooty" atmosphere of this star is seen softly glowing like a ruby red ember, -- beautiful!

OC	CON	DIST	AGE	COMMENT
Cr 121	CMa	3.3 Kly (1 Kpc)	15-20 Myr	Aka CMa OB2; originating OC of the **GSH 238+00+09** supershell and the Puppis window.
Tr 5	MON	11 Kly	~3000 Myr	A distant OC observable through the Puppis widow
NGC 2362 NGC 2354	CMa CMa	4.8 Kly (1.5 Kpc) 13.3 Kly (4.1 Kpc)	5 Myr 700 Myr	Another "room with a view" deep perspective target, down the Puppis window, though rather low south (~8°) as viewed from Copehagen.



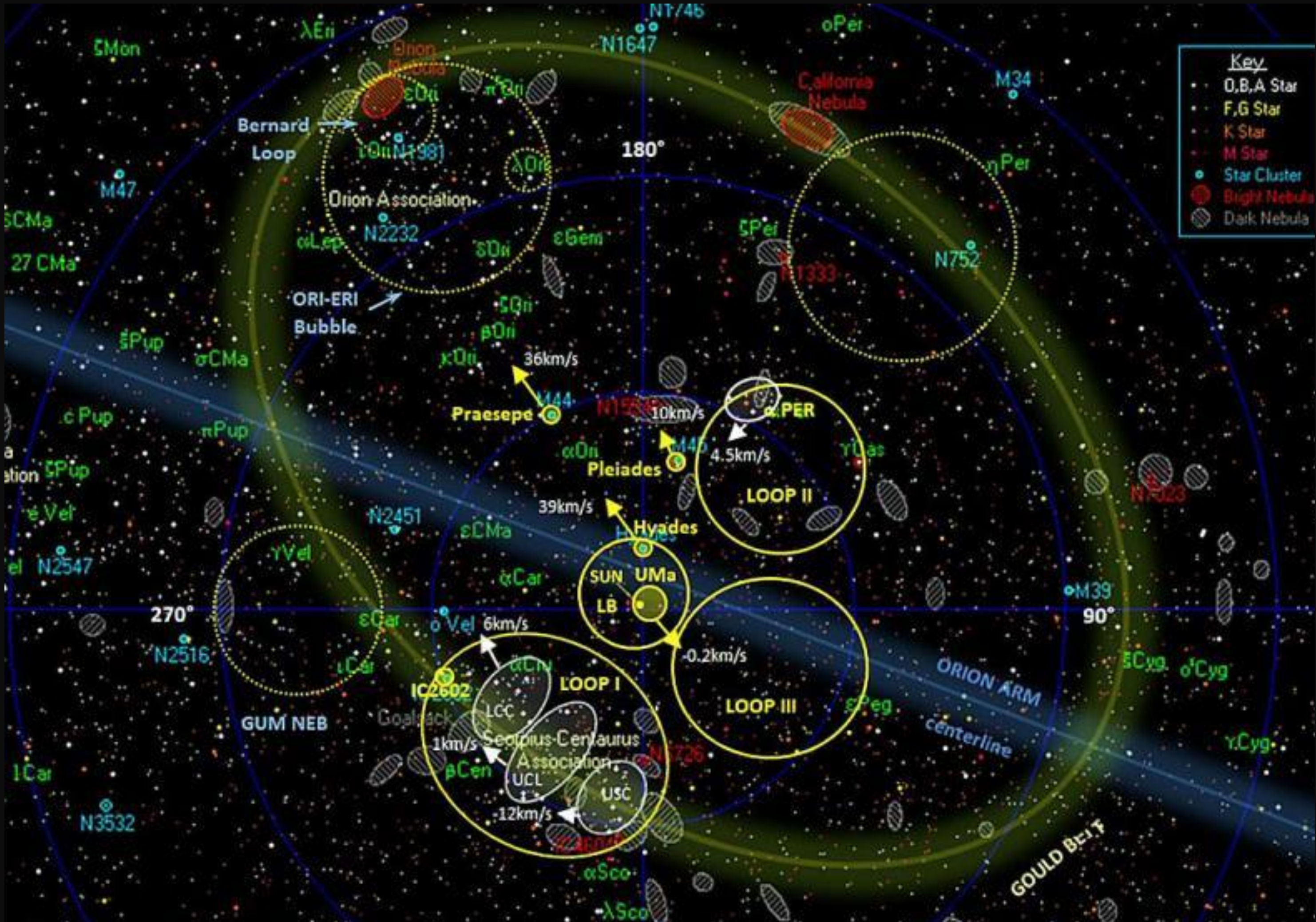


STELLAR STREAMS (Galactic plot)

In the next part of my rich field observation project, my primary goal was to study the stars in the smaller bubbles immediately surrounding our solar system, inside the star forming regions that I had observed previously in the OB-association project. Our sun and most of the older stars we can see out to ca. 1000 lightyears were born outside the current Local spiral arm, and are now just drifting through the galactic area of the Solar system neighborhood at relatively low-velocities (~30 km/s).

Some of these nearby stars still show evidence of being born together as separate open galactic clusters, but they are now mostly gravitationally unbound and in the process of being broken up under the influence of dynamic kinematic resonances from the rotating bar at the center of the Milky Way. The stars in each of these aging clusters are however still co-moving in the same general direction, which can be observed as **stellar streams** on the night sky. From the vantage point of our solar system close to the center of the Local Bubble, we can identify 3 large such stellar streams.

http://gruze.org/galaxymap/map_2020/



Stellar streams in our nearest Bubbles

The closest moving stellar stream surrounding and including the Sun is the **Sirius (Ursa Major)** stream in our own *Local Bubble*. Most of the bright stars in the Plough asterism are members of this stream. The nearest unbound co-moving groups of stars outside the Local Bubble are the **Hyades-Praesepe** stream and the **Pleiades** stream.

In adjacent Loops are seen some younger stellar association, which - although not entirely unbound - are so close that they appear as co-moving groups: The Loop-II α-Perseus stream and the Loop-I Scorpius LLC-UCL-USC streams.

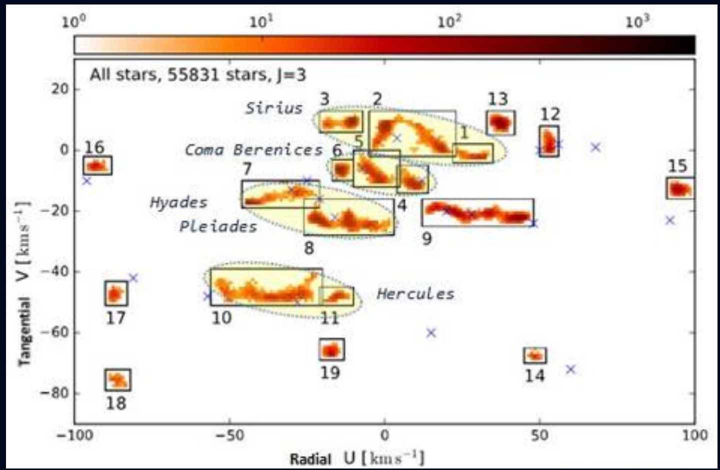
← Hipparchos star map, Atlas of the Universe, Richard Powell (my annotations).
http://www.atlasoftheuniverse.com/2000lys.html

Praesepe (SpaceEngine)

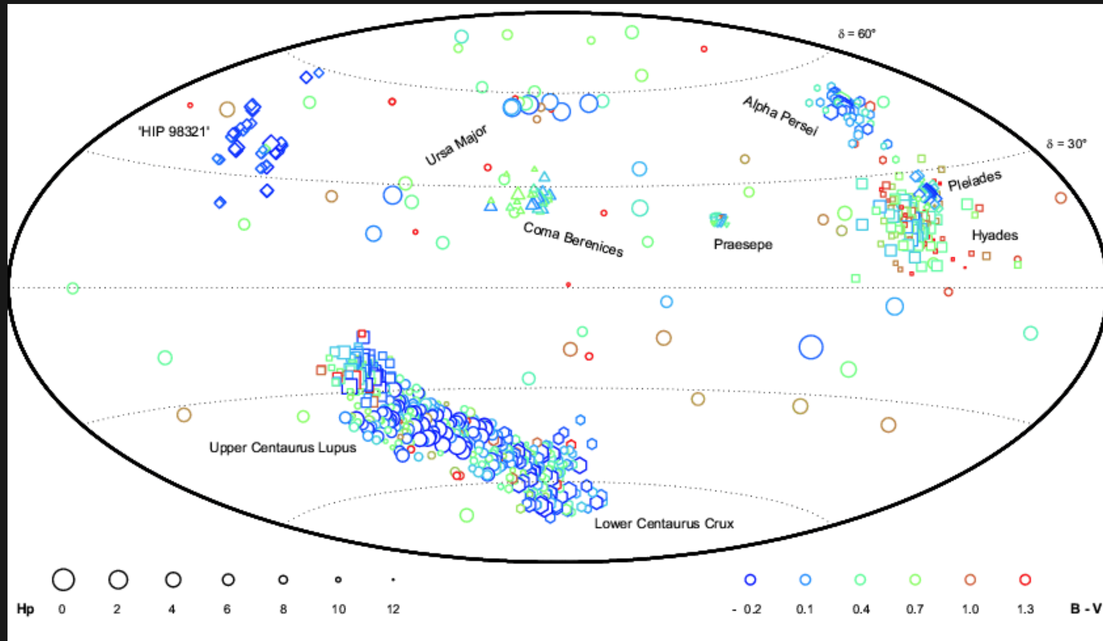
STELLAR STREAMS on the night sky.

In the co-moving clusters project, I observed the largest of the stellar streams (*Ursa Major, Hyades*) using my excellent modern **Zeiss 10x56** T*P* Abbe-König prism binocular clamped to a classic Unitron 2" Alt-Az mount on Berlebach adjustable tripod legs. This bino has a wide 6° FOV, so for smaller streams like the *Pleiades, Praesepe, α-Perseus* and *Coma Berenices* moving groups, I switched to my small **Vixen 2" and 3" refractors** on Zeiss TM mount to obtain a better framing (23x @ 3.2° or 31x @ 1.3° FOV).

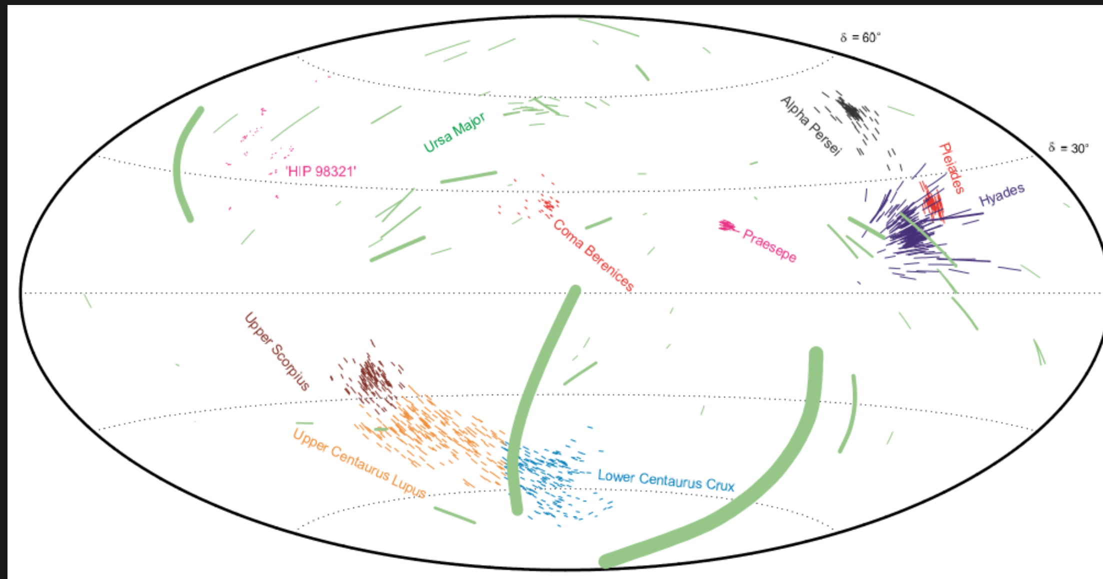
Kinematic structure of the solar neighborhood. GAIA DR1 ->



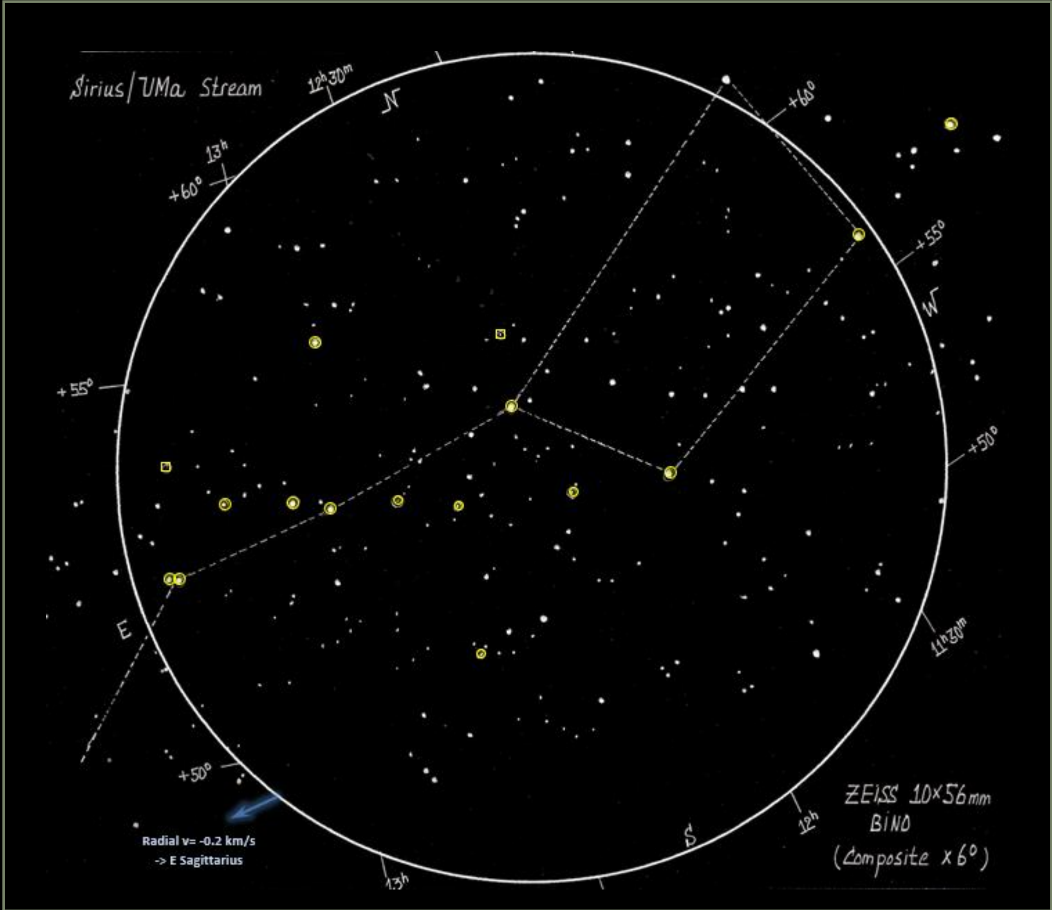
Full sky plot of moving groups (plus some larger open clusters / associations) based on Hipparcos data. Magnitude (Hp ~ m_v) and color index (B-V) are indicated.



Proper motion traces (astrometric radial velocities) for nearby stellar moving groups; Green UMa covers a large part of the sky. Vector thickness is inversely proportional to stellar distance.



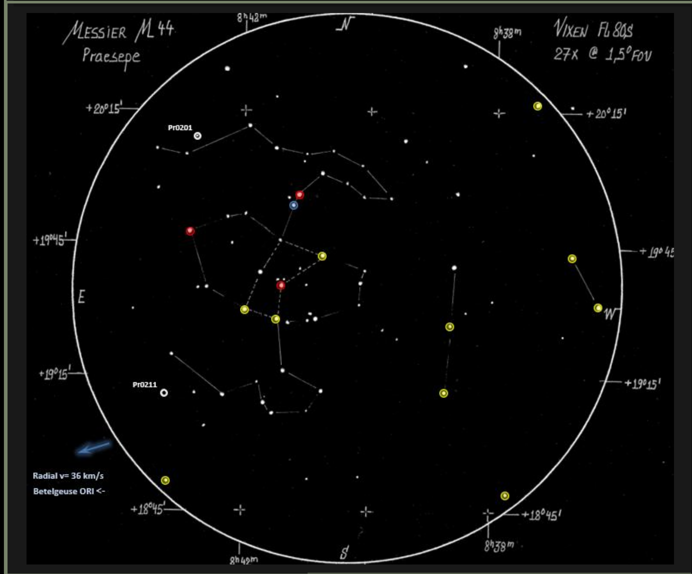
A&A 381, 446-463, S. Madsen et.al., ESO 2002

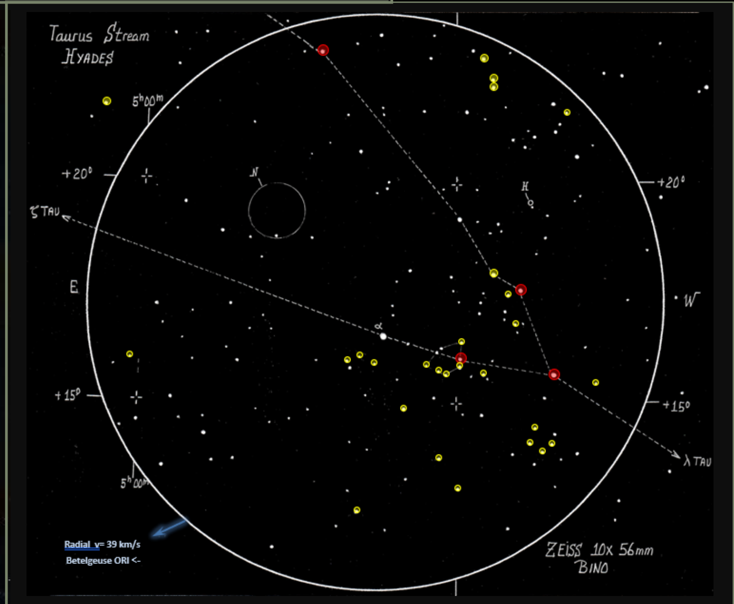


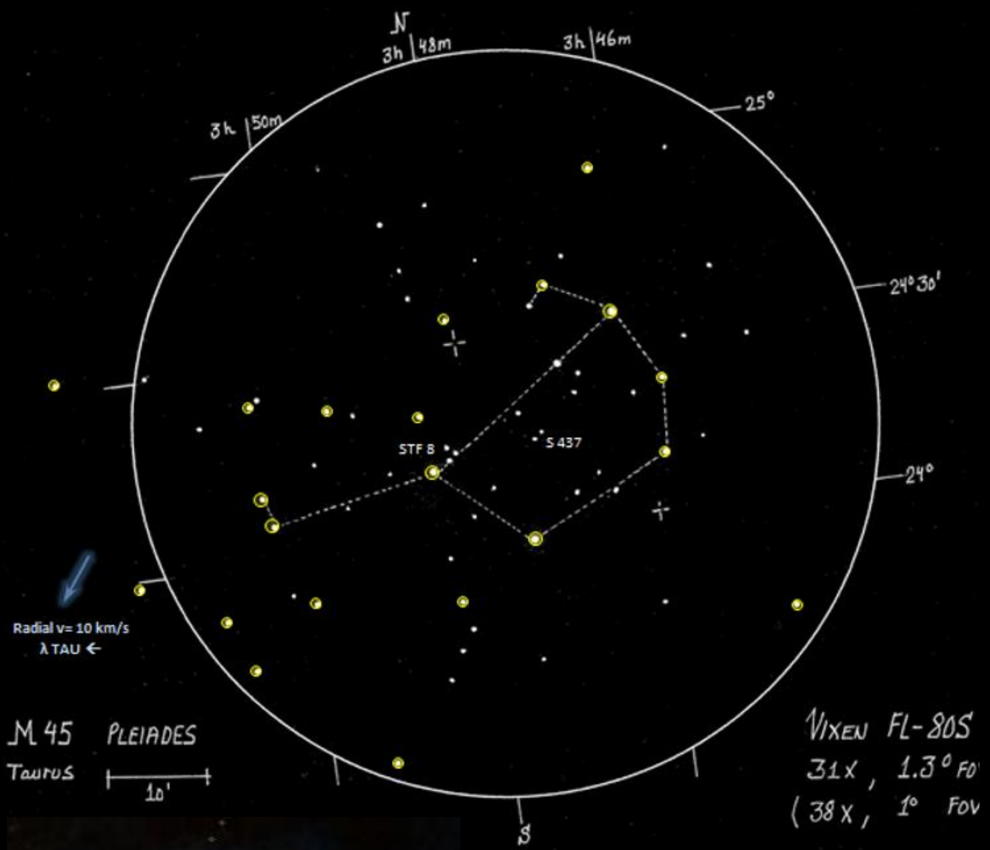
The **Ursa Major Stream** is the co-moving group closest to our Sun (80ly, 300 Myr age, with many type A0-1 stars). **The core** of the stream is located at the center of the Local Bubble, and it contains **14 stars** including the UMa *Big Dipper* group (Cr 285): ε (Alioth), ζ (Mizar), 80 (Alcor), β (Mirak), γ (Phad) and δ (Megrez). Around **100 more stars** are scattered widely around the core, to mention a few: α CMa (*Sirius*), β Aur (*Menkalinan*), β Eri (*Cursa*), α CrB (*Alphecca*), δ Leo (*Zosma*), δ Aqr (*Skat*), β Ser (*Chow*), γ Lep and further members "all over the map", -- to mention some more constellations with members of the extended UMa co-moving group (also known as the **Sirius Stream**): And, Aqr, Boo, Cam, CVn, Cap, Cen, Cet, Col, Com, Crt, Cyg, Dra, Gem, Her, Hya, Lac, LMi, Lyn, Mic, Ori, Pyx, Sgr, Sex, Tau, UMi and Vir). Our Sun is located on the outskirts of this stream, but is NOT a proper stream member (being > 10x older). The Sirius Stream incl. the UMa group is dispersing down the local Orion Spiral Arm towards the galactic center (east towards Sagittarius on the celestial sphere).

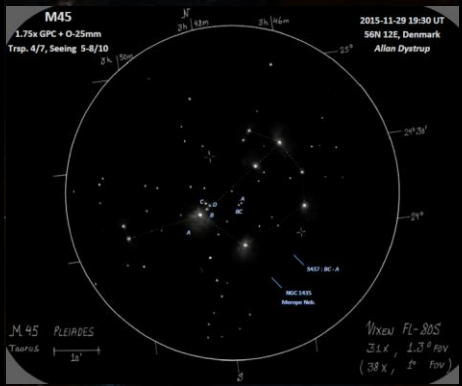
I can of course easily see the six main, bright (2-4^m) *"Big Dipper"* stars of the stream: *80 (Alcor) - ζ (Mizar), ε (Alioth), δ (Megrez), γ (Phecda)* and *β (Merak),* and also the somewhat fainter (~5^m) stream members: *78, 37* and *HIP62512*. Furthermore - with some patience and scrutiny – I am able to locate the still fainter (8-9.5^m) members stretching in a line from Phecda up NE past Alcor-Mizar, -- which I consider not bad at all, given the mediocre circumstances for the observation I've indicated the general direction and proper movement velocity vector for these stars.

The **Taurus (Praesepe-Hyades) Stream** is an old 625 Myr stellar stream located at the outskirts of our Local Bubble. Its most massive type-O stars have long time ago detonated as supernovae, and differential galactic rotation has since sheered the association into a lengthened ellipsoid stream, with two condensations: the distant Praesepe (Beehive) at ~577 ly distance plus the closer by Hyades at 150 ly, the latter currently partly inside the *Local Bubble* (LB). Its old age implies that the Taurus stream, including its two stellar associations, have travelled around the Galactic center together three times by now. The old, large bimodal stream is currently dispersing opposite the younger (~300 Myr) *UMa Stream* at the center of the LB with a velocity of ~37 km/s in the direction up and out towards Orion in the Local Arm (i.e. ESE on the celestial sphere with a P.A. ~105°, roughly towards *Betelgeuse*).









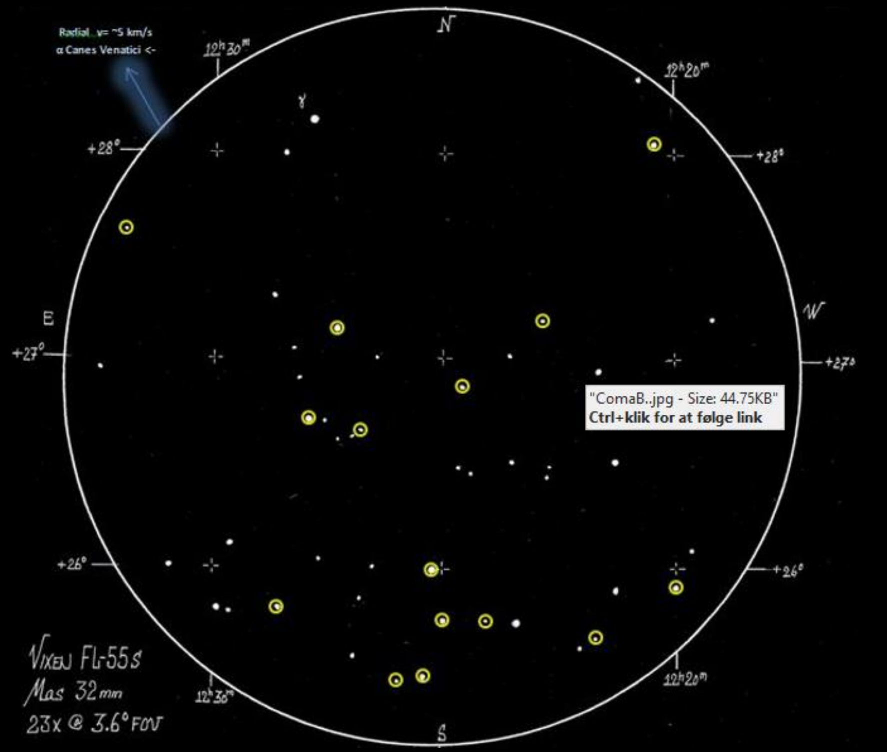
The **Pleiades Stream** is the youngest co-moving group in our solar neighborhood (410ly, 70 Myr);

It contains >400 stars located outside the Local Bubble, close to the dark *Taurus Molecular Cloud* (TMC); Many of the members are late-B giant, subgiant and main seq. stars, and the brightest B-stars in the central "dipper bowl" are lightening up some outlying dust of the TMC as faint reflection nebulae.

The Pleiades group is moving away from us at a radial velocity of 5km/s in the direction towards λ Tau. At a particular velocity of 5s/arc-sec per century, it will take the Pleiades >30,000 years to move a distance on the night sky equivalent to the visible diameter of the full Moon (½°).

The Coma Berenices cluster is a loose group of semi-bright stars (~40 members of 5m-10m) seen dangling like a filigree pendant necklace below Gamma Com.; It is a splendid sight in the 6° FOV of my 10x56mm bino, and still impressive at 23x and ~ 3.6° FOV in my small 55mm Vixen refractor. Although there's a high haze of thin Cirrus clouds, the central part of the Coma B. group is easily seen as more than a dozen, bright (5^m-8^m) stars, predominantly being yellow type A-F main sequence dwarfs.

The Coma Berenices star cluster (aka. Mel 111) consists of a total of ~40 relatively bright (5^m-10^m) stars with a common proper motion towards the North-East (-12.5, -9 mas/Yr), and a radial velocity of ~ 5.5 km/s. The distance to Coma B. is ~86 pc (280ly), almost twice the distance to the Hyades (151 ly), but only half way out to the Pleiades (444 ly). Coma B. is also intermediary with respect to age (450 Myr), but this time with the Pleiades as the youngest (100 Myr) and the Hyades as the older brother (800 Myr).



OB-associations as co-moving stellar streams.

Besides the close by old open clusters in the solar system neighborhood, some nearby OB-associations also show up as co-moving streams on our night sky. Examples of this are the old B-association α Persei and the much younger OB-associations in Scorpius-Centaurus and Vela.

The Per OB-3, the Alpha Persei Moving Cluster (Cr39).

The most luminous stars in the association are the yellowish type-F supergiant Alpha Per (~2^m "*Mirfak*") and ~4^m type-K Sigma, but the association also includes several blue type-B stars such as Delta, Psi, 29, 30, 31, 34 and 48 Persei. The cluster has a beautiful overall "S"-shape, somewhat like the Orion OB-1b association. O'Meara has described it as an outline of the serpentine body of the sea monster that Perseus turned to stone (using Algol, the fierce eye in the snake-haired head of the Gorgon Medusa). I find this description very fitting , although O'Meara interpreted the outline a little different than the way I see it.

The Sco-CMa Blue Stream

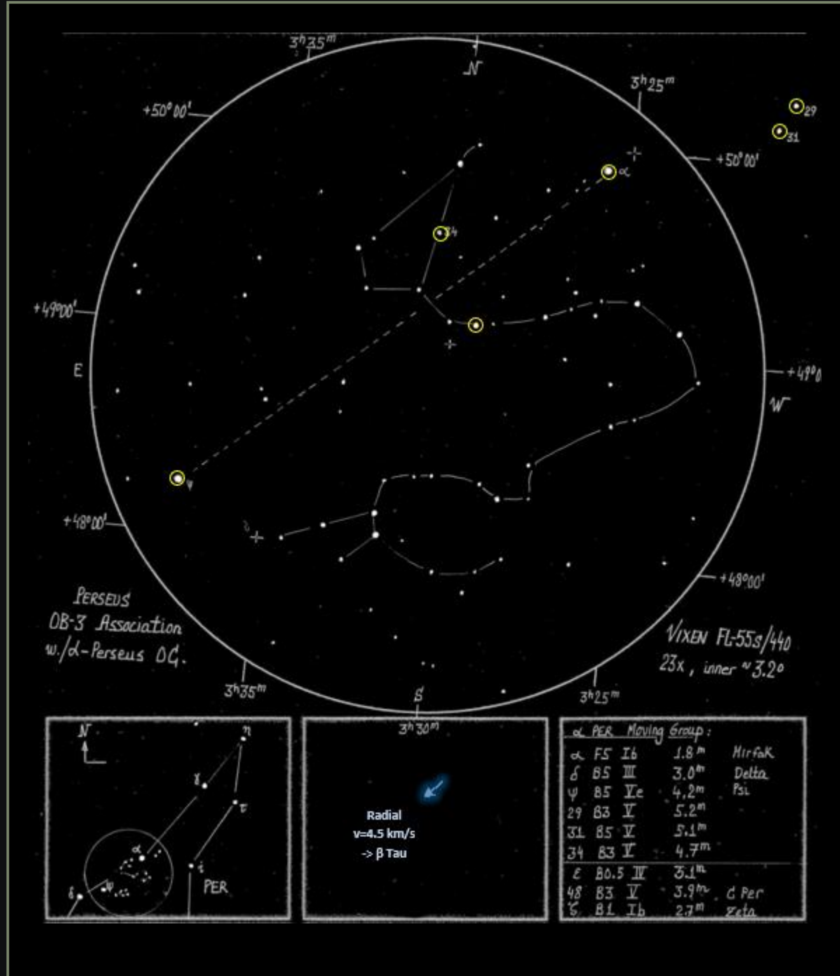
The OB associations and clusters inside this stream are spatially coherent and continuous over ~350 pc, and they display an age and distance gradient that clearly indicates a common origin:

- starting from the old open clusters in Puppis (65 Myr NGC 2451A OC and 40 Myr Cr 135, at 400-350 pc),
- then down south through the 50-30 Myr OCs in Vela-Carina (IC 2391, IC 2602 and A-Car OCs, around 200 pc),
- then sequentially passing up through the large 15–20 Myr LCC and UCL associations (100-50 pc),
- to finally reaching the young and close (4 ~ 11 Myr) USco.

The Vela Blue Stream.

The OB associations and clusters in the Vela stream are a ~150 pc long and young (< 35 Myr) separate "clump" at the old end of the Sco-CMa stream; The Vela stream is at 300-400 pc distance,

- centered on Vela OB2 with the the 5-10 Myr young open cluster Gamma Velorum;
- It also includes the somewhat older (~30 Myr) OCs: Tr 10 and NGC 2547

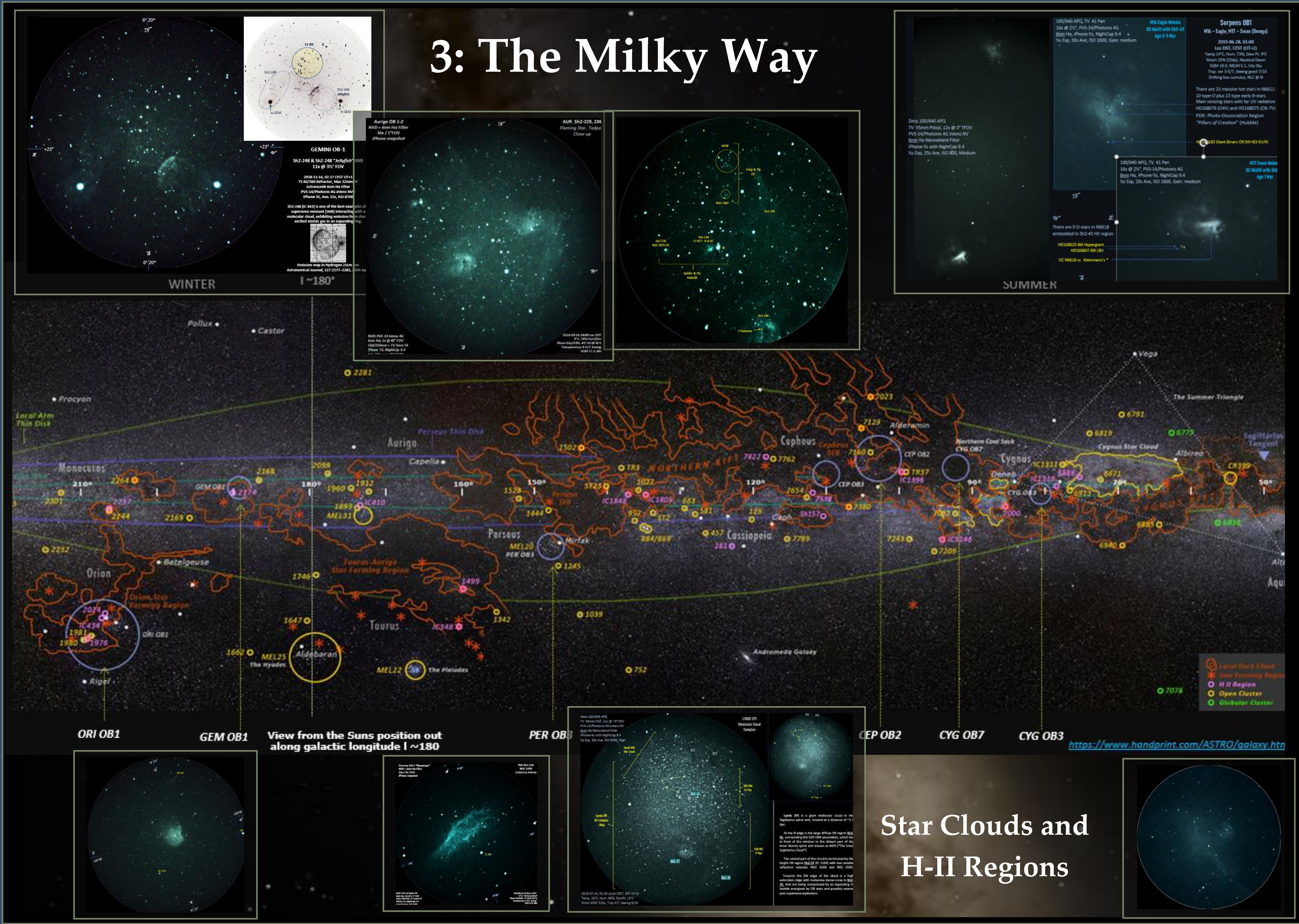


Having observed the bright associations of newborn massive type OB-stars in the blue streams lining the wall in the galactic plane of our Local Superbubble, and having continued with a survey of the ageing dispersing star clusters now scattering as co-moving streams through our solar system Local Bubble and its surrounding Loops, my next goal now became a wide-field study of the interstellar medium (ISM) that originally gave birth to these star clusters, and to which much of the stellar material will eventually return in the form of inflated atmospheres of dying stars, planetary nebulae, WR-stars, novae and supernova explosions.

If you want to read more about the Local Arm Bubbles & streams, I have shared several of my observations in depth at the Cloudy Nights astro-forum, in this thread: http://www.cloudynights.com/topic/565226-classic-rich-field/?p=8252539

In the next chapter in this summary of my Classic Rich Field project I will focus on **3: The Milky Way– Star clouds and H-II regions.**

3: The Milky Way



Looking out into the Milky Way from our Local Arm

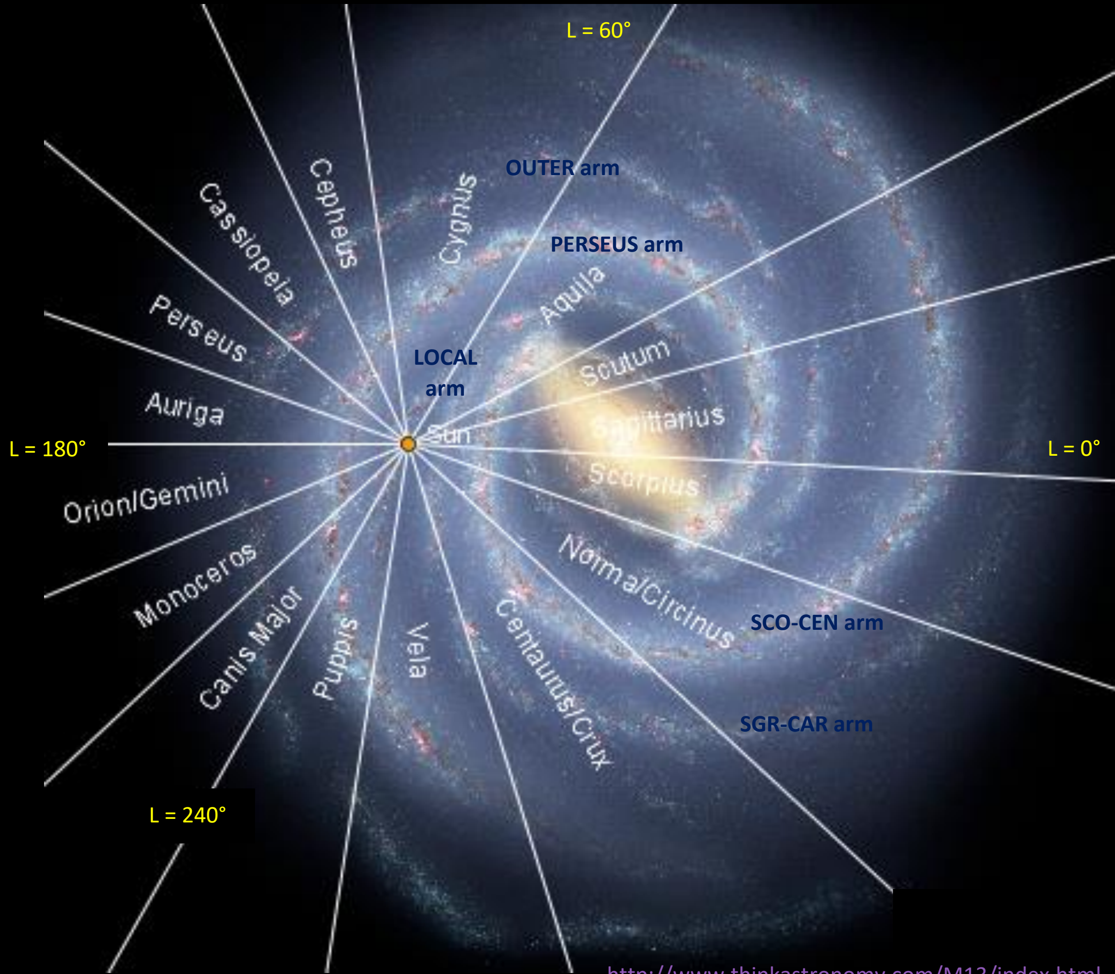
When we point our telescope south in summer on the N hemisphere, we face towards the galactic center (gal. long. 0°). Here we see part of the Milky Way central bulge at 30 Kly distance as the *Great Sagittarius Star Cloud*, and part of the innermost incurving Norma Spiral Arm at 15 Kly as the *Small Sagittarius Star Cloud* (M24). Most of the open clusters and nebulae in this direction (*Lagoon-Trifid-Swan-Eagle*) are however located at only ~6 Kly in the nearest inner spiral arm from our solar system: the Sagittarius-Carina arm. The Sco-Cen OB association is an even closer (0.5 Kly) Gould Belt feature of the inner edge of our own Local Orion-Cygnus spiral arm.

In Scutum (l ~30°) we are beginning to look lengthwise down the Sag-Car arm (the *Scutum Star Cloud*), while in Aquila (between VUL and SER) we are facing the interarm gap between the two Ori-Cyg and the Sco-Cen galactic spiral arms. Finally, in Cygnus (l~60°) we are looking directly into the incurving arc in the rotational direction of our own Ori-Cyg arm (the Cygnus Star Cloud).

When pointing the telescope south in winter on the northern hemisphere, we are looking from our Local Arm out of the Milky Way, towards the *outer Perseus Arm* of the galaxy (gal. long.: l ~180°),

The view in winter is relatively unobstructed, with the close by molecular clouds and OB-associations of the Orion-Eridanus superbubble as the major showpiece. In contrast, the view in summer towards the big Cygnus star cloud is heavily obstructed by dark dust, including *the Cygnus Rift,* to such an extent, that the nebulae and OB-associations of the Cygnus superbubble (CSB) are severely dimmed.

As an example, the Orion star forming region (with M42 and the Orion OB-1 associations) can be visually studied in detail, as it is located close to our Sun (0,5 kpc ~ 1.5 Kly) in the *Gould Belt*, while the Cygnus-X star forming region is more than 3x as distant (1.8 kpc ~ 6 Kly), but even with over 30x the mass of the Orion region, it is still dimmed by up to 95% in the central part, and is thus best studied in IR and radio emissions. Some structures though can still be caught visually with a good RFT.

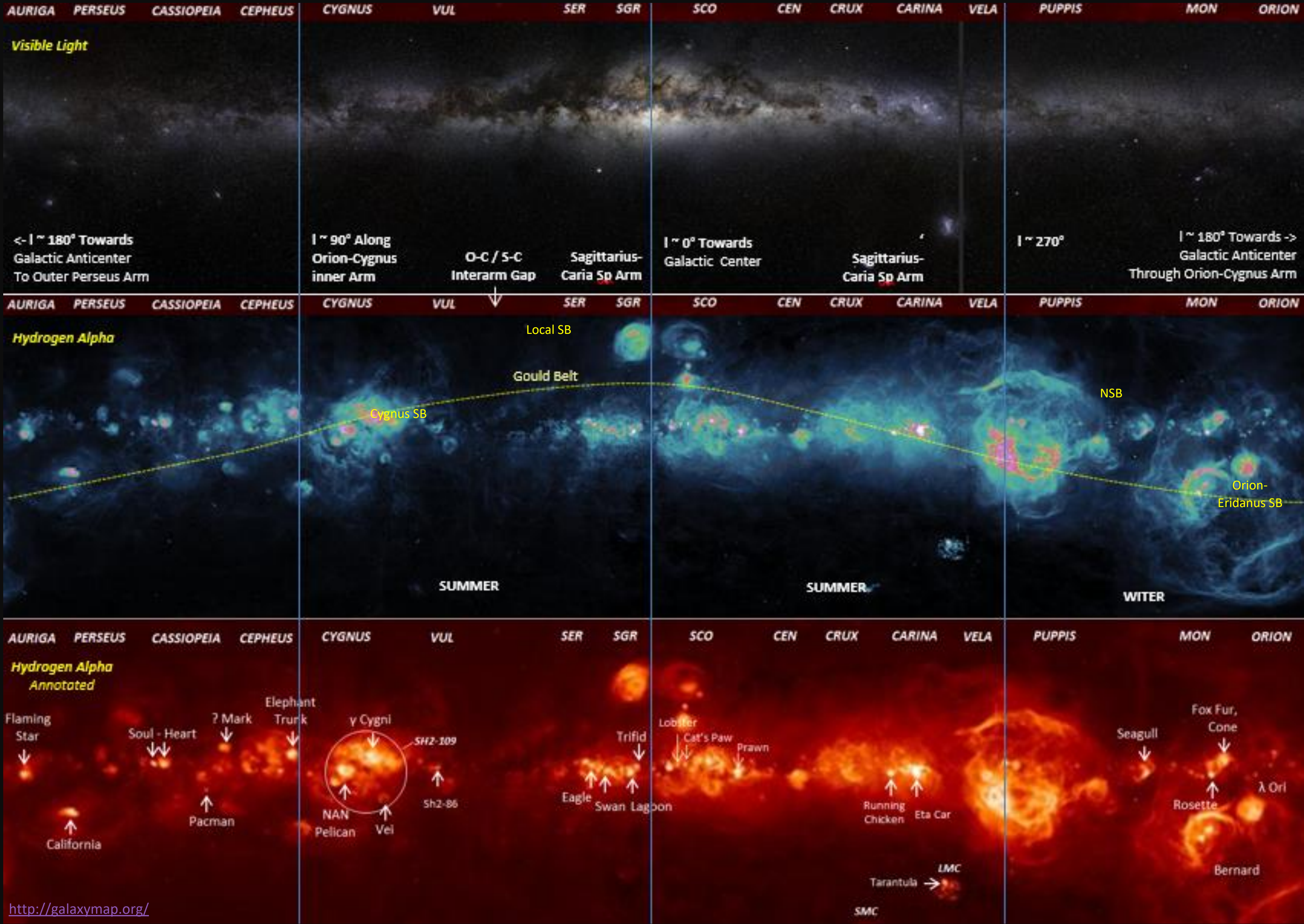


http://www.thinkastronomy.com/M13/index.html

The star clouds in the arms of our Milky Way galaxy contain a multitude of young OB-associations as well as older open clusters, all born from dense nebulae of neutral Hydrogen gas (H-I) in the galactic disc. The massive hot type-O and early B stars in the young stellar associations emit high energy UV-radiation that excites the electrons in the interstellar medium (ionized Hydrogen: H-II), which then emit photons at the red wavelength of 656nm (Hα spectral line) when the hydrogen atoms jump back to their lower energy state. The Milky Way arms are rich in such star birth areas with Hα emission nebulae (H-II regions), as is evident when looking at Hα images of our galaxy.

In the first section of this article I have described some of the major OB-associations in our Milky Way galaxy, and also briefly touched upon a few of the emissions nebulae connected with these associations, -- but my main focus back then was on stellar astronomy, for the primary reason that my observing conditions (suburban backyard) and tools (2-3" refractors, glass eyepieces, R2 live video cam) simply did not allow a detailed study of delicate wide field nebula structures.

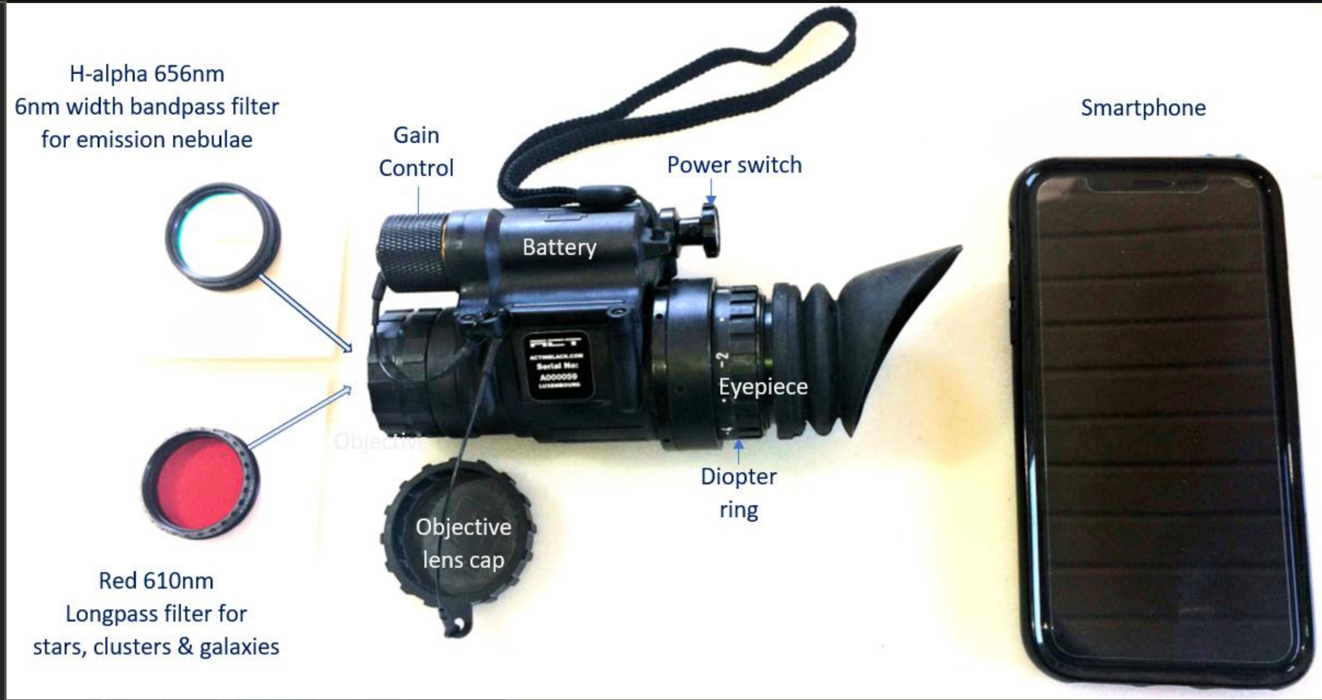
This situation did however change when, in the spring 2018, I acquired a modern gen-2+ military NV monocular that allowed me to study the H-II regions in our galaxy in rich detail, opening a whole new portal to the Milky Way ISM (interstellar medium) structures. For an overview, I first created an annotated map of the Milky Way in galactic coordinates, using '*Galaxy Map*'. The solar system position is on the inner edge of our Orion-Cygnus spiral arm, so when we look towards the galactic center (i.e. south in the summer from mid-northern latitudes), this is what we see (next page):

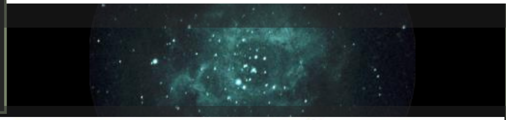

AURIGA
PERSEUS
CASSIOPEIA
CEPHEUS
CYGNUS
VUL
SER
SGR
SCO
CEN
CRUX
CARINA
VELA
PUPPIS
MON
ORION
Visible Light
<- l ~ 180° Towards
Galactic Anticenter
To Outer Perseus Arm
l ~ 90° Along
Orion-Cygnus
inner Arm
O-C / S-C
Interarm Gap
Sagittarius-
Caria Sp Arm
l ~ 0° Towards
Galactic Center
Sagittarius-
Caria Sp Arm
l ~ 270°
l ~ 180° Towards ->
Galactic Anticenter
Through Orion-Cygnus Arm
Hydrogen Alpha
Local SB
Gould Belt
Cygnus SB
NSB
Orion-
Eridanus SB
SUMMER
SUMMER
WITER
Hydrogen Alpha
Annotated
Flaming
Star
Soul - Heart
? Mark
Elephant
Trunk
γ Cygni
SH2-109
California
Pacman
NAN
Pelican
Vei
Sh2-86
Trifid
Eagle
Swan
Lagoon
Lobster
Cat's Paw
Prawn
Running
Chicken
Eta Car
LMC
Tarantula
SMC
Seagull
Fox Fur,
Cone
Rosette
λ Ori
Bernard
http://galaxymap.org/

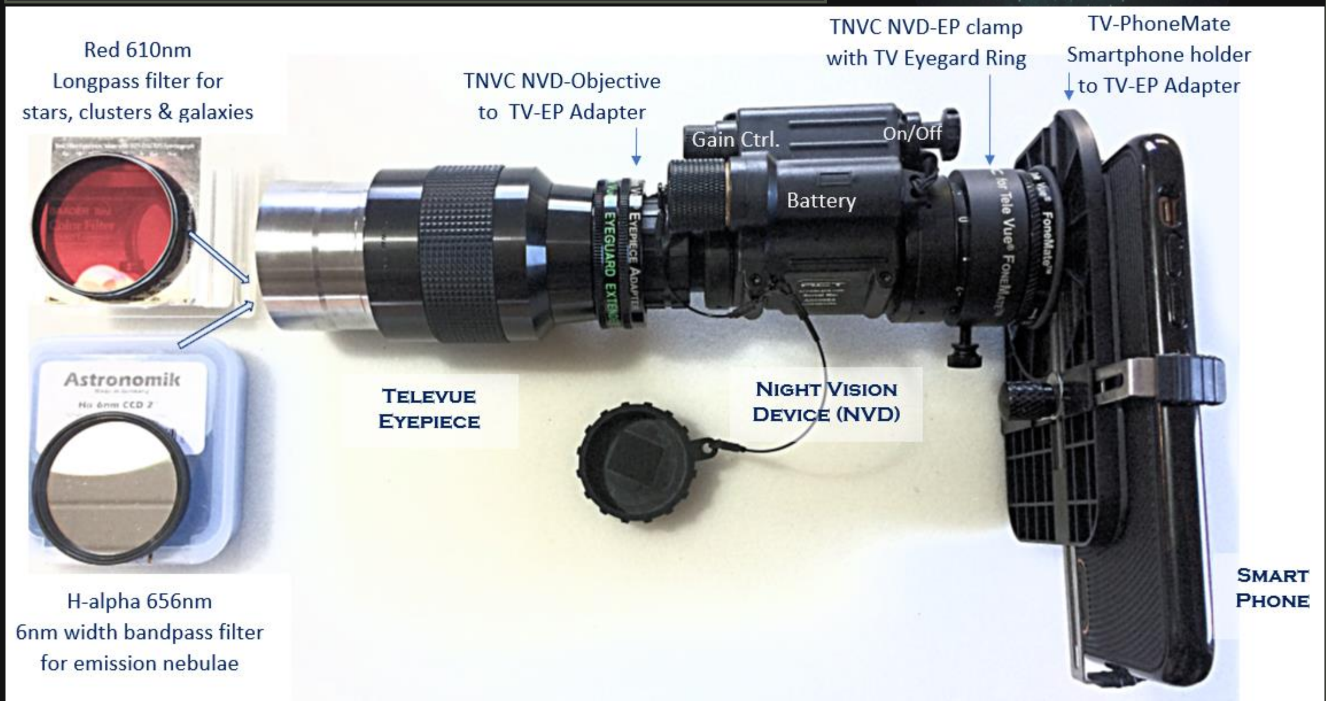
Equipment for rich field emission nebula observation.

My **PVS-14 night-vision device (NVD)** is in itself a small refractor with a 22mm f/1.2 objective and a 26mm eyepiece, yielding 1x magnification in a 40° field of view. The NVD, however, is able to achieve a dramatic opto-electronic amplification by passing the incoming light through an internal image intensifier tube: each photon is directed by the objective to a micro-channel plate where it causes a cascade of electrons; the electrons are then accelerated by a photocathode to hit a phosphor screen at the back of the NVD, where it releases a burst of photons producing a bright image that is viewable through the eyepiece. The NVD is sensitive to both visible and near-infrared light.

When used **at 1x, the NVD shows a huge 40° true wide field view** of the Milky Way star clouds (using a 610nm red longpass filter) and a jaw dropping view of emission nebulae (using a 656nm Hα 6- or 12nm narrowband filter). Both filters cut off light pollution, but they also introduce some band shift when used on the very fast f/1.2 objective of the NVD. This is usually not an issue when panning around and observing visually, but filter de-tuning does shows up off-axis as contrast-loss at the edge of the wide FOV when snapshots are taken through the NVD.







For **higher magnifications** the NVD can be mounted on top of any TeleVue eyepiece (with a DIOPTRX compatible eyeguard ring) for live viewing through a telescope. The objective of the NVD is placed at the exit pupil of the eyepiece (a-focally, i.e. after the main telescope focal point), so the exit pupil can be as large as the objective diameter of the NVD (~20mm), and still be fully utilized by the image intensifier. A combination of a fast telescope and a long FL eyepiece will yield the brightest image, but my medium-FL refractors (~f/6-8) also give quite satisfying results.

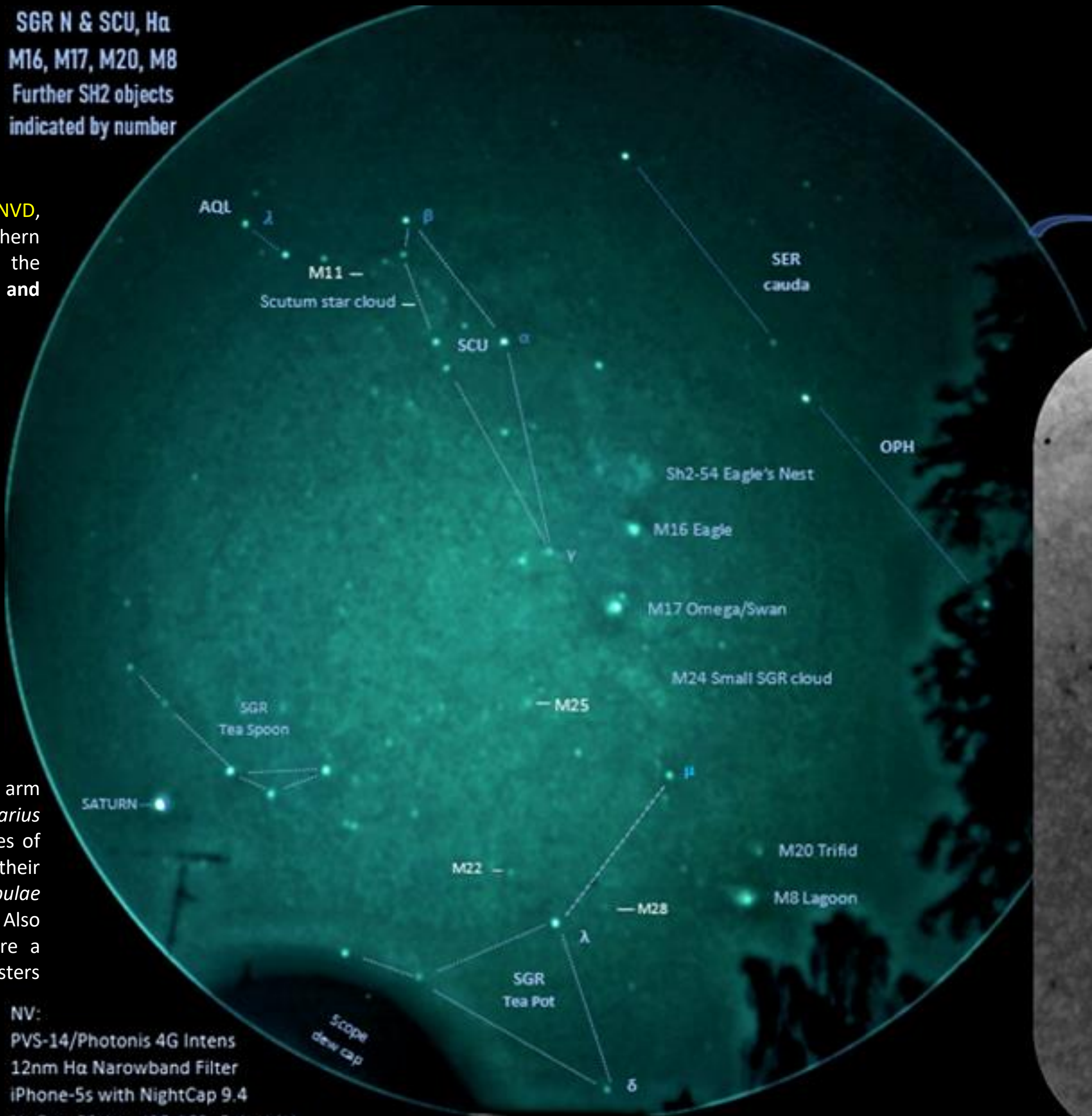
A **smartphone** can be connected to the NVD eyepiece for recording snapshots or small live video sequences of the observations. I've used this setup with good results on several telescopes, from my small 2" f/4 finder scope to my big 4" f/6.4 refractor. Granted, the resolution is not quite at the level of traditional electronically assisted live video with stacking (not to speak of classic long-exposure astrophotography), BUT the boost in light gathering allows astonishing wide-field real-time viewing of emission nebulae combined with quick and yet quite decent 10-30s averaged exposures.

The Summer Milky Way
Galactic longitude ~0°

Here's a view facing south in Summer towards the Milky Way center (gal. long. 0°). We can see part of the innermost incurving Norma Spiral Arm at 15 Kyr distance (the *Small Sagittarius Star Cloud:* M24), and we can also spot several bright emission nebulae in this direction (*Lagoon-Trifid-Swan-Eagle*, all in the nearest inner Sagittarius-Carina spiral arm). Up in Scutum we are looking lengthwise down the Sag-Car arm (seen as the *Scutum Star Cloud*), until in northern Aquila (from Serpens to Vulpecula) we meet the interarm gap between Sco-Cen and our Local Ori-Cyg spiral arms.

SGR N & SCU, Hα
M16, M17, M20, M8
Further SH2 objects
indicated by number

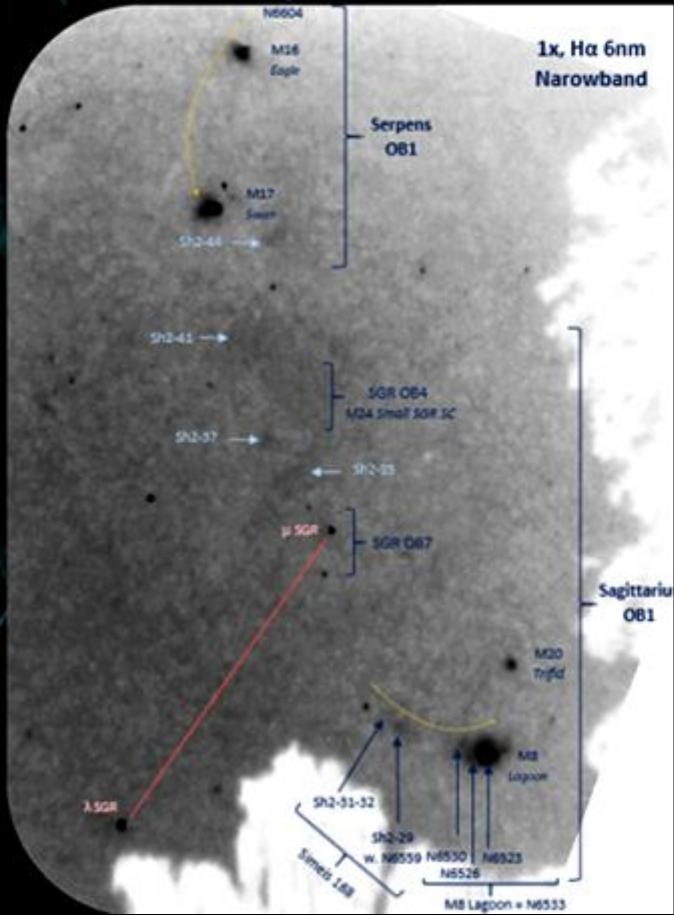
Here's a **1x view** through my NVD, showing a 40° field of the southern summer night sky, centered on the area between **Sagittarius and Scutum**.



2019-06-23, 01:30 CEST DST (UT+2)
Trsp. 3/7, Seeing 2/10, NELM 4.8 (SQM 17.5)
Temp.: 9°C, Hum.: 93%, DewPt: 8°C
Moon 71% (20dy) in AQR at SE horizon
Summer solstice, thin high NLC at N-NW horizon

1x Mag @ 40°FOV
Hα 12nm Narowband

Zoom-in

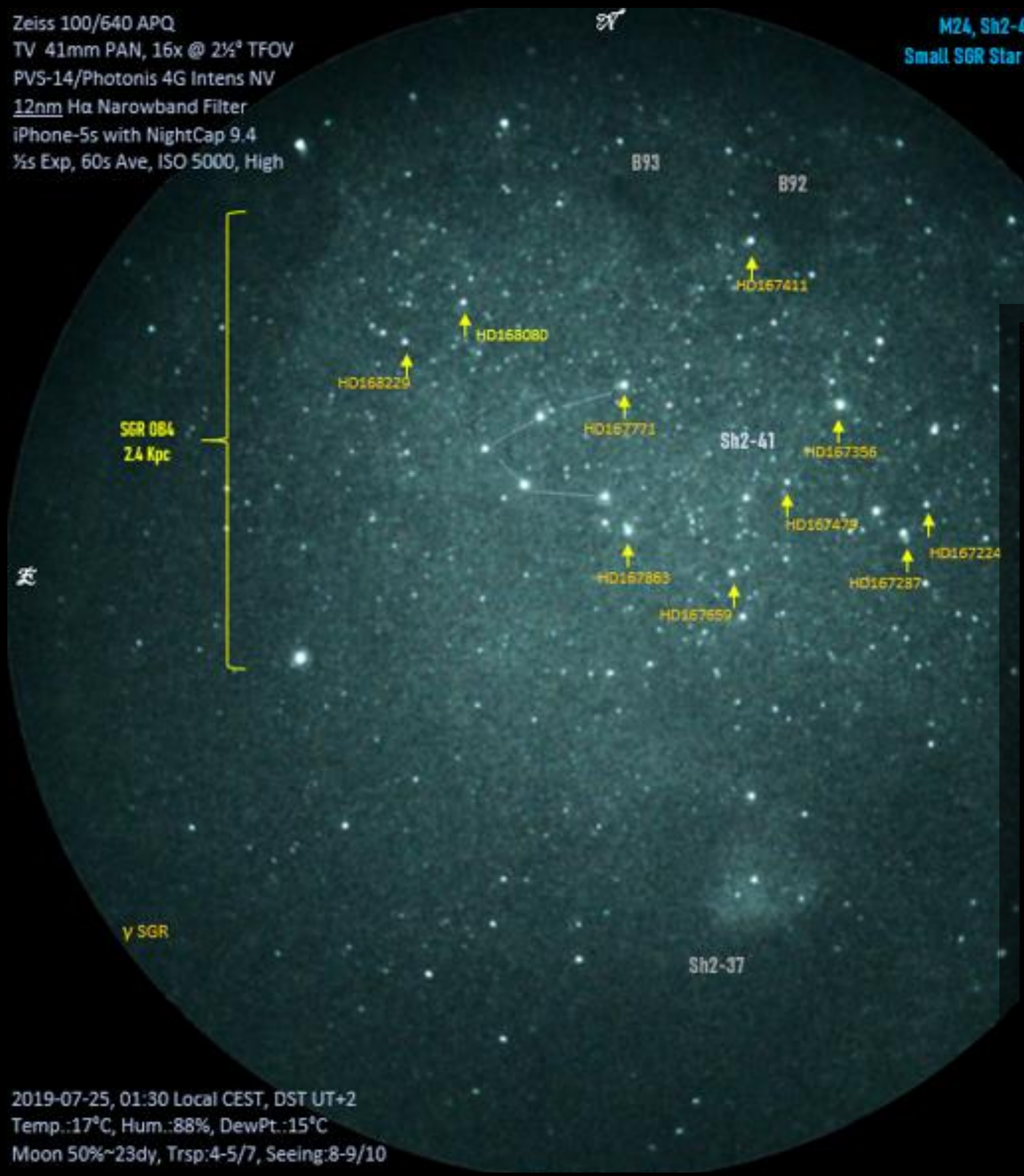


We see the two large galactic arm *star clouds (Scutum and Sagittarius aka M24),* sprinkled with a series of young OB-associations plus their surrounding emission *nebulae (Lagoon, Trifid, Eagle, Swan)*; Also visible along the Milky Way are a couple of older open galactic clusters (M11, M25).

NV:
PVS-14/Photonis 4G Intens
12nm Hα Narowband Filter
iPhone-5s with NightCap 9.4
⅓s Exp, 30 Ave, ISO 160, Gain: high

Looking S towards the Milky Way galactic center, I start my sweep of the Sgr-Car spiral arm from the part closest by (1.3 kpc) at the horizon, and then I'll pan up N and farther away (2 kpc), as the Sgr-Car spiral arm winds inwards and around the galactic bulge in Scutum.

SGR OB1 is the nearest and largest OB-association in this area, as seen from our position here on the inner edge on the Ori-Cyg arm; It stretches from the M8 (Lagoon) and M20 (Trifid) nebulae in the S, up to and including the Sharpless 35-37-41 HII regions in the N (aka *the Lynds 291 molecular cloud complex*). My observation tonight of SGR OB1 will focus on M8 and M20, so I'll save the structures in L291, including the bordering SGR OB7 (1.75 kpc) and SGR OB4 (2.4 kpc), for another time. As I've tentatively indicated in previous posts, the SGR-SCU area of the night sky is very "busy", overlaid by several regions of star associations and molecular clouds of all sorts (emission, reflection, dark), so it can be difficult to piece together a coherent 3D spatial description of the objects (much like the Cygnus area btw).

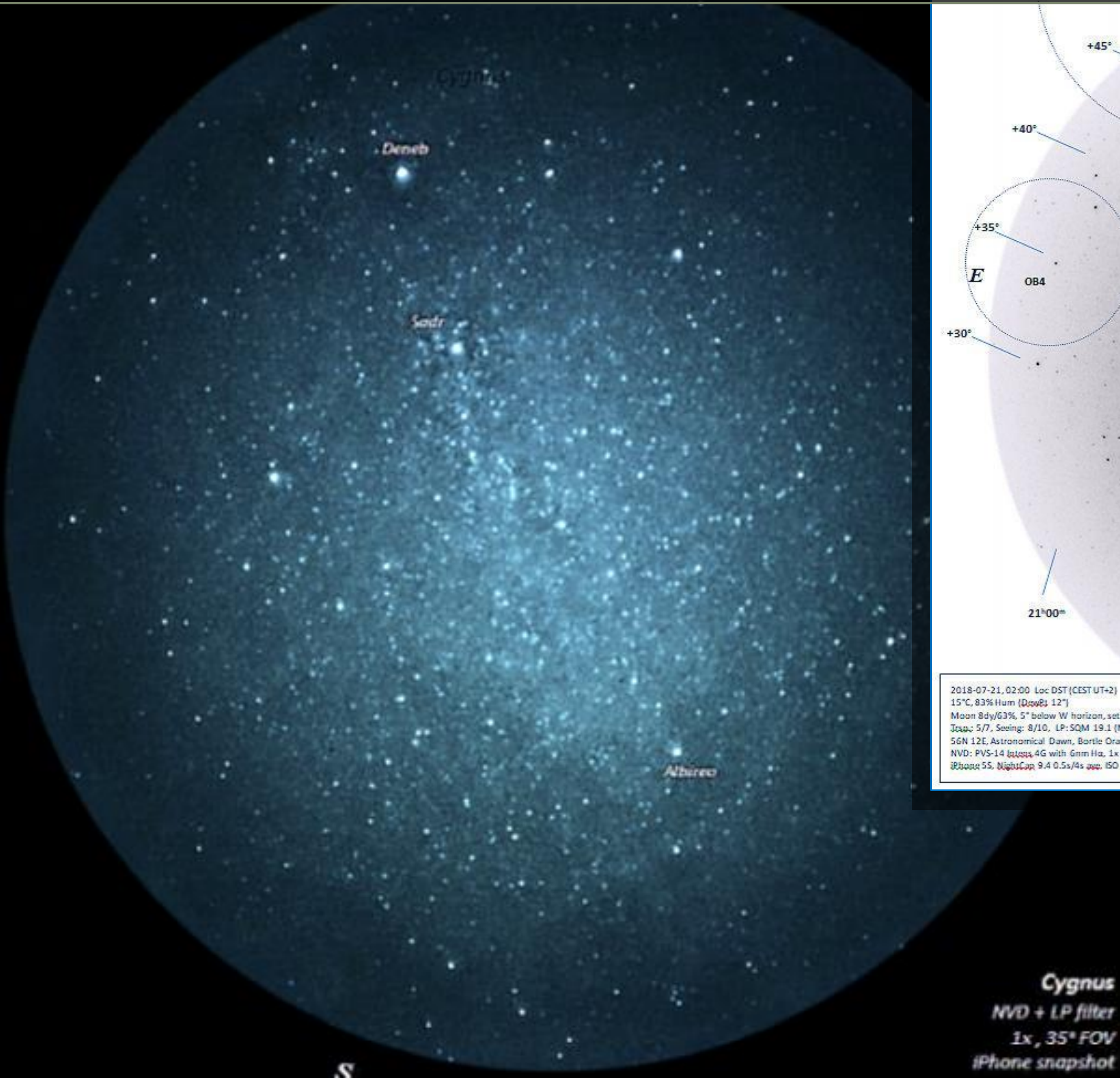


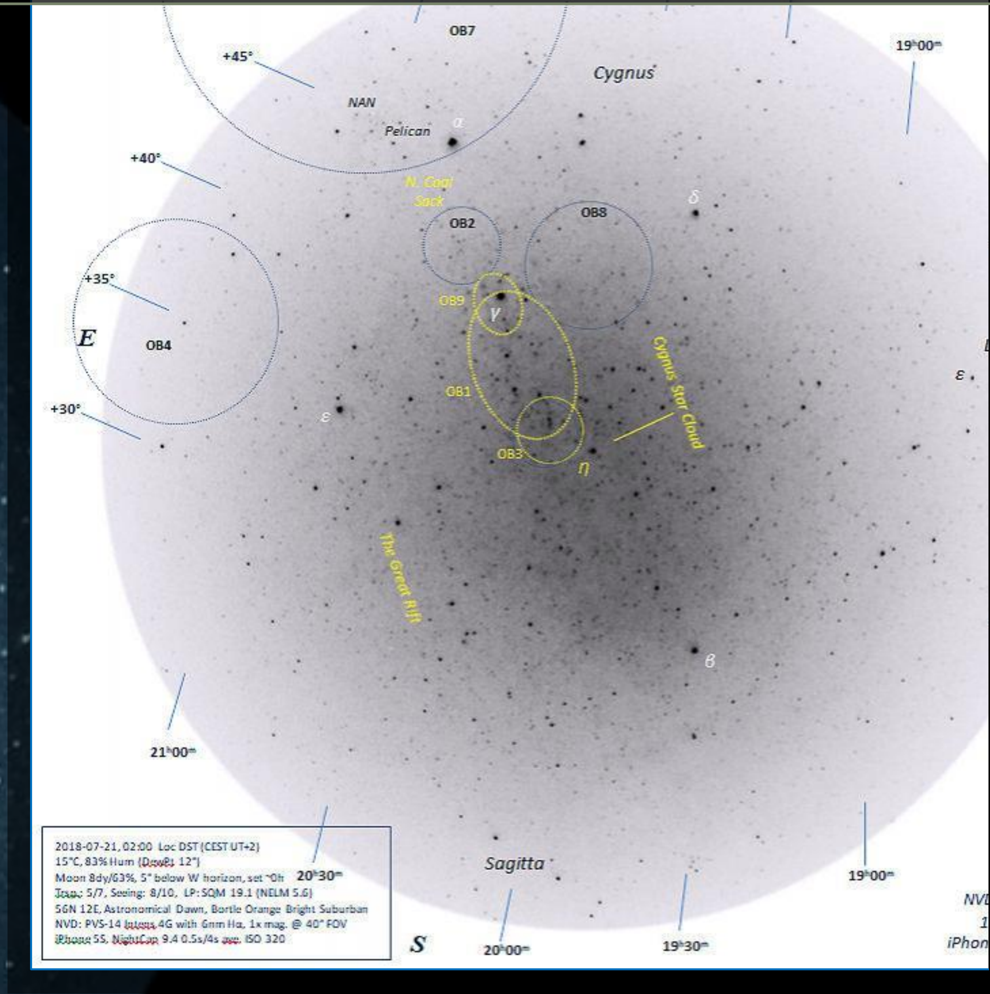
Lynds 291 is a giant molecular cloud in the Sagittarius spiral arm, located at a distance of ~1.7 Kpc. At the N edge is the large diffuse HII region Sh2-41, surrounding the SGR OB4 association, which lies in front of the window to the distant part of the inner Norma spiral arm known as M24 *("The Small Sagittarius Star Cloud").*

The central part of the cloud is dominated by the bright HII region Sh2-37 (IC 1284) with two smaller reflection nebulae: NGC 6589 and NGC 6595. Towards the SW edge of the cloud is a high extinction ridge with numerous dense cores in Sh2-35 (not seen in this snapshot) , that are being compressed by an expanding HI bubble energized by OB stars and possibly several past supernova explosions.

Galactic longitude ~90°

When sweeping further up the Milky Way to **Cygnus** (gal. long. 90°), we are now looking tangentially in the rotational direction of the incurving arc of our own Ori-Cyg spiral arm (seen as the *Cygnus Star Cloud*), with a superposition of objects at distances from 0.5 kpc (NAN-Pelican, Veil), past 1 kpc (CYG OB4, OB7, E Cyg Rift) and 1.5 kpc (CYG OB1, OB2, OB9) and out to the ~2 kpc distant structures (CYG OB3, OB8, W Cyg Rift). The emission nebulosity in this area shows up on the night sky in Hα as a continuous giant glowing cloud with brighter knots in a patchwork from the *NAN-Pelican* at α Cyg, past the *Butterfly* at γ Cyg to the *Tulip* at η Cyg.





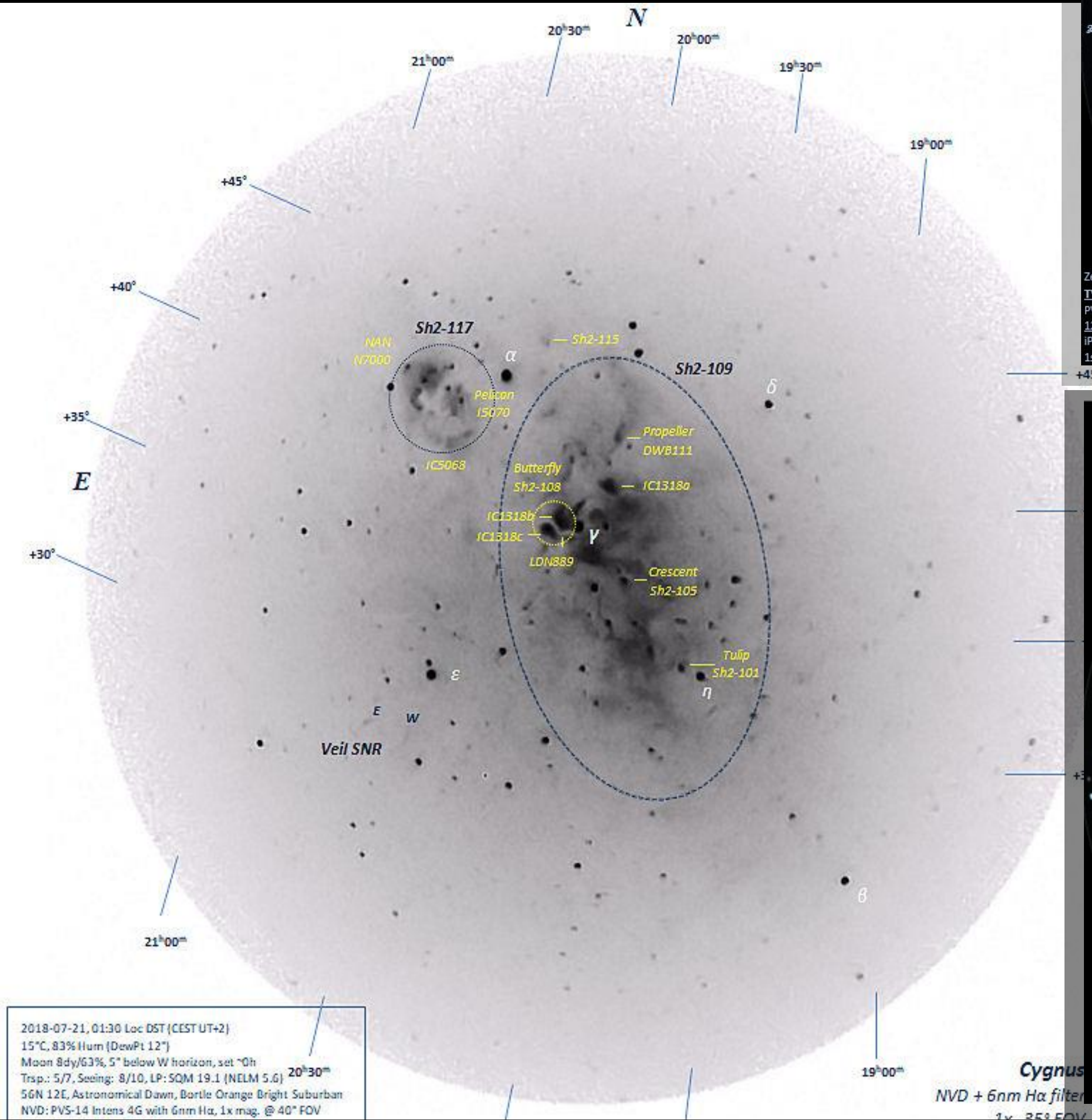
Here's first an observation of the *Cygnus Star Cloud*, annotated with the major OB-associations found towards the edge of the *Cygnus Superbubble* (CSB). The image is an iPhone snapshot through the NV monocular with a **610nm red longpass-filter at 1x**. It shows 35° of the field, including the Cygnus, Lyra and part of the Aquila constellations.

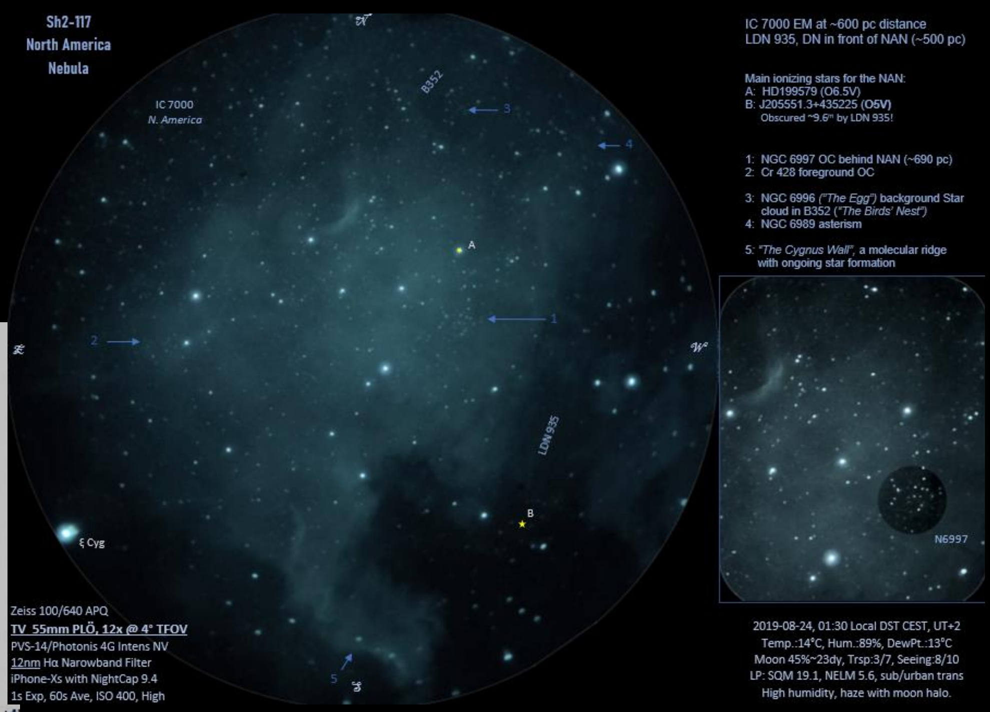
The central region of the view is dominated by countless stars along the length of our inner Orion-Cygnus spiral arm, winding up around the galactic center. Our sun, together with the UMa co-moving star group, is currently headed up this spiral arm towards Deneb.

And here's the same field of view as shown on the previous page: 1x magnification, but now with **a 656nm Hα-filter** on the NV device. You can see the dark dust lane along the Galactic plane of our Orion-Cygnus spiral arm (the *"Great Cygnus Rift")*.

This structure of dark molecular clouds harbors many regions of nebulosity with active star formation, the largest HII-regions being the W80 in Cyg OB7 including the *NAN-Pelican* nebulae E of Deneb (aka Sh2-117), plus CYG-X in Cyg OB 2/9 with the *Butterfly* nebula around Sadr (aka Sh2-108, IC1318 and LBN234). Also seen are the smaller *Propeller* (OB8,9) plus the *Crescent* and *Tulip* nebulae (OB1,3) further south towards η Cygni.

To the right: a couple og closer up observations of the North America and the Butterfly emission nebulae:

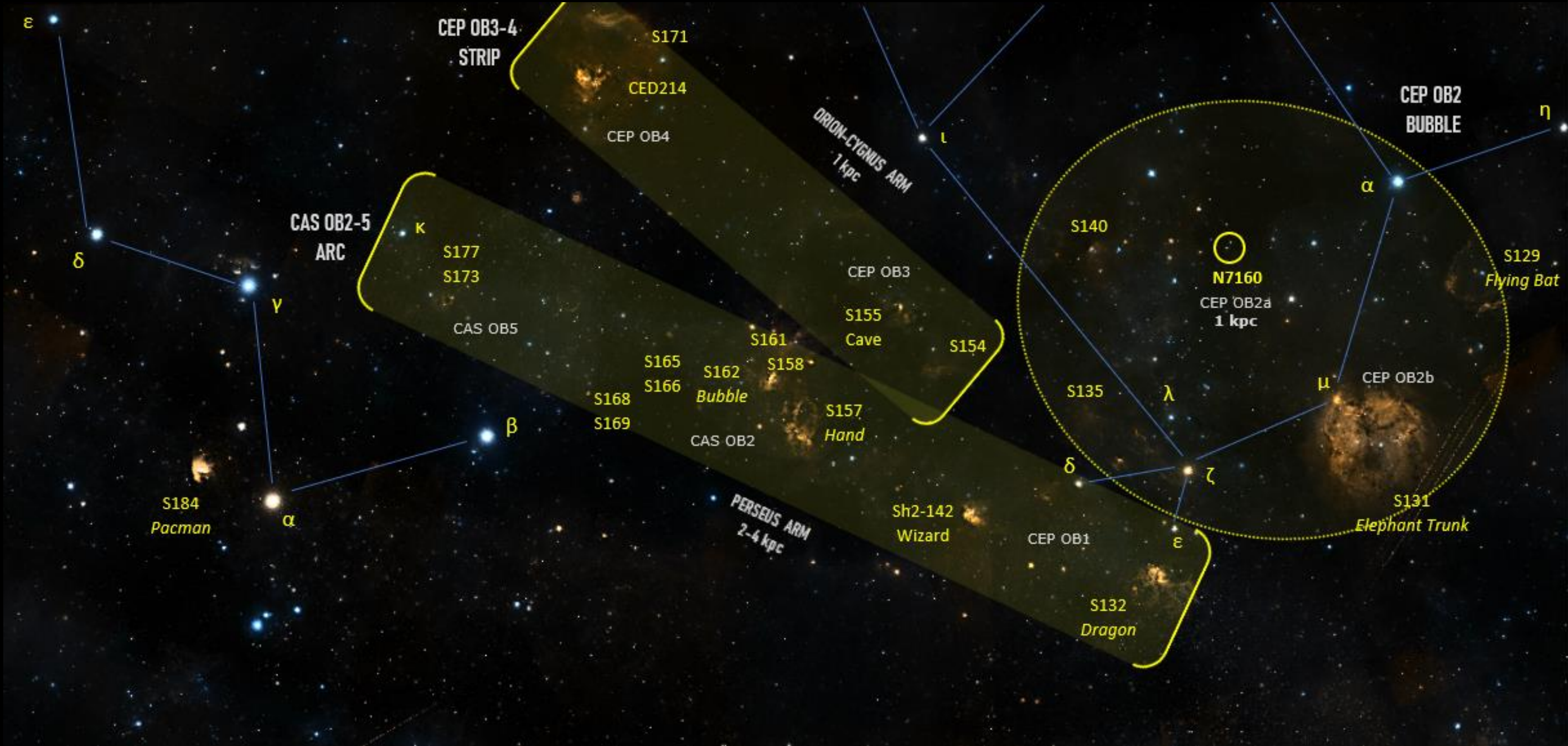




The Autumn Milky Way
Galactic longitude ~120°

Looking further up the Milky Way in **Autumn**, we're now moving through **Cepheus and Cassiopeia,** towards the galactic anticenter (gal. long. 120°). Here we begin to see through the outer part of our local *Ori-Cyg arm* at 1 Kpc, with many HII objects in the *Cepheus Bubble* around CEP OB2 (Sh2-129 Flying Bat, OB2b/Sh2-131/IC1396 Elephant, Sh2-133, -134, -140). Just to the E of the CEP Bubble and at an equal distance of ~1 kpc we find the *Cepheus OB3-4 Strip* with CEP OB3 (Sh2-155 Cave) and CEP OB4 (Sh2-171/CED214 'Parachute').

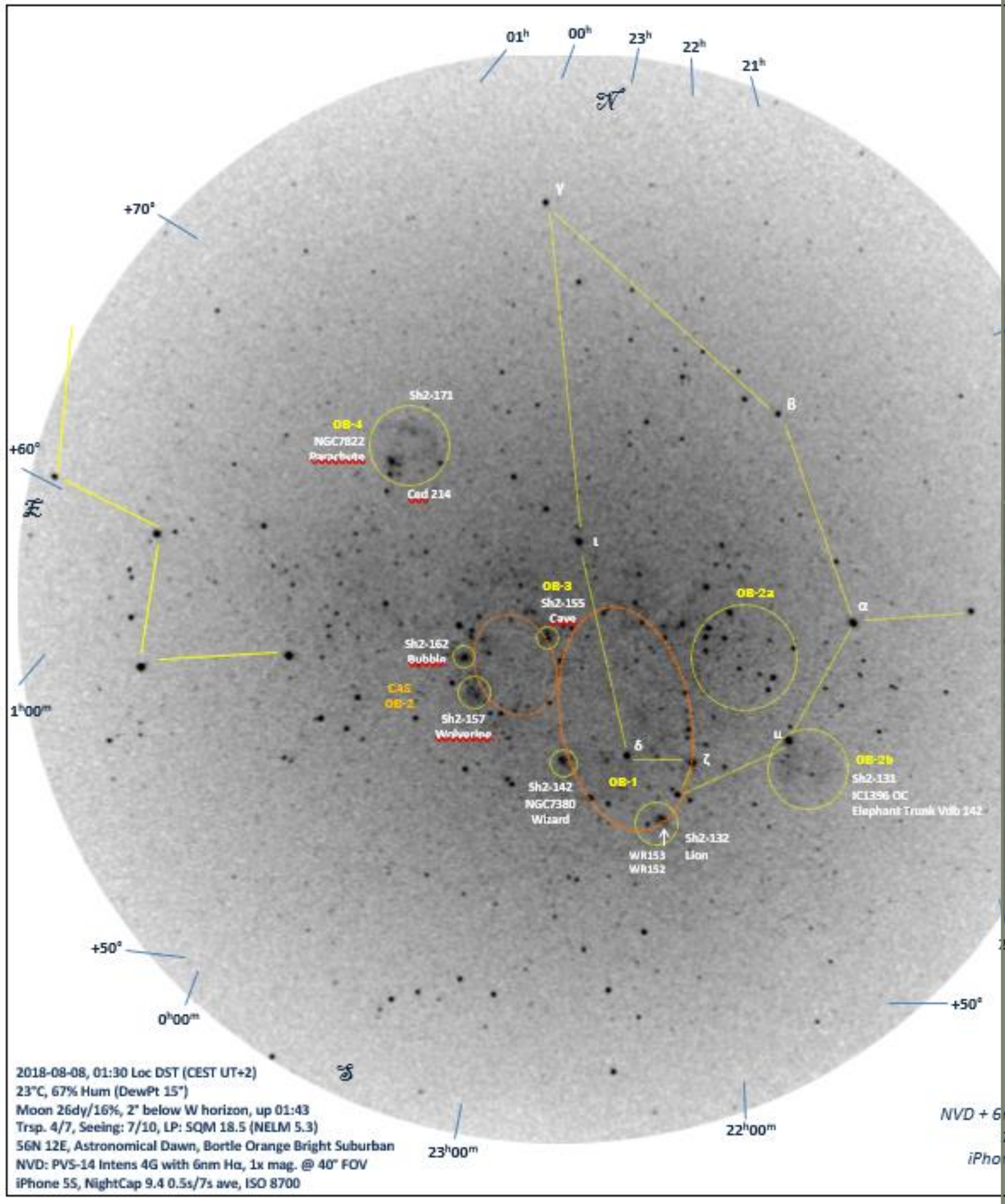
Further east of the *Cave* and *"Parachute"* on the night sky, we cross the interarm gap from our local Ori-Cyg Arm out to the distant Perseus Arm, where we at ~2-3 Kpc find the CEP OB1 (Sh2-132 Dragon/Lion, Sh2-142 Wizard), CEP OB5 (Sh2-135) and CAS-OB2 (Sh2-162 *Bubble* and Sh2-157 '*Wolverine*') associations. These HII-regions in the Perseus Arm form the *Cassiopeia Arc* of emission nebulae together with several smaller (and more distant, at ~4-5 kpc) HII-patches, such as Sh2-147, -148/49, -152/53. Still further out beyond the Perseus arm at a whopping distance of ~9 kpc can be spotted a small pair of faint EN, seen in the background just to the SW of IC1396 (Sh2-127, -128).

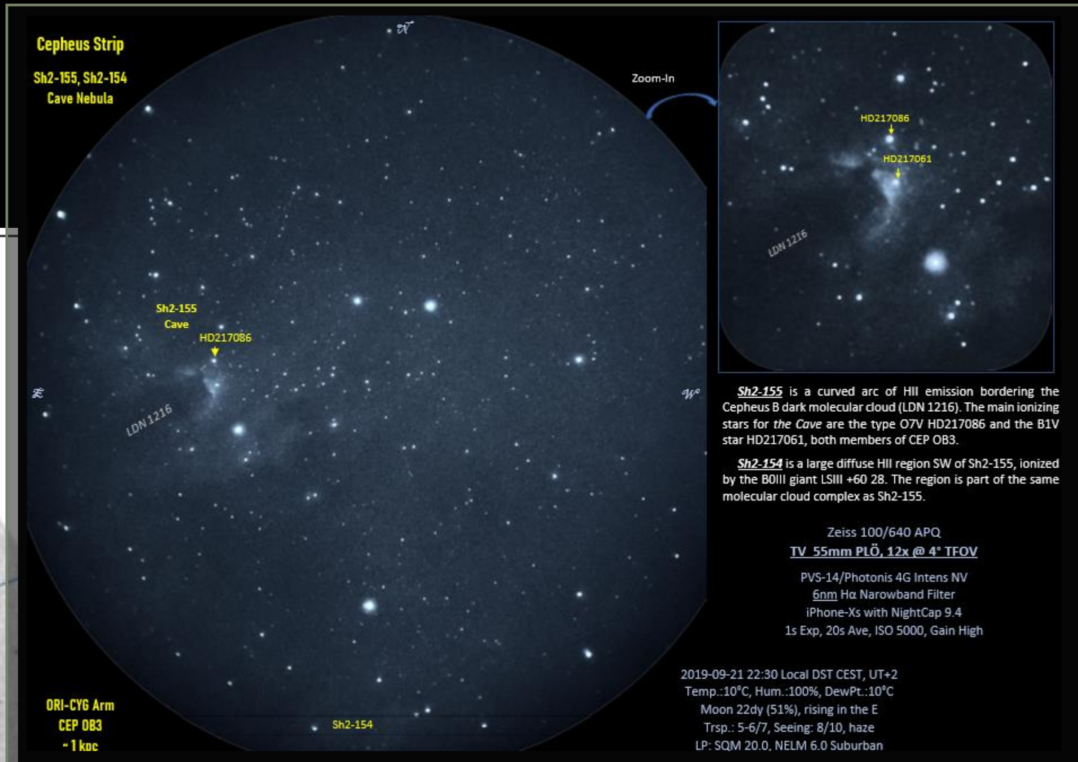


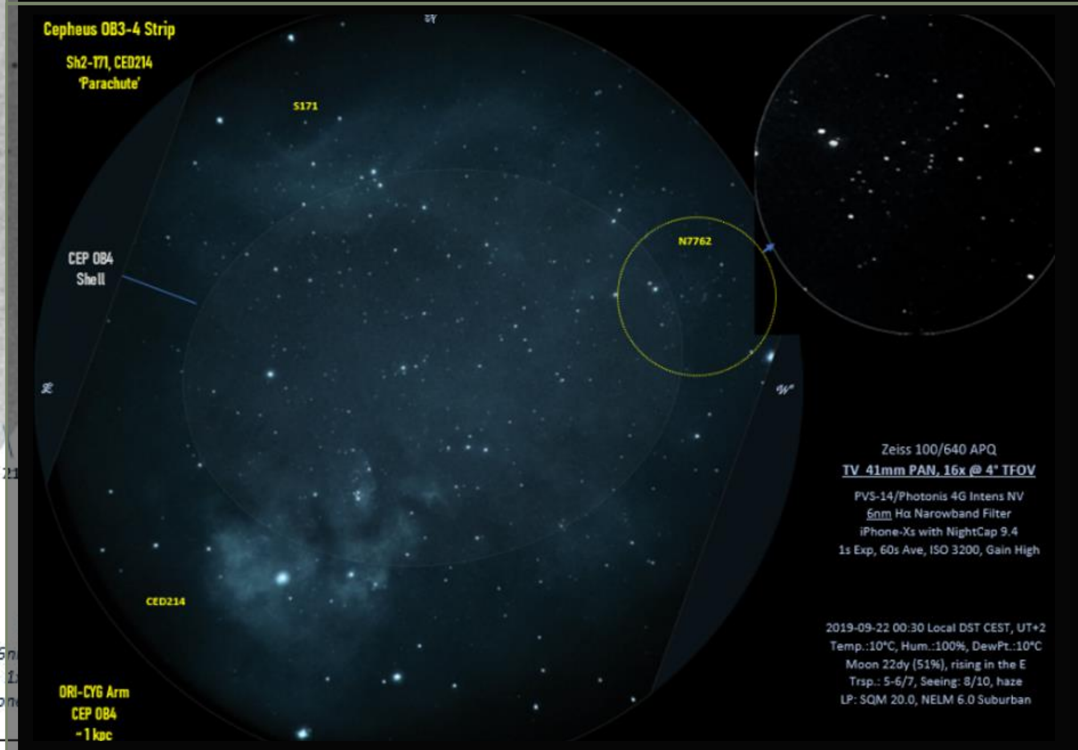
Aladin Lite star map, CDS, Strasbourg Observatory, France. © GPLv3. (My annotations)

Here's first an overview of the region as seen through my NVD at 1x with a 656nm filter Hα-filter. Many of the bright HII-nebulae in Cepheus can be spotted, from the OB2b/Sh2-131 "*Elephant Trunk*" below the Garnet Star (µ Cepheus), up past the *Lion, Wizard, Hand* and *Bubble* to the '*Parachute'* (OB4/Sh2-171) above Cassiopeia.

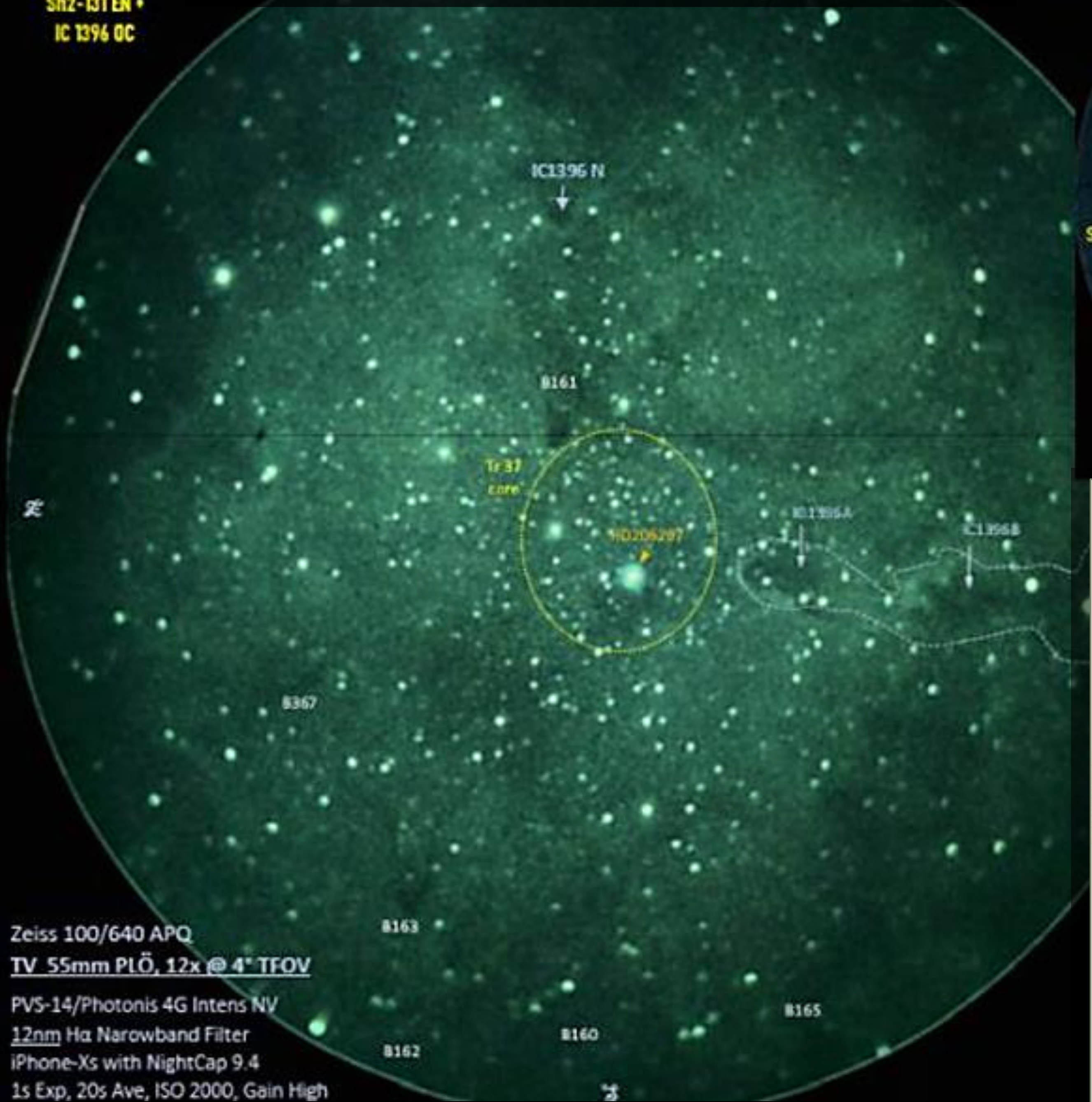
To the right: a couple of close-up observations of Cepheus emission nebulae:

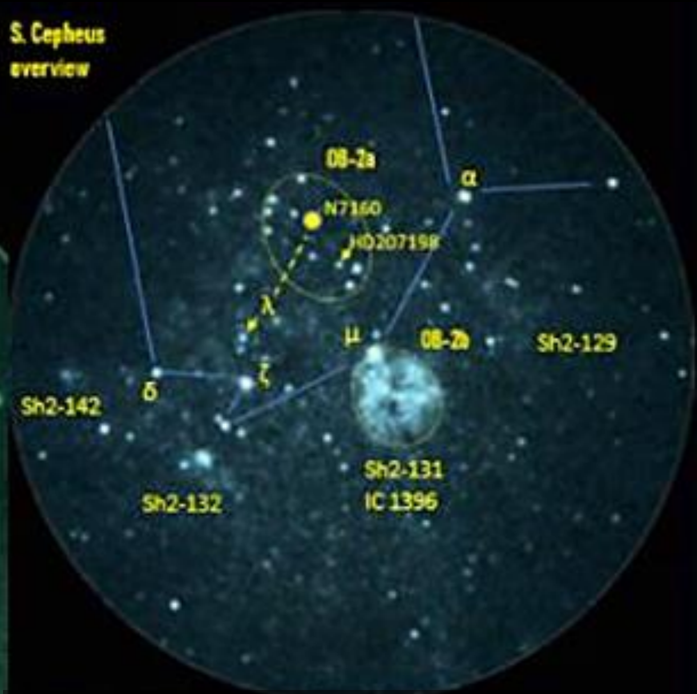


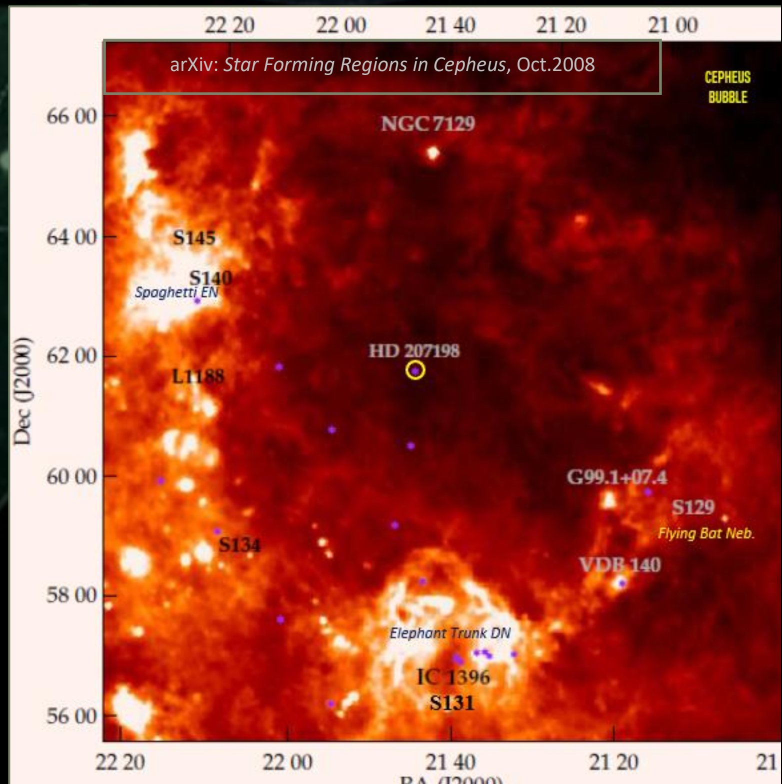




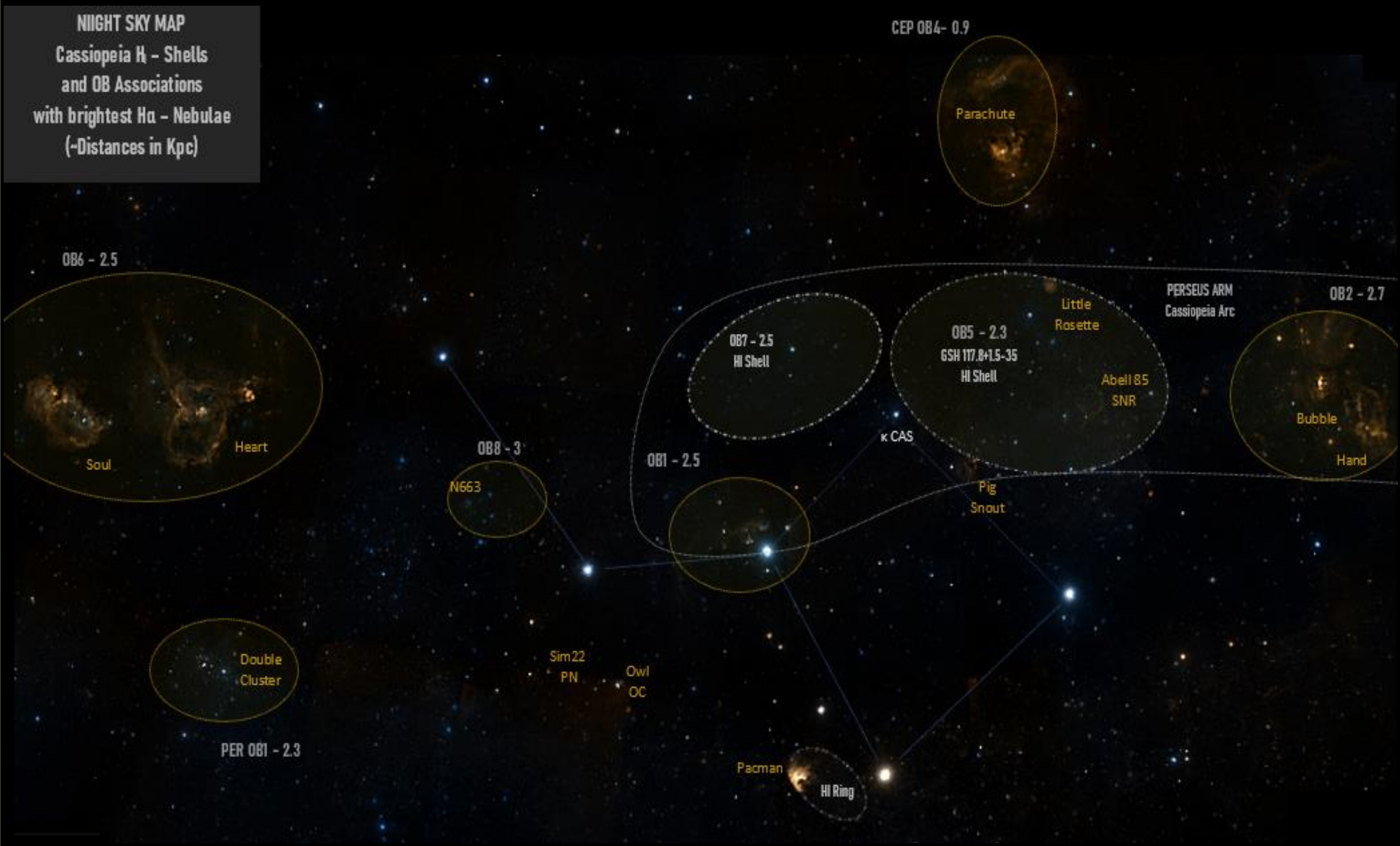
And here's a closer-up 12x view through my 4" f/6.4 refractor, showing the Elephant Trunk nebula (IC1396), which is located in the southern wall of in the Cepheus Bubble. My first Milky Way emission nebula observations were recorded through the NV monocular with an iPhone 5s (8MP), but in the fall 2018 I upgraded to a newer iPhone Xs model, with somewhat better resolution (12 MP).



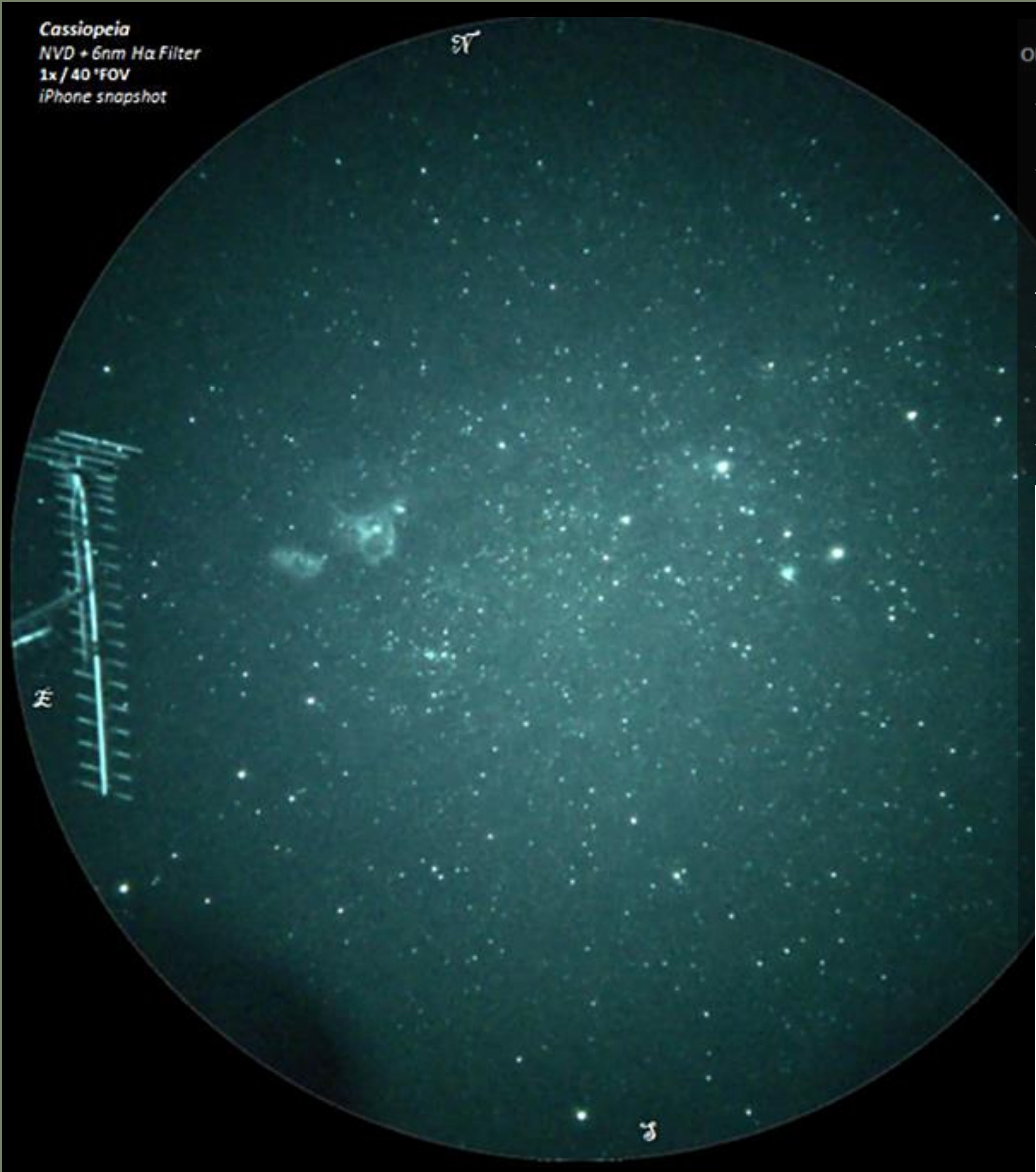




From SE Cepheus all the way east along the Gould's Belt to the *Double Cluster* in Perseus, there's an opening in the star- and dust-clouds of our local Orion-Cygnus Spiral Arm, and in this transparent "**Cassiopeia Window**" we can see past a few star groups in our local Ori-Cyg arm (Cas OB-14, Stock2, NGC225, all at ~1 Kpc) out through the inter-arm gap to a rich collection of very young (<25 Myr) OB–associations with clusters of newborn stars and surrounding emission nebulae in the outer Perseus Spiral Arm (at 2-3 Kpc). Further down the Perseus arm we find the Cas OB6 group with the bright *Heart and Soul* nebulae.



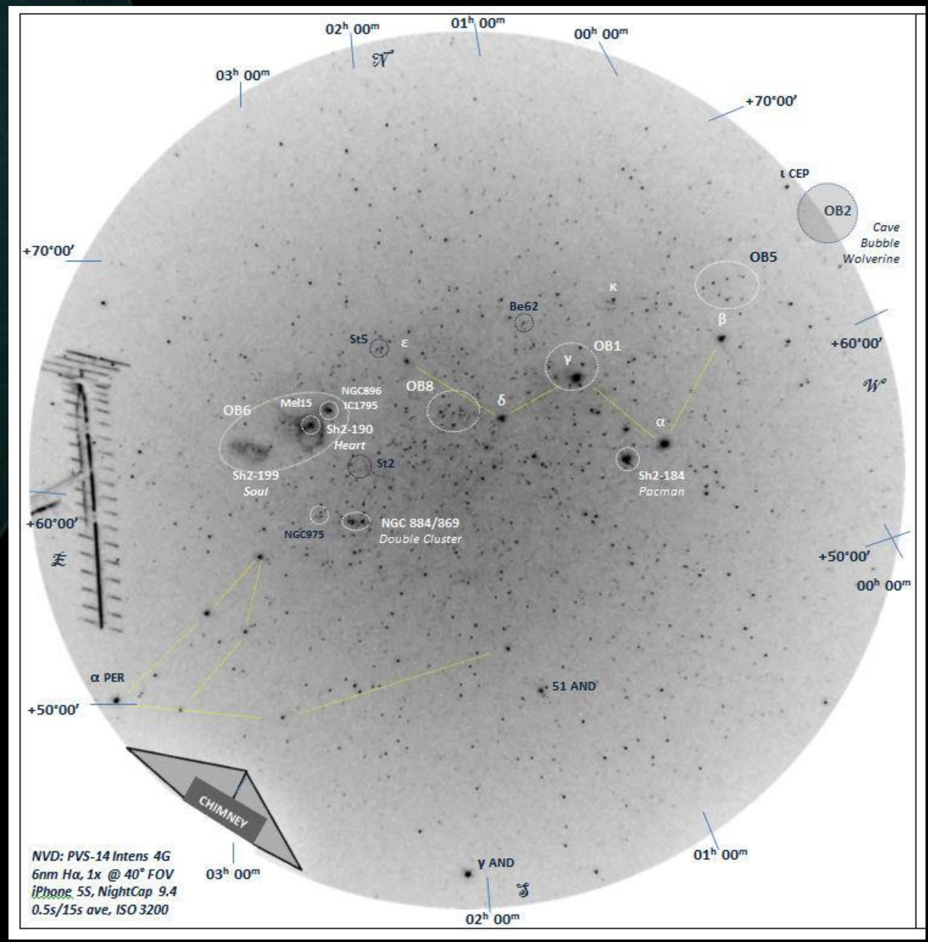
Aladin Lite star map, CDS, Strasbourg Observatory, France. © GPLv3. (My annotations)



CAS OB & Sh2

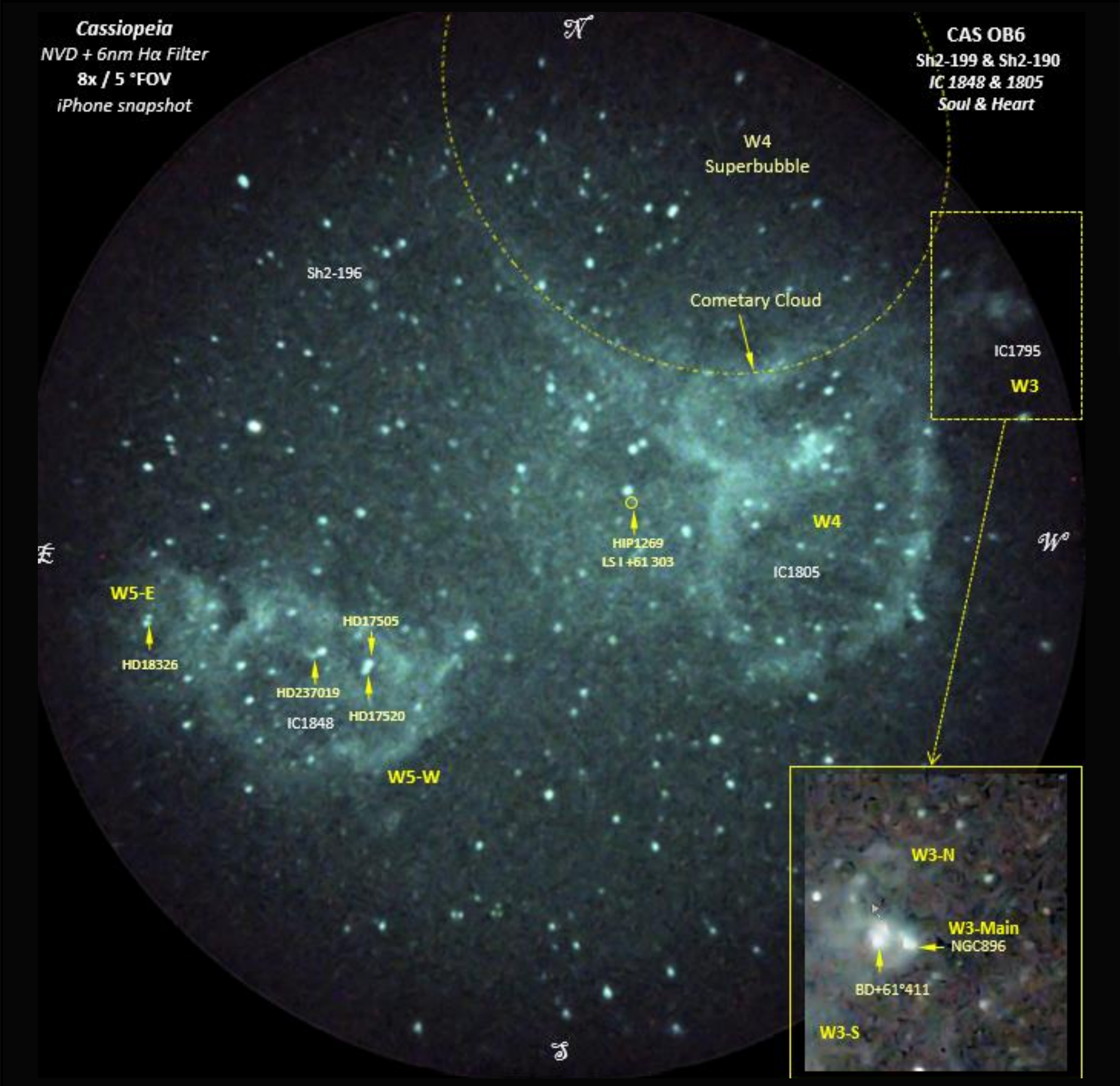
I now start panning my finder scope towards the E to pick up the Cassiopeia OB-6 association with its associated nebulosity. I have observed CAS OB-6 before with glass eyepieces, and the Mel-15 OC at the center of IC 1805 is a beautiful and interesting sight in my 80mm refractor with a 25mm ortho (44x @ 0.9°), -- but the nebulosity is even more difficult to pick up with "glass only" than the Pacman (same integrated apparent magnitude ~8^m actually, but spread out over a much larger area). Getting close to the chimney of our house, however … it seems clouds have rolled in from north-east and are now closing the sky… Dang!

But wait… then it dawns on me: THAT is not cirrocumulus floccus clouds… holy cow! That is the ionized hydrogen clouds of Cassiopeia OB-6, -- and in what exquisite detail!... This experience is for me fully on par with seeing the Orion M42 Nebula and the Lyra Ring Nebula for the first time. Just WOW! Right there and then I stop and send a thankful thought to those pioneers on CN and SGL, that have generously shared their experiences with NV equipment and observation, thereby enabling others like me to start my own journey down this road: Eddgie, *PEterW*, *Gavster*, *Moshen*, *GeezerGazer*, *alanjgreen*, *Jeff Morgan*, and others… THANK YOU – you made my night!



Here's a 40° field showing my look out of the *Cassiopeia Window* at 1x through the NVD with a Hα-filter.

Mounting the NVD on my small 2" f/4 finder scope, the Heart-and-Soul nebulae are shown in greater detail at 8x magnification in a 5° FOV. There is evidence of a triggered star formation in the W3/4/5 complex, starting with a first generation in W4 6-10 Myr ago, which generated a blow-out creating an extra-planar loop that is now seen as the Perseus Chimney; The current super-bubble was then created by a second star formation ~2.5 Myr ago, which furthermore swept up the gas into the shells of molecular and atomic clouds around W4. Additionally, the gas in the W4/W5 shells have been compressed by UV radiation, stellar winds and supernovae, with embedded third generation star formation as seen today in W3 plus the walls of W4 (such as the cometary cloud) and W5.



The Heart nebula (Sh2-190, IC1805) is ionized by at least 10 type-O stars, including three rare ultra-hot stars in Mel-15: the type O4-I supergiant HD15570 plus two O4.5 stars: the main sequence HD15629 and the giant triple YSO HD15558. To the E of young Mel-15 OC is an interesting binary system HIP12469 composed of a massive B0-V star with a compact companion. The compact object is a neutron star or more likely a black hole shooting out a ray of material at 60% the speed of light (such an X-ray binary with relativistic jets is also known as a microquasar); the system is believed to have been kicked out of Mel-15 in a supernova explosion 1.7 Myr ago.

The Soul nebula (Sh2-199, IC1848) is ionized by the two binary systems located close to each other: HD17505: O6.5-III + O8-V with one additional spectroscopic component, all in a tight cluster of 7 more visual members, plus HD17520: O8-V + O9-V

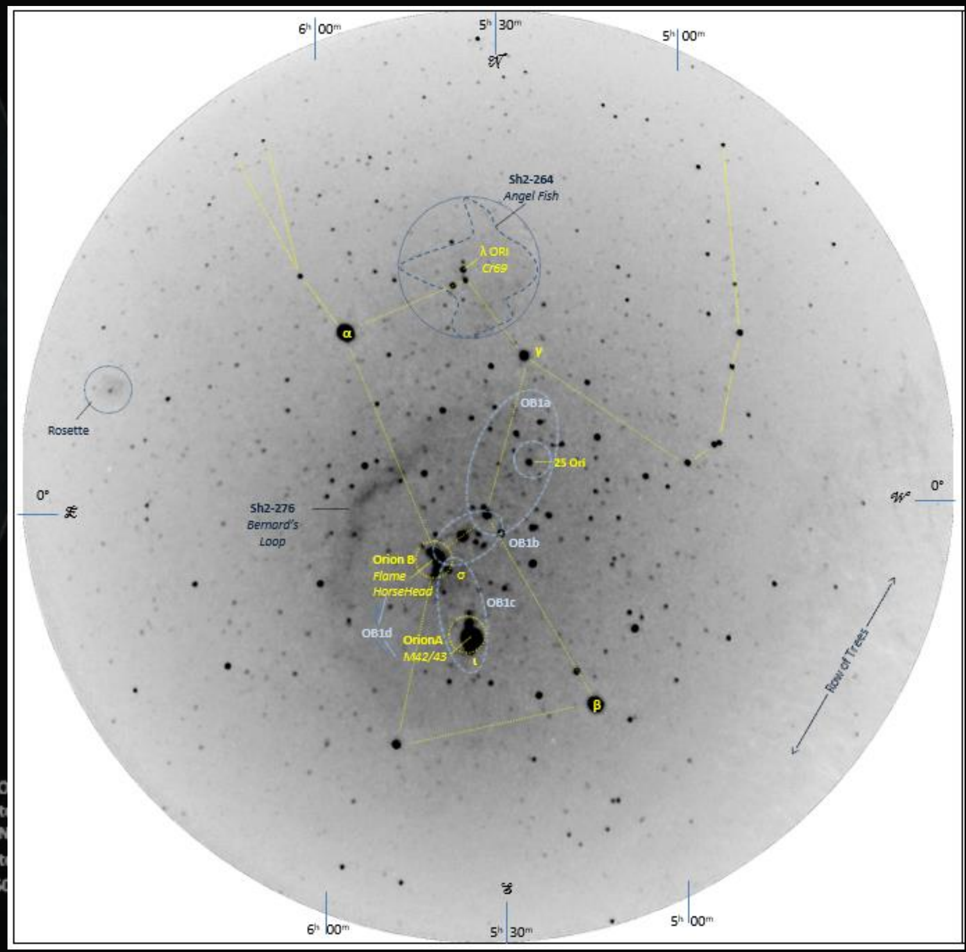
Below is shown the compact Sh2-184, aka NGC281 or *"Pacman Nebula"* found in Cassiopeia. The central star HD5005 forming "the eye" of the Pacman is a multiple 7.9^m system (ADS 719 or β1 after Burnham) with four hot components of types: O4-V, O97-II, O8.5-V and O9.2-V. This multiple system powerhouse is surrounded by a tight OC of fainter stars (IC1590).

The Winter Milky Way

Galactic longitude ~180°

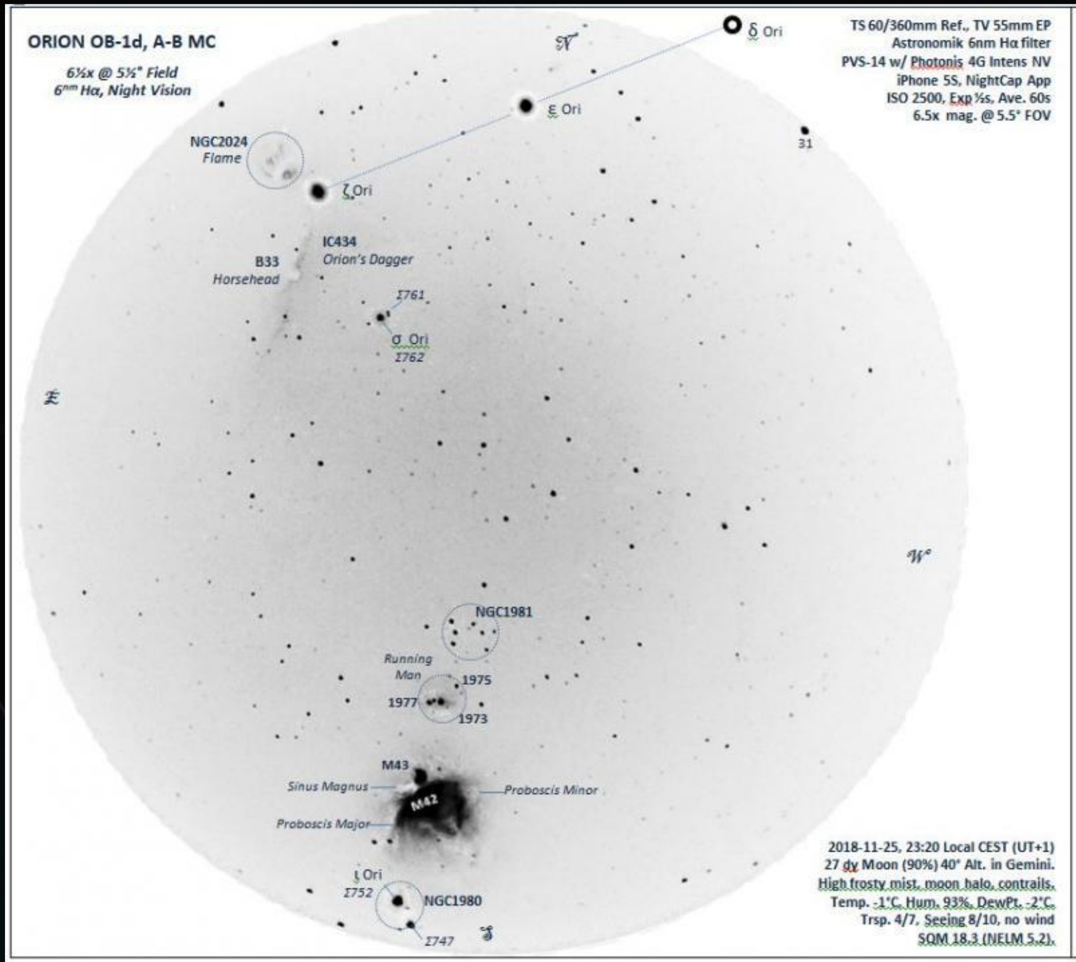
In **Winter** we face directly in the direction of the galactic anticenter (gal. long. 180°), and we are thus looking out through our own Ori-Cyg spiral arm at relatively nearby (2-3 Kly) open clusters, associations and nebulae in the Gould's Belt: from Perseus (α Per OB) to Taurus (Pleiades, Hyades) and Orion. Further south opens a view along the length of our trailing Ori-Cyg arm at still more distant open clusters and nebulae: from Auriga – Gemini (4-5 Kly) to Monoceros – Canis Major (5 up to 20 Kly at the Galaxy's far outer edge).

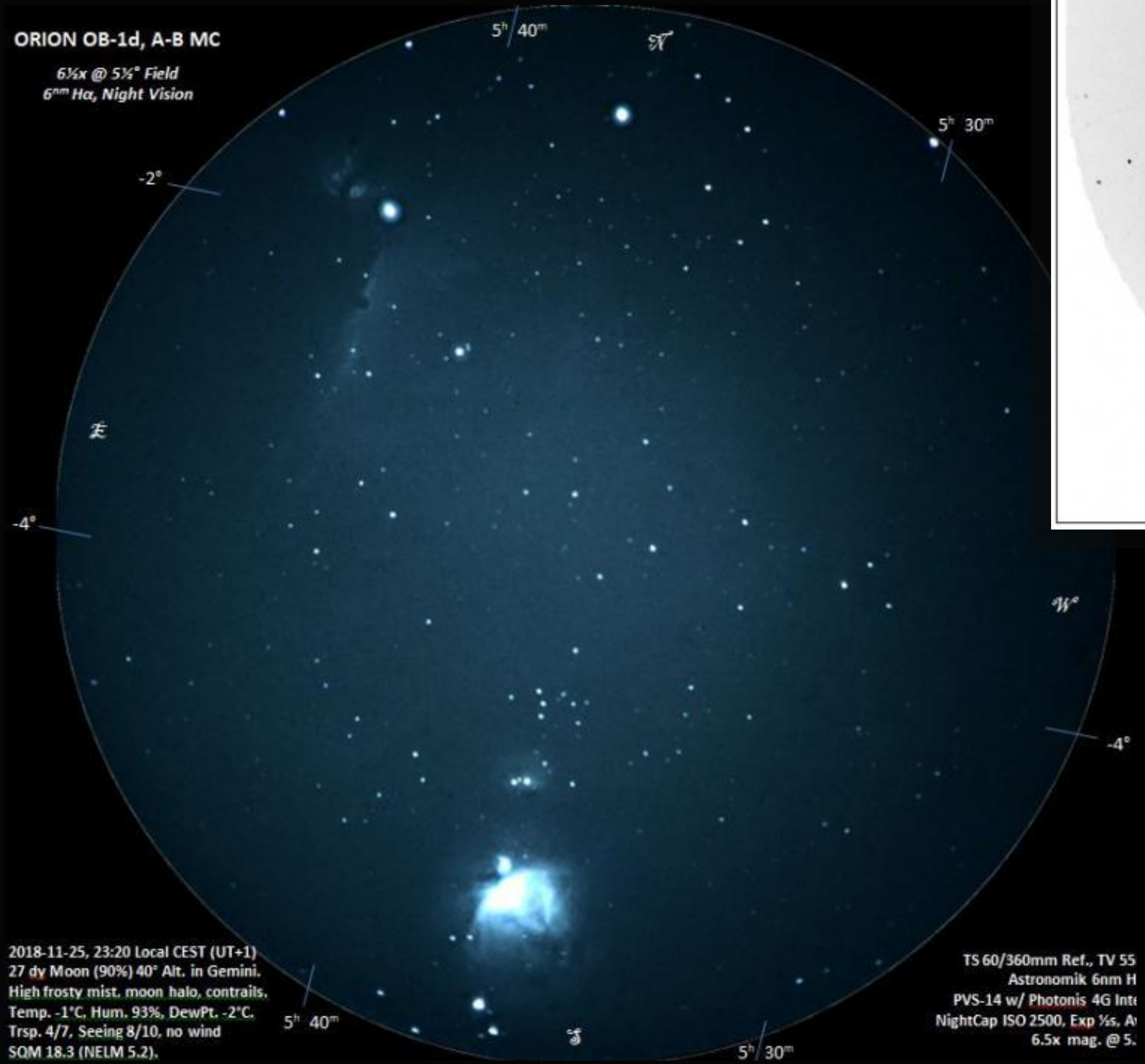
In this area of the Milky Way my first stop was the structures of the Orion-Eridanus superbubble (with the *λ-Orionis Angel Fish*, *Bernard's Loop* and the *Fishhook*), and to the north of this bubble (in galactic coordinates): *The Flaming Star* and *Tadpole* in Auriga plus the *Fox Fur* and *Rosette* in Monoceros. Floating further down the stream of the winter Milky Way, cradled in the Perseus arm, are the GUM 2 SNR bubble with the *Seagull* plus the Gum 8 bubble in CMa and the Gum 12 Superbubble in Puppis-Vela.



Here's a closer-up view using my 2" finder scope for 6x in a 5° field, showing the Ori B Molecular Cloud (L1630) east of Alnitak. Now this is quite an interesting view compared to what I've been able to see with glass only, -- the Flame (NGC2024), Dagger (IC434) and Horsehead (B33) are all easily seen in a FOV that includes the multiple OB-system σ Ori with the central Σ762- Σ761 components plus several more outlying type-B members (of which I've labelled 4 here).

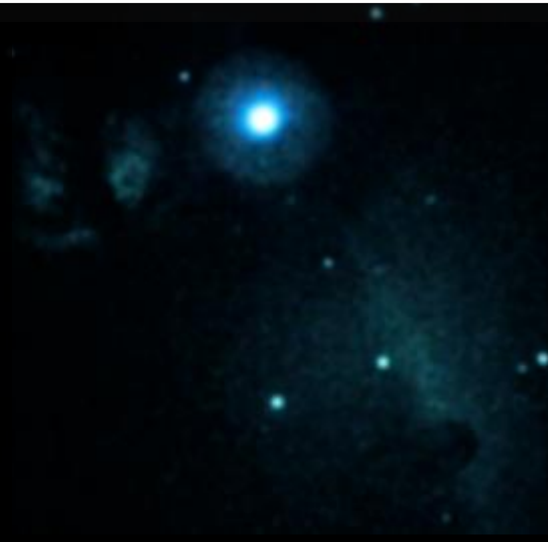
The central σ Ori AB-components are hot massive stars of type O9.5V + B0.5V, and they are responsible for ionizing the emission nebula known as "Orion's Dagger" (IC 434). To the E of IC434 is the B1.5-IV subgiant star HD37903 which is illuminating the bright reflection nebula NGC2023, but this RN of course does not show up in 12nm Hα (I've marked the star on the snapshot anyway). The dense MC of NGC2023 contains a small cluster of Young Stellar Objects (YSO), including proto-stellar HH objects and Pre-Main Sequence (PMS) T-Tauri stars. Silhouetted against the bright HII region IC434 (Orion's Dagger) is the dark cloud of dense gas and dust B33, with an emerging "pillar" known as the Horsehead Nebula.



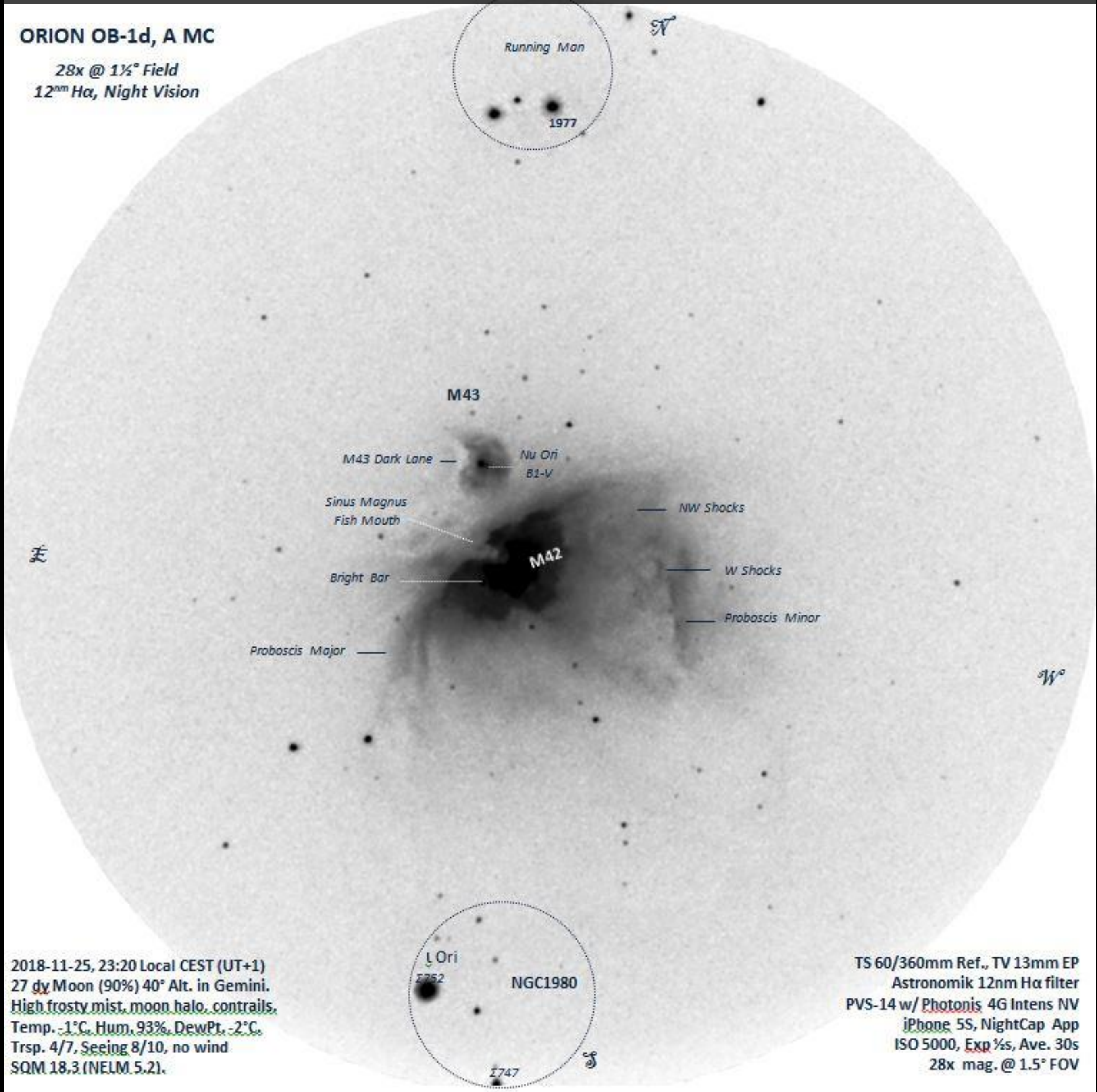


The source of the ionization of IC434 as well as the photo-evaporation of the Horsehead pillar is as mentioned the σ Orionis multiple star system.

East of Alnitak is seen the extensive HII region NGC2024, the Flame Nebula, with a broad N-S dark lane and a heavily obscured embedded cluster with associated HII regions blowing out from the N but still bounded by a sharp ionization front towards the S, and two filamentary bubbles: one E and one W. The Flame cluster contains many YSO (HH objects, accretion discs) and also of course some hot ionizing stars, though the ionization sources of the nebula are too obscured to be identified.



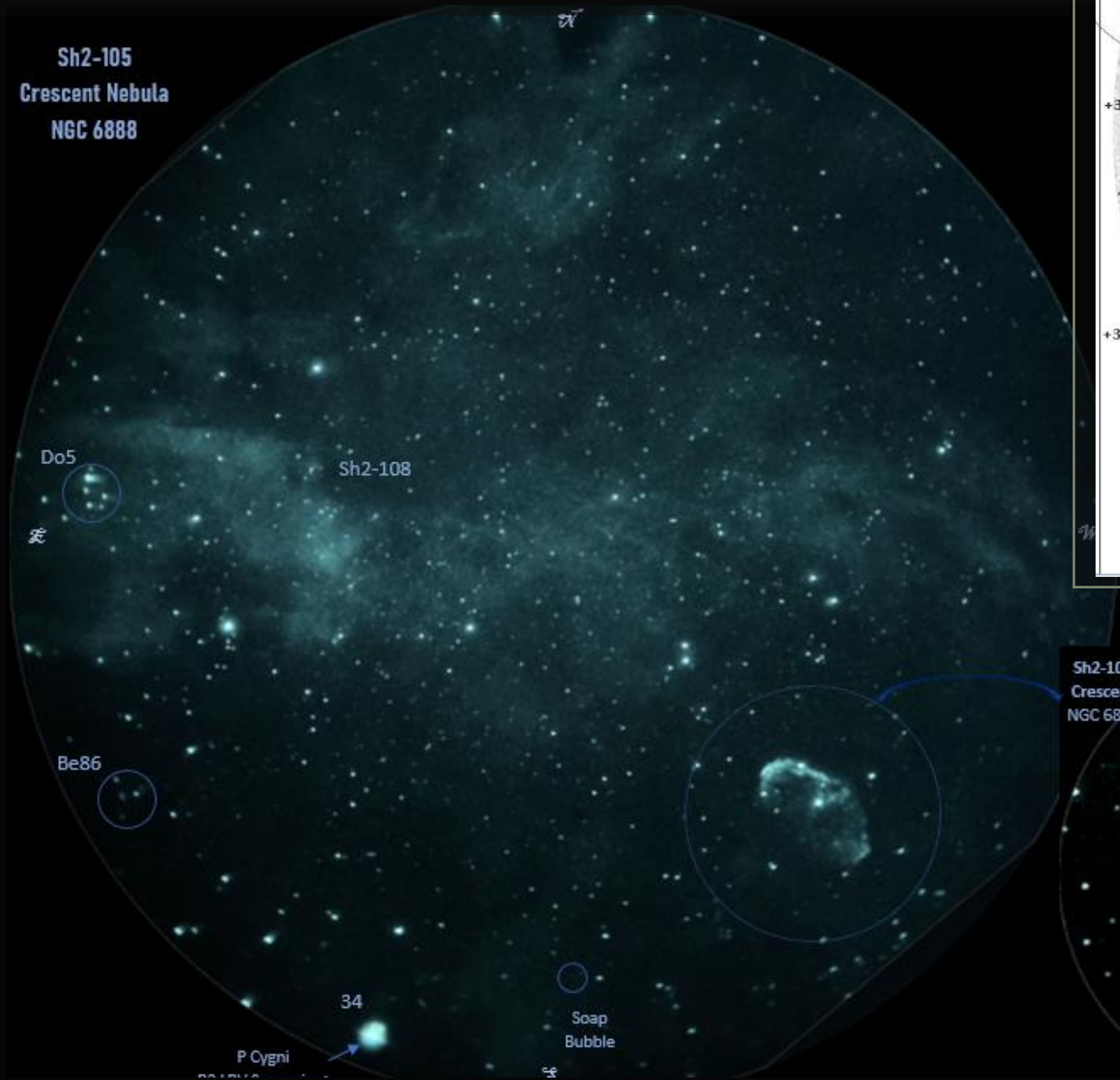
I now increase the magnification to 28x in 1.5° FOV, using a 13mm EP and a 12nm filter to have a closer look at the young Orion OB-1d molecular clouds; First the Ori A-MC with the M42/M43 nebulae. The view is rather good for NV with a 60mm scope (I think),

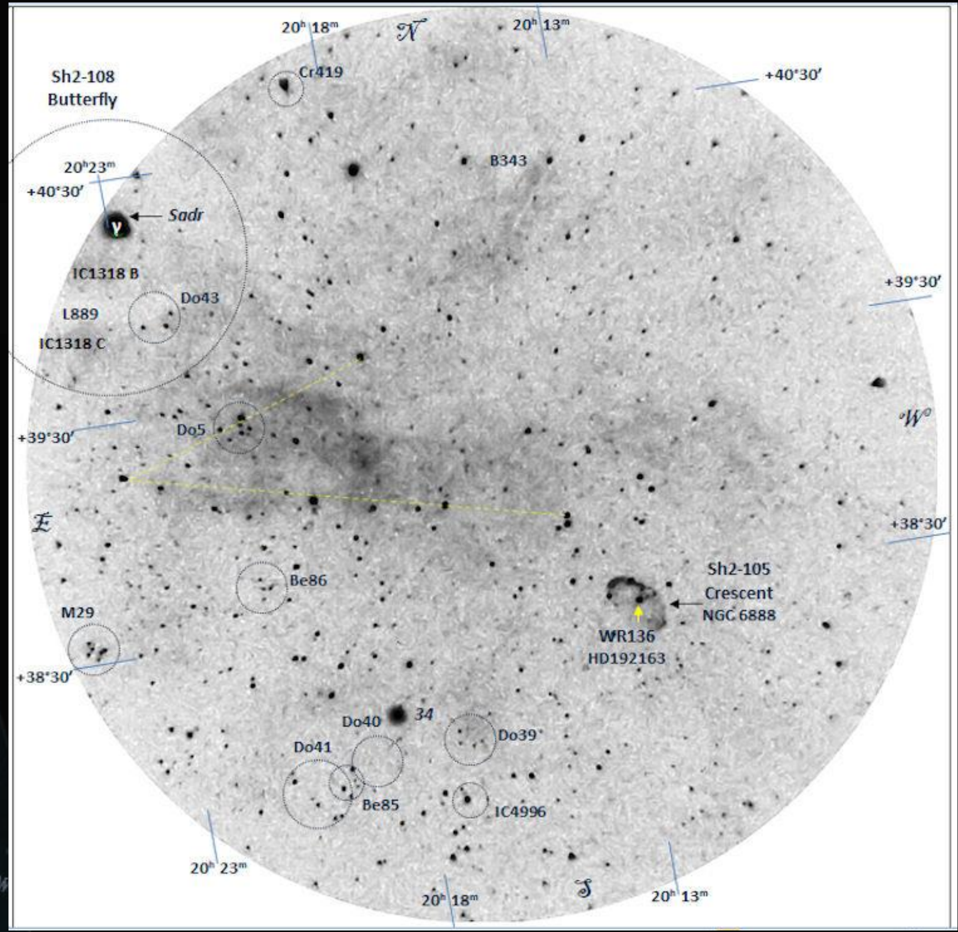


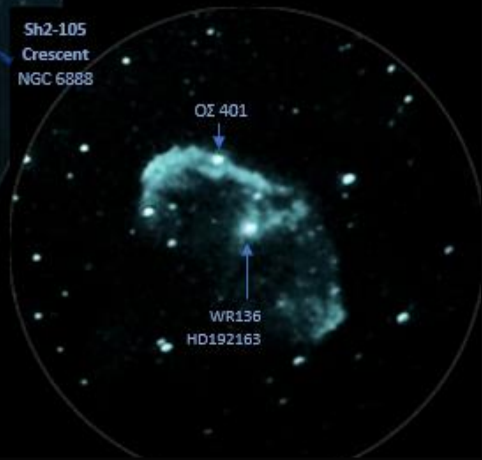
The core of M42 (the Huygens Region with the Trap) is easily burned out of course, but by varying the gain on the NV device and the ISO on the phone app I can study quite a lot of details in the wings and body close to real-time, though not at the same resolution as using longer exposure live video with stacking (HH objects, proplyds/YSO, outflows, bow-shocks etc.).

In the previous sections I've only been able to describe a few of the most impressive emission nebulae in star forming regions that I observed along the Milky Way during this part of my rich field project. During the project I tracked down all the largest nebulae in the Sharpless catalog, as visible from my 56° northern latitude, but I also stopped many times to study interesting smaller emission objects, such as: bow shocks in front of runaway stars (Sh2-119), Luminous Blue Variable (LBV) and Wolf-Rayet star bubbles, accretion disks around stars (Sh2-106) and black holes (Cyg X-1), decretion disks around fast spinning BE stars (Gamma Cas), supernova remnants (Cygnus loop, Little Veil Sh2-91, Abell 85), dark molecular clouds and filaments (B168 at the Cocoon, Flame and Horsehead), wind-blown stellar bubbles (Sh2-162), galactic superbubbles (Orion-Eridanus, Cygnus SB, Cassiopeia OB5, Cepheus with Sh2-131, Gum2 with Seagull), planetary nebulae (Sh2-188) and a multitude of open galactic clusters. For details on these observations, check out my CRF-thread at the Cloudy Nights forum, here:

https://www.cloudynights.com/topic/565226-classic-rich-field/?p=8718615







The area of the Cygnus Star Cloud SE of γ CYG (Sadr) has to be one of my favorite parts of the sky to observe, -- both with glass eyepieces and with my new NVD: It is filled to the brim with diverse, interesting and visually contrasting objects, from dark molecular clouds to fluoresced Hydrogen-II "Cirrus", all teeming with open clusters scattered across the whole field.

On top of that is seen the Crescent nebula, blown up by the fierce stellar wind from the giant Wolf-Rayet star WR136, floating like a bubble down the celestial white-water river in the canyon of the Cygnus Rift.

The Spring Milky Way
-- of galaxies!

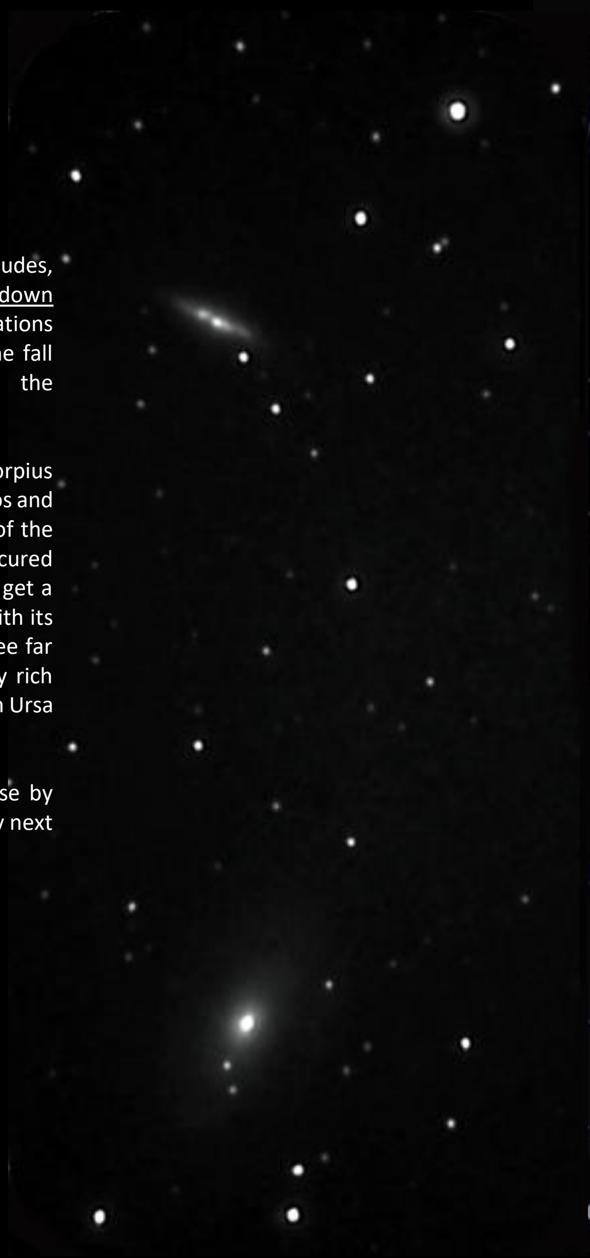
In **AUTUMN** the Milky Way is stretched in a grand arch up across the night sky, from Auriga towards the north-east, high up through Perseus, Cassiopeia, Cepheus, Cygnus, Aquila, and descending to Scutum in the south-west. When facing south at this time of the year we are thus looking under the plane of the Milky Way and out through the relatively transparent constellations Andromeda, Perseus and Pisces, where we have a fine view of our own close-by Local Group of galaxies, including M31, M33 and a multitude of smaller dwarf galaxies.

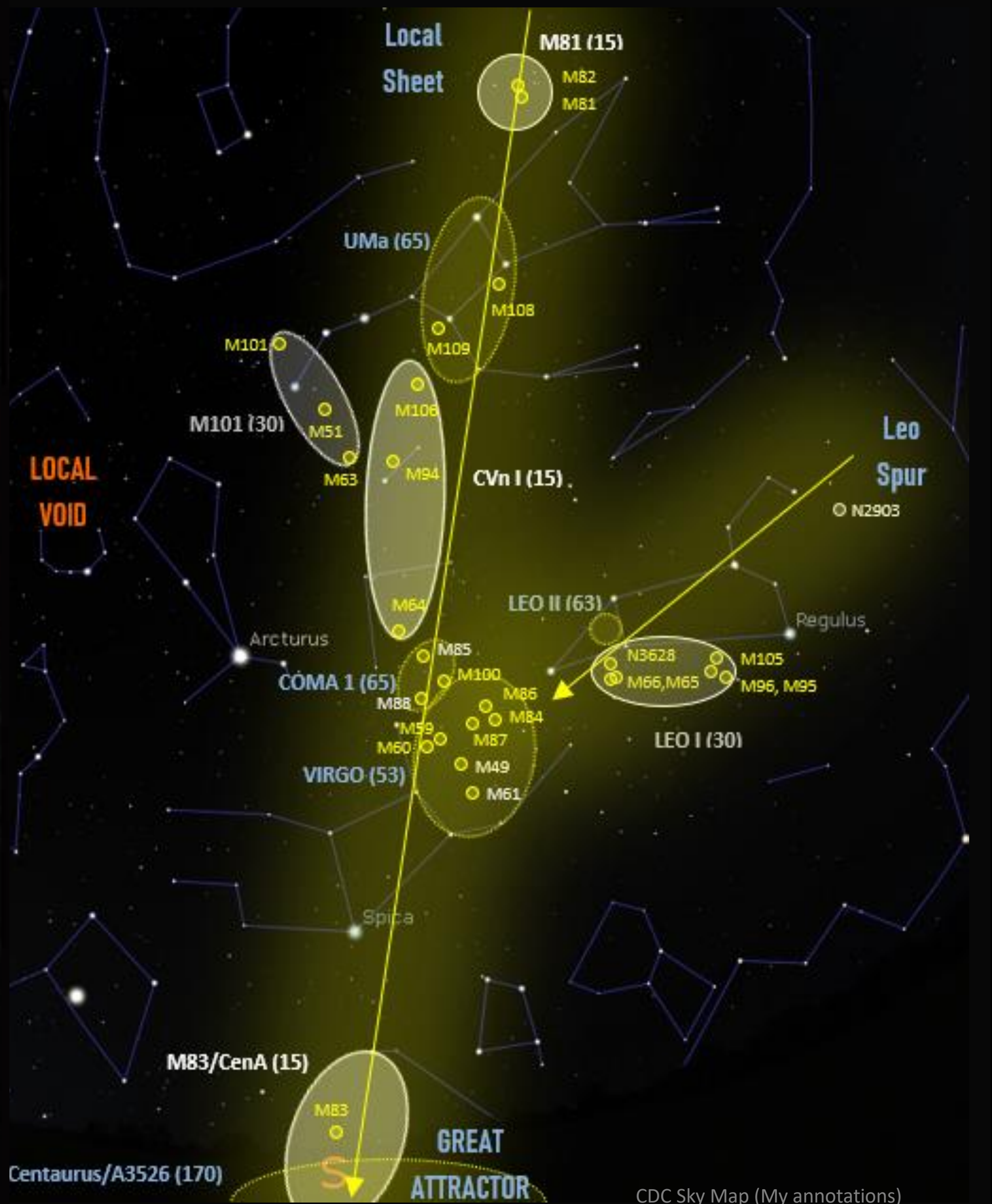
In contrast, in **SPRING** on the mid-northern latitudes, we find the Milky Way plane (the Ecliptic) bending down below the horizon, with the summer constellations (Cygnus, Eagle) flying low towards the east and the fall constellations (Auriga, Perseus) just skimming the western horizon.

The Milky Way from Sagittarius and southern Scorpius through Lupus, Centaurus, Vela, Puppis to Monoceros and Orion are now not visible, and the low-lying parts of the summer and winter Milky Way are often mostly obscured by trees and haze close to the horizon. Instead we get a grand view up over the spiral arms of our galaxy, with its dust, star clusters and nebulae, and here we can see far into deep space, where we find another extremely rich field object: the "Spring Milky Way" of galaxies: from Ursa Major through Coma and Leo down to Virgo;

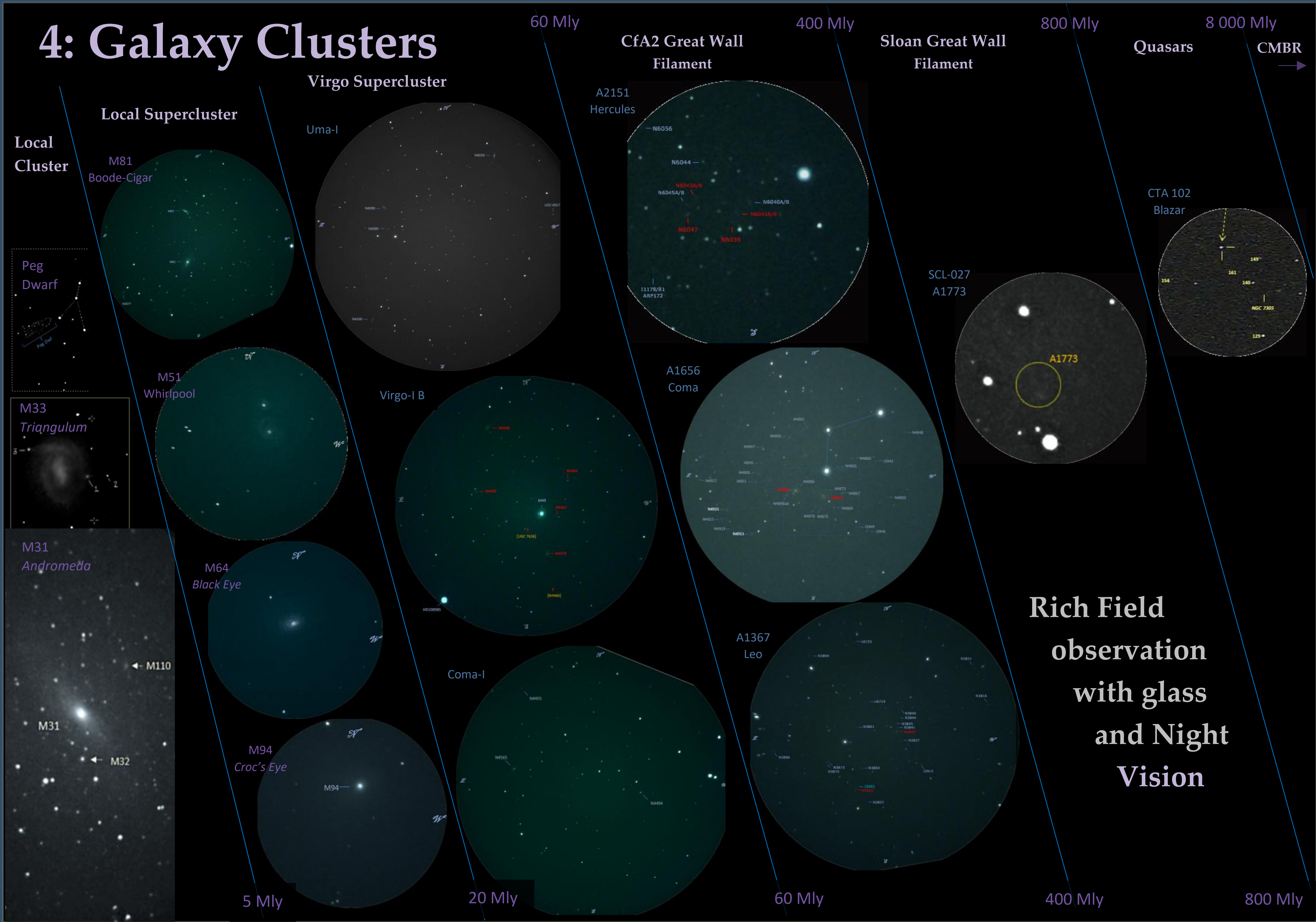
This defines the super-galactic plane of our close by universe, and that is what I chose as the topic for my next rich field project:

4: Galaxy Clusters – Rich field with glass and night vision.





CDC Sky Map (My annotations)


4: Galaxy Clusters
60 Mly
400 Mly
800 Mly
8 000 Mly
CfA2 Great Wall Filament
Sloan Great Wall Filament
Quasars
CMBR
Virgo Supercluster
Local Supercluster
Local Cluster
M81 Boode-Cigar
Uma-I
A2151 Hercules
Peg Dwarf
M33 Triangulum
M51 Whirlpool
Virgo-I B
A1656 Coma
SCL-027 A1773
A1773
CTA 102 Blazar
M31 Andromeda
M110
M31
M32
M64 Black Eye
M94 Croc's Eye
Coma-I
A1367 Leo
Rich Field observation with glass and Night Vision
5 Mly
20 Mly
60 Mly
400 Mly
800 Mly

Galaxy Distribution

Most galaxies as seen in binoculars and small telescopes from my suburban backyard show up as just faint patches or stellar points surrounded by tiny halos; My interest in the rich-field galaxy project though, was not so much what I'd be able to catch of details in the individual objects, but rather the large scale location and distribution of the galaxies, that is: how the groups could be seen "wide field" on the celestial dome as I zoomed out from our Milky Way in steps of (see list to the right):

1: -> 5 Mly **The Local Cluster:** Milky Way and Andromeda–Triangulum spiral galaxies with satellites plus the Sculptor galaxy group — Autumn Local Group
2: -> 20 Mly **The Local Supercluster:** M81, CVn-I, M83/CenA (~15 Mly) sheet plus the M101 and Leo-I clouds (~30 Mly)
3: -> 60 Mly **The Virgo Supercluster:** Our own Virgo-I supercluster plus the nearest surrounding UMa-I and Coma-I associations — (2–3:) Spring 'Milky Way' Local SC
4: -> 500 Mly **The Supercluster Filaments and Voids**, e.g. the Perseus-Pisces wall and the Taurus Void. — The Deep End…
5: And Beyond

The Autumn *Local Group* and the Spring *'Milky Way'* of Galaxies

I created a couple of maps to illustrate the overall galaxy distribution in the Milky Way deep space neighborhood (c.f. next page).

First (left map, Step 1) the **Local Cluster** of galaxies around R.A. 0^h, seen in the *Autumn* when we look out below the Milky Way galaxy disc, from Cassiopeia down through Andromeda-Pegasus to Pisces and Sculptor.

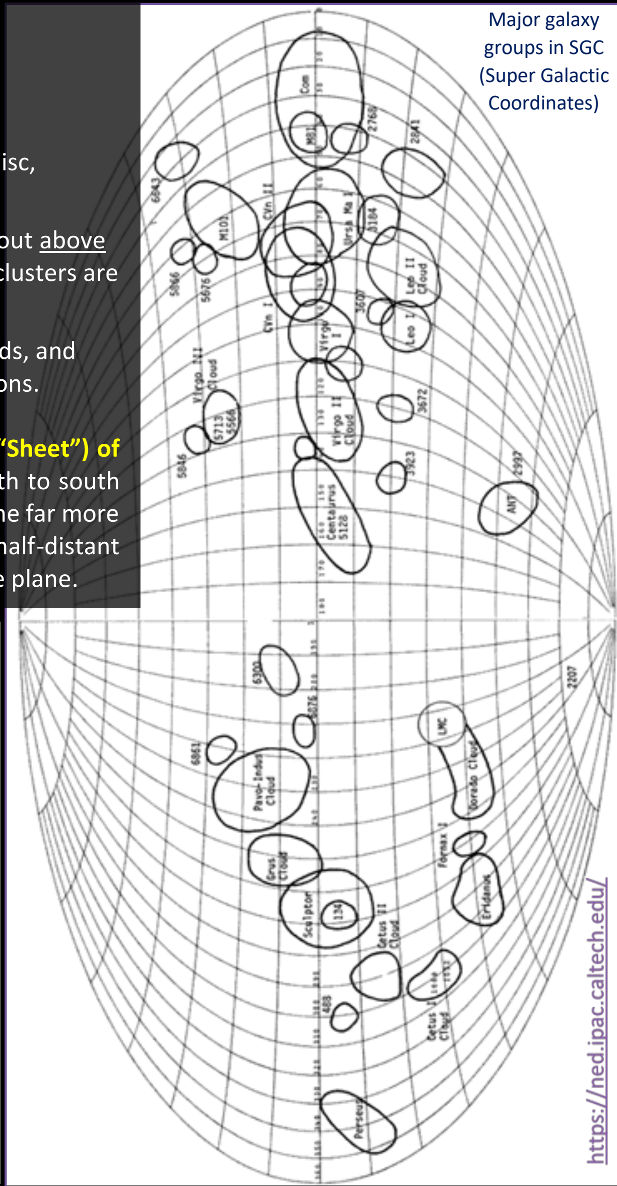
Then (right map, Step 2-3) the **Local plus the Virgo Superclusters** of galaxies, both along R.A. 12^h30^m, and seen in *Spring* when we look out above the Milky Way galaxy disc, from Ursa Major down through Canes Venatici, Leo, Coma and Virgo to Centaurus. The galaxies in these superclusters are found at different distances from our Local Group of galaxies:

Step 2: The foreground (white) **Local Supercluster** with the *M81, Canes-I, M83/CenA sheet,* plus the outlying *M101 and Leo-I* clouds, and
Step 3: The background (yellow) **Virgo Supercluster** with the large *Virgo-I* core, plus the *UMa-I, Coma-I* and surrounding associations.

As seen on our night sky here from the northern hemisphere, the galaxy groups in Step 2-3 together form the **Spring Milky Way (or "Sheet") of galaxies** that define the Super-Galactic Coordinate System equator on the celestial dome, roughly along R.A. 12^h30^m. Moving from north to south along this line, we encounter: in the foreground (~15 MLY) the close by galaxy groups: [*M81, Canes-I, M83/CenA*], and in the background the far more distant (~50 MLY) groups: [*UMa-I, Coma-I, Virgo-I*], while midway along this axis of the Supercluster "Sheet ", we find the two "Clouds" of half-distant (~30 MLY) galaxy groups: *M101* floating above (celestial east of) the SG equatorial plane, and *LEO* submerged below (celestial west of) the plane.

Here's a list of the major galaxy groups found along 12^h30^m R.A.:

Gxy Group	Distance Mly	Bright Members	Brightest members for Rich Field viewing	Comment
				Local Supercluster: Sheet
M81	12	11	**M81**, M82, N2403	34 galaxies, 3 brighter than 10^m
Canes-I (M94)	13	10	**M94**, M106, M64, N5005, N4490	14 galaxies
Cen A (M83)	22		**M83**, N5068	29 (Cen A) + 15 (M84) galaxies in 2 subgroups
				Local Supercluster: Clouds
M101+M51 Cloud	25	7	**M101**, M63, **M51**	9 galaxies + M51-M63
Leo Spur	33	3	**M66**, M65, N3628	E Triplet, 15 members
(LEO I Association)		14	**M96**, M95, M105	W triplet + N3384 and 36 fainter galaxies
				Virgo Supercluster Core associations
UMa-I	70		**M106**,N4449,N4278,N4026,N3938	M109 in the background
Coma--I	60	12	**M64**	A1656, >1000 members, most type E and S0
Virgo-I	60	177	**M87**,M84,M86,**M49**,M51,M59,**M60**	3 large subclusters: A, B, C.

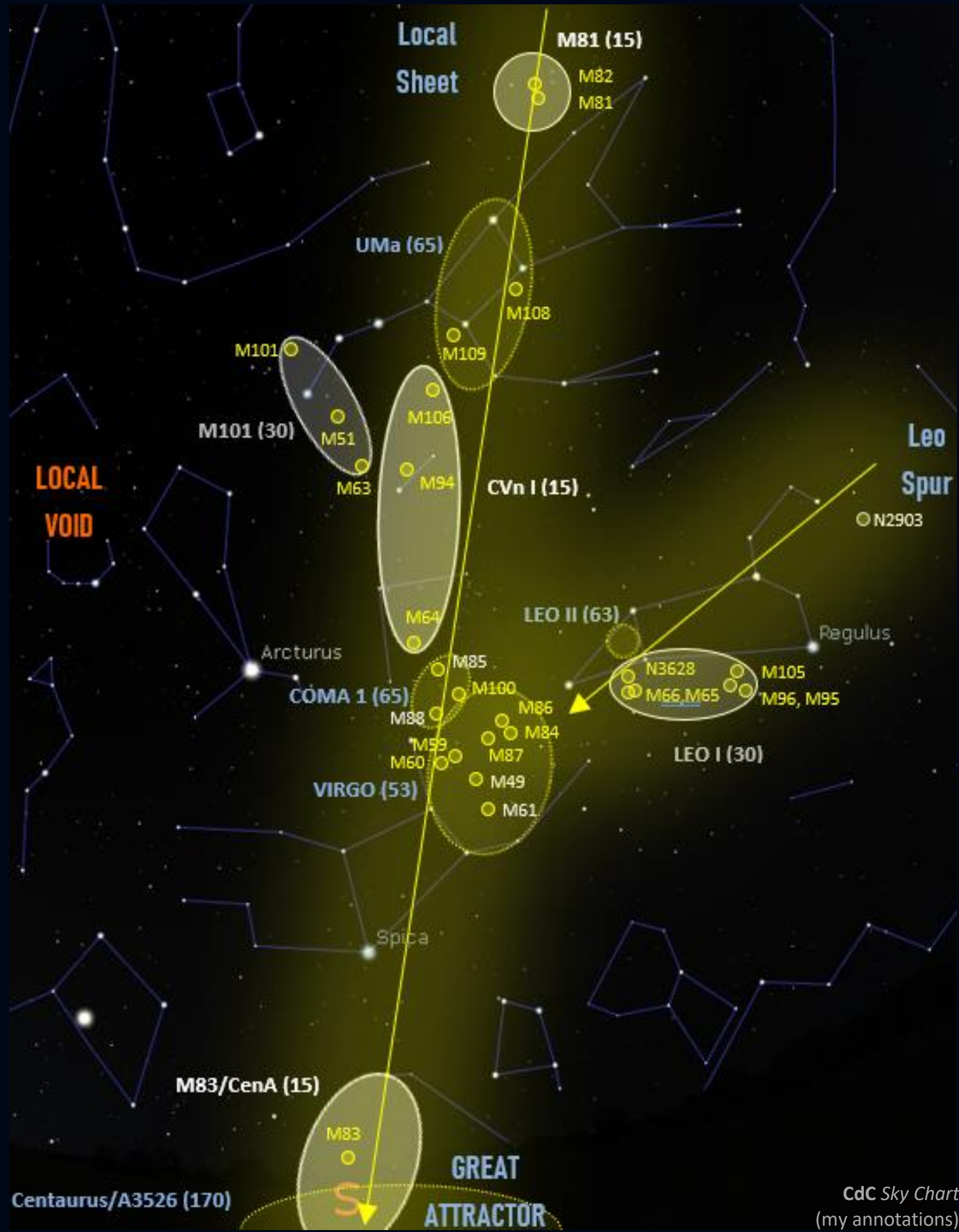


Major galaxy groups in SGC (Super Galactic Coordinates)

Maps of galaxy distribution, as seen on the night sky.

Step 1 (the **Local** and **Sculptor** Groups) are mostly centered around R.A. 0-1^h on the celestial dome (galactic long. ~120°), i.e. from *Cassiopeia-Andromeda-Triangulum* down to *Pisces-Cetus-Sculptor*. As such these nearby groups are most conveniently studied in ***autumn*** here from the N. hemisphere

Step 2-3 (the **Local Supercluster** plus the **Virgo supercluster**) are both centered around R.A. 12-13^h on the celestial dome (galactic long. ~ 330°), stretching like a ***"Summer Milky Way of Galaxies"*** from the nearby white (15 Mly) [*M81, CVn-I, M83/CenA*] groups to the far more distant yellow (50 Mly) [*UMa-I, Coma–I, Virgo-I*] groups.



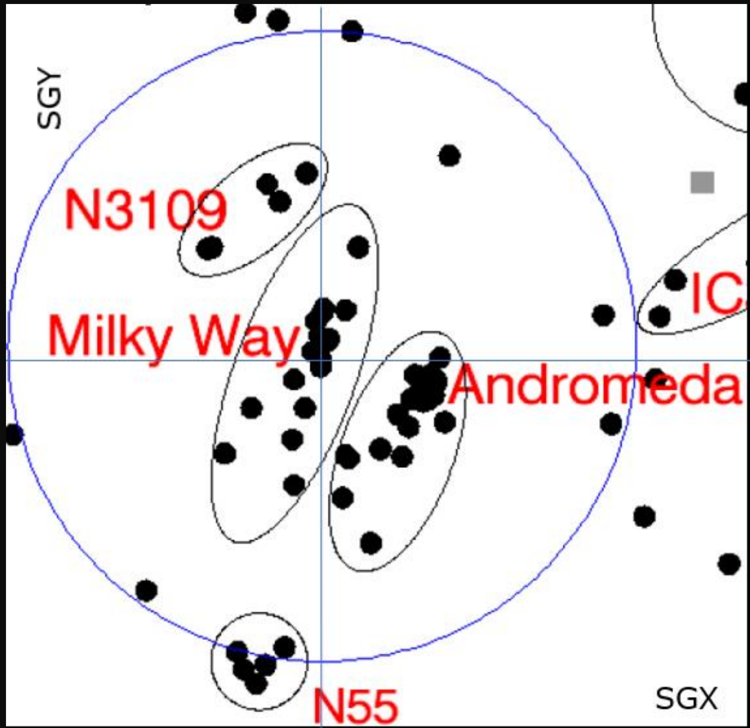
Rich Field Galaxy observing equipment.

For this part of my rich field project, I used initially my 10x56 bino plus my Vixen 2” FL55 & 3” FL80S F/8 refractors, but later I switched to my Zeiss 4” f/6.4 APQ refractor, all on manual mounts with R.A. drive.

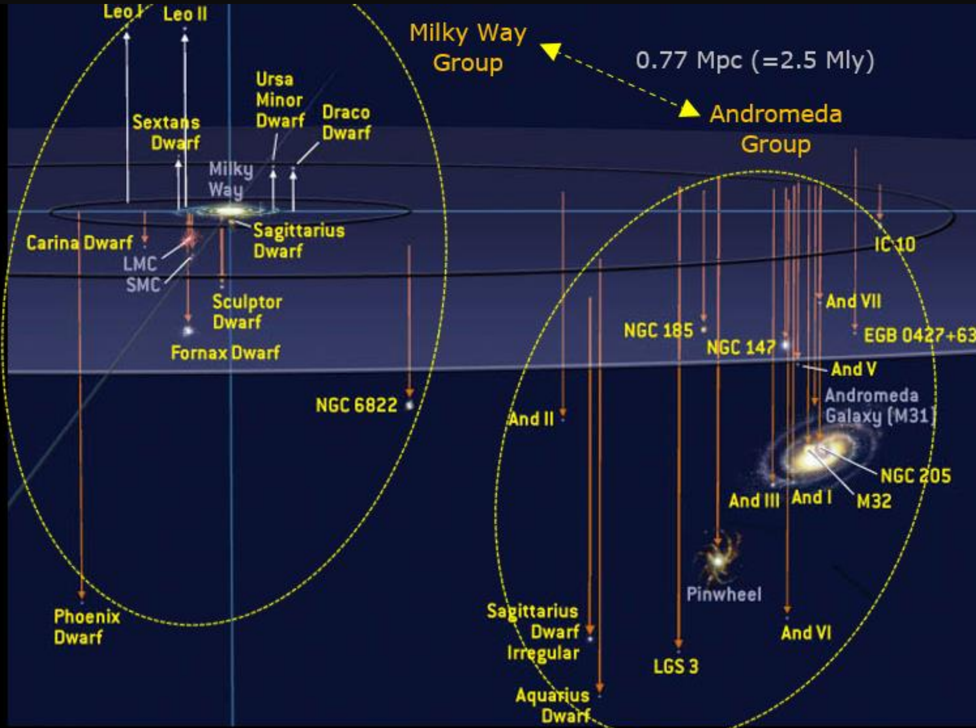
The galaxy groups were first located and observed visually, then studied in more detail using at initially live video but later in the project mostly my live night vision setup with red longpass filter, mounted a-focally on a wide field eyepiece.

Step 1 (->5 Mly): The Local Cluster.

(The Milky Way + Andromeda groups with satellites)



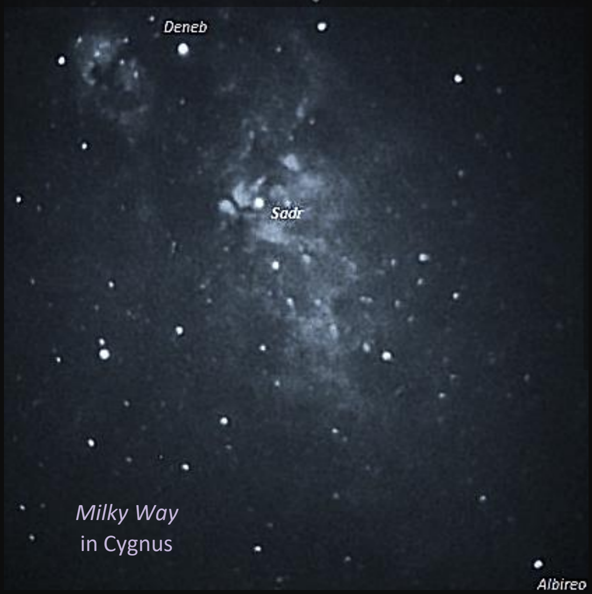
Courtois et al.: COSMOGRAPHY OF THE LOCAL UNIVERSEarxiv:1306.0091v4, 13. June 2013
Distance circle: 2 Mpc (= 6.5 Mly)



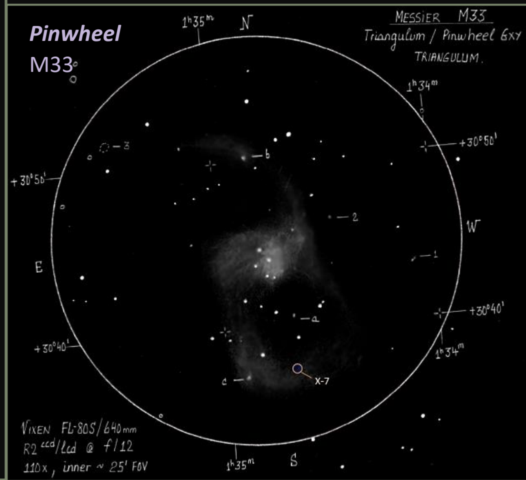
Astronomy, 2005
Each of the Milky Way and the Andromeda-M33 groups contain > 50 smaller dwarf/satellite galaxies

In 2015 around 30 dwarf galaxies were known to belong to our Milky Way spiral; As of 2018 the number was up at ~50 dwarf companions with still more expected in the coming years, probably 100+ out to 0.3 kpc. The largest and most massive satellites of our MW are of course the two Magellanic Cloud irregular galaxies (LMC, SMC), while Andromeda (M31) has the Triangulum spiral (M33) as its largest companion.

The dwarf galaxy companions to both the MW and M31 are all comparatively small, but some are still detectable in amateur telescopes. On the N celestial hemisphere, we can see the Leo I-II, UMi and Draco dwarfs in orbit around the Milky Way, but these are all faint 11-13^m and not easy to spot in small instruments. It is actually easier to study the brightest dwarf galaxy companions of the Andromeda galaxy here from the N hemisphere.



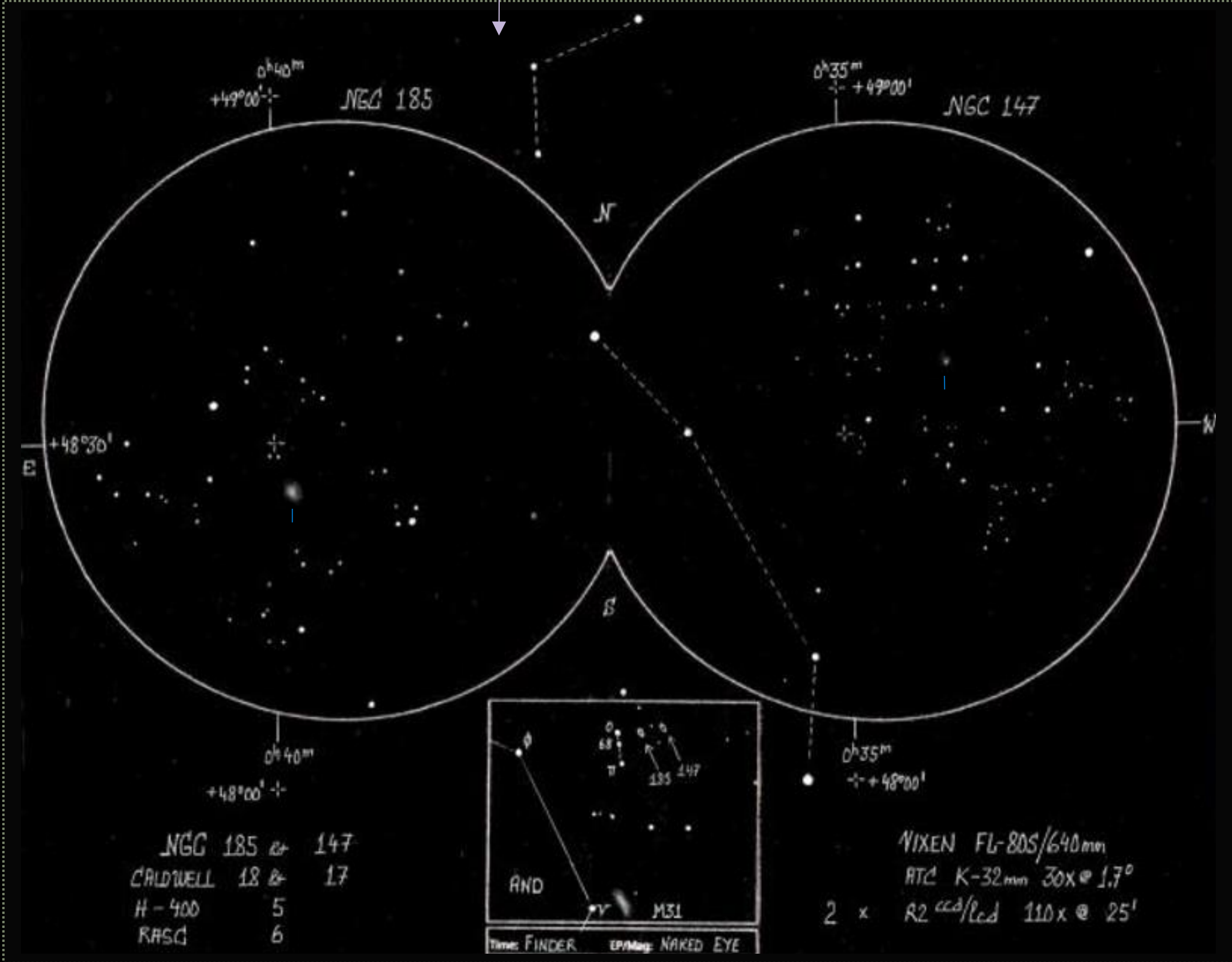
Pegasus Dwarf spheroidal galaxy (aka *And. VI*)

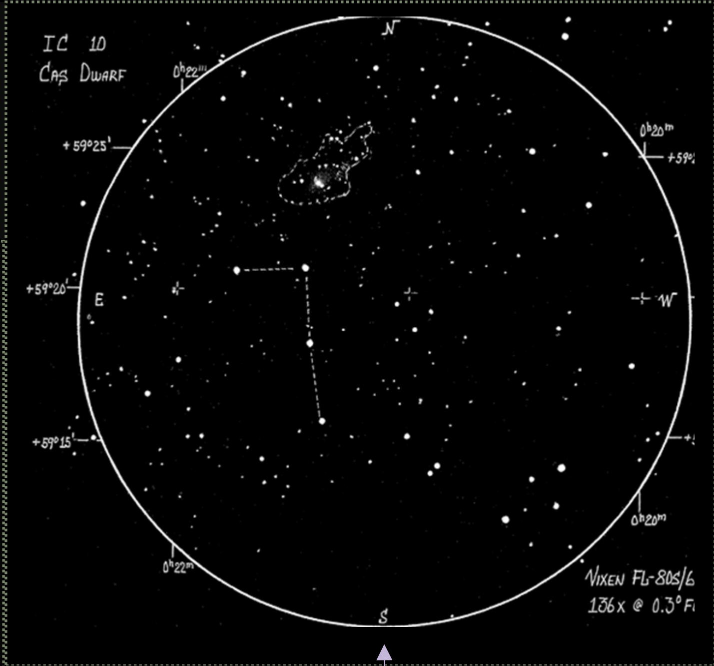


Local Group dwarf galaxies.

As an example-observation of local system dwarf galaxies, here's my view of the two dwarf spheroidal satellite galaxies to the great Andromeda spiral galaxy**: NGC 184 and NGC 147**. They are both located a good 2 Mly from our Milky Way in southern Cassiopeia, bordering on Andromeda. Each dwarf is massive ~1/10 the mass of its parent galaxy (the same ratio as the LMC to our Milky Way), and they form a stable bound binary system orbiting M31 together, but at a distance further out from their parent galaxy than the Magellanic clouds are from the Milky Way.

In my 3" refractor I could easily frame both satellites at 30x in the 1.6° FOV of my **finder eyepiece (ATC-K32m)**. The 9.2^m NGC 185 spheroidal dwarf shows up as a faint oblique glow in the field, while the 9.5^m NGC 145 is harder to identify at this low magnification, unless you have a clear, dark sky. For more detail I switch to study these two Andromeda companions using **live video (R2 ccd/lcd)** for 110x @ 2.5° FOV; NGC 185 now shows a brighter active galactic nucleus (AGN) rich in gas, dust and young blue stars, which contribute to the higher surface brightness. Both spheroidal companions are accompanied by several globular clusters, some of which are bright enough to be spotted in amateur telescopes.





IC 10, the *Cassiopeia Dwarf satellite* of M31

This dwarf is located just N of a right-angle asterism of four ~11^m stars, -- but I can't spot it tonight with glass eyepieces only (I tried 34x – 108x). IC 10 is a starburst galaxy due to tidal disruption from M31; It is relatively rich in heavy WR and neutron stars plus X-Ray binaries (with a black hole), but as it is located near the plane of the MW, it is heavily obscured by interstellar dust (around 3^m extinction).

Using my small *R2 ccd/lcd* for live video, I can detect a bright star at the center of IC 10, and a couple of fainter (probably WR) stars just to the E of this, which mark the location of the brightest HII star-forming region in the dwarf galaxy: **[HL90]111**.

Further identification of stars and nebulosity in IC 10 is however extremely difficult, and I cannot determine the outline of the dwarf galaxy (but I have indicated it anyway on my drawing using a dotted line to facilitate latter attempts at identification in better observing conditions).

Step 2 (->20 Mly): **The Local Supercluster.**

The *"Local Sheet"* [M81, CVn-I, M83/CenA] groups, plus the *"Galaxy Clouds"* [M101, Leo-I] groups.

From galaxy clusters to a hierarchy of superclusters and to cluster filaments

Our own **Local Cluster of galaxies** with members at distances less than 5 Mly is as mentioned best studied in autumn, when we have a window below the Milky Way disc through which we can see relatively unobstructed along R.A. 0^h30^m, from Cassiopeia in the north down through Andromeda, Pegasus, Pisces, Cetus and Sculptor.

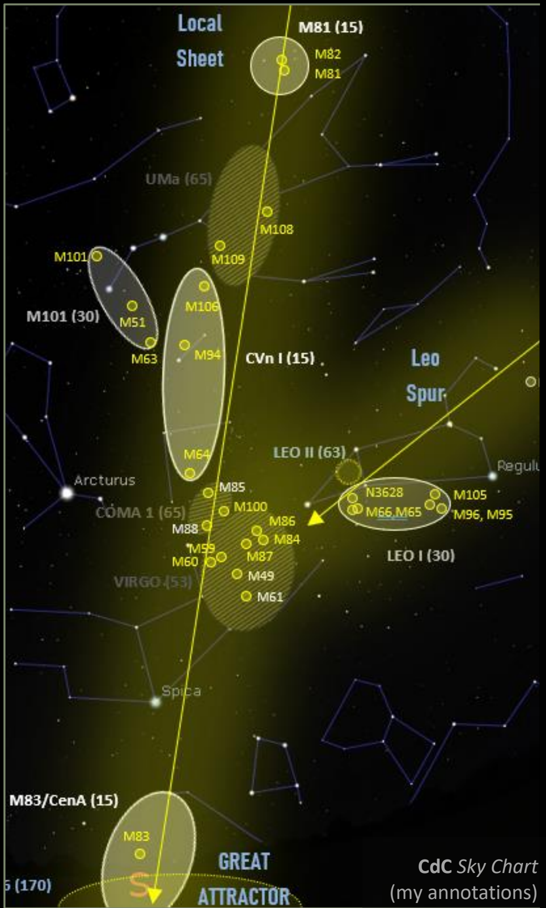
On a larger scale out to 20 Mly, our Local Cluster is just one member of the Local Supercluster, which is best seen in springtime with its member galaxy clusters spread out above the Milky Way disc along R.A. 12^h30^m, from Ursa Major in the north, down through Canes Venatici, Leo, Virgo to Centaurus.

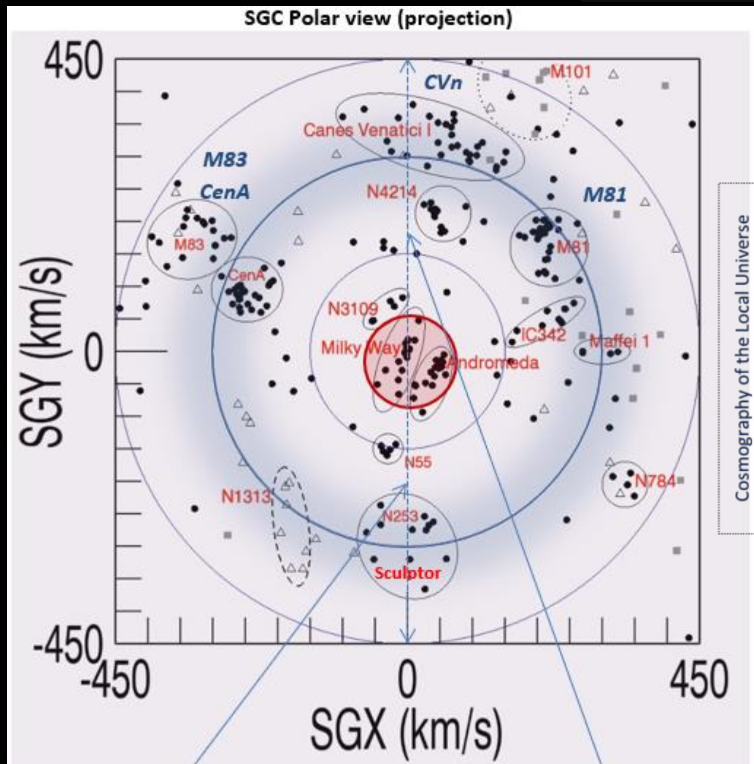
On a still larger scale out to 60 Mly, our own Local Supercluster is but one member of the giant Virgo Supercluster, with the member Superclusters also distributed roughly along the 12^h30^m axis that defines the supergalactic plane. (The reason for this distribution of galaxies in a "local sheet" must be found in the large-scale filamentary structure of matter seen throughout our observable universe).

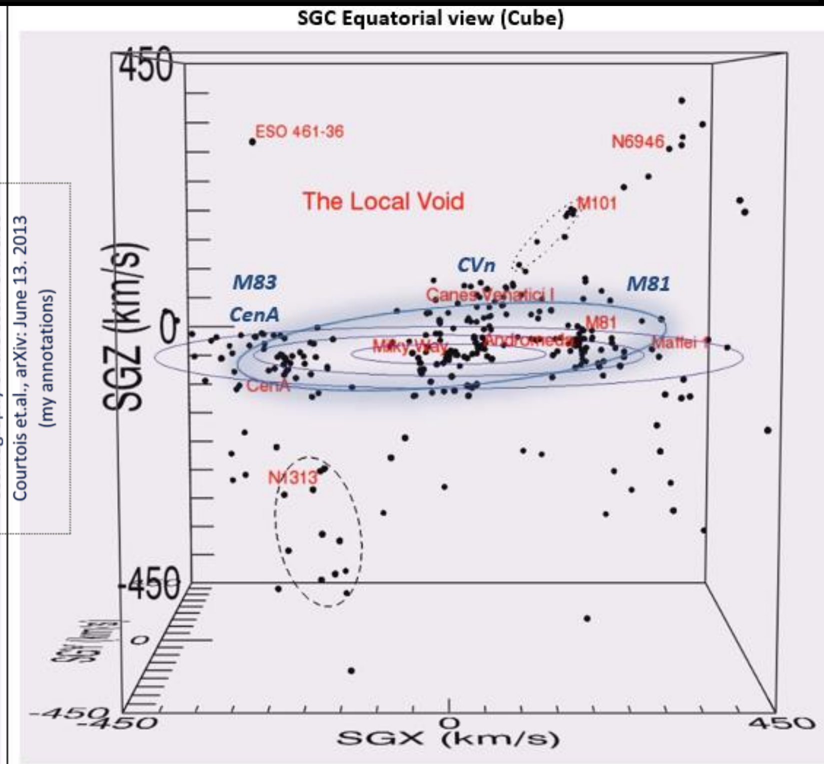
The Local Supercluster

Here's a context-view of the major galaxy associations in our Local Supercluster out to a distance of ~20 Mly (6 Mpc), all plotted in Supergalactic Coordinates (SGC). Our **Local Cluster** with the MW and M31 are seen at the center of the maps, inside the red circle out to ~1 Mpc, and the fall view below our Milky Way galactic plane is "downwards" from Andromeda to Pisces-Sculptor at X,Y ~0,-450 in supergalactic polar view. The spring "Milky Way" of galaxy groups from M81 to M83/CenA in our **Local Supercluster** is found "upwards" above our Milky Way galactic plane around X,Y ~0,+450 in supergalactic polar view.

On the following pages I include some example-observations **of the Local Supercluster members.** Being ~3x closer to our Milky Way than the Virgo Supercluster, the galaxies in these local groups show up more widely scattered on the night sky, but they also offer greater detail in structure as compared to the more distant galaxy groups.







FALL (R.A.: 00^h30^m)

5-10 MLY LOCAL & SCULPTOR GROUPs

1: MILKY WAY: LMC, SMC, M54, M79
2: ANDROMEDA: M32, M32, N147-N185, N205
3: SCULPTOR: N 253, N55

SPRING (R.A.: 12^h30^m)

15-20 MLY M81-CVn-Cen GROUPs

1: M81/M82
2: CVn I
3: M83 - CenA

Looking from outside the nearby *Sculptor Group (N253)* through our *Local Group* with the Milky Way-Andromeda-Triangulum galaxies towards the ~15 Myr distant groups : *M81* to *CVn* to *CenA* and *M83*

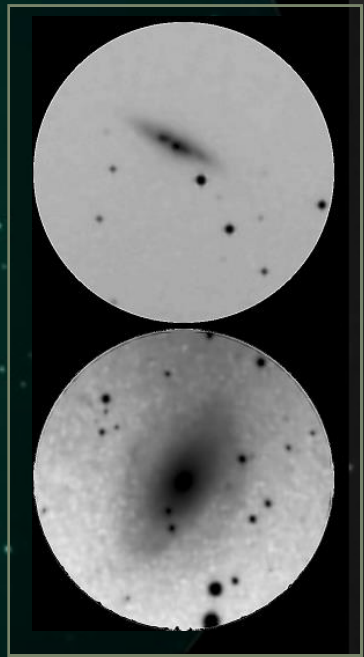
Cosmography of the Local Universe. Courtois et.al., arXiv: June 13. 2013 (my annotations)

Local Supercluster: M81 Galaxy Group

I start out by focusing on the nearby galaxy groups in our own Local Supercluster (~5 Mpc - 15 Mly), starting from the north with the M81 Group in UMa, then moving south to the CVn-I galaxy group in Canes Venatici, surrounded by the M101 and the Leo galaxy clouds, and finally ending up deep south with the M83 Group in Hydra. I first point my 4" refractor with a 41mm ETH eyepiece towards M81, the largest galaxy in the M81 Group that counts 41 members, including 4 NGCs: 3031 (M81), 3034 (M82), 3077 and 2976. The two large Messier galaxies (M81-M82) are clearly seen using glass only, and the main structure of both galaxies can be glimpsed with averted vision. With my image intensifier on top of the 41-ETH, all four mentioned NGC galaxies can now be studied in greater detail (though I can only frame 3 galaxies in the 2° FOV @ 15x magnification).

M81 (NGC 3031 *aka Bode's Galaxy*) is a SA spiral with a bulge that is significantly larger than the one found in our Milky Way. The bulge has an active galactic nucleus (AGN) with a supermassive black hole ~15x the mass of the black hole in our Milky Way. M81 is surrounded by two prominent spiral arms with large quantities of dust as well as starburst regions. Observing M81, the large central bulge is evident, and already at 15x I can glimpse the pair of closely wound spiral arms. At higher resolution some small H-II regions should be visible in the spiral arms, but I'm not able to spot these with the 610nm longpass tonight; Maybe I'll try later with a 12nm Hα filter, but my guess is I'll need more aperture than my 4" for this. (A better option will probably be to do a live video observation of this object).

Here's a view of the core galaxies in the M81-group, through my 4" at 15x in a 2° FOV, using NVD + a red longpass.



M82 (NGC 3034 aka *the Cigar Galaxy*) has been classified as an I_0 irregular, and I can see the bright starburst core divided in two by dark gas and dust filaments. Recent research has however shown M82 to be a nearly edge-on spiral galaxy with a bright central bar plus two spiral arms that both have a bright starburst knot at the point where they emerge from the bar; Looking for this morphology, I can indeed identify the bar plus the two knots where the arms connect to the bar, all embedded in the fainter glow of the pair of closely wrapped spiral arms.

Gravitational interactions of M81 with the smaller, surrounding NGCs in the group have stripped hydrogen gas from all galaxies into gaseous filamentary structures in the group. Some of this gas has subsequently fallen into the centers of M82 and NGC 3077, leading to vigorous starburst in these companions.

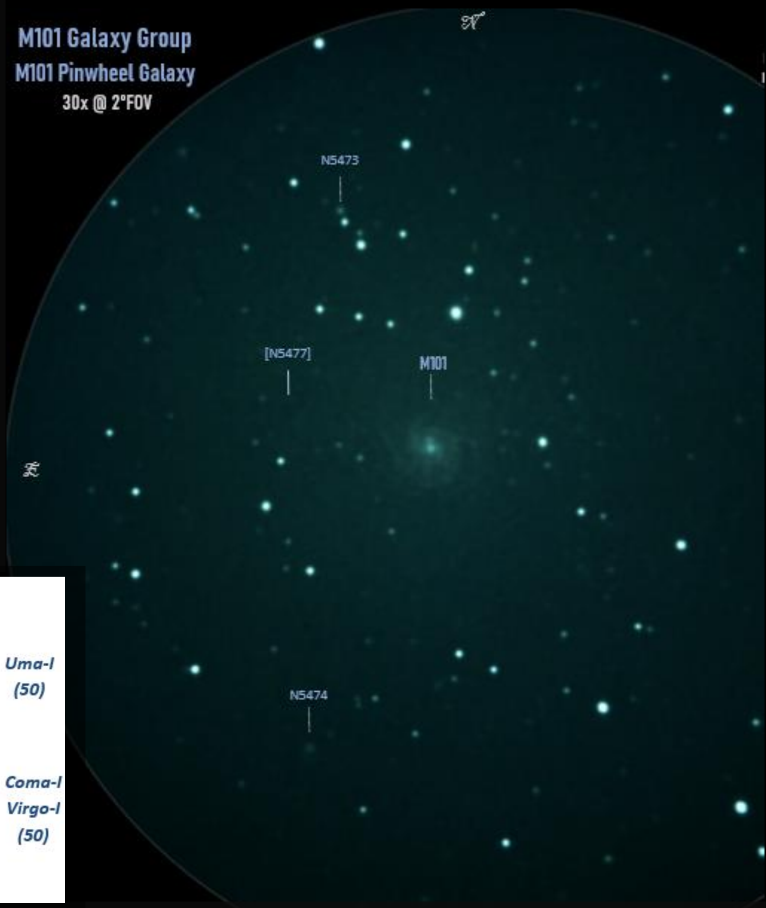
Local Supercluster: The M101 Cloud

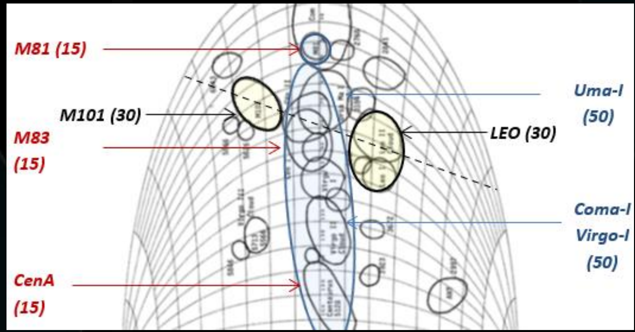
The **M101 cloud of galaxies in the extended sense** includes the *M101 subgroup* (with NGC 5457 *Pinwheel*) plus the *M51 subgroup* (with NGC 5194 *Whirlpool* and NGC 5055 *Sunflower*), both at a distance of around 25 Mly:

- the **M101 subgroup** contains - besides the Messier *Pinwheel* Galaxy (N5454) - also the two NGC dwarfs: N5474 (peculiar SA) and N5477 plus 6 smaller galaxies.
- The **M51 subgroup** contains 4 galaxies around the Messier *Whirlpool* (pair M51a-b, aka N5194-5195) including NGC 5229 (edge-on spiral), while another 6 galaxies are grouped around the Messier Sunflower (N5055), including edge-on NGC 5023.

In my 4” refractor at 16x in 2½° FOV, the mixed SAB face-on spiral NGC 5457 (M101 itself, the “Pinwheel”) shows up using glass only as an E-W elongated hazy splotch with a small brighter nucleus. Using image intensification, I can glimpse the 3 main spiral arms: two branching out and down from the NW side, and one coming out and up from the SE side. Also, in the same field SE of the “mothership”, I can spot the companion NGC galaxy 5474 as a N-S elongated faint hazy spot, with a somewhat brighter core at the N tip.

For higher magnification, I now switch from the TV 41mm PAN to a TV 21mm ETH eyepiece, yielding 30x @ 2° FOV (still with IIT). The galaxy structure is now seen more clearly, with the large disc (1.7x the size of our Milky Way) and the three far-flung main arms that are sprinkled with large knots of star-forming H-II regions, several of which have received their own NGC. The asymmetric spiral arms with intense star formation in M101 are caused by tidal gravitational interaction with its four prominent NGC companion galaxies: N5474 (closest to M101) plus N5477, N5204 and N5585. As mentioned, the dwarf Sc spiral NGC 5474 is easily observed S of M101, and I can glimpse its distorted shape with the brighter nucleus displaced N (towards M101) and the fainter haze of the arms offset to the SW. Interesting!





Local Supercluster: The Leo Cloud. (*Spur*).

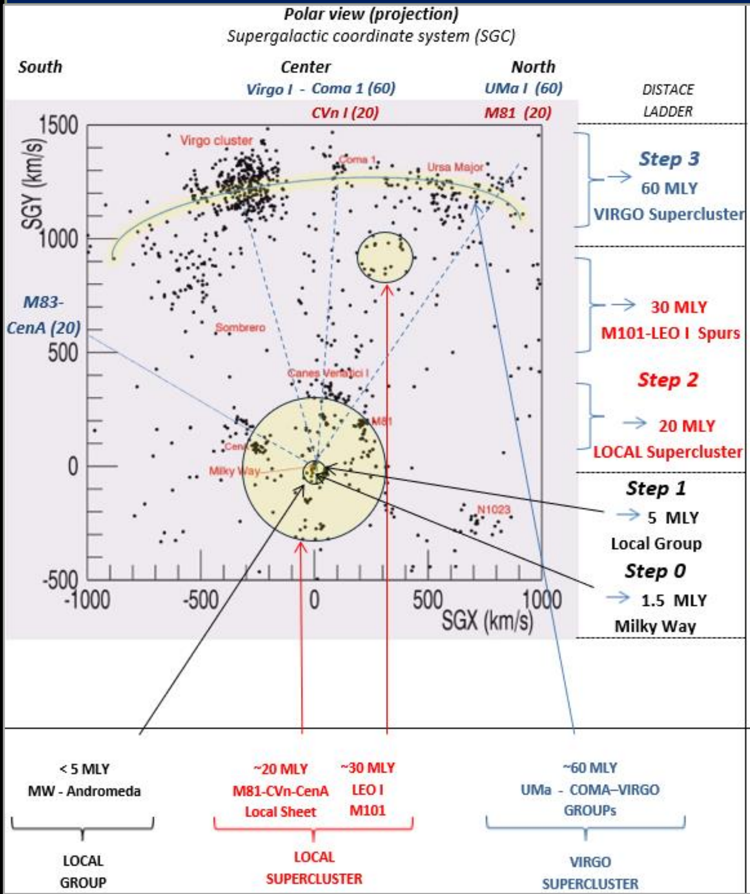
The Leo Cloud of galaxies (*“Leo Spur”)* includes the **M66 subgroup** (the E Leo Triplet) plus the **M96 subgroup** (the W Leo Triplet)

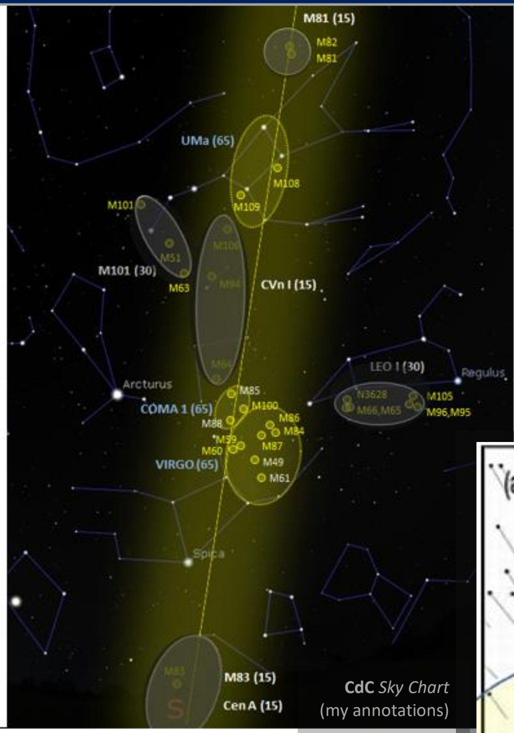
- In the M66 subgroup, the distance between M66 (NGC3627) and M65 (NGC3623) is only ~150 Kly (about the same distance as from our Milky Way to the LMC), while NGC3628 is a little further away at double this distance ~300 Kly. There’s ample morphologival evidence of close enfounters between NGC3628 and M66 in the form of distortions in the galaxy disks plus a tidal bridge of gas with an optical plume between them.
- In the M96 subgroup, **M105** (NGC 3379) is a classic elliptical galaxy, while **M95** (NGC 3351) is a barred spiral galaxy with a star-forming circumnuclear ring plus a larger ring of HII regions, both presumably formed by resonance with the stellar bar. **M96** (NGC3368) has a high surface brightness inner disk with a faint outer ring formed by a set of spiral arms. The outer disk is offset by more than 20° from the inner one, and shows mild star-formation which may be triggered by accretion from a HI ring in the area.

A 200 kpc diameter Leo Ring of neutral (HI) gas has been described surrounding the M105-NGC3384 galaxy pair; The origin of this ring may be primordial or it may be the expanding density wave of stripped gas from a head on collision of two spiral galaxies, leaving two ellipticals near the center (M105 + NGC3384). It seems that currently M96 is drawing a tidal plume from the Leo Ring, and is accreting gas onto its outer disk; this can explain the asymmetry as well as the star formation observed in this galaxy.

Step 3 (->60 Mly): The Virgo Supercluster.

Our Virgo Supercluster plus the nearest surrounding UMa-I and Coma-I galaxy associations.





The spring Milky Way of Galaxies :

	Near (~20 Mly) : Local Supercluster		*Far (~60 Mly) :* Virgo Supercluster
North :	M81 (20)	–	UMa I (60)
Center:	CVn I (20)	–	Coma –Virgo (60)
South :	M83, CenA (20)		

Cosmography of the Local Universe. Courtois et.al., arXiv: June 13. 2013 (my annotations)

← Local Supercluster galaxy locations

As previously described, the **Local** and the **Virgo Superclusters** both line up together on the northern hemisphere in the sheet called the *Spring Milky Way of Galaxies*, roughly along 12^h30^m R.A. in projection on the celestial dome.

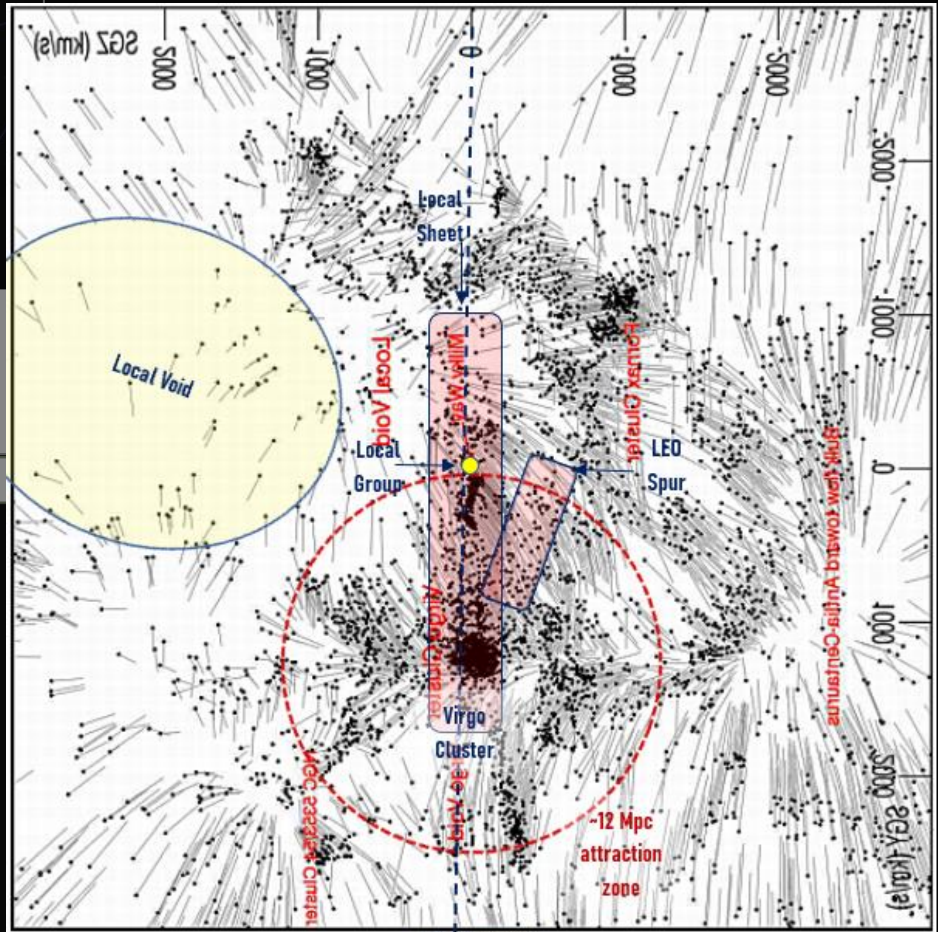
The **Local SC** (Step-2: *M81, CVn-I, -CenA; M101, Leo-I*) is seen in the foreground at 20-30 Mly, while the **Virgo SC** (Step 3: Virgo-I, Coma-I, UMa-I) is found in the far background at ~60 Mly.

(The nearby **Fornax SC** is located on the southern hemisphere, roughly along 03^h30^m R.A. in projection, but it is unfortunately below -35° DEC on my night sky, and thus impossible for me to observe from 56°N here in Denmark).

Local Supercluster galaxy motions →

To the right is shown a plot of the motions of galaxies in our cosmic neighborhood, from 13 billion years in the past to the present day. The plot is in Super-Galactic coordinates (SG X projected on the SG Y-Z plane); The depth of the plot -500 km/s < SGX < 500 km/s redshift. I've oriented the plots so as to best fit the view on our night sky, as seen from the N hemisphere of Earth.

This plot shows the full region of infall around the Virgo Cluster as well as all pertinent nearby attractors. The main gravitational attractor in the area is of course the Virgo-I Cluster. Over a thousand galaxies have already fallen into Virgo-I, and in the future all galaxies that are currently within 12 Mpc of the cluster will be captured. Our Milky Way galaxy lies just at the border of the Virgo capture zone, but the Milky Way and Andromeda galaxies are destined to collide and merge in around 5 Byr .

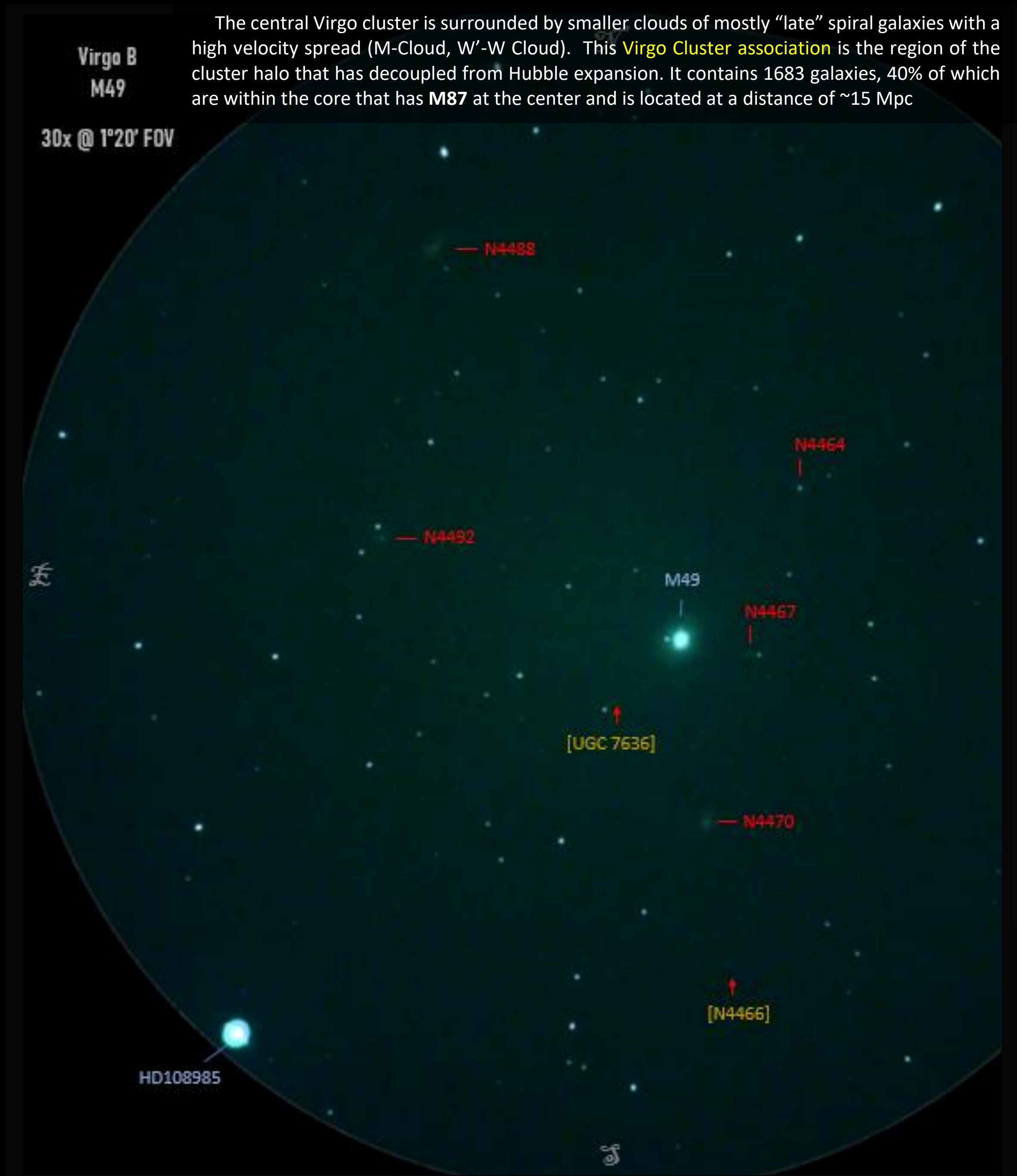


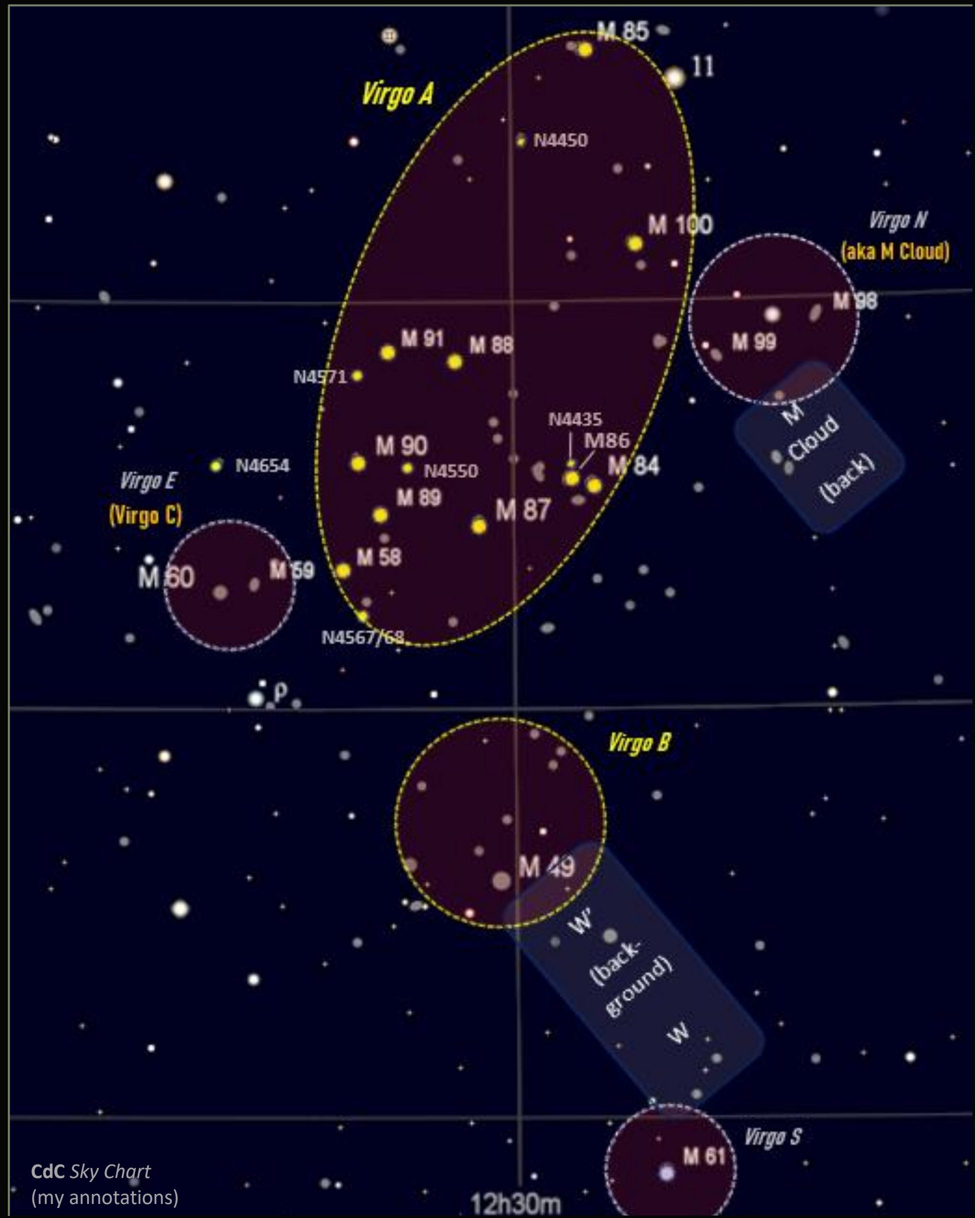
Cosmography of the Local Universe. Courtois et.al. arXiv: June 13. 2013 (my annotations)

The Virgo-I Cluster structure.

The **Virgo Supercluster** contains at its core the old, large and very massive **Virgo-I Cluster** with >2000 galaxies located in three distinct substructures. Each Virgo subcluster has at its center some old and massive "early" spherical/elliptical systems, most prominent: *Virgo A*: M87, M86 - M84, *Virgo B*: M49 and *Virgo C*: M60 and M59.

The central Virgo cluster is surrounded by smaller clouds of mostly "late" spiral galaxies with a high velocity spread (M-Cloud, W'-W Cloud). This Virgo Cluster association is the region of the cluster halo that has decoupled from Hubble expansion. It contains 1683 galaxies, 40% of which are within the core that has **M87** at the center and is located at a distance of ~15 Mpc





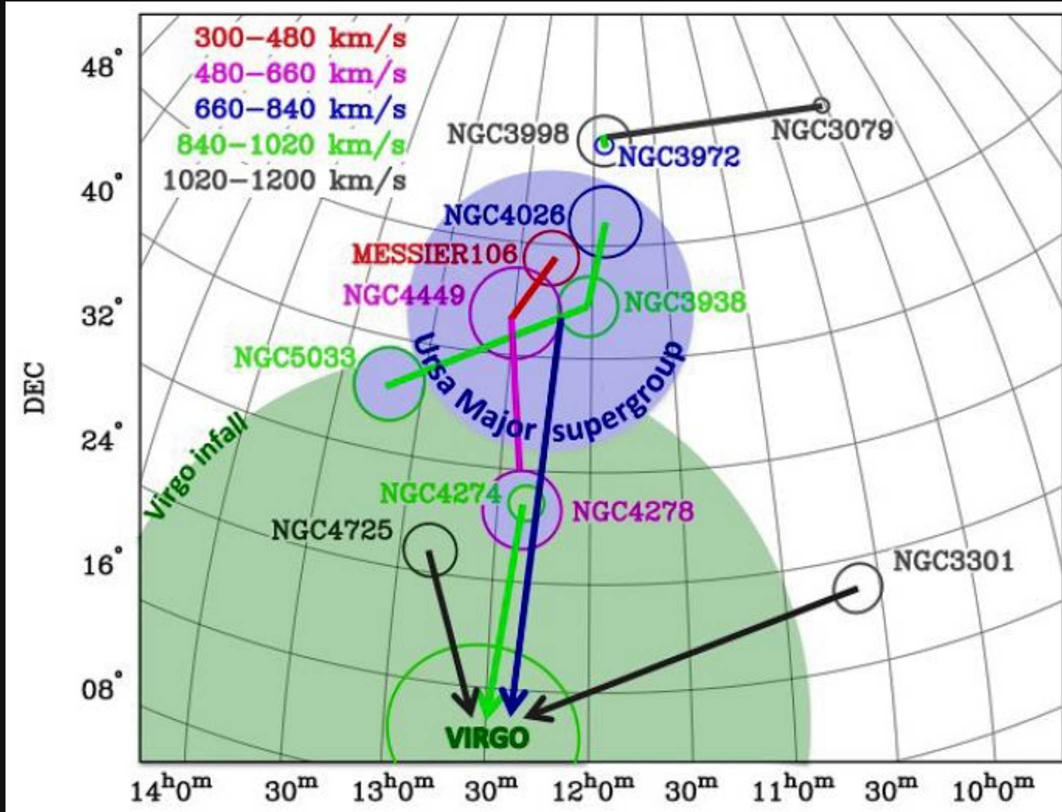
The **Virgo Cluster itself** (PGC 41220: 714 major galaxies) has a weighted distance of ~16 Mpc. The farther out W'-W and M clouds are falling toward us from the back side of the cluster, while some of the closer galaxies in the S-group are falling away from us from the front side of the cluster. The Virgo Cluster proper is an aggregate of several **separate sub-clusters**:

Virgo A: the ellipticals M87 E_{0-1} plus M86 E_3 - M84 E_1 the largest subgroup that also includes M89 E_0, M84 E_1 - M85 S_0 and the spirals M58 SBb, M88 Sb - M91 SBb, M90 SBab, M100 SBbc.
Virgo B, the elliptical M49 E_2
Virgo C, or E: East: the ellipticals 60 E_1 and M59 E_5

The UMa-I Cluster structure.

The **Ursa Major Cluster,** in contrast to the Virgo-I cluster, is younger, still very large (scattered), but with a relatively low mass and small velocity spread. It contains mostly late-type spiral galaxies and has no obvious center. There are several galaxy subgroups within the UMa cluster, many bound to one another and in the early evolutionary process of merging (see figure right). →

The **Virgo-Icluster** is likely in the process of slowly accreting the UMa-I association as well as the N4274, N4725 (Coma-I) and N3301 galaxy groups.



The Ursa Major cluster redefined as a `supergroup'
Wolfinger et.al., arXiv 4 Aug 2016

Galaxy groups that are likely to be in the Ursa Major supergroup: **M106, N4449, N4278, N4026, N3938 & N5033. Bound structures** are marked by lines; the red/magenta and blue/green structures are likely galaxy group filaments bound to one another and therefore together constitute the UMa supergroup (highlighted in blue).

The zone of infall into the Virgo cluster is highlighted in light green. The Virgo cluster is likely to be accreting galaxy groups such as the **NGC4274, NGC4725 and NGC3301** groups as well as the UMa supergroup as a whole (marked with arrows towards the Virgo cluster), while the **NGC3998, NGC3972 and NGC3079** groups are just beyond the reach of the Virgo attractor and thus unlikely to be bound to both the UMA supergroup and the Virgo cluster.

N4449 GC

N3938 GC

N4026 GC

The Coma-I Cluster structure.

The ***Coma Berenices*** constellation is a "busy" area, with the Coma star cluster of our own Milky Way in the foreground at ~300 Ly, the Coma-I galaxy group at a medium distance of ~50 Mly, and, *"in a kingdom far, far away"*, the Coma Cluster (Abell 1656) in the background at a whopping 325 Mly distance, located in the Hercules-Coma-Leo supercluster that forms the center of the *"Great Wall"* filament of galaxies beyond our own Local Sheet (I'll return to the *"Great Wall"*, when I'm done with our Local Sheet of galaxies). Talk about "a room with a view" here...

The **Coma-I Galaxy Cluster** features many young spiral galaxies, with only three interspersed ellipticals/lenticulars. The group has **two main gravitational centers**: a dense subgroup centered on **N4274/78**, plus a looser subgroup surrounding **N4565** and including the galaxies around the bright **N4725/47.**

Coma-I First Subgroup

The **first subgroup** features three prominent almost face-on SB barred spiral galaxies (***N4274, 4245, 4314***) plus one bright $E_{1\text{-}2}$ elliptical (***N4278***). All are well seen in my 4" refractor at 15x magnification (TV 41 PAN+IIT). The brighter nucleus and main orientation of the spiral discs are clearly observed (SE-NW), but I can't detect that all three are ring galaxies (caused by Lindblad resonance in their barred discs). The elliptical galaxy to the S of the spirals shows up as a bright but hazy star. It is known to have an active core (AGN) with a supermassive black hole at the center; Much like M87 in Virgo, the black hole has an accretion disc shooting out two jets, but in N4278 the jets are relatively small (1½ Pc) and only visible in radio emission.

Coma-I Second Subgroup

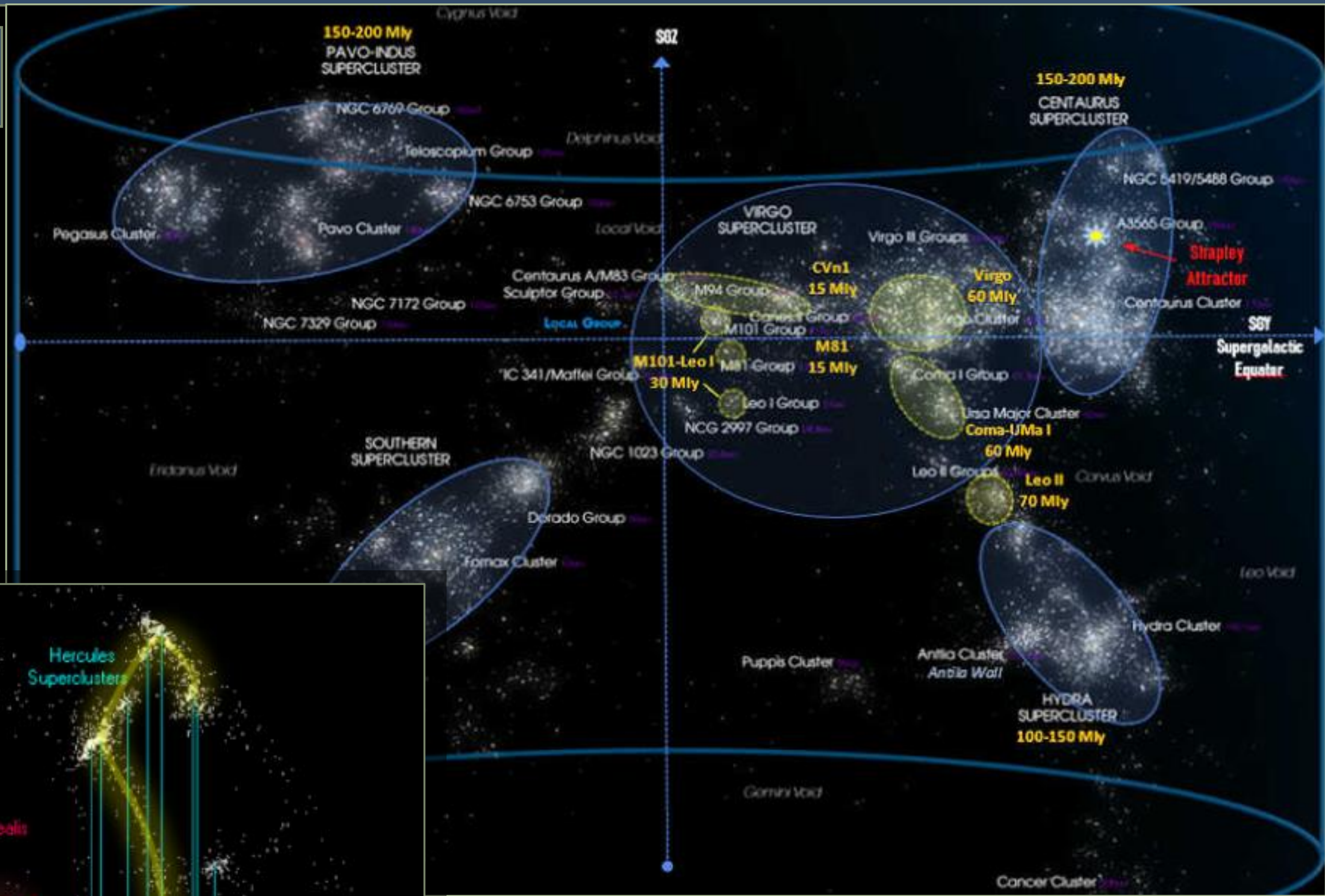
The **second subgroup around N4725** resides in a beautiful *star field* →
with N4725 at the center of a large triangle of ~7^m stars plus several chains of still bright 9-10^m stars. **N4725** is a peculiar SAB mixed giant spiral that shows a very bright central core with a bar encircled by a prominent starburst ring. The galaxy disc is tilted ~45° from face-on, so the stellar ring shows up brightest where we're looking through the peripheral "bending" part of the ring (giving the galaxy the look of Darth Vader's two-winged *Tie Fighter* from Star Wars!). To the NE of N4725 is seen the fain streak of the smaller edge-on SB spiral **N4747** companion galaxy. The two galaxies are an interacting pair, where gravitational pull has warped the disc of N4747 and pulled out gas into three tidal tails, whereas the close encounter has left N4725 with an active Seyfert nucleus and only one circular galaxy arm. Close by N2725 to the E, I can just with some effort glimpse the small spiral companion N4712.

The **second subgroup around N4565** includes 3 NGC galaxies →
plus 6 smaller members. As seen in my 4" refractor, ***N4565*** is a beautiful edge-on SA spindle (the *"Needle"* or *"Flying Saucer"* galaxy) with a bright central bulge (I was not able to resolve the dark dust band in front of the galaxy nucleus though). I can see the core of the type $E_{1\text{-}2}$ group member **N4494** E of N4565 as a hazy star, while the faint companion N4562 (aka N4565A) is just beyond the resolution of my setup tonight.

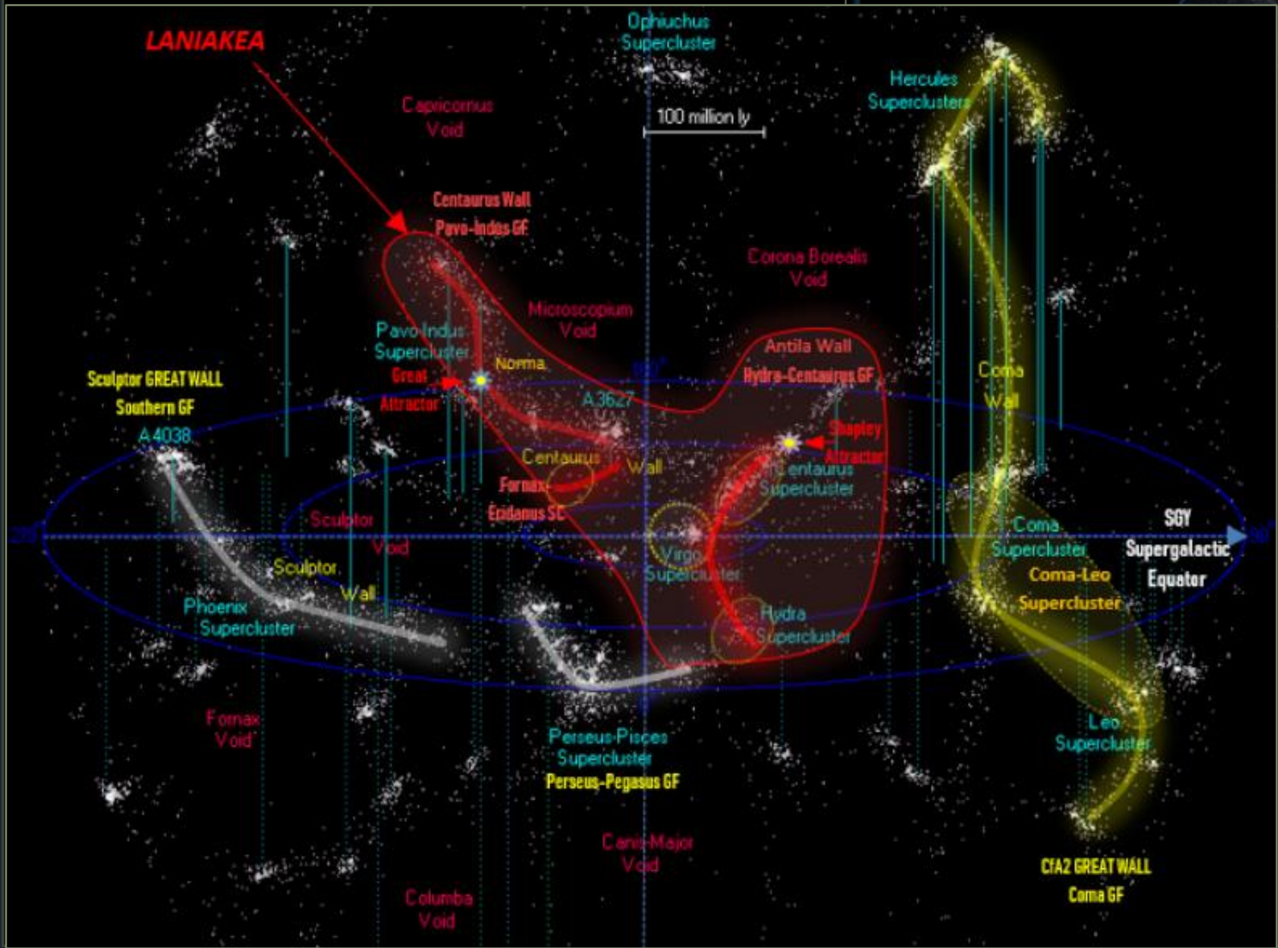
Step 4 (->500 Mly): **Supercluster Filaments and Voids.**
(Laniakea, Perseus-Pegasus Galaxy filament, CfA2 Great Wall)

At the next step up the distance ladder, the Virgo Supercluster (~60 Mly distance) is seen residing at the center of a large galaxy cluster filament that spans from the *Hydra Supercluster* at one end to the *Centaurus Supercluster* at the other: **The Hydra-Centaurus Galaxy Filament** (~100 Mly distance). →

The central Virgo-I Cluster is the main gravitational attractor with a region of infall out to around 40 Mly, and thus draws in both our Local Supercluster (with the Local Sheet and Clouds of galaxies in the foreground) but also the neighboring background Coma-I and Uma-I galaxy groups in the Virgo Supercluster.



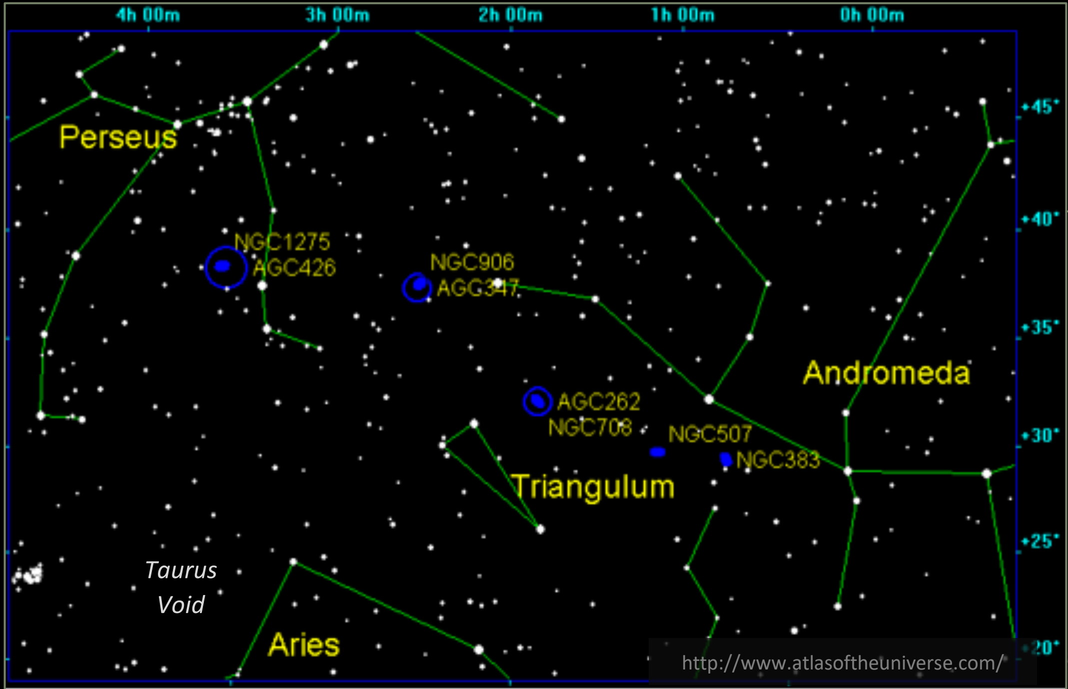
https://en.wikipedia.org/wiki/Laniakea_Supercluster
(my annotations)

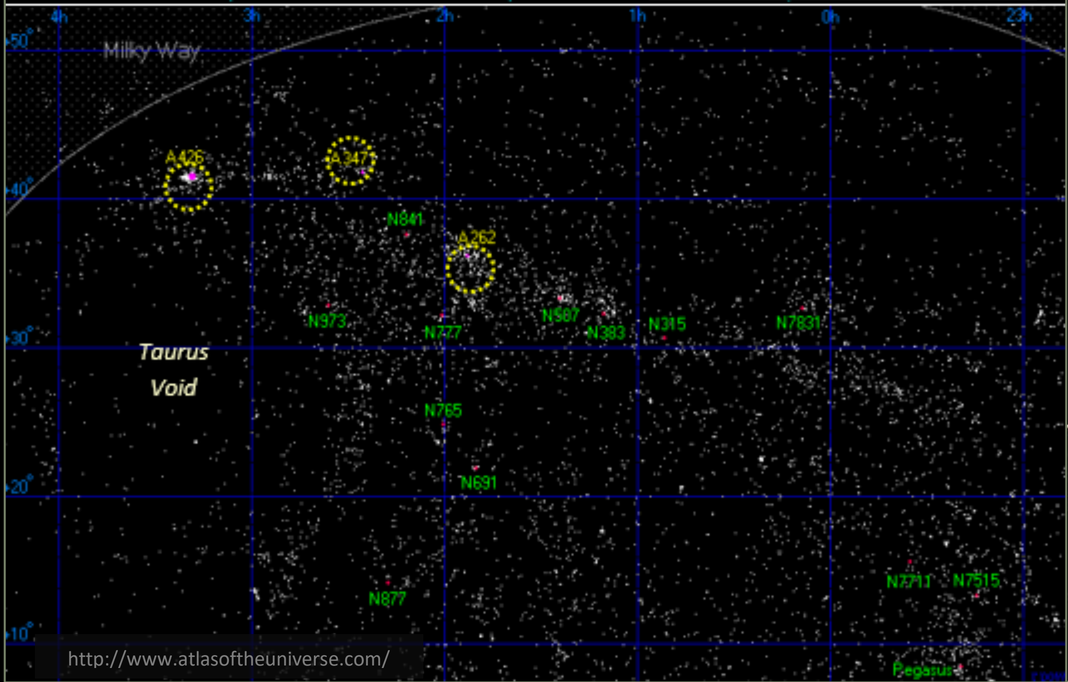


← At a still larger scale out to 500 Mly distance, we encounter yet **other Supercluster filaments** (*Perseus-Pisces, Pavo-Indus*), **walls** (*Great Wall, Southern Wall*) and **voids** (*Local, Sculptor, Hercules*).

All galaxy flows in the Hydra-Centaurus Filament and the neighboring Pavo-Indus filament are ultimately draining towards the Shapley Supercluster Attractor, which is located at 800 Mly distance from us, behind the Centaurus Cluster. The region "drained" by this deep gravitational well is known as the Laniakea Basin (Hawaiian: "*lani akea*" = heaven immeasurable).

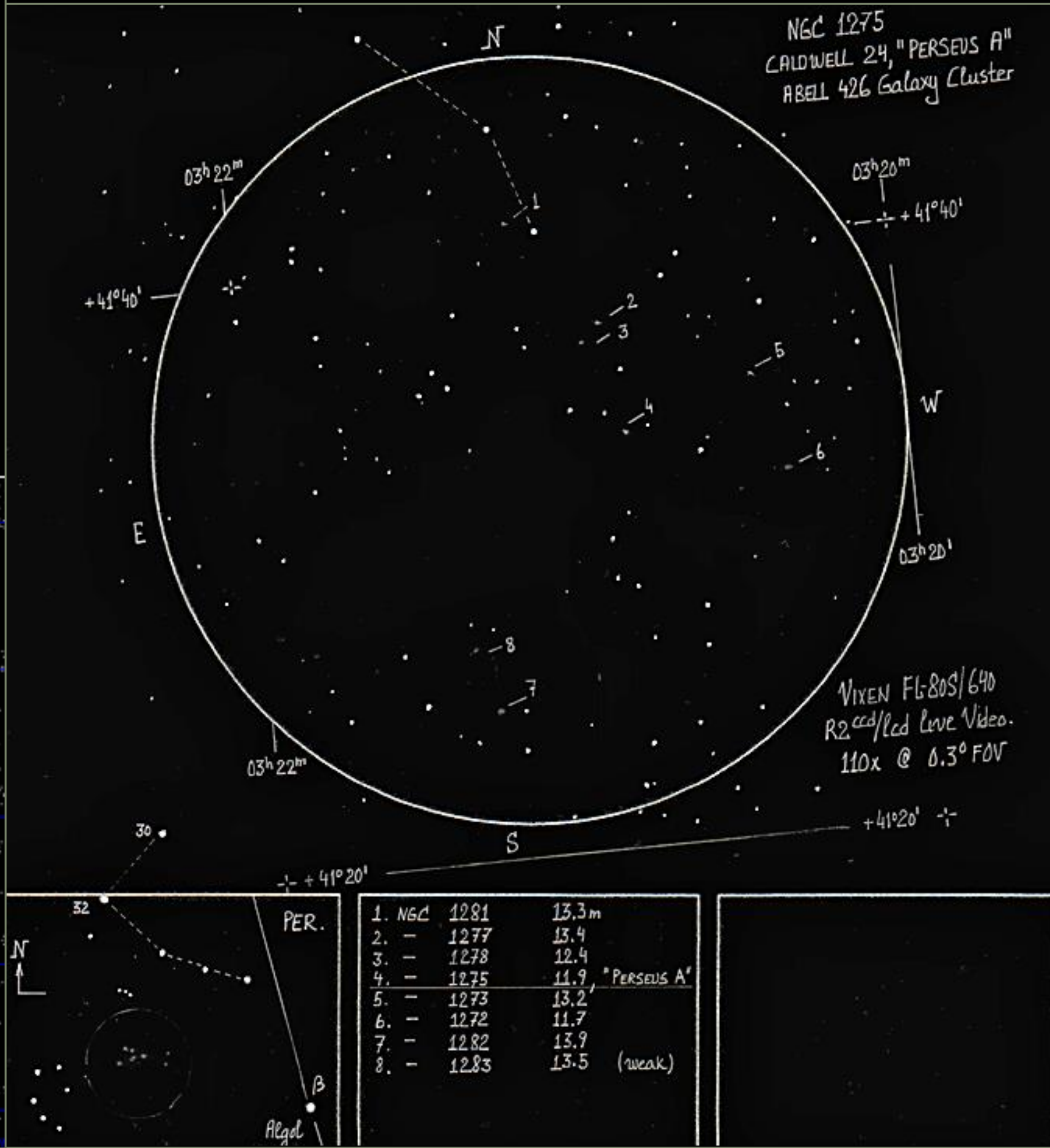
The Perseus-Pisces Galaxy Filament [~230 Mly]





We now move out from our own Hydra-Centaurus galaxy filament, until we cross the gravitational "watershed" of the *Laniakea* basin. Here we first encounter the large Perseus-Pegasus galaxy filament that has the massive Perseus-Pisces supercluster at its center. The Perseus-Pisces supercluster forms a long, dense wall of galaxies with a length of almost 300 Mly. At the eastern end of the supercluster lies the giant *Perseus cluster* (A426), one of the most massive clusters of galaxies within 500 Mly.

Not only is the Perseus-Pisces supercluster the most obvious supercluster on the night sky, but it also lies next to the most obvious void in the sky: the Taurus void, which is is a large, spheric region of relative emptiness, bounded by walls of galaxies on all sides. The void has a diameter of about 100 Mly. Most of the galaxies plotted in the area of the void on the map are background galaxies that lie behind the void.



The CfA2 Great Wall [~700 Mly]

Beyond the distance scale out to 500 Mly, I first observed the brightest galaxies in the **CfA2 "Great Wall" filament**, which was discovered in 1989 during the Second Redshift Survey of the Harvard-Smithsonian Center for Astrophysics. This supercluster of galaxy groups stretches 240 Mpc from Hercules to Coma-Leo, at a distance of 211 Mpc from the Milky Way. I observed this truly "wide field" object from the Leo (A1367) to the Coma (A1656) and Hercules (A2151) superclusters. For example, in the Leo part of the *"Great Wall"* I could identify >20 galaxies in the A1367 supercluster using my 4" refractor @ 16x in a 2½° field.

A2151
Hercules GC

Abell 1367 : The Leo Galaxy Cluster in the CfA2 "Great Wall" filament

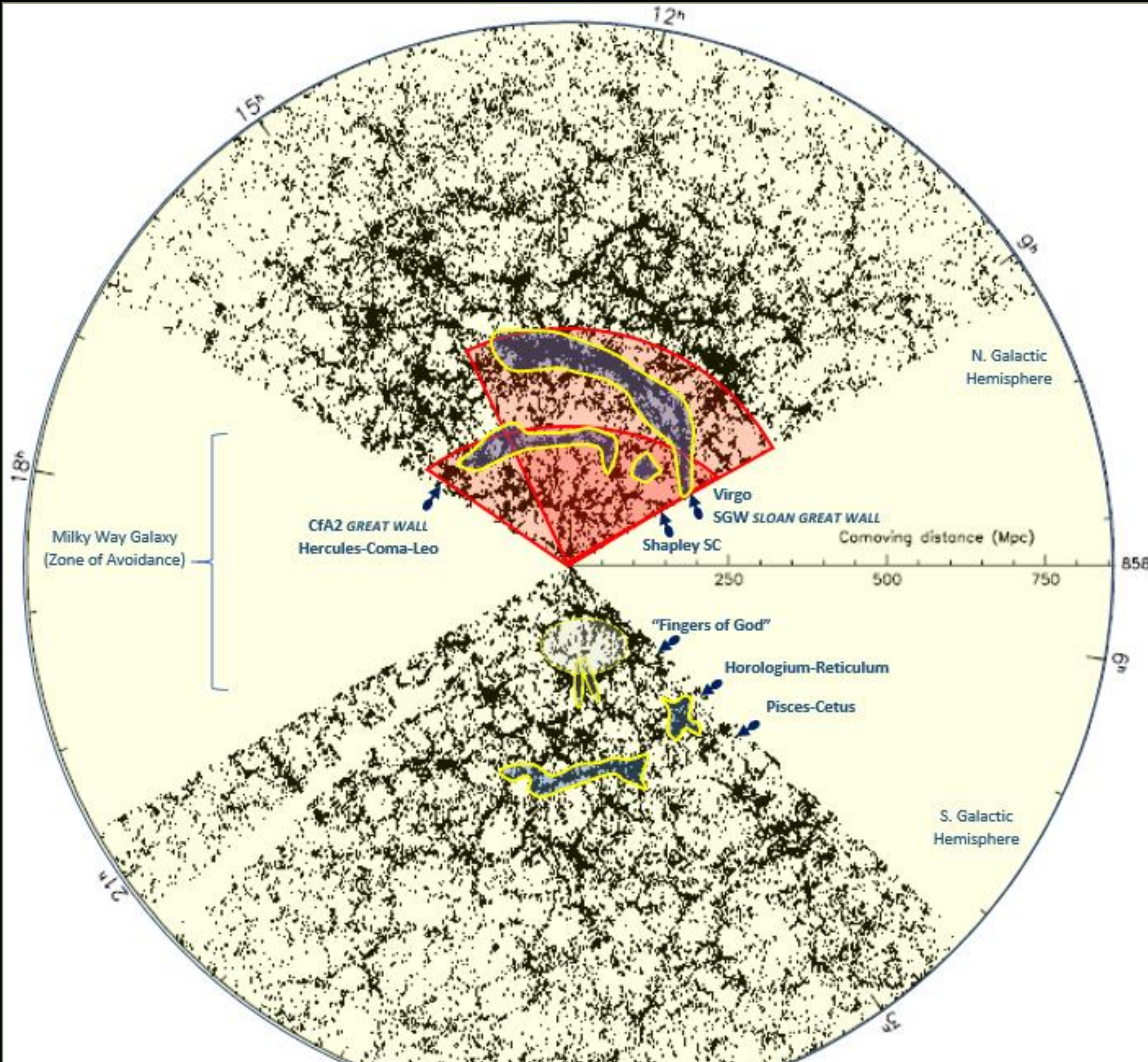
A1367 contains >70 major galaxies, including a pair of old, massive ellipticals at its gravitational centers: **N3842** and **N3862.** Both these giant elliptical galaxies have a supermassive black hole in their nucleus, and are surrounded by lenticular galaxies plus many infalling young er spirals with active star formation.

N3842 is positioned in the middle of a line of fainter galaxies, reminiscent of *"Markarian's Chain"* in the Virgo cluster. Far behind the N3842 elliptical there is a group of three distant quasars at ~10 Bly, receding from us at ~80% the speed of light; I did look for those, but couldn't resolve any of them in my 4" refractor... Now, 10 Bly is ~1/5 the way to the edge of the observable universe, so the light from those quasars has trave lled across empty space for 3 Byr and is now down at ~21^{m} (z2.2). So much darkness out there, -- less than 5% baryonic elliptical and spiral sunshine floating on the endless waves of dark emptiness. "Those empty streets, no one around", enough to give you the blues, -- *Hello sunshine, won't you stay!.*

Close to N3842 is seen the lenticular galaxies **N3841 & N3845**, plus the infalling large starburst spiral **U6697**. Several interesting interacting galaxy pairs can be spotted in the 2½° field at 15x mag., notably **N3873/75**, **N3862/I2955** and **N3861a/b** (a tight barred spiral pair).

N3862 is the other large elliptical galaxy, seen at lower left in the snapshot. It has active jets powered by a black hole that can be seen in visible light as recorded by the Hubble Space Telescope.

Step 5.1 (out to 2 700 Mly): Sloan Great Wall (~1000 Mly)



J. Richard Gott III et al, **A MAP OF THE UNIVERSE**
The Astrophysical Journal, 624:463–484, 2005 May 10

Left is shown a map of the universe out to a distance of ~900 Mpc (2.7 Gly) corresponding to a lookback time of 2.7 billion years. At this scale the Big Bang horizon is way out at a distance of a good 2m (6.75 ft), while the distance from Earth to the Virgo Cluster is only ~2mm, -- so our "local" universe is still "in a grain of sand (and eternity in an hour...)".

Each point on this map is a galaxy, and a lot of large-scale structures show up here. The general impression is that of a sponge with **many voids**, for instance a large void at 125 Mpc around 1.5h R.A., with a couple of prominent galaxy clusters at the far end, pointing towards Earth known as *"the Fingers of God"*.

Surrounding the voids are spurs, sheets and walls of galaxy groups, and we can recognize the CfA2 **Great Wall** with a length of 240 Mpc and a distance of 211 Mpc, from 9-16.7h R.A (i.e. across 7.7 h of R.A.)

The Sloan Great Wall [~1000 Mly]

Further out though, beyond the *CfA2 Great Wall*, is seen an even larger structure spanning 450 Mpc (1000 Mly) through central Virgo at 310 Mpc distance, -- the currently largest known structure in our visible universe: the **Sloan Great Wall (SGW).**

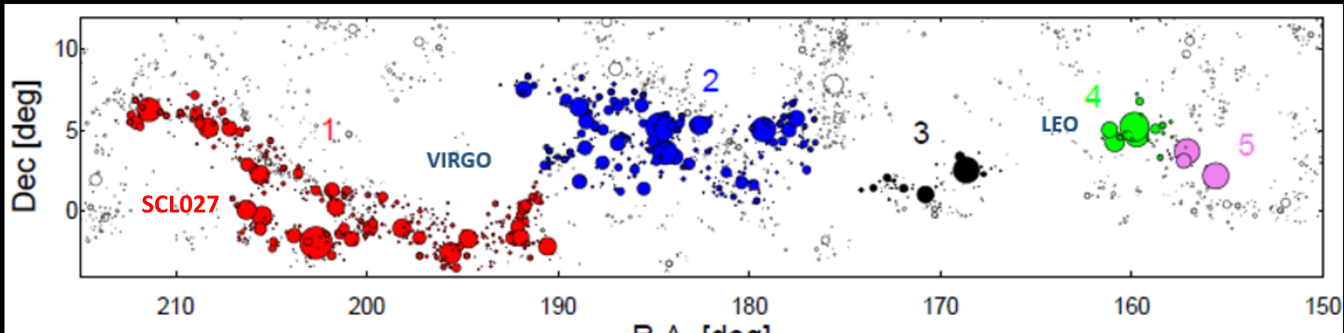
This galaxy cluster wall was discovered in the *Sloan Digital Sky Survey* (SDSS), - a collaboration funded partly by A. P. Sloan and conducted by several astrophysical institutions, starting in 2000 and still ongoing as of 2020. The **Sloan Great Wall** (SGW) has a length of 450 Mpc at ~310 Mpc distance (lookback time ~0.9 Gyr), stretching from 8.7-13.7h in R.A. (i.e. 7.7h of R.A.), so though the closer by CfA2 GW is stretched out longest on the night sky, in reality the SGW is more than 1.7x as long, and thus the largest known galaxy group structure in our known universe.

Note that the CfA2 Great Walls and the Sloan Great Wall are both detected tangentially to the line of sight, which is no surprise, as a great wall structure perpendicular to the 4^{o} sample slice would be more difficult to determine except as a dense pillar structure like the "Fingers of God".

The Sloan Great Wall it is easiest to spot on our night sky from 11-14h through central Virgo. There are 5 galaxy superclusters (SCL) along the SGW, with high-density cores in the richest eastern superclusters: 3 cores in SCL027 and two cores in SCL019. These cores are the largest, still dynamically evolving objects in this part of the cosmic web, and they will probably each collapse gravitationally during their future evolution.

The Sloan Great Wall [~1000 Mly]

Super Cluster SCL027, Galaxy cluster Abell 1773

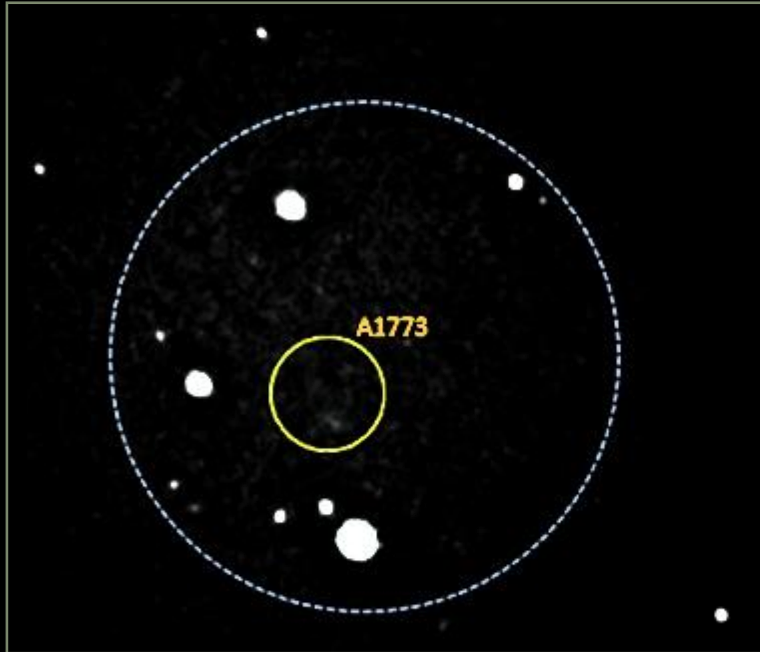


"Sloan Great Wall as a complex of superclusters with collapsing cores". Einastro et al, Astronomy and Astrophysics, Aug. 2016

CdC *Sky Chart* (my annotations)

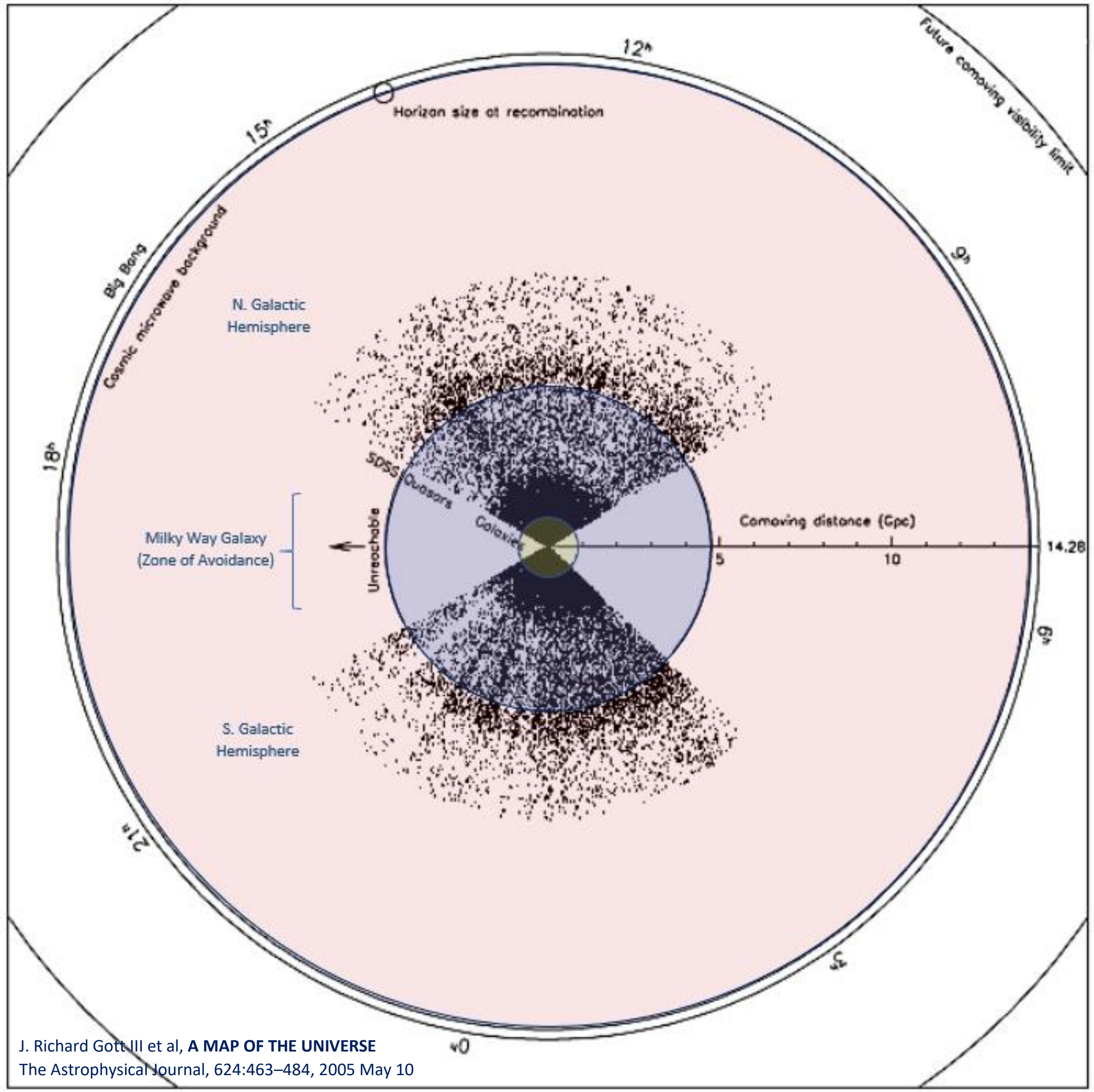
Below is seen my observation of the SGW in E Virgo, showing **the Abell 1773 galaxy cluster in SCL027.**

Using a 13mm eyepiece + IIT (49x @ 0.4° FOV), I could faintly glimpse the center of this part of the galaxy group filament, dominated by a tight knot of 5 galaxy groups (which I couldn't resolve), plus some smudges of fainter galaxies in groups to the N and S. I saw no detail of orientation or morphology for any individual galaxy in the clusters, but this is not surprising, as we're here out at a distance of 256 Mpc (834 Mly).



Step 5.2 (out to 10 000 Mly, and beyond): Quasars and CMBR.

Though the galaxy clusters in the SGW do not form a coherent (gravitationally bound) unit, they do share a common origin in being gravitationally "deposited" along a "trough" formed by a dark matter strand between "void bubbles" in the cosmological sponge of baryonic matter. To truly grasp the size and distance of this structure, we need a map covering the entire visible universe



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In the figure to the left, galaxies and quasars in the equatorial slice ($-2^o < \delta < 2^o$) of the **Sloan Digital Sky Survey** (SDSS) are displayed in a shape-preserving map with *comoving coordinates out to the horizon. [*Comoving distance is the distance between two points measured along a path defined at the present cosmological time. For objects moving with the Hubble flow, it is deemed to remain constant – and thus large-scale structure-preserving in time]

The inner yellow circle at ~0.9 Gpc (lookback time ~3 Gyr, aka 3 Billion years) marks the volume containing the majority of interesting **large-scale galaxy group structures** crammed into a blob at the center. This is the region I displayed on the previous map, featuring among other structures: the CfA2 and Sloan Great Walls. At the larger scale here, the region is waaay too small and crowded to show any detail at all.

The next, blue circle at ~5 Gpc (lookback time ~10 Gyr) marks the horizon beyond which no light signal from Earth can ever reach (redshift >z= 1.69 implies "**unreachable**").

The next, red circle at ~14 Gpc (lookback time 13.7 Gyr) shows the horizon of the **cosmic microwave background radiation** (CMBR) at the epoch of recombination after the Big Bang.

Finally, **the Big Bang itself has a horizon slightly beyond the CMBR at ~14.3 Gpc**. SDSS quasars extend out to about halfway the CMBR distance, but show no noticeable clustering or large-scale structure in their distribution (the radial shelves and spokes seen are due to a combination of data incompleteness and the use of several different spectral analysis techniques).

Beyond the current Big Bang horizon is indicated the sphere of the **future co-moving visibility**; If we wait until the infinite future, we will be able to see out to this distance limit, detecting particles as they appeared at the Big Bang (assuming our current cosmological model is at least approximately correct...)

CTA-102 is an Optically Violent Variable **(OVV)** quasar, which I here caught in the midst of a historically bright outburst — as super-heated material spiral into the accretion disc surrounding the black hole, an intense magnetic field produces high-energy, relativistic plasma jets. That jet happens to be pointed directly at us, so we are here looking down the throat of the jet...

The CTA 102 blazar is a quasar with a redshift of 1.037, implying a light-travel time of nearly 8 billion years. That is old! (the age of our solar system is ~4.5 billion years...)

Epilogue

My rich field observations with small vintage refractors have now taken me from my suburban backyard north of Copenhagen in Denmark, to aging star clusters dispersing around our solar system as still co-moving stellar streams across the night sky in our Local Bubble, to the surrounding Superbubble with a galactic-plane belt of star-forming regions giving birth to blazing OB-associations and bright emission nebulae in waving gas and dust filaments in our Local Spiral Arm, out to more distant Superbubbles in neighboring Milky Way arms with their own star-forming rings and with occasional glimpses through clear "windows" to far-away star clouds and to ancient clusters towards the very edge of our own galaxy.

From here, I journeyed further out from our own Milky Way with its satellites, through our Local Group of galaxies including the neighboring large *Andromeda* spiral and its *Triangulum* companion, to the supergalactic sheet of galaxy groups , where I first moved through our own Local Supercluster with the *Boode-Cigar* pair, the *Whirlpool* and the *Black & Crock Eye* galaxies plus the surrounding galaxy clouds with the northern *Pinwheel* and the *Leo Triplets*. I then followed the galaxy flows, all streaming towards the center of the Virgo Supercluster lurking in the background, with the Virgo-I galaxy group at its center pulling in our *Local Supercluster* as well as the surrounding *Uma-I* and *Coma-I* galaxy superclusters.

Stepping on the gas pedal, I then zoomed out to observe that our own Virgo Supercluster is but at the center of a larger string of superclusters: the Hydra-Centaurus filament that is being pulled towards the *Shapley* attractor, and that our Hydra-Centaurus filament together with the nearby Pavo-Indus filament is but residing in a larger gravitational "basin" known as Laniakea, which is gravitationally "drained" towards the *Great Attractor* hiding somewhere behind the Centaurus cluster.

Outside the supercluster filaments in our local Laniakea basin, I could then observe other, even larger supercluster filaments, the nearest being the CfA2 Great Wall, stretching on my night sky from *Leo* through *Coma* and *Hercules*, and the even larger and further out Sloan Great Wall in *Virgo*. Finally, peeking over the edge of the Sloan Great Wall into the really deep end of cosmos, I could spot a far-far away lighthouse in the form of the 8 000 000 000 light year distant, blazing quasar CTA-102.

Now my gas was running low, so I decided it was time to zoom back to my own backyard and reflect on what I had accomplished.

And so, to conclude this writeup of my rich field observation journey, I'd like to underline that my aim in this endeavor has not been to write a structured, complete and consistent introduction *to Backyard Rich Field Astronomy*, -- that would be a book, and I would love to buy it and *read* it, but it would be more work than pleasure for me to *write* it, at least at this point in time.

What I've done instead here is rather to try and condense into a summary the essence of my classic rich-field projects the past couple of years, with a focus on my motivations, equipment and on the evolution of the projects, flavored with a few sample observation reports, all presented in a multi-layered layout that could be - maybe overwhelming - but mostly should be enjoyable and hopefully at times inspiring and motivating to dive into.

Looking back, I can see that I have had to leave out a lot of both astrophysical information as well as observation descriptions and illustrations found in my observation reports, so my summary here is in no way extensive nor even comprehensive, but I'm reasonably satisfied with the end result as an overview and an appetizer. Though the present result is in ways incomplete, the writing and layout process has been fun, and it has helped me to collect and structure my experiences from the long and winding CRF journey in a way that I hope fits reasonably well with the requirements for a *Nightfall* special report.

I'd like to end by thanking Doug Bullis, editor of the *Astronomical Society of South Africa* deep-sky journal *Nightfall*, for encouraging me to undertake this summary of my rambling *Classic Rich Field* thread at the *Cloudy Nights* astro-forum, and for supporting me along the way in finding a workable form for the content and presentation in this *Nightfall* issue. Thank you! ☺

https://www.astro.princeton.edu/universe

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CLASSIC RICH FIELD

A remarkable celestial journey

ALLAN DYSTRUP

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