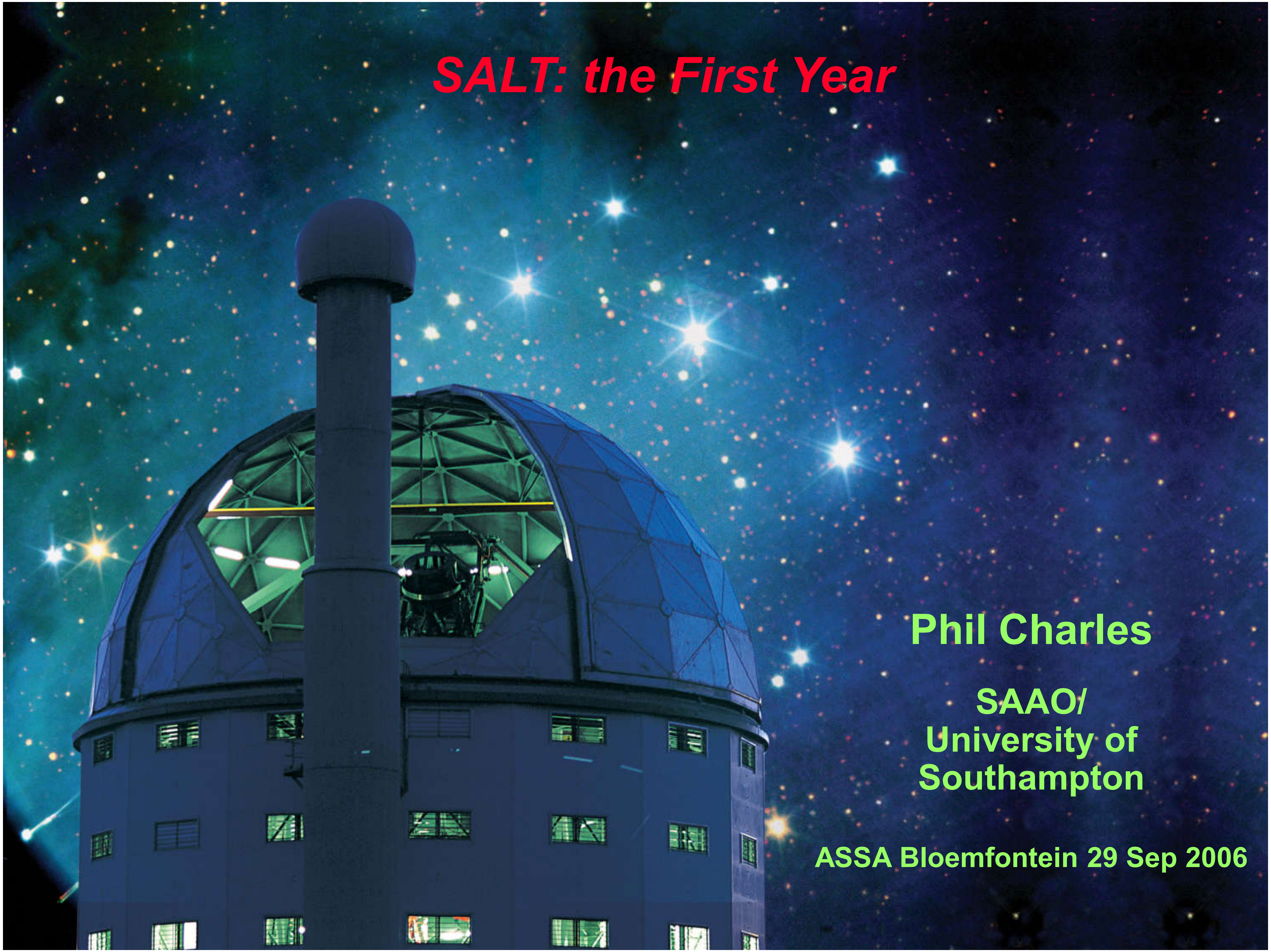
SALT: the First Year



Phil Charles

**SAAO/
University of
Southampton**

ASSA Bloemfontein 29 Sep 2006

27 Apr 2005 :
all 91 segments
installed!

Where is SALT located?

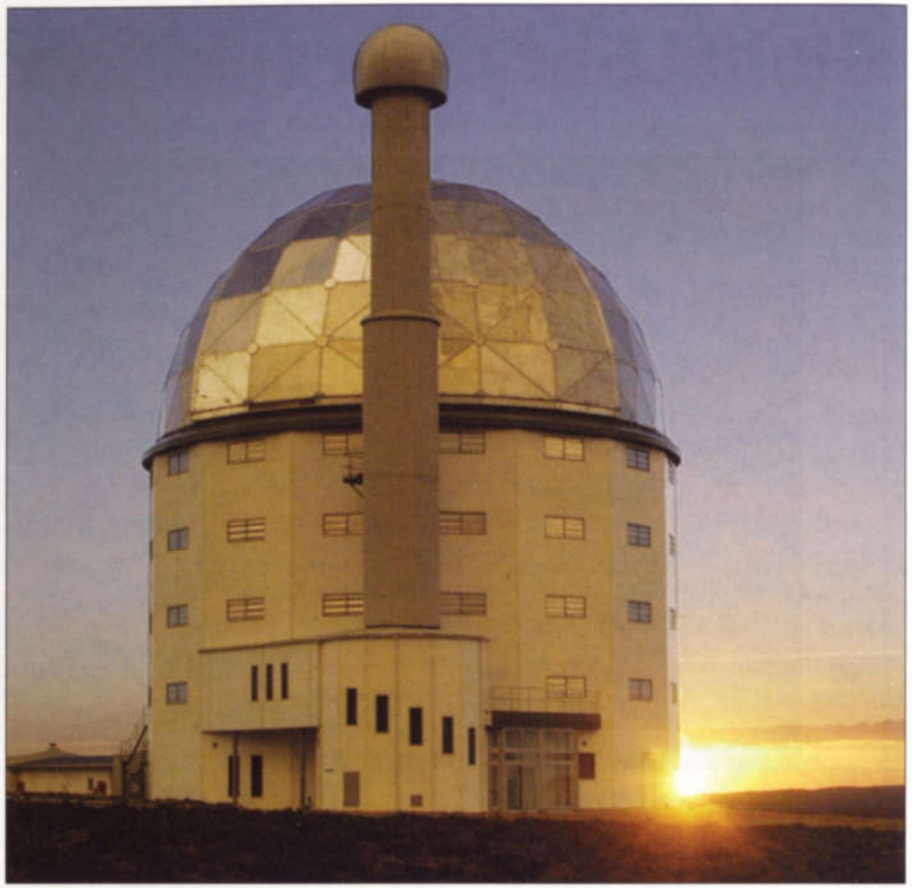
Giant eye opens in Namibia

The South African Large Telescope, known as Africa's giant eye, was formally opened by the President of South Africa, Thabo Mbeki, on 10 November.

SALT, with its 11 m mirror, is the southern hemisphere's largest telescope. An important part of its role is to give African astronomers the opportunity to work on a world-class instrument. They – and others – will be able to do so remotely, submitting observing requests and receiving the data back via the internet.

At the official opening, South African President Thabo Mbeki said: "SALT means that our country will remain at the forefront of cutting-edge astronomical research. The telescope will enable us to observe the earliest stars and learn about the formation of our galaxy, which will help us reveal clues about the future. We are also proud that SALT will not only enable Southern African scientists to undertake important research, but also provide significant opportunities for international collaboration and scientific partnerships with the rest of the world."

The £11m project is an international partnership backed by six different countries including a UK consortium consisting of the University of Central Lancashire, Keele, Nottingham and Southampton universities, the Open University and Armagh Observatory. The telescope has already seen first light; the next stage is installation of the Prime Focus Imaging Spectrograph.



Right: The SALT enclosure in Namibia. (K Crause 2004)

RAS' A&G Dec 05 issue!

Where is SALT ?

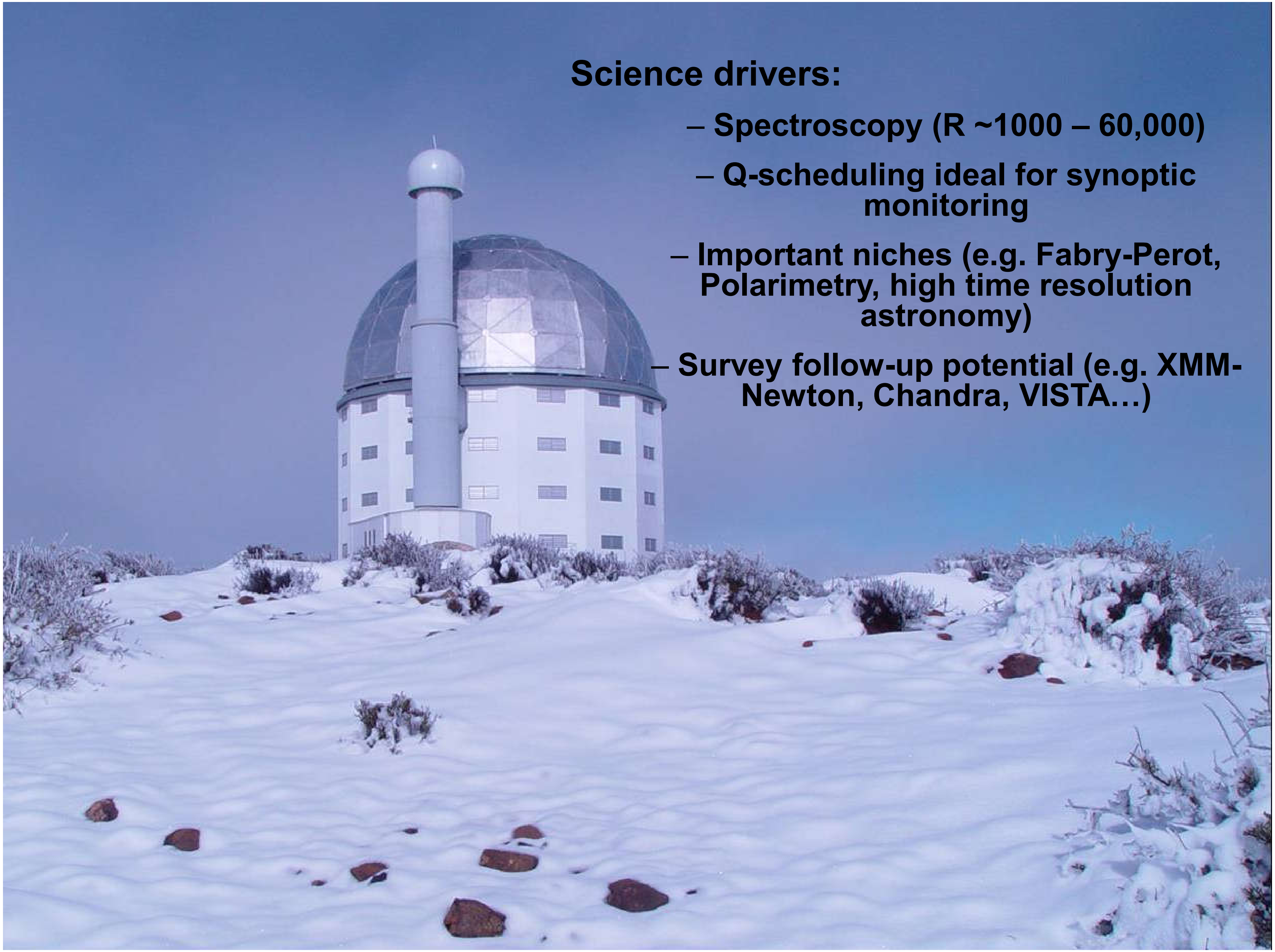
Sutherland:
Good, dark astronomical site; used by SAAO for 30 years

Aseasonal with 75% nights useable

Median seeing of 0.9 arcsec

~1800 m altitude

SAAO:
Host institution and SALT operator.



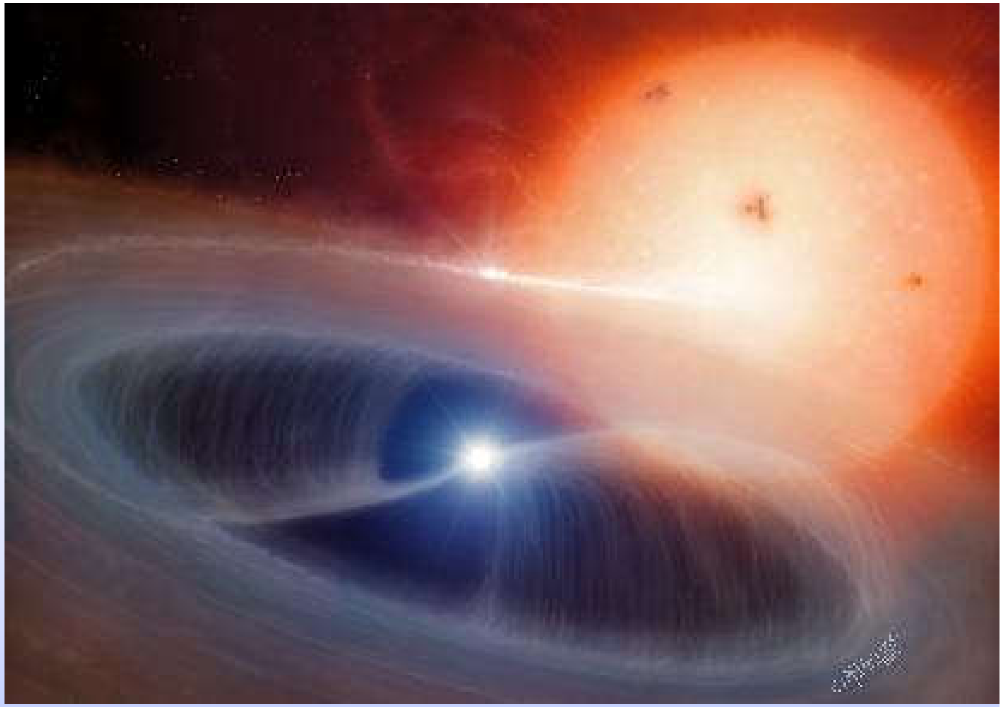
Science drivers:

– **Spectroscopy (R ~1000 – 60,000)**

– **Q-scheduling ideal for synoptic monitoring**

– **Important niches (e.g. Fabry-Perot, Polarimetry, high time resolution astronomy)**

– **Survey follow-up potential (e.g. XMM-Newton, Chandra, VISTA…)**



Astrophysics on the shortest timescales:

- eclipses, eclipse mapping
- asteroseismology
- flickering in accretion disks
- DNOs, QPOs, etc
- echo mapping
- pulsar studies
- black hole/neutron star inner orbits
- occultations/eclipses of accretion spots, etc.

Time resolution capability of ~50-100 ms from frame transfer CCDs.

Such a capability in photometry, spectroscopy and spectropolarimetry crucial for phenomenology and physics of many accreting systems

Who owns SALT?

- National Research Foundation 34.4%
- University of Wisconsin 15.5%
- CAMK (Poland) 11.0%
- Rutgers University 10.8%
- Dartmouth College 9.4%
- Goettingen University 4.9%
- University of Canterbury (NZ) 4.1%
- UK SALT Consortium 3.9%
- University of North Carolina 3.1%
- Carnegie - Mellon University 3.1%

(Original shareholding)

Total Cost is ~$40.6M

$19.86M: telescope construction

$8.35M: three first-generation instruments (2 constructed, being commissioned)

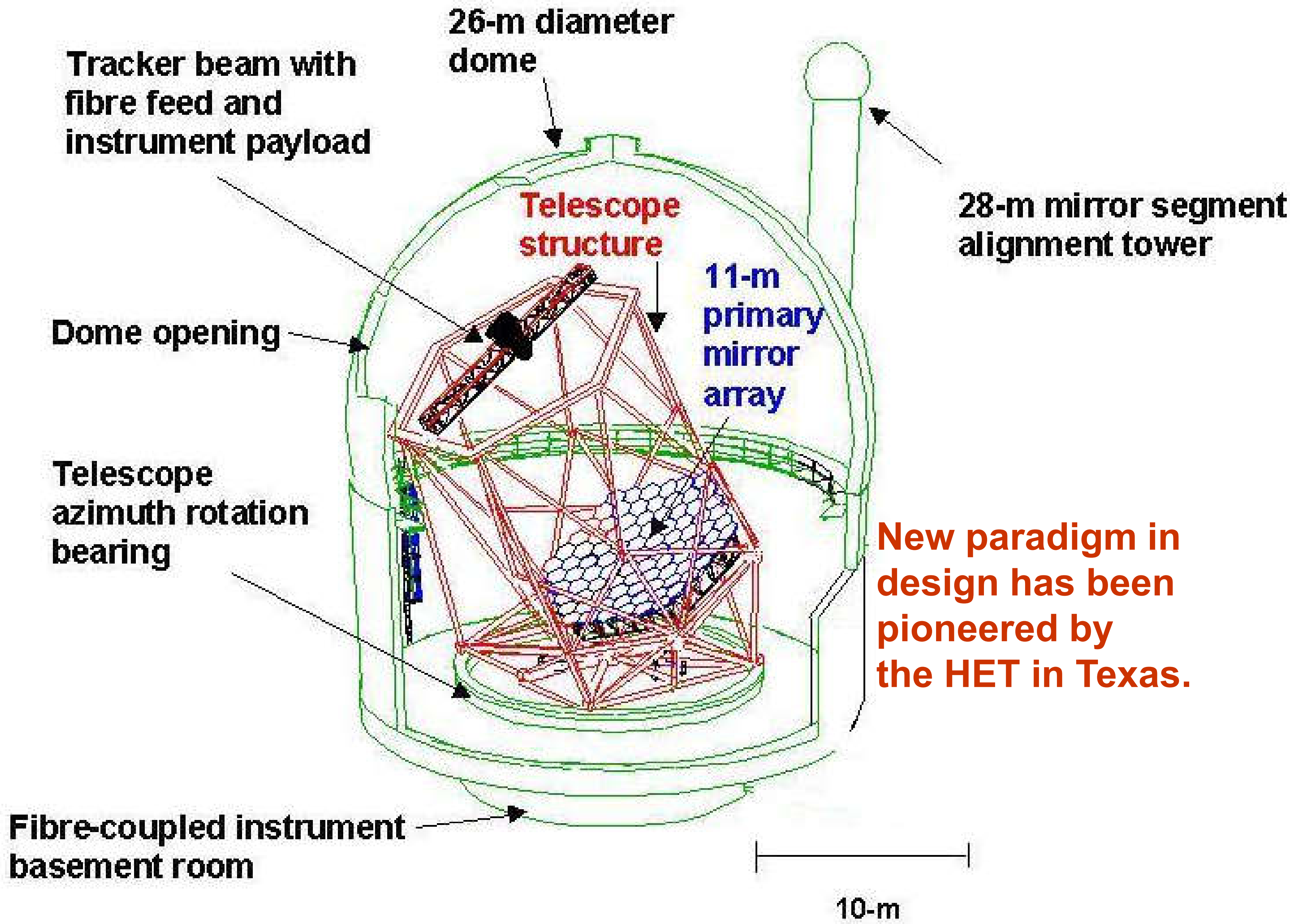
$12.4M: 10 years operations

SALT Ground-breaking: 1 Sept 2000

SALT First Light Press Release: Sep 1, 2005

NGC6744
d=10Mpc
U-10s
V-10s
I-10s

Southern African Large Telescope

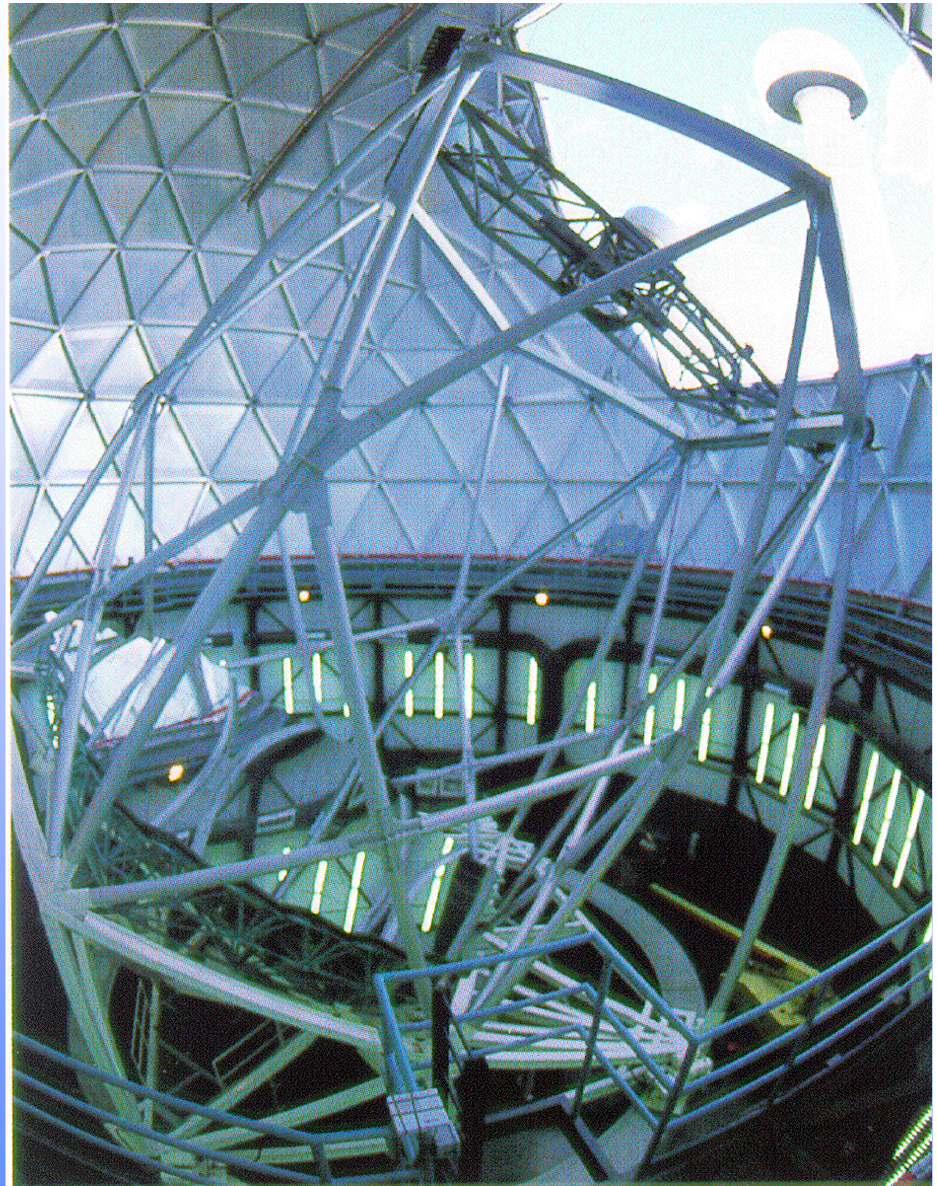


New paradigm in design has been pioneered by the HET in Texas.

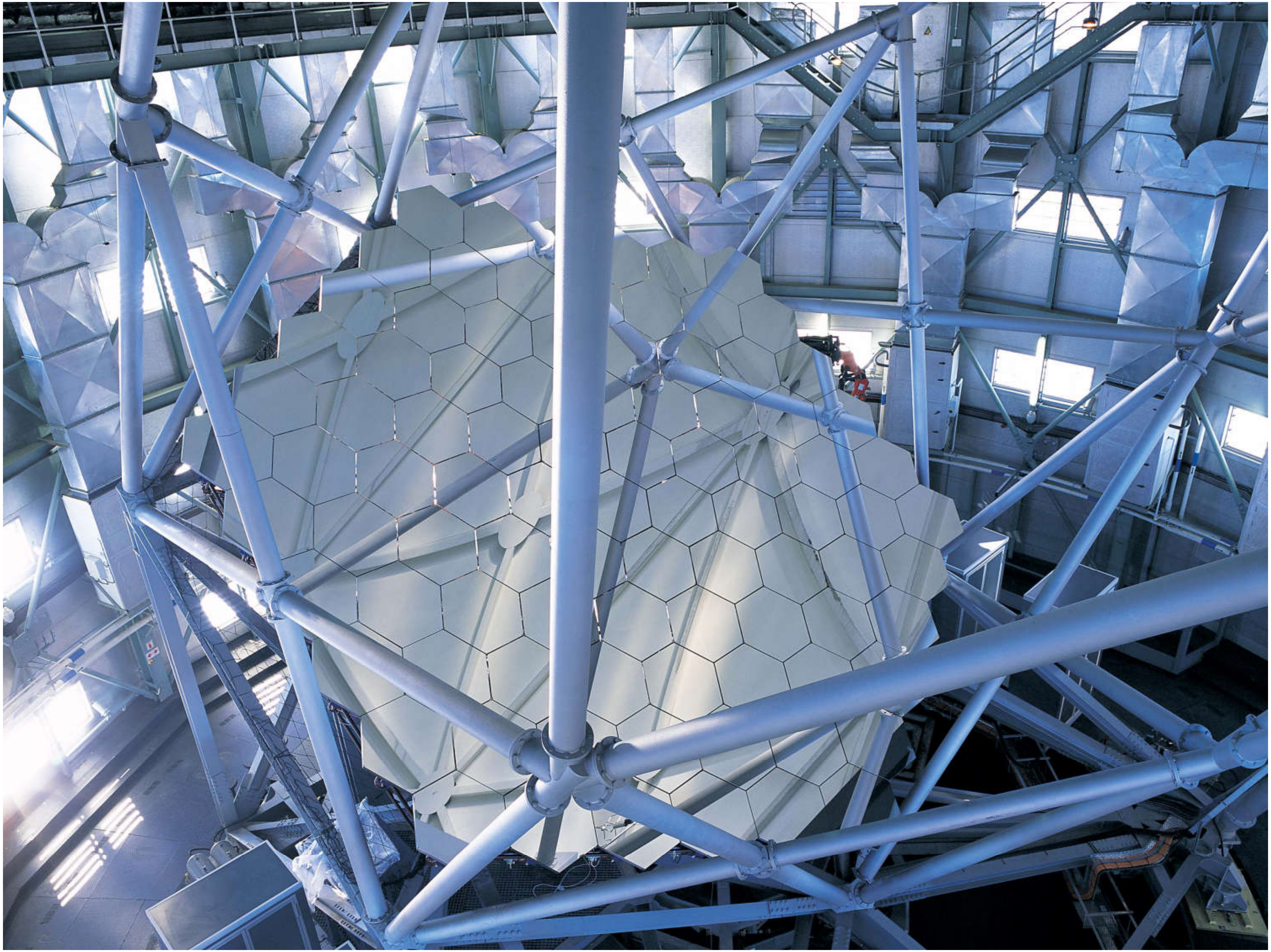
SALT: *A Fixed Elevation Optical-IR Telescope modelled on the Hobby-Eberly Telescope*

BASIC ATTRIBUTES

- **PRIMARY MIRROR ARRAY**
  - **Spherical Figure**
  - **91 identical hexagonal segments**
  - **Unphased (i.e. not diffraction limited 10-m, just 1-m)**
- **TELESCOPE TILTED AT 37°**
  - **Declination Coverage +10° < δ < -75°**
  - **Azimuth rotation for pointing only**
- **OBJECTS TRACKED OVER 12° FOCAL SURFACE**
  - **Tracker contains Spherical Aberration Corrector (SAC) with 8 arcminute FOV (*Prime Focus*)**
  - **Large instruments fibre-coupled**
- **IMAGE QUALITY**
  - **Designed to be seeing limited (median = 0.9 arcsec)**



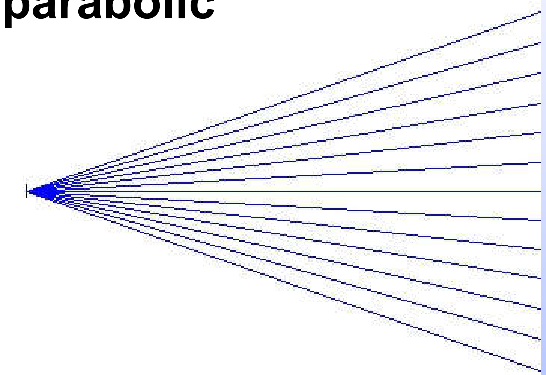
HET



Spherical Aberration in the HET & SALT

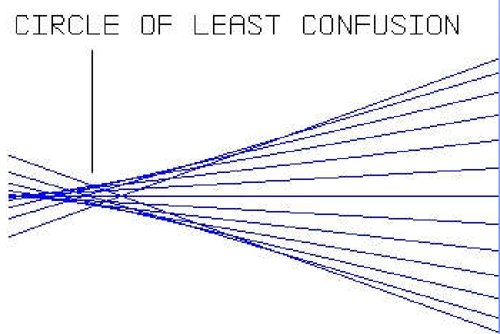
Perfect image

If the primary were parabolic

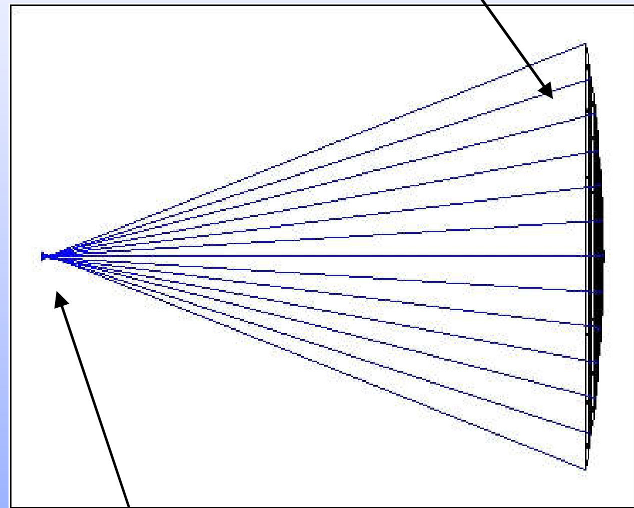


… BUT the primary is spherical

Very bad Image: ~10 arcmin, about 1/3 size of moon



Primary Mirror array

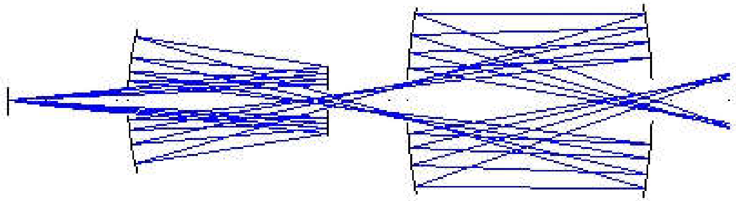


Prime Focus

Therefore both HET and SALT employ a prime-focus Spherical Aberration Corrector (SAC)

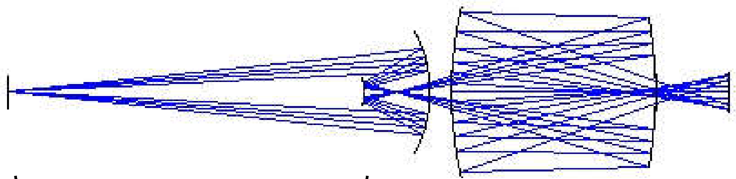
Spherical aberration corrector comparisons

HET SAC

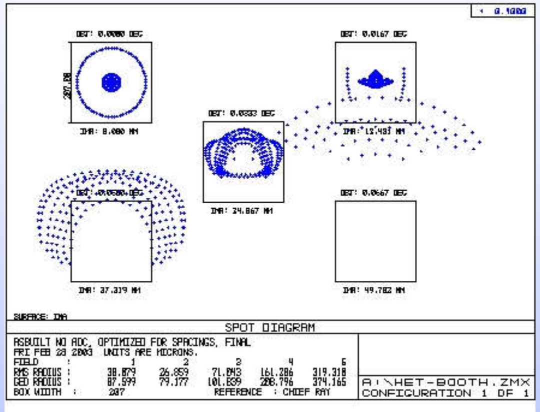


Focal Plane

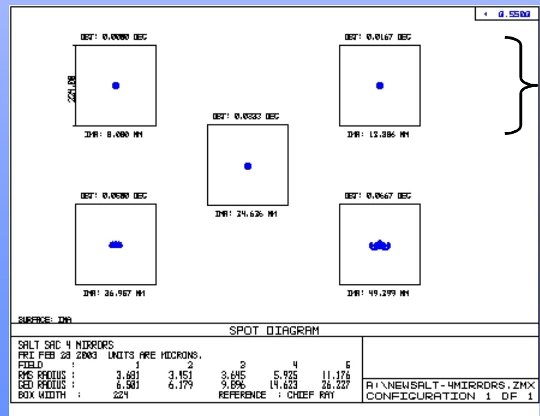
SALT SAC



Large back focal distance

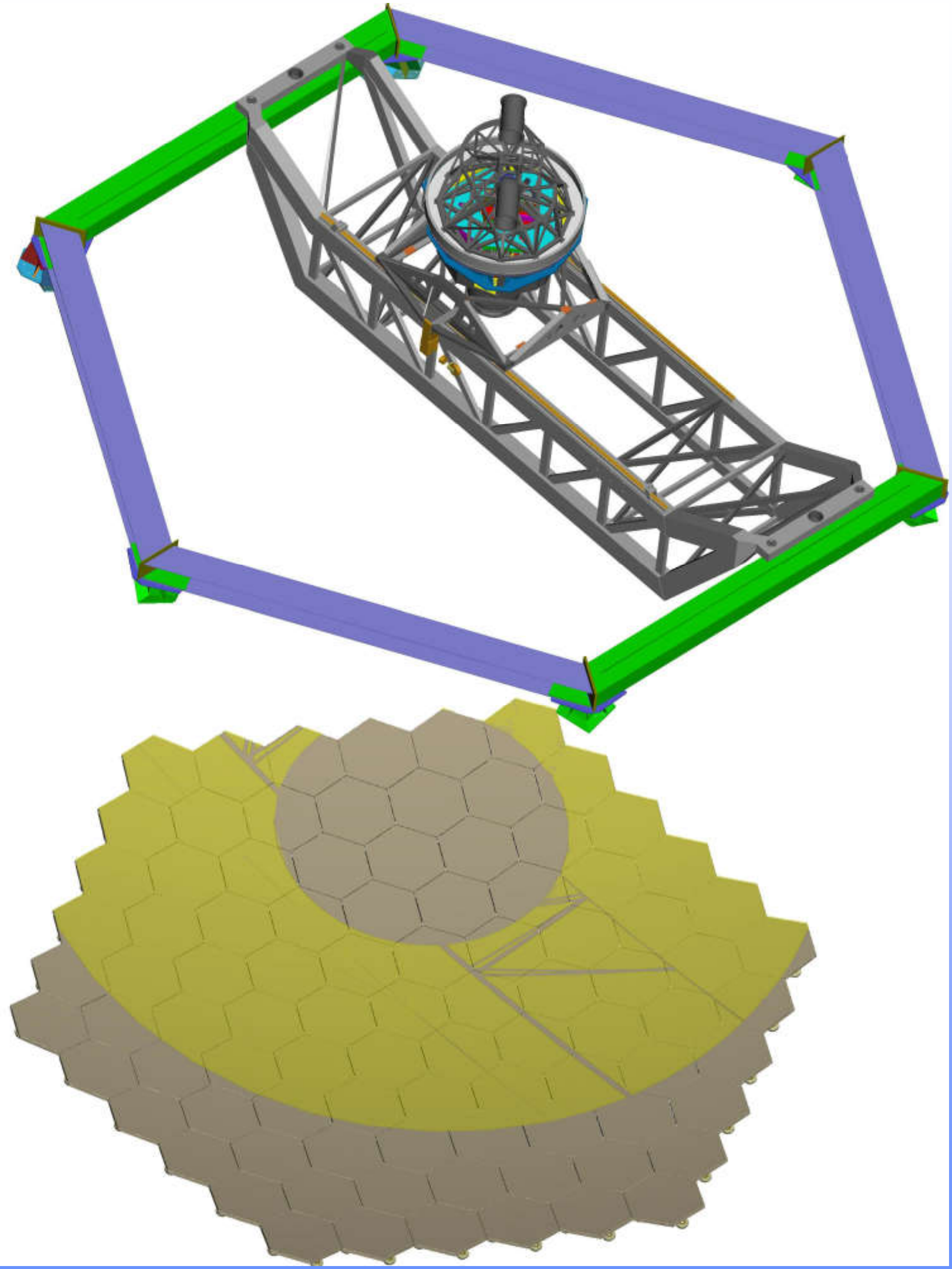


Spot diagrams



One arcsec boxes

SALT/HET Tracking Principle

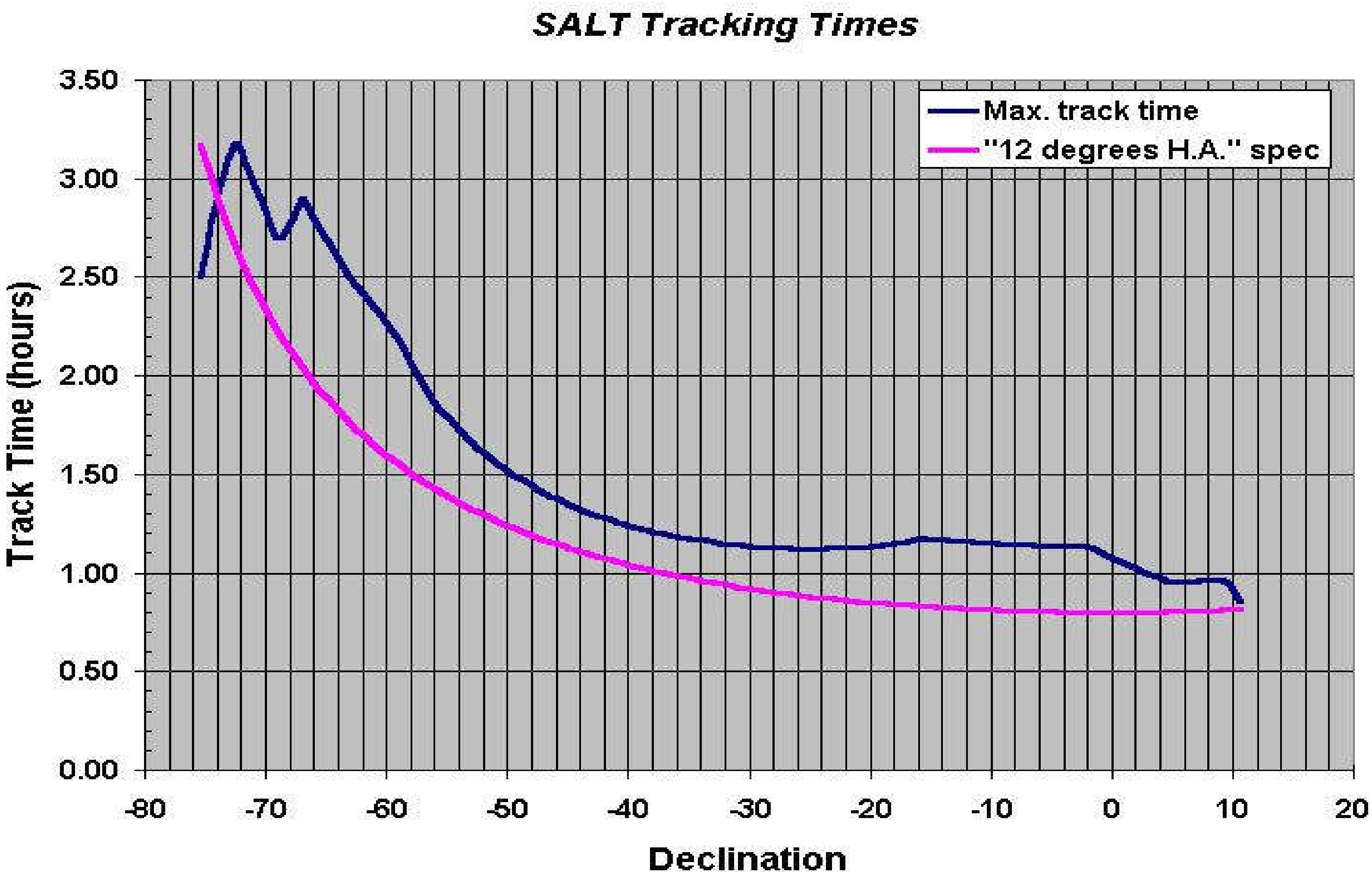


Tracker off-centre
and pupil partially on primary
mirror array. At worst extreme,
still a ~7 m telescope.

With tracker and 11-m pupil centred on primary mirror array, use full diameter of telescope (HET only 9.1m pupil)

Pupil is always underfilled (→ baffled at exit pupil)

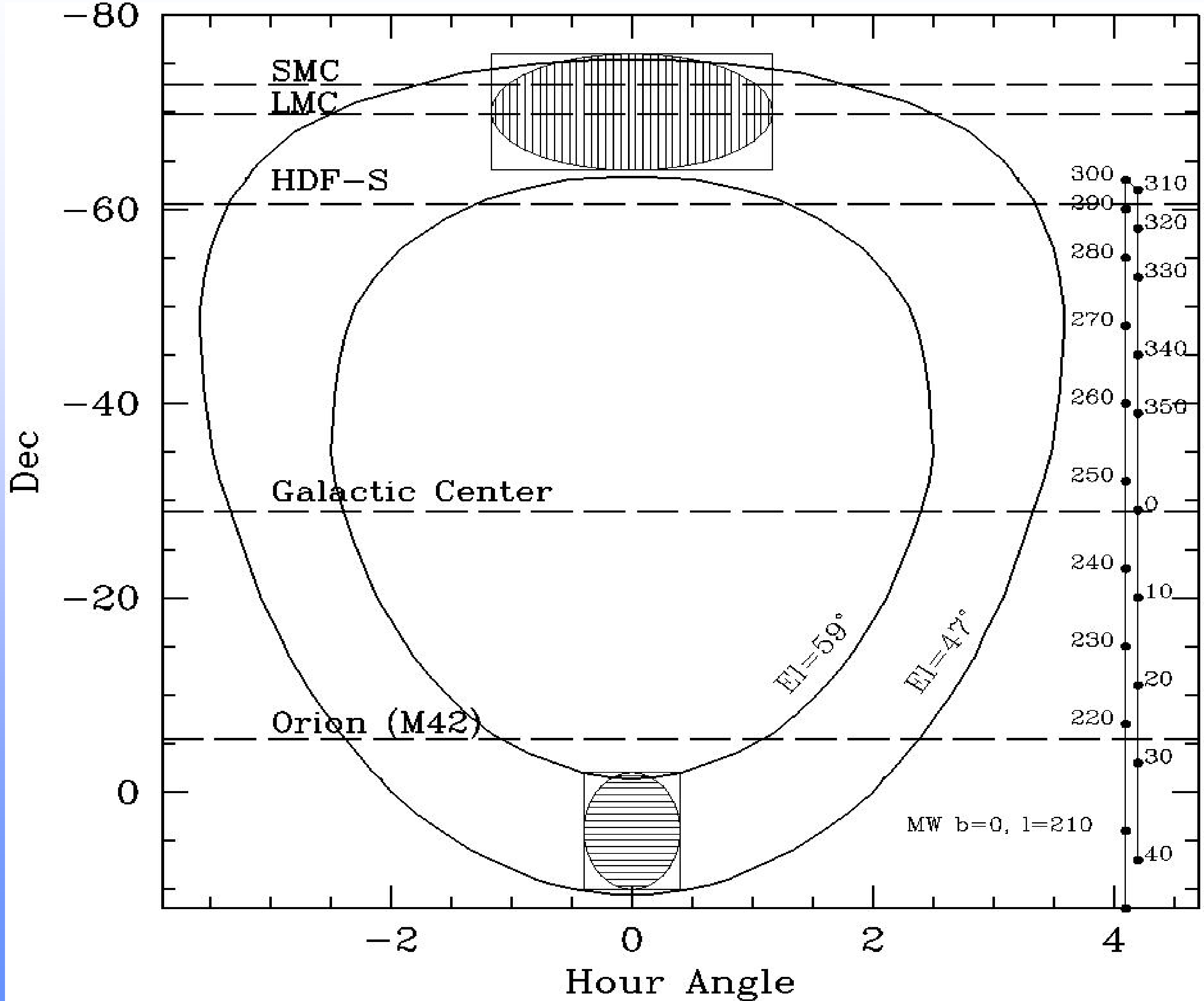
SALT characteristics



Annulus of visibility for SALT:

12.5% of visible sky

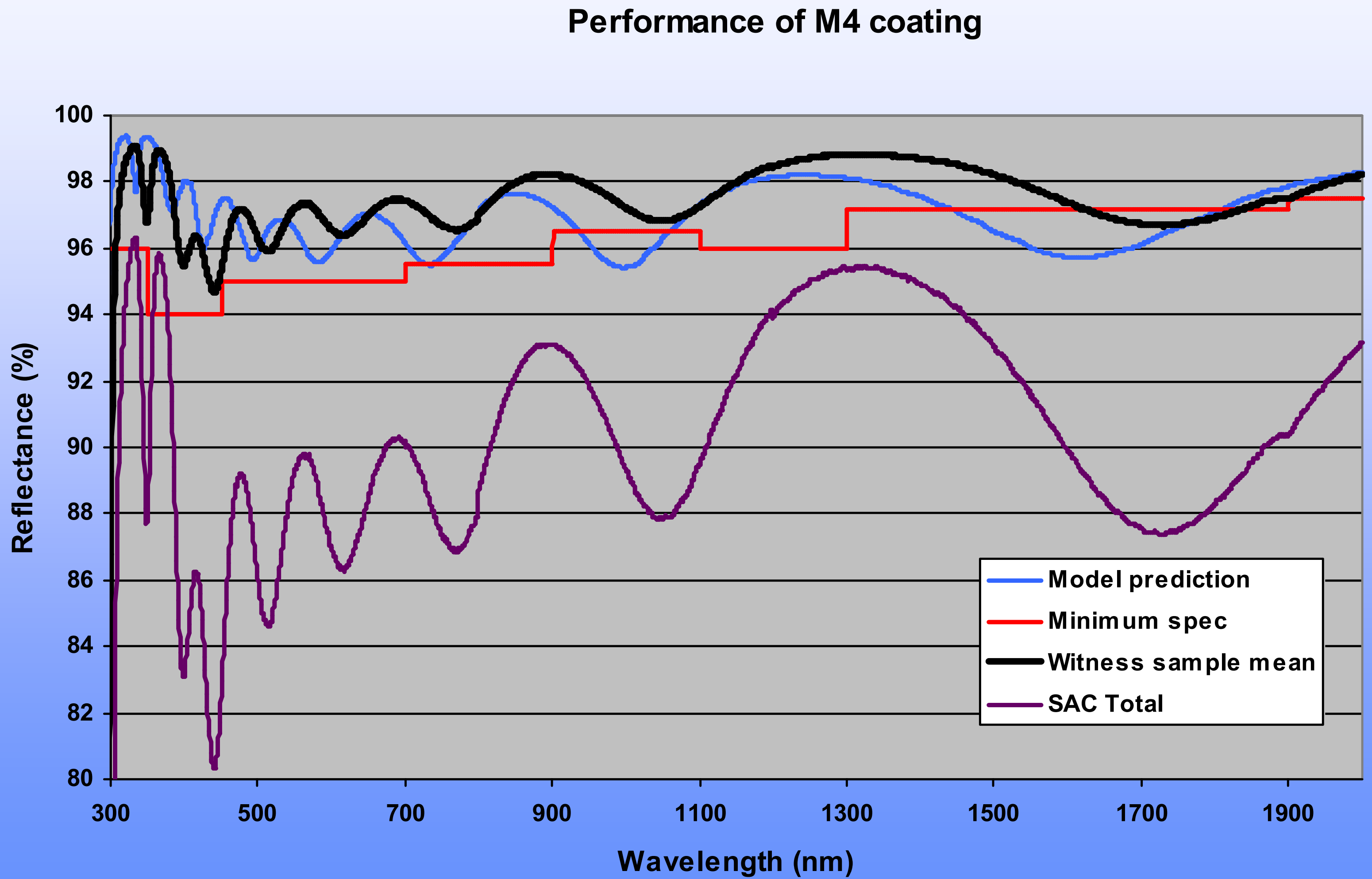
Shaded regions continuously visible



Rotate in azimuth, to access different parts of sky

SAC Mirror coatings

SALT has utilized new Ag/Al combination multi-layer coatings from LLNL



SALT Prime Focus Payload

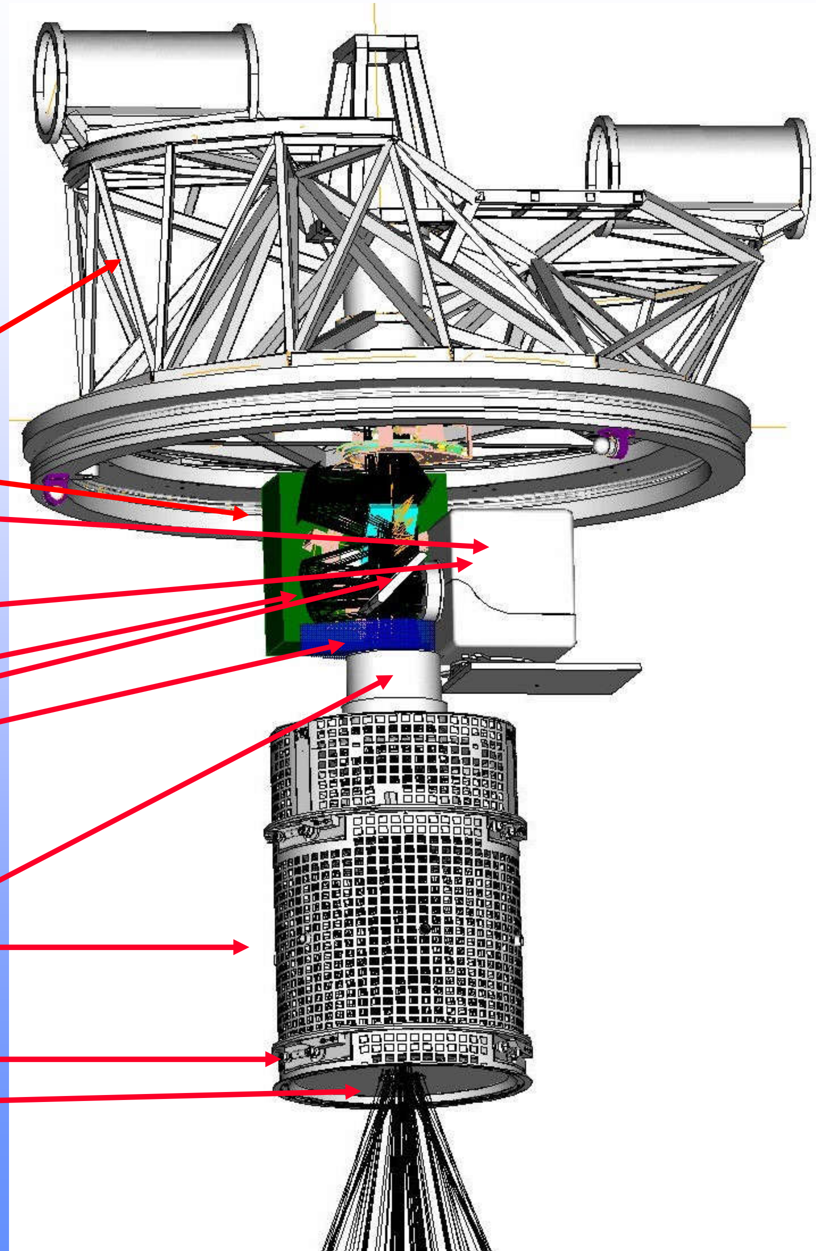
Prime Focus Payload (~1000 kg) mounts via hexapod to tracker and comprises of:

Science instruments:

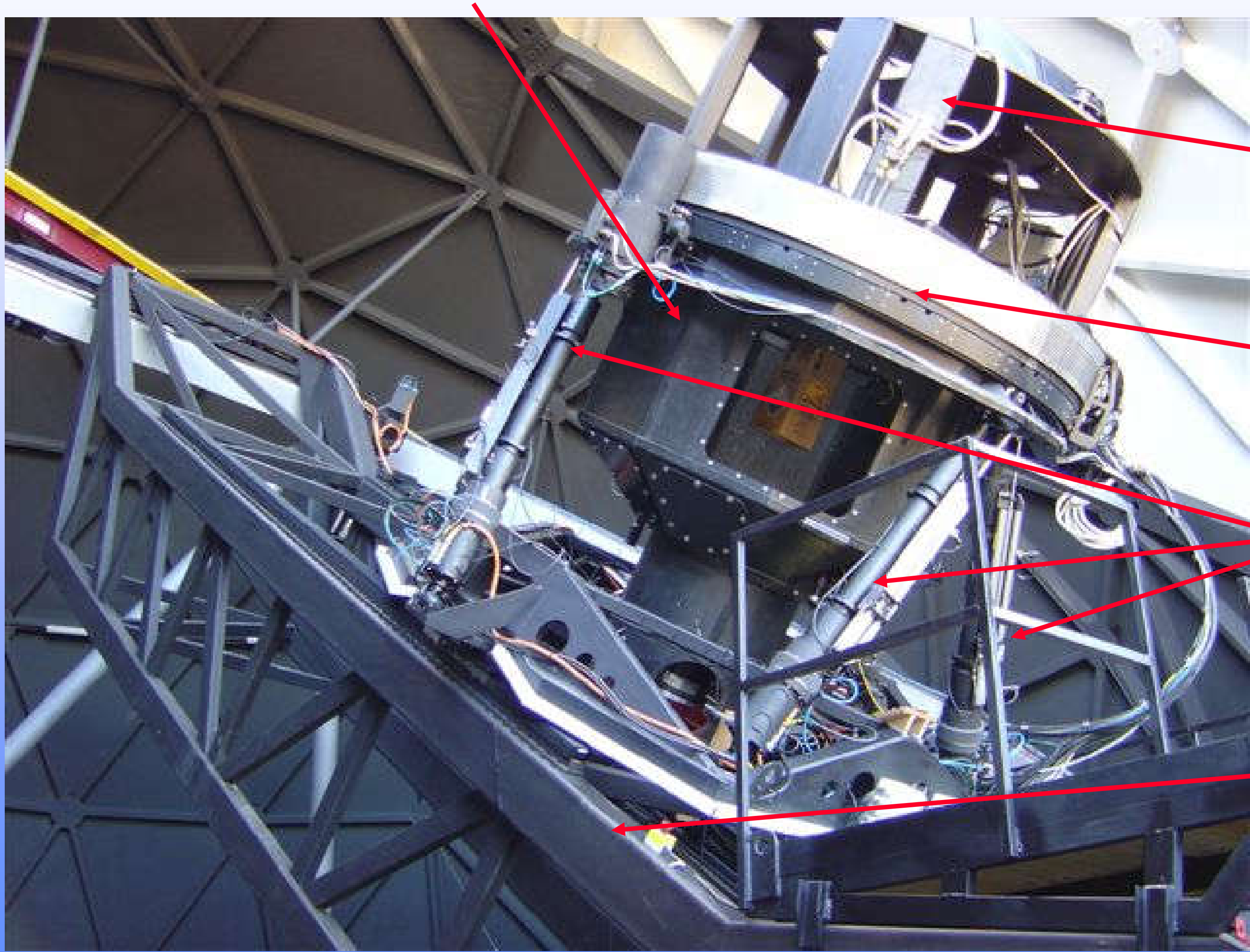
- **Prime Focus Imaging Spectrograph (PFIS)**
- **Fibre Instrument Feed (FIF)**
- **SALTICAM (optical imager)**

Facility instruments:

- **Acquisition camera (SALTICAM)**
- **Guidance & focus system**
- **PFIS slit-viewing optics**
- **Fold mirrors (to 3 focii)**
- **Moving pupil baffle**
- **Atmospheric Dispersion Compensator (ADC)**
- **SAC structure**
- **Payload alignment system (autocollimator and interferometer)**
- **Calibration system (flats, arcs)**



Instruments are all mounted on Payload

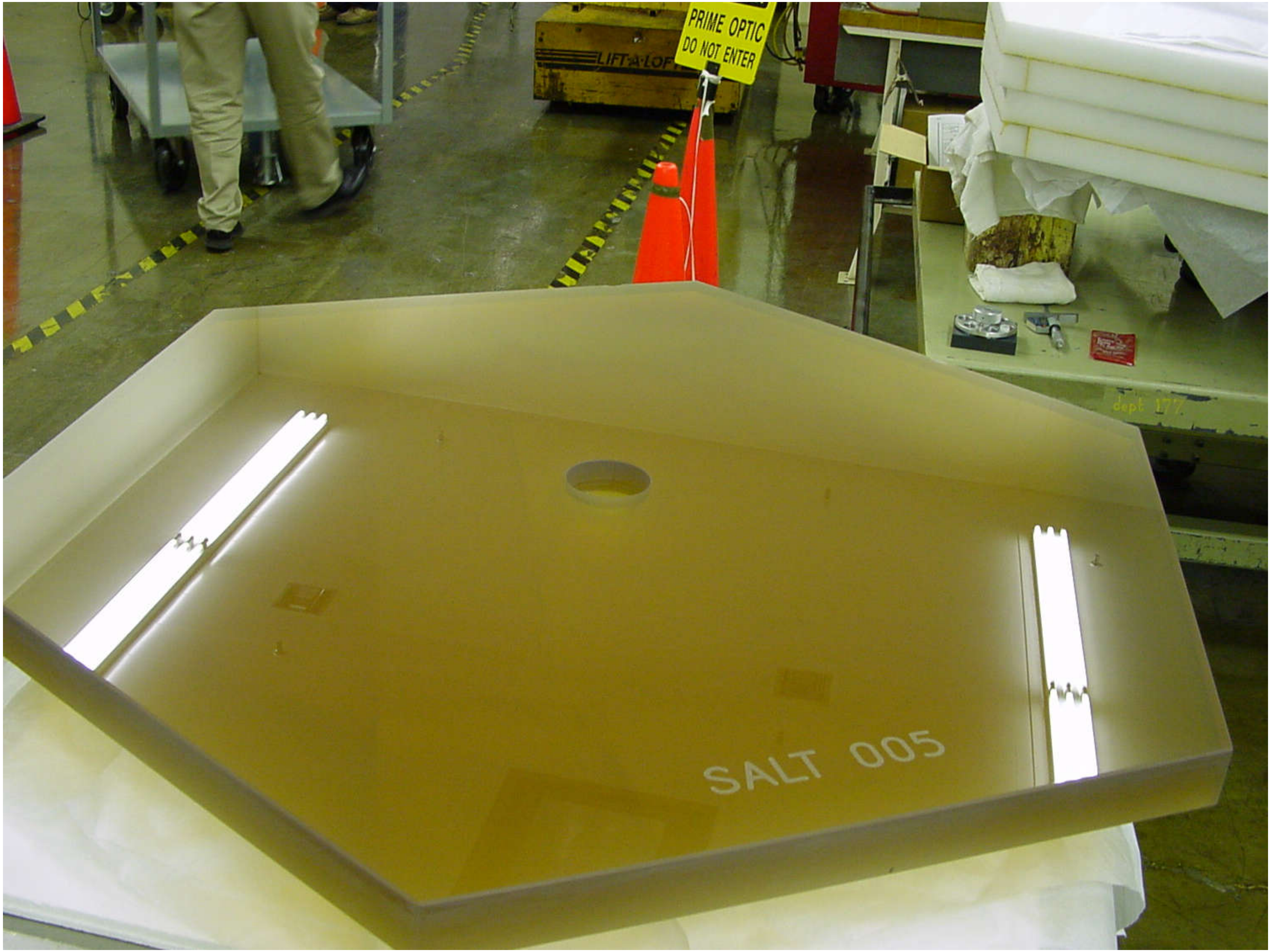


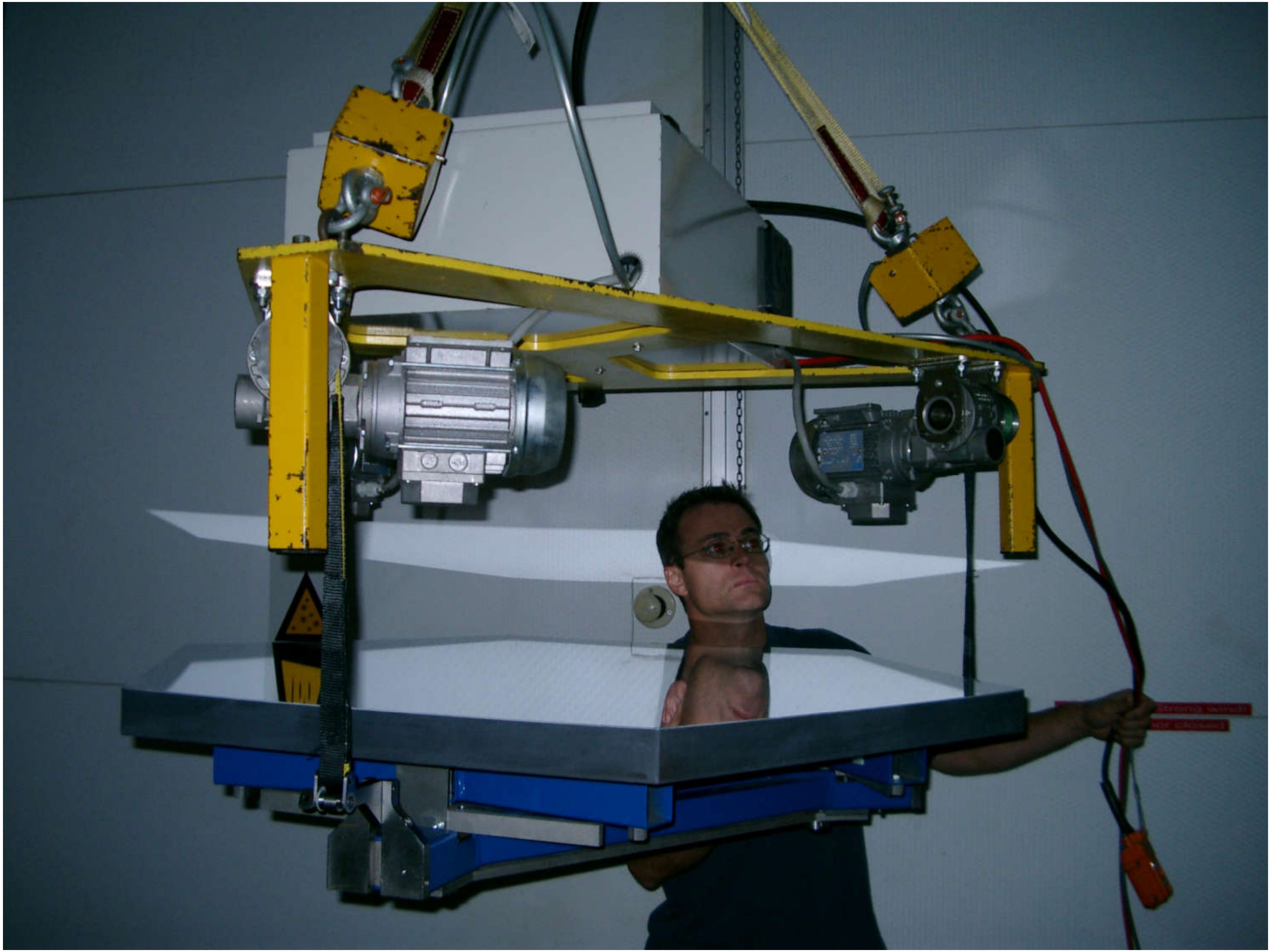
RSS location

Instrument rotator ring

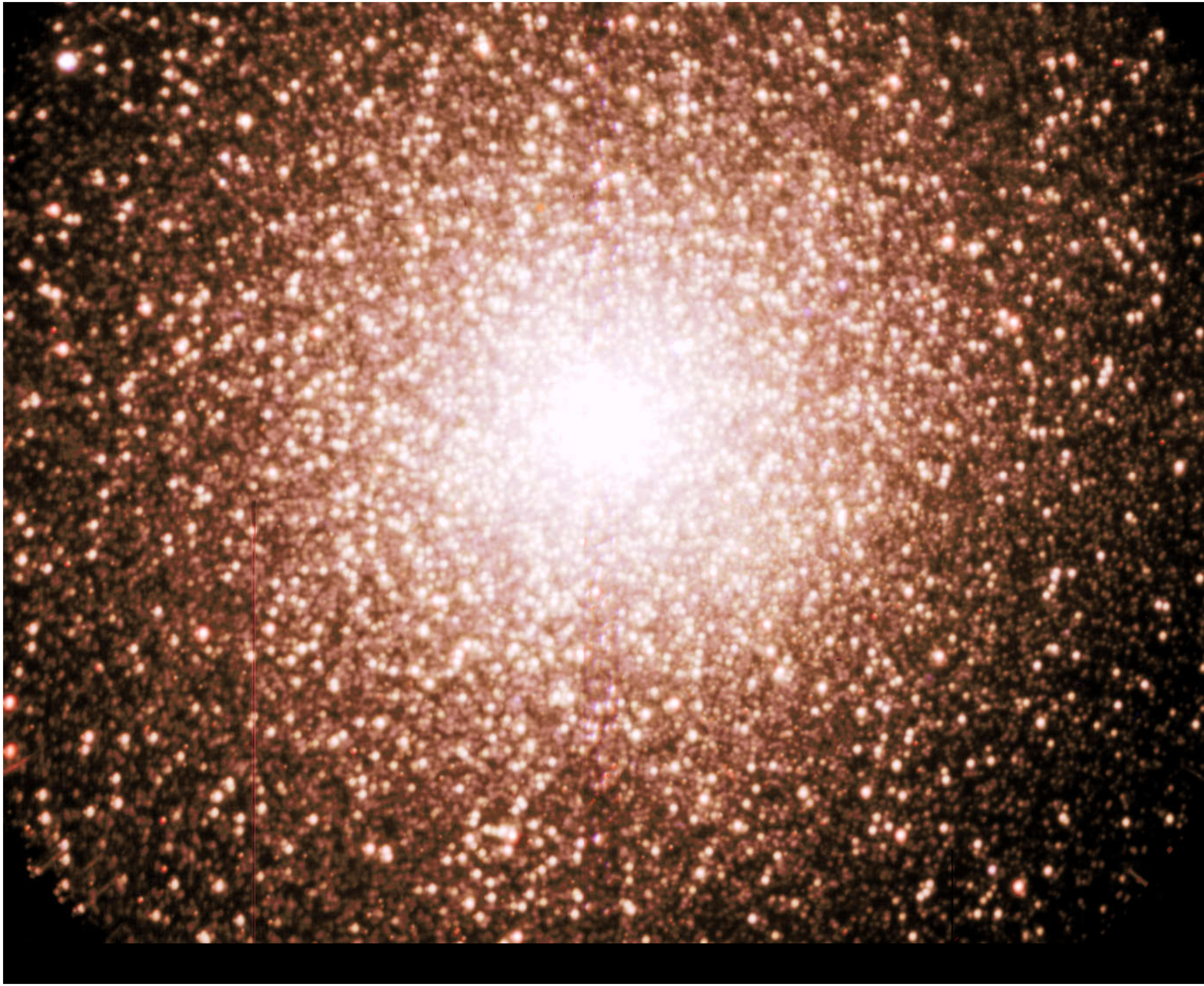
Hexapod legs

Tracker beam


PRIME OPTIC
DO NOT ENTER
LIFT-A-LOFT
dept 177
SALT 005



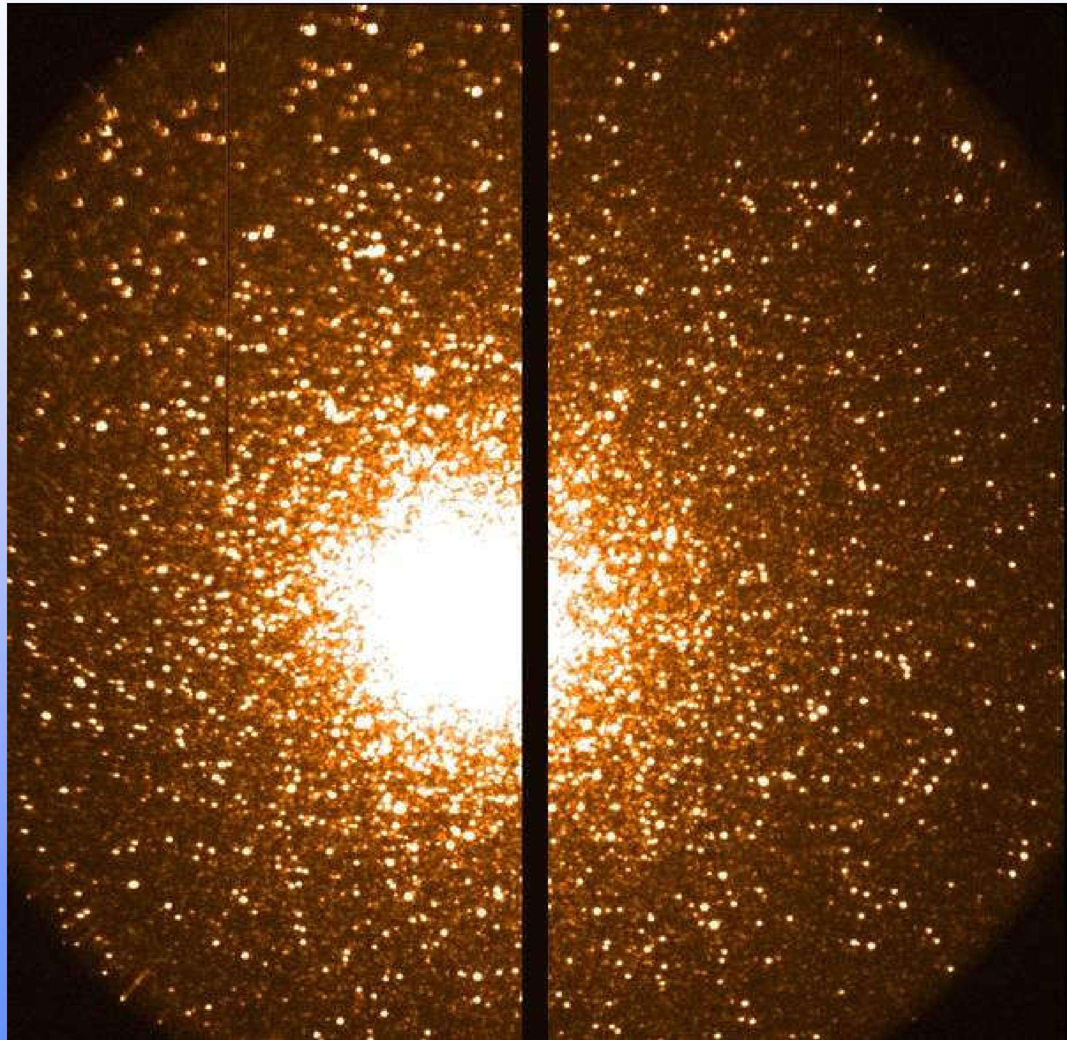
Cleaning and aluminizing



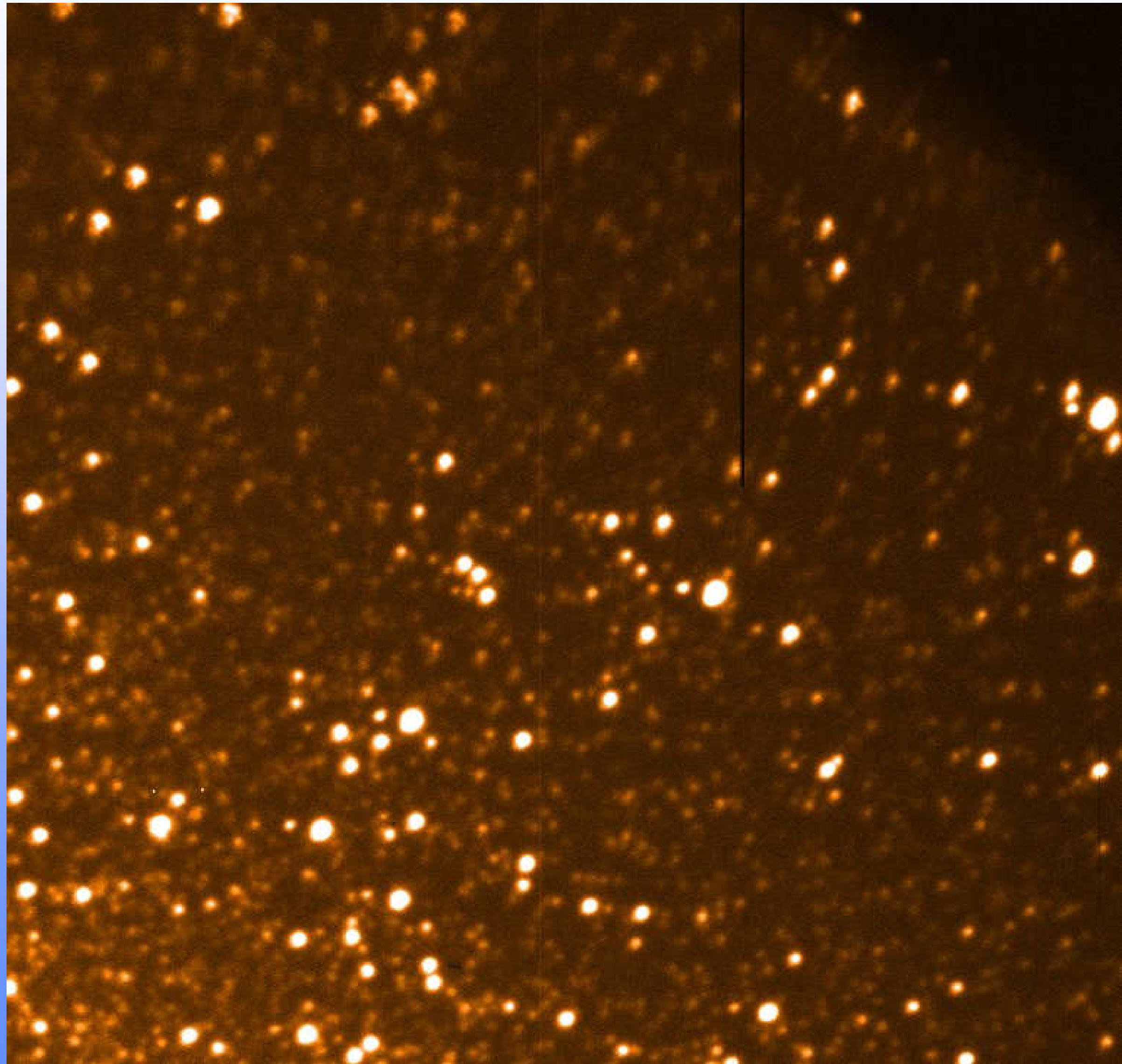
47 Tuc

U-120s
V-20s
I-20s

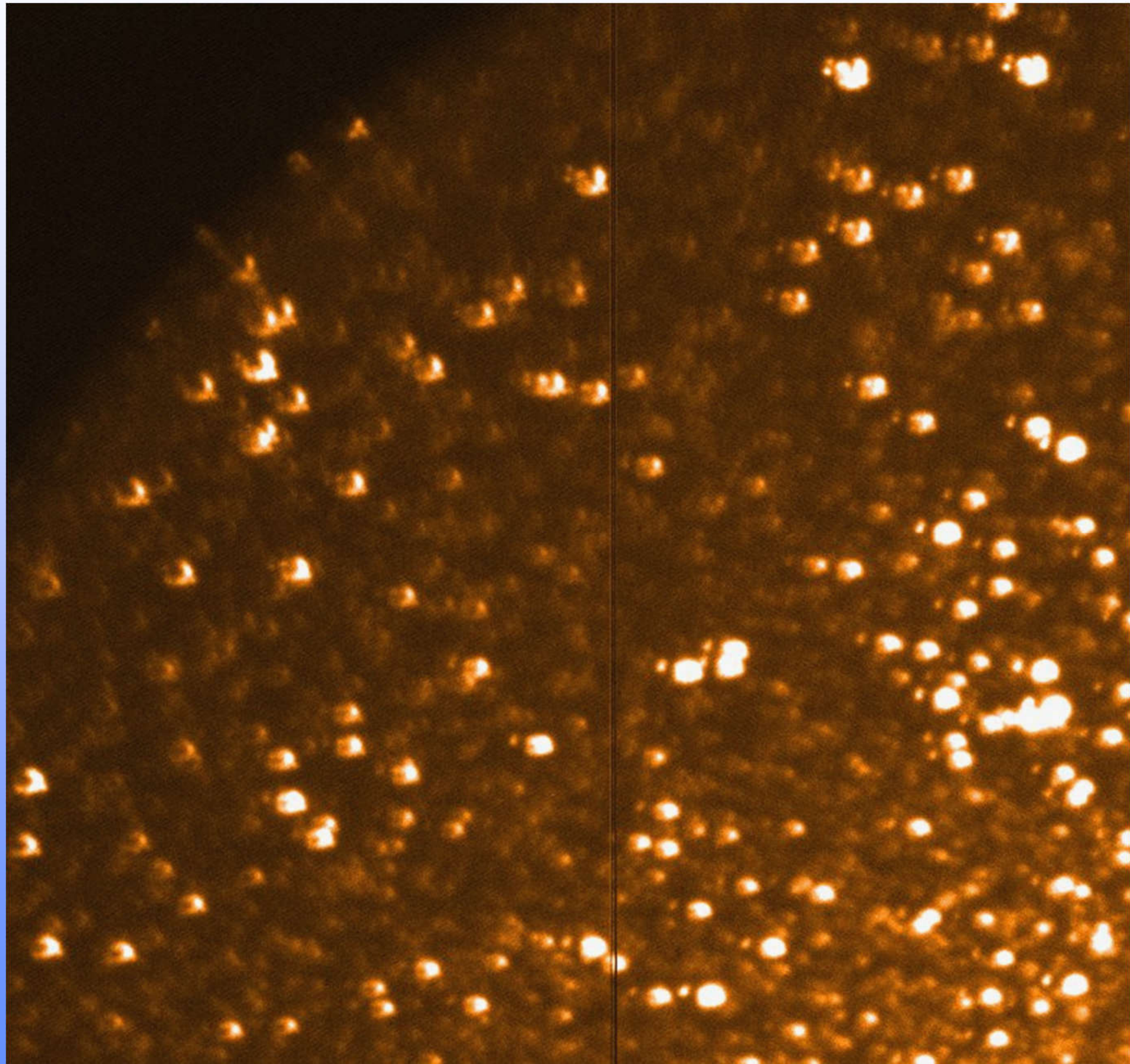
47 Tuc: S200511240007.fits: November 2005



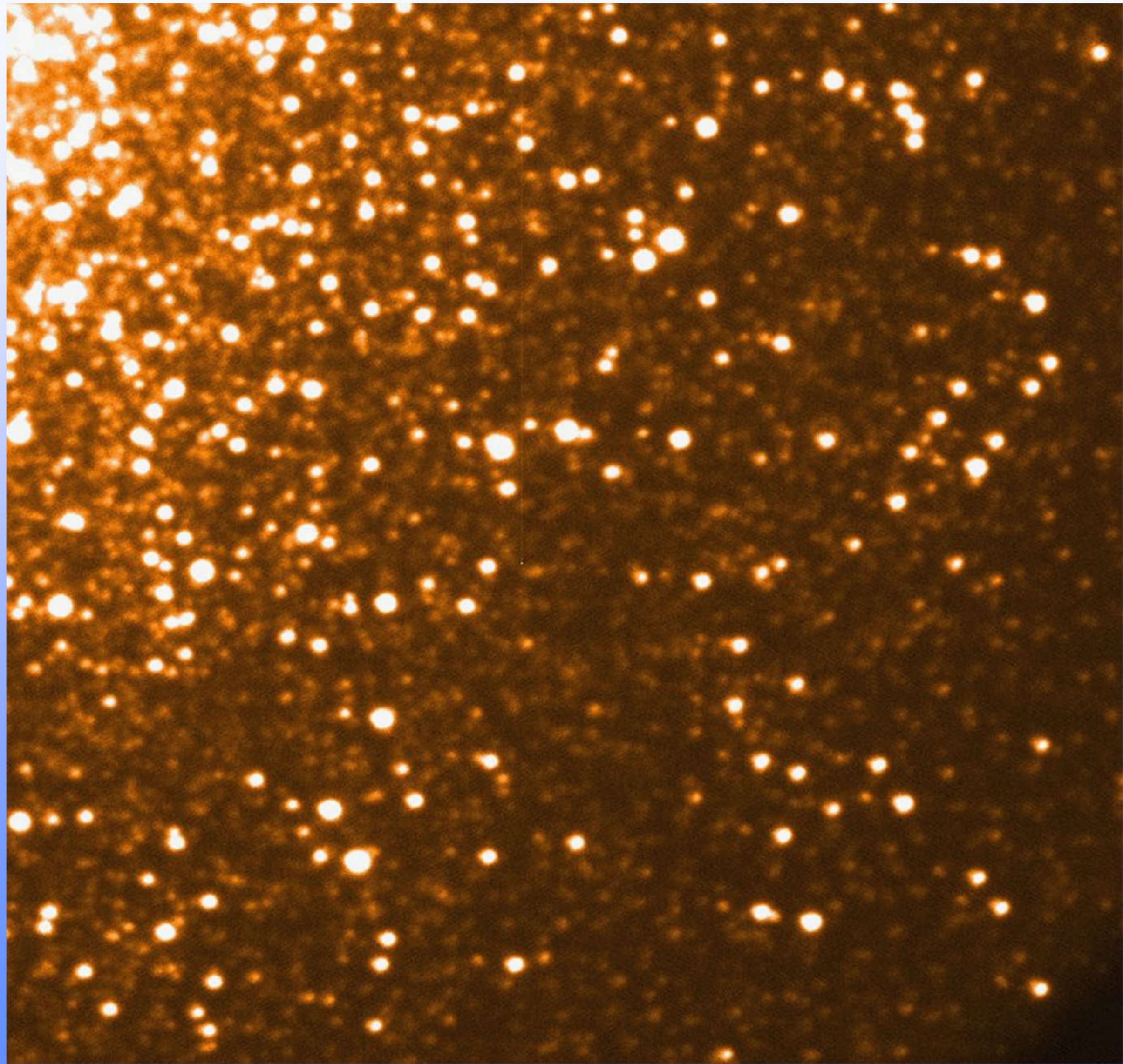
47 Tuc: S200511240007.fits: top right



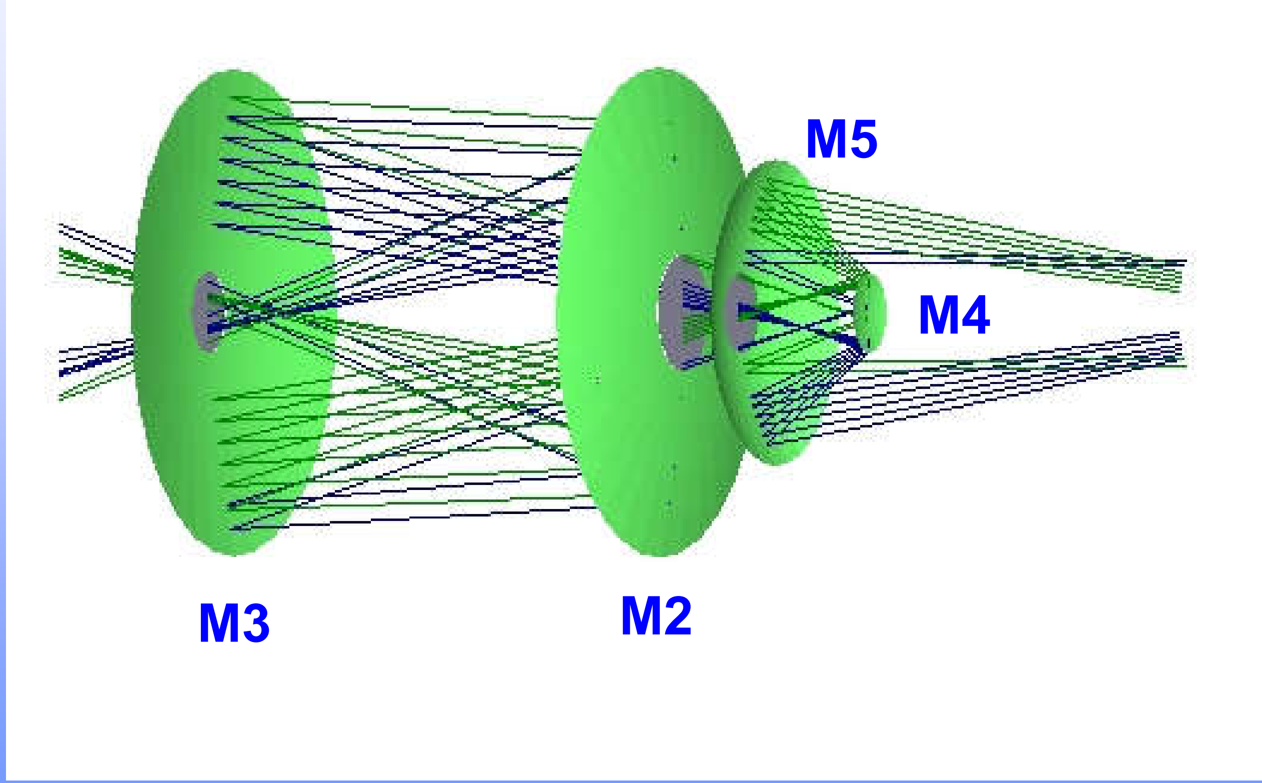
47 Tuc: S200511240007.fits: top left



47 Tuc: S200511240007.fits: bottom right



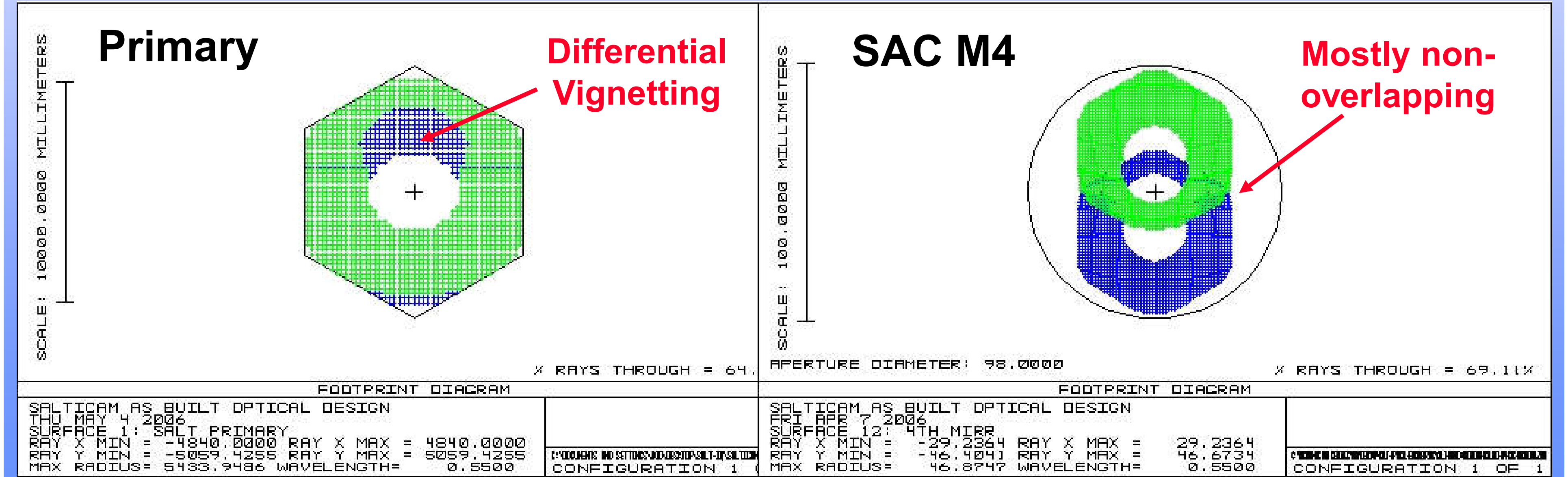
The Bad News: It's The SAC



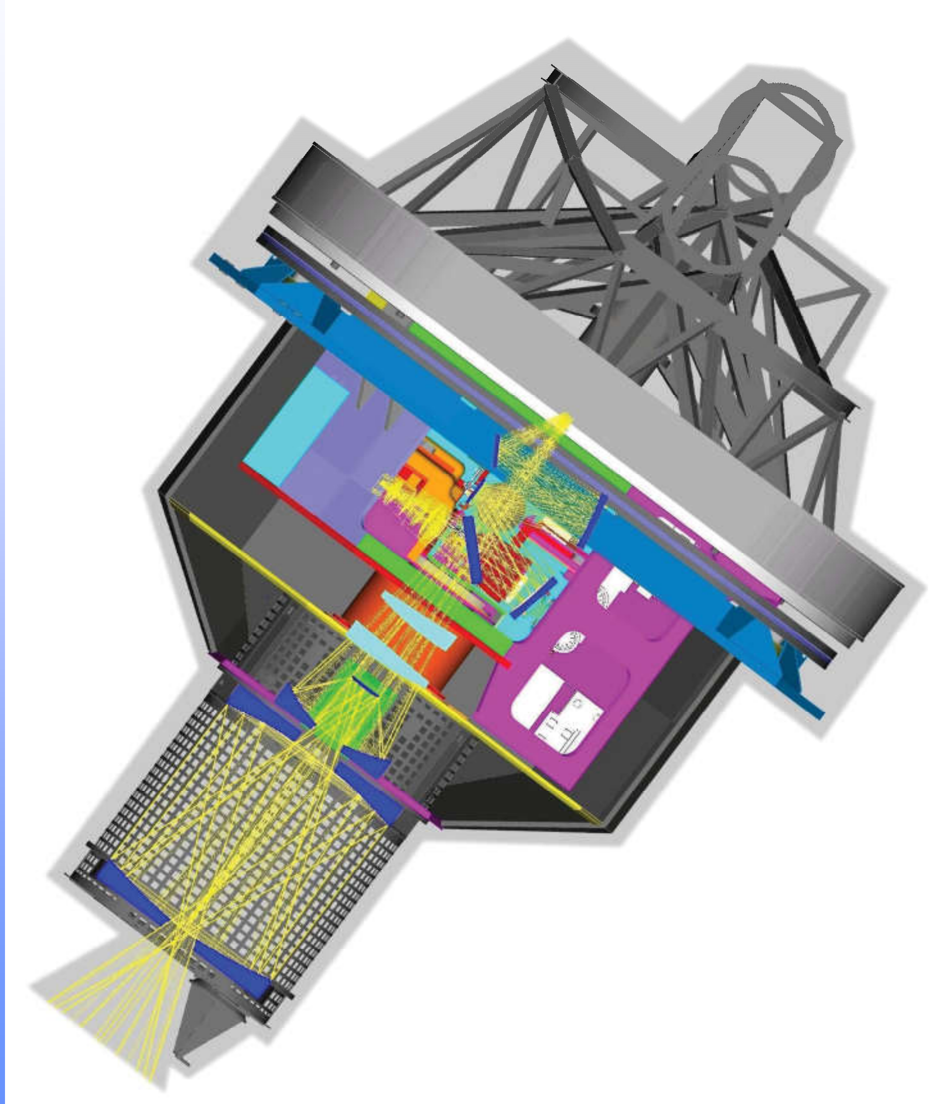
The SAC

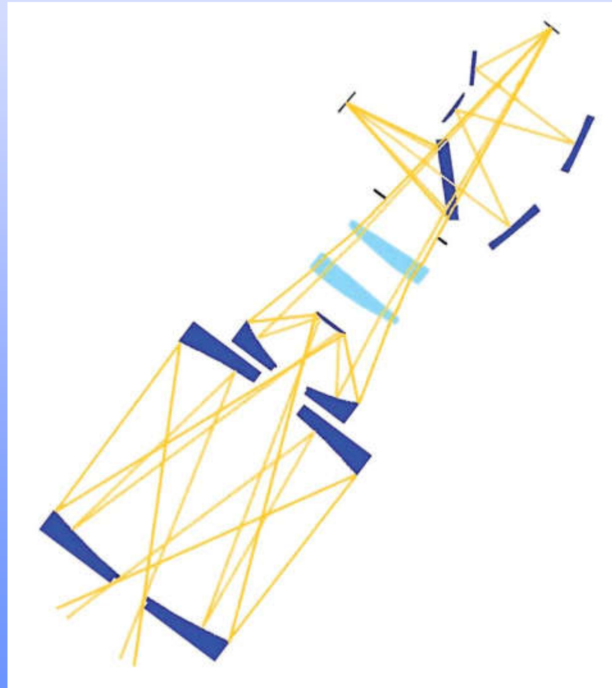
In fact, only SAC mirrors M4 and M5 can deliver focus and astigmatism varying over the field of view: M2 and M3 behave like the Primary: M3 is a pupil mirror and M2 nearly so. On M4/5, different field angles see different parts of the mirror:

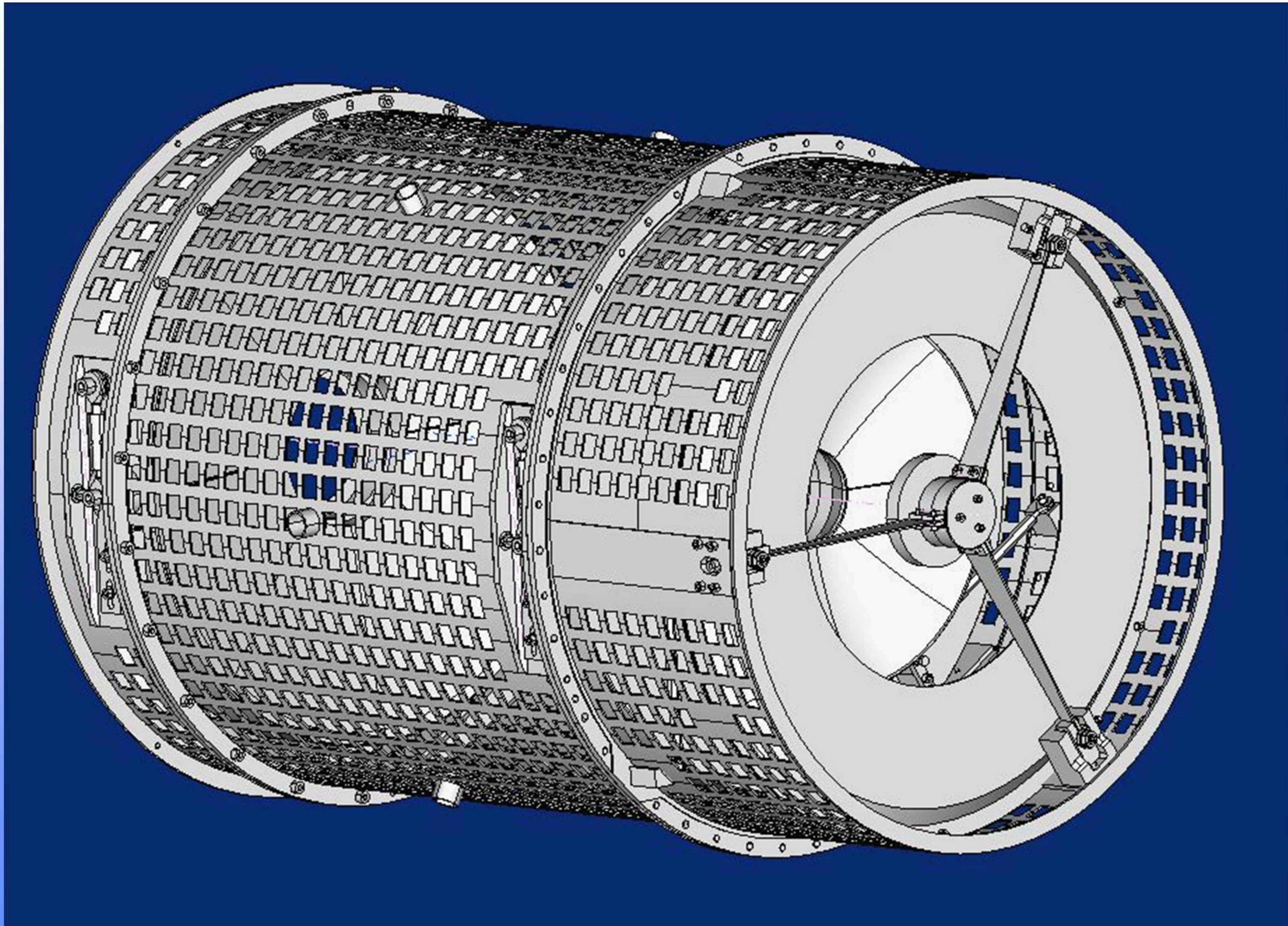
"Footprint" Of Light From Opposite Sides Of Science Field On M1/M4



Prime Focus Payload layout







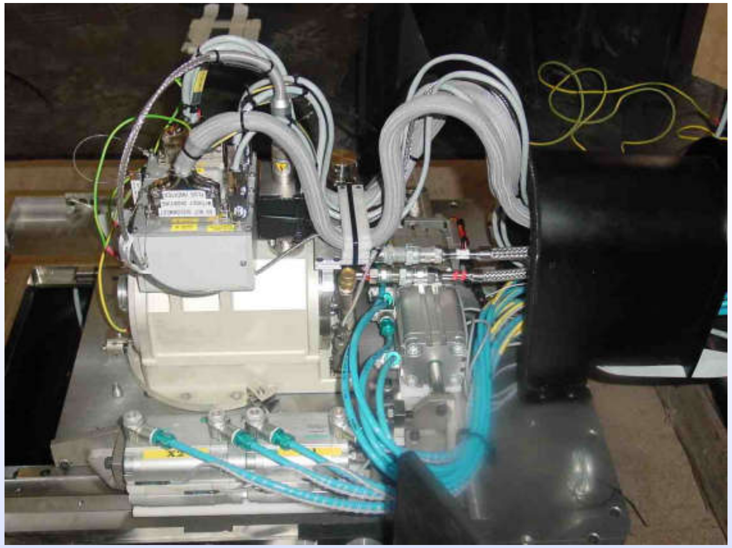
SALT INSTRUMENTS

1. SALTICAM

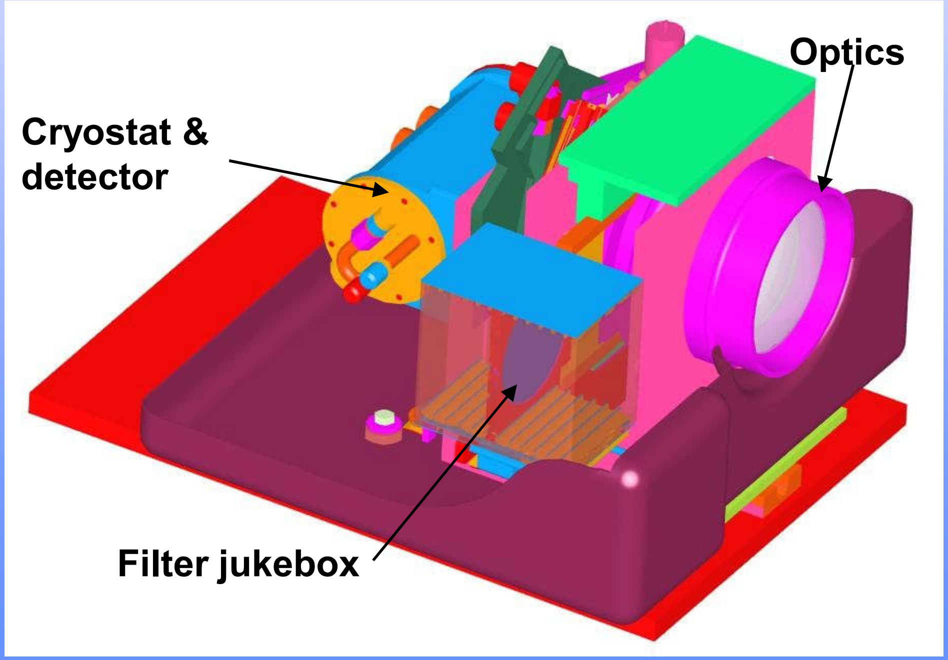
PI: Darragh O'Donoghue (SAAO)
An efficient CCD imager
(8 arcmin FOV).

.

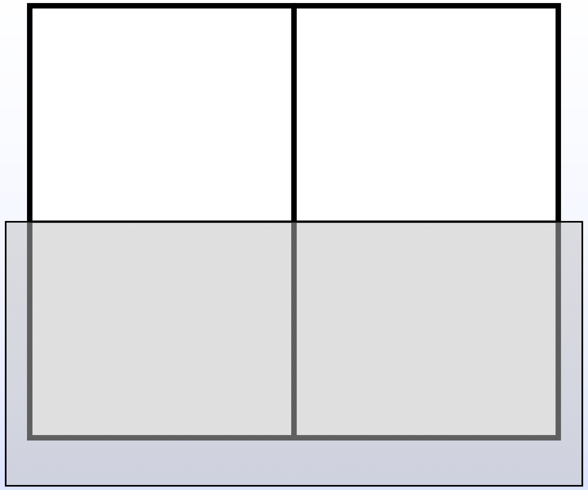
SALTICAM will enable unique science, particularly UV and fast photometry (~70-50 ms).



SALTICAM



SALTICAM: how do you make a CCD operate in "fast" mode?



Answer: use moveable frame-transfer mask

Full Frame Readout Mode (using shutter)

8 arcmin FoV:	12.3 sec (@3.3e read noise)
	4.6 sec (@5e)

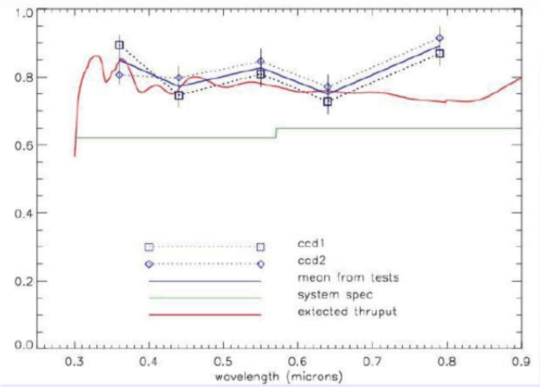
Frame Transfer Mode

Half of 8 arcmin circular FoV	6.3 sec (@3.3e)
	2.4 sec (@5e)

Fastest windowed photometry

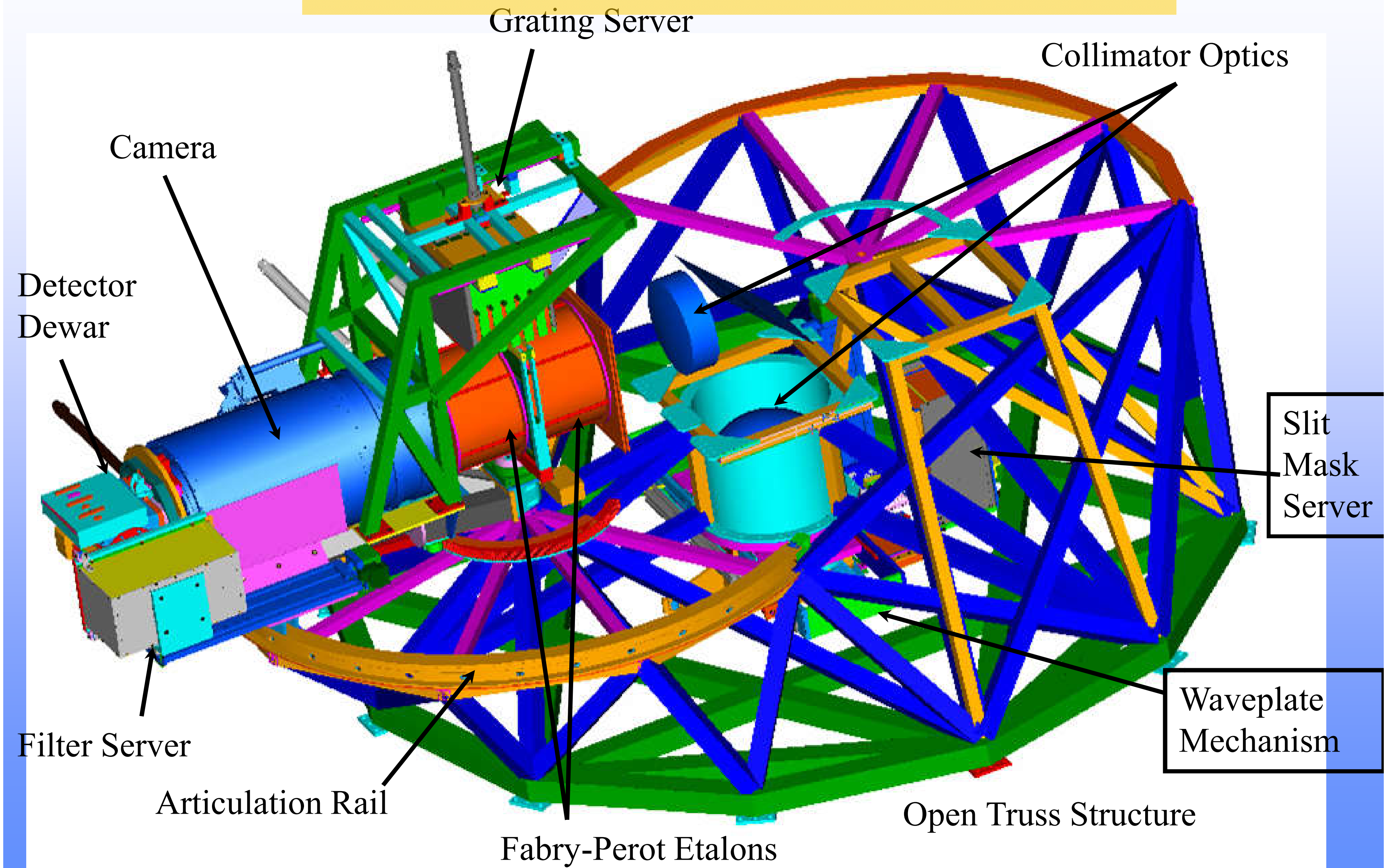
Slot mode	0.089 sec (@5 e)
Slot + windowed mode	0.058 sec

SALTICAM thruput tests (Petri Vaisanen)



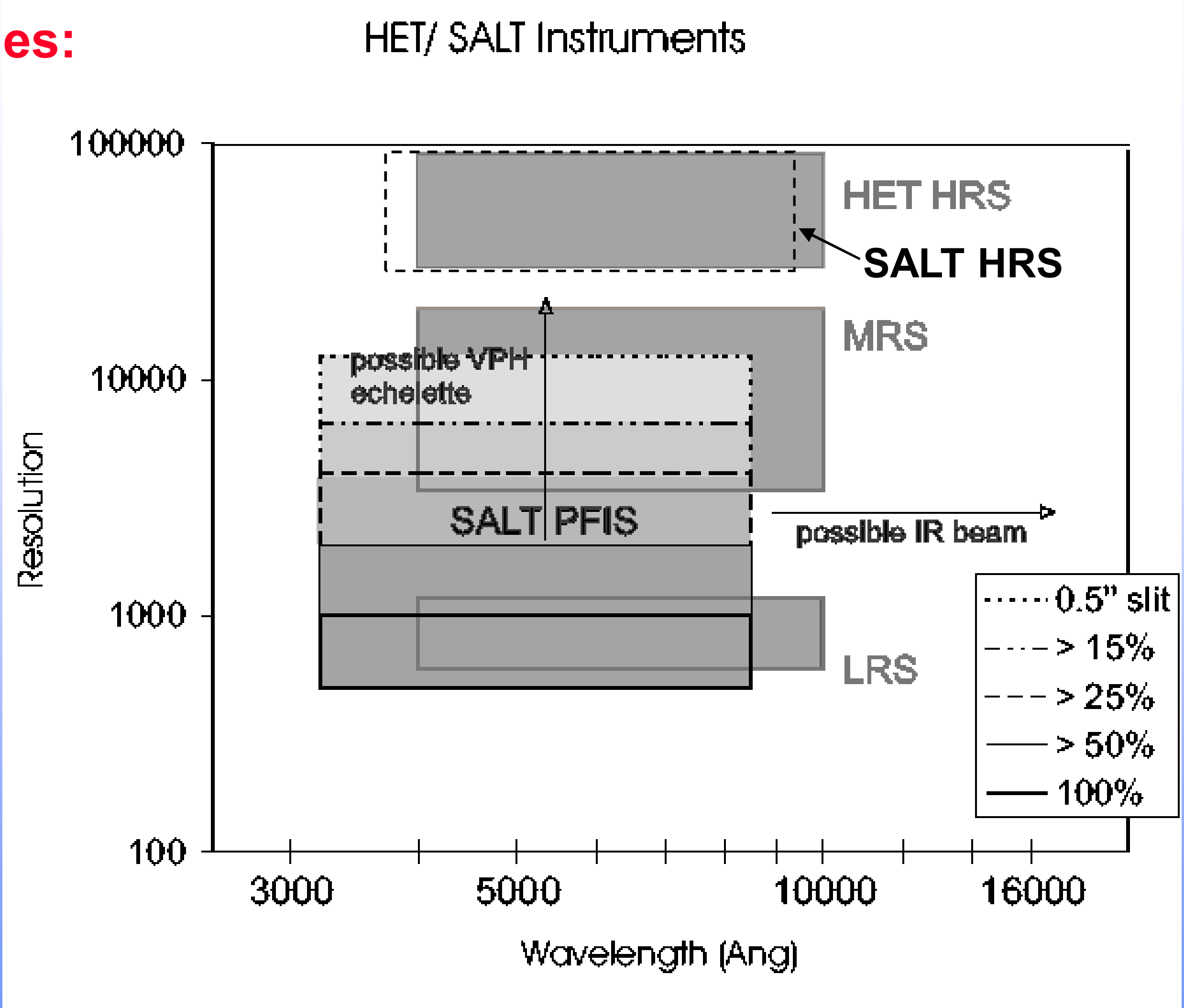
2. PFIS: Prime Focus Imaging Spectrograph (now renamed *Robert Stobie Spectrograph*)

PI: **Ken Nordsieck, University of Wisconsin-Madison**

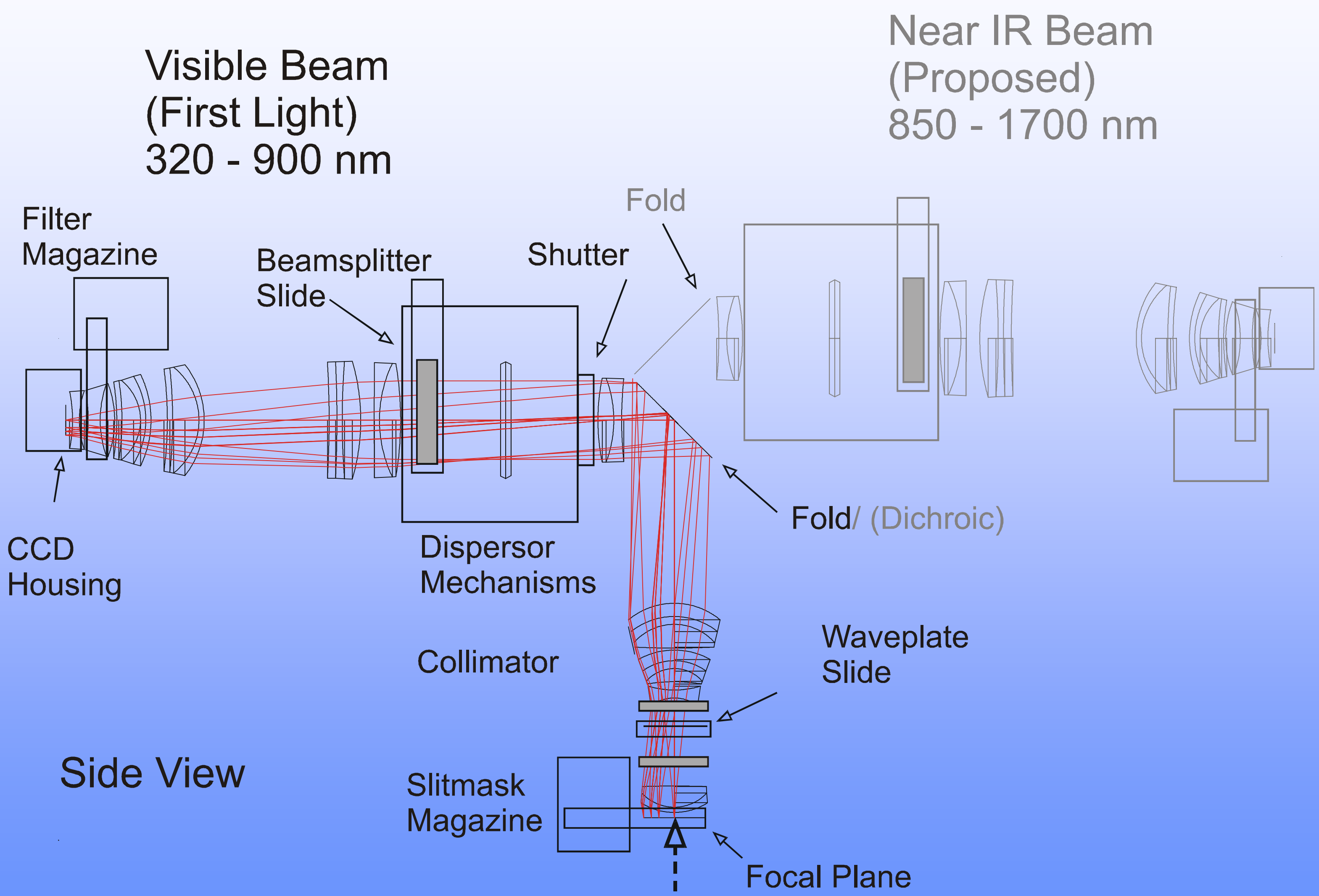


PFIS capabilities:

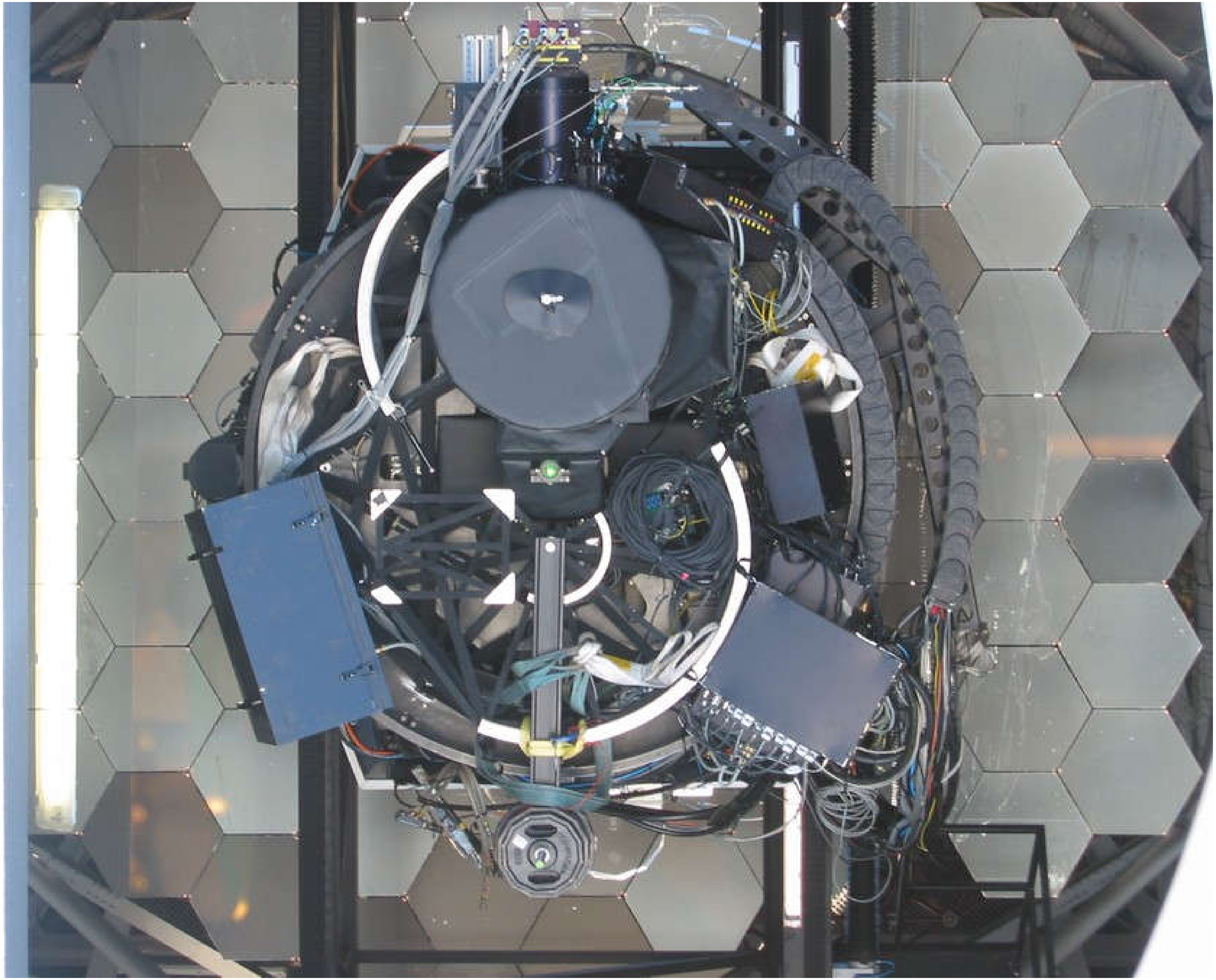
Will fulfill most of the major science goals of SALT, *as presently conceived.*

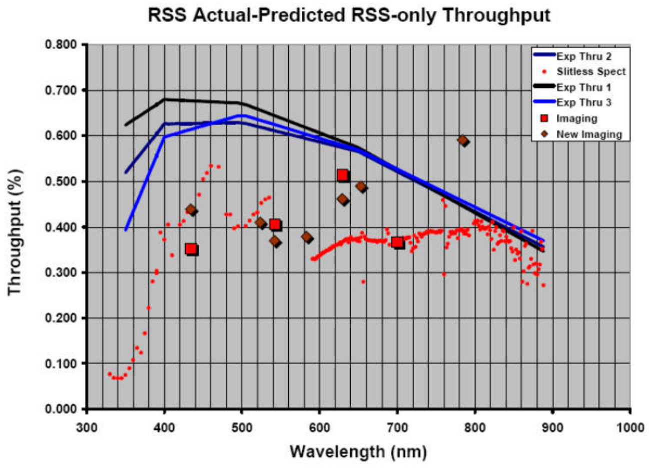


PFIS Layout:


Visible Beam
(First Light)
320 - 900 nm
Near IR Beam
(Proposed)
850 - 1700 nm
Filter
Magazine
Beamsplitter
Slide
Shutter
Fold
CCD
Housing
Dispersor
Mechanisms
Fold/ (Dichroic)
Collimator
Waveplate
Slide
Side View
Slitmask
Magazine
Focal Plane

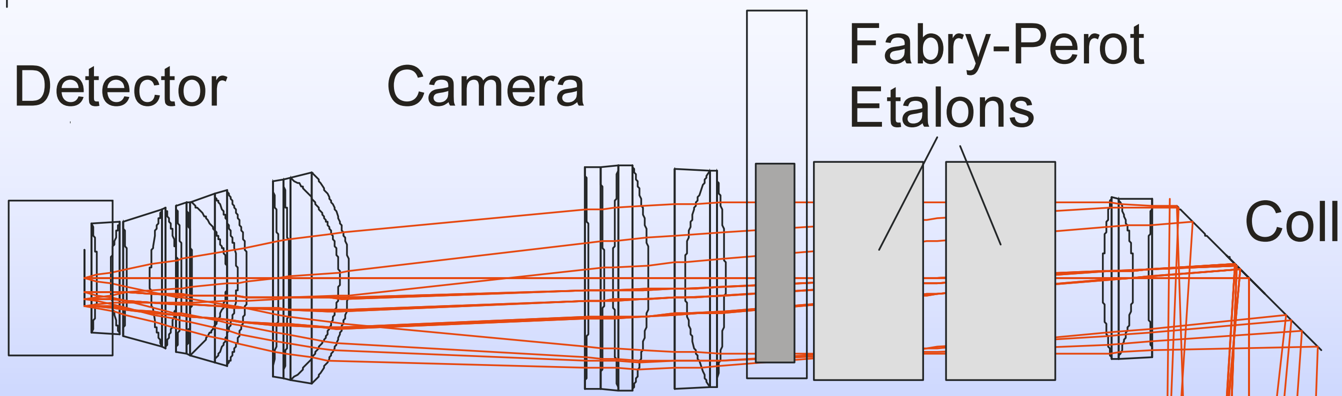

"University of Wisconsin -- Madison SAL PFIS webcam 2005-02-25 16:30:04 (USA Central Time)"

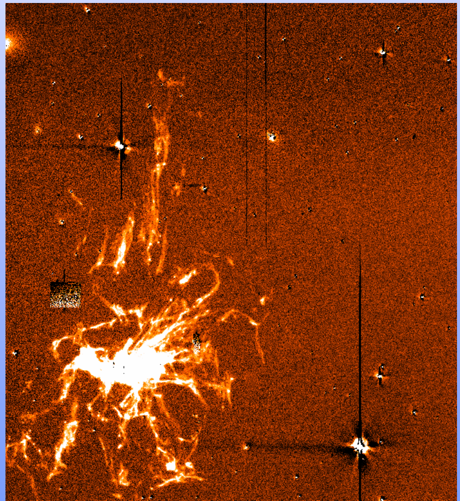




RSS Actual-Predicted RSS-only Throughput
Exp Thru 2
Slitless Spect
Exp Thru 1
Exp Thru 3
Imaging
New Imaging
Throughput (%)
Wavelength (nm)
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
300
400
500
600
700
800
900
1000

PFIS F-P Imaging Spectroscopy Mode





Perseus A in Hα

Perseus Cluster of Galaxies

RSS commissioning

Imaging

Work	*Description*	*Who*	*Sky*
Calibrations	Focus runs through all imaging filters using pinhole slitmask	SAOps	No

Spectroscopy (long slit and slitless)

Work	*Description*	*Who*	*Sky*
Fall arrester	Needs to be Installed	SAOps	No
	Mechanical testing	SAOps	No
	Electrical testing	SAOps	No
	Software testing	SAOps	No
Grating and Etalon interlock	Requires testing	RSS/SAOps	No
Slit mask mechanism	Needs a new design to be built	RSS/SAOps	No
	Installation	SAOps	No
	Mechanical testing	SAOps	No
	Electrical testing	SAOps	No
	Software implementation and testing	SAOps	No
Calibrations	Focus runs: For each grating and angles,	SAOps	No
	Throughput tests	SAOps	Yes

Linear and/or Circular Polarimetry (Imaging and spectroscopy)

Work	*Description*	*Who*	*Sky*
Slit mask mechanism	Same as in spectroscopy	RSS/SAOps	No
Beam splitter	Re-design	SAOps	No
	Installation	SAOps	No
	Mechanical testing	SAOps	No
	Electrical testing	SAOps	No
	Software testing	SAOps	No
	Alignment	SAOps	No
½ and ¼ waveplates	Mechanical testing	SAOps	No
	Electrical testing	SAOps	No
	Software implementation and testing	**RSS**/SAOps	No
Calibrations	Requires reliable telescope time	**RSS**/SAOps	Yes

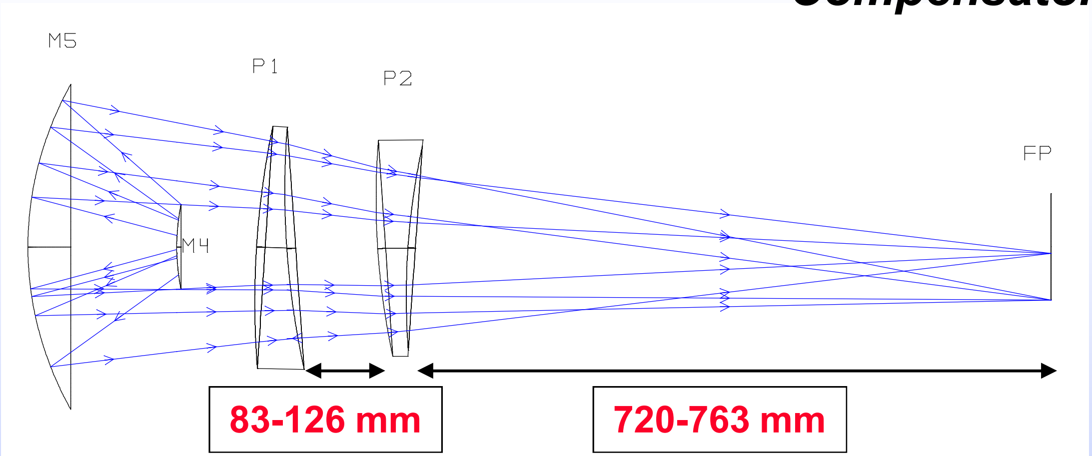
Multi-Object Spectroscopy

Work	*Description*	*Who*	*Sky*
Slit mask mechanism	Same work as in Spectroscopy	RSS/SAOps	No
Calibrations	Software implementation of the MOS acquisition procedure.	**RSS**	Yes
	Requires good telescope image quality and then calibration of SALT FOV to slit mask cutter	SAOps	Yes

Fabry-Perot

Work	*Description*	*Who*	*Sky*
Etalons	Installation	**RSS**	No
	Mechanical testing	**RSS**	No
	Electrical testing	**RSS**	No
	Software implementation and testing	**RSS**	No
Calibrations	Requires understanding and removal of "ghost" images, and good image quality	**RSS**	Yes

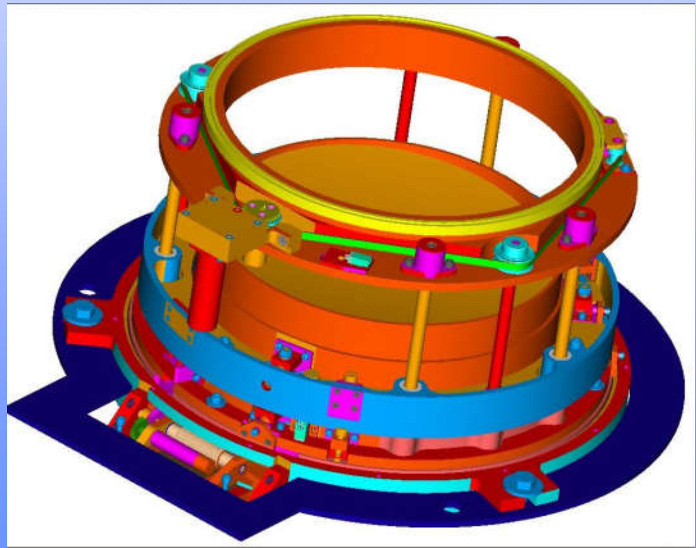
Facility Instruments:
Atmospheric Dispersion Compensator



Corrects dispersion
- **over 320-1700 nm**
- **amounting to 3.5 arcsec**
- **zenith distance 31-43º**
- **residual <0.15 arcsec in 320 – 900nm range**

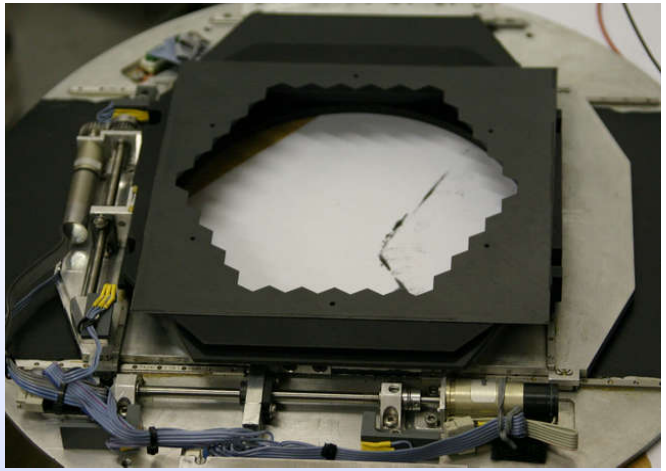
Uses fused silica translating prisms (280 mm diameter)

Payload subsystems designed in-house (SALT/SAAO), prisms from *Optical Surfaces,* and mechanism manufactured locally.

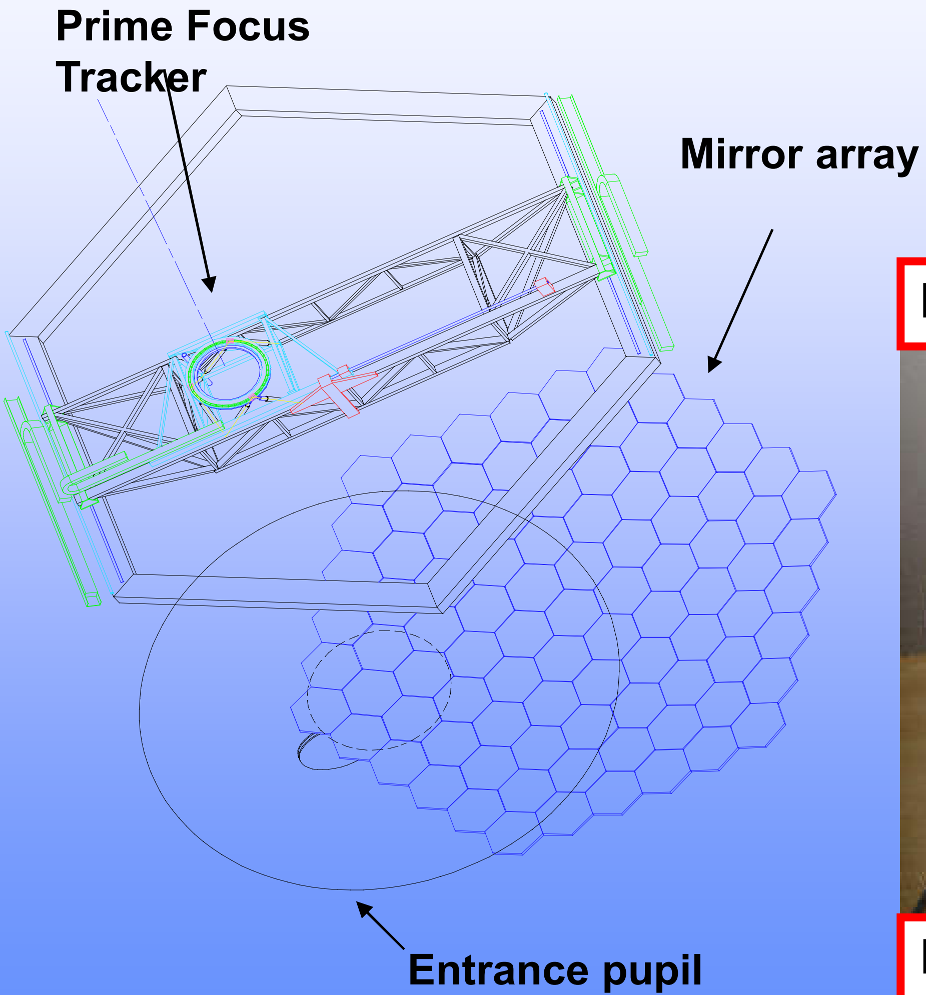


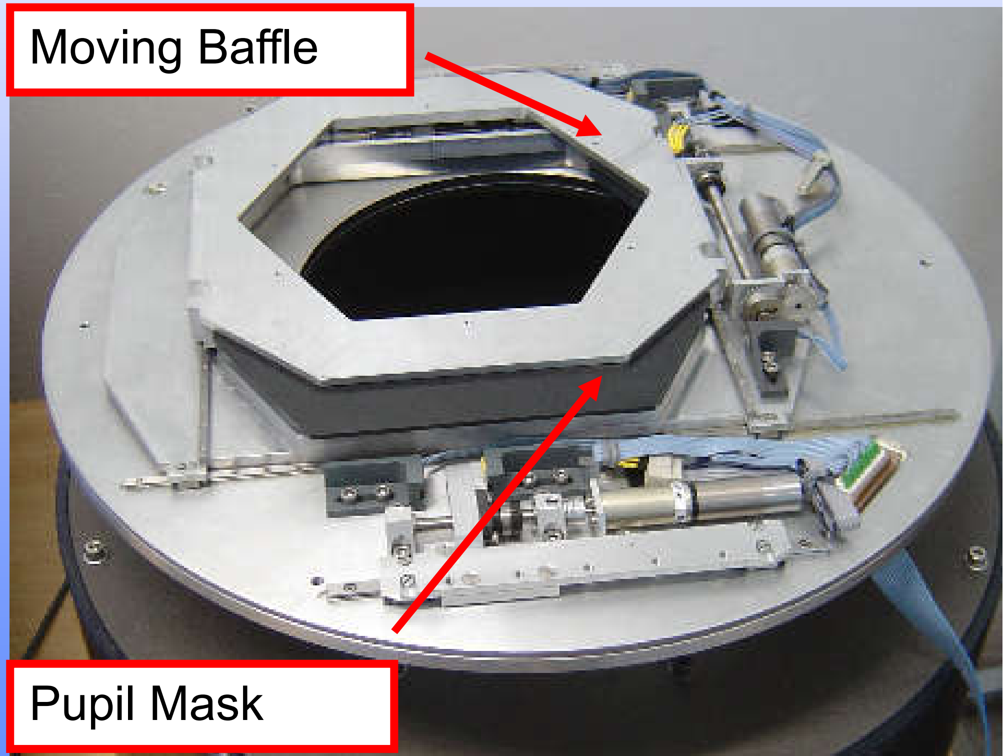
ADC mechanism design

Facility Instruments:



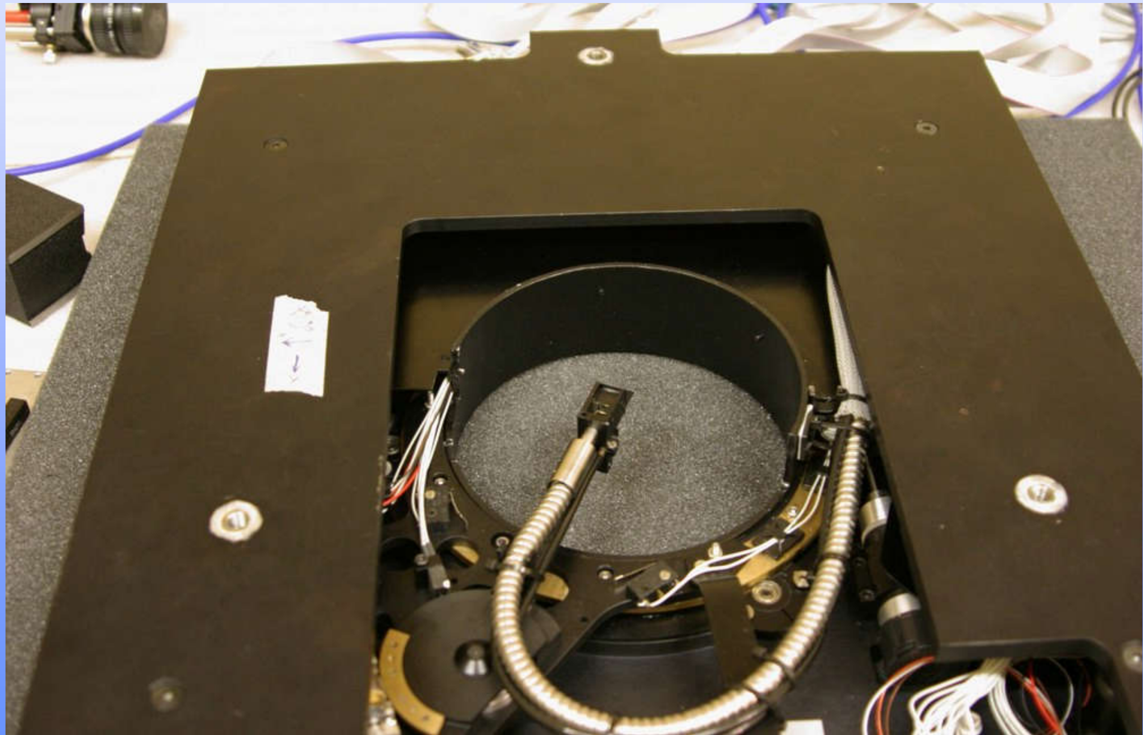
Moving baffle at exit pupil cuts out light *not* coming directly from primary mirror segments

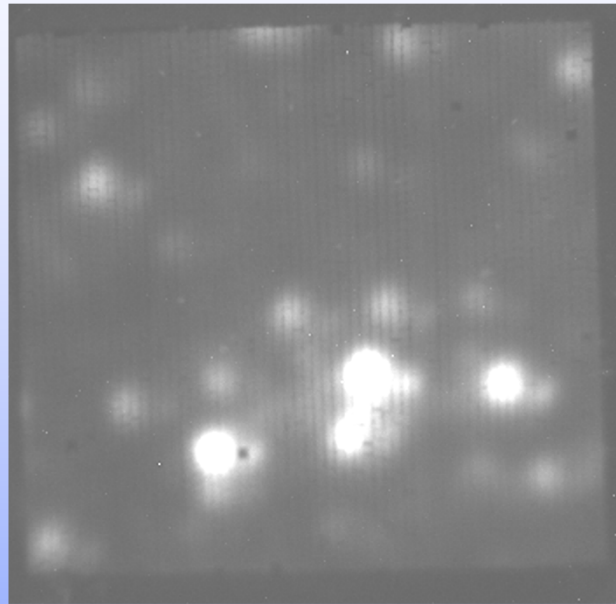




Autoguiding & focussing

- Uses image fibre bundles on a ϕ-θ stage
- 50% in focus, 25% inside/outside focus
- Guide to V = 19





Press Release: August 16, 2006!

First science with SALT: peering at the accreting polar caps of the eclipsing polar SDSS J015543.40+002807.2

Darragh O'Donoghue & SALTICAM Team

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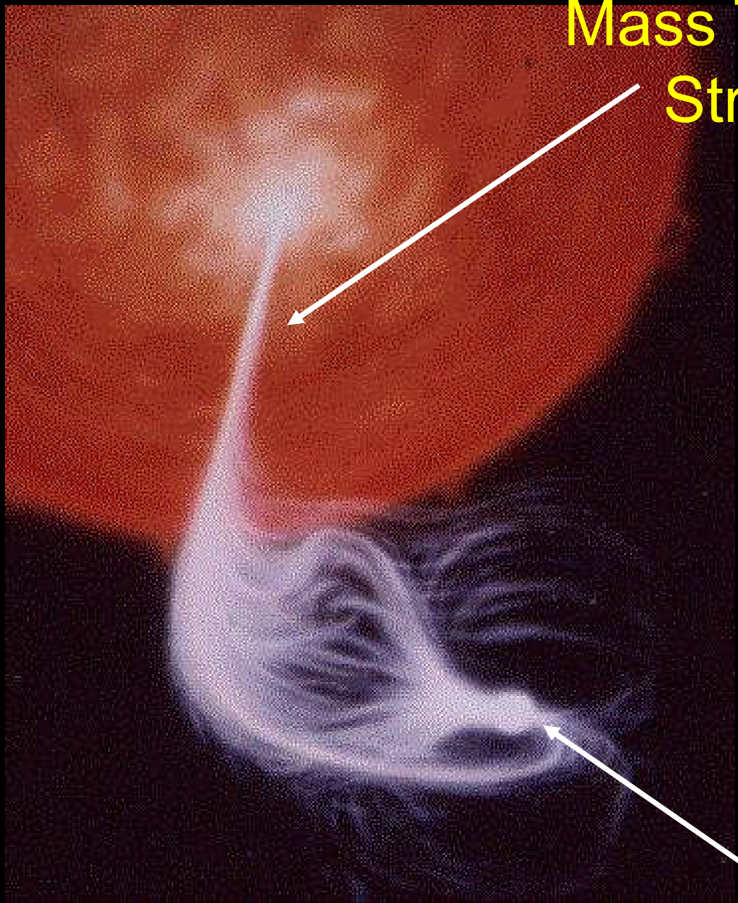
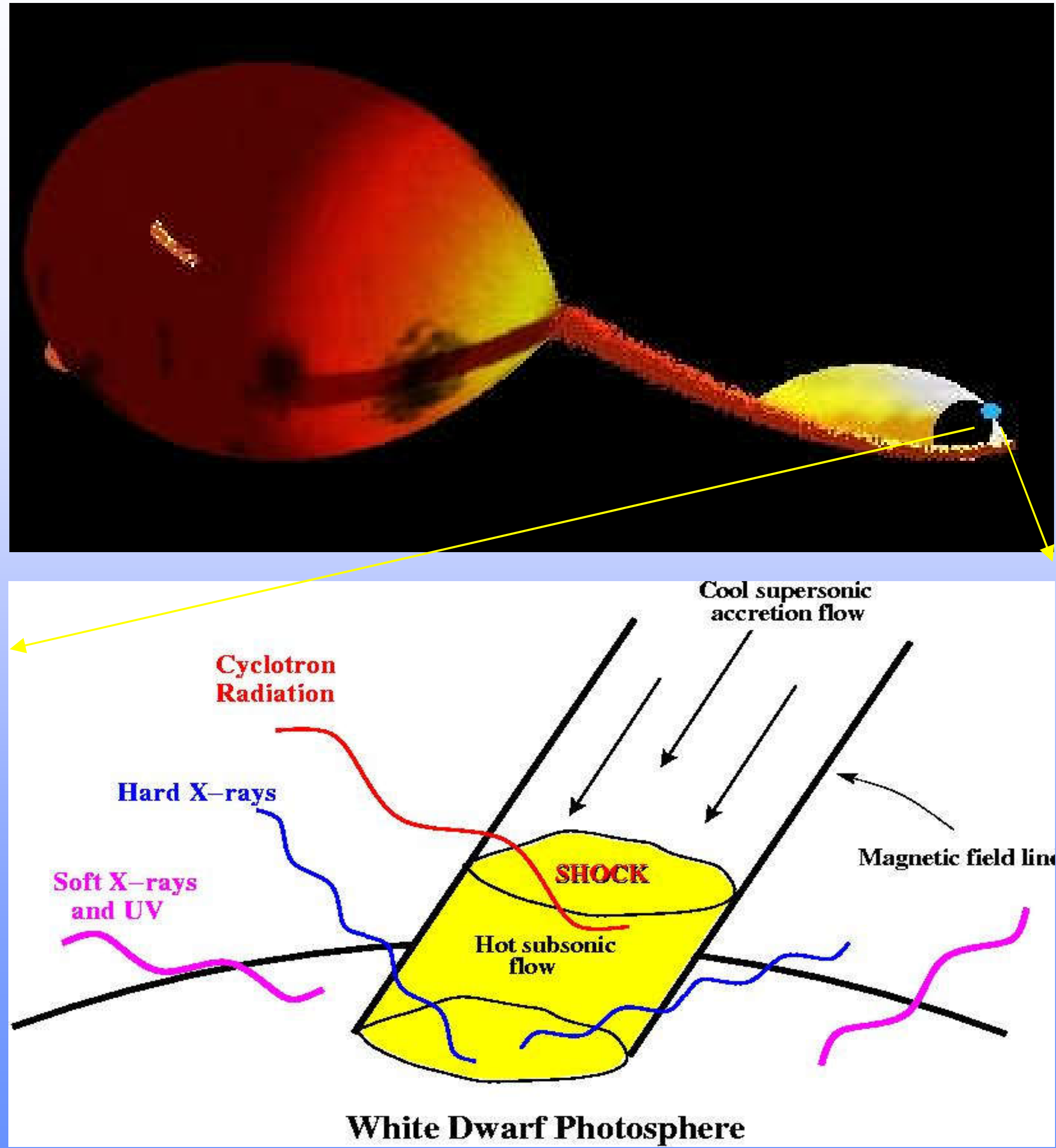
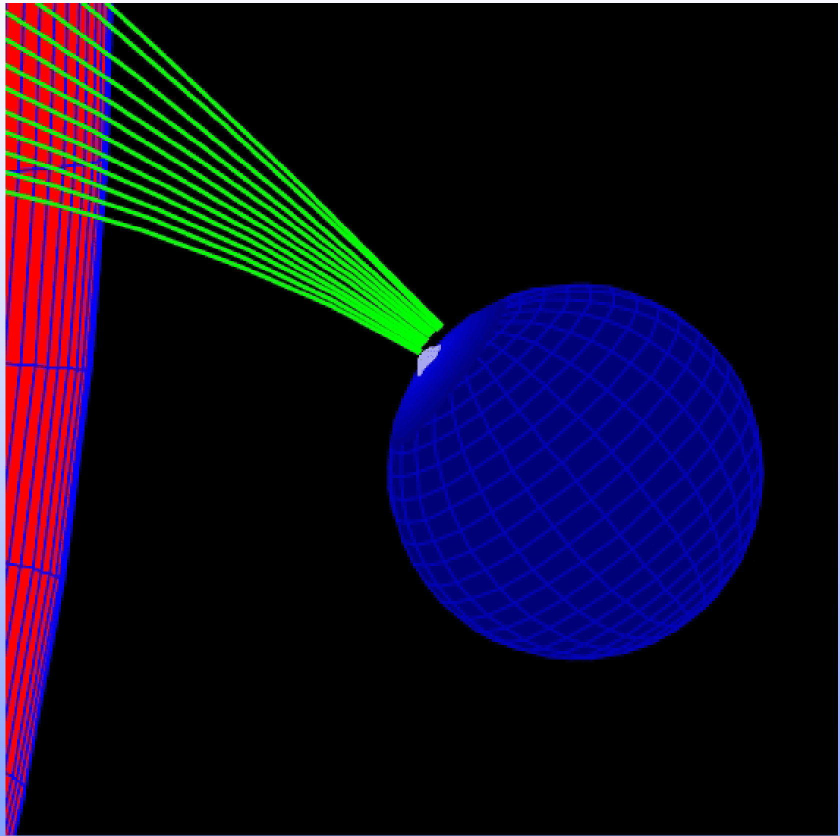
Eclipsing CV identified by SDSS   Szkody et al 2002

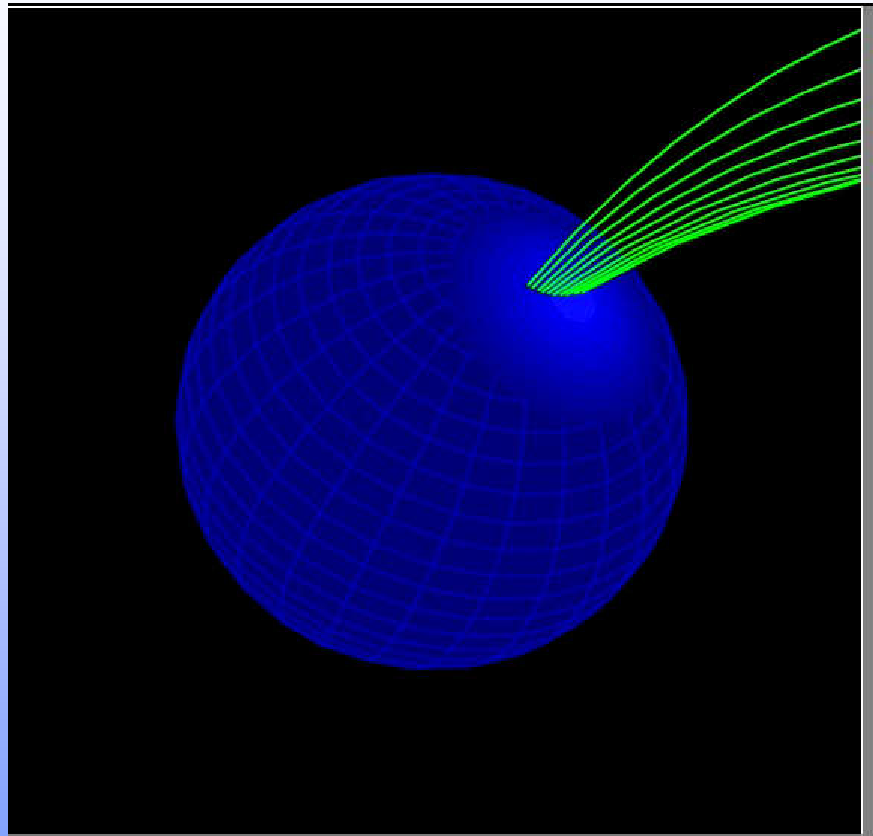
Polars (Magnetic CVs)



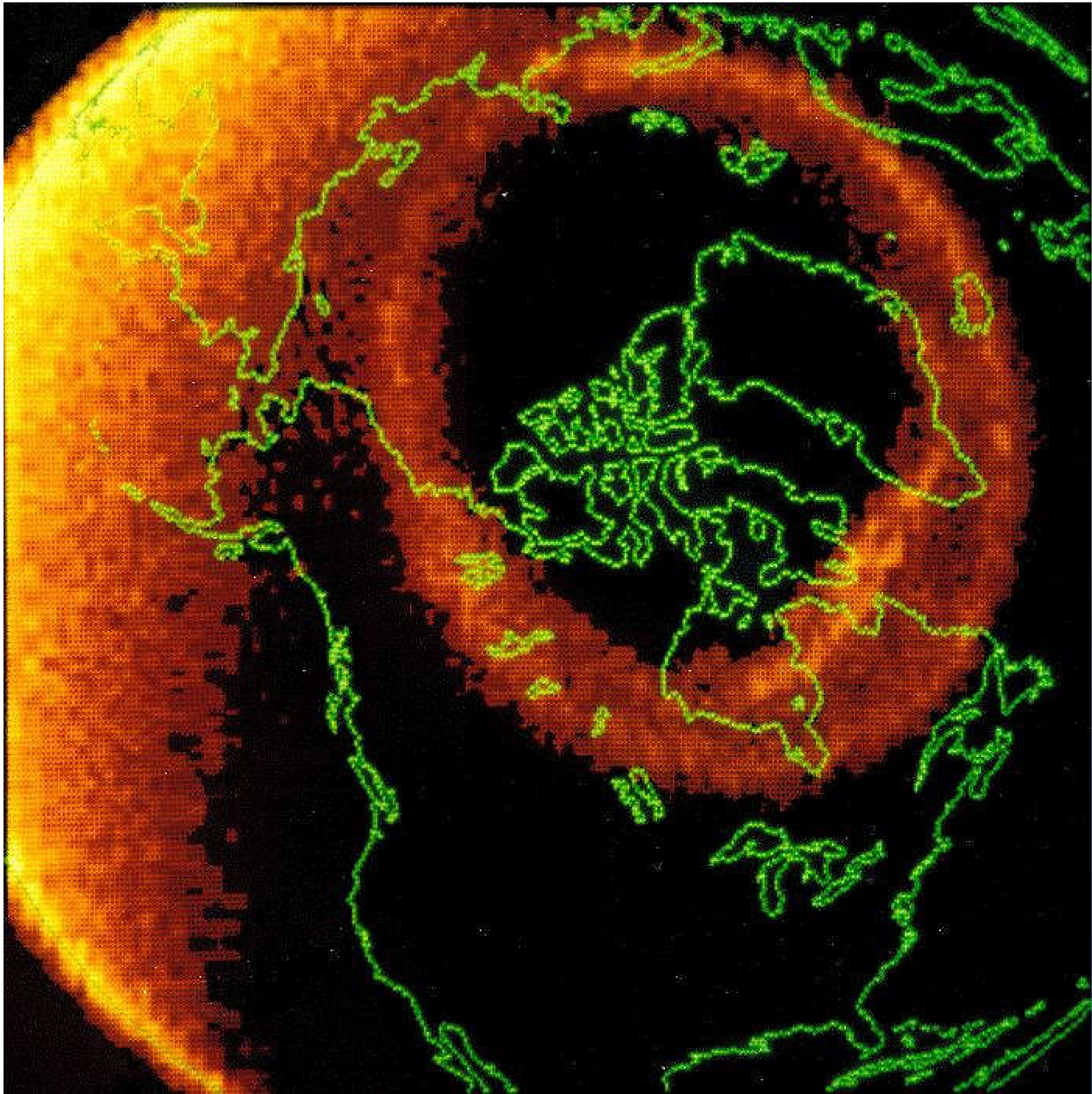
- Strongly magnetic white dwarf inhibits accretion disc formation
- Instead, magnetic field channels accretion directly to magnetic poles of white dwarf
- White dwarf magnetic field is huge: 10-200 Megagauss


Cool supersonic
accretion flow
Cyclotron
Radiation
Hard X–rays
Magnetic field lin
SHOCK
Soft X–rays
and UV
Hot subsonic
flow
White Dwarf Photosphere

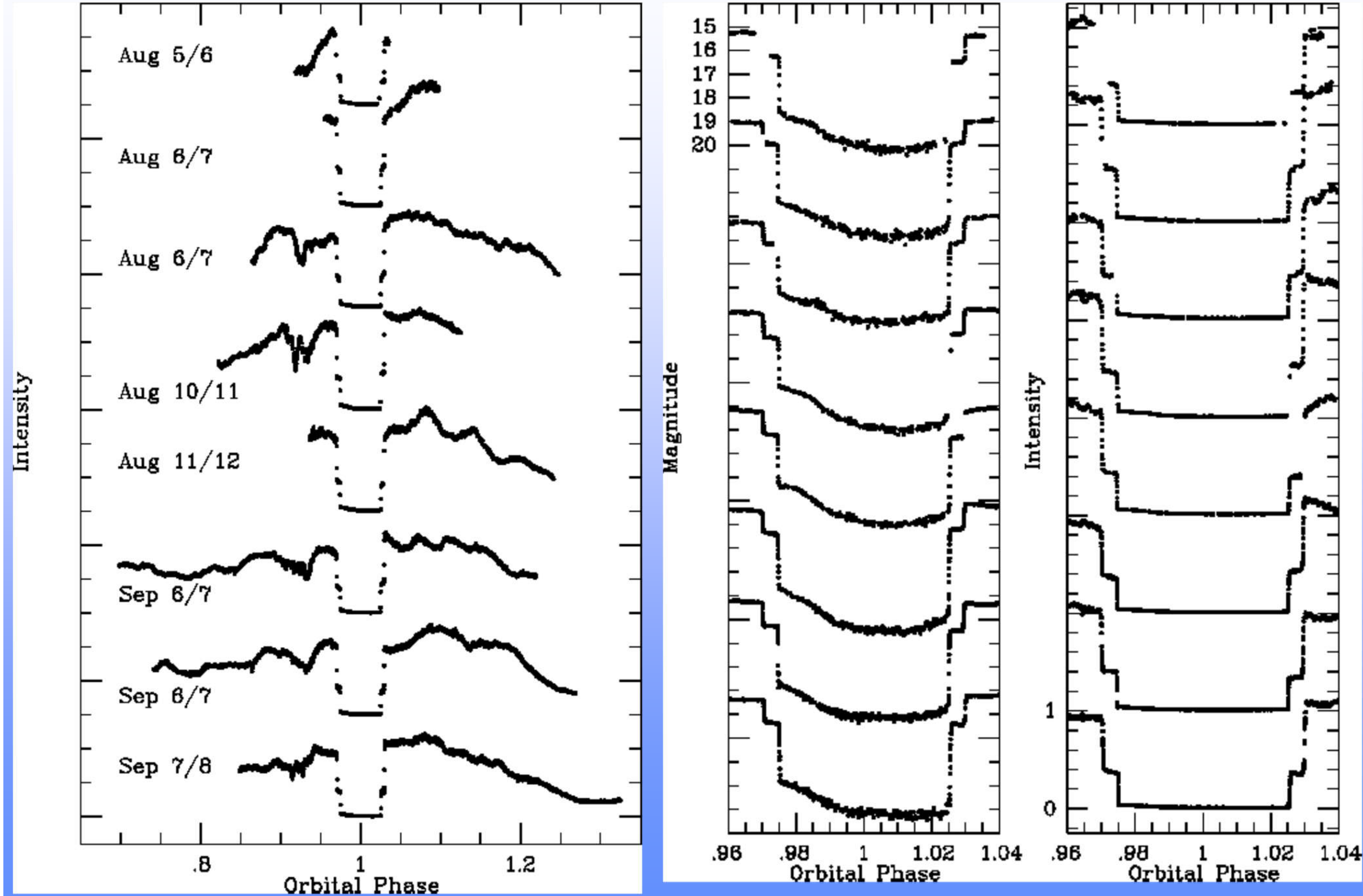


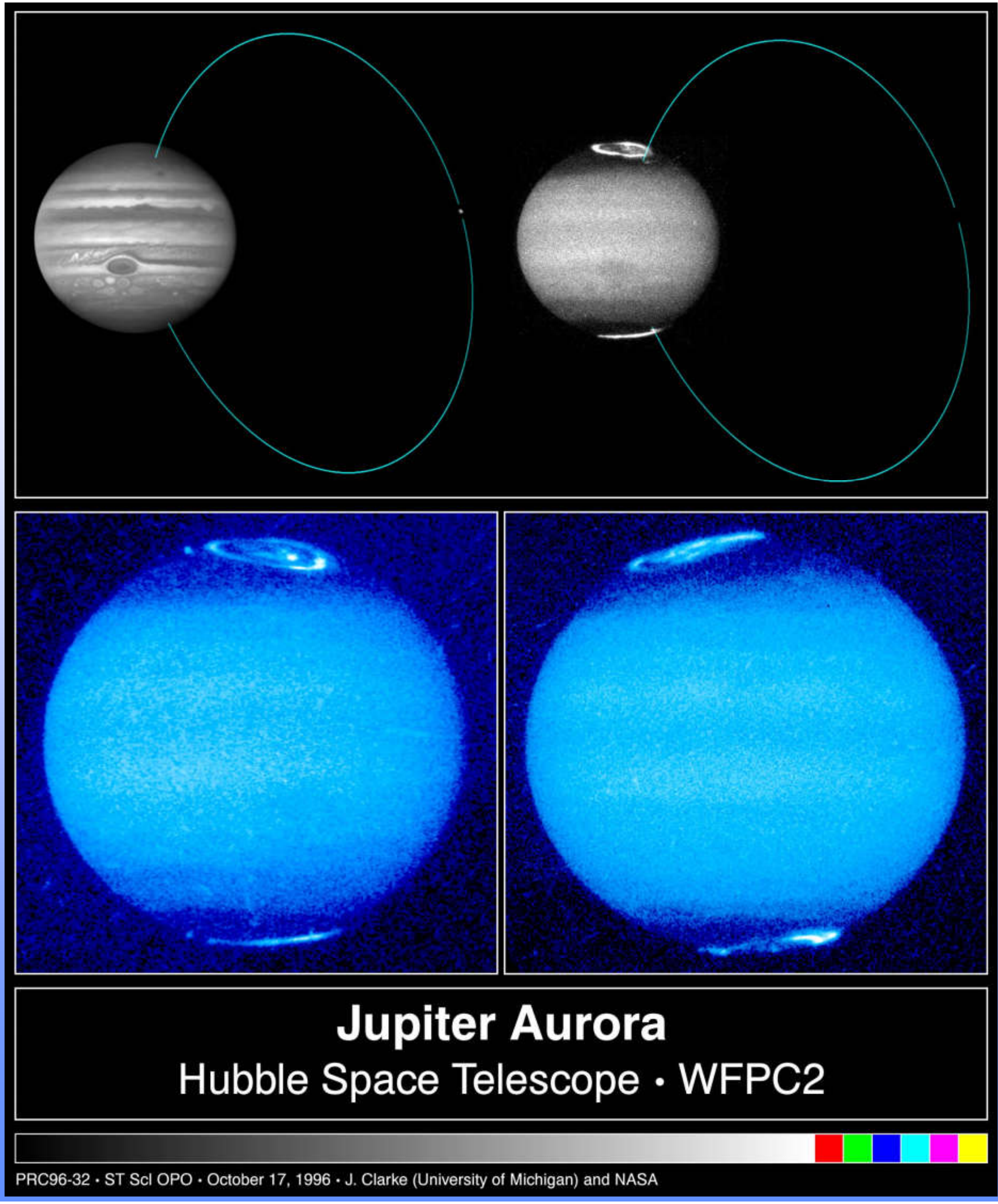


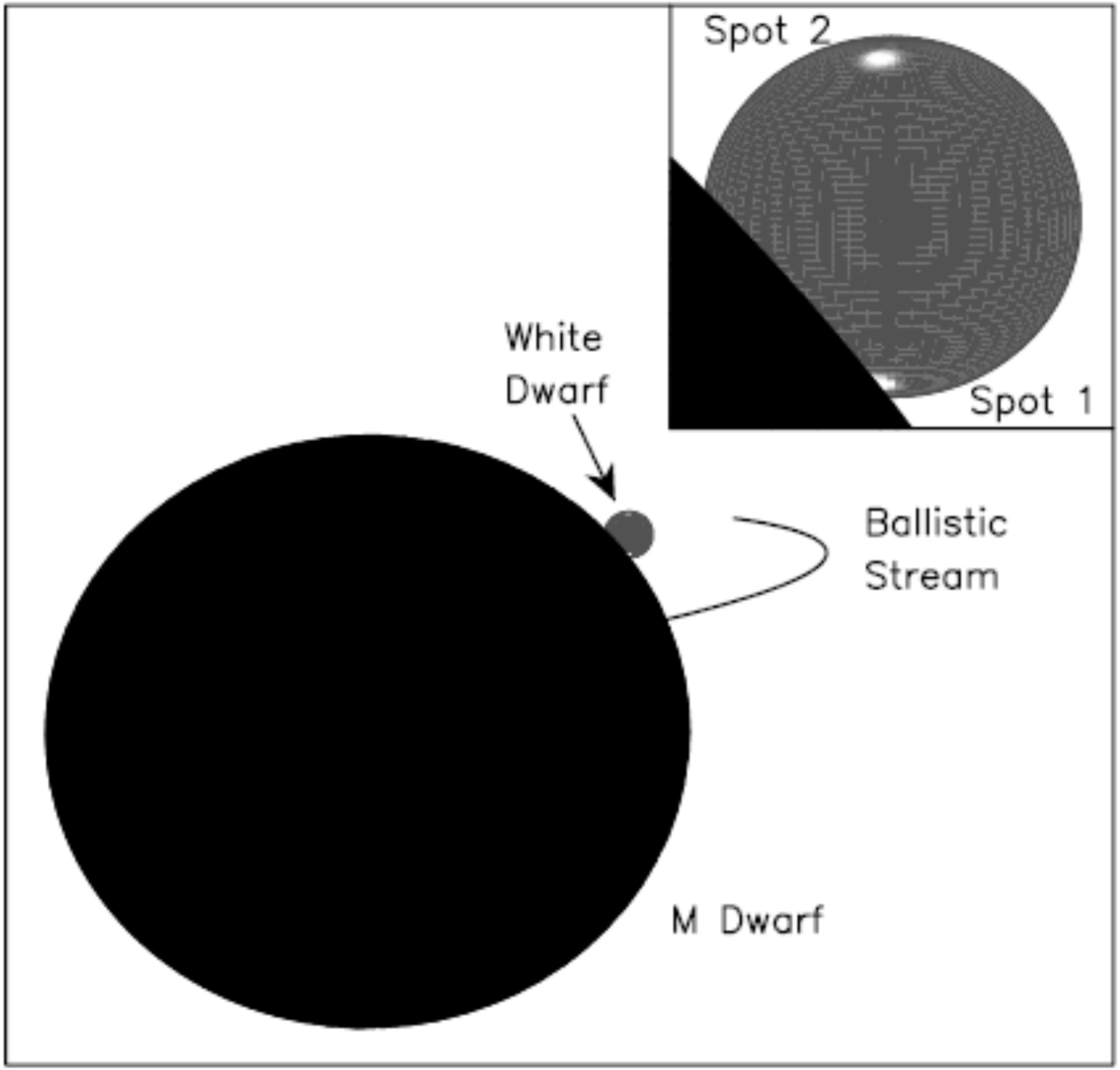
Eclipsing systems can be used to derive dimensions, intensity distributions, energy densities.
Need high t resolution as accreting regions eclipsed in `1-6s!

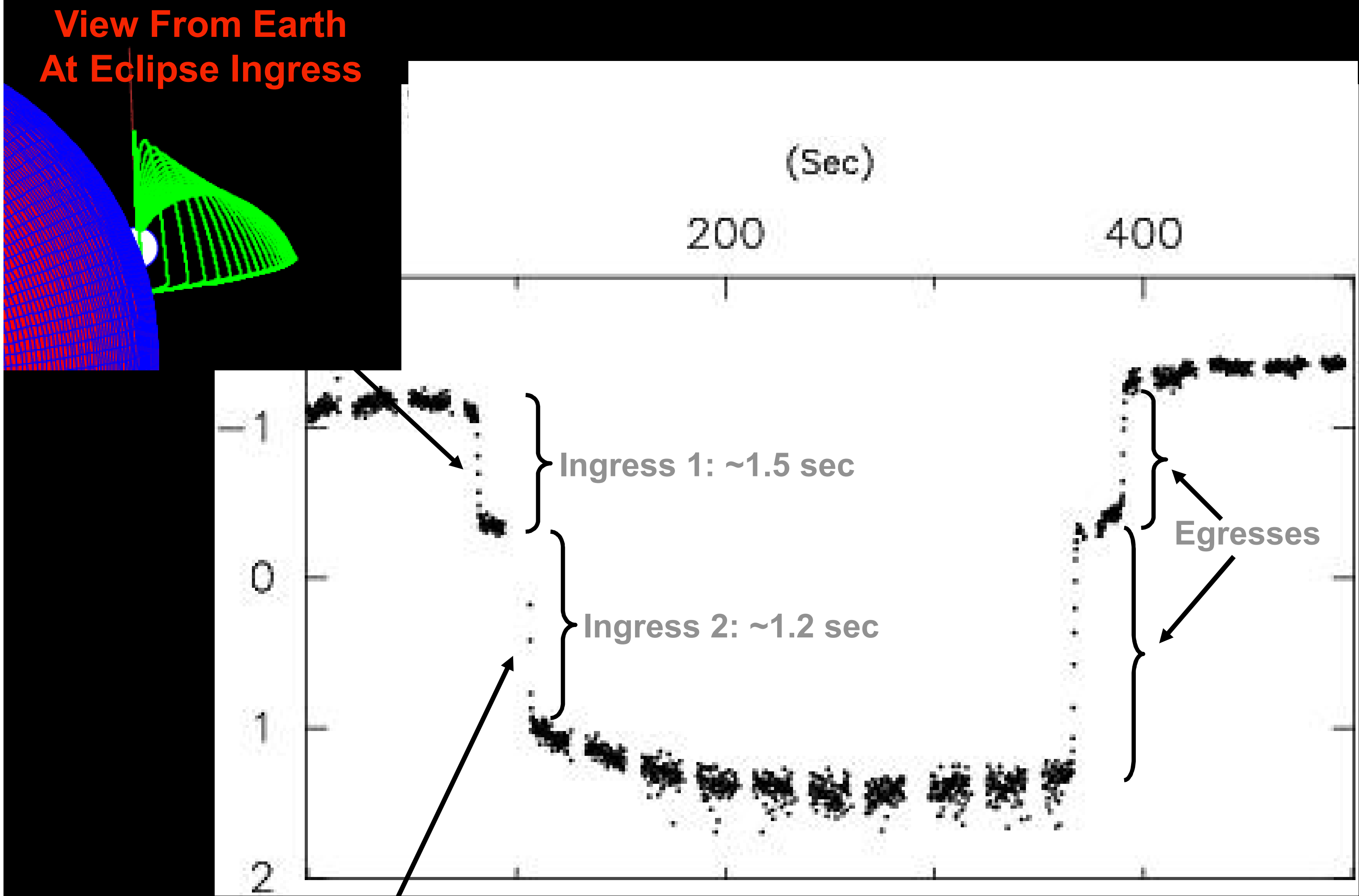


Eclipse curves of SDSS J015543.30+002807.2



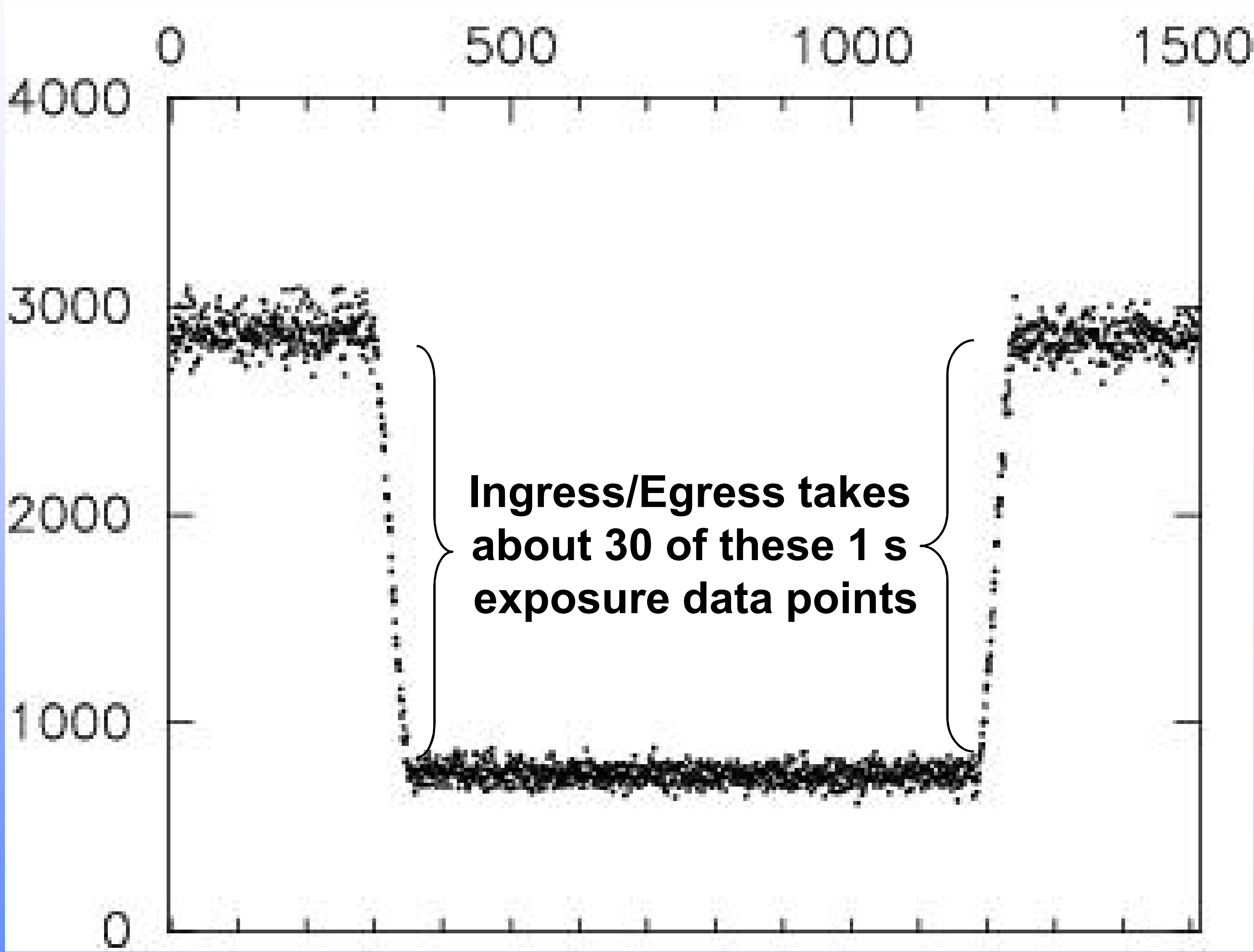

Jupiter Aurora
Hubble Space Telescope • WFPC2
PRC96-32 • ST ScI OPO • October 17, 1996 • J. Clarke (University of Michigan) and NASA


Spot 2
White
Dwarf
Spot 1
Ballistic
Stream
M Dwarf



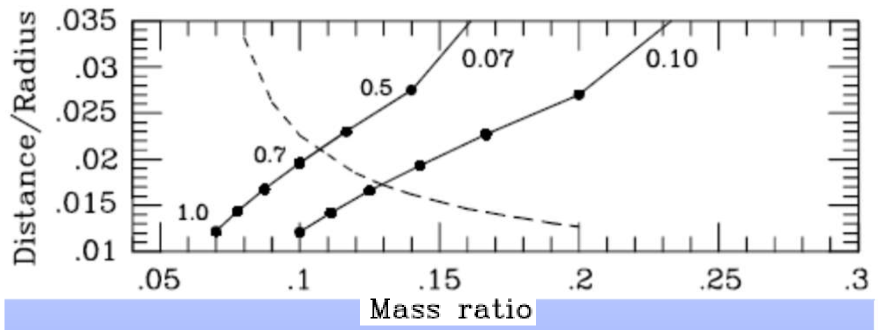
Each point 0.2 sec exposure

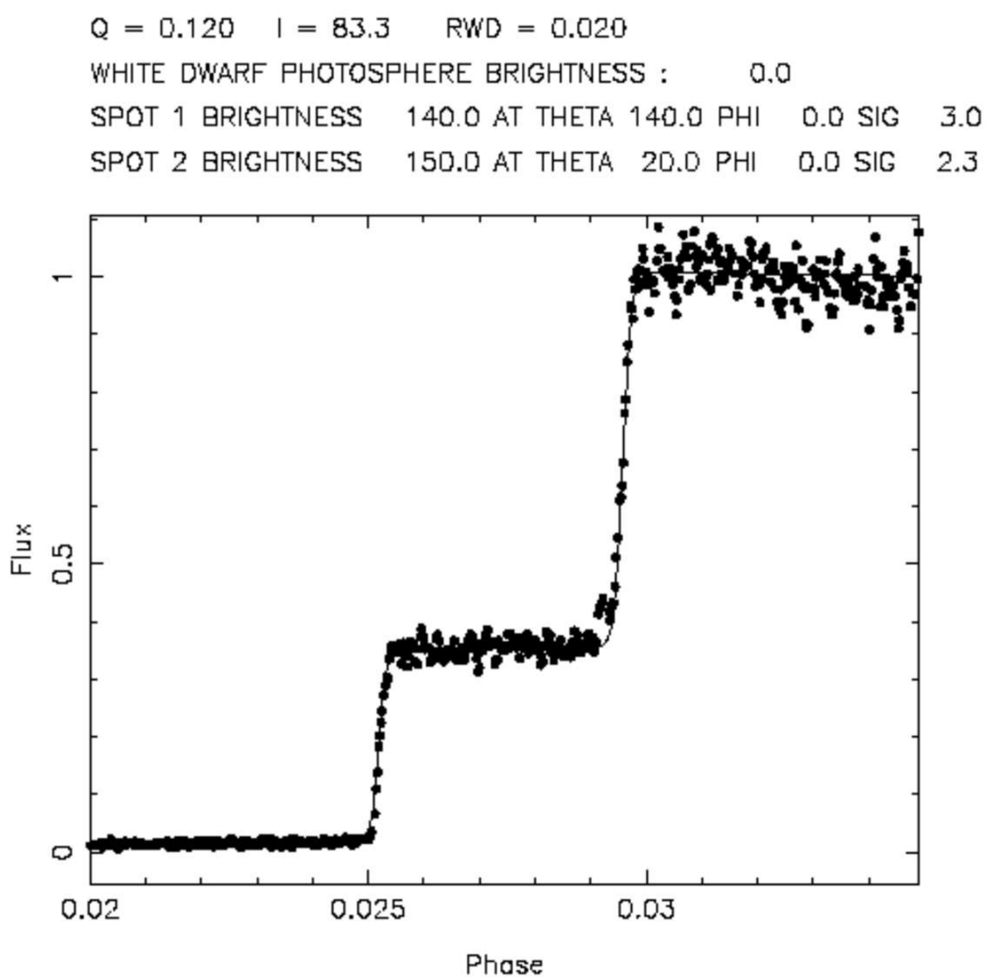
Compare to a White Dwarf eclipse:



Model fit

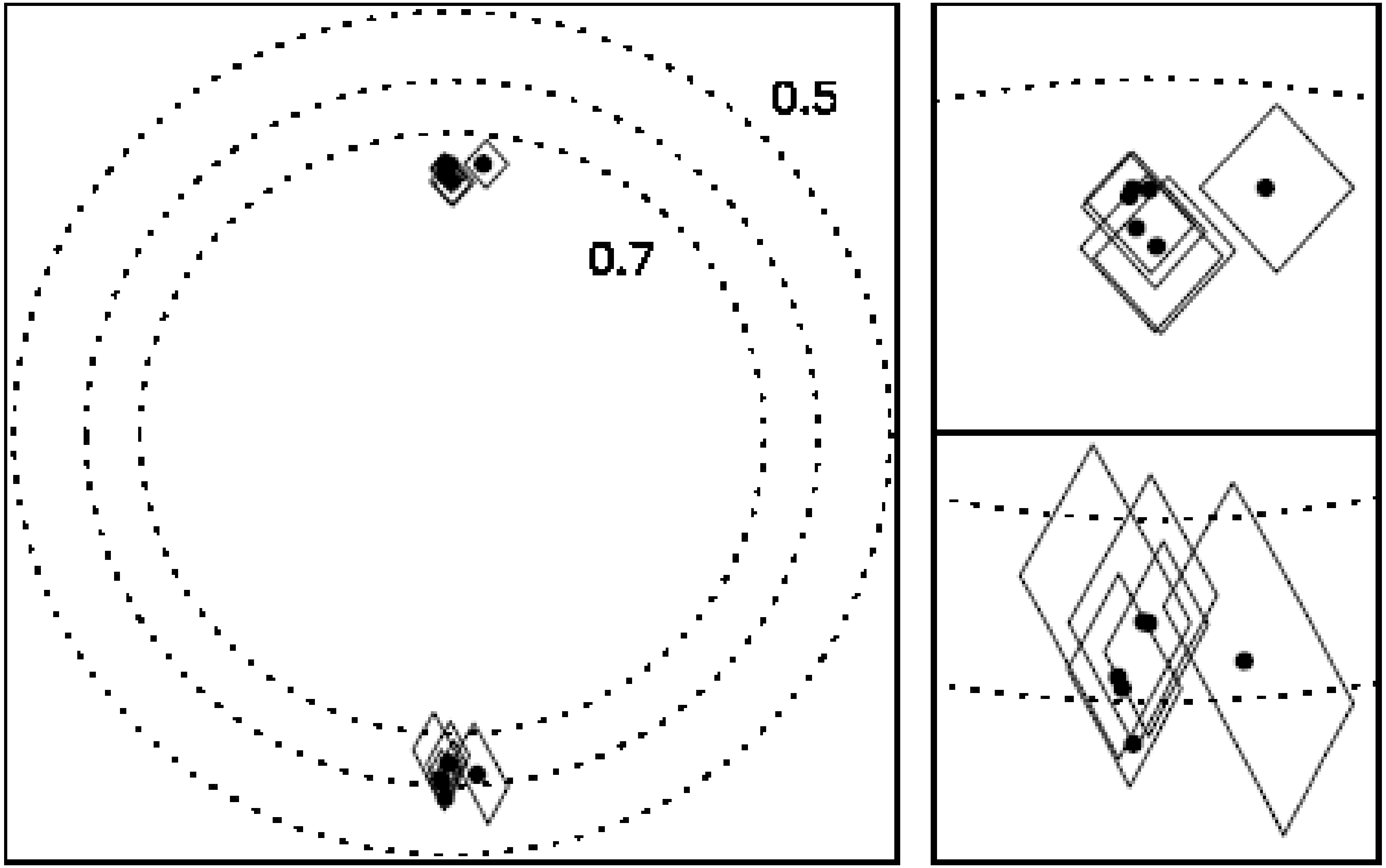
P-M relation (Smith & Dhillon 98) → $M_2 = 0.07M_O$





→take $M_1 = 0.6M_O$, fit *i* and spot parameters

Location of spots on white dwarf



- constrains mass of WD!
- but need low state observations to determine extent of WD photosphere
  - → happening now!

Immediate Deductions:

- A white dwarf take ~30-50 sec to be eclipsed in such short orbital period binaries.
- The ingress/egress times observed here are 1.5 orders of magnitude shorter.
- Quite consistent with being the eclipse of TWO accreting polar caps
- This is an exciting new result and exactly what the high speed SALT Instrument detectors were built to do.

- SALT mostly complete by mid-05, close to budget + schedule.
- Telescope + Instrument commissioning ongoing (mostly RSS)
- First semester of significant science operations begins ~ 07

  » Has unique, important capabilities to enhance SALT's competitiveness (cf. VLT & Keck)

- aim to translate engineering success of SALT into a scientific success for SA → help drive science education in SA.
- It really is the beginning of a new era for Southern African astronomy!!

SALT: inaugurated on Nov 10, 2005 !