Detection of Meteor Streams and Potentially Hazardous Comets using CAMS

Tim Cooper

Detection of Meteor Streams and Potentially Hazardous Comets using CAMS*

- History of imaging of meteors
- Meteor streams and their relation to comets
- Incidence of meteor showers and known parent bodies
- Detection of meteor streams and determining orbital parameters using CAMS
- Set up of CAMS@SA, first results, future development

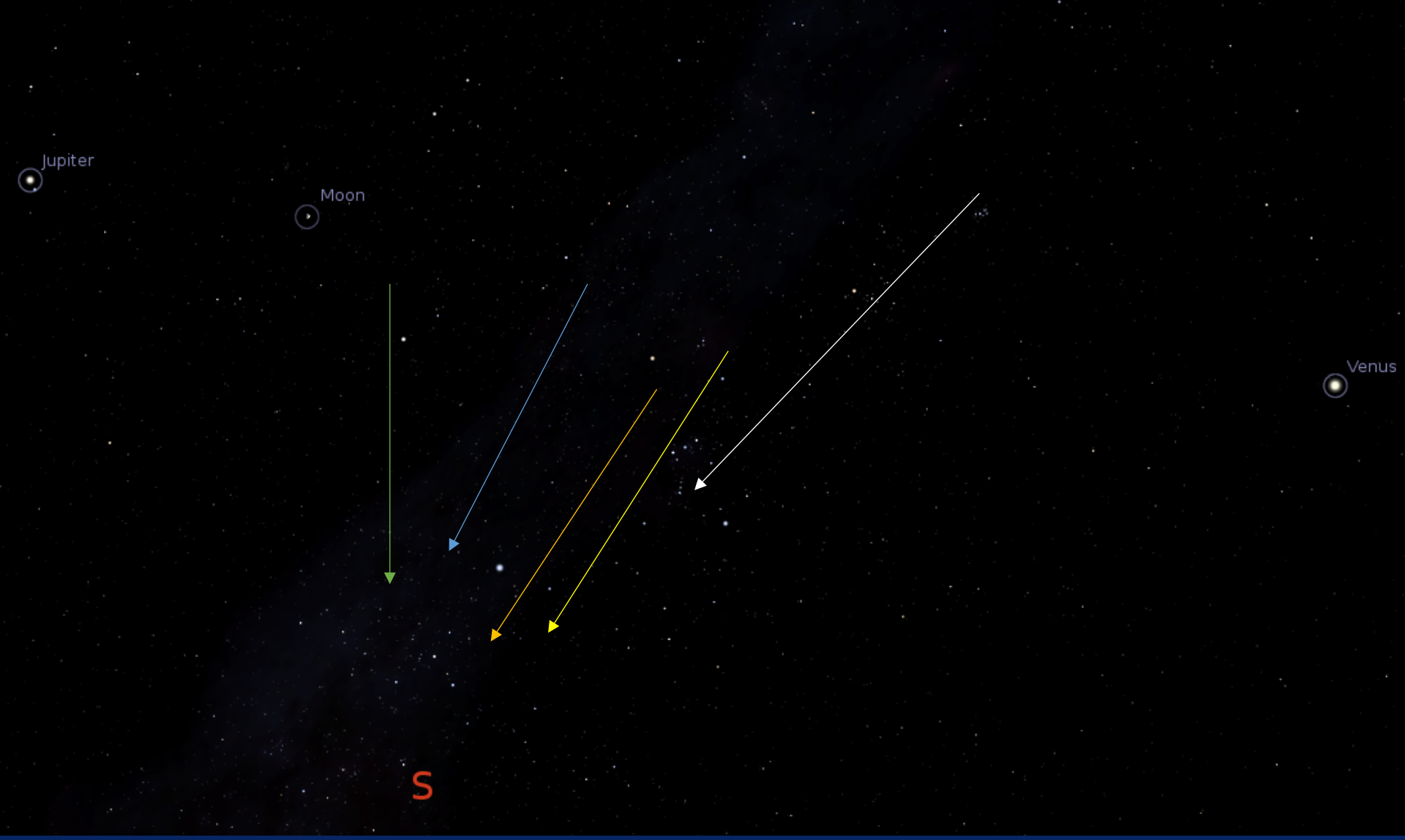
* Cameras for All-Sky Meteor Surveillance

Edmund Halley (1656-1742)

First triangulation, bolide of 19 March 1719

VII. *An Account of the Extraordinary* METEOR *ſeen all over* England, *on the 19th of* March 171$\frac{8}{9}$. *With a Demonſtration of the uncommon Height thereof. By* Edm. Halley, *LL. D. and Secretary to the* Royal Society.

THIS wonderful luminous *Meteor* which was ſeen in the Heavens on the 19th of *March* laſt, as it was matter of Surprize and Aſtoniſhment to the Vulgar Spectator, ſo it afforded no leſs Subject of Enquiry and Entertainment to the ſpeculative and curious in Phyſical things: Some of its *Phænomena* being exceeding hard to account for, according to the Notions hitherto received by our Naturaliſts; ſuch are the very great Height thereof above the Earth; the vaſt Quantity of the Matter thereof; the extravagant Velocity wherewith it moved; and the prodigious Exploſions thereof heard at ſo great a Diſtance, whoſe Sound, attended with a very ſenſible Tremour of the ſubject Air, was certainly propagated through a *Medium* incredibly rare and next to a *Vacuum*.



Samuel Cruuys
Tiverton

Nicolas Fatio
Worcester

Rev Willm. Ella
Rampton, Notts.

John Whiteside
Oxford

Sir Hans Sloan
London

Path and altitude of 1719 bolide from triangulations by Halley

"they abundantly evince the height thereof to have exceeded sixty English

Ernst Chladni (1756-1827)

1794 Catalogue of recorded observations of fireballs

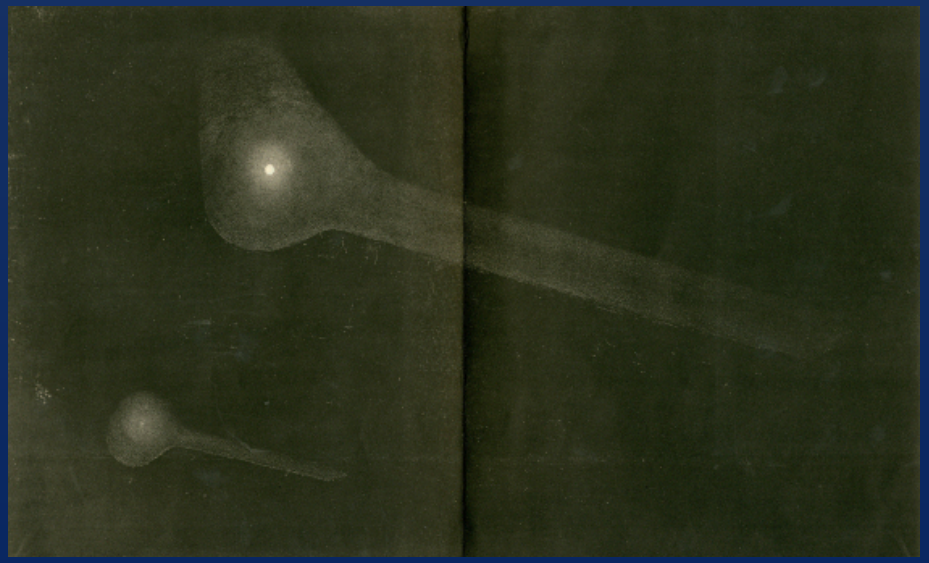
1798 showed that meteors could not be ‘explained from
the accumulations in the upper regions of the atmosphere’

First relation of meteors as debris from comets

- Leonid storms of 1799, 1833 and 1866 – comet 55P Tempel-Tuttle
- Perseids in 1866 – comet 109P Swift-Tuttle
- April Lyrids in 1867 – comet C/1861 Thatcher

Ladislaus Weinek (1848-1913)

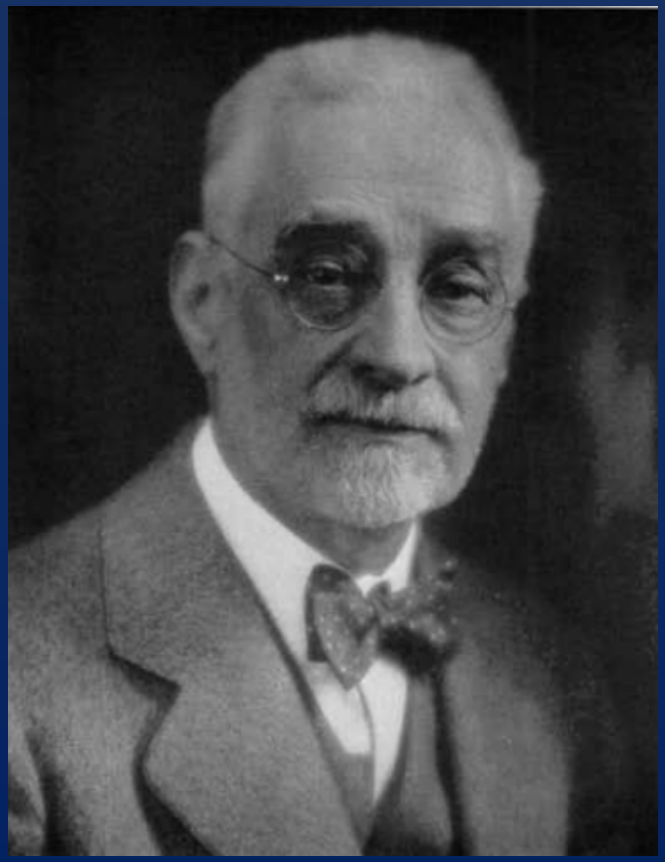
First image of meteor, 27 November 1885

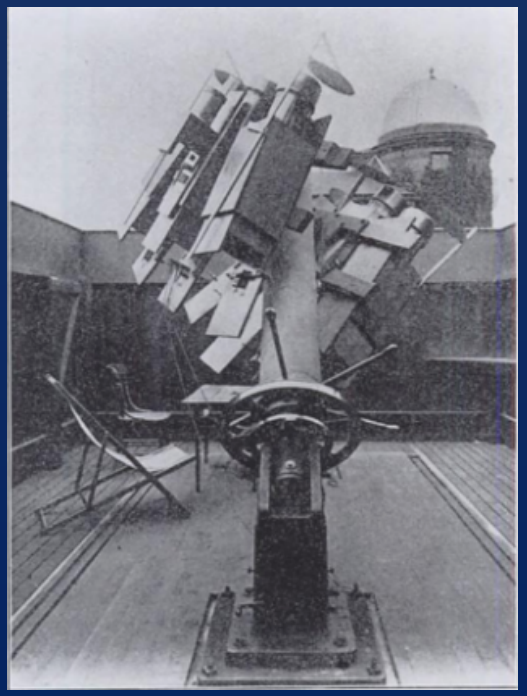


The two fragments of Biela's comet observed in 1846, drawing
by Otto Struve.
Credit: University of Cambridge, Institute of Astronomy.

Lewis Elkin (1855-1922)

First images with rotating shutter, 1889





Dorrit Hoffleit (1907-2007)

Catalogued meteor images on HCO plates

TABLE I

Meteor No.	Plate No.		Date	E.S.T.	Exp. m	Appr'x Position α (1900)	Appr'x Position δ	Length °	Description	No. Seg.	Shower	Zen. Mag.	Vis. Mag.	Vis. Train
1	F3A	1932	Aug. 12	3.17	31	h m 0 40	+16	11	faint	8	Perseid	−4		
2	14		Nov. 16	*1.31*	30.5	11 13.6 11 21.4	+47.1 +49.6	4	faint	9	Leonid	−5	−1.5, −1, 0, +1	3 sec
3	17		Nov. 16	*2.21*	19	10 19	+ 7.3	2	faint	8	Leonid	−4	−1.5, −1, −1, −1	green
4	18		Nov. 16	*3.13*	27	10 56	+36.5	3	faint	5	Leonid	−3	−1, −2, −2	green-blue
5	107	1933	Nov. 16	0.38	71	5 53	+54.3	7	faint	20	Sporadic	−2		
6	AI 32219	1935	Aug. 10	*1.28*	161	20 33 19 20	+57.6 +44.6	17	strong	13	Perseid	−6	−7	green, 15°, 20 sec
7	32275		Sept. 7	1.36	120	2 17 3 09	−13.9 −15.6	13	faint, burst at end	25	Sporadic	−4		
8	32323		Sept. 30	20.28	73	21 40 21 28	− 7.1 −14.4	8		24	Sporadic	−4		
9	32373		Oct. 20	1.04	72	5 19 5 28	−21.2 −21.8	2		8	Sporadic	−5		
10	32380a		Oct. 21	2.50	82	7 58 8 27	+30.1 +32.7	7	burst at end	8	Orionid	−5		
11	32380b		Oct. 21	2.50	82	7 02 7 15	+15.4 +23.5	4	burst at end	8	Orionid	−5		
12	32491		Dec. 29	4.36	120	13 39 13 52	−19.7 −24.5	7	strong	8	Sporadic	−9		
13	32610	1936,	Feb. 29	4.08	117	16 08 16 20	−20.9 −28.9	10	faint	10	Sporadic	−4		
14	32760		July 6	23.55	98	21 14 23 09	+58.3 +53.4	19		32	Sporadic	−6		

obable evolution of C/2014 S3 (PANSTARR
860 years

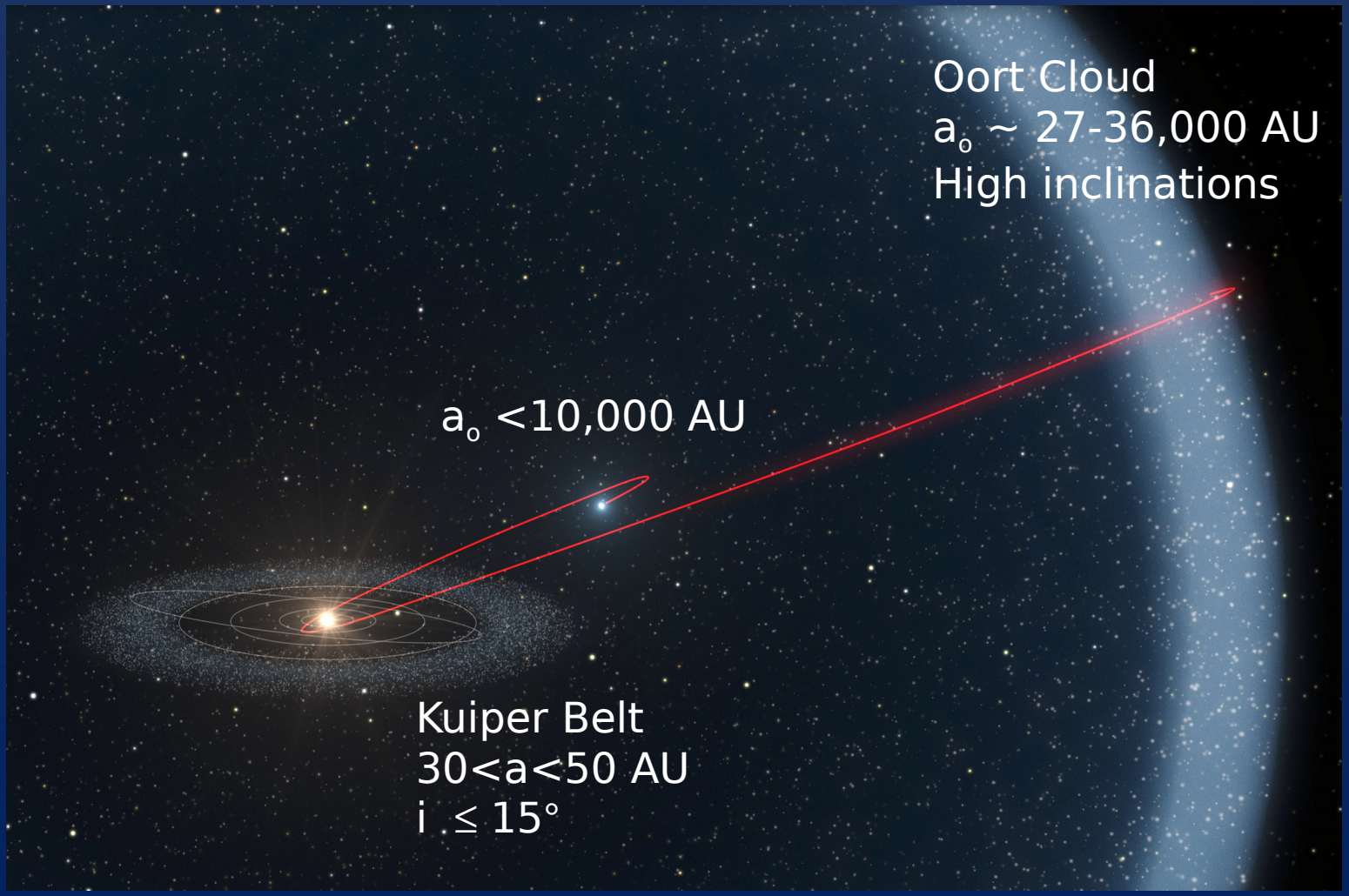
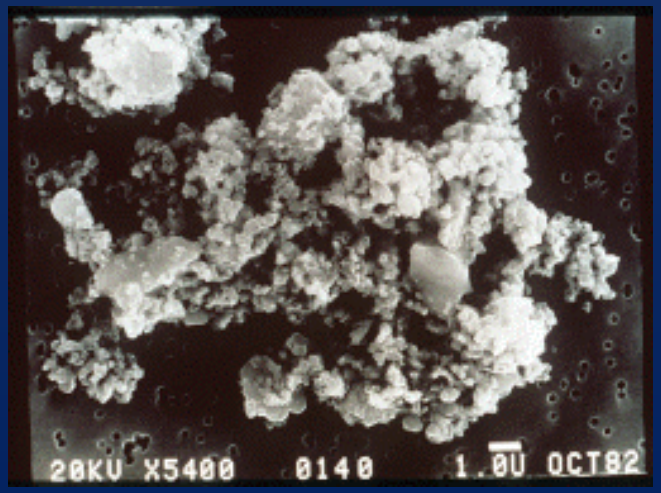


Illustration credit: ESO/L. Calçada.

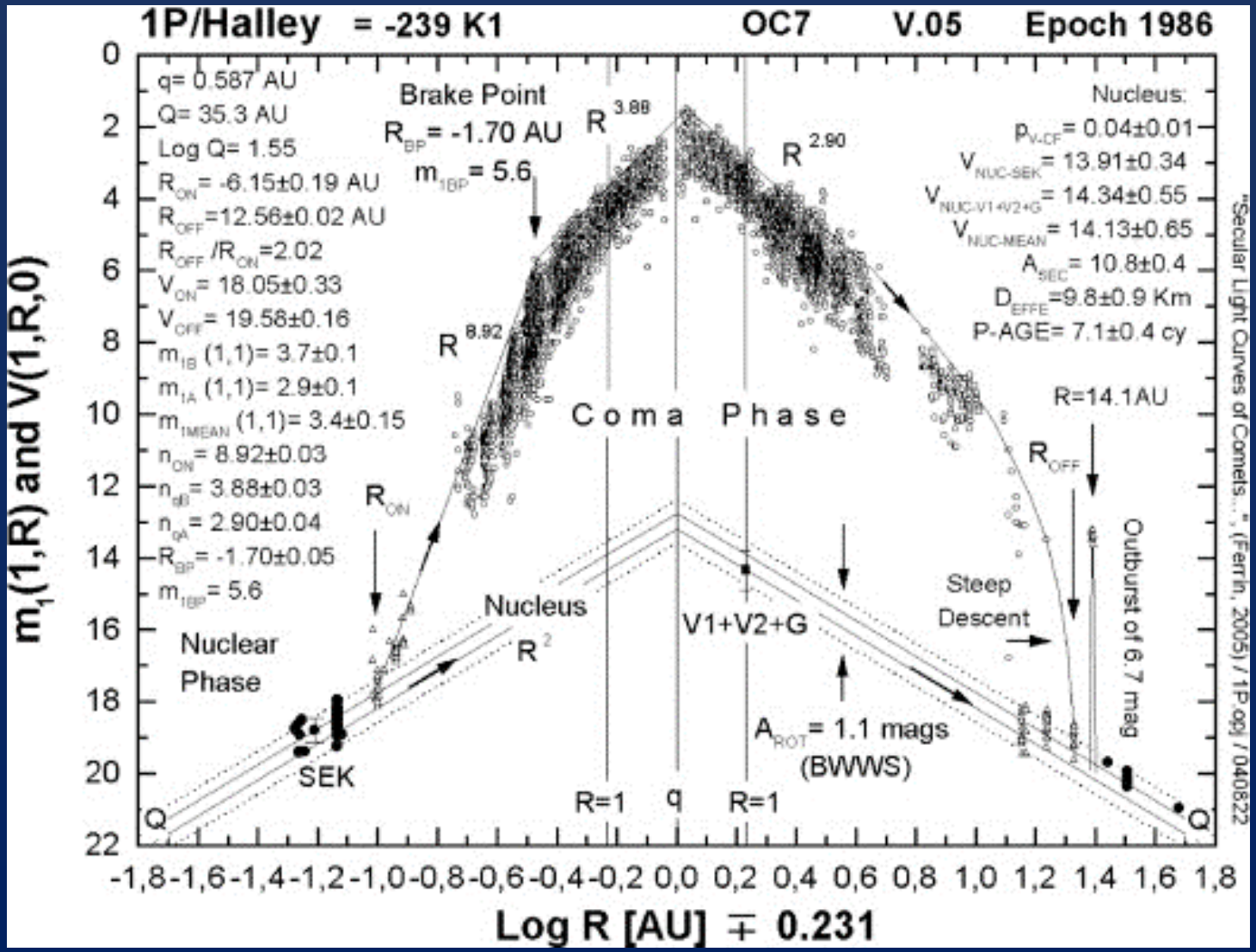
Formation of meteor stream

Volatiles and dust

- CO, CO_2, H_2O
- Silicates



Nuclear activity for 1P Halley



Nuclear activity for several comets
R_{ON} and R_{OFF} (Ferrin 2009)

Comet	Rank	Figure	R_{ON} [AU]	R_{OFF} [AU]	T_{ON} [d]	T_{OFF} [d]	P-AGE [cy]	T-AGE [cy]	m_1	V_N (1,1,0)	A_{SEC} (1,1)	LAG [d]	q [AU]	Q [AU]	D_{EFFE} [km]
29P/SW 1	1	16,45	~80	[illegible]	~7800	~6700	~0.5	~0.5	-3.6	10.9	~14.7	-----	5.44	7.28	54
C/1995O1 Hale-Bopp	2	33,60	-17.3	33.9	-2550	~7650	2.4	~0.75	-1.2	10.6	11.5	+45	0.91	370	54
C/1984 K1 Shoemaker	3	32	-7.3	[illegible]	----	----	<4.8	----	3.8	<13.4	>9.6	----	2.70	e=1	<14
1P/Halley	4	7,36	-6.1	12.6	-497	1495	7.1	4.2	3.4	14.13	10.8	+11.2	0.59	35.3	9.8
39P/Oterma	5	18,47	-7.7	6.6	-2747	3000	9	1.4	3.0	14.52	11.5	0	3.39	4.53	6.3
65P/Gunn	6	20,49	-8.3	6.1	-1417	1550	9	2.8	1.0	14.8	10.8	+242	2.46	4.74	7.4
81P/Wild 2	7	24,53	-5.1	4.5	-648	690	13	6	5.8	16.53	11.4	-13	1.58	5.30	3.9
19P/Borrelly	8	12,41	-2.9	5.8	-266	>300	14	----	4.2	15.9	11.6	+6	1.37	5.87	4.5
73P/SW3C (2001)	9	23,52	-5.2	4.2	-950	478	18	7	8.3	17.1	8.7	----	0.94	5.18	2.2
C/1996B2 Hyakutake	10	34,61	-3.2	3.52	-167	189	18	22	4.3	15.7	11.6	-6	0.23	1901	4.8
101P/Chernykh	11	26	-3.1	4.9	----	----	22	----	10.2	16.1	-----	----	2.36	9.24	5.0
21P/Giacobini-Zinner	12	13,42	-3.6	4.4	-280	470	22	15	8.2	16.1	7.9	-10	1.03	6.0	3.1
9P/Tempel 1	13	11,40	-3.5	4.2	-410	659	22	9	6.4	15.3	9.0	-10	1.50	4.74	5.5
109P/Swift-Tuttle	15	28,56	-2.8	3.4	-123	156	28	40	3.8	12.0	8.2	+1	0.96	52	27
32P/Comas-Sola	17	17,46	-3.3	3.6	-324	372	30	19	8.6	15.6	7.0	0	1.85	6.67	3.0
6P/D'Arrest	14	10,39	-1.6	<3.2	-70	>250	32	<26	7.2	18.3	9.5	+42	1.35	5.62	1.6
67P/Churyumov-G	16	21,50	-2.8	4.0	-232	408	37	21	9.6	15.4	5.8	+33	1.30	5.73	5.5
85P/Boethin	18	25,54	-1.8	1.7	-107	91	49	54	5.9	14.3	8.4	-4	1.11	8.91	6.3
C/1983 J1 SSF	19	31,59	~1.5	1.5	~-60	60	55	84	10.5	19.8	8.8	----	0.47	e=1	0.7
45P/Honda-Mrkos-P	20	19,48	-1.5	2.0	-70	118	55	64	12.0	19.5	7.5	+2	0.53	5.5	0.9
2P/Encke 1858	21	8,37	-2.2	1.7	-126	105	58	61	9.1	15.5	6.4	-13	0.34	4.09	5.1
C/1983H1 IRAS-A-A	22	30,58	-1.2	1.5	-45	80	84	113	7.8	14.6	6.4	+10	0.99	199	8.6
26P/G-Skjellerup	23	14,43	-1.4	1.8	-73	132	89	85	11.4	16.7	5.2	+14	0.99	4.93	3.0
2P/Encke 2003	24	9,36	-1.6	1.5	-87	94	98	103	10.8	15.5	4.8	+6	0.34	4.09	5.1
28P/Neujmin 1	25	15,44	-2.1	2.4	-115	167	100	100	9.6	12.8	3.2	+7	1.53	12.1	23
C/2001 OG108 LON	26	35,62	-1.6	1.6	-78	96	102	117	8.7	13.1	4.4	-5	0.99	25.6	15.8
107P/Wilson-Harrington	27	27,55	+1.1	1.4	+38	74	----	760*	12.9	16.3	3.3*	+42	1.00	4.28	3.3
133P/Elst-Pizarro	28	29,57	+2.6	2.8	+42	233	----	280*	---	16.0	1.4*	+155	2.63	3.68	4.6

* T-AGE(1,LAG) is given because P-AGE(1,1) can not be calculated.

Incidence of meteor streams

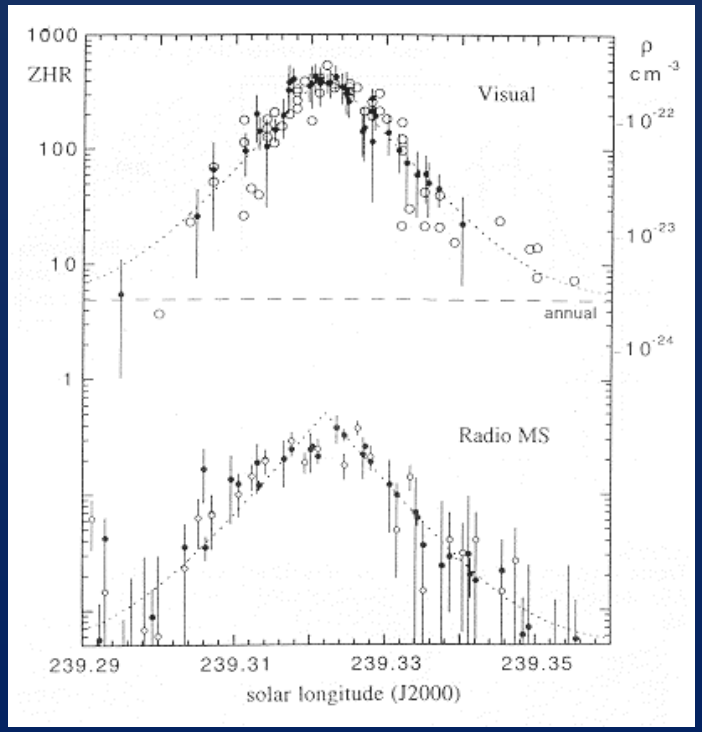
- Major meteor streams ~ dozen showers
- IAU Confirmed active 119 showers
- IAU Working List 790 showers
- Known parent body 36 showers
- Still leaves 754 potential showers with unknown parent.
- Growing list of new detections with no known parent.
- These showers are the smoking gun for potentially hazardous comets.

Name	IAU No/Code	Parent	i	q	Period
Jan Comae Berenicids	90 JCO	C/1913 I Lowe	188		123
Quadrantids	10 QUA	2014 TB18	18.7	1.83	2.84
β Tucanids	108 BTU	C/1976 D1 Bradfield	46.8	0.85	~1600
δ Pavonids	120 DPA	C/1907 G1 Grigg-Mellish	110.0	0.92	162
Daytime q Pegasids	129 QPE	2005 EM169	10.9	0.75	4.83
Lyrids	6 LYR	C/1861 G1 Thatcher	79.8	0.92	415.5
π Puppids	137 PPU	26P Grigg-Skjellerup	22.4	1.09	5.24
η Aquariids	31 ETA	1P Halley	162.3	0.59	75.3
η Lyrids	145 ELY	C/1983 H1 Iras-Araki-Alcock	73.3	0.99	959
π Cetids *	158 CET	C/1874 G1 Winnecke ?	148.3	0.89	
τ Herculids	61 TAH	73P Schwassmann-Wachmann 3	11.2	0.97	5.44
June Boötids	170 JBO	7P Pons-Winnecke	22.3	1.24	6.32
Daytime Arietids	171 ARI	Marsden Group	ẋ=26	ẋ=0.05	
Daytime β Taurids	173 BTA	2004 TG10	4.2	0.31	3.34
α Capricornids	1 CAP	169P NEAT = 2002 EX12	11.3	0.61	4.20
South δ Aquariids	5 SDA	Marsden Group	ẋ=26	ẋ=0.05	
ψ Casseiopeids	197 PCA	1973 NA	68.0	0.89	3.80

Name	IAU No/Code	Parent	i	q	Period
β Indids	195 BIN	C/1991 L3 Levy	19.2	0.98	51.3
ζ Draconids	73 ZDR	6P d'Arrest	19.5	1.36	6.56
Aug δ Capricornids	199 ADC	45P Honda-Mrkos-Pajdusakova	4.2	0.53	5.26
α Aurigids	206 AUR	C/1911 N1 Kiess	148.4	0.68	2497
κ Leonids	212 KLE	C/1917 F1 Mellish	32.7	0.19	145.0
Daytime Sextantids	221 DSX	2005 UD	28.7	0.16	1.44
Orionids	8 ORI	1P Halley	162.3	0.59	75.3
Leo Minorids	22 LMI	C/1739 K1 Zanotti	124.3	0.67	
October Capricornids	233 OCC	D/1978 R1 Haneda-Campos	5.9	1.10	5.97
October Draconids	9 DRA	21P Giacobini-Zinner	31.9	1.03	6.59
Leonids	13 LEO	55P Tempel-Tuttle	162.5	0.98	33.2
Northern Taurids	17 NTA	2004 TG10	4.2	0.31	3.34
Southern Taurids	2 STA	2P Encke	11.8	0.36	3.30
Andromedids	18 AND	3D Biela	13.2	0.88	6.65

alpha Monocerotids
Outbursts 1925, 1935, 1985, 1995

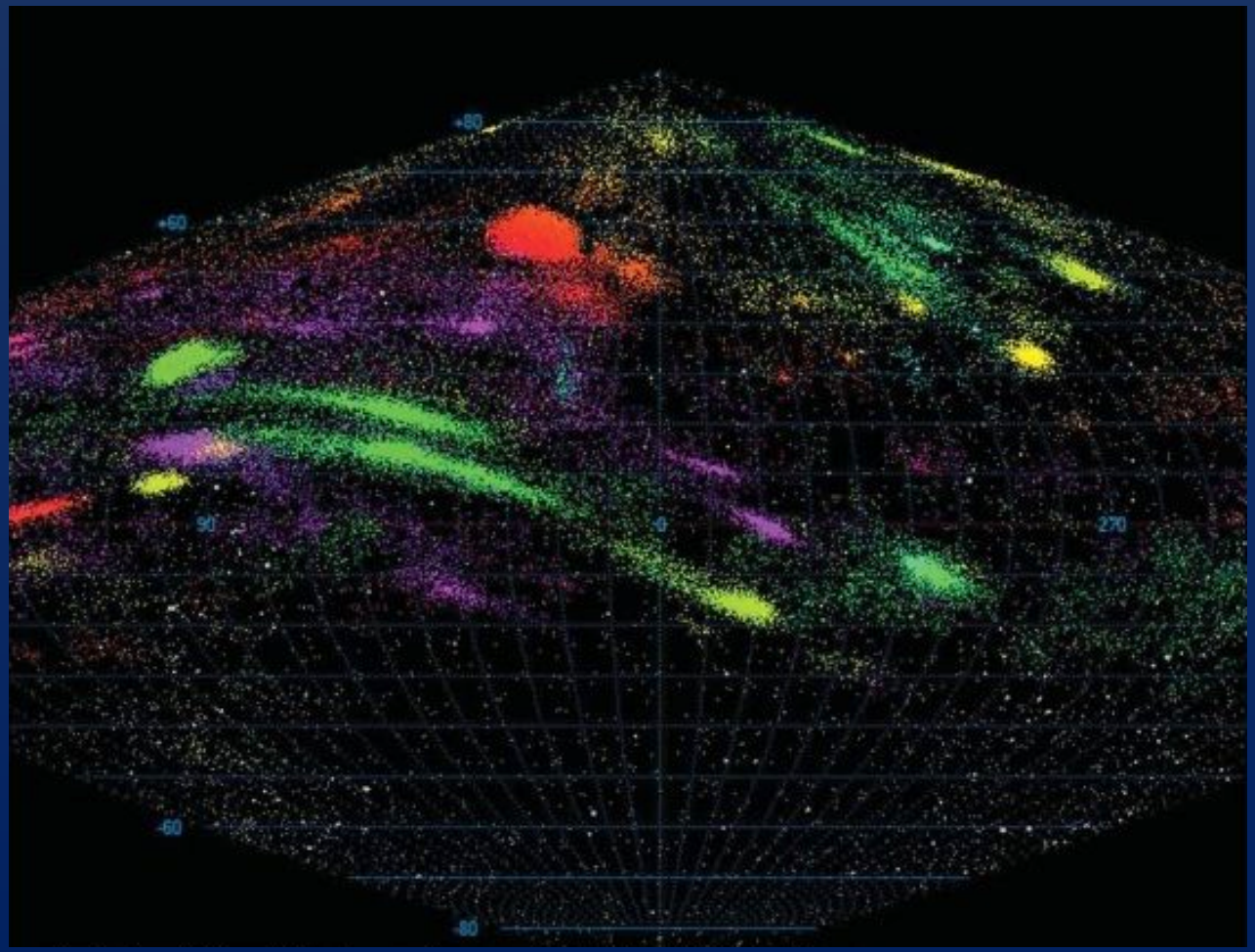
Year	1995	1995	1995	1995	1995	1995	1995	Mean
Month	11	11	11	11	11	11	11	
Day	22.0563	22.059	22.0618	22.0632	22.0674	22.0701	22.0729	
N stations	2	2	2	2	2	2	2	
Stream	α- Mon	α- Mon	α- Mon	α- Mon	α- Mon	α- Mon	α- Mon	
Mv	3	2	1	5	2	0	1	2
q (AU)	0.4803	0.4811	0.495	0.4743	0.4934	0.5087	0.4891	0.488843
e	0.9628	0.9989	1.0136	0.9824	1.0205	0.9976	0.9981	0.996271
i	133.379	134.31	134.479	133.796	134.627	134.074	134.105	134.11
omega	92.7096	91.5178	89.482	92.8136	89.4854	88.3462	90.6068	90.70877
Node	59.3156	59.3182	59.3213	59.3224	59.3269	59.3299	59.3327	59.32386
Vg	61.89	62.68	63.11	62.24	63.23	62.91	62.72	62.68



P>140 years

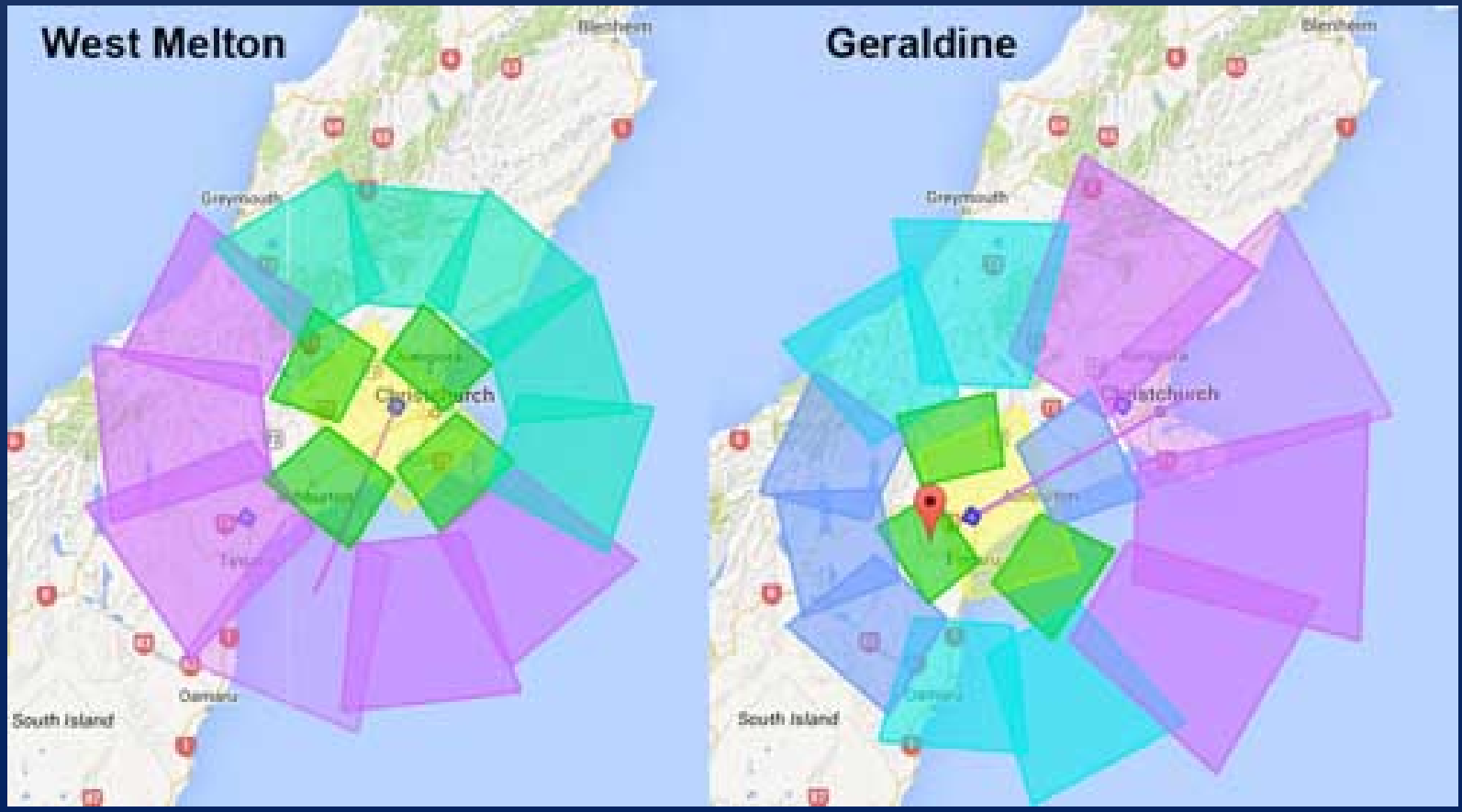
Annual radiant detections from CAMS

An automated video surveillance of the night sky to validate minor showers in the IAU Working List of Meteor Showers



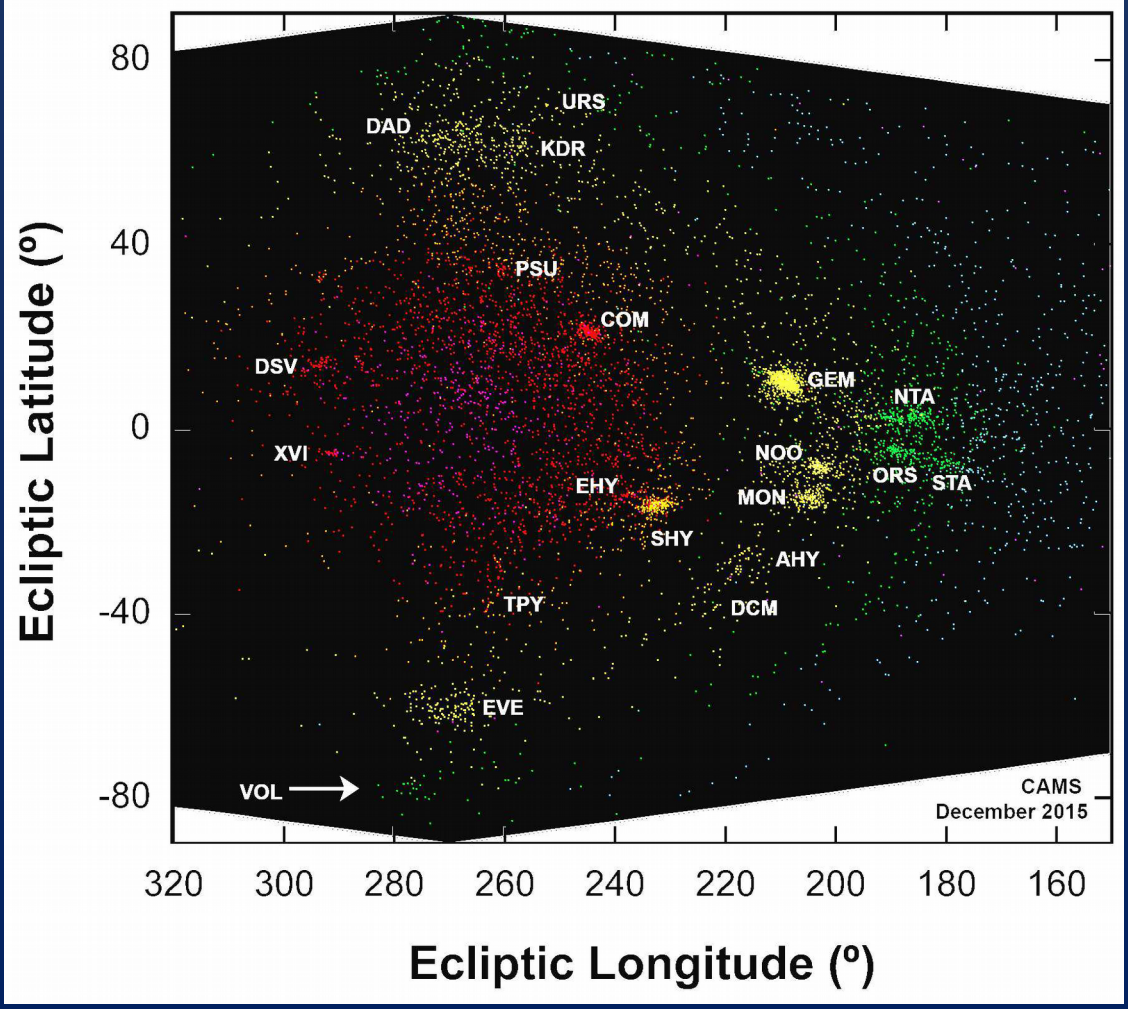
CAMS station at West Melton, NZ

Camera alignment for CAMS NZ

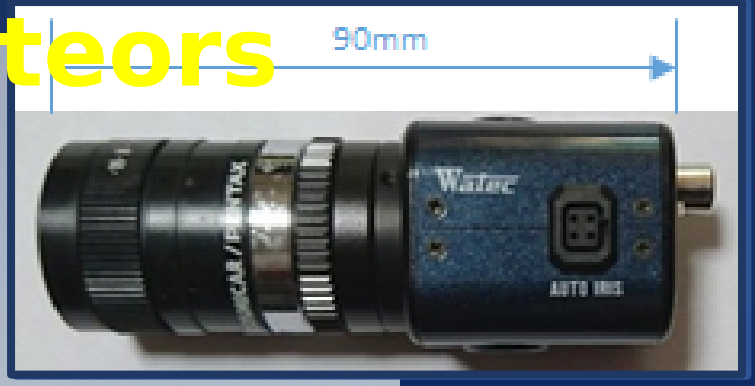


Detection of new Volantid meteor shower

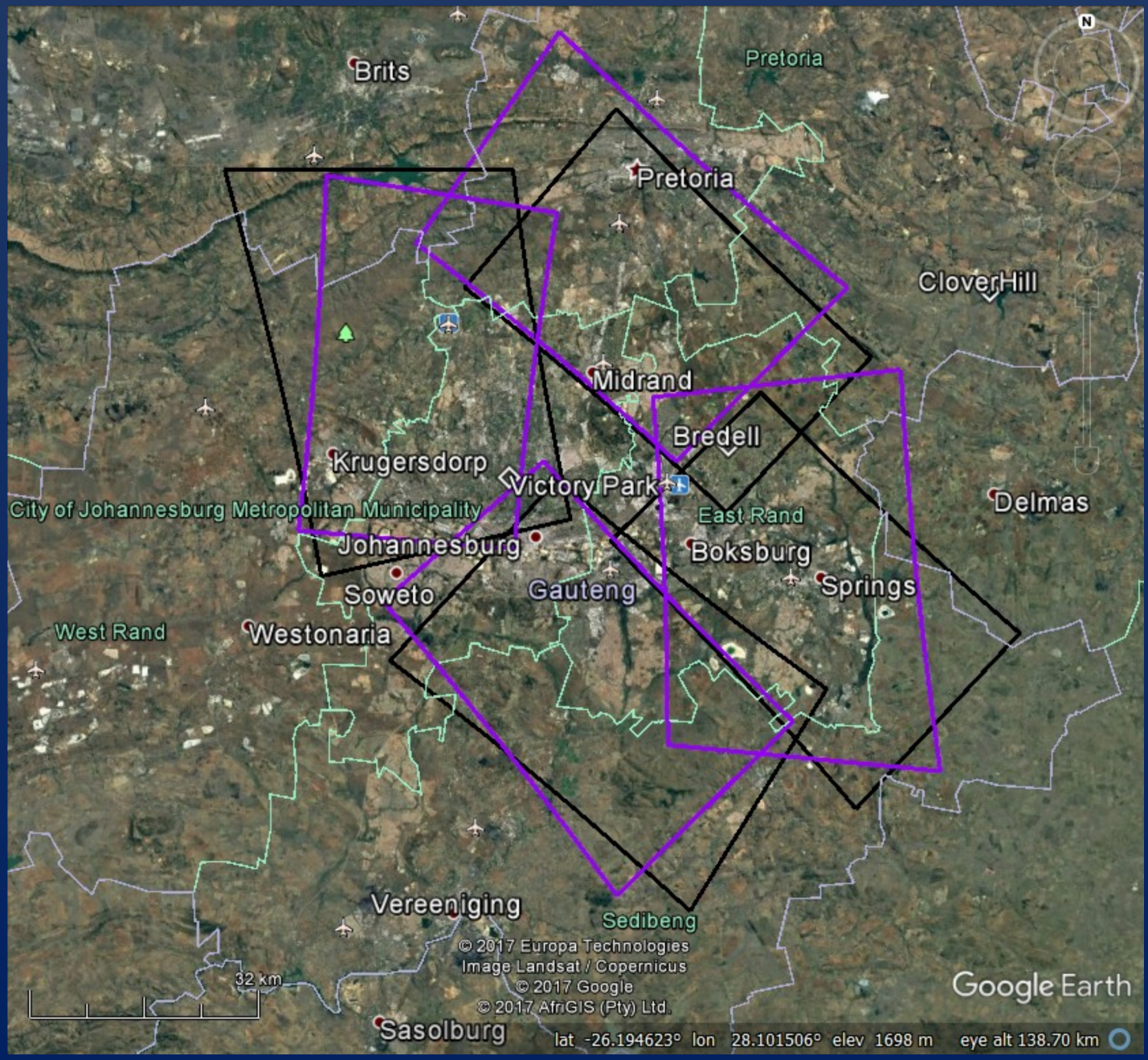
New Year's Eve 2015



Cameras and alignment, CAMS@SA
Comet Borisov meteors



Watec 902 camera
811x508 pixels
1 x 10^{-4} lux
Pentax 12mm f1.2 lens
FOV 30° x 25°

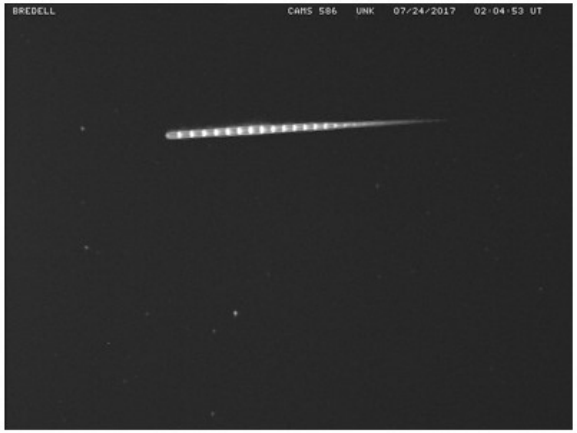

Brits
Pretoria
Pretoria
CloverHill
Midrand
Bredell
Krugersdorp
Victory Park
City of Johannesburg Metropolitan Municipality
East Rand
Delmas
Johannesburg
Boksburg
Soweto
Gauteng
Springs
West Rand
Westonaria
Vereeniging
Sedibeng
© 2017 Europa Technologies
Image Landsat / Copernicus
© 2017 Google
© 2017 AfriGIS (Pty) Ltd
32 km
Sasolburg
Google Earth
lat -26.194623° lon 28.101506° elev 1698 m eye alt 138.70 km

Double station meteors from Bredell

CAP

SDA

CAP



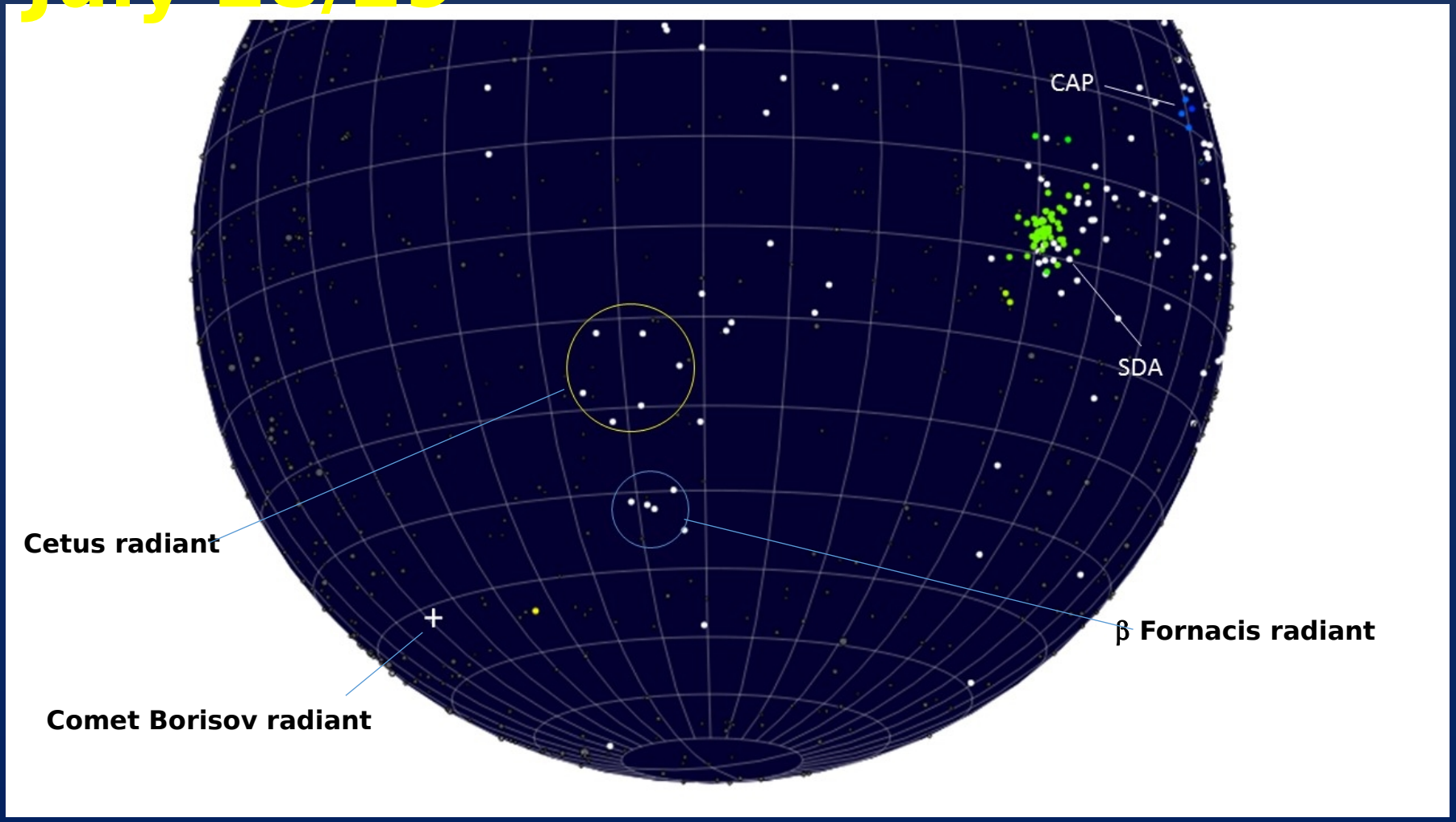
SPO

SDA

SDA

Southern delta Aquariid (SDA) observed on both camera 579 at Victory Park and camera 587 at Bredell.

CAMS@SA radiant map, 2017 July 28/29



Probable fireball recorded by two cameras at Victory Park

Conclusions

- CAMS@SA trial runs very successful
- Site selection in progress for permanent operation
- Will fill gaps in real time southern hemisphere radiant mapping due to unique position on the globe
- Will contribute to knowledge of showers from potentially hazardous comets
- Will refine trajectories of observed fireballs

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Edmund Halley (1656-1742)

First triangulation, bolide of 19 March 1719

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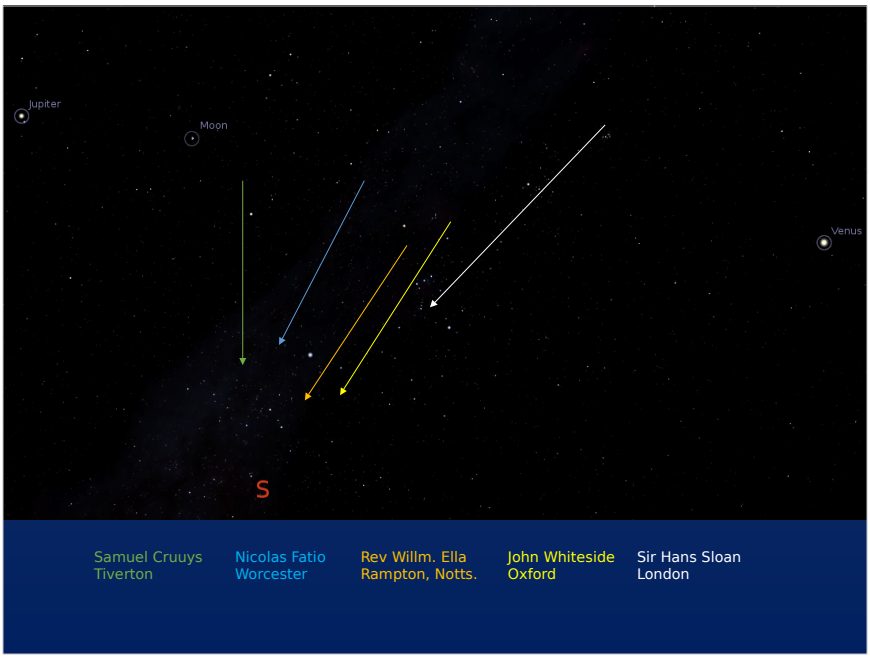
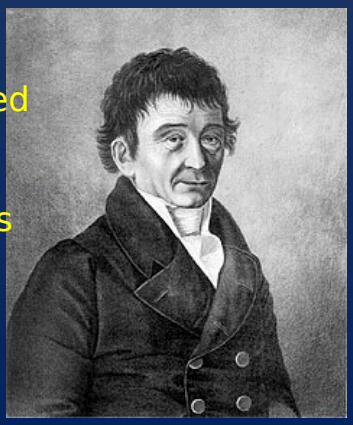

Jupiter
Moon
Venus
S
Samuel Cruuys
Tiverton
Nicolas Fatio
Worcester
Rev Willm. Ella
Rampton, Notts.
John Whiteside
Oxford
Sir Hans Sloan
London

Path and altitude of 1719 bolide from triangulations by Halley

Ernst Chladni (1756-1827)



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1798 showed that meteors could not be ‘explained from
the accumulations in the upper regions of the atmosphere’

First relation of meteors as debris from comets

- Leonid storms of 1799, 1833 and 1866 – comet 55P Tempel-Tuttle
- Perseids in 1866 – comet 109P Swift-Tuttle
- April Lyrids in 1867 – comet C/1861 Thatcher

Ladislaus Weinek (1848-1913)

First image of meteor, 27 November 1885

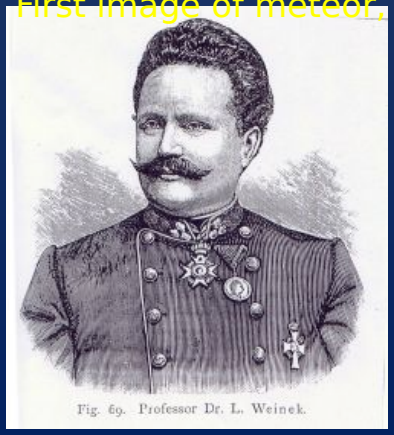
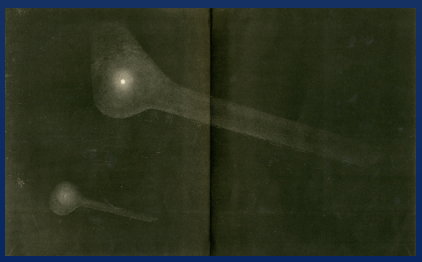


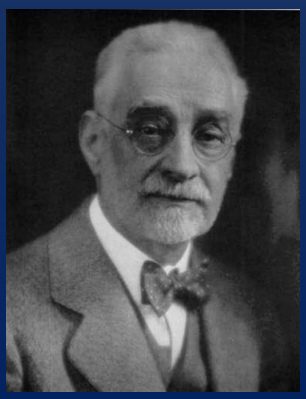
Fig. 69. Professor Dr. L. Weinek.

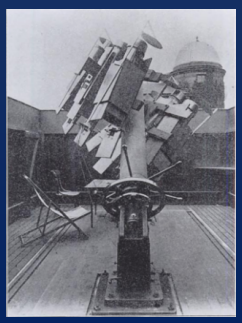


The two fragments of Biela's comet observed in 1846, drawing
by Otto Struve.
Credit: University of Cambridge, Institute of Astronomy.

Lewis Elkin (1855-1922)

First images with rotating shutter, 1889





Dorrit Hoffleit (1907-2007)

Catalogued meteor images on HCO plates

TABLE I

Meteor No.	Plate No.	Date	E.S.T.	Exp. m	Appr'x Position α (1900) h m	δ °	Length °	Description	No. Seg.	Shower	Zen. Mag.	Vis. Mag.	Vis. Train
1	F3A	1932 Aug. 12	3.17	31	0 40	+16	11	faint	8	Perseid	−4		
2	14	Nov. 16	1.31	30.5	11 13.6 11 21.4	+47.1 +49.6	4	faint	9	Leonid	−5	−1.5, −1, 0, +1	3 sec
3	17	Nov. 16	2.21	19	10 19	+ 7.3	2	faint	8	Leonid	−4	−1.5, −1, −1, −1	green
4	18	Nov. 16	3.13	27	10 56	+36.5	3	faint	5	Leonid	−3	−1, −2, −2	green-blue
5	107	1933 Nov. 16	0.38	71	5 53	+54.3	7	faint	20	Sporadic	−2		
6	AI 32219	1935 Aug. 10	1.28	161	20 33 19 20	+57.6 +44.6	17	strong	13	Perseid	−6	−7	green, 15°, 20 sec
7	32275	Sept. 7	1.36	120	2 17 3 09	−13.9 −15.6	13	faint, burst at end	25	Sporadic	−4		
8	32323	Sept. 30	20.28	73	21 40 21 28	− 7.1 −14.4	8		24	Sporadic	−4		
9	32373	Oct. 20	1.04	72	5 19 5 28	−21.2 −21.8	2		8	Sporadic	−5		
10	32380a	Oct. 21	2.50	82	7 58 8 27	+30.1 +32.7	7	burst at end	8	Orionid	−5		
11	32380b	Oct. 21	2.50	82	7 02 7 15	+15.4 +23.5	4	burst at end	8	Orionid	−5		
12	32491	Dec. 29	4.36	120	13 39 13 52	−19.7 −24.5	7	strong	8	Sporadic	−9		
13	32610	1936, Feb. 29	4.08	117	16 08 16 20	−20.9 −28.9	10	faint	10	Sporadic	−4		
14	32760	July 6	23.55	98	21 14 23 09	+58.3 +53.4	19		32	Sporadic	−6		

bable evolution of C/2014 S3 (PANSTAR
860 years

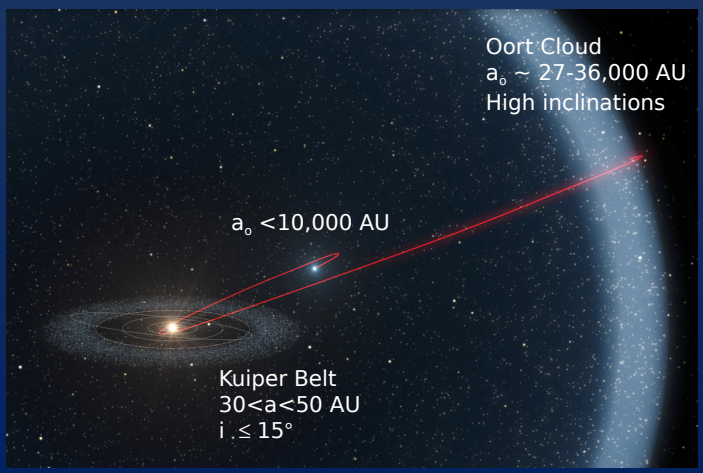


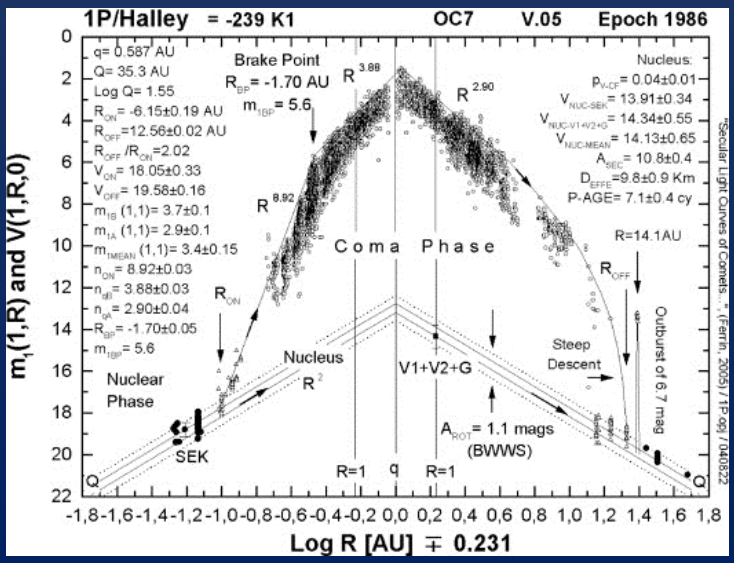
Illustration credit: ESO/L. Calçada.

Formation of meteor stream

Volatiles and dust

- CO, CO_2, H_2O
- Silicates

Nuclear activity for 1P Halley



Nuclear activity for several comets
R_{ON} and R_{OFF} (Ferrin 2009)

Comet	Rank	Figure	R_{ON} [AU]	R_{OFF} [AU]	T_{ON} [d]	T_{OFF} [d]	P-AGE [cy]	T-AGE [cy]	m_1	V_N (1,1,0)	A_{SEC} (1,1)	LAG [d]	q [AU]	Q [AU]	D_{EFFE} [km]
29P/SW 1	1	16,45	~80	880	~7800	~6700	~0.5	~0.5	-3.6	10.9	~14.7	-----	5.44	7.28	54
C/1995O1 Hale-Bopp	2	33,60	-17.3	33.9	-2550	~7650	2.4	~0.75	-1.2	10.6	11.5	+45	0.91	370	54
C/1984 K1 Shoemaker	3	32	-7.3	24.8	----	----	<4.8	----	3.8	<13.4	>9.6	----	2.70	e=1	<14
1P/Halley	4	7,36	-6.15	12.6	-497	1495	7.1	4.2	3.4	14.13	10.8	+11.2	0.59	35.3	9.8
39P/Oterma	5	18,47	-7.7	6.6	-2747	3000	9	1.4	3.0	14.52	11.5	0	3.39	4.53	6.3
65P/Gunn	6	20,49	-8.3	6.1	-1417	1550	9	2.8	1.0	14.8	10.8	+242	2.46	4.74	7.4
81P/Wild 2	7	24,53	-5.1	4.5	-648	690	13	6	5.8	16.53	11.4	-13	1.58	5.30	3.9
19P/Borrelly	8	12,41	-2.9	5.8	-266	>300	14	----	4.2	15.9	11.6	+6	1.37	5.87	4.5
73P/SW3C (2001)	9	23,52	-5.2	4.2	-950	478	18	7	8.3	17.1	8.7	----	0.94	5.18	2.2
C/1996B2 Hyakutake	10	34,61	-3.2	3.52	-167	189	18	22	4.3	15.7	11.6	-6	0.23	1901	4.8
101P/Chernykh	11	26	-3.1	4.9	----	----	22	----	10.2	16.1	-----	----	2.36	9.24	5.0
21P/Giacobini-Zinner	12	13,42	-3.6	4.4	-280	470	22	15	8.2	16.1	7.9	-10	1.03	6.0	3.1
9P/Tempel 1	13	11,40	-3.5	4.2	-410	659	22	9	6.4	15.3	9.0	-10	1.50	4.74	5.5
109P/Swift-Tuttle	15	28,56	-2.8	3.4	-123	156	28	40	3.8	12.0	8.2	+1	0.96	52	27
32P/Comas-Sola	17	17,46	-3.3	3.6	-324	372	30	19	8.6	15.6	7.0	0	1.85	6.67	3.0
6P/D'Arrest	14	10,39	-1.6	<3.2	-70	>250	32	<26	7.2	18.3	9.5	+42	1.35	5.62	1.6
67P/Churyumov-G	16	21,50	-2.8	4.0	-232	408	37	21	9.6	15.4	5.8	+33	1.30	5.73	5.5
85P/Boethin	18	25,54	-1.8	1.7	-107	91	49	54	5.9	14.3	8.4	-4	1.11	8.91	6.3
C/1983 J1 SSF	19	31,59	~1.5	1.5	~-60	60	55	84	10.5	19.8	8.8	----	0.47	e=1	0.7
45P/Honda-Mrkos-P	20	19,48	-1.5	2.0	-70	118	55	64	12.0	19.5	7.5	+2	0.53	5.5	0.9
2P/Encke 1858	21	8,37	-2.2	1.7	-126	105	58	61	9.1	15.5	6.4	-13	0.34	4.09	5.1
C/1983H1 IRAS-A-A	22	30,58	-1.2	1.5	-45	80	84	113	7.8	14.6	6.4	+10	0.99	199	8.6
26P/G-Skjellerup	23	14,43	-1.4	1.8	-73	132	89	85	11.4	16.7	5.2	+14	0.99	4.93	3.0
2P/Encke 2003	24	9,36	-1.6	1.5	-87	94	98	103	10.8	15.5	4.8	+6	0.34	4.09	5.1
28P/Neujmin 1	25	15,44	-2.1	2.4	-115	167	100	100	9.6	12.8	3.2	+7	1.53	12.1	23
C/2001 OG108 LON	26	35,62	-1.6	1.6	-78	96	102	117	8.7	13.1	4.4	-5	0.99	25.6	15.8
107P/Wilson-Harrington	27	27,55	+1.1	1.4	+38	74	----	760*	12.9	16.3	3.3*	+42	1.00	4.28	3.3
133P/Elst-Pizarro	28	29,57	+2.6	2.8	+42	233	----	280*	---	16.0	1.4*	+155	2.63	3.68	4.6

* T-AGE(1,LAG) is given because P-AGE(1,1) can not be calculated.

Incidence of meteor streams

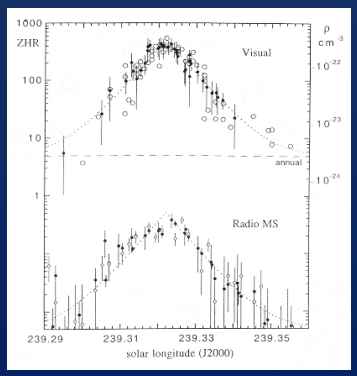
- Major meteor streams ~ dozen showers
- IAU Confirmed active 119 showers
- IAU Working List 790 showers
- Known parent body 36 showers
- Still leaves 754 potential showers with unknown parent.
- Growing list of new detections with no known parent.
- These showers are the smoking gun for potentially hazardous comets.

Name	IAU No/Code	Parent	i	q	Period
Jan Comae Berenicids	90 JCO	C/1913 I Lowe	188		123
Quadrantids	10 QUA	2014 TB18	18.7	1.83	2.84
β Tucanids	108 BTU	C/1976 D1 Bradfield	46.8	0.85	~1600
δ Pavonids	120 DPA	C/1907 G1 Grigg-Mellish	110.0	0.92	162
Daytime q Pegasids	129 QPE	2005 EM169	10.9	0.75	4.83
Lyrids	6 LYR	C/1861 G1 Thatcher	79.8	0.92	415.5
π Puppids	137 PPU	26P Grigg-Skjellerup	22.4	1.09	5.24
η Aquariids	31 ETA	1P Halley	162.3	0.59	75.3
η Lyrids	145 ELY	C/1983 H1 Iras-Araki-Alcock	73.3	0.99	959
π Cetids *	158 CET	C/1874 G1 Winnecke ?	148.3	0.89	
τ Herculids	61 TAH	73P Schwassmann-Wachmann 3	11.2	0.97	5.44
June Boötids	170 JBO	7P Pons-Winnecke	22.3	1.24	6.32
Daytime Arietids	171 ARI	Marsden Group	ẋ=26	ẋ=0.05	
Daytime β Taurids	173 BTA	2004 TG10	4.2	0.31	3.34
α Capricornids	1 CAP	169P NEAT = 2002 EX12	11.3	0.61	4.20
South δ Aquariids	5 SDA	Marsden Group	ẋ=26	ẋ=0.05	
ψ Casseiopeids	197 PCA	1973 NA	68.0	0.89	3.80

Name	IAU No/Code	Parent	i	q	Period
β Indids	195 BIN	C/1991 L3 Levy	19.2	0.98	51.3
ζ Draconids	73 ZDR	6P d'Arrest	19.5	1.36	6.56
Aug δ Capricornids	199 ADC	45P Honda-Mrkos-Pajdusakova	4.2	0.53	5.26
α Aurigids	206 AUR	C/1911 N1 Kiess	148.4	0.68	2497
κ Leonids	212 KLE	C/1917 F1 Mellish	32.7	0.19	145.0
Daytime Sextantids	221 DSX	2005 UD	28.7	0.16	1.44
Orionids	8 ORI	1P Halley	162.3	0.59	75.3
Leo Minorids	22 LMI	C/1739 K1 Zanotti	124.3	0.67	
October Capricornids	233 OCC	D/1978 R1 Haneda-Campos	5.9	1.10	5.97
October Draconids	9 DRA	21P Giacobini-Zinner	31.9	1.03	6.59
Leonids	13 LEO	55P Tempel-Tuttle	162.5	0.98	33.2
Northern Taurids	17 NTA	2004 TG10	4.2	0.31	3.34
Southern Taurids	2 STA	2P Encke	11.8	0.36	3.30
Andromedids	18 AND	3D Biela	13.2	0.88	6.65

alpha Monocerotids
Outbursts 1925, 1935, 1985, 1995

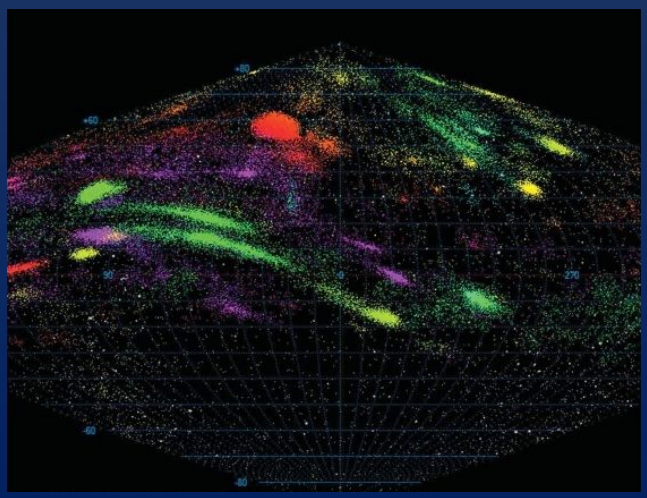
Year	1995	1995	1995	1995	1995	1995	1995	Mean
Month	11	11	11	11	11	11	11	
Day	22.0563	22.059	22.0618	22.0632	22.0674	22.0701	22.0729	
N stations	2	2	2	2	2	2	2	
Stream	α- Mon	α- Mon	α- Mon	α- Mon	α- Mon	α- Mon	α- Mon	
Mv	3	2	1	5	2	0	1	2
q (AU)	0.4803	0.4811	0.495	0.4743	0.4934	0.5087	0.4891	0.488843
e	0.9628	0.9989	1.0136	0.9824	1.0205	0.9976	0.9981	0.996271
i	133.379	134.31	134.479	133.796	134.627	134.074	134.105	134.11
omega	92.7096	91.5178	89.482	92.8136	89.4854	88.3462	90.6068	90.70877
Node	59.3156	59.3182	59.3213	59.3224	59.3269	59.3299	59.3327	59.32386
V g	61.89	62.68	63.11	62.24	63.23	62.91	62.72	62.68



P>140 years

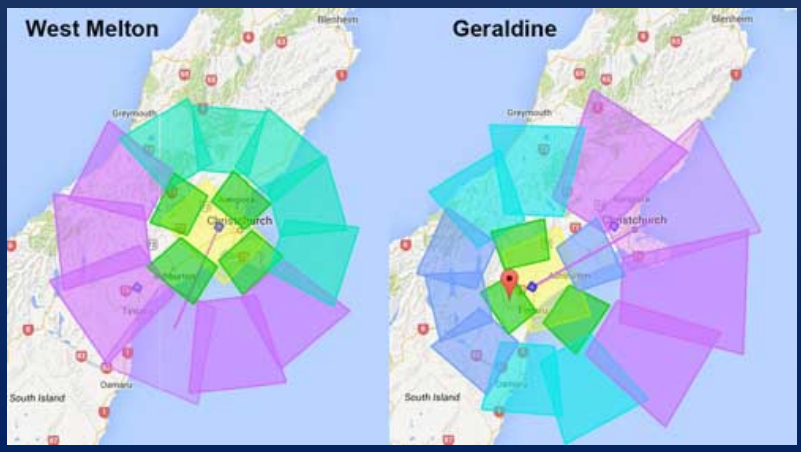
Annual radiant detections from CAMS

An automated video surveillance of the night sky to validate minor showers in the IAU Working List of Meteor Showers



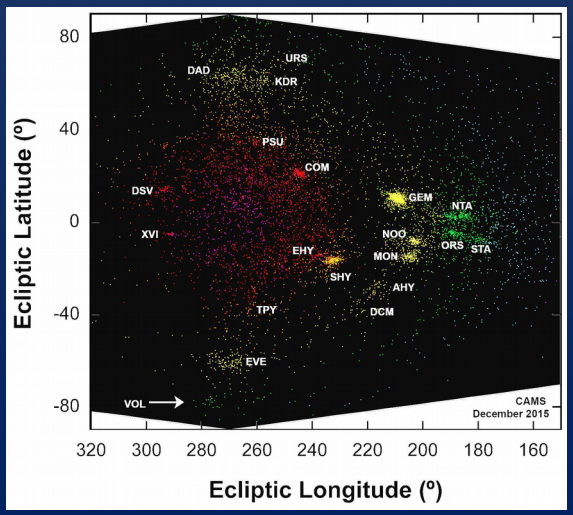
CAMS station at West Melton, NZ

Camera alignment for CAMS NZ

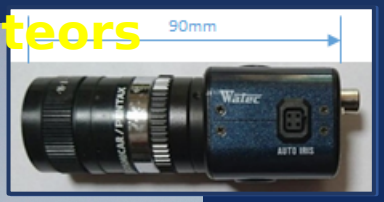


Detection of new Volantid meteor shower

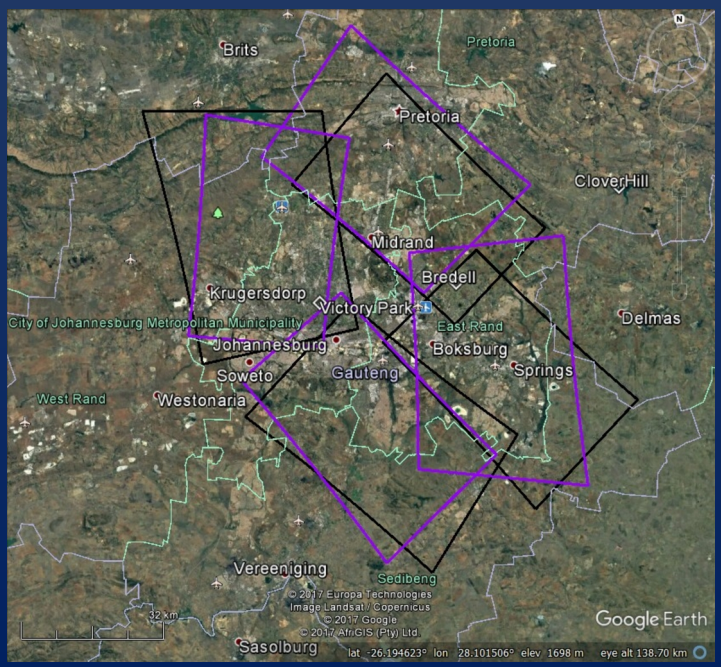
New Year's Eve 2015



Cameras and alignment, CAMS@SA
Comet Borisov meteors



Watec 902 camera
811x508 pixels
1 x 10^{-4} lux
Pentax 12mm f1.2 lens
FOV 30° x 25°


Brits
Pretoria
Pretoria
CloverHill
Midrand
Bredell
Krugersdorp
Victory Park
City of Johannesburg Metropolitan Municipality
East Rand
Delmas
Johannesburg
Boksburg
Soweto
Gauteng
Springs
West Rand
Westonaria
Vereeniging
Sedibeng
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© 2017 AfriGIS (Pty) Ltd
32 km
Google Earth
Sasolburg
lat -26.194623° lon 28.101506° elev 1698 m eye alt 138.70 km

Double station meteors from Bredell

CAP

SDA

CAP

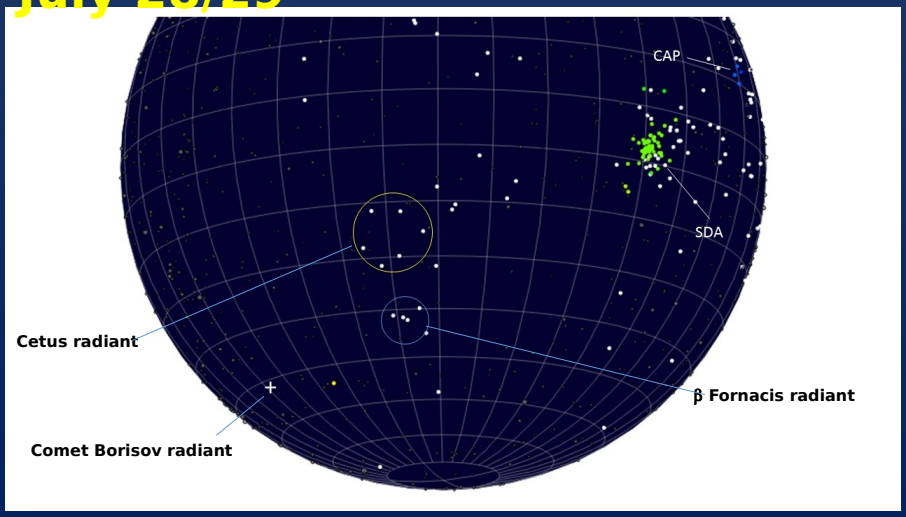
SPO

SDA

SDA

Southern delta Aquariid (SDA) observed on both camera 579 at Victory Park and camera 587 at Bredell.

CAMS@SA radiant map, 2017 July 28/29



Probable fireball recorded by two cameras at Victory Park

Conclusions

- CAMS@SA trial runs very successful
- Site selection in progress for permanent operation
- Will fill gaps in real time southern hemisphere radiant mapping due to unique position on the globe
- Will contribute to knowledge of showers from potentially hazardous comets
- Will refine trajectories of observed fireballs