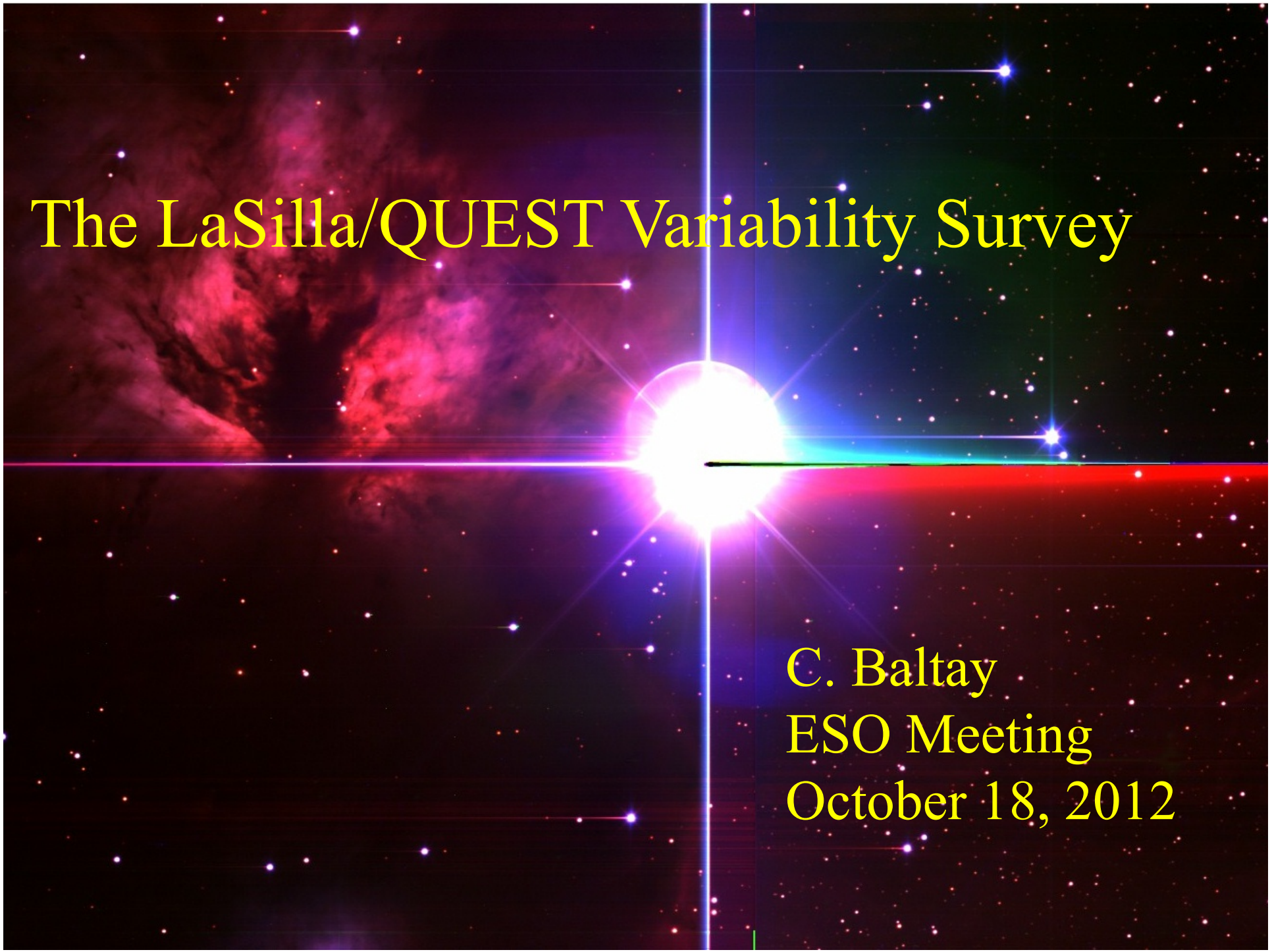

The LaSilla/QUEST Variability Survey
C. Baltay
ESO Meeting
October 18, 2012

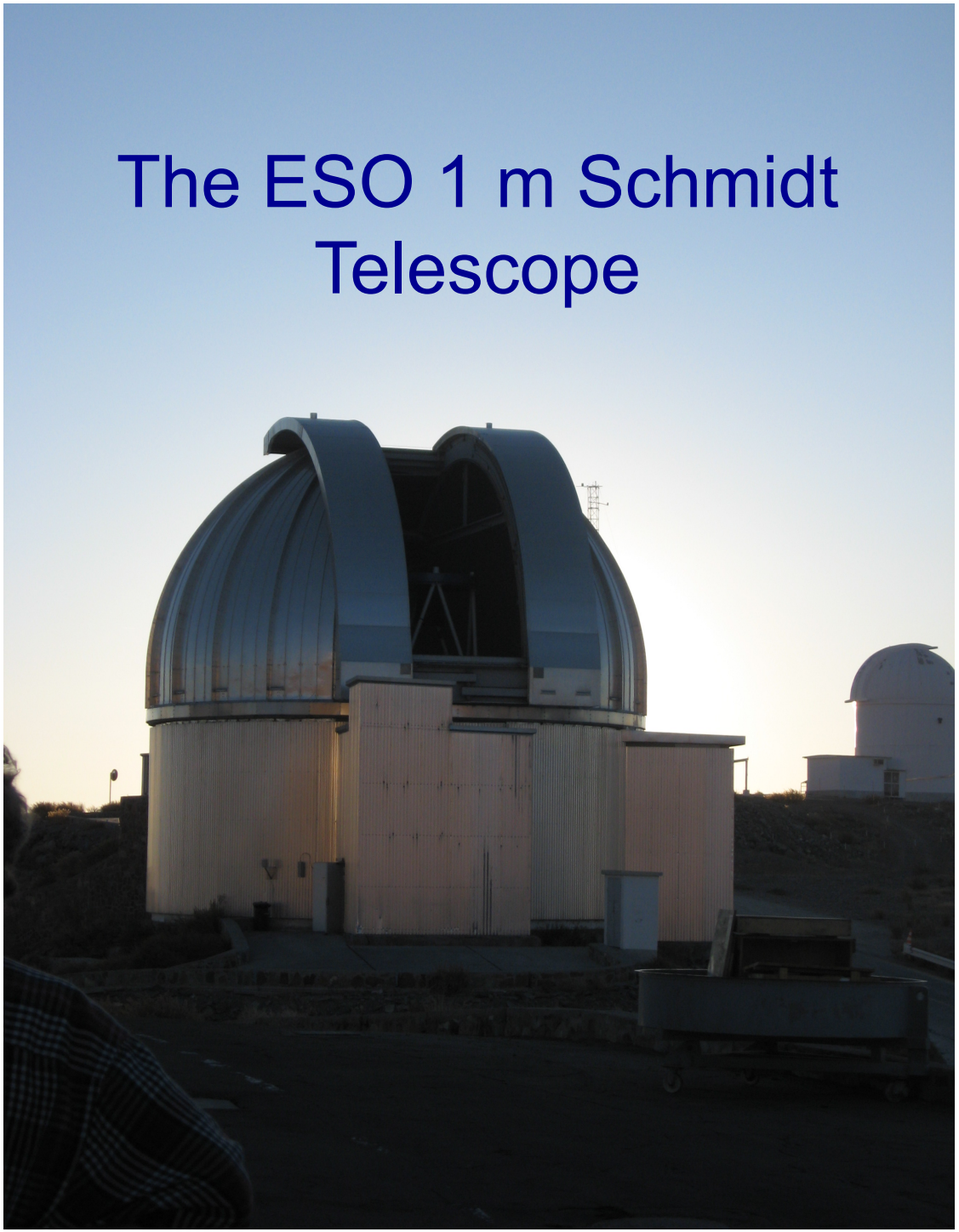
The La Silla/QUEST Variability Survey

- Southern Hemisphere survey of ~20,000 square degrees (south of +25^{o} declination)
- Repeated scans of the same area of the sky with a 2 day cadence to find variable and transient objects
- Scientific motivation
  - Collect a large sample of well studied nearby supernovae for cosmological studies
  - Search for Trans Neptunian Objects (TNO's) and small planets in our solar system
  - RRLyrae variable stars
  - Other unusual transients

Instrumentation of the Survey

- The ESO 1 m Schmidt Telescope at the La Silla Observatory, available essentially full time to this survey except for the 10% potentially available to Chilean users.
- The 10 square degree QUEST Camera, permanently installed at the prime focus of the telescope
- A dedicated radio link to Cerro Tololo which we designed and built to allow real time transfer of 50 to 100 Gigabytes of data each night.

The ESO 1 m Schmidt Telescope

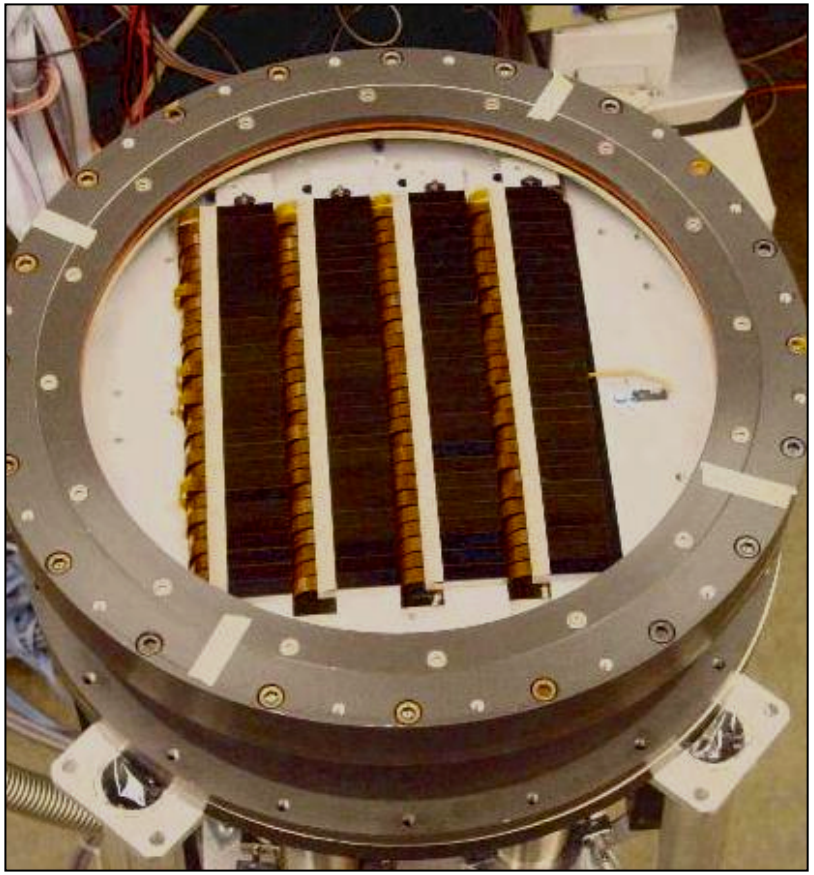


The ESO Schmidt Telescope

Properties of the telescope

- 1 m clear aperture
- f/3 (3 m focal length)
- 15 microns/arcsec plate scale
- Curved primary focal plane
- Located 30^{o} south of the equator

The 10 Square degree QUEST Camera

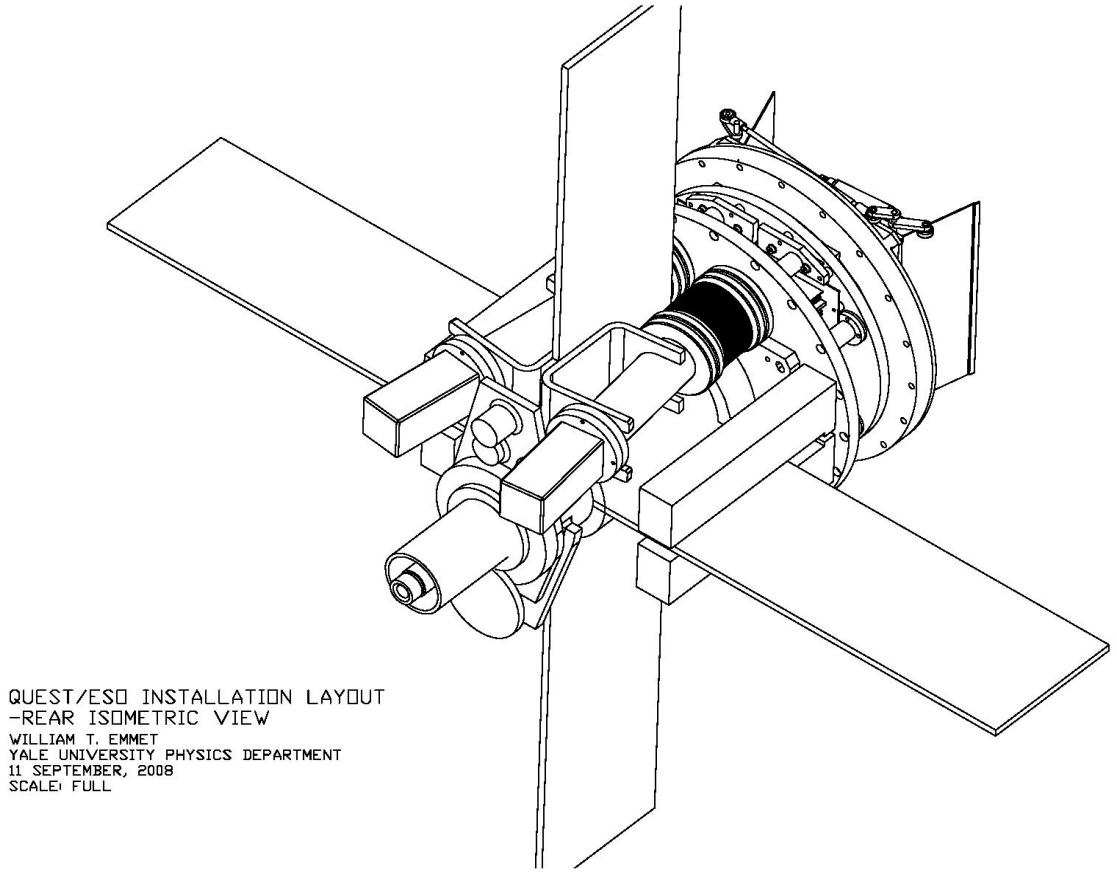


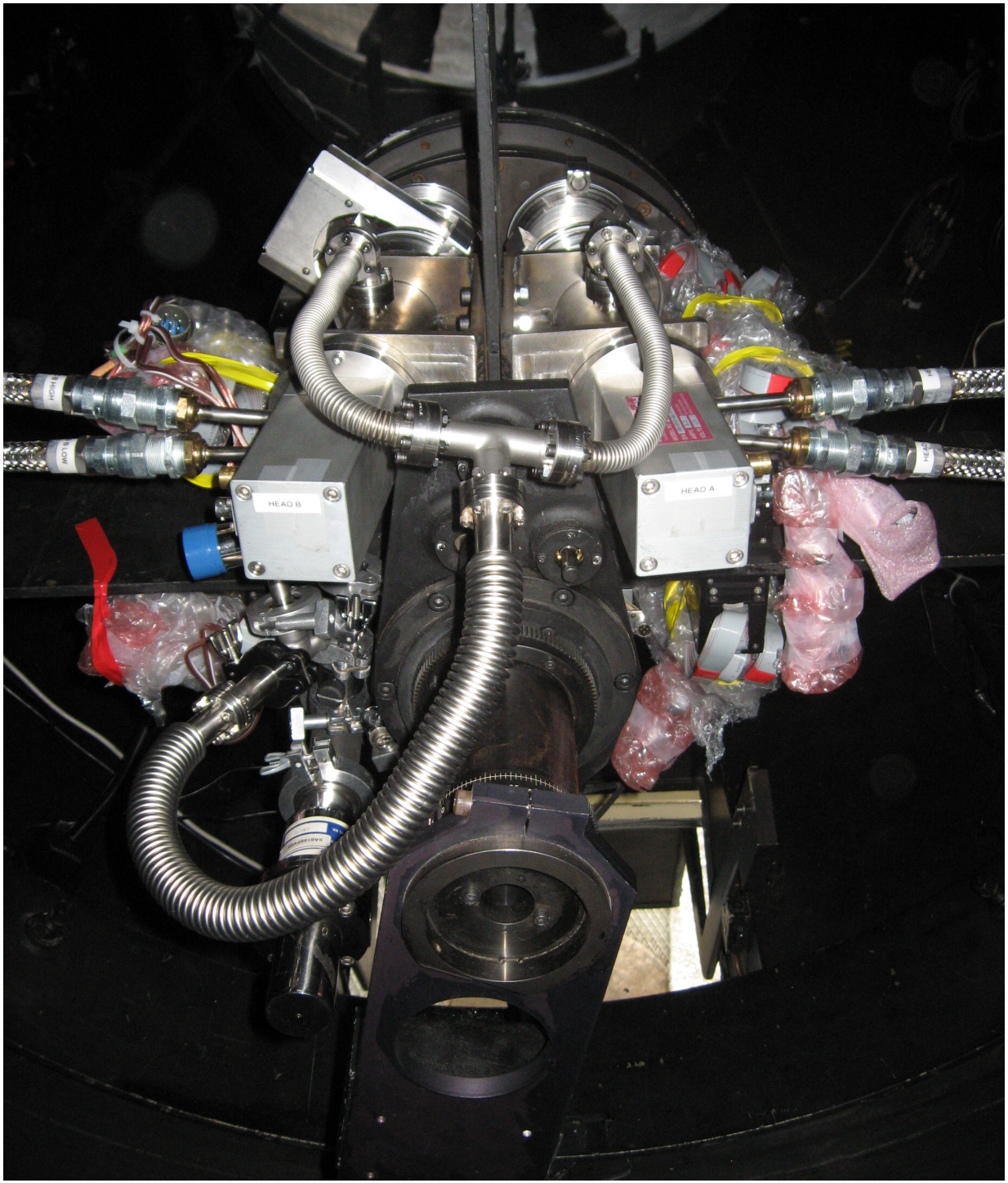
Property	Value
Number of CCDs	112
For each CCD:	
Pixel size	13μ x 13μ
Number of pixels	600 x 2400
Pixel size on sky	0.876" x 0.876"
Array size, CCDs	4 x 28
Array size, pixels	9600 x 16,800
Array size, cm^2	19.3 x 25.0
Array size on sky	3.6^0 x 4.6^0
Sensitive area	9.6 sq deg
Total pixels	161 x 10^6

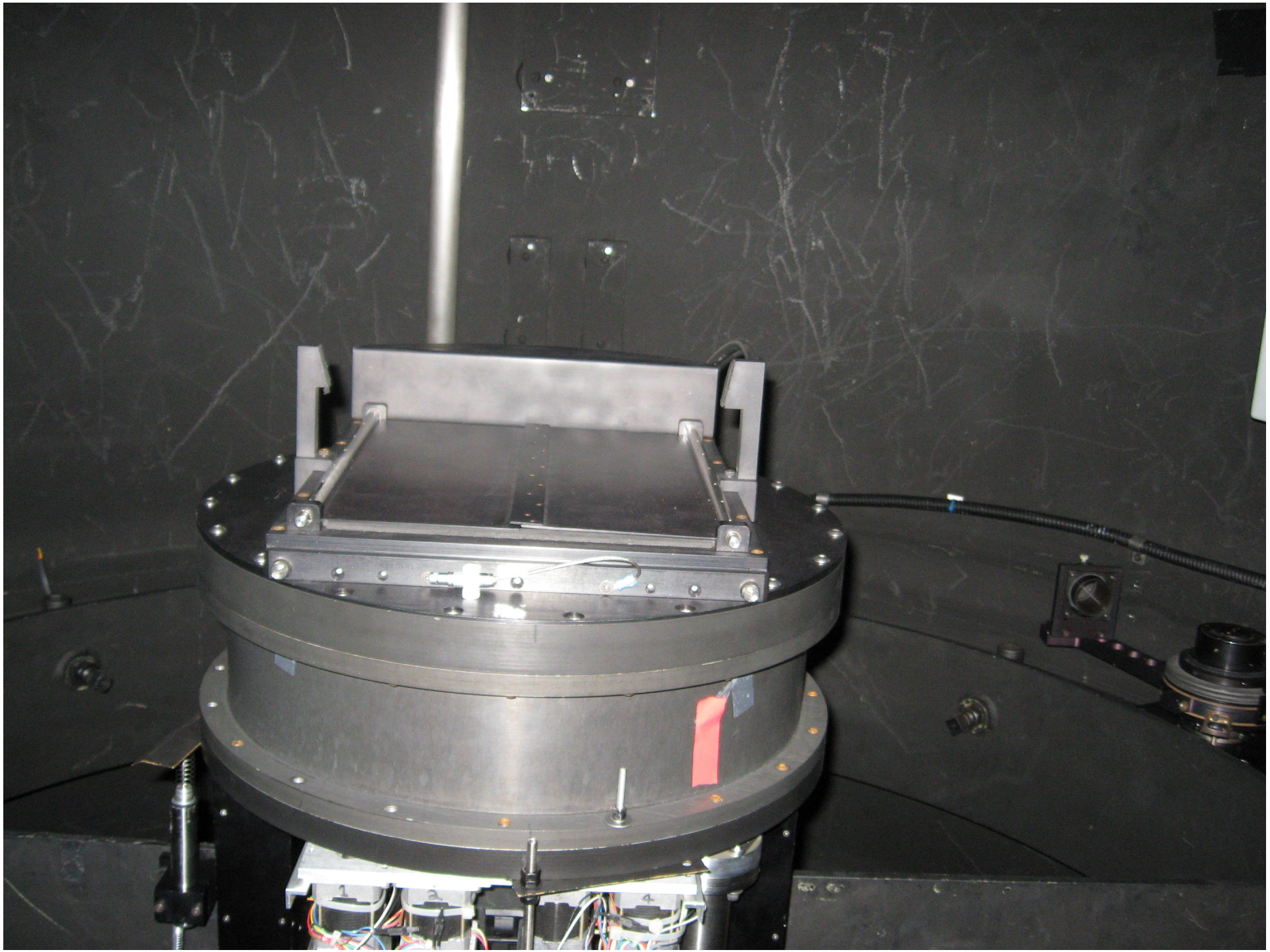

SCANIA
DH·67·19
CHILE
INTERCOOLER
112 H
360

Isometric View of the Camera

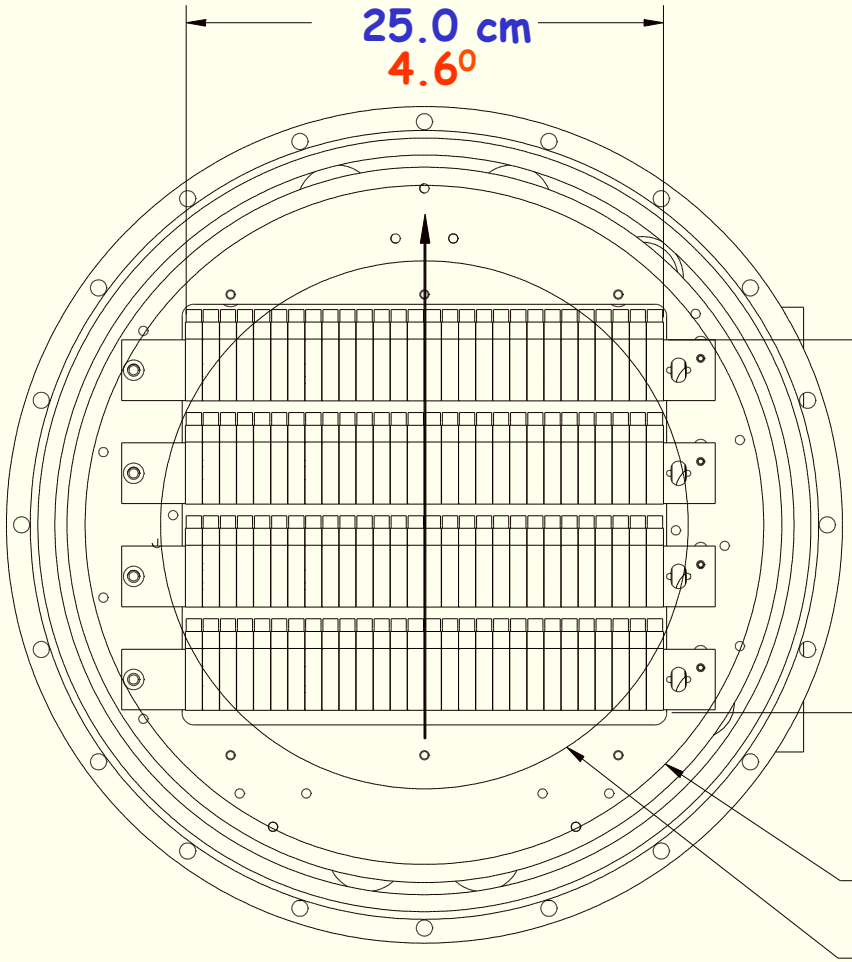
Installed at the prime focus of the ESO Schmidt




HEAD B
HEAD A



The Large Area QUEST CCD Camera



~10 square degrees
Active area

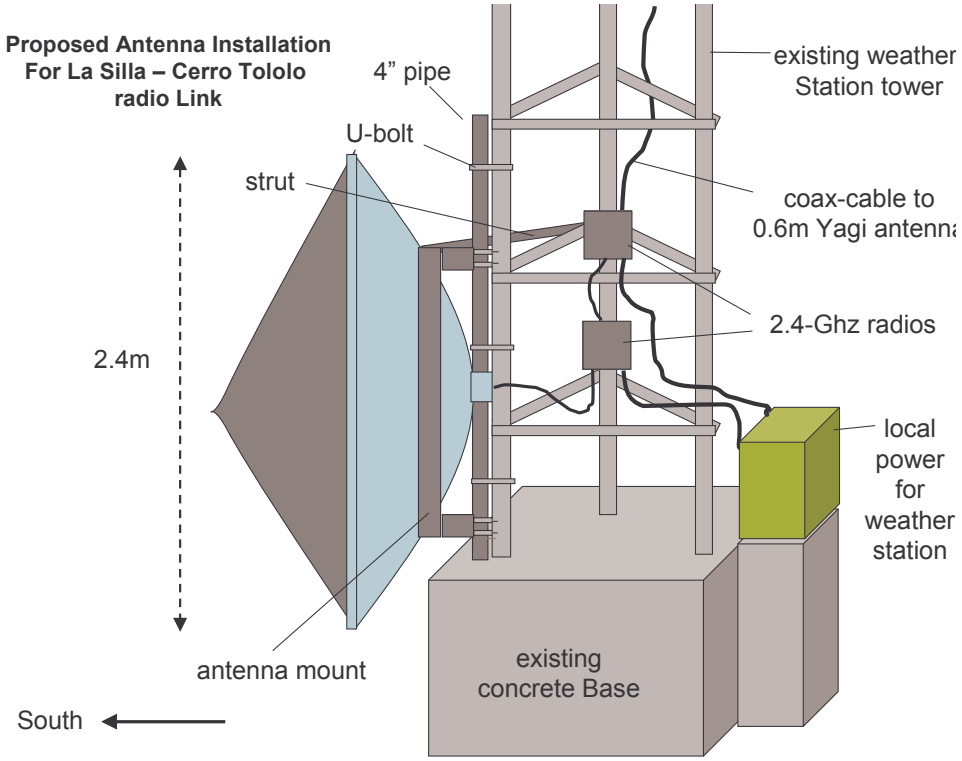
4 Rows of 28 CCD's each 112 CCD's total
Each CCD has 2400 x 600 13μ pixels-0.86"/pxl
Array 16,800 x 9,600 pixels 161 Megapixels tot.

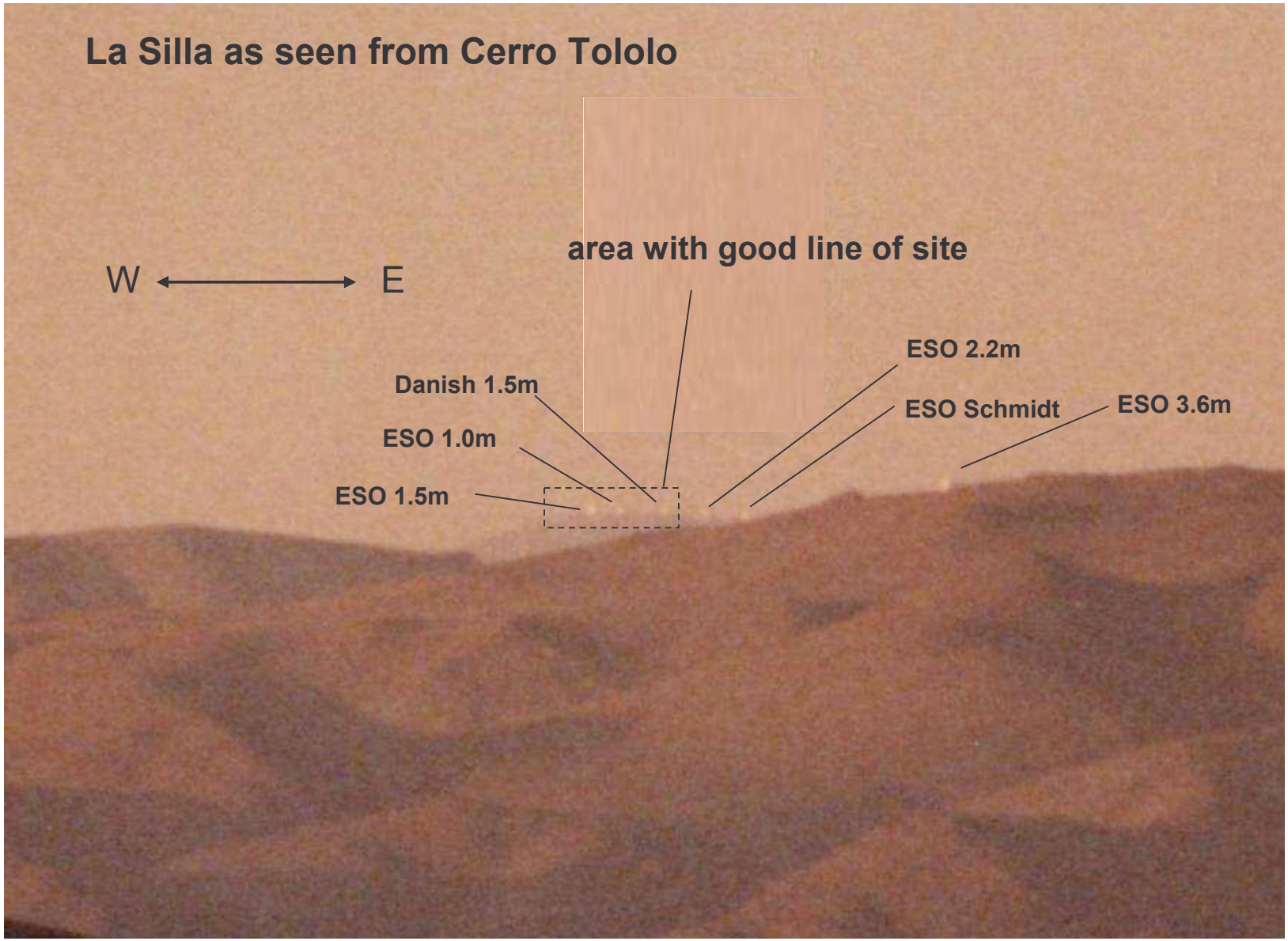
Data Rate Example

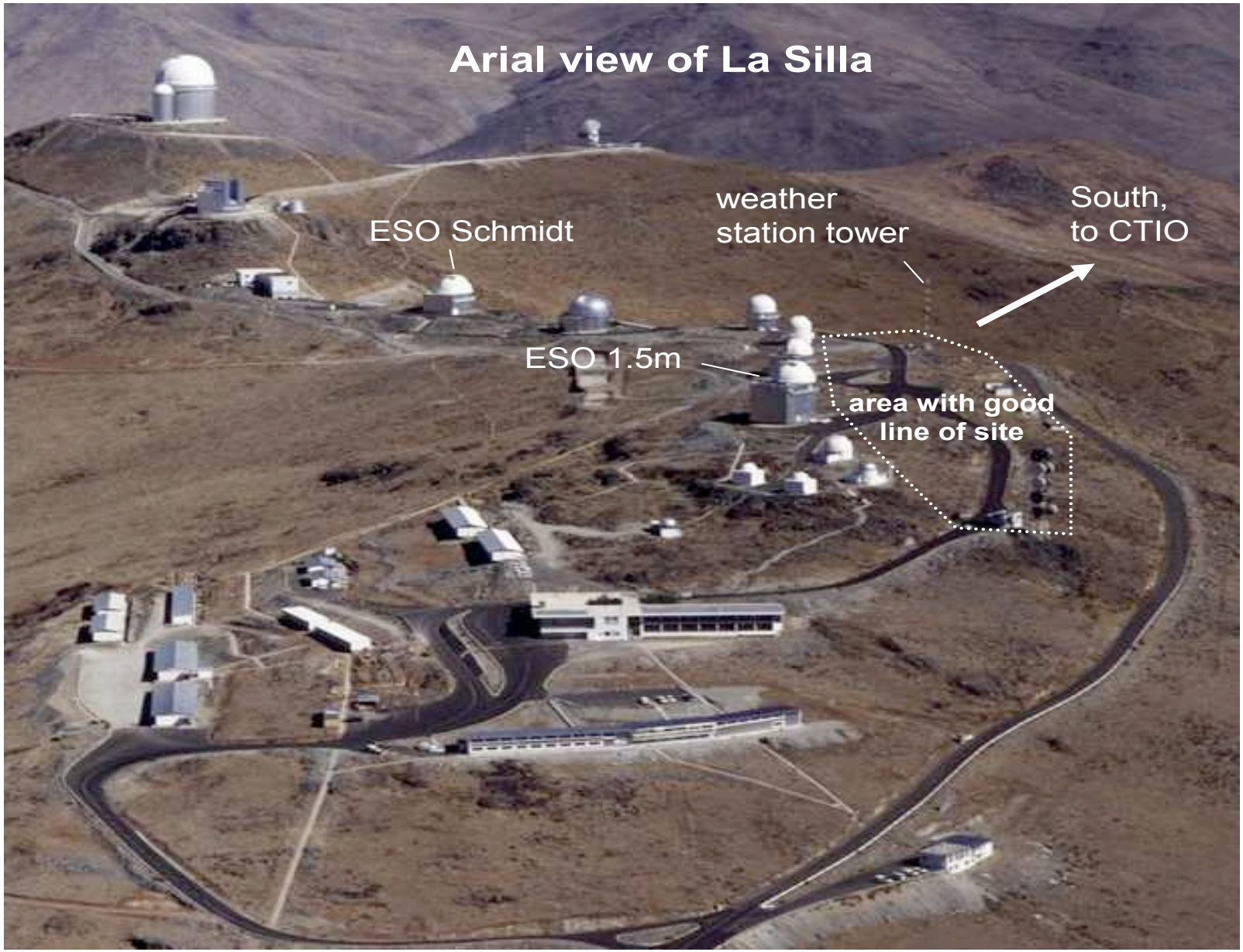
- For 60 sec exposure with 40 sec readout plus telescope move time get 100 sec per exposure
- 161 Mpixels x 16 bits/pixel/100 sec = 25.6 Mbits/sec
- Lossless compression by x 2 = 13 Mbits/sec
- 13 Mbits/sec x 3600 x 8 = 368 Gbits/day
  = 46 Gbytes/day

La Silla to Cerro Tololo Radio Link

- Camera generates 50 to 100 Gbytes/night
- Designed and implemented a radio link to transfer data in real time to Cerro Tololo
- High bandwidth trunk line from Cerro Tololo to the US




La Silla as seen from Cerro Tololo
W
E
area with good line of site
ESO 2.2m
Danish 1.5m
ESO Schmidt
ESO 3.6m
ESO 1.0m
ESO 1.5m


Arial view of La Silla
ESO Schmidt
weather
station tower
South,
to CTIO
ESO 1.5m
area with good
line of site

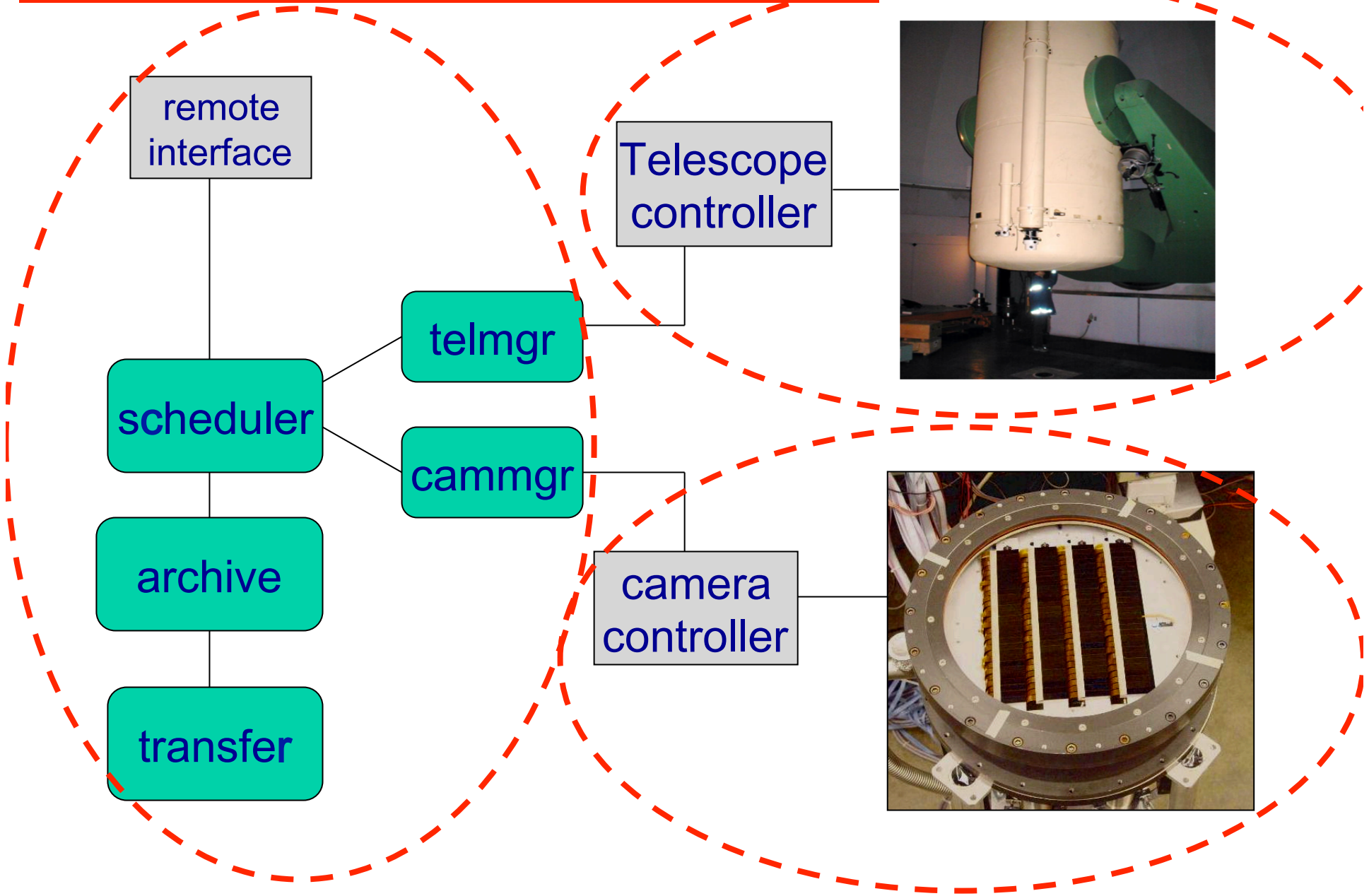
La Silla to Cerro Tololo Radio Link

- Camera generates 50 to 100 Gbytes/night
- Designed and implemented a radio link to transfer data in real time to Cerro Tololo
- High bandwidth trunk line from Cerro Tololo to the US

Fully Robotic Operation

- Replaced telescope control mechanisms (servo amplifiers,encoders etc for both telescope axes, focus control, and dome rotation and slit control)
- New TCS (Telescope Control System) and control computers allow remote operation of telescope, camera, and data transfer
- Weather sensing station closes dome and stops operation if necessary
- This was essential for operation every clear night of the year

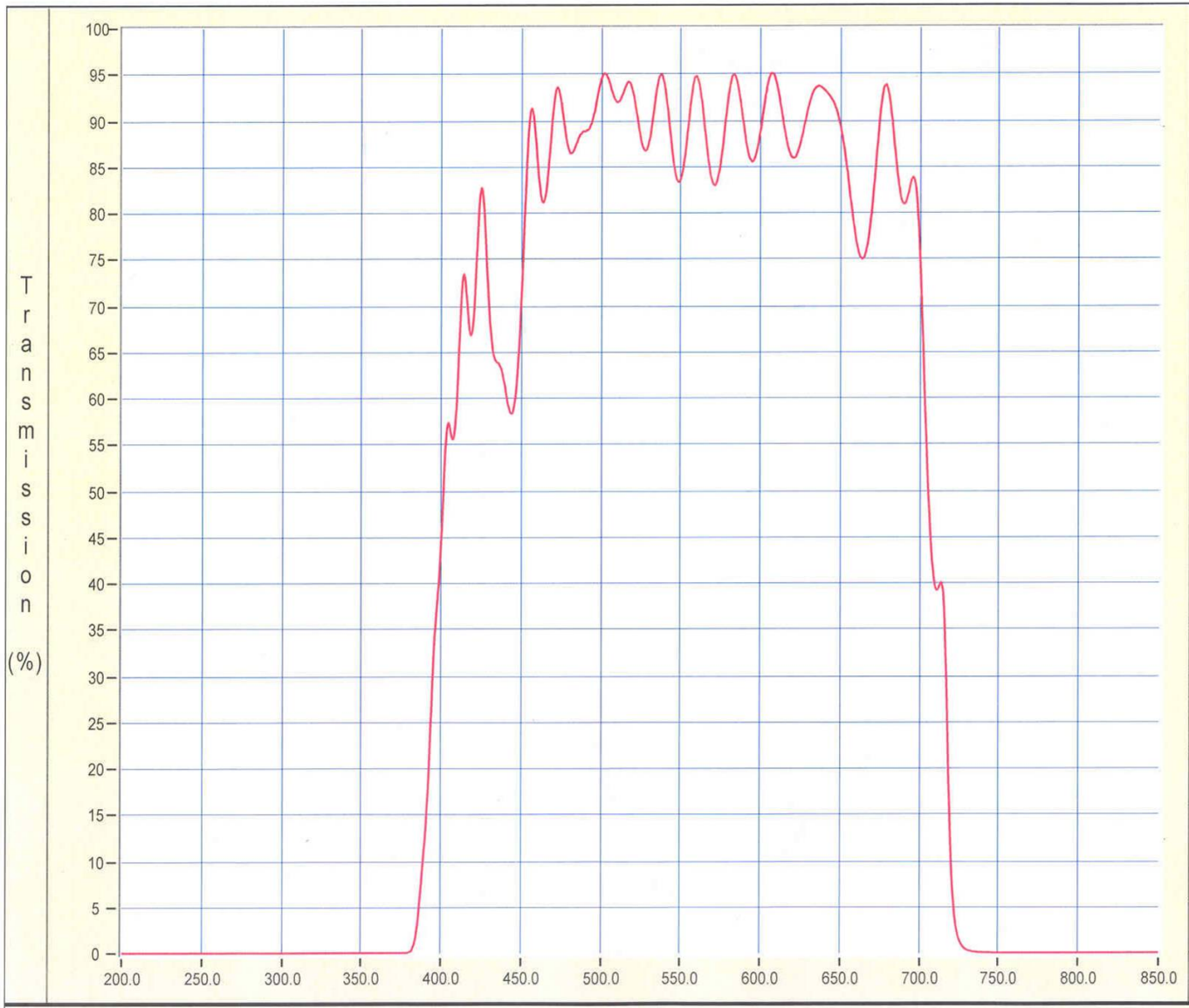
Automated Telescope and Camera Control



Survey Strategy

- Sensitivity to transients comes from repeated observations of a given area of sky
  - 2 day cadence
  - Area A on night 1, area B on night 2, area A on night 3, area B on night 4, etc etc
- To eliminate short time transients like asteroids, airplanes, cosmics etc cover each area twice a night with a one to two hour separation. These repeated scans provide sensitivity to Kuiper Belt Objects
- Use 60 second exposures in a single wide filter
- Typically cover 1500 sq degrees twice a night
- Program schedules observations each night
  - Declinations between +20 and -25 degrees
  - Less then 2 airmasses, more then 15^{o} from galaxy
  - Far enough east to be visible to followup for 60 days

Andover Corporation



Filter I.D.

Test Instrument:
Cary 500 (1437)

Test Technician:
C. Richards

Date:
Tue, Jun 23, 2009

Customer Name:
Yale University

Job Number:
AM-72267

Part Number:
ANDV11541

Serial Number:
01

Lot Number:
37839

Filter Data

Center Wavelength:
553.45 nm

Bandwidth:
50%: 305.29 nm
10%: 331.50 nm
1%: 343.01 nm

Peak Transmission:
95.05 %

FWHM Coordinates:
400.803 nm
706.096 nm

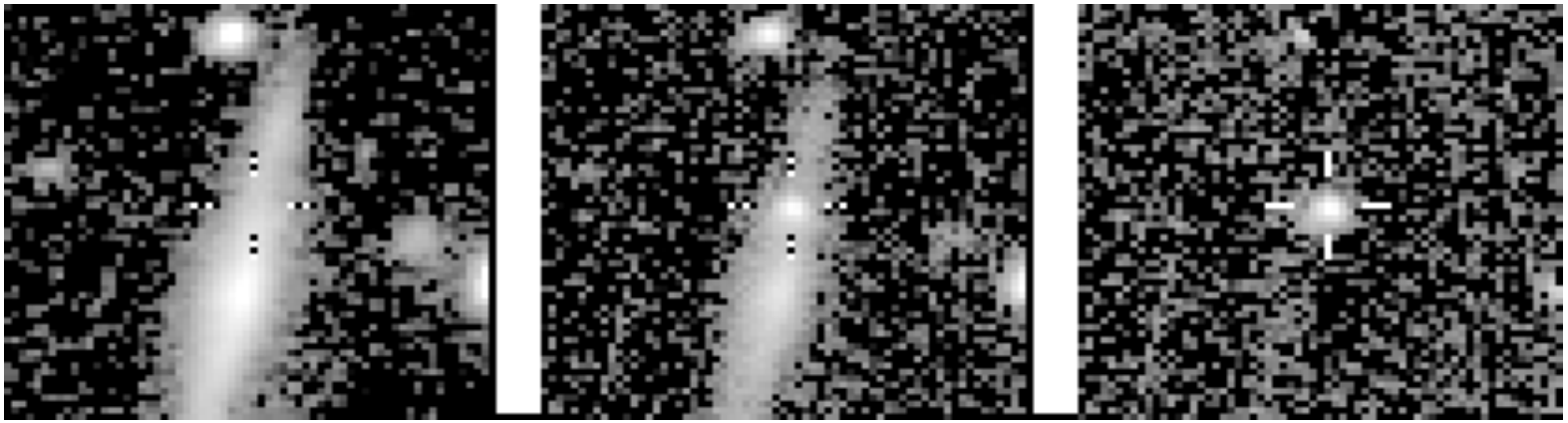
Angle of Incidence:
0.00 °

Ambient Temperature:
23.0 ° C.

Software Running Well

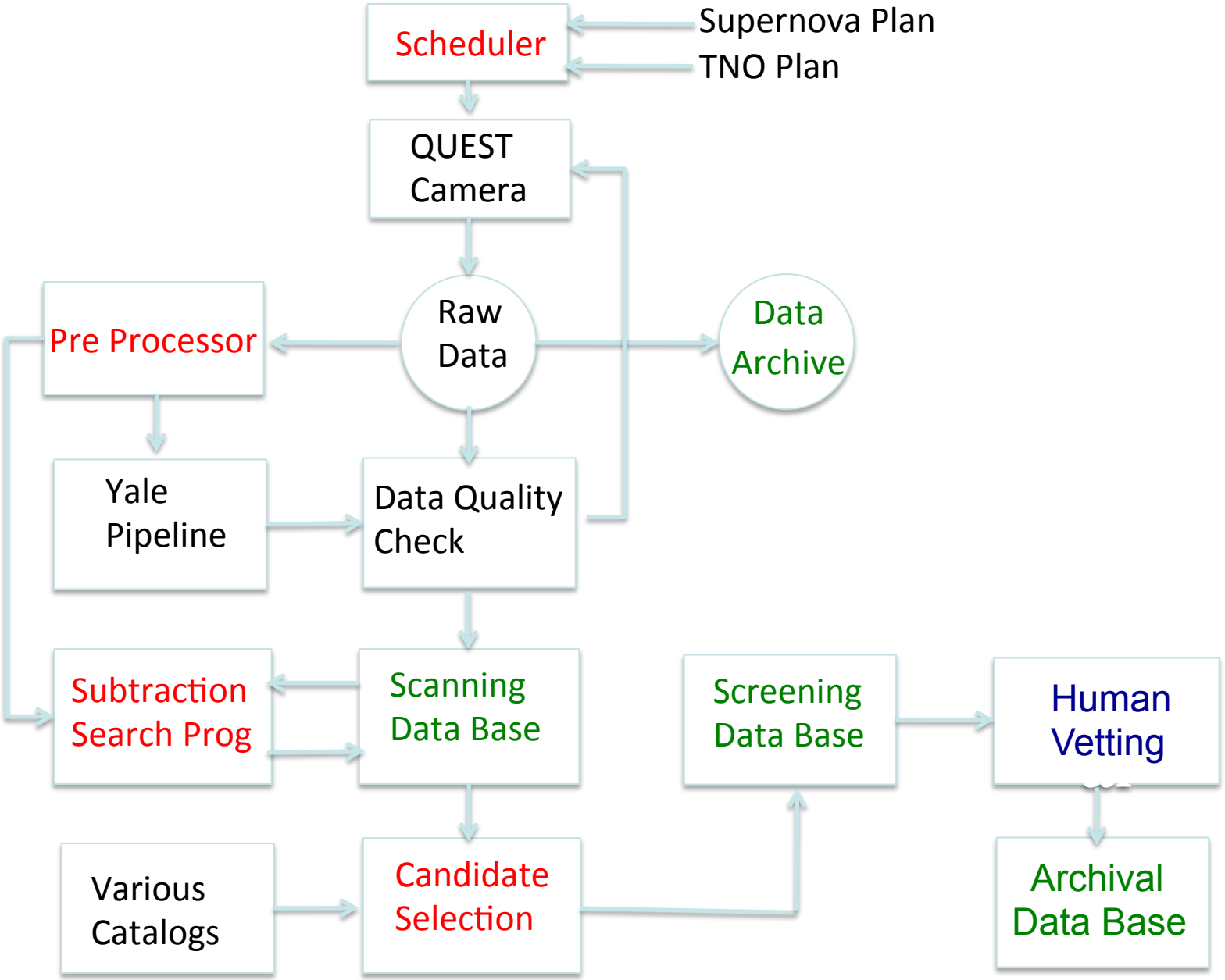
- Preprocessor does the usual dark subtraction, flat fielding and astrometry using USNO A2.0 catalog
- Subtraction Program subtracts reference image pixel by pixel from new image, developed by Peter Nugent
  - Uses reference image from usually a few weeks before new
  - Precise coordinate alignment, flux normalization and PSF adjustment of new image to reference image
  - Uses Sextractor on subtracted image to find transient candidates and calculate position and magnitude
- Candidate Selection Program reduces huge number of transient candidates to a manageable number of supernova candidates, typically half a dozen to a dozen per night

Subtraction program for LSQ11ot



Reference image **New image** **Subtracted image**

La Silla Transient Search



Typical numbers at this point

- Output of candidates from SExtractor run on subtracted images
  - Millions per night
- Crude cuts (mag error less then 0.5, no bad SExtrator flags,etc) to put candidates on Scanning Data Base
  - Typically thousands to tens of thousands per night
- Quality cuts to send candidates to human screener on Screening Data Base
  - Typically around 500 per night
- Human Screening removes remaining bad subtractions and artifacts, passes good candidates to Archival Data Base
  - Typically about a dozen per night

The Archival Data Base

- Has a web based interface accessible to all members of the consortium
- Has three kinds of “pages”
  - Main list of candidates-has one line for each candidate selected by the candidate selection program and passed by the human vetter
  - History page-has all QUEST observations both before and after discovery, as well as all followup images and spectra
  - Details page-detailed comments and other information
- Data Base where all collaborators can choose the candidates they wish to follow up

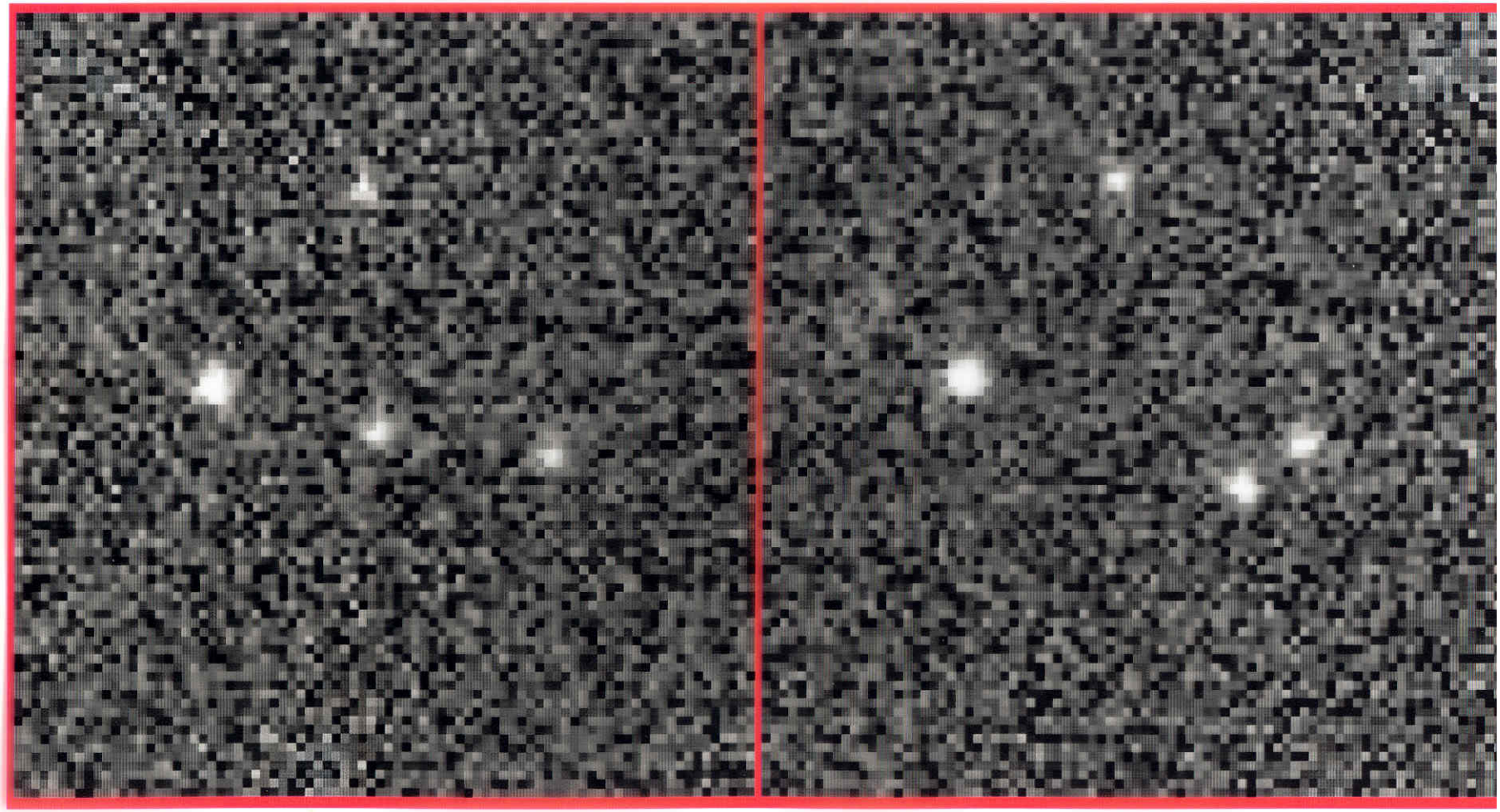
Search for Trans Neptunian Objects

- Sensitivity to Trans Neptunian Objects, TNO's (also called Kuiper Belt Objects, KBO's) comes from repeated observations (two or three times a night) of the same area of the sky, look for objects moving with respect to background of distant stars
- So far found 65 new objects in our solar system beyond Neptune, some as big as half of Pluto
- Sensitive to objects down to mag 21.5
- One of the more interesting new objects is

  2010 WG9, a distant body with an inclination exceeding 70 deg and a perihelion near the orbit of Uranus

Search for New Objects in our Solar System

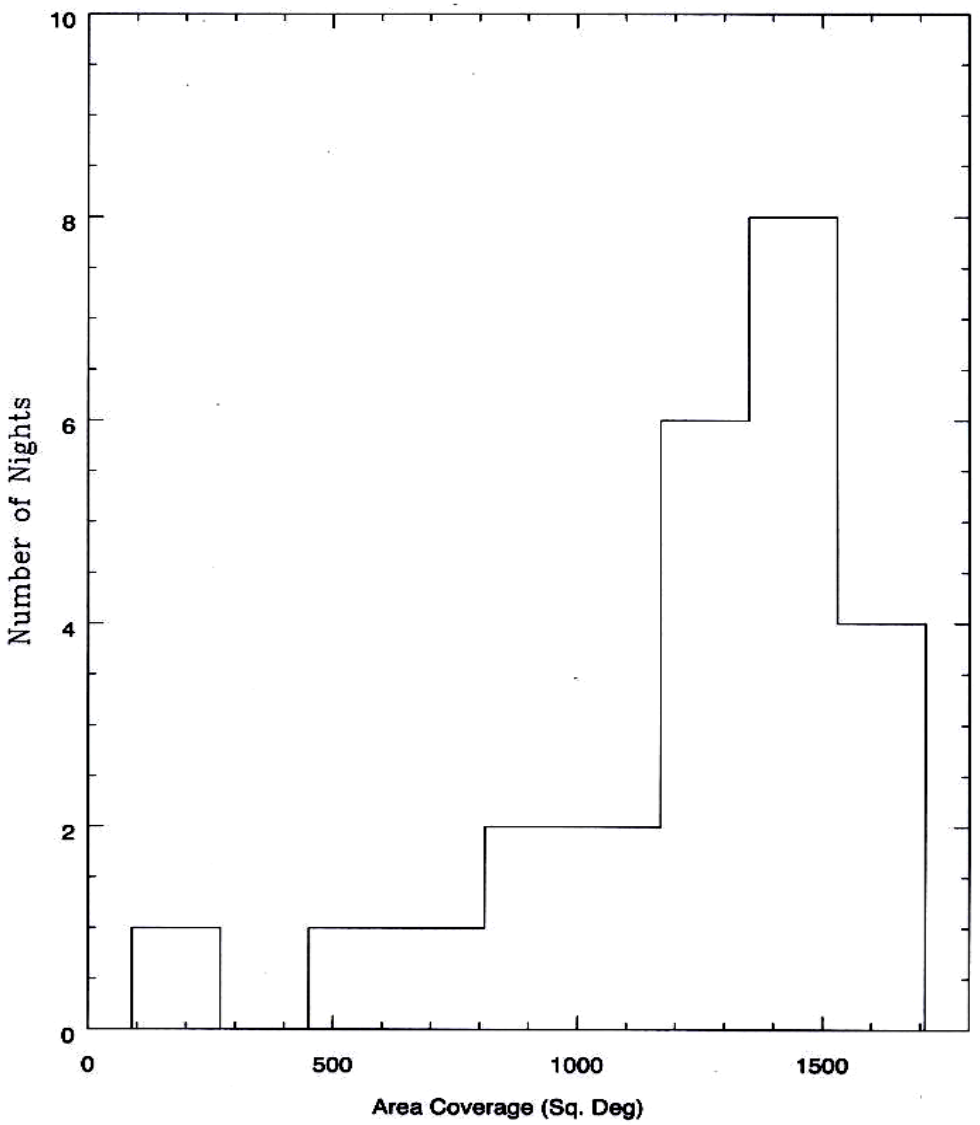
Two exposures about 1 hour apart



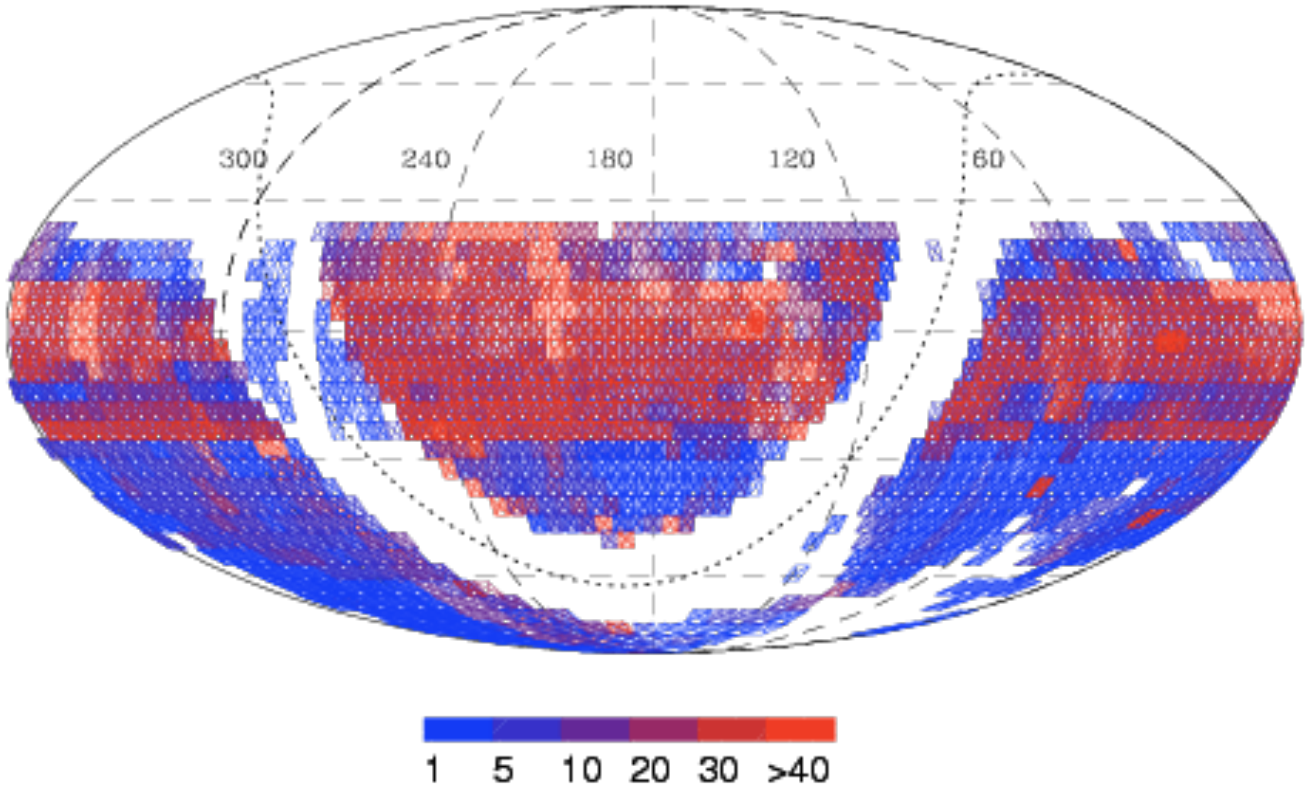
Survey running smoothly since Sept 2009

- Searched for TNO's and transient stars, laid down reference frames in preparation for supernova search
  - Covered 22,000 square degrees multiple times
- Started Supernova search Dec 7, 2011
  - Scanned Typically 1500 square degrees twice a night
  - 60 sec exposures with wide band filter(4000 to 7000 A)
  - Seeing 1.7 arcsec on average
  - Limiting magnitude is 21.5
  - Photometry stable to 1.5% after relative calibration using field stars

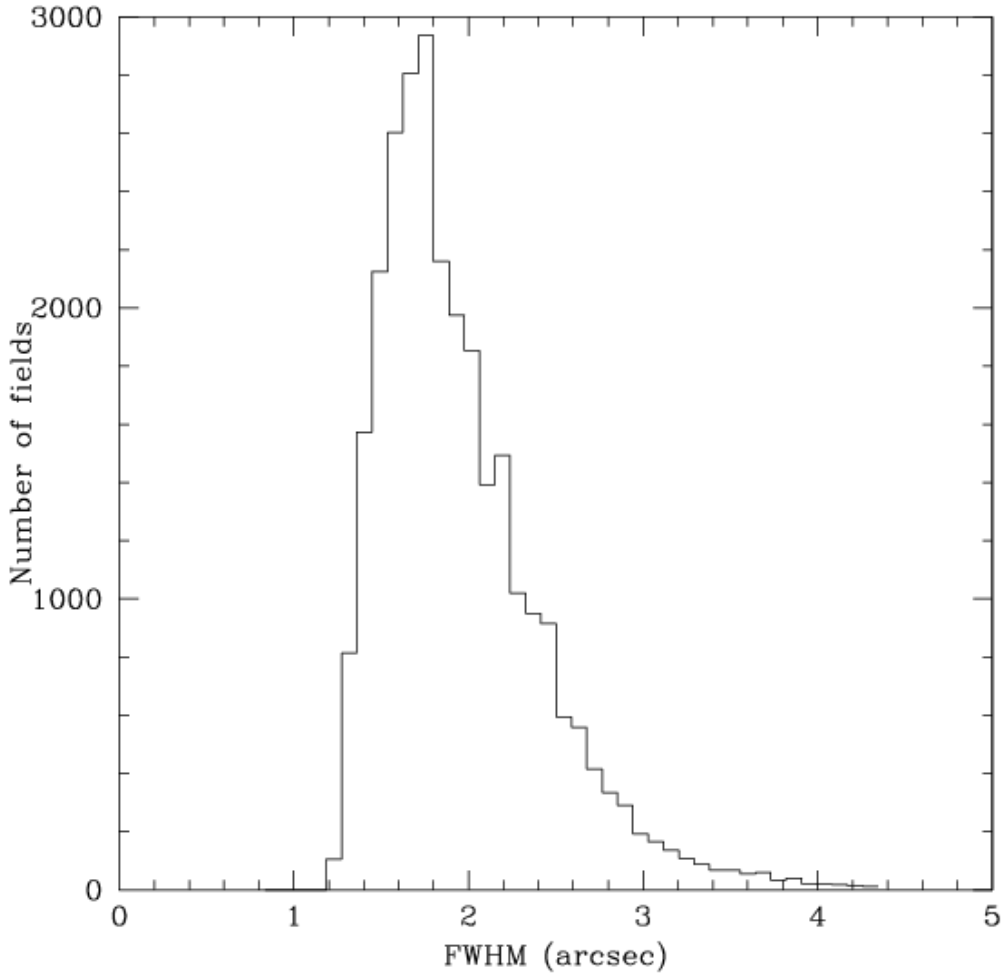
Area Covered twice each night



Accumulated Sky Coverage

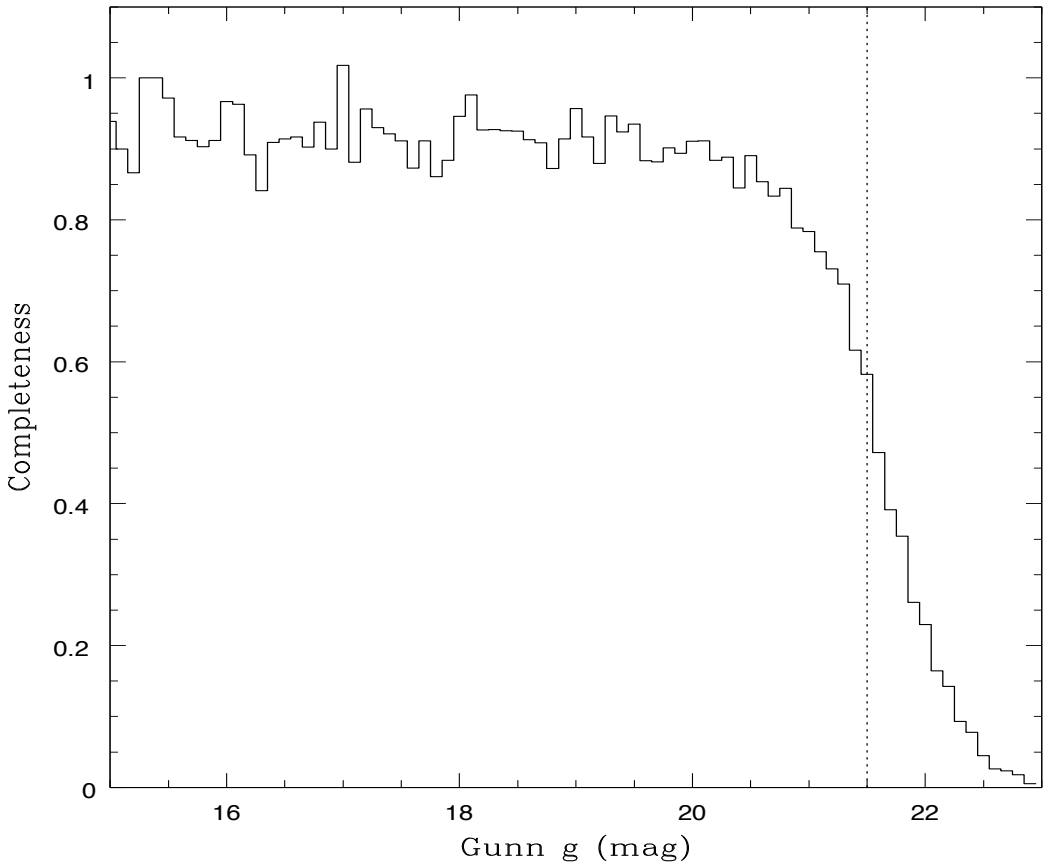


Seeing Peaks around 1.7 arcsec

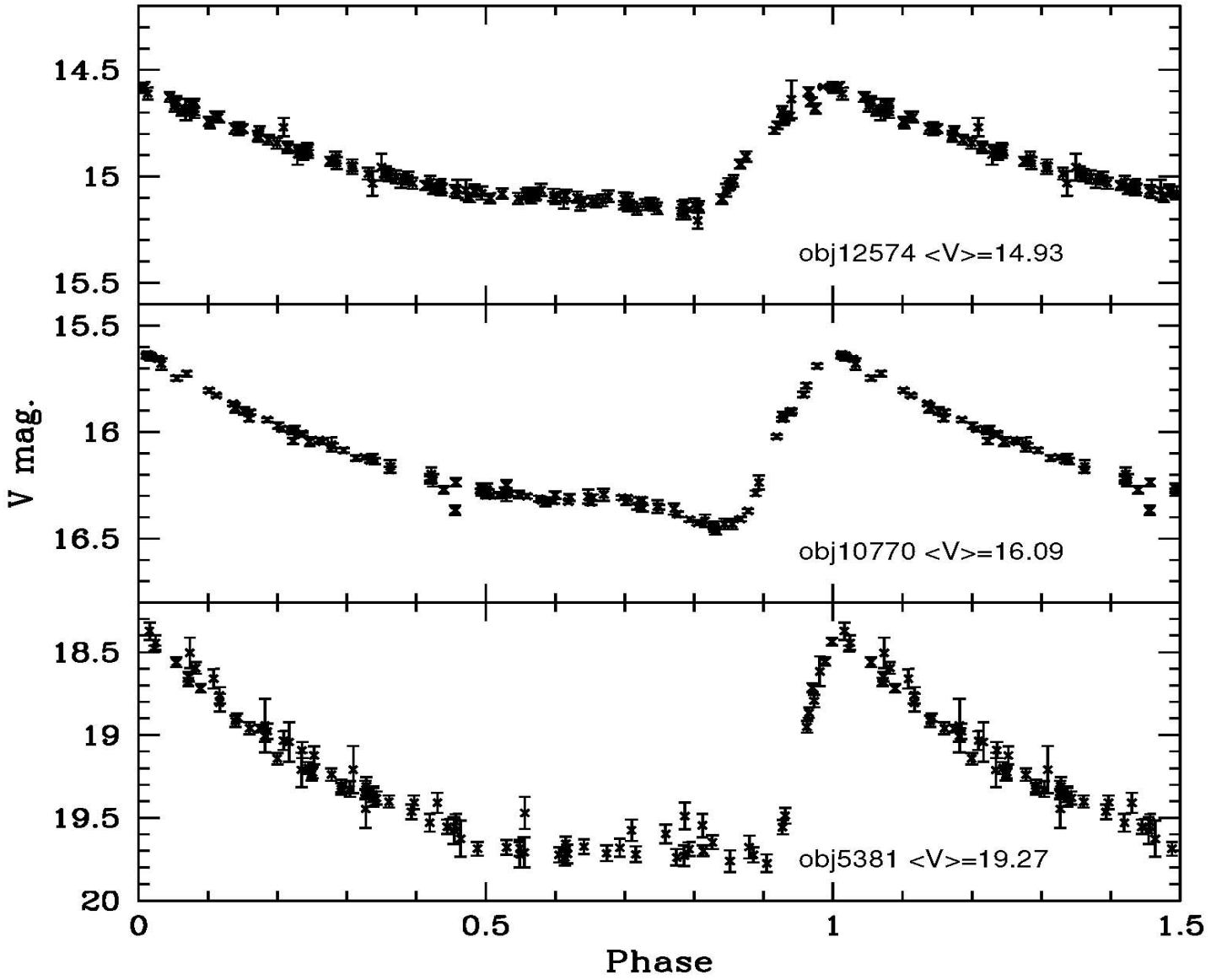


Completeness in finding SDSS Stars

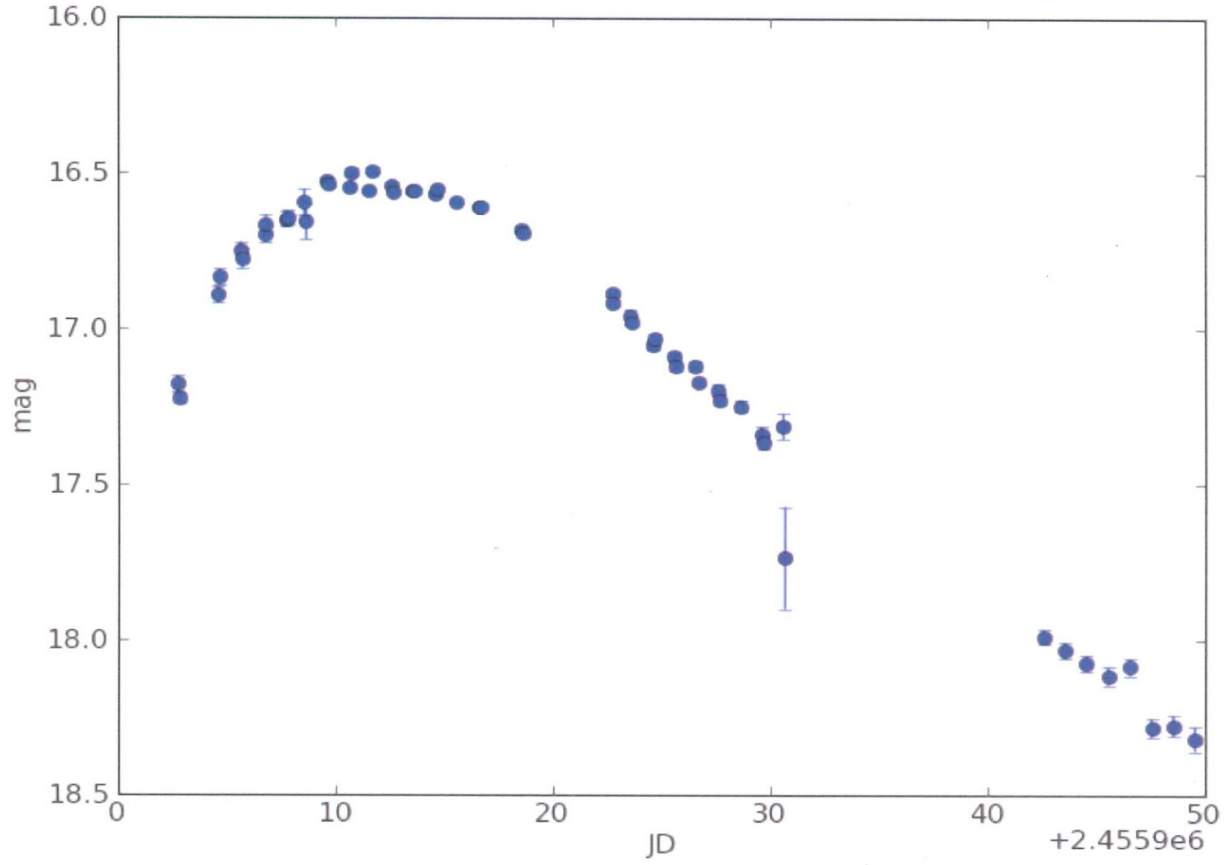
Limiting magnitude 21.5



LaSilla/QUEST RRLyrae Lightcurves



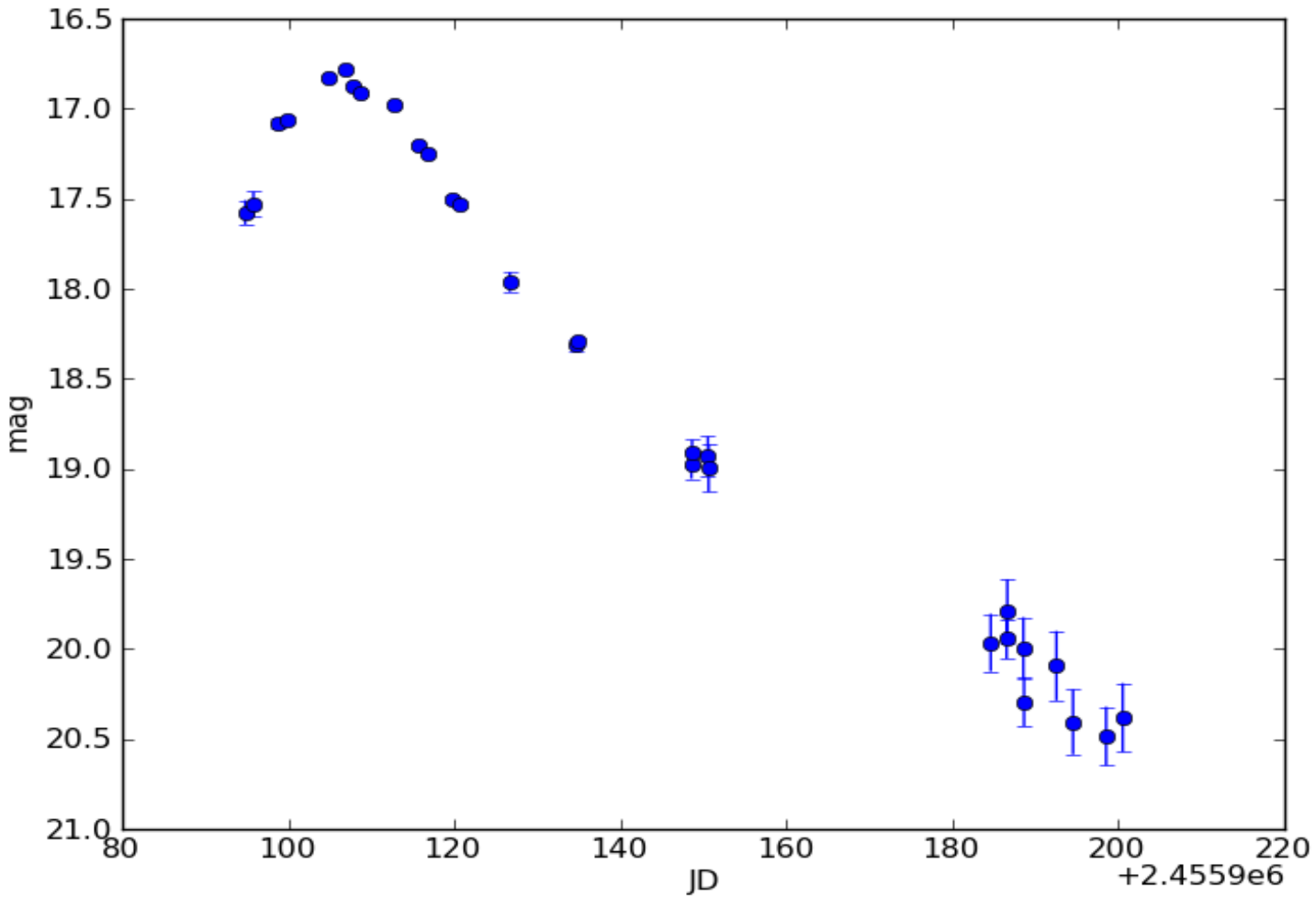
Lightcurve for LSQ11bk from LaSilla/QUEST



Lightcurve from host + source (if image exists):

lc.LSQ11bk

Lightcurve for LSQ12pn from La Silla/QUEST



The supernovae discovered by LaSilla/QUEST

are followed up by four different follow up streams, organized as the LRSC, the Low Redshift Supernova Consortium

- The Nearby Supernova Factory II (G. Aldering and S. Perlmutter et al) using the SNIFS spectrometer on the Hawaii 2.2 m telescope to take a time series of spectra for each supernova.
- The Carnegie Supernova Project (M. Phillips et al) using the 2.5 m Dupont telescope at Las Campanas to carry out a time series of infrared observations.
- The PESSTO project (S. Smartt and M. Sullivan et al) using the EFOSC spectrometer on the 3.5 m NTT telescope at La Silla for spectroscopic followup.
- A time series of optical photometric observations using the 1.0 m SWOPE Telescope at Las Campanas.

The PESSTO Survey

Public ESO Spectroscopic Survey for Transient Objects

- The PESSTO survey uses the EFOSC2 and the SOFI spectrometers on the 3.5 m NTT telescope at the La Silla Observatory in Chile to follow up supernovae with both optical and infrared spectroscopy.
- It is a collaboration of two U.S. institutions, Yale University and Berkeley, with seventeen European and other international institutions.
- The survey follows up supernovae discovered by La Silla/QUEST, PTF, and SkyMapper.
- The main scientific goals of PESSTO are unusual, nonstandard supernovae.

The PESSTO Survey

- The survey has 25% of the time on the NTT telescope for 5 years
  - 90 nights per year
  - observes 9 months per year, August through April
  - 10 nights per month with a cadence of 4 nights on/ 5 off/3 on/5 off/3 on/8 off
  - 80% of the time for optical spectroscopy with EFOSC2 and 20% of the time NIR spectroscopy with SOFI
  - Expect to screen a total of 2000 supernova candidates, 44 each month for the 5 years. This is a significant contribution of PESSTO to the supernovae for cosmology effort.

Spectroscopic Typing of LSQ Candidates

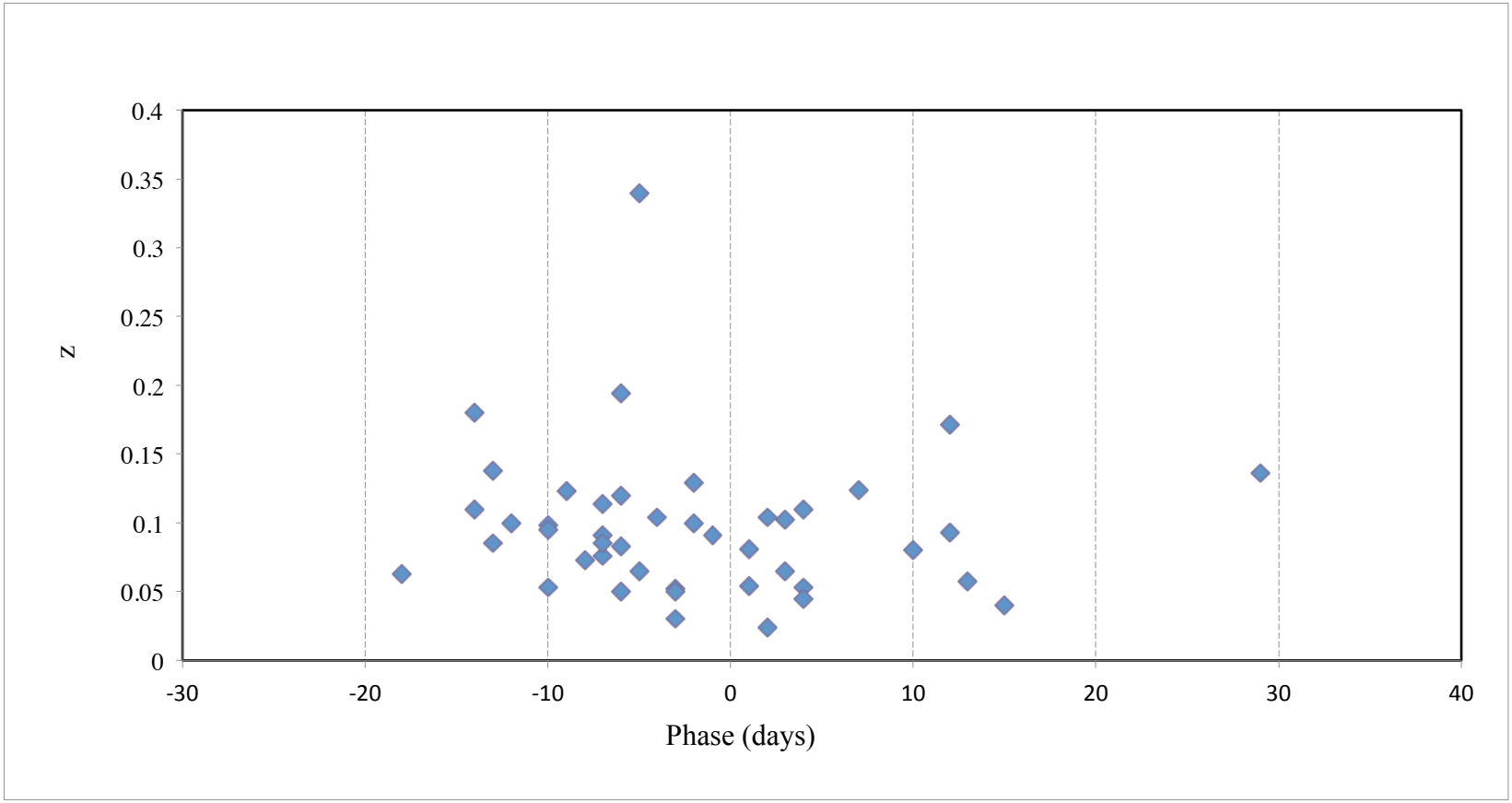
Spectroscopic typing from Dec 2011 to June 1, 2012

Source of Spectra	Total spectra Taken	Total Supernovae	Type 1a	Type 1b, c	Type II
PESSTO	50 *	46	37	3	6
SNfactory	14	10	8	1	1
Carnegie SP	10	10	7	1	2
Other	22	15	11	1	3
TOTALS	**96**	**81**	**63**	**6**	**12**

* PESSTO data for one month only (April 2012)

Phase of Supernovae at Discovery

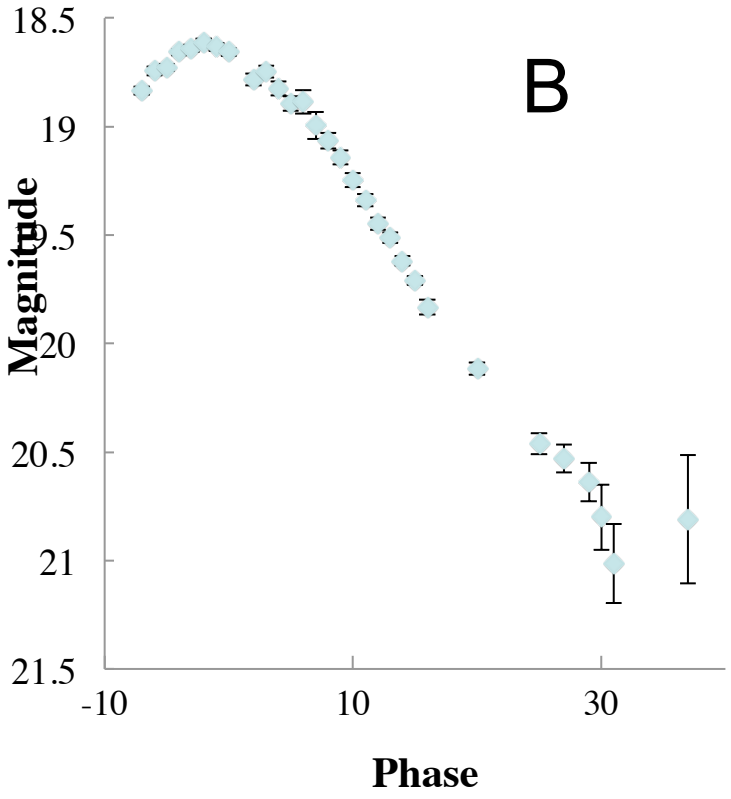
46 Supernovae Spectroscopically confirmed by PESSTO

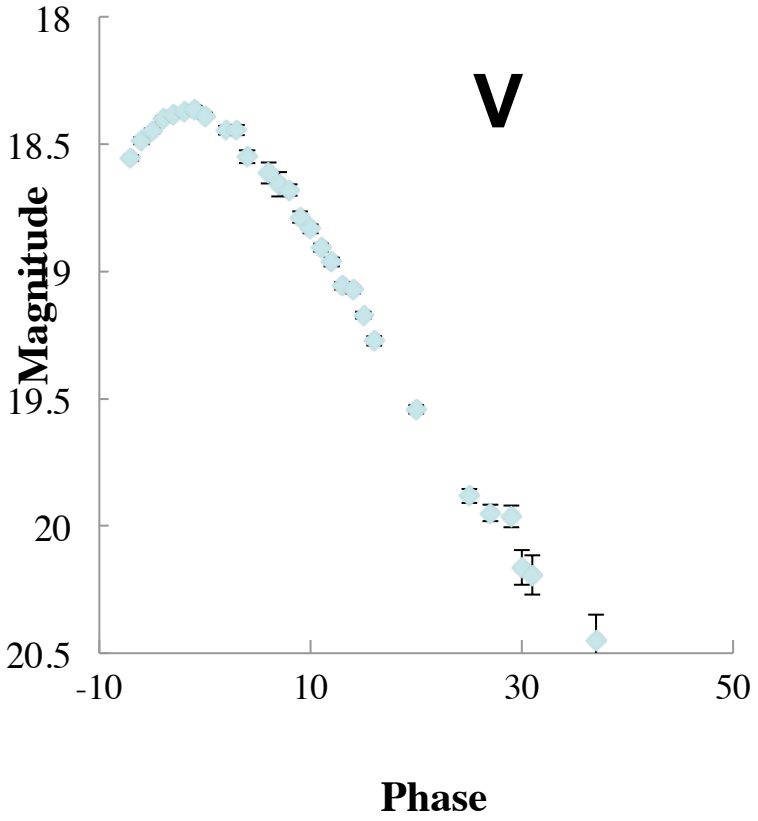


SWOPE Photometric Followup

- SWOPE telescope has started photometric follow up of LSQ supernova in six filters B, V, u, g, r, i
- Dec 2011 to June 2012 has followed 11 LSQ Type 1a supernova with typically 30 observations each in each of the 6 filters
- Beautiful lightcurves

SWOPE Lightcurves for LSQ11ot





SALT2 fits to LSQ11ot

Lightcurves from SWOPE 1 m telescope at Las Campanas