SkyMapper

Brian Schmidt

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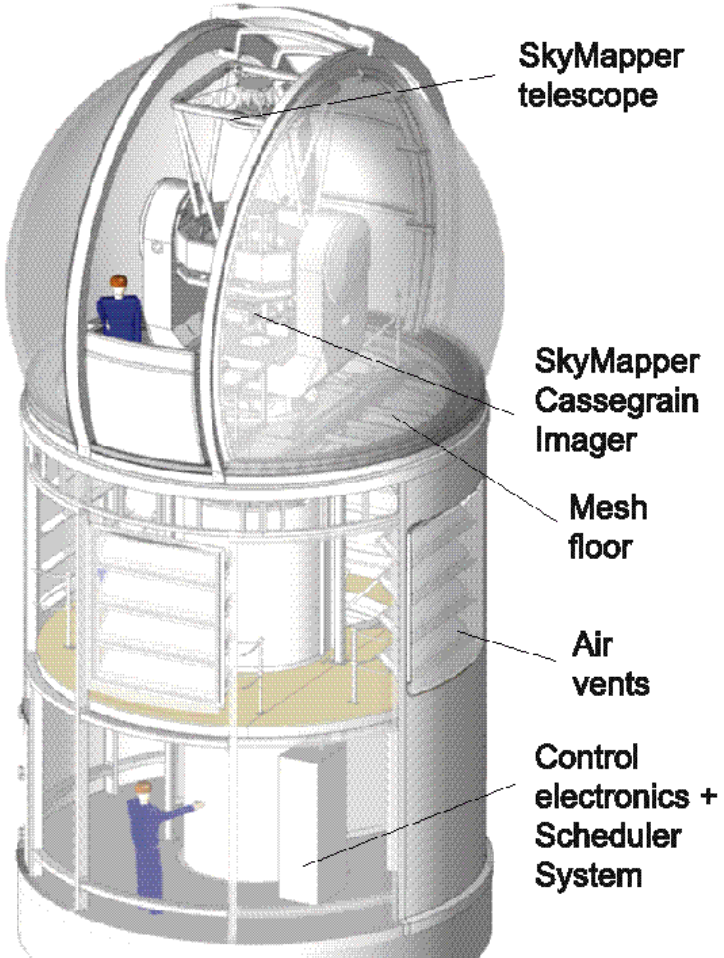
CAASTRO
ALL-SKY ASTROPHYSICS

What is SkyMapper?

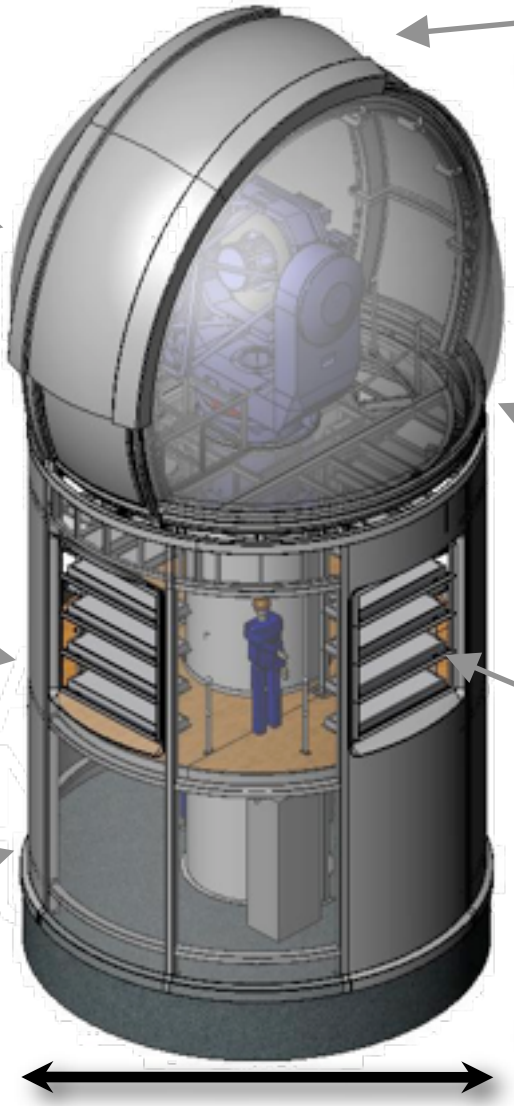
- 1.35m telescope with a 5.7 sq. degree field of view
- Fully Autonomous observing
- To conduct the Southern Sky Survey:
  - Five year
  - Multi-colour (6 filters)
  - Multi-epoch (6 exposures, each filter)
  - 2π steradians
  - Limiting mag. g~23
- Aiming for regular operations this year
- Summary of program: Keller et al. 2007 PASA 24,1



Total Cost: Hardware €10M Software: €1.2M
Dedicated Science/Operations: ~ €0.4M/yr

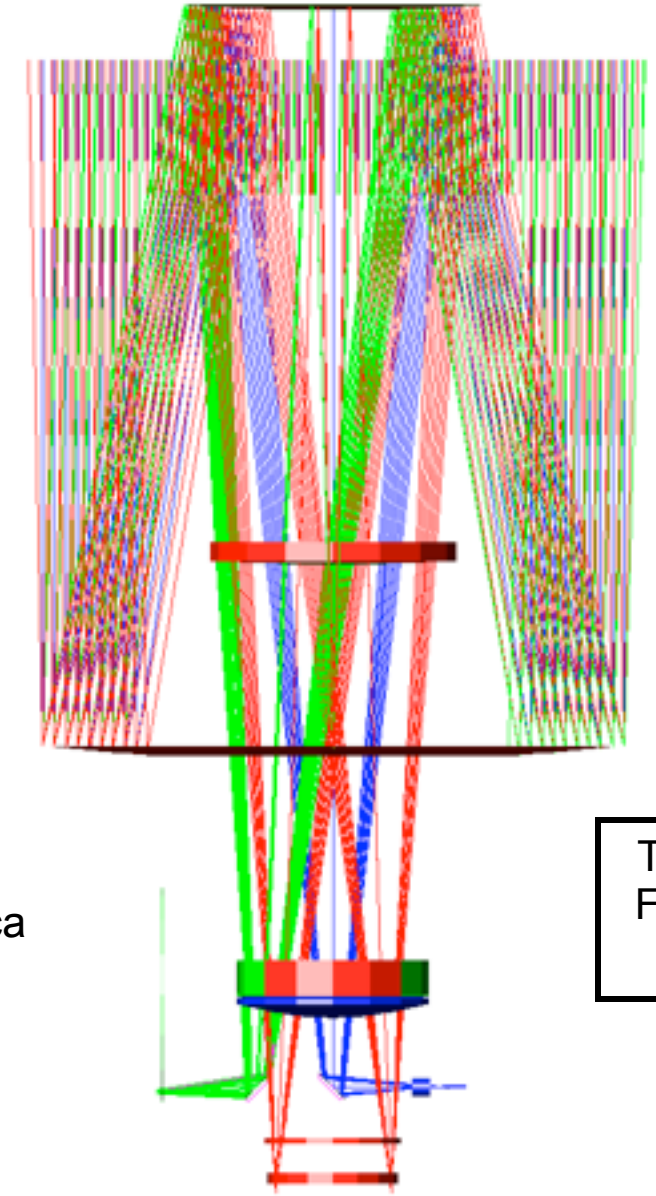
Who is SkyMapper?

The SkyMapper Enclosure



Telescope Optics

0.75m secondary



Modified Cassegrain design

0.6m fused silica asphere

1.3m primary

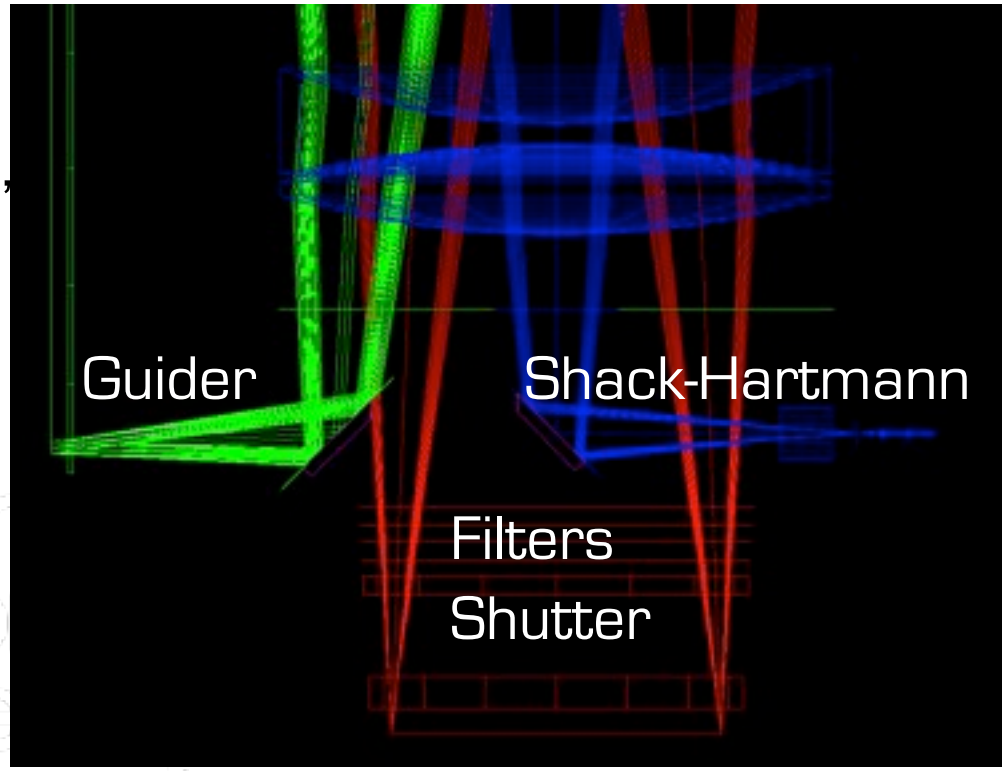
2 x 0.45m fused silica spherics

Telescope – Focal length & f/ ratio.	16224.75mm f/4.78

SkyMapper Cassegrain Imager

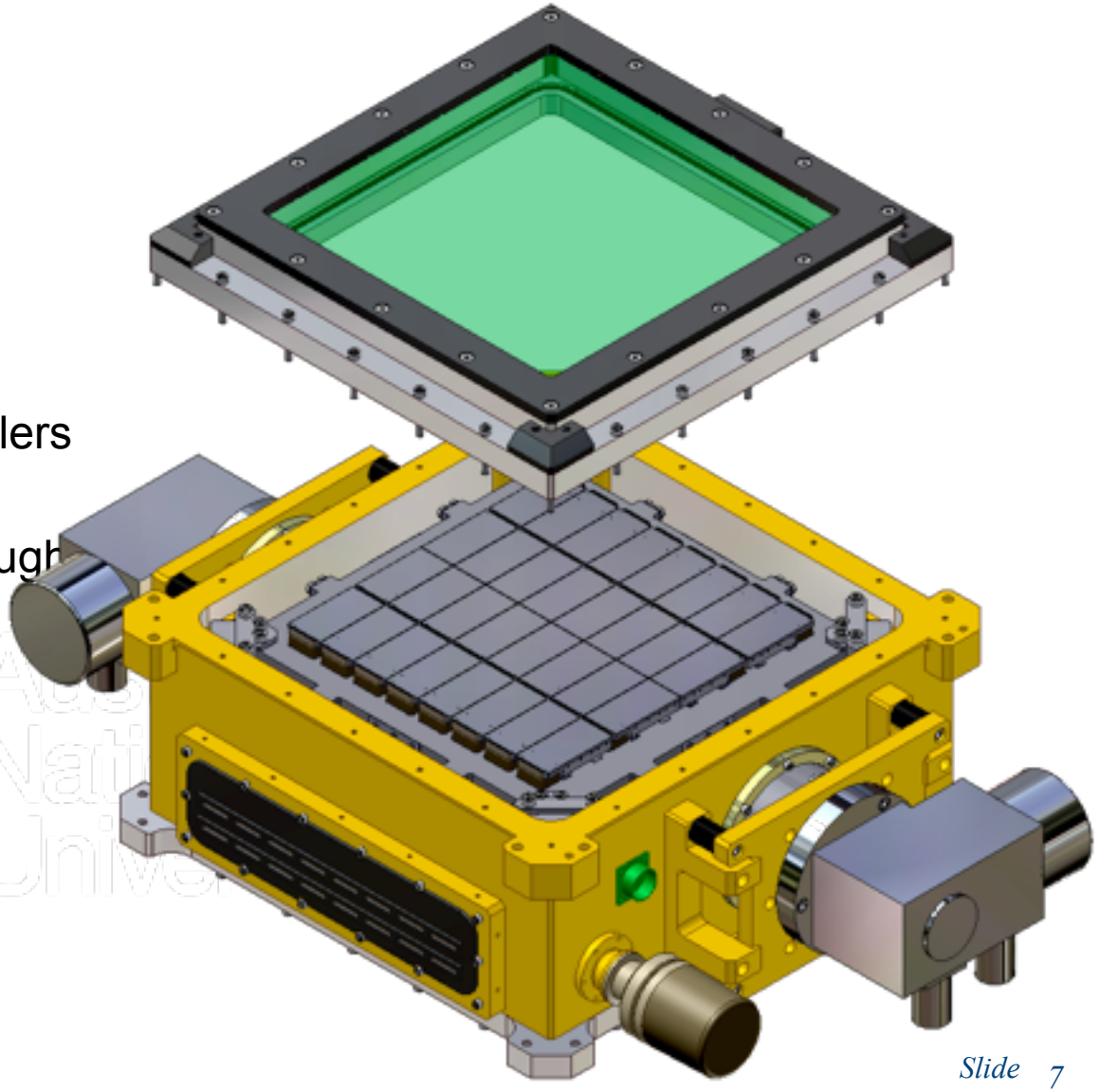
- Being built by RSAA

- 16384x16384 pixel array Cooled with Closed-Cycle He system
- Shack-Hartmann system for focus, collimation, etc.
- 6 Filters slots (~8 second exchange time)
- Bonn shutter (2ms accuracy)



The SkyMapper CCDs

- 32 E2V CCD44-82 devices:
  2048x4096 15 micron pixel CCDs
  - Broadband coated
  - 40 micron (thick) devices
  - Reduced fringing, inc. red response, without bad blue
- 16384x16384 0.5” pixels
- Using new Pan Starrs controllers (Onaka at IfA)
- Readout in ~14 seconds through 64 channels (300 kpix/s)
- Readnoise ~6e



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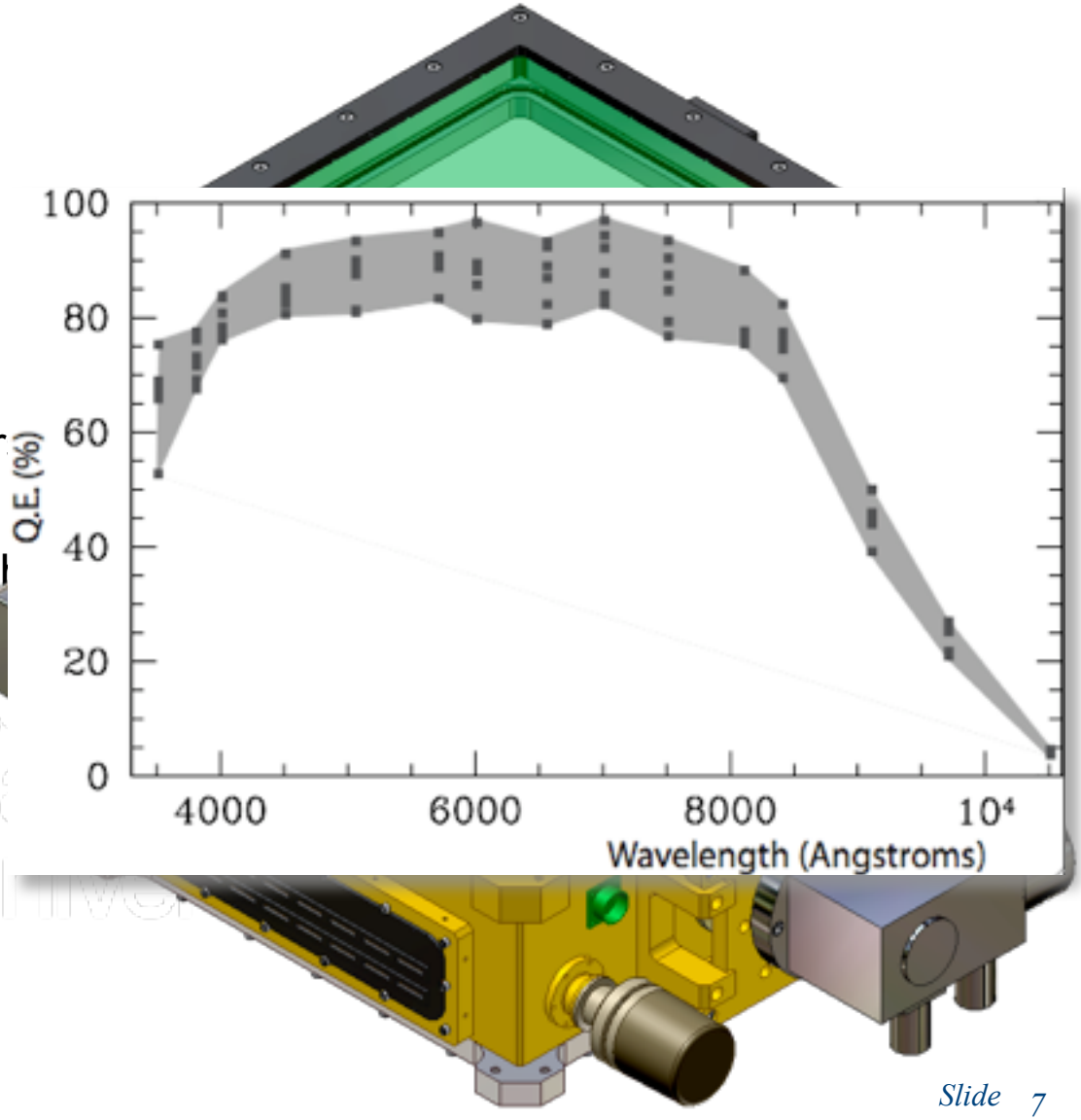
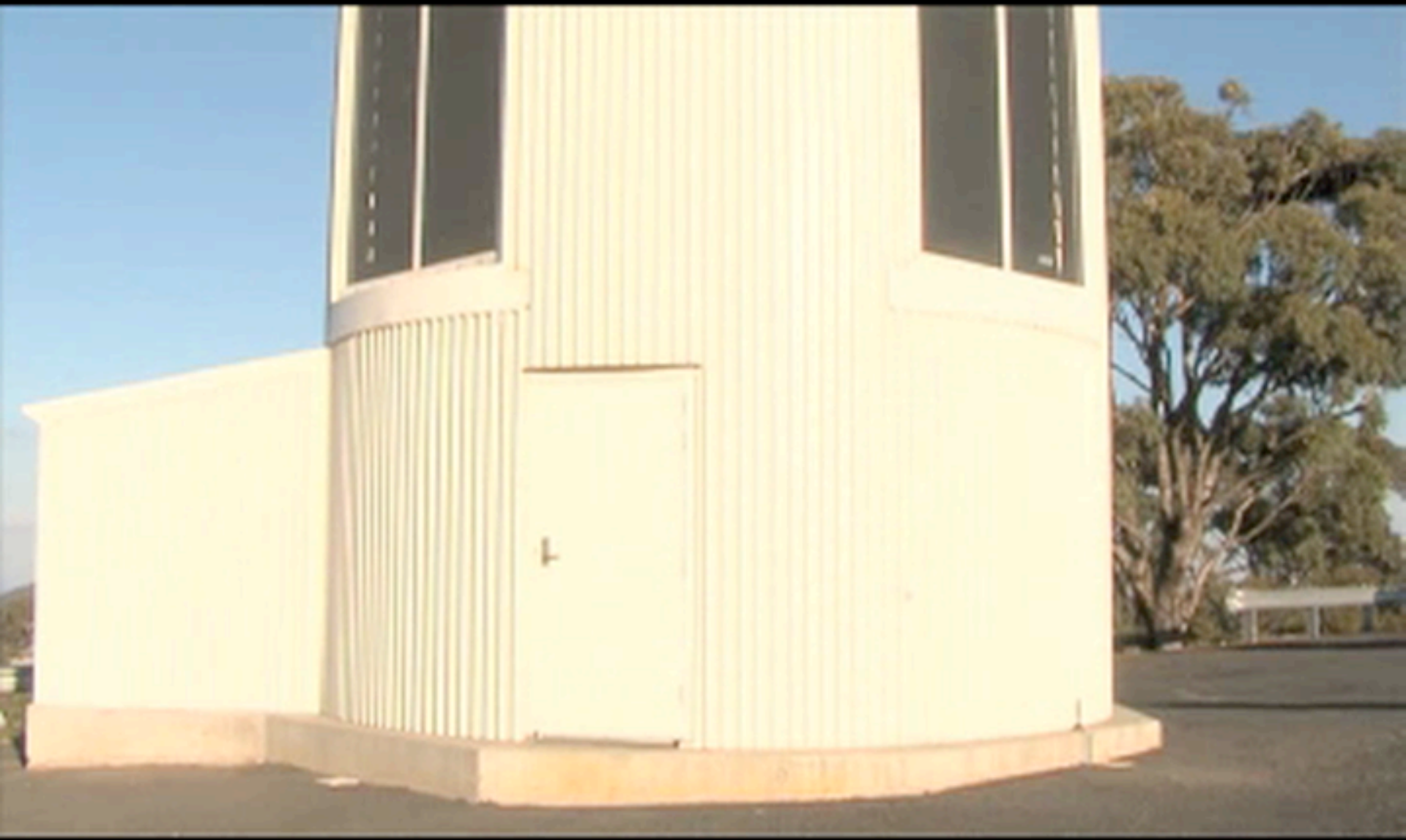
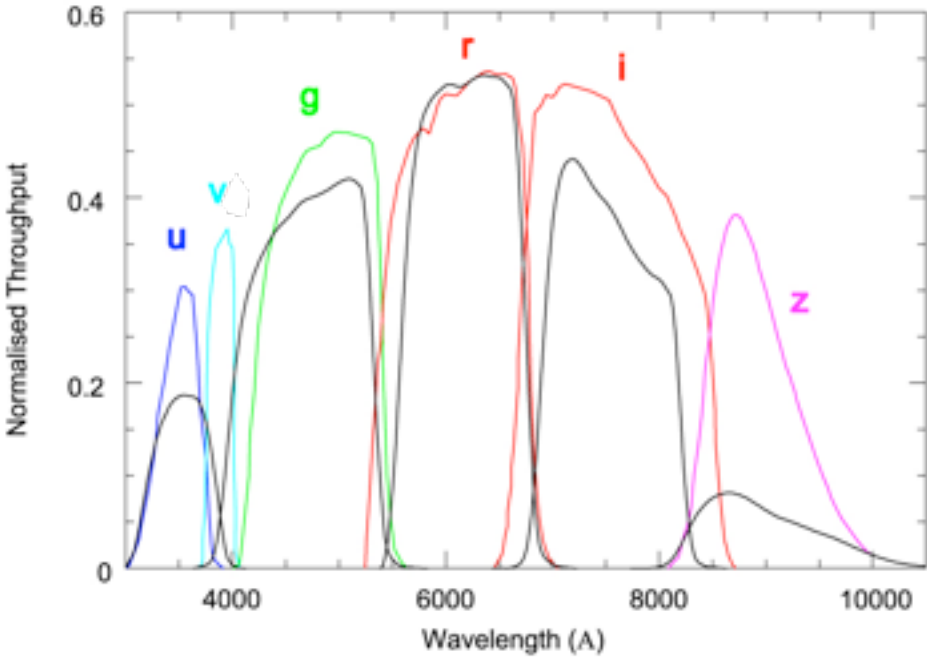




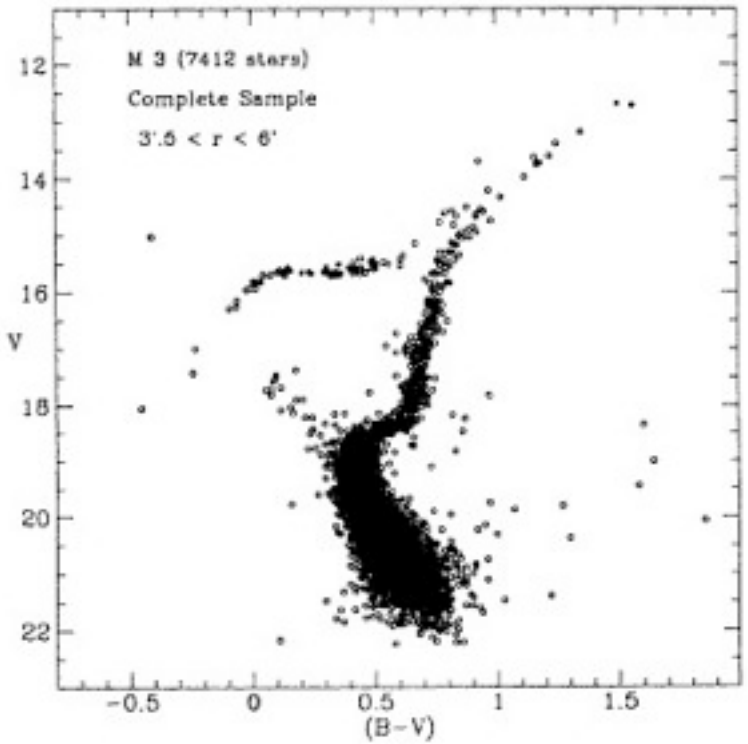
SkyMapper

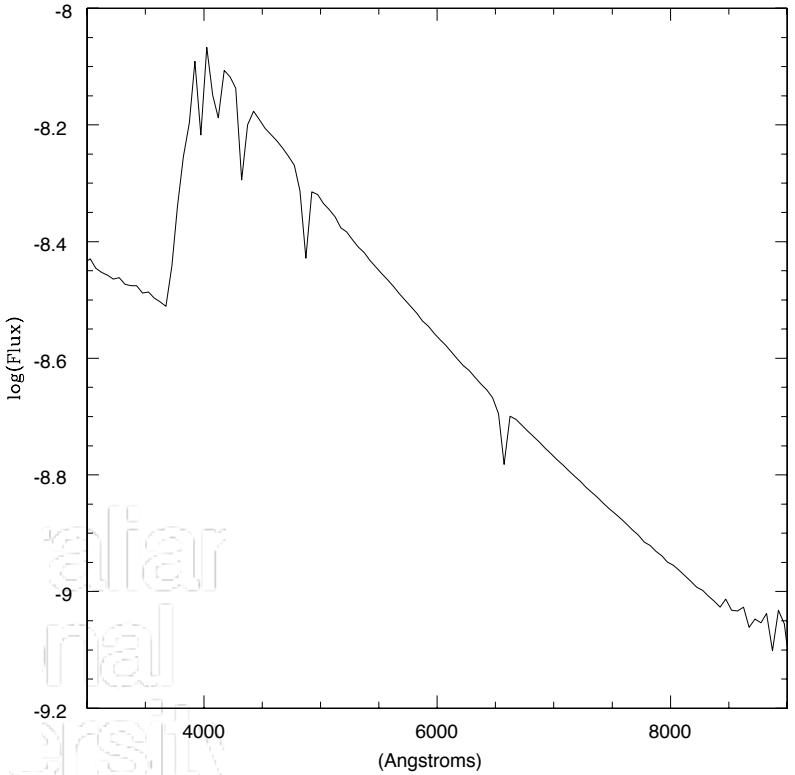
Optimised for Stellar Astrophysics

- Encoded in the spectrum of each star
- Using filters we can isolate portions of the spectrum
- In designing our survey we sought to optimise our ability to determine the three important stellar parameters (T,log(g), Z)
- so SkyMapper not only compliments survey efforts in the northern hemisphere but enables us to tackle important astrophysics in an exciting new way.



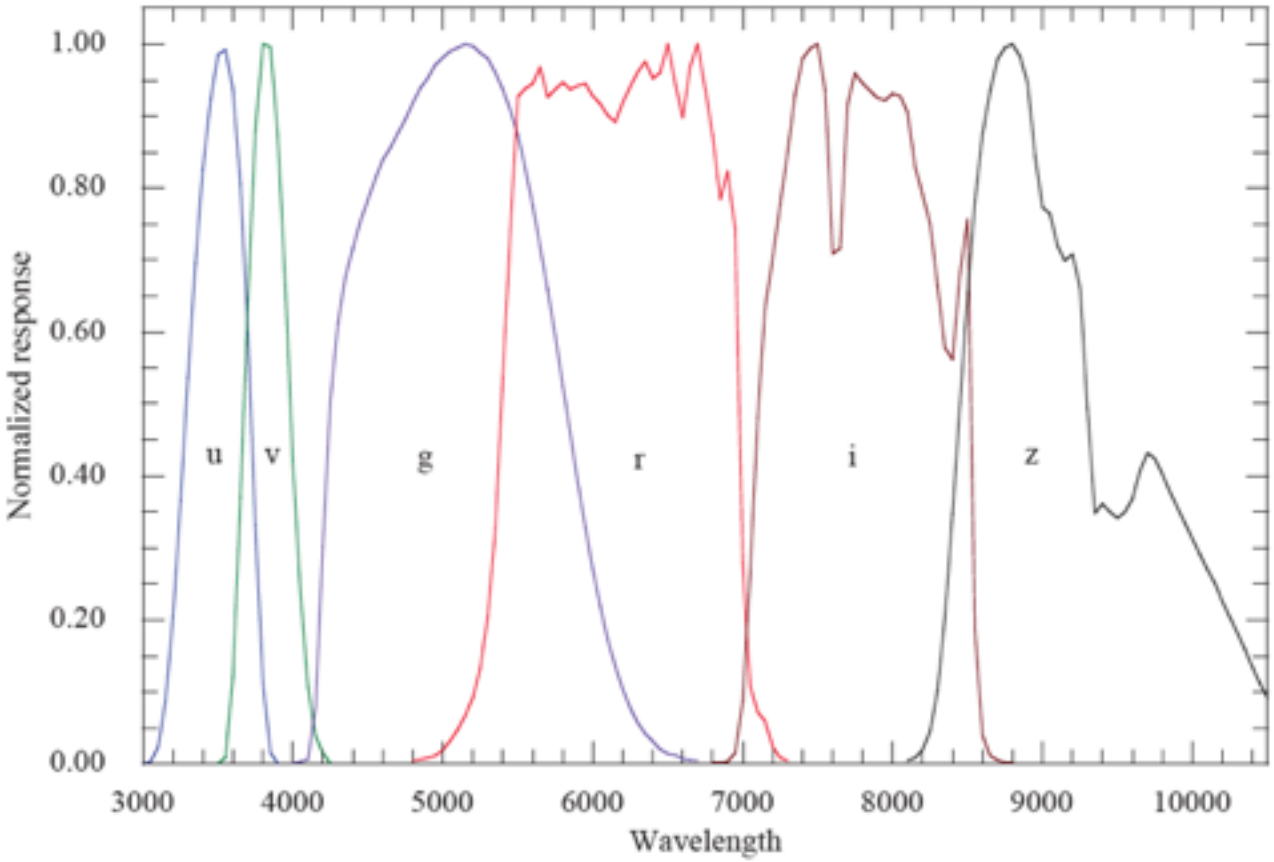
SkyMapper Filter Set is sensitive to Stellar Parameters





SkyMapper Filter Set

Filter+CCD
+Atmosphere



Expected Survey Limits

	u	*v*	*g*	*r*	*i*	*z*
1 epoch	21.5	21.3	21.9	21.6	21.0	20.6
6 epochs	22.9	22.7	22.9	22.6	22.0	21.5
Sloan Digital Sky Survey comparison	22.0	n/a	22.2	22.2	21.3	20.5

AB mag. for signal-to-noise = 5 from 110s exposures

Cadence

- 1st epoch : all filters consecutively (colour + short term variability in uv)
- 3 first epochs in (g,r) in less than 7 days : for Astrometric and photometric short term variation (TNO + RRlyrae/Cepheids+young SN):
- (i,z) spread out to measure parallax over the year.
  - in total, 160,000 sq-degrees observed per year to g~22
- Use a "Score" algorithm for field priority - weighted by amount of time field is observable in survey's remaining time.
- Deal with "Quick Data Quality Check" + DataBase Quality to validate each field meets criteria to be in main survey.
- Take care : distance of the Moon, Planets, Sky conditions, Satellites...

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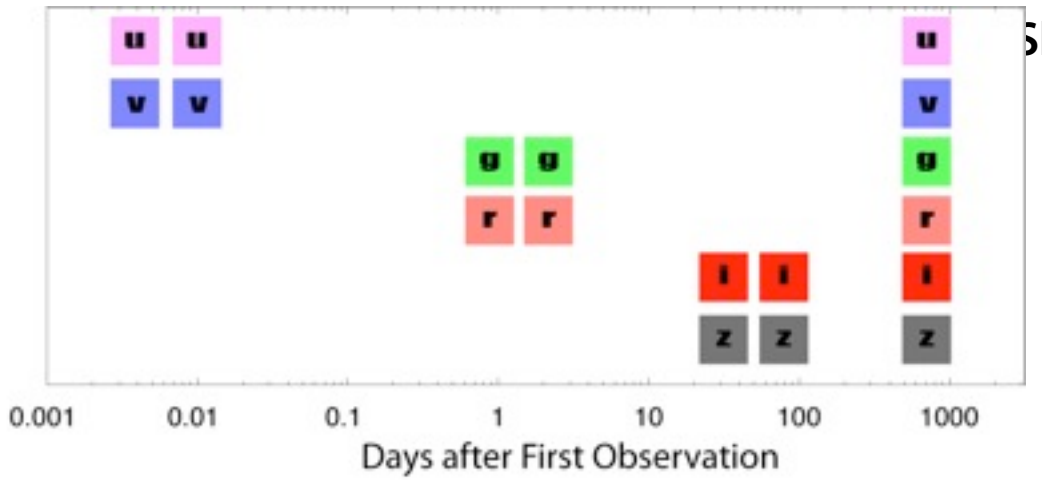
Sky conditions, Satellites...



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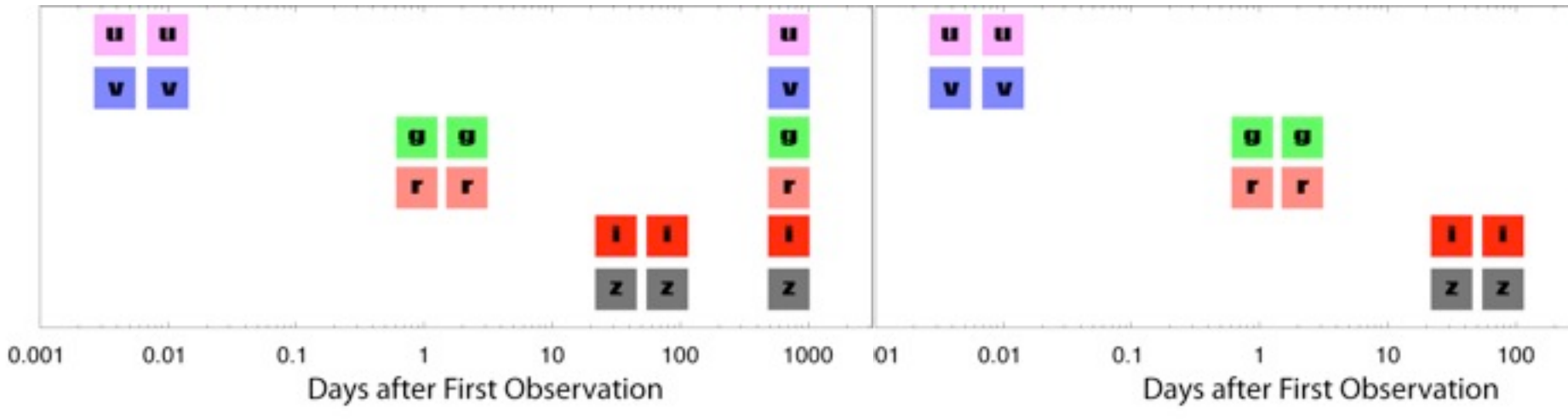


Calibration Plans

- Conduct a Shallow Survey
  - in photometric conditions cover the southern sky with 3 exposures: 8-15th mag
  - Observe the highest two reference fields every 90 minutes

- Anchor the deeper Main Survey to the Five-Second photometry and astrometry
  - Enables the Main Survey to proceed under non-photometric conditions.
- Self Calibration via overlaps, colour of main sequence (in low dust areas) and on photometric nights.

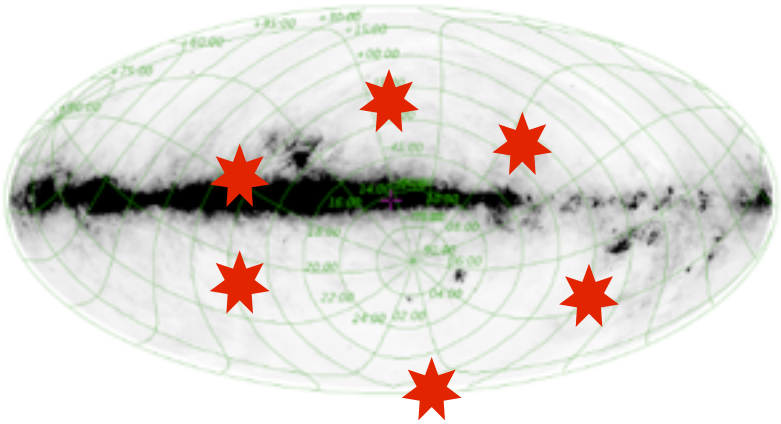
Calibration Plans

- Primary Standards
  - Chosen from the STIS Next Generation Spectral Library (Heap and Lindler)

    http://archive.stsci.edu/prepds/stisngsl/index.html
  - Normalised by Hipparchos B and V photometry via Bessell (2000)
  - Provides 373 spectrophotometric standards across the sky
- 6 secondary standard fields chosen with Primary standards in them. These fields observed with dithers and rotations to produce a photometric flat field, with all stars calibrated to primary standards

New Standard System

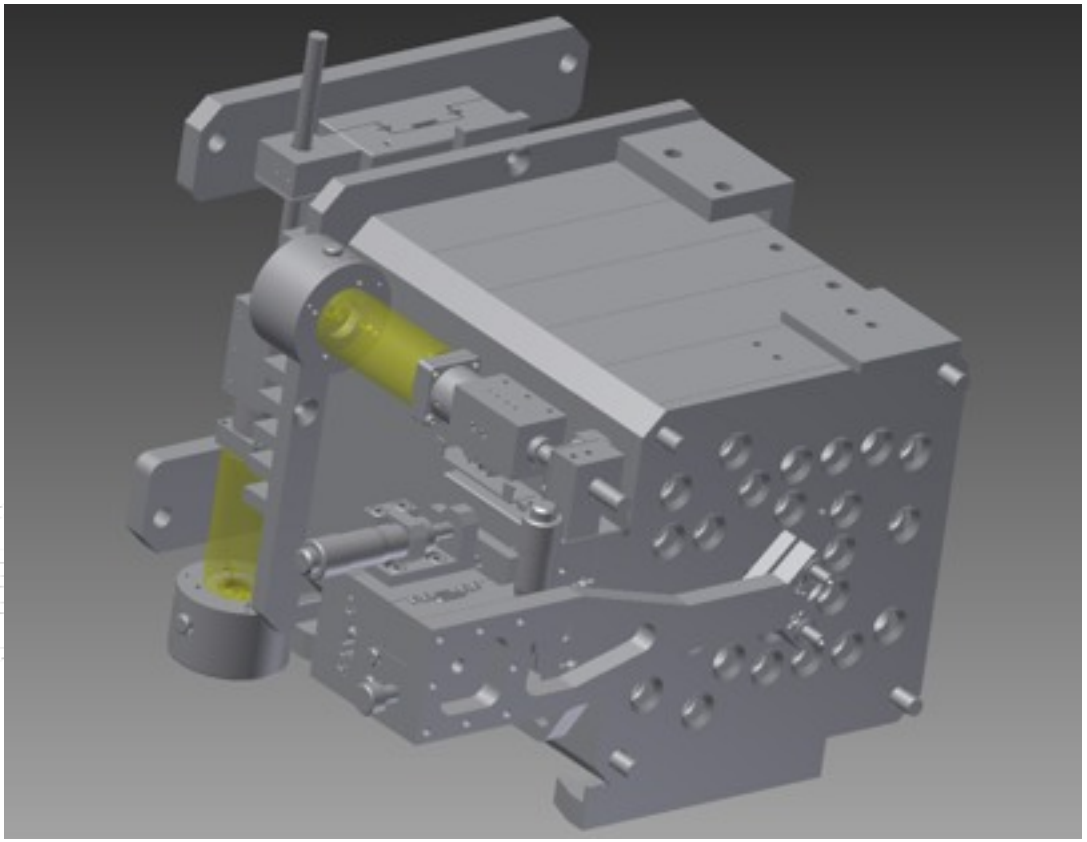
- 6-colour photometry will be reduced as soon as possible.
- 6-colours should provide accurate transformations to most other systems
- Standard Stars in every southern field



Calibration Plans

SkyDice - PI Nicolas Regnault - LPNHE

- >20 LEDs covering 0.3-1μ
- observed through telescope with NIS calibrated photo diode
- absolute calibration and monitoring of optics

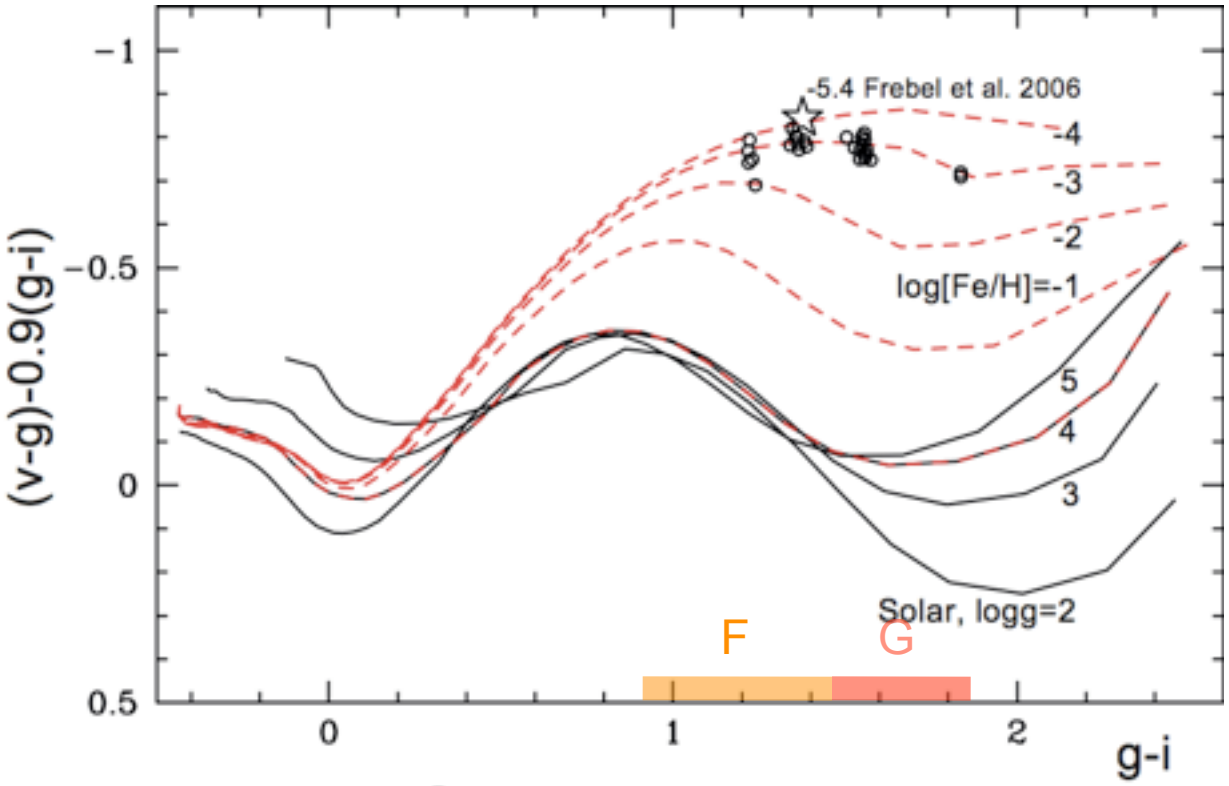


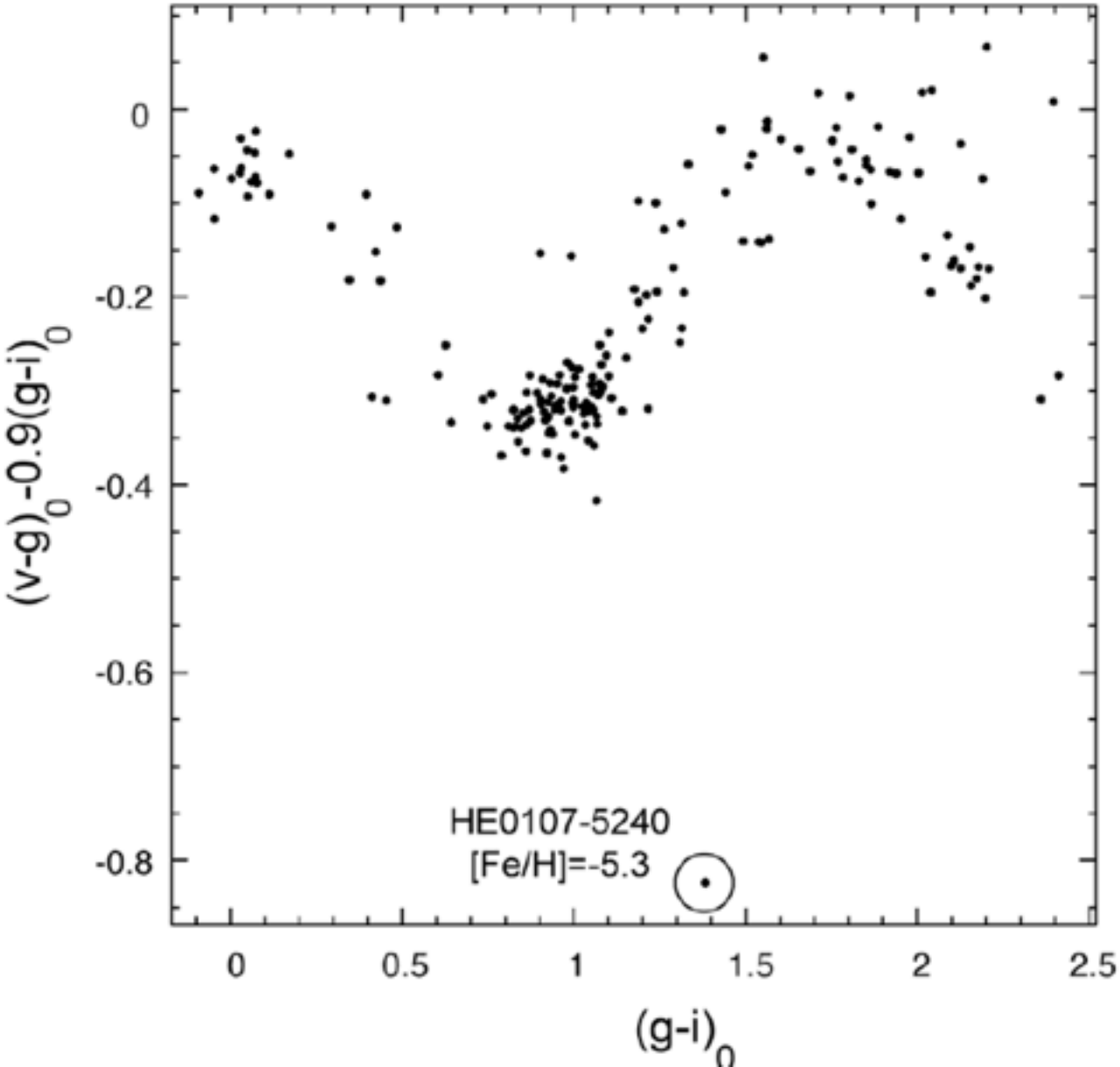
Some Science Themes

Extremely Metal-poor Stars in the Halo

- Goal: find the first stars to have formed in the Universe: tell us about the assembly and chemical enrichment of the Galaxy
- v-g is dependent on the level of metal line blanketing in the blue continuum

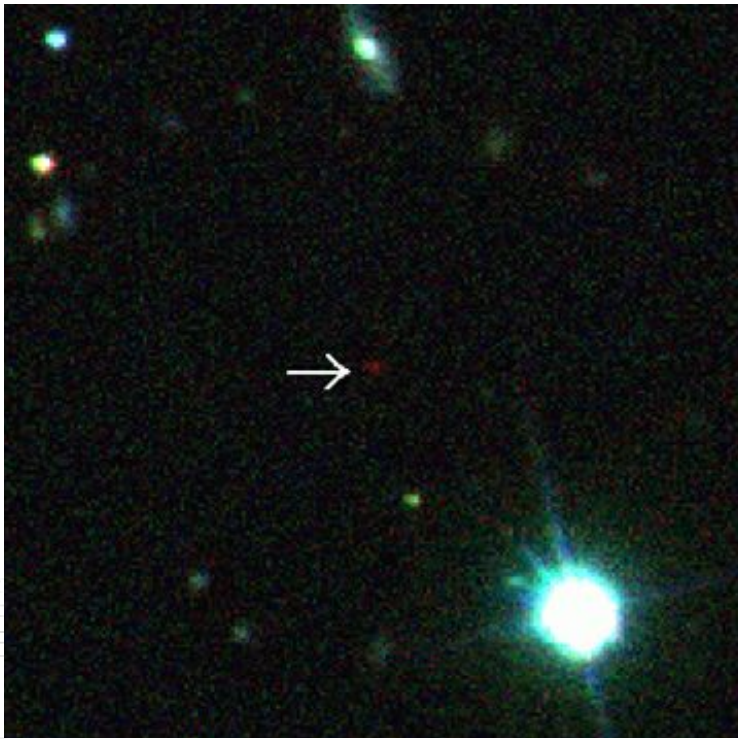
✓ not perturbed dramatically by C-enhancement, chromospheric emission as affects objective-prism surveys



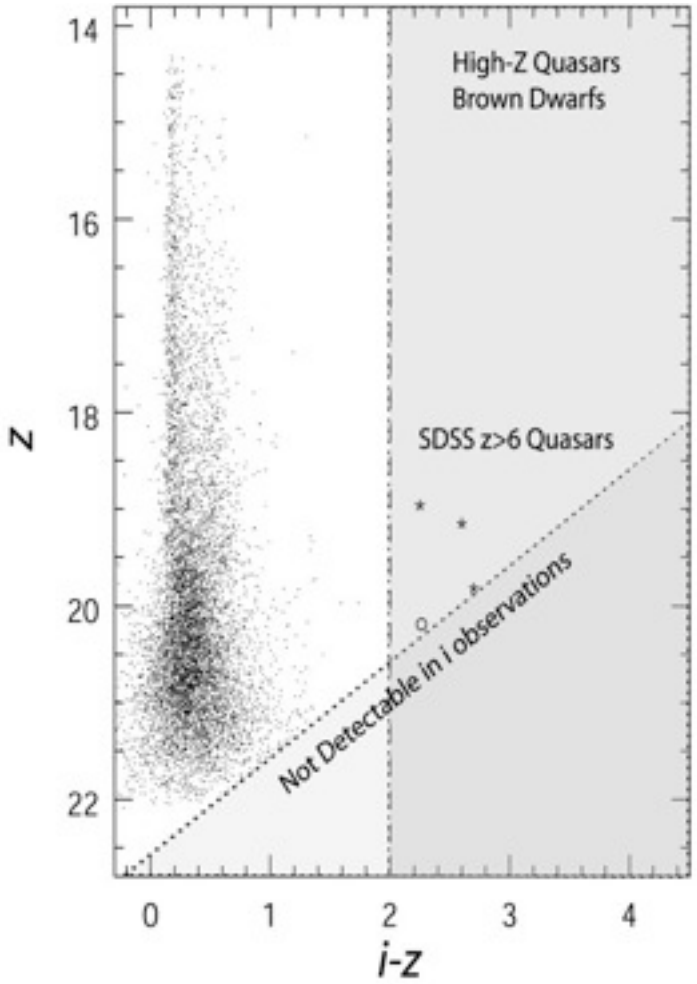

0
-0.2
-0.4
-0.6
-0.8
$(v-g)_0-0.9(g-i)_0$
HE0107-5240
[Fe/H]=-5.3
0
0.5
1
1.5
2
2.5
$(g-i)_0$

High-redshift QSOs

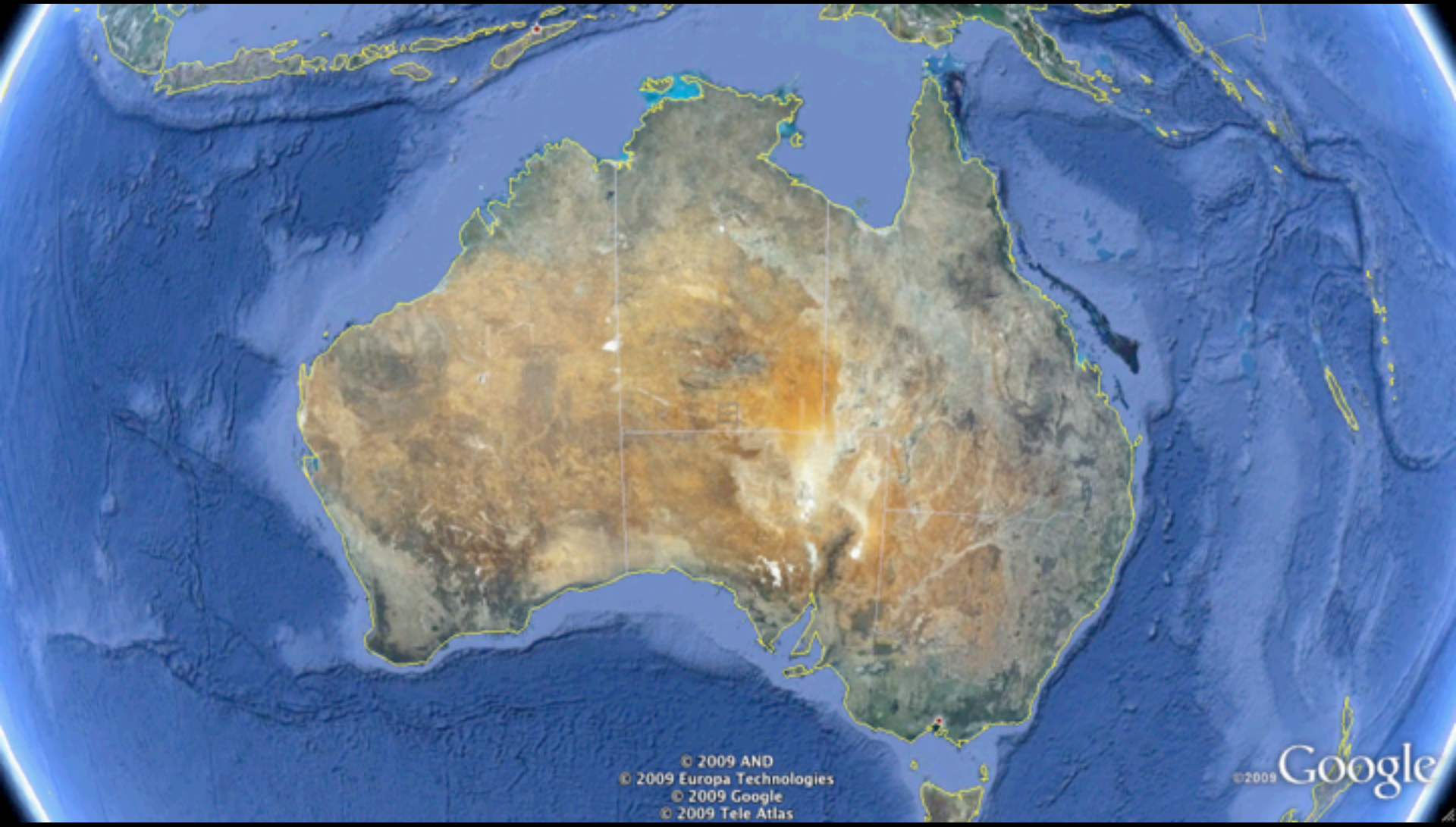
- High-redshift QSOs are among the most distant optical objects in the Universe, probing the Universe and host galaxies at 6% of its current age.
- Key objects for studying reionisation - Murchison Widefield Array targets.
- 50 objects are expected in the southern hemisphere
- Exercise in data mining - these are faint, very red objects



High-z QSOs



- Detection is simple: i-band dropouts.
- Contaminants: L+T dwarfs
- SDSS tells us we can expect of order 50 objects z<20.5 in the SSSS
  - Detection limited by our i sensitivity (not z!)
  - Proper motions can help remove most L+T dwarfs
  - as will J,H,K photometry
  - initial follow-up with WiFES+2.3m and IRIS2+AAT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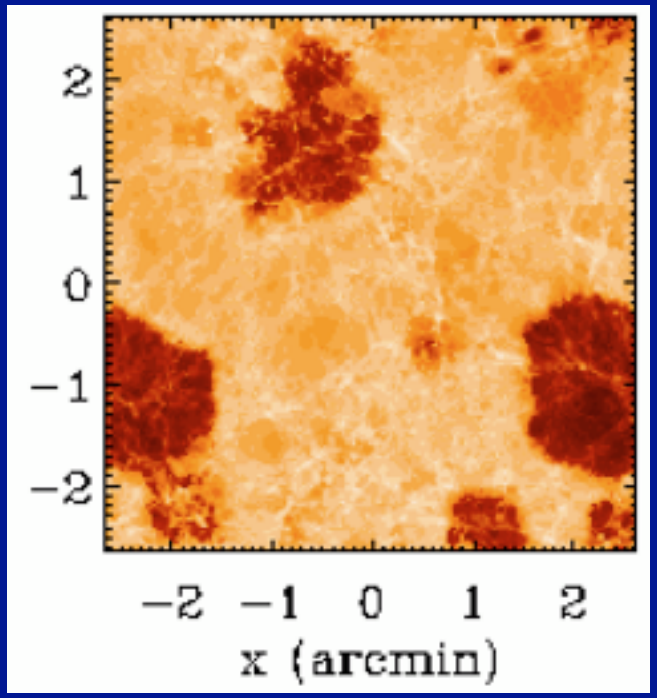
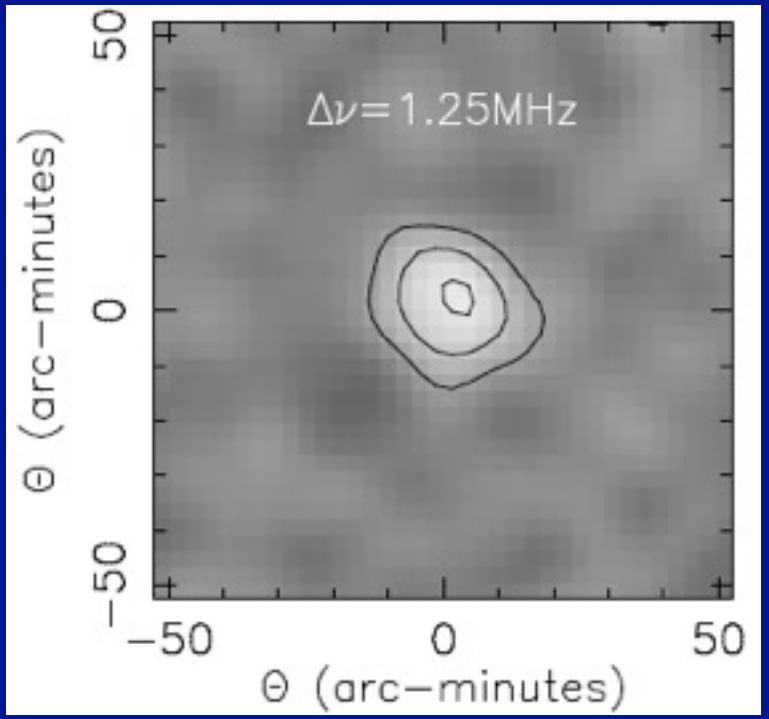
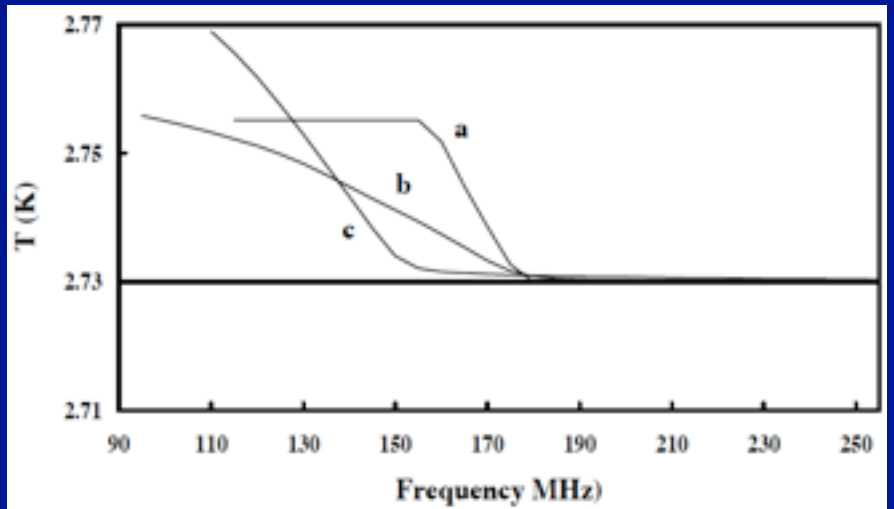
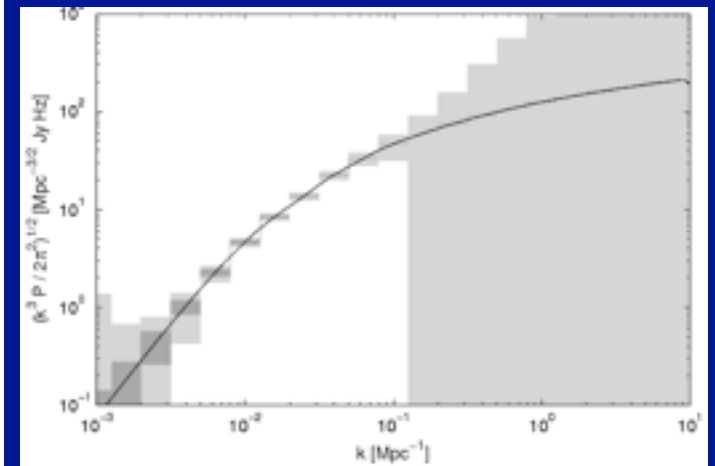
What will MWA see?







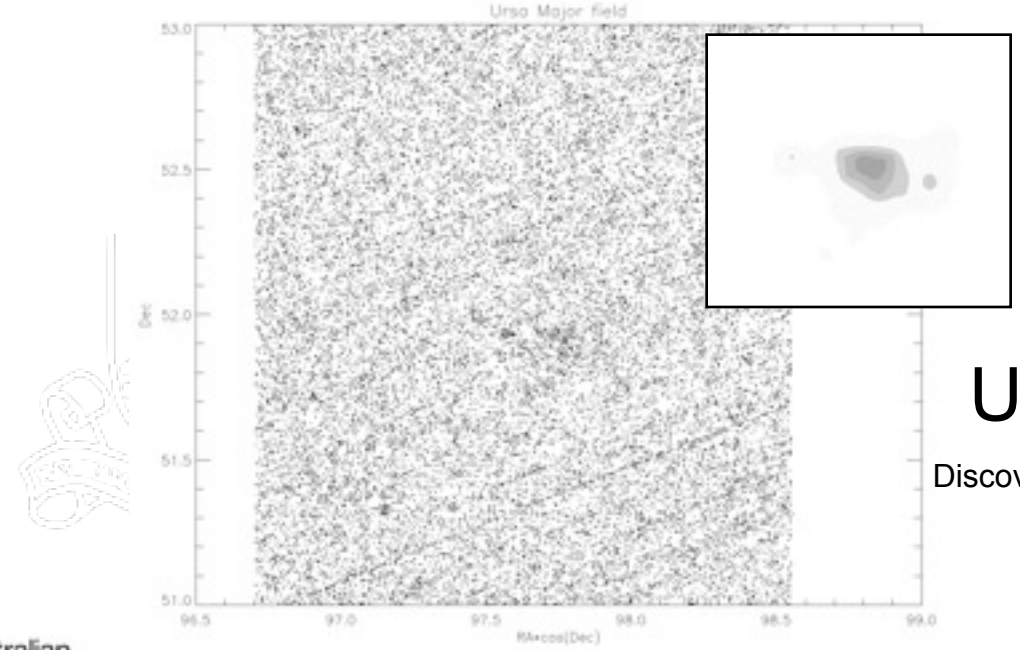


Search for extreme LSB MW satellites

Jerjen, Willman, Mateo ...

- Chemical abundance measurements of individual stars to learn about SN yields, Pop-III stars?, and how smallest galaxies form.

SkyMapper will cover an uncharted 20000 sq-degrees 0.7 mag deeper than SDSS.



UMa, 100kpc, -6.8?

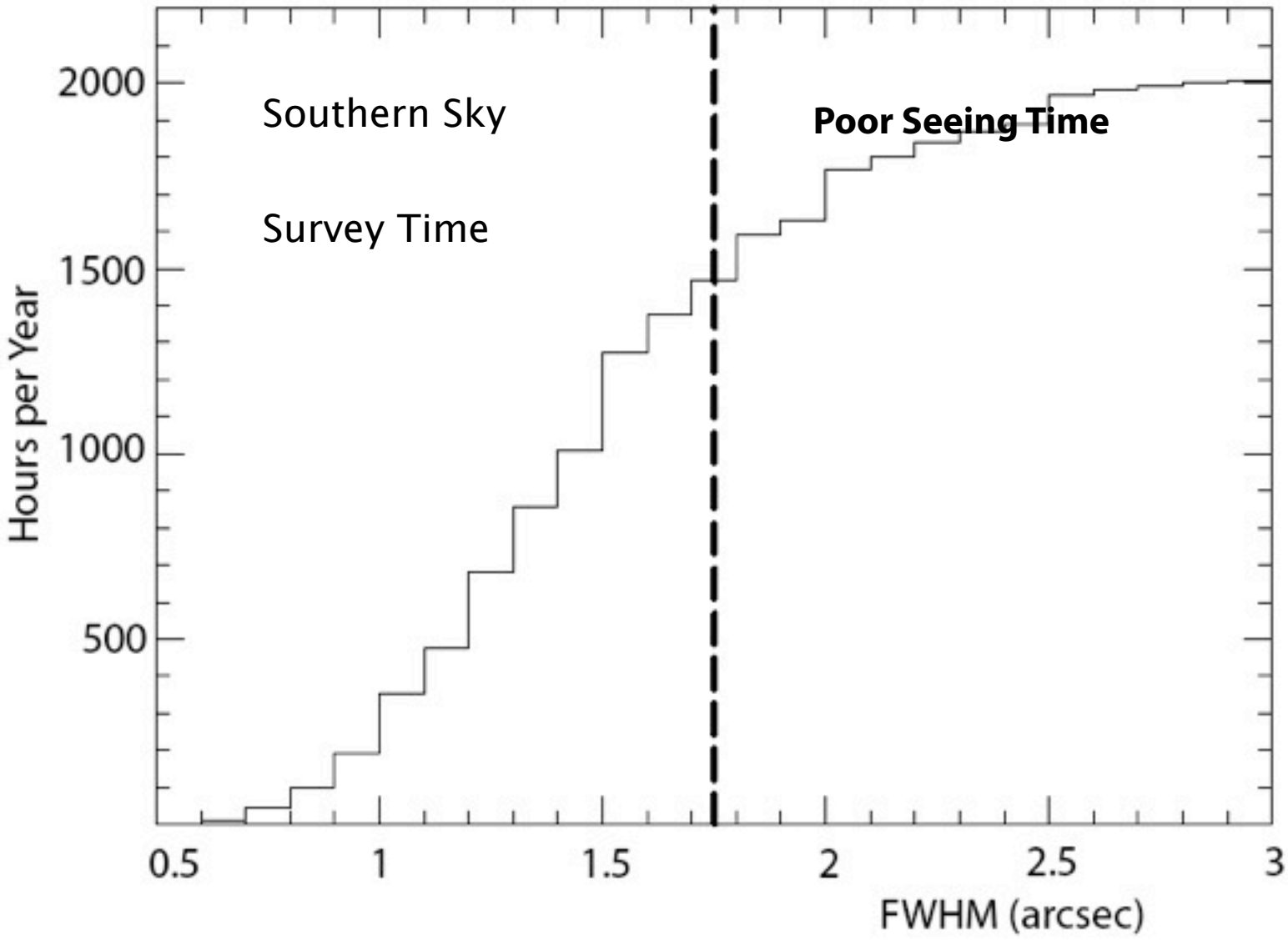
Discovered by Willman et al. 2005 from SDSS data

And a whole lot more

- All Sky Tully-Fisher peculiar velocity survey when combined with ASKAP (25000 galaxies)
- input catalog for HERMES (+T_{eff} and g)
- QSOs (Bright QSOs for dz/dt, dα/dz, TPE)
- large sample of hyper-velocity stars in halo based on gravity+metallicity
- structure of outer Halo of galaxy with giants, BHBs and RR-Lyrae
- Transiting planet discrimination (HAT-South based at SSO)
- Discovery of rare stars (e.g. R Cor Bor, AM CVn)

up to 25% of time for other things

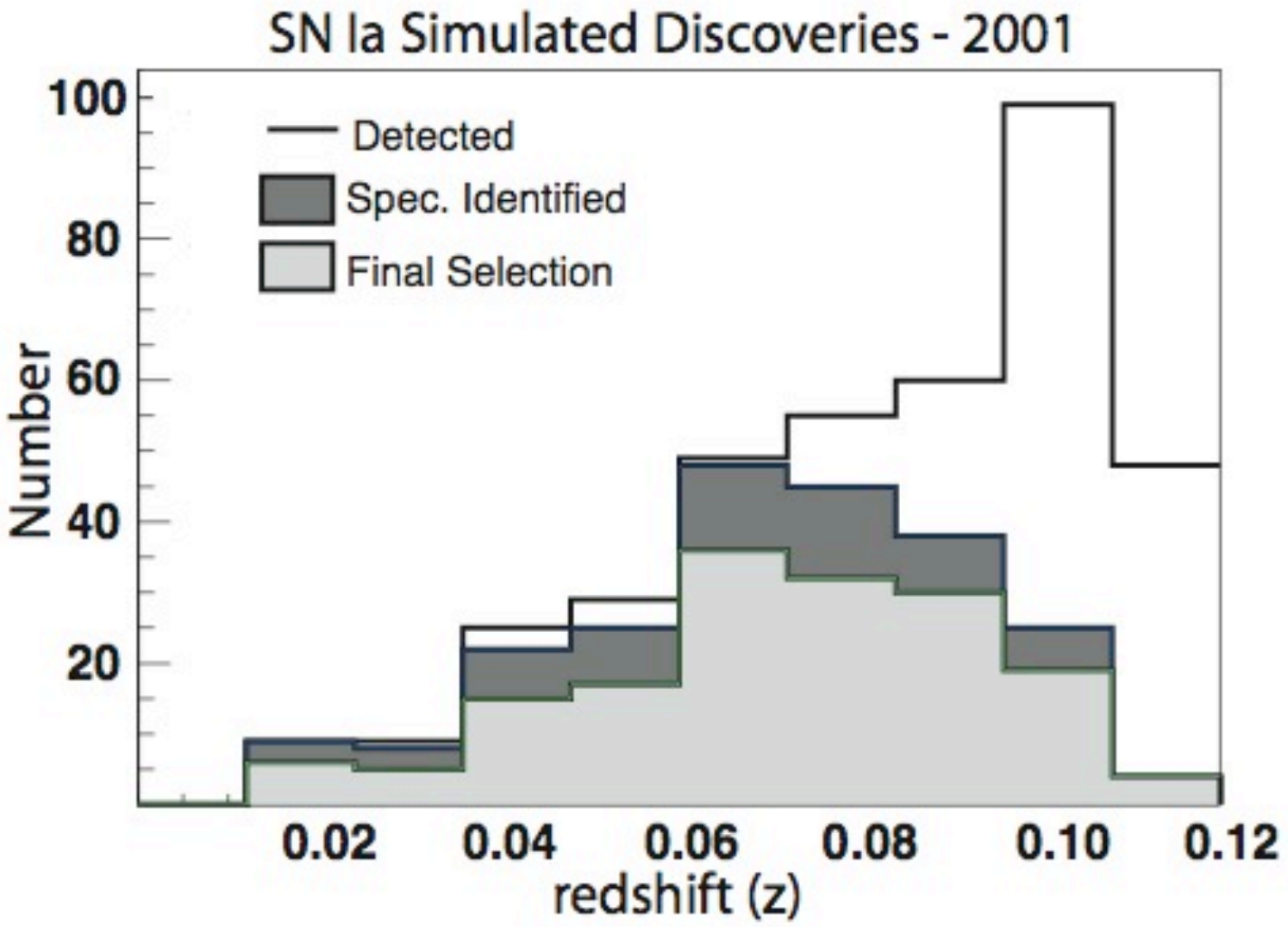
- Hα of Southern Sky
- Mg 5100 filter for K Giants (maybe not needed)
- GRB, Gravity Wave, Radio Transient TOOs
- SN Search override
- High Cadence Variability surveys


Southern Sky
Survey Time
Poor Seeing Time
Hours per Year
2000
1500
1000
500
0.5
1
1.5
2
2.5
3
FWHM (arcsec)

Supernova Poor Seeing Progam (>1.7")

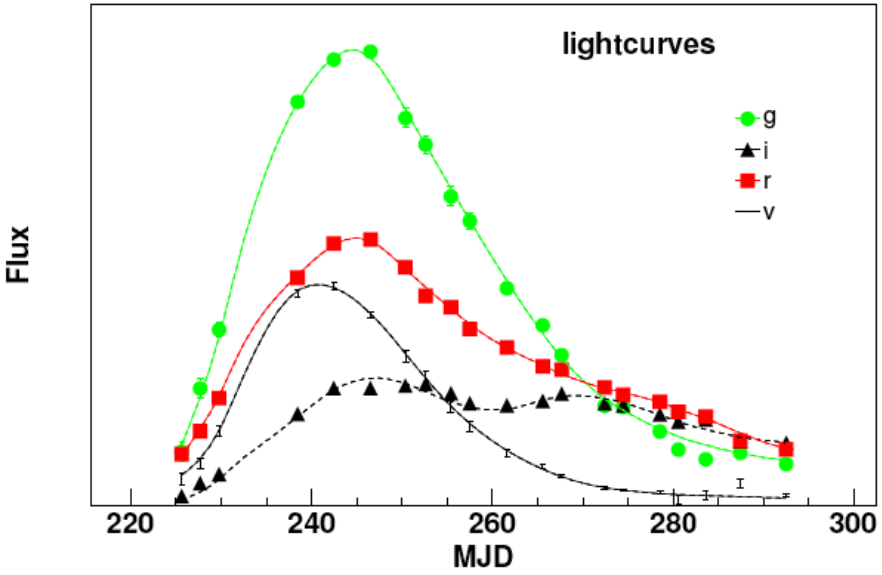
In Collaboration With LPNHE

- 1250 sq-degrees v,g,r,i to g~19. Augment with some good seeing data to achieve a 3-4 day cadence.
- (125,000 sq degrees per year with a 3-4 day cadence to v,g,r,i~19)
- Fields still be determined - balance between very far south (easy to observe), and coverage for peculiar velocity surveys (like to go North and into the Galaxy)

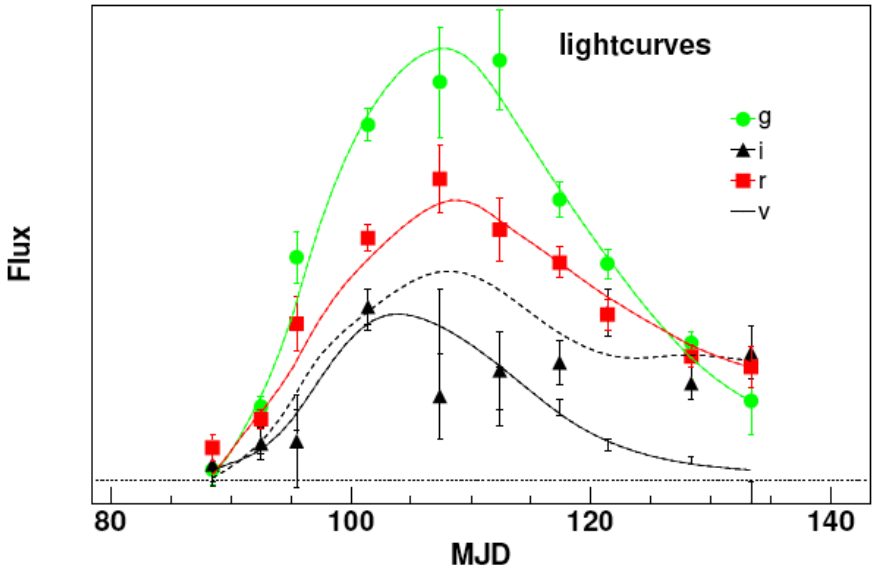


Regnault and Guy (IN2P3)

Sample Light Curves



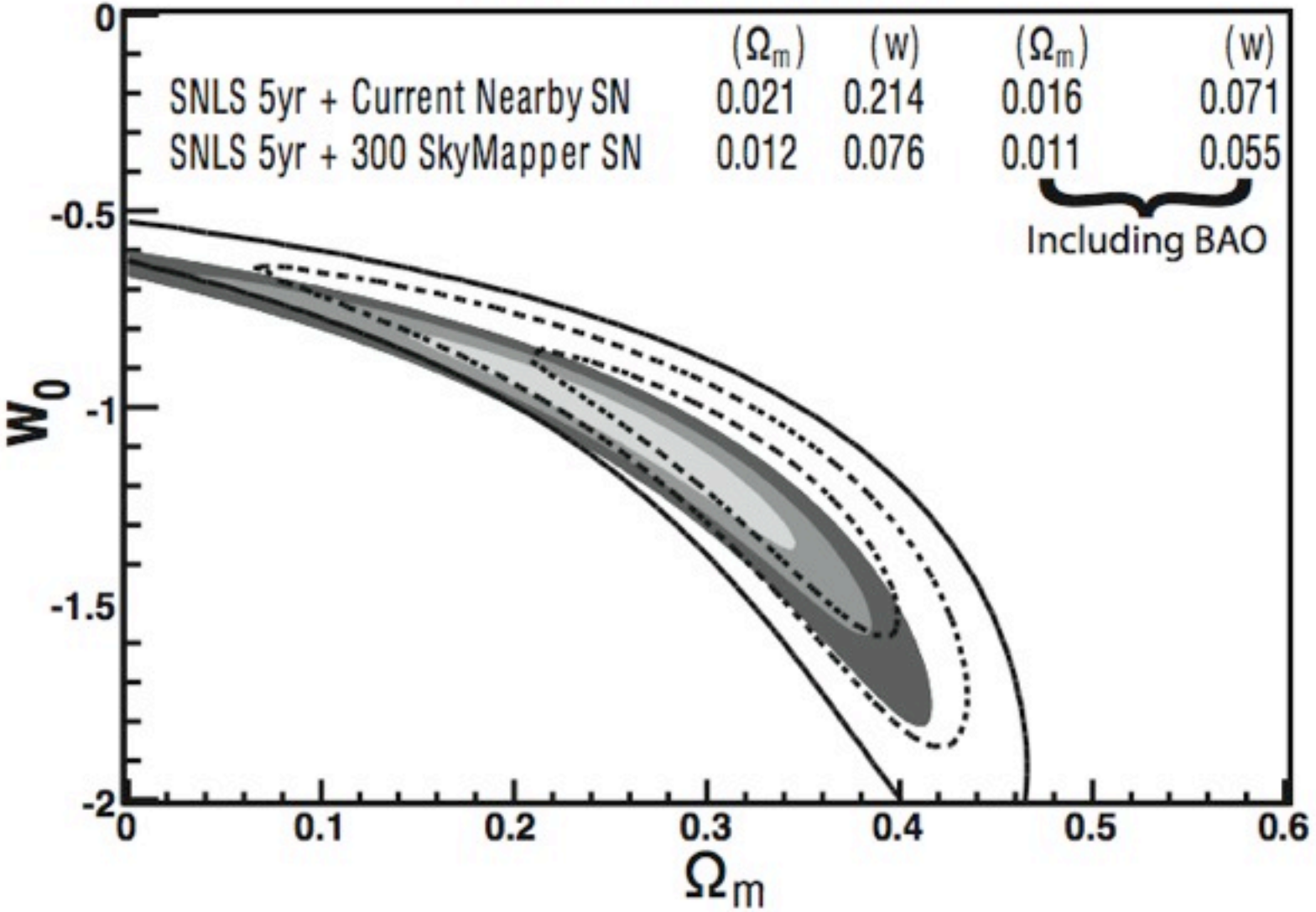
(a) SN09151 @ $z = 0.045$



(b) SN07560 @ $z = 0.094$

Regnault and Guy (IN2P3)

Equation of State of Dark Energy in a Flat Universe



Data Release

Deliverables to the Outside User:

- Data (epoch, RA, DEC, mags, galaxy shape info,…) to be available through a web-served interface which provides catalogs over a user defined area
- Images to be available through a web-served interface which provides images over a user defined area (1 degree max, cut out of a 2-degree TAN projection across the sky), or individual frames.

Data release will occur after extensive data validation:

- Five-Second data after closure in RA and trial application to concurrently obtained main-survey data
- FDR Main Survey 3 epochs all filters
- SDR Main Survey 6 epochs all filters

Non-ANU parties can gain access to data during data characterisation period:

•Request is forwarded to Project Scientist for SkyMapper. Project Scientist will ensure Project does not overlap/interfere with existing projects.

•Establish a memorandum of understanding (MOU) between the external investigators and the School regarding the usage of data for specific purposes and authorship policy (inclusion of SkyMapper Development Group). External groups will be expected to visit Stromlo (we will try to support) as part of the MOU.

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We want to work with you!

Looks scary, but seems to be a very small ripple on the primary from milling which does not affect overall imaging of telescope. (pattern goes away at different focus values)

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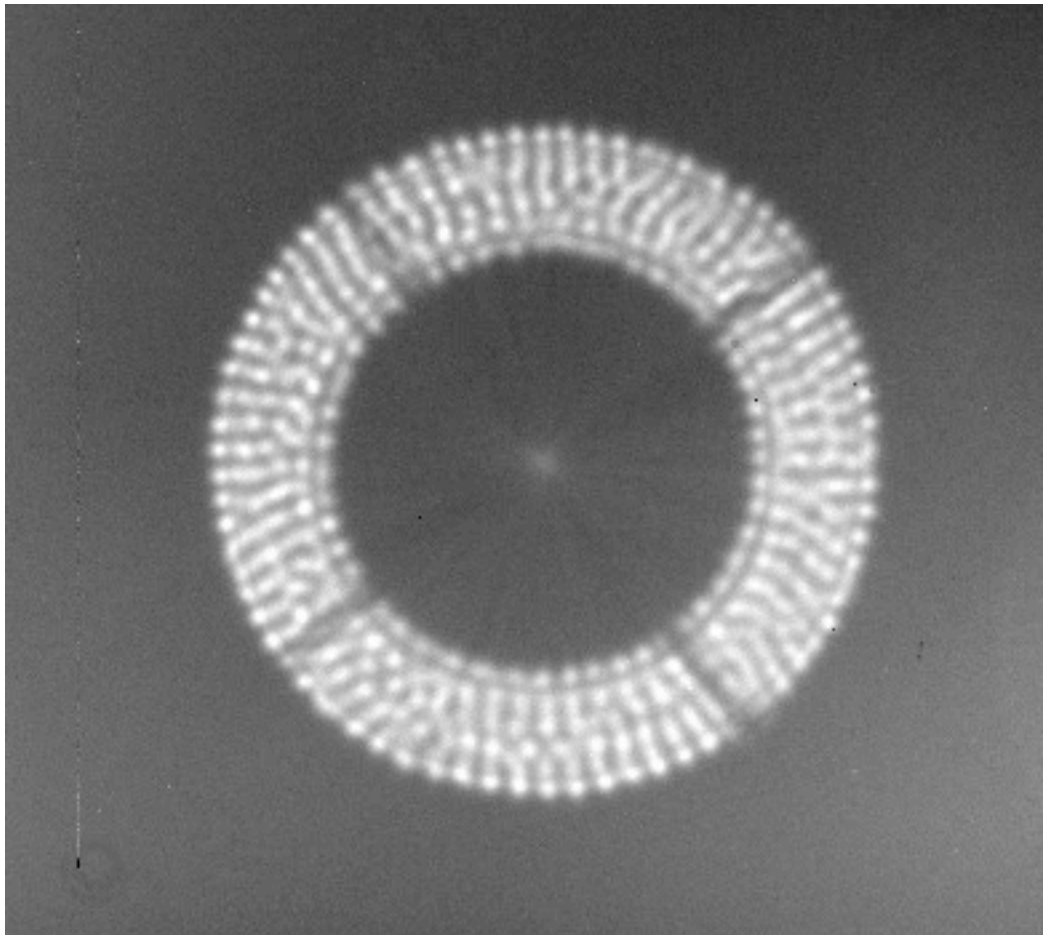
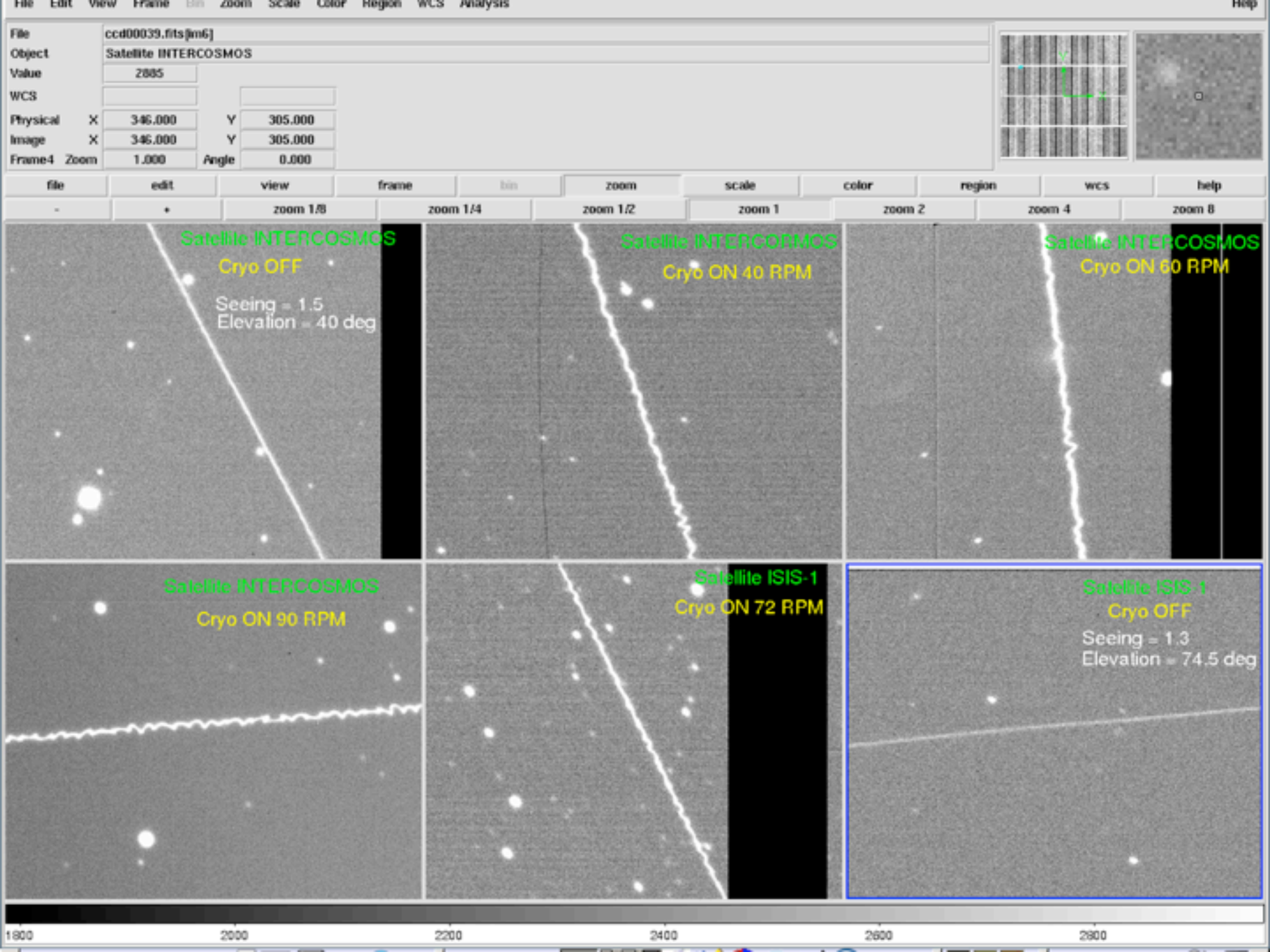


AN OUT OF FOCUS IMAGE

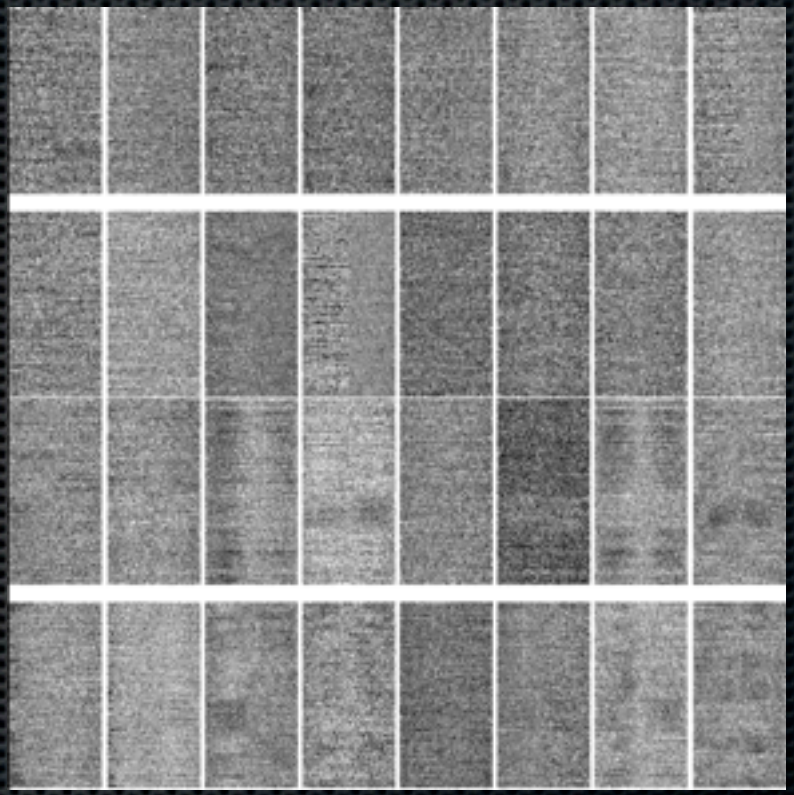

File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
File ccd00039.fits[im6]
Object Satellite INTERCOSMOS
Value 2885
WCS
Physical X 346.000 Y 305.000
Image X 346.000 Y 305.000
Frame4 Zoom 1.000 Angle 0.000
file edit view frame bin zoom scale color region wcs help
- + zoom 1/8 zoom 1/4 zoom 1/2 zoom 1 zoom 2 zoom 4 zoom 8
Satellite INTERCOSMOS
Cryo OFF
Seeing = 1.5
Elevation = 40 deg
Satellite INTERCOSMOS
Cryo ON 40 RPM
Satellite INTERCOSMOS
Cryo ON 60 RPM
Satellite INTERCOSMOS
Cryo ON 90 RPM
Satellite ISIS-1
Cryo ON 72 RPM
Satellite ISIS-1
Cryo OFF
Seeing = 1.3
Elevation = 74.5 deg
1800 2000 2200 2400 2600 2800

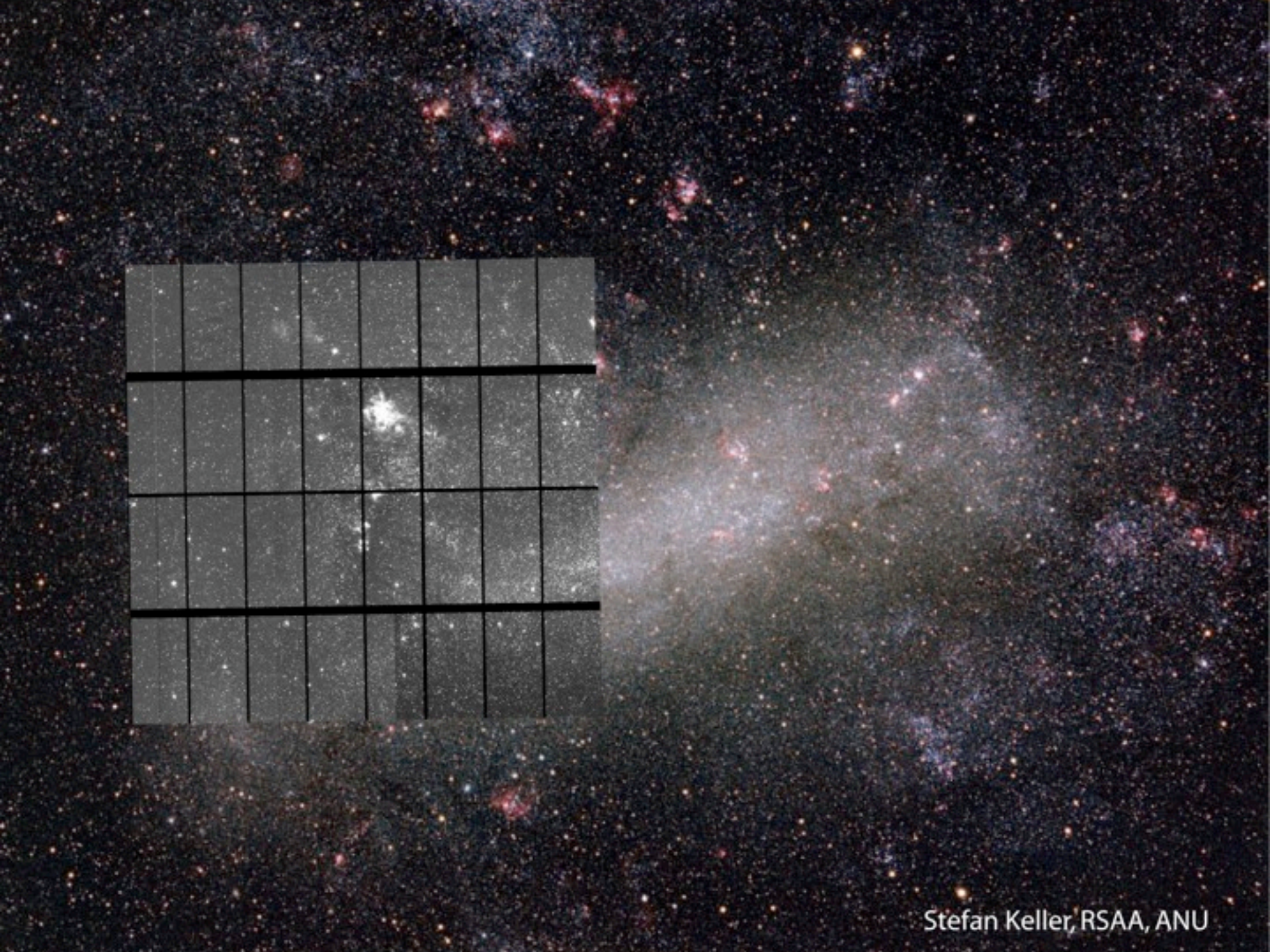
CCD Array

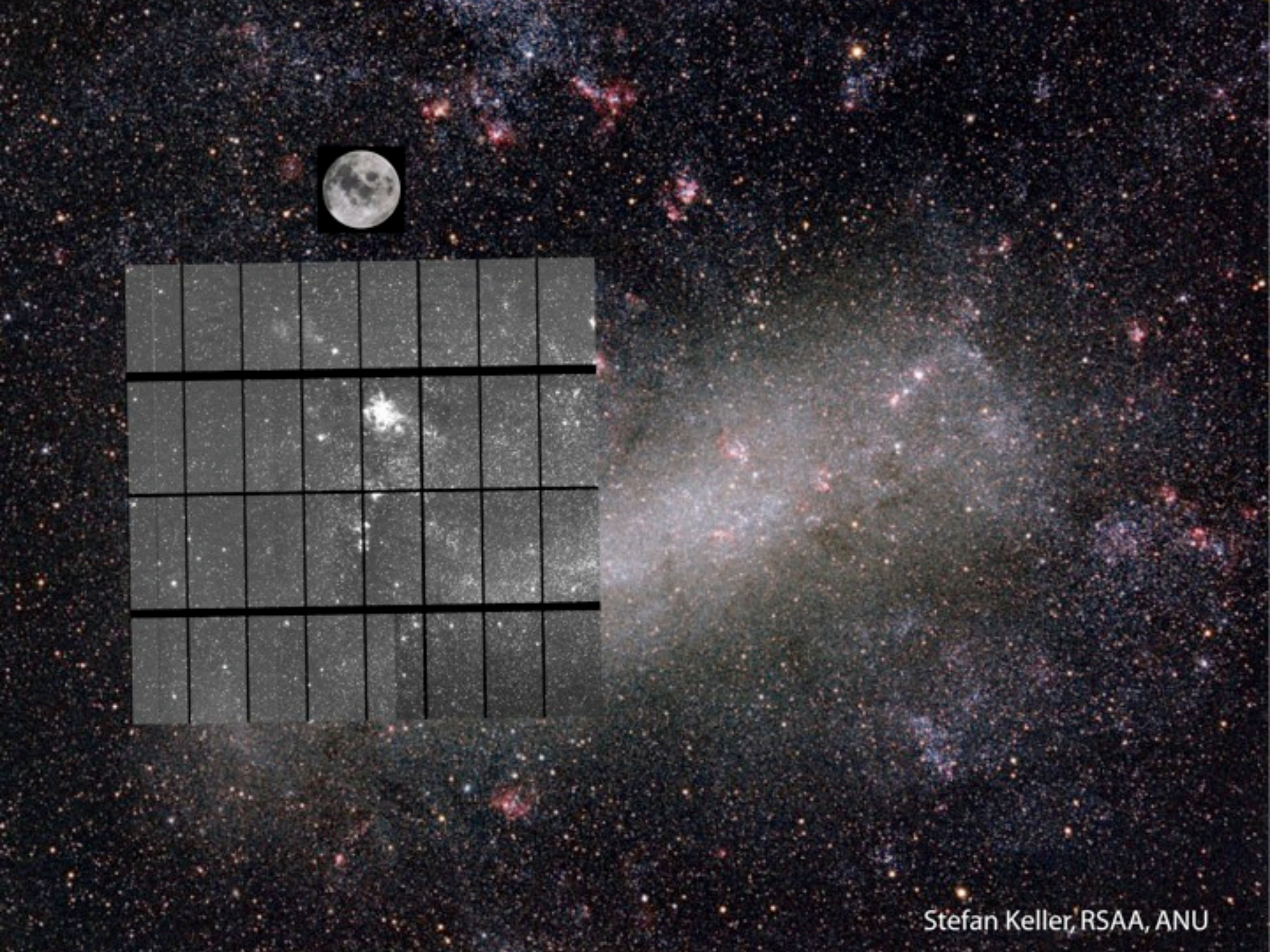
CCD Array is stable.

RN is between 6-8e- for entire array, except 2 amps - we await DAQs from Hawaii to solve. We expect to lower RN < 7e- for all amps

Total Cycle time being reduced to hopefully meet our 20s cycle time




Stefan Keller, RSAA, ANU


Stefan Keller, RSAA, ANU

It's a long way to the top of S S O

It's a long way to the top of S S O

E1 Title: The Southern Sky Survey

E2 Project Description, Aims and Background

Project Description and Aims: We propose to use the robotic Great Melbourne Telescope (GMT) to carry out an optical survey of the entire southern sky. The survey will be:

- Multi-Colour. We will observe at six wavelengths, from the near-UV to the near-IR
  1. **Photometric. We will measure the brightness of each object detected, at each wavelength, with systematic errors of less than 0.02 mag**
  2. **Astrometric. We will determine the absolute positions of the objects we detect with an accuracy of better than 0.05 arcsec.**
  3. **Sensitive to variability. Each part of the sky will be observed multiple times, to look for time variability and movement.**

The RSAA director has guaranteed that at least 80% of the Great Melbourne Telescope observing time will be devoted to this project, over 5 years. We will generate 25 terabytes of data and will detect more than 10^9 objects. All calibrated data will be made publicly available on-line via the ANU supercomputer facility.

We anticipate that the survey will be used for an enormous variety of scientific projects by astrophysicists worldwide for decades to come. The team members, however, are particularly interested in the following science goals:

- Mapping the distribution of dark matter in the outer regions of our own galaxy.
- Searching for high redshift QSOs to probe the reionisation of the universe.

It's a long way to the top of S S O

1 Jan 2003 - Our ARC DP grant starts.

E1 Title: The Southern Sky Survey

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My own picture from 20th January 2003

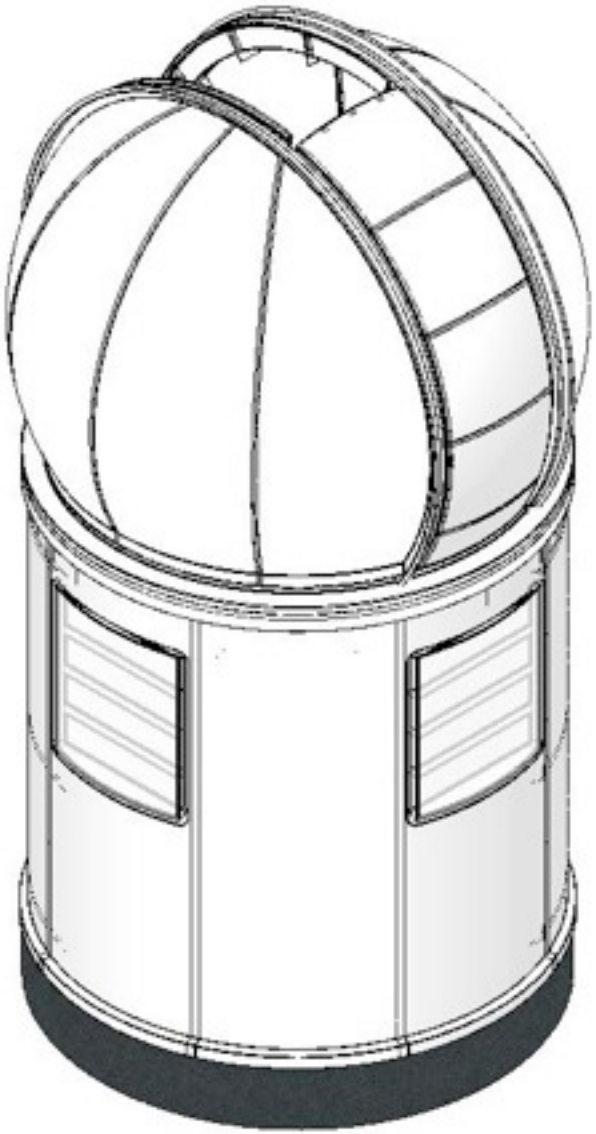
8 April 2003... Bushfire report to ARC

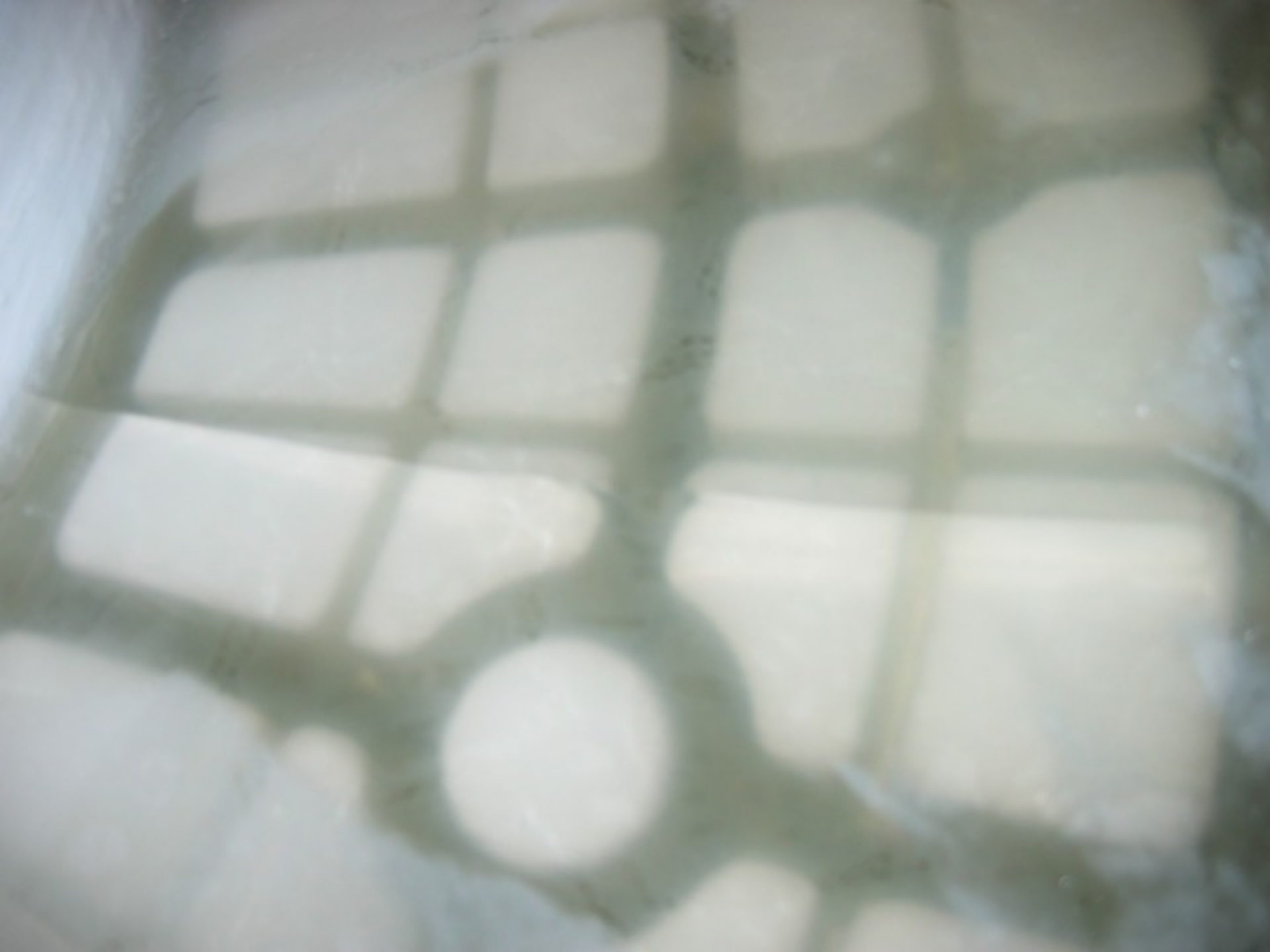
- 5. Supervise construction of a wide field (approx 7sq degree field of view) 1.8 meter telescope at Siding Spring Observatory. (New Goal)

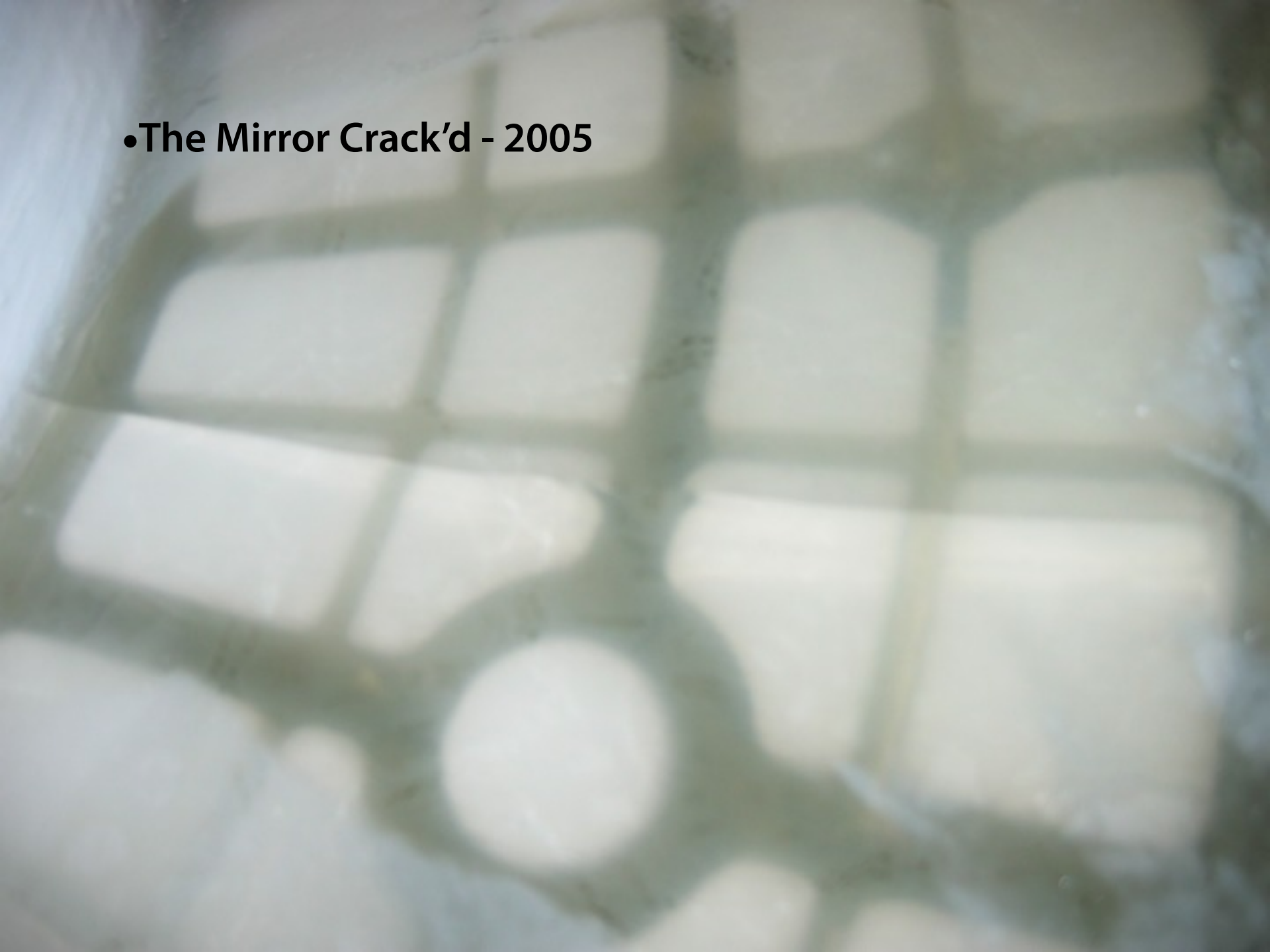
- 6. Supervise construction of a >100 million pixel CCD array for the Siding Spring Survey Telescope. (New Goal)

- 7. Start taking data for the Southern Sky survey using the new Survey Telescope.

- *Aug 2004*
- *Contract let for 1.35m SkyMapper Telescope to EOS.*







- The Mirror Crack'd - 2005


•The Mirror Crack'd - 2005
•The sequel

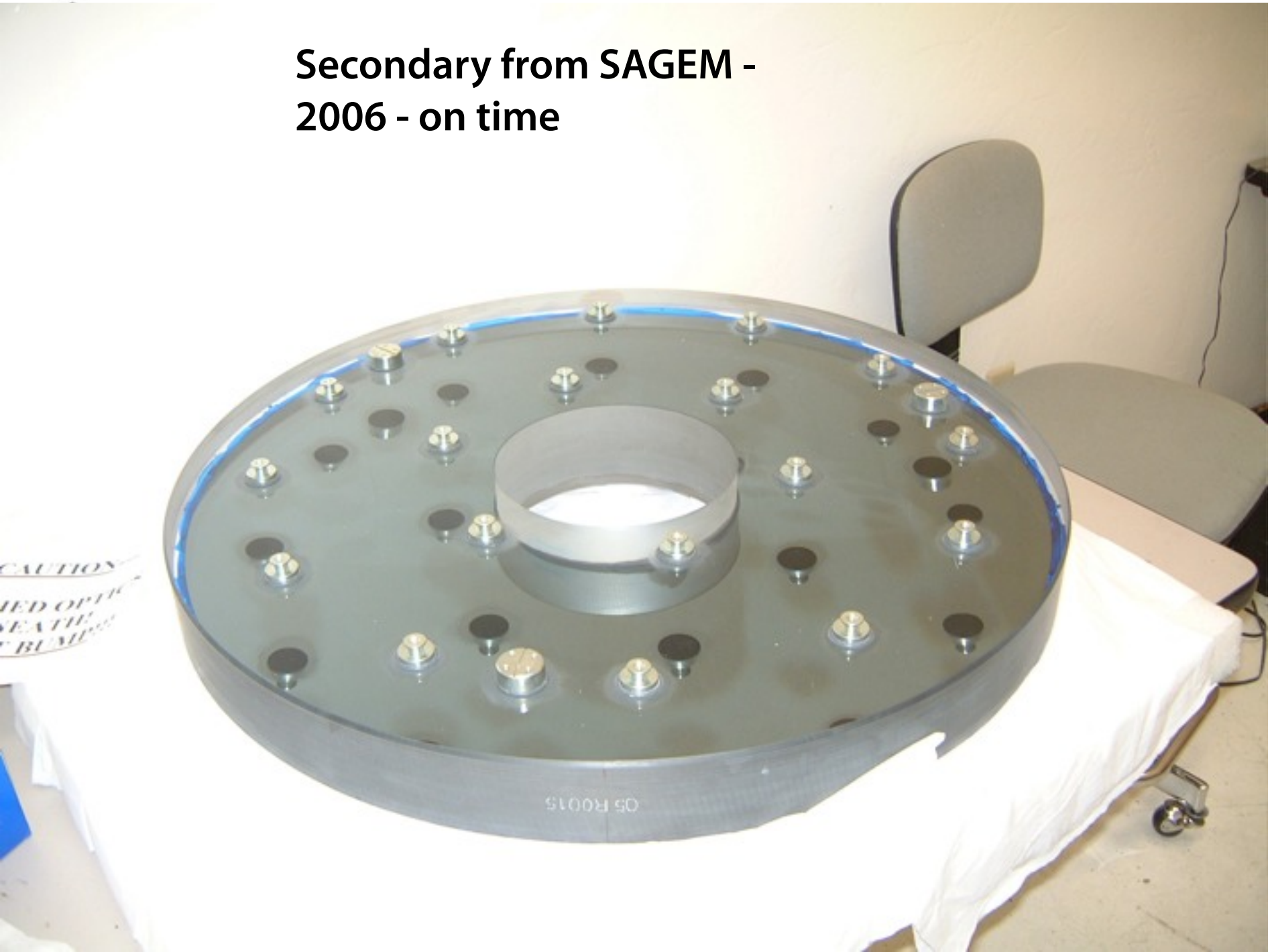

•The Mirror Crack'd - 2005
•The sequel
•The Mirror Crack'd Part III

- The Mirror Crack'd - 2005
  - The sequel
  - The Mirror Crack'd Part III
  - The Mirror Crack'd - The Final Chapter

- The Mirror Crack'd - 2005
  - The sequel
  - The Mirror Crack'd Part III
  - The Mirror Crack'd - The Final Chapter
  - Dr. Zhivago to the rescue...

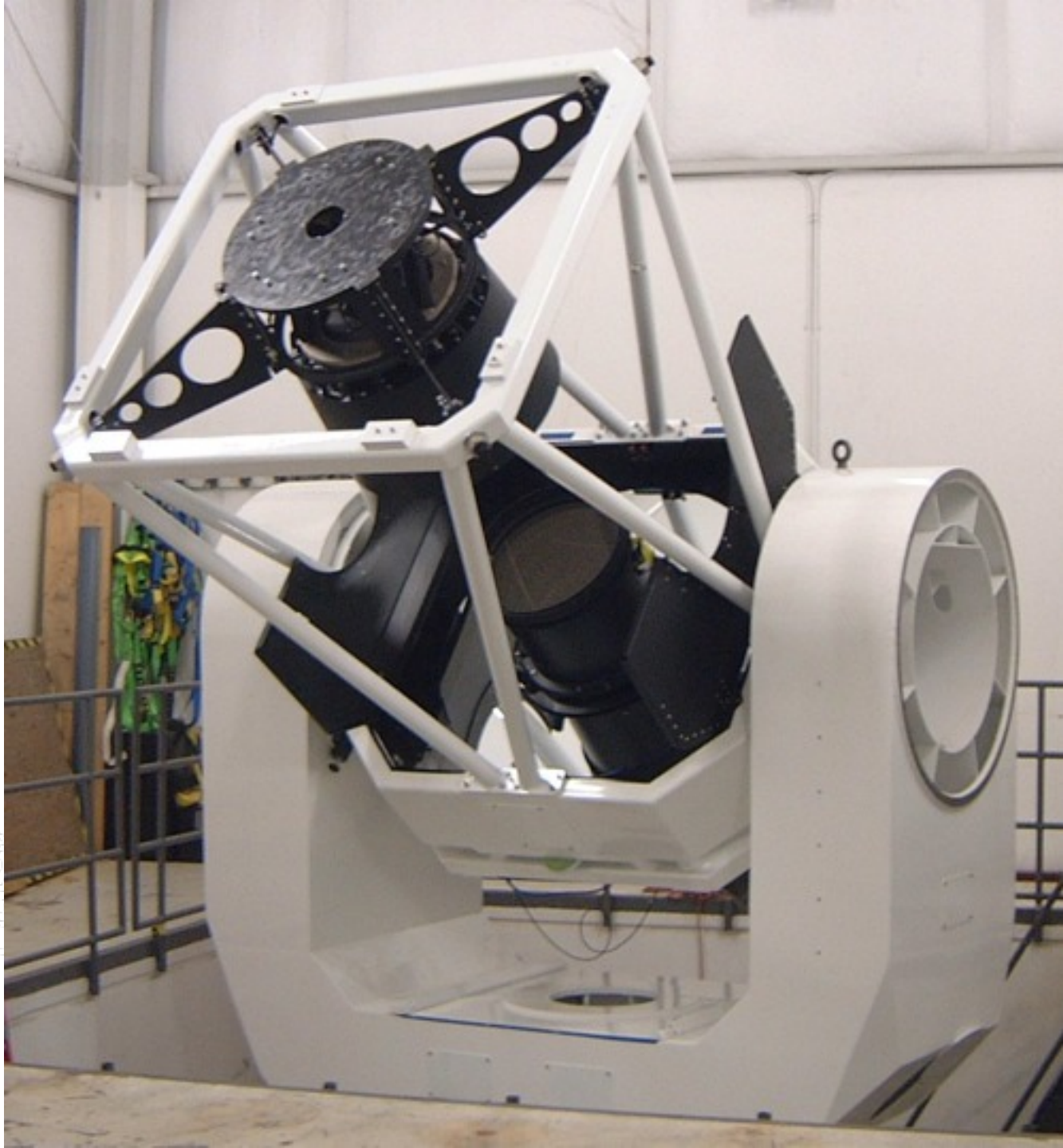
2006 - Russian Deliver more or less on time

Secondary from SAGEM - 2006 - on time



SkyMapper

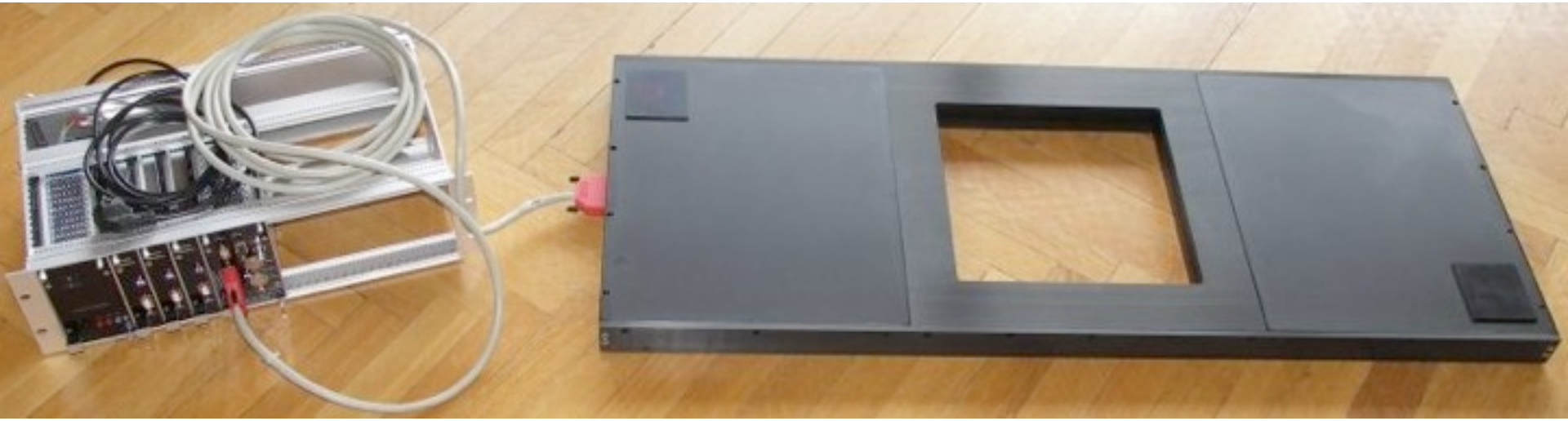
- The whole thing put together mid 2007, in Tucson



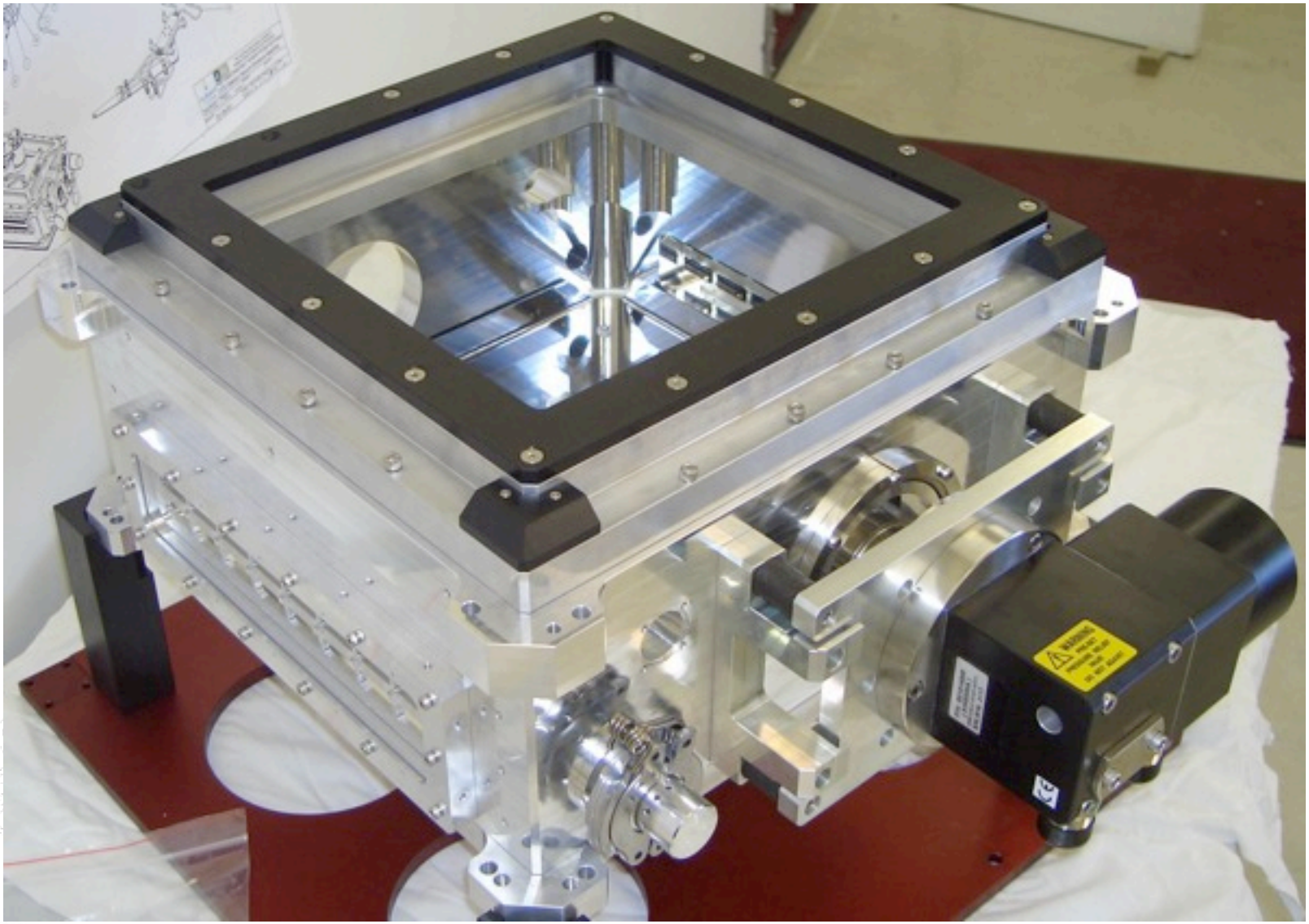
Australian National University

- First light, Tucson,
- July 2007

- **Bonn-Shutter - 2006 - arrives on time**



2006 - Focal Plane Dewar assembled




Text
ЗАКАЖИ ПИЦЦУ У ПАПЫ
ПАПА ДЖОН'С

$40,000 of filter glass from Russia...

Complete with with Cheese & Pepperoni


$2.5M of CCDs from E2V - arrive in 2006, on time


Dome - 2007


July 2008
FSCU
030584 2
22U1
FLORENS
CAUTION
OVERHEIGHT!
T-800
950-MINI

Telescope to SSO Sep 2008

Telescope to SSO Sep 2008

Telescope to SSO Sep 2008