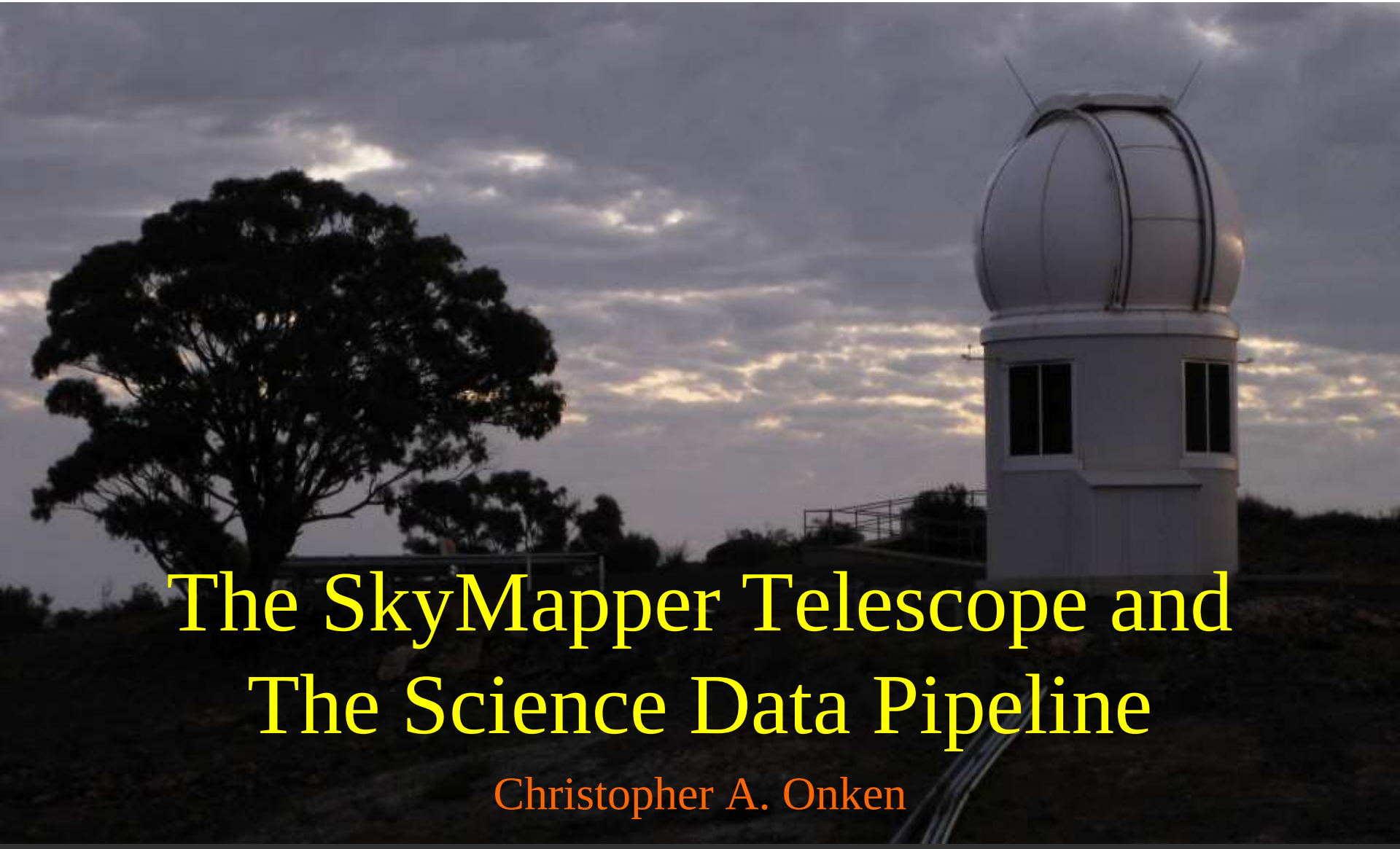


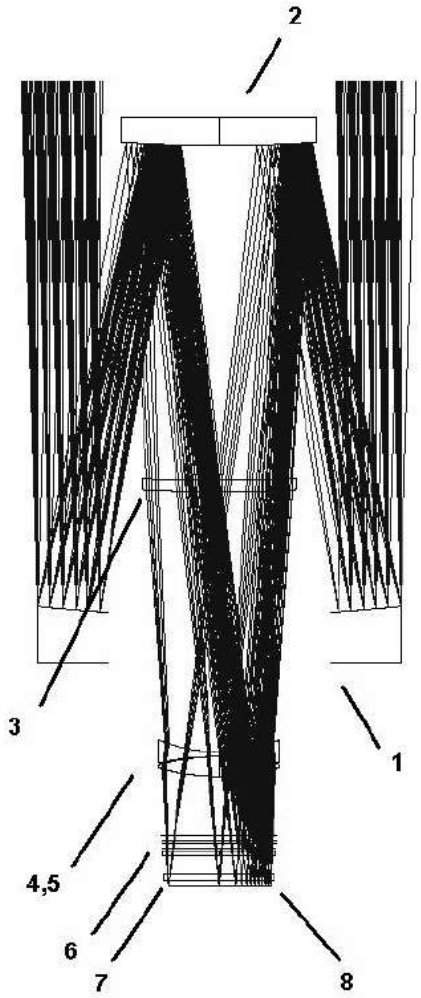
The SkyMapper Telescope and The Science Data Pipeline

Christopher A. Onken

Australian National University

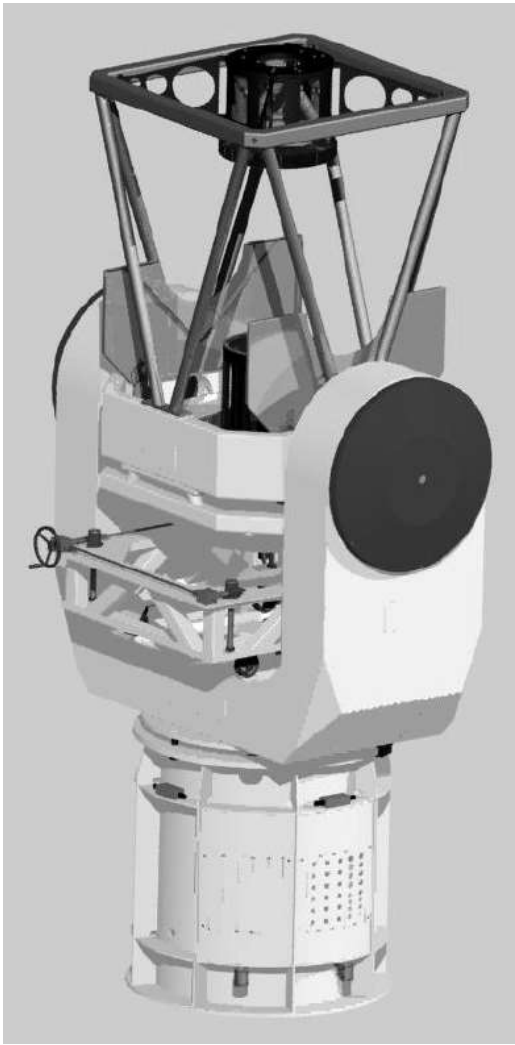
Research School of Astronomy and Astrophysics

Basic Elements



Rakich et al. 2006

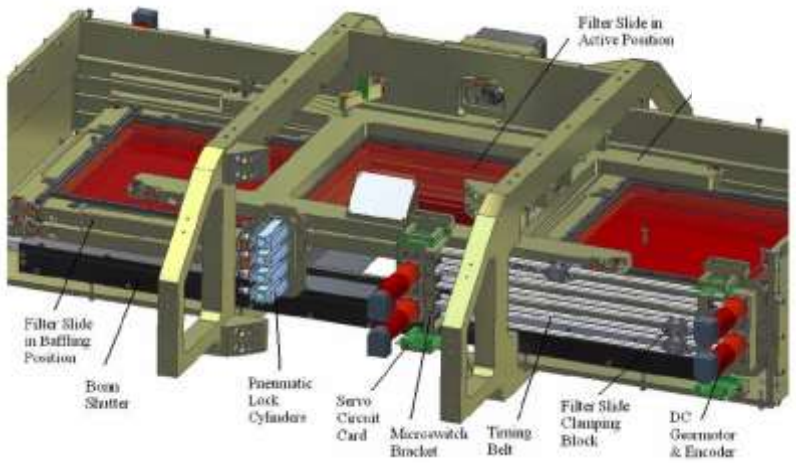
- Dome
  - EOS Space Systems (AU)
- Modified Cassegrain
  - EOS Technologies (USA)
- Primary mirror
  - 1.33m
  - LZOS (Russia)
- Secondary mirror
  - 70cm
  - SAGEM-REOSC (France)
- Corrector lens assembly
  - 3-element corrector
  - SAGEM, Kiwistar (NZ)

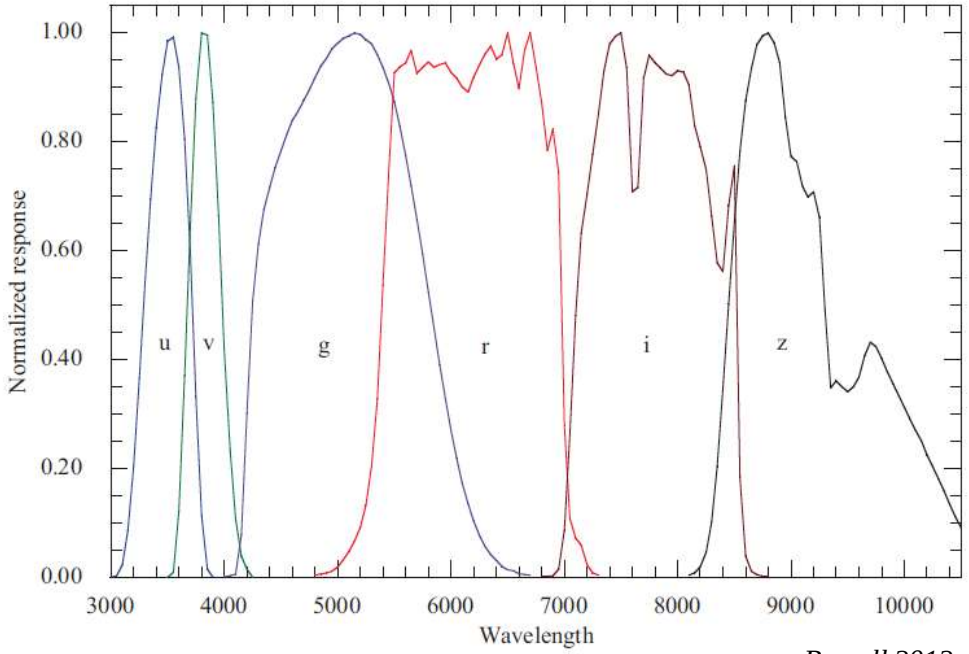


SkyMapper Filters

- 6 survey filters: *uvgriz*
  - modified version of SDSS filter set:
    - bigger gap between *u* and *g*
    - addition of narrow *v*
  - large format filters: 309 × 309 × 15mm
  - *uvgz*: coloured glass
  - *i*: glass + short-λ coating
  - *r*: full dielectric coating
  - *u*: 0.7% red leak @ 7170Å
  - fabrication described by Bessell et al. 2011

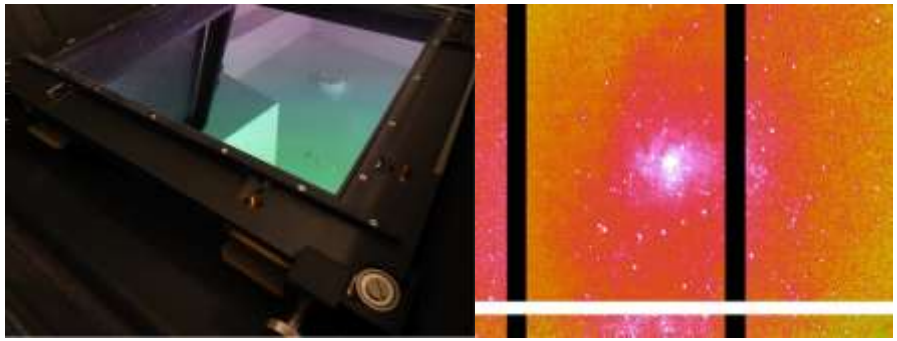
Granlund et al. 2006



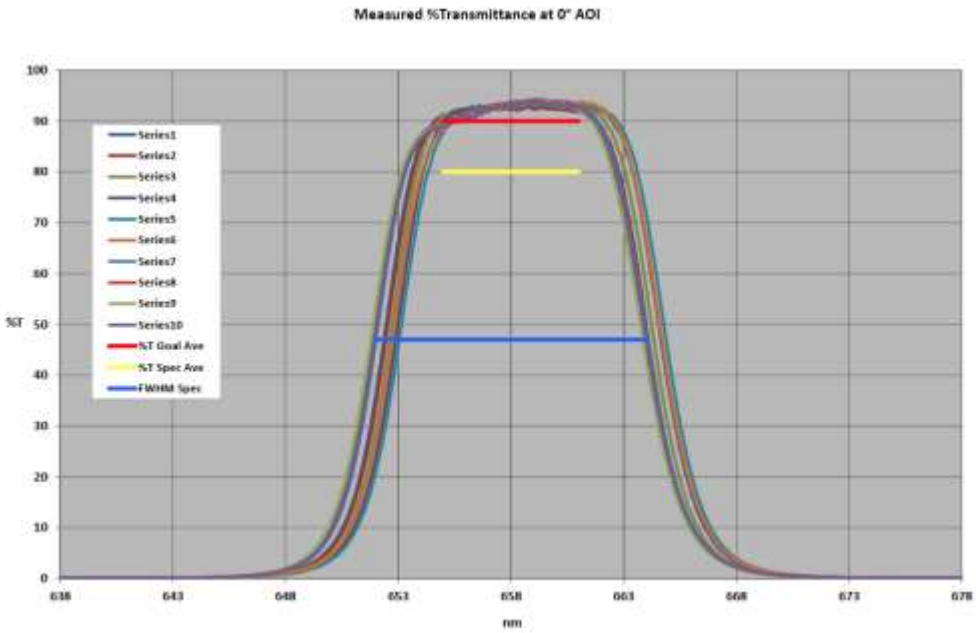


Bessell 2012

Hα Filter



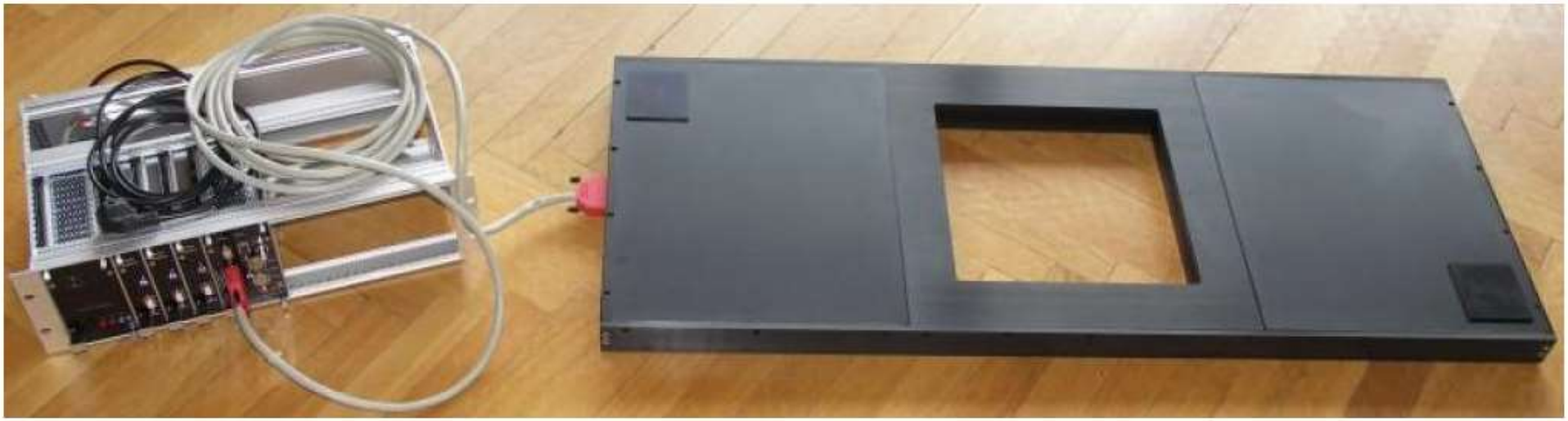
Courtesy G. Bloxham



- New Hα filter manufactured by Materion (née Barr)
- First images taken in December 2013
- Quality is excellent
- Filter mechanism only holds 6 filters ➔ Hα installed for limited periods of time
- Not currently part of Southern Sky Survey

Bonn Shutter

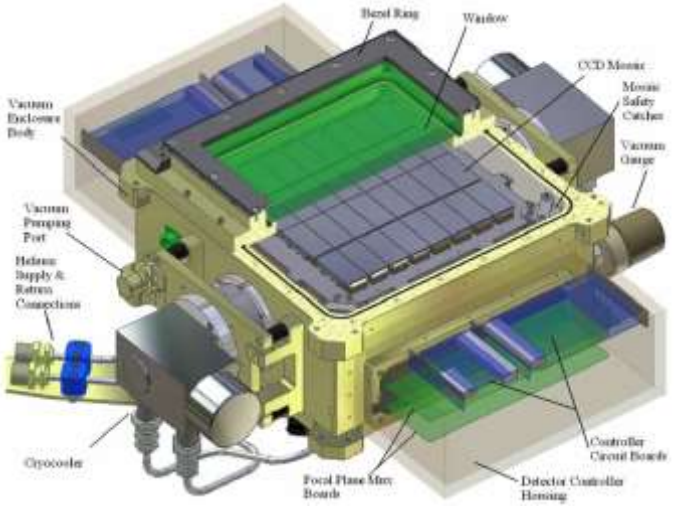
- High-precision shutter
  - Designed for exposures as short as 1ms, but system currently limited to exposure time of 1s
  - 0.3% homogeneity
  - University of Bonn



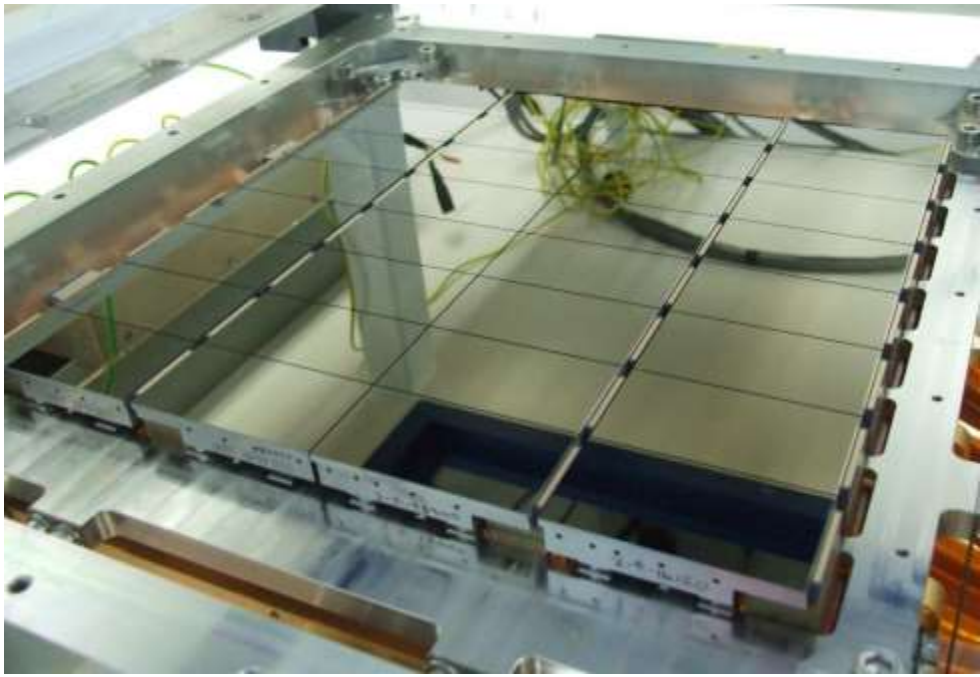
Granlund et al. 2006

Detector

- 32 2k × 4k CCDs
  - 15 μm pixels, 0.5”/pixel
  - 268 million pixels
  - 90% filling of 5.7 deg^2
  - deep-depletion for red sensitivity while limiting fringing
  - e2v 44-82 devices
  - Gain ≈ 1 e$^-$/ADU
  - 2 amplifiers/CCD
- Readout time: 12.09s
- Median time between images: 21s



Granlund et al. 2006



Courtesy P. Oates

Stefan Keller, RSAA, ANU

CHALLENGES ALONG THE WAY

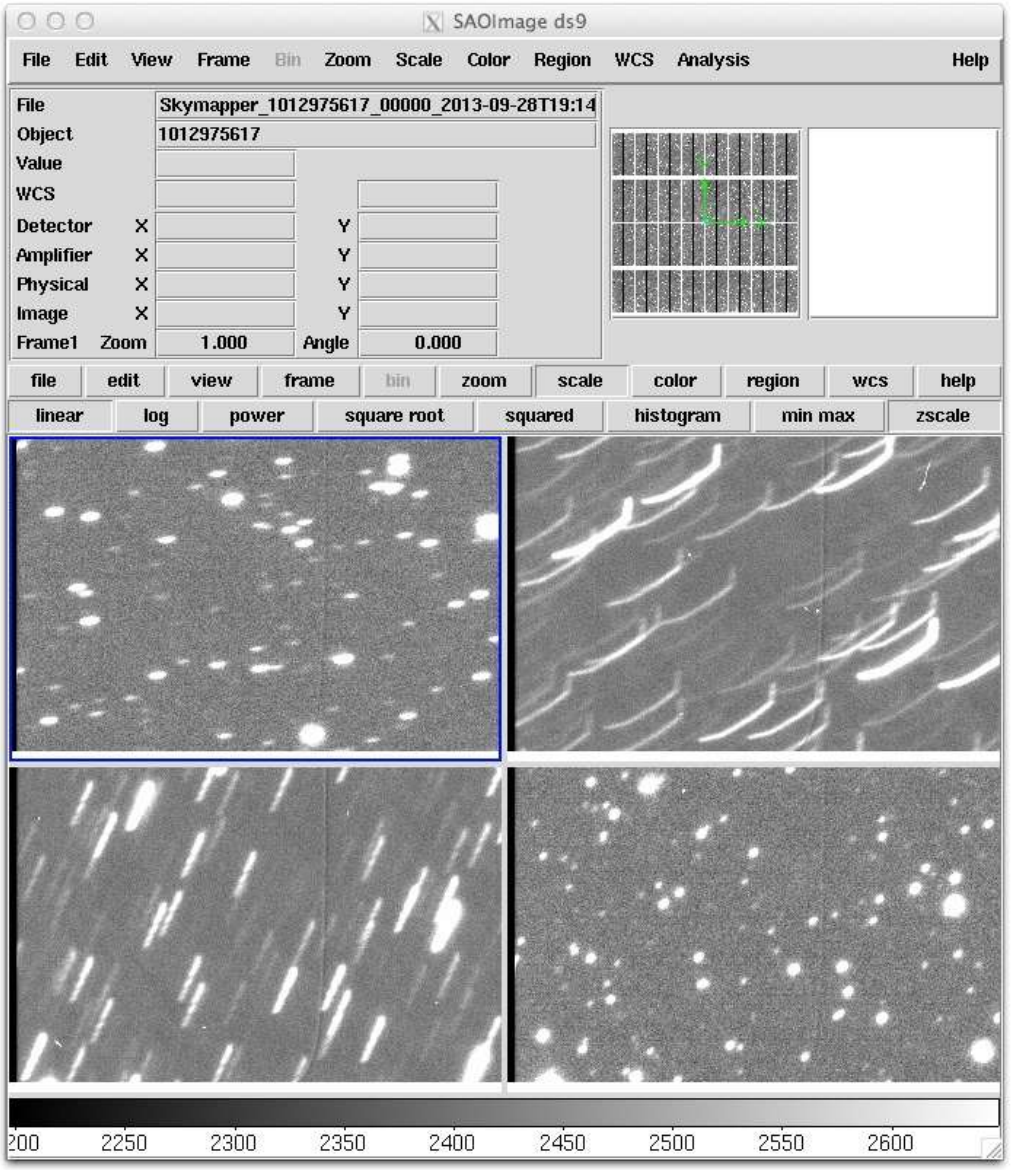
Ladybirds

- 50 kg of ladybird beetles removed from dome

Tracking

Courtesy I. Adams

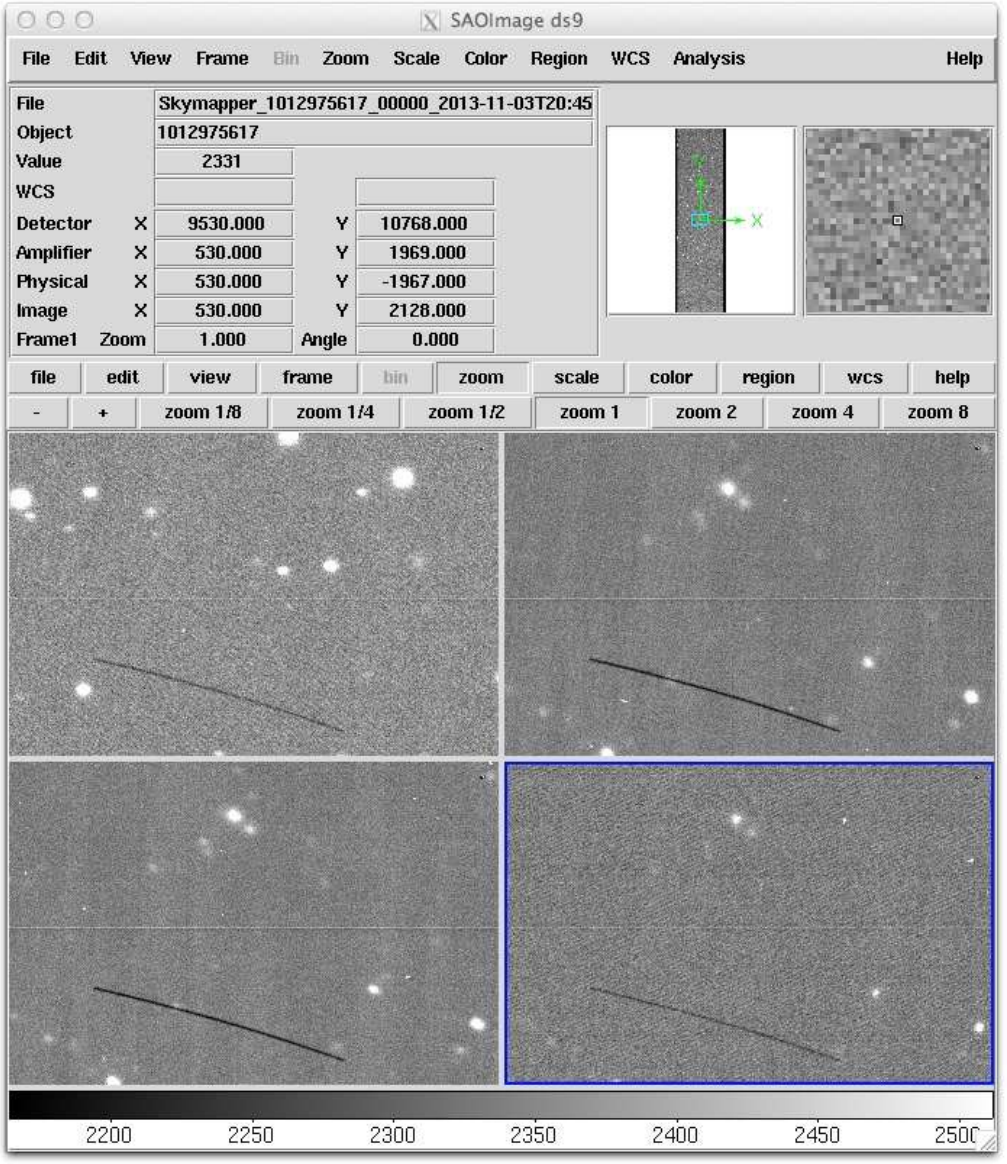
150 sec	1500 sec
1500 sec	150 sec



Tracking

- Cleaned elevation and azimuth encoder tapes

- Additional contribution to tracking problems from resource-hogging process on TCS computer



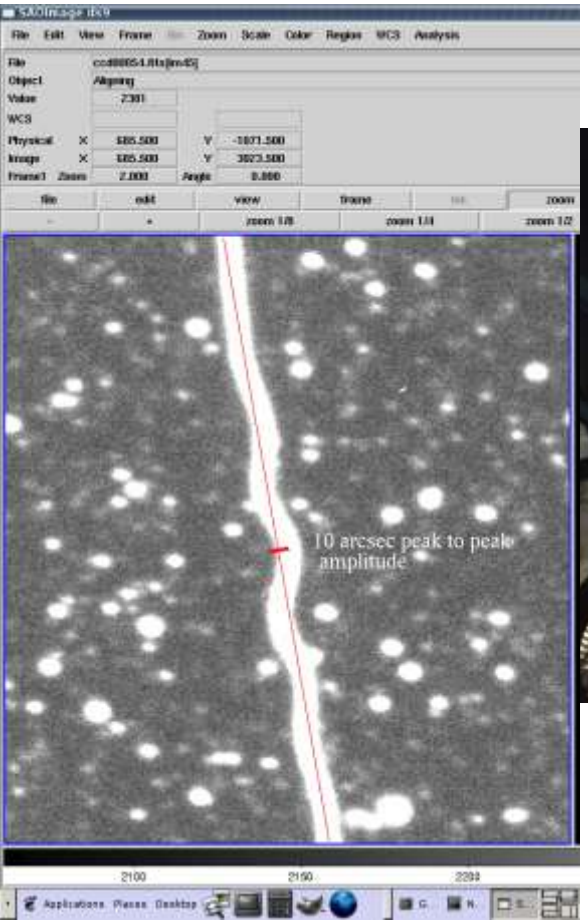
13 January 2013

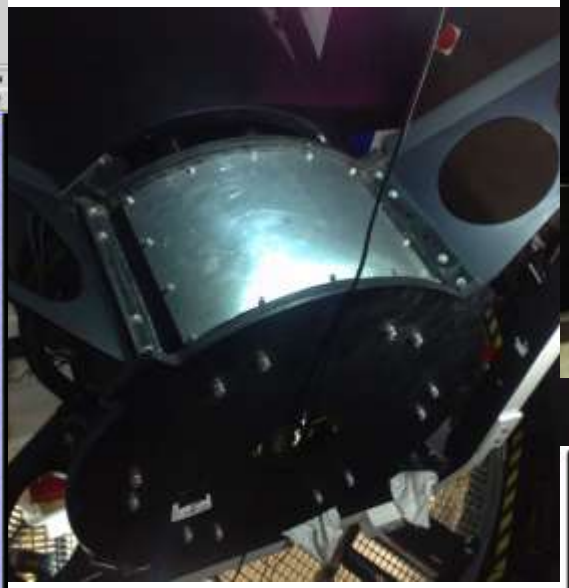
Courtesy The Northern Daily Leader

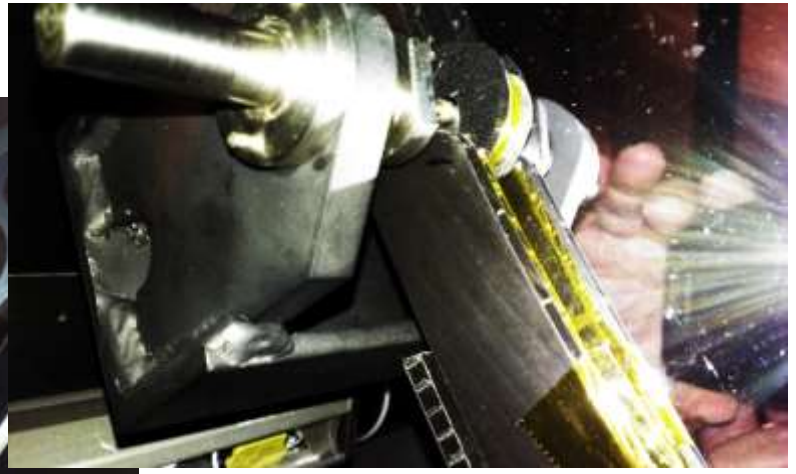
HAT-South Webcam

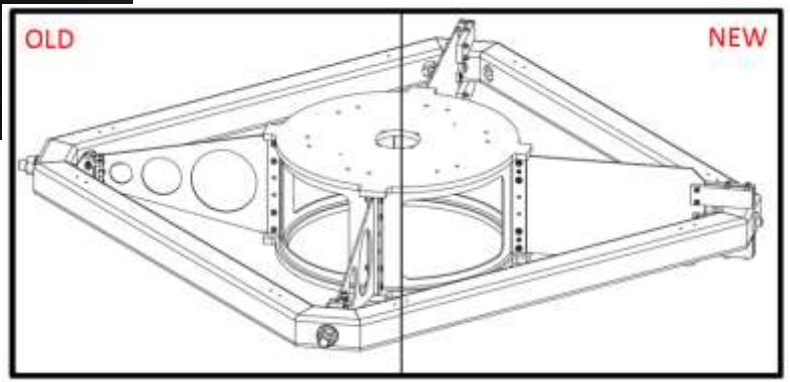
Courtesy I. Adams

Telescope Vibrations



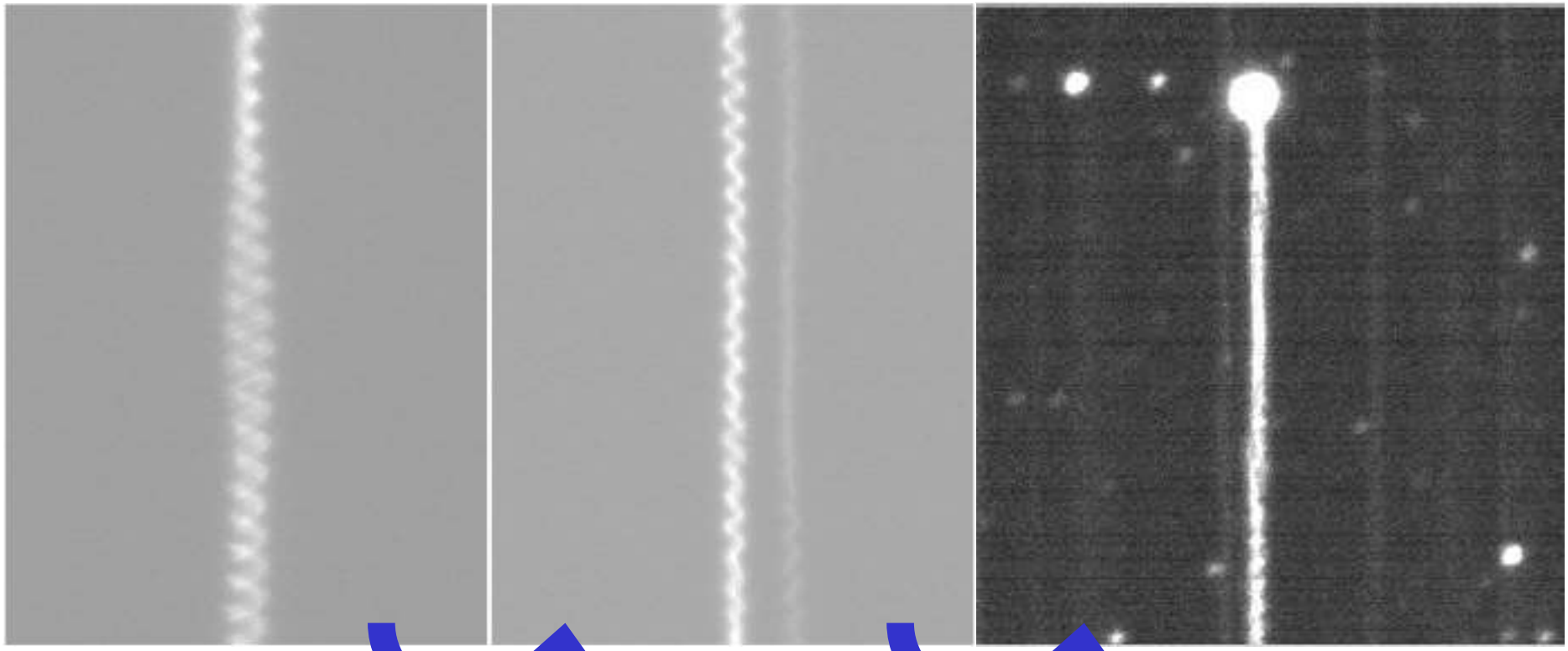






Courtesy J. Hart & G. Bloxham

Telescope Vibrations

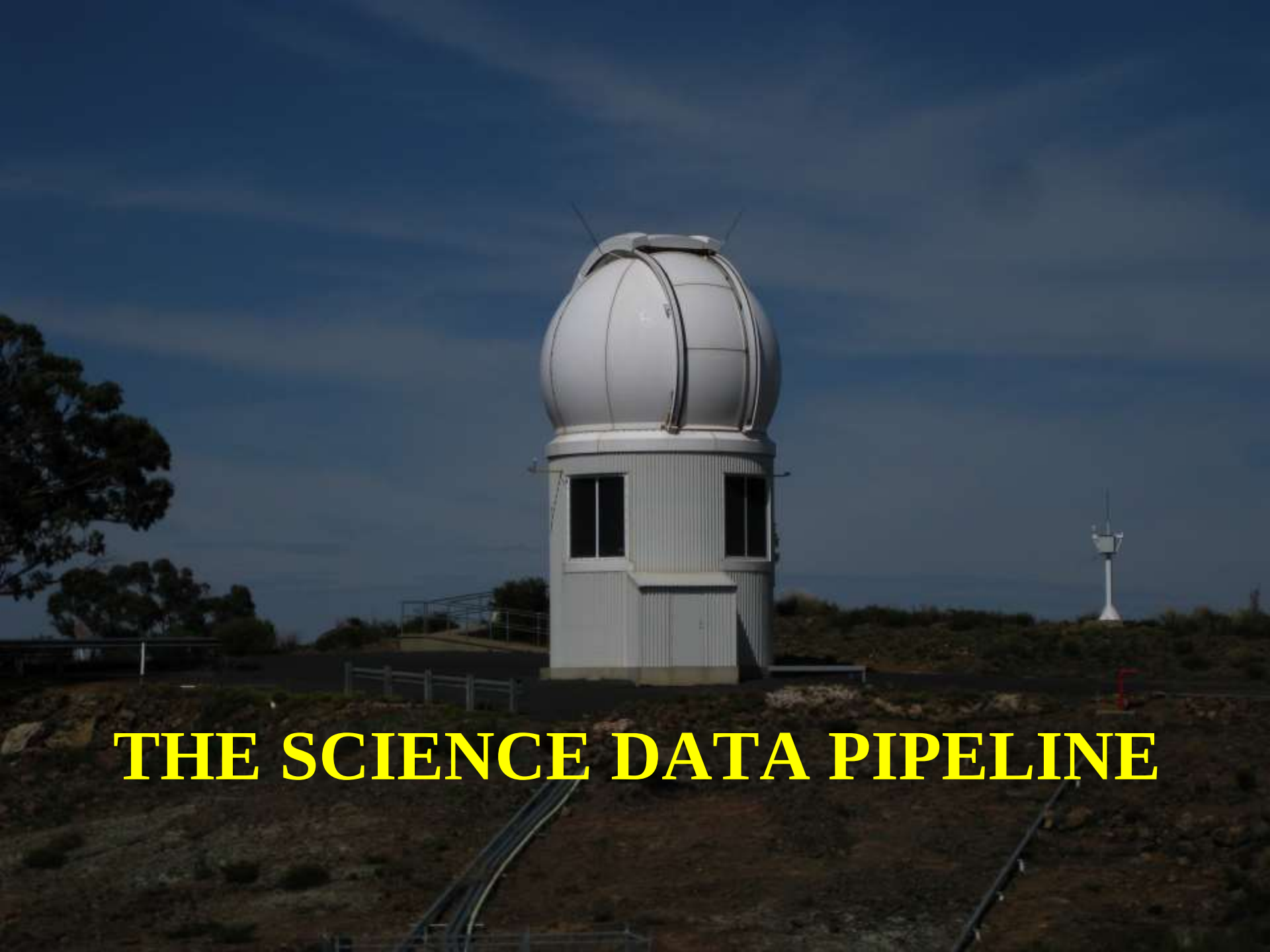


Primary Clamping

Spider Vane Stiffening

Telescope Automation

- Automatic monitoring of light, clouds, humidity, rain, wind, and system status
- Scheduler queues all calibration and science observations through the night
  - including 3rd-party and Target-of-Opportunity observations
- After morning calibrations, scheduler stops itself and e-mails a nightly summary to Operations staff



THE SCIENCE DATA PIPELINE

Moving The Pixels

- A winter night's observing could generate 900+ images
  - Each image is 563 MB
- The next morning, raw images get transferred from SkyMapper to the National Computational Infrastructure (NCI) for archiving on "massdata"
  - Current transfer rates fluctuate between 15 MB/s and 50 MB/s
  - Upgrades of fibre link being considered (led by CSIRO for VLBI science)

- Current model:
  - Pull data from massdata to an active filesystem ("short")
  - Process through the SDP
  - Archive results to massdata

- Forthcoming model:
  - Pull data to new SDP server at RSAA
  - Process through the SDP
  - Archive results to massdata

NCI PROVIDING AUSTRALIAN RESEARCHERS WITH WORLD-CLASS HIGH-END COMPUTING SERVICES

Data Prep

- Nights are processed as a unit
- Each image is ingested into the SDP
  - From 64 extensions in each integer FITS image, data are merged into 32 floating-point FITS images (one per CCD)
  - Overscan correction (by-line fit to pre- and post-scan)
  - Trimmed to science region
  - Saturation and cross-talk are flagged in bad pixel mask
  - Cross-talk (~0.05%) is corrected
  - Basic image info is recorded in SDP database

Calibrations

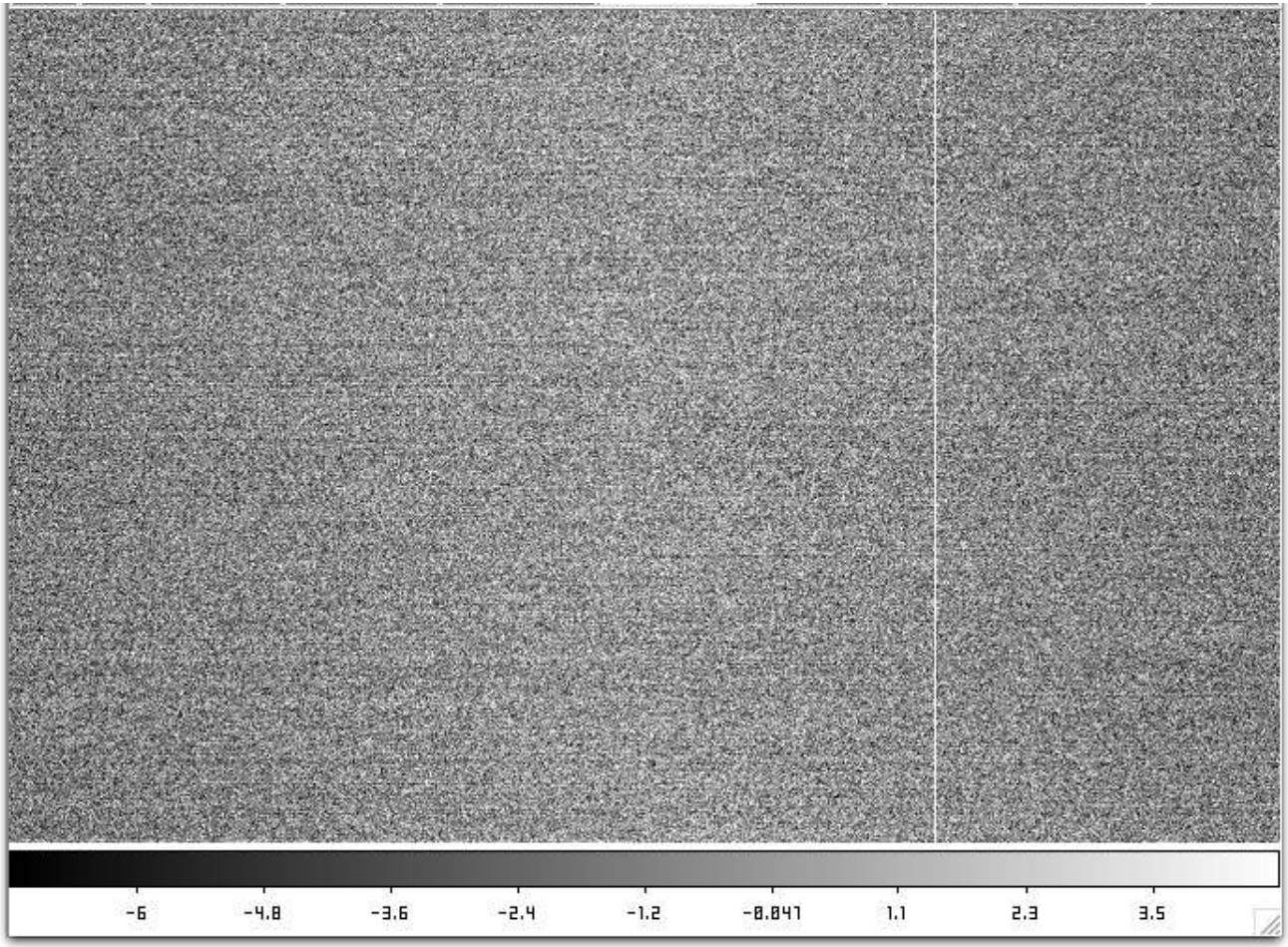
- Biases
  - created, but not currently applied in the SDP
- Flats
  - evening and morning twilight flats taken when possible
- Fringes
  - generated for reddest filters from images of sparse fields having sufficient exposure time
- Illumination Correction
  - manual process (not created within SDP)

Generated for each night with sufficient number of input images

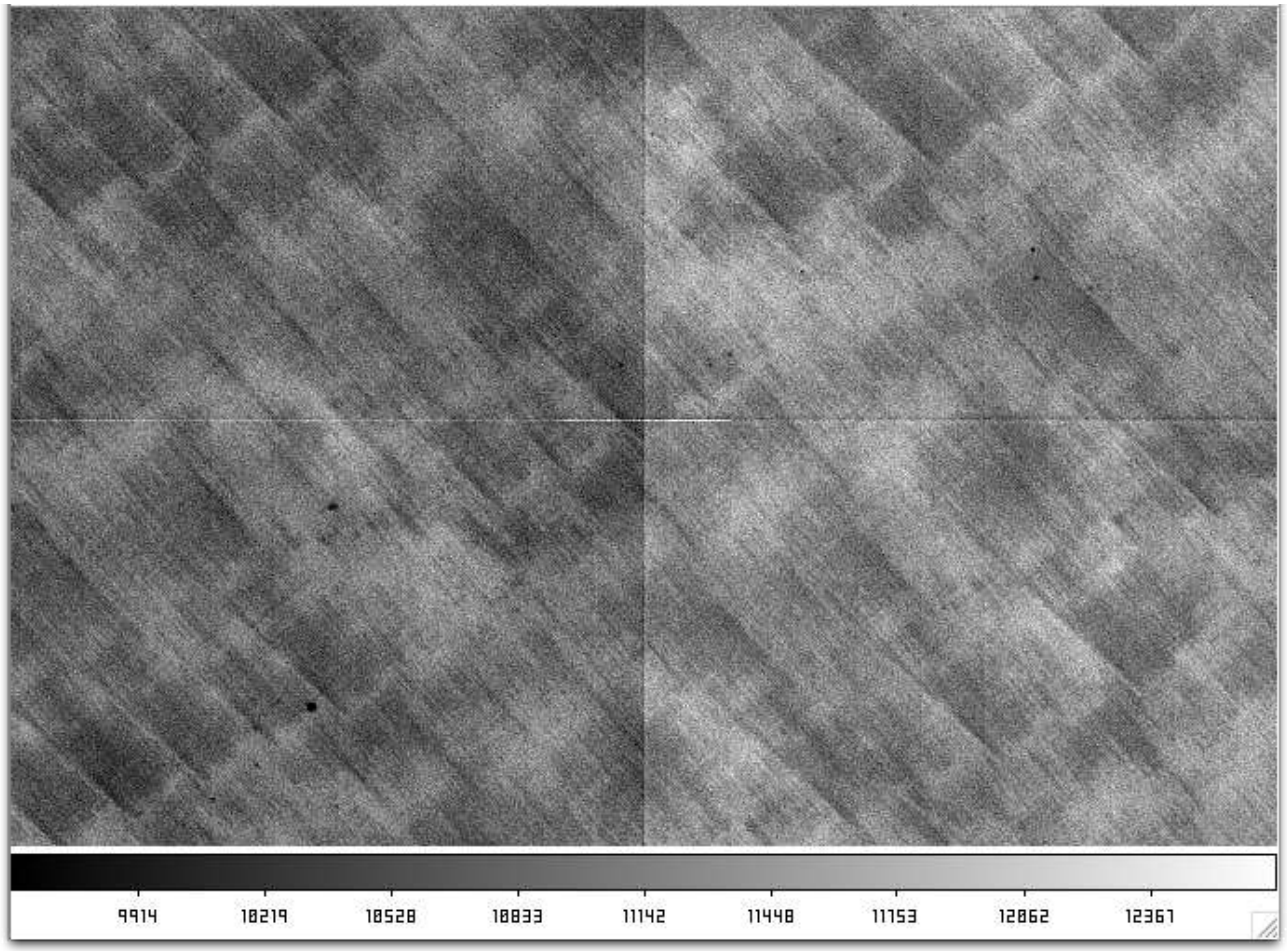
Compared against previous “approved” calibration (valid up to 30 days)

Stats & images presented for SDP-operator consideration

Bias



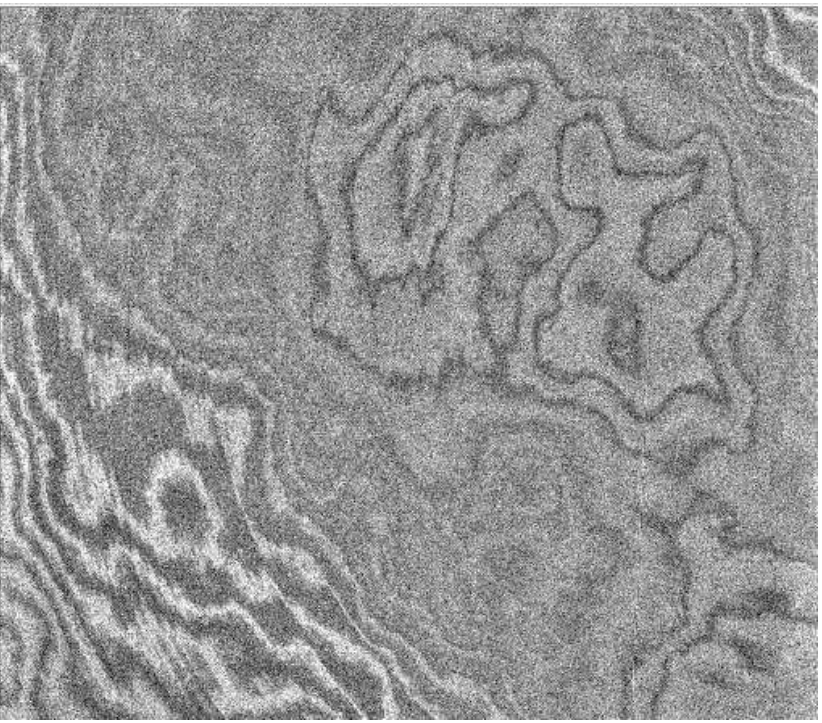
Flats

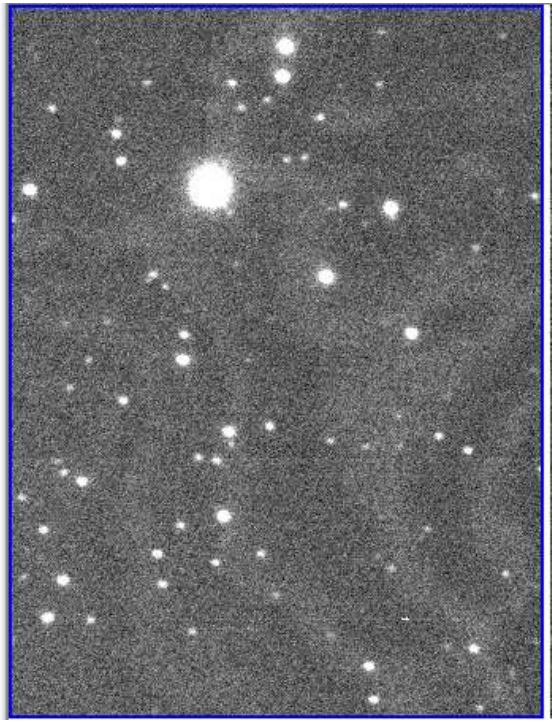


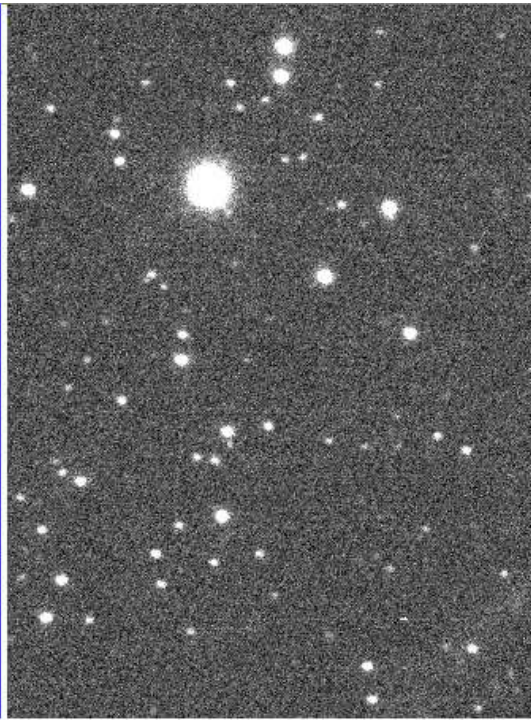
Cross-hatch pattern from laser annealing. Seen in *u* and *v* frames.

Fringing

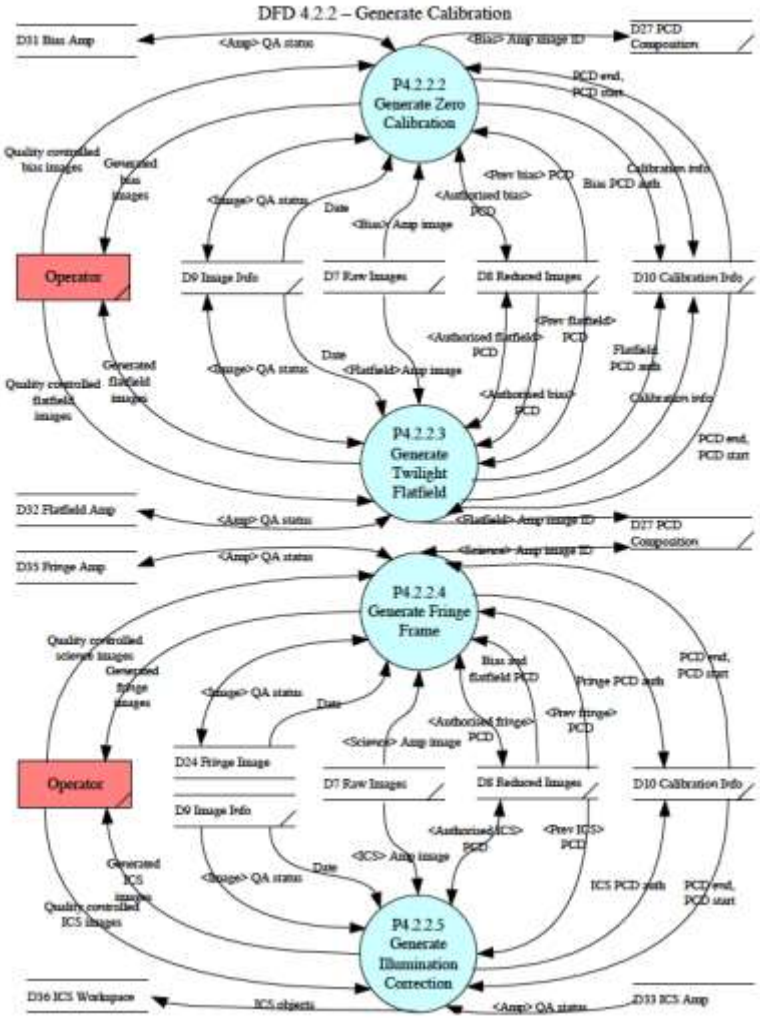
z-band







Calibrations



Science Data

- All science images receive basic processing:
  - Corrected for overscan & cross-talk, trimmed, merged into 32 individual images, bad pixel mask created (at SDP ingestion)
  - (Bias frame not currently applied)
  - Flatfielded (including correcting for CCD-to-CCD gain differences)
  - Fringing scaled and subtracted (if applicable)
  - Illumination-corrected

Science Data

- After basic calibration, frames receive preliminary World Coordinate System (WCS) from local installation of Astrometry.net
- Customised version of Source Extractor measures astrometry and photometry
- Compare against 2MASS catalogs
  - generates final WCS solution, accounting for distortions in focal plane via TNX parameterisation (tangent projection + polynomial terms)
  - photometric zero-point estimated using catalog sources with (J-K)=0.3-0.6 [G/K stars]

End of First SDP Phase

- For each original science image, we now have
  - 32 overscan-corrected, cross-talk-corrected, flatfielded, de-fringed, illumination-corrected, WCSed images with rough zero-points
    - 33.6 MB × 32 FITS files = 1.00044 GB
  - 32 bad pixel masks
    - 8.1 MB × 32 FITS files = 256 MB
- **Non-survey images exit the SDP here**
- Standard Field & Short Survey photometry for the night is calculated next
- Main Survey photometry is calculated when a field has a complete dataset