



# Liverpool Telescope

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<http://telescope.livjmu.ac.uk/>

LT Control room Mon Apr 28 19:16:02 2008



# A Robotic Telescope

- One that can operate without night-time supervision.
- Not “remote controlled”.
- Software is responsible for the safety of the telescope and observatory.



# Our Vision for a Robotic Telescope

- Robotic “National facility class” telescope
- Diverse instrumentation
- Common user – scheduled by TACs. Not devoted to or dominated by any one project.
- Software decides what (and how) to observe. No “queue”.
- Flexible operations responsive to changing needs of time-domain astrophysics

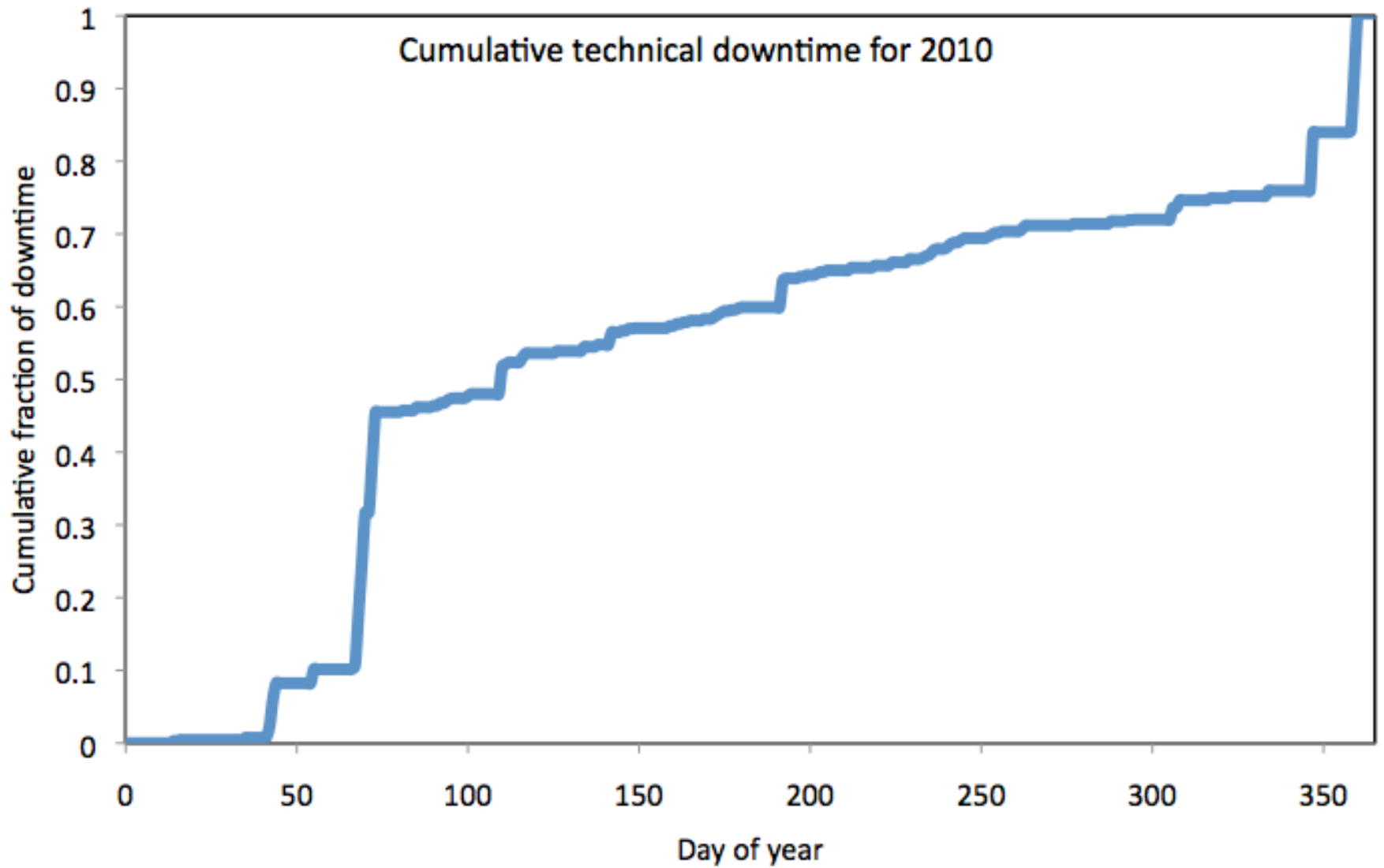
# Advantages of Robotic (as opposed to remote)

- Unstaffed
  - Cheaper to run? (space, facilities, accommodation, food, water)
  - No night working
  - Reduced travel (also true for remote operations)
- Flexibly scheduled
  - Both better and qualitatively new science
  - Shared facility for diverse monitoring timescales (minutes - months)
  - Respond rapidly to changing conditions
  - Painless Targets of Opportunity
- Standardized data taking procedures
  - Homologous data quality
  - Allows automated pipeline data reduction to scientifically useful quantities
- Simplifies inter-observatory collaboration and hand-offs between telescopes

# Operational Challenges for a Robotic Telescope

- Real-time observer interaction
  - Can be automated in very many cases
- Management and being fair to all
  - Traditional block schedules are cleaner
- Reliability
  - When time lost, typically in large chunks
  - Avoid fragile instruments (Can still be innovative)

## Technical Downtime



**YEAR**

# Talk Outline

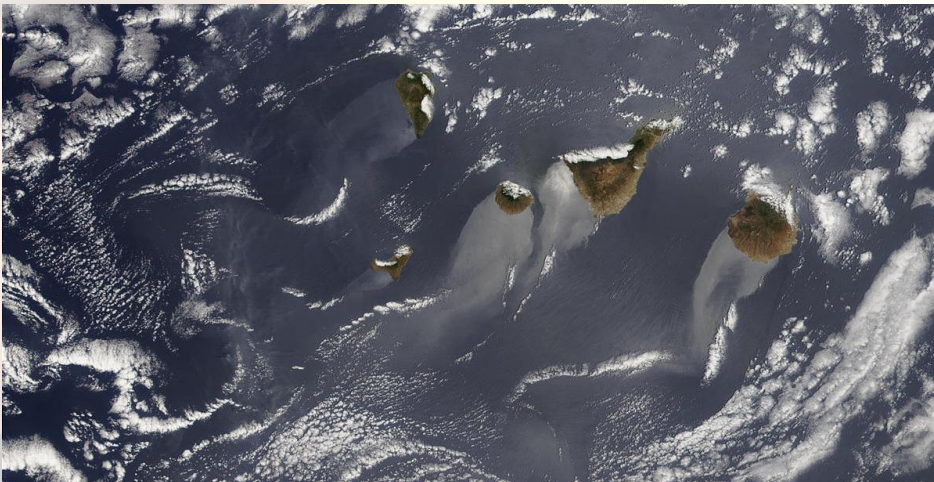
- Robotic
- Hardware: Telescope & Instruments
- A User's Perspective
- Operations Staff Perspective
- Our current user community





# LT Specifications

- 2m primary (f/3), f/10 at Cass
- Designed and built by TTL (now LCO)
- Alt-Az (hydrostatic bearings)
- Image quality < 0.6" on-axis
- Pointing < 10" rms
- Integrated autoguider
- Closed loop tracking < 0.2" over 1hr
- Max slew rate > 2° per sec
- Zenith blind spot < 2°
- Clamshell enclosure
- Science Operations Jan 2004
- Sited on La Palma, Islas Canarias



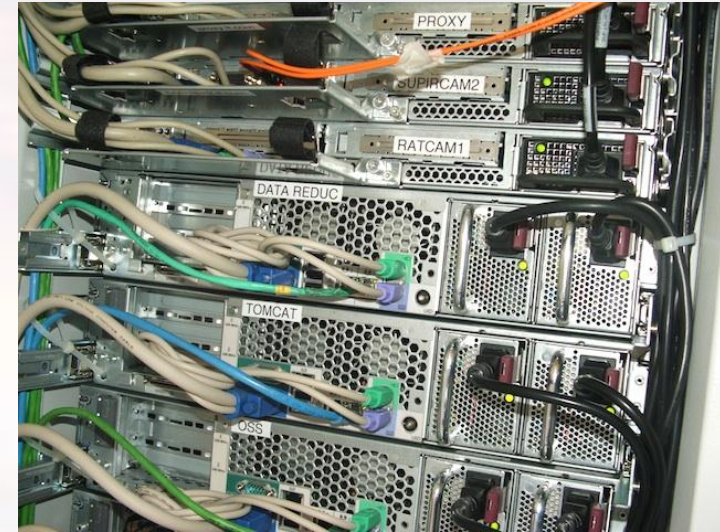
# Requirements for an automatic telescope

## Remote & Robotic

- Automated startup and shut down procedure.
- Very reliable weather information.
- High degree of reliability
- Fault recovery/logging/management procedures.
- Failsafe operation - make sure it is protected if it does fail.

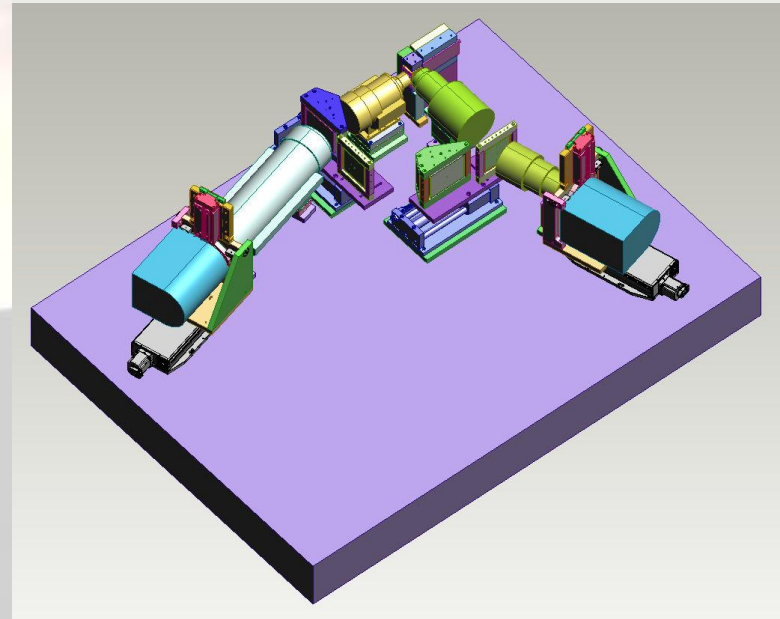
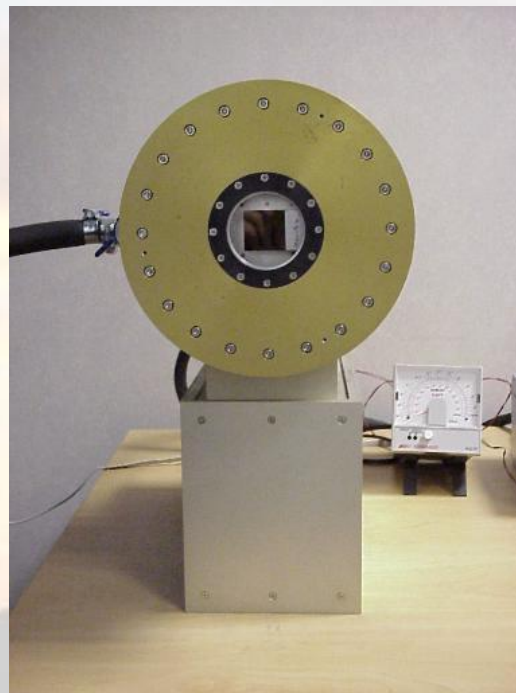
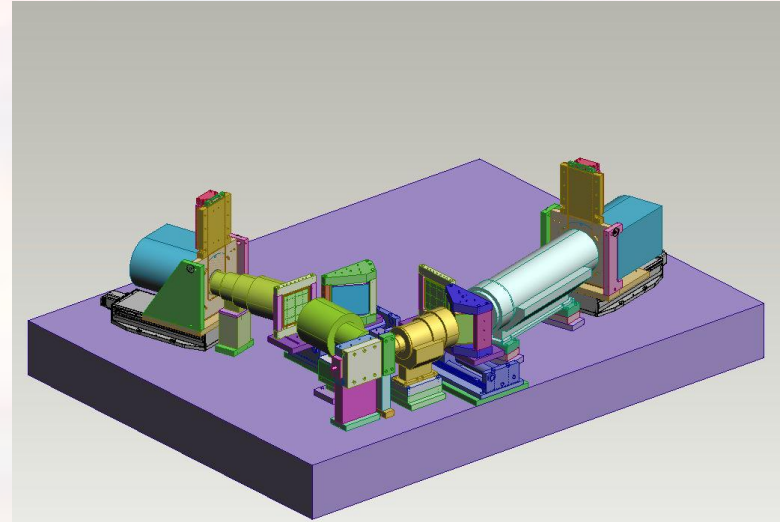
## Additional for Robotic

- Well defined sequence of observations including calibration observations.
- Autonomous scheduler for robotic operation.



# Instrumentation

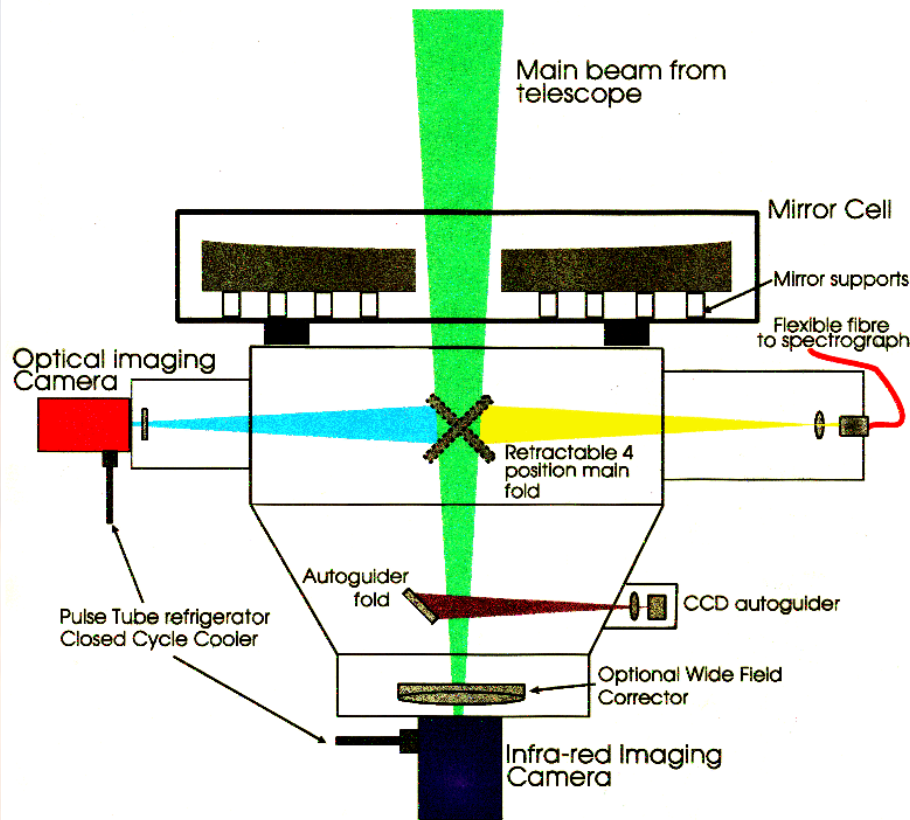
Iain Steele, Chris Mottram, Alan Scott, Stuart Bates, Steve Fraser, Robert Smith (JMU)  
John Meaburn, Dan Harman (Manchester)  
Phil Charles, Luisa Morales (Southampton)  
Peter Meikle (ICSTM)  
David Clarke (Glasgow)  
Don Pollacco, Ian Todd (QUB)  
Sue Worswick (Optical design)



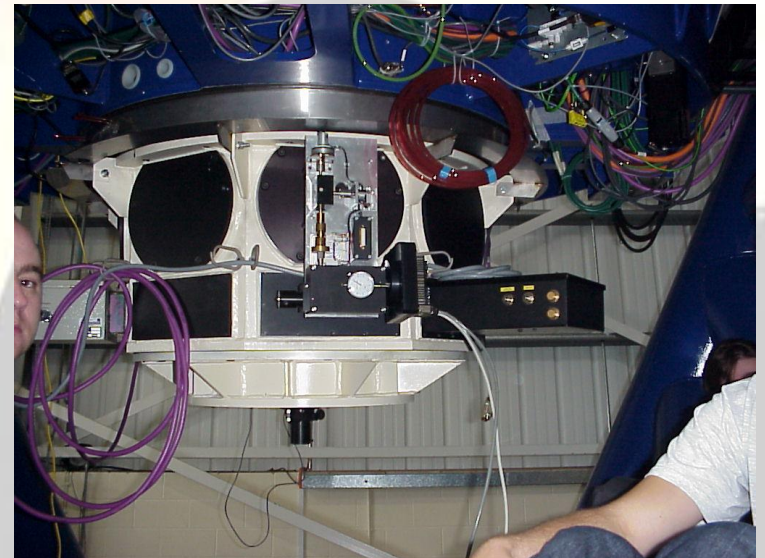
# Acquisition & Guidance Box

## Liverpool Telescope A&G Box schematic layout

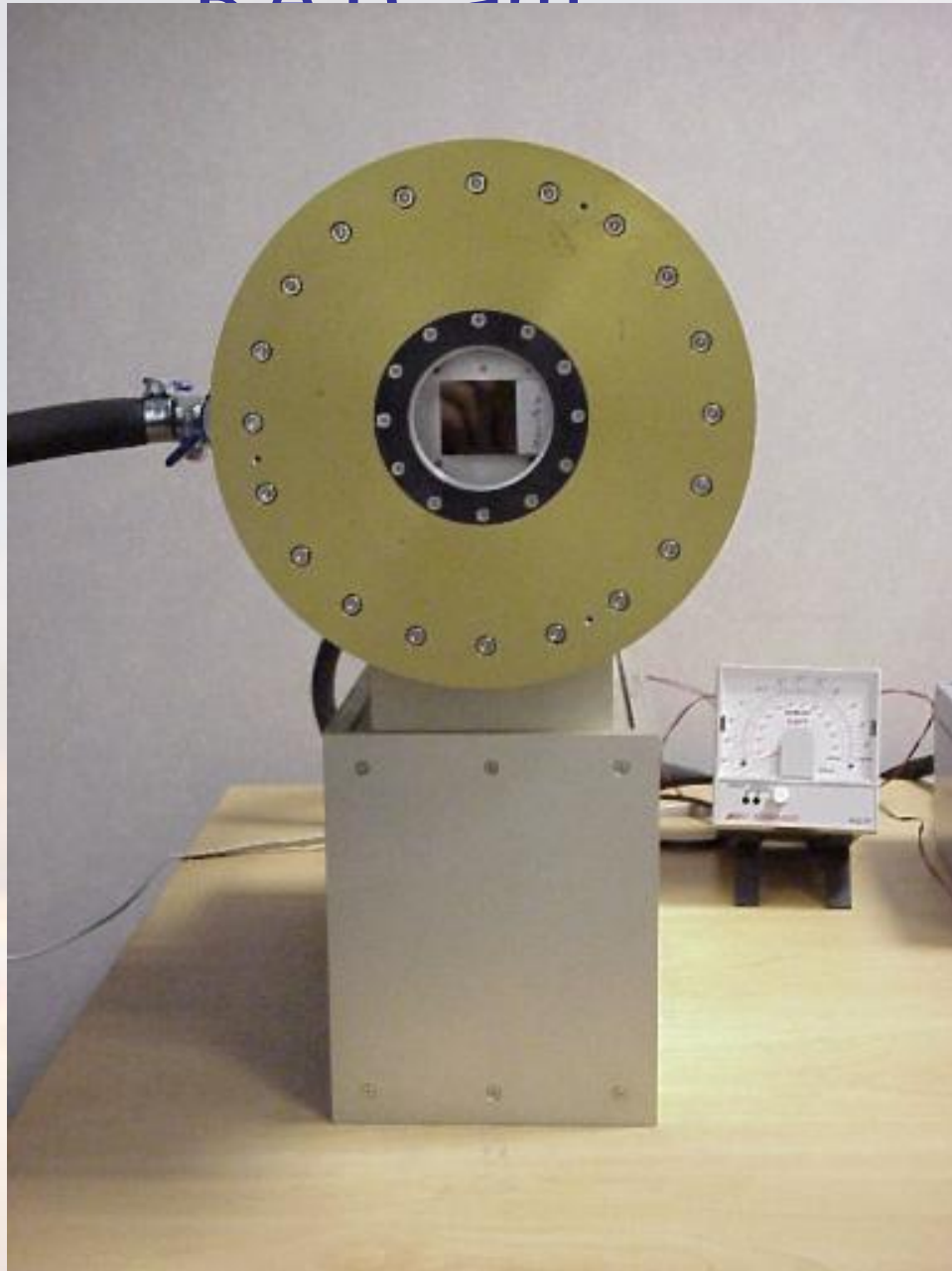
With one possible instrument configuration



- 1 straight-through port
- 18 side ports
- Off axis frame transfer autoguider (limit  $V=17$ )
- Retractable, folding mirror gives instrument change time  $< 30$  seconds



# RATCam



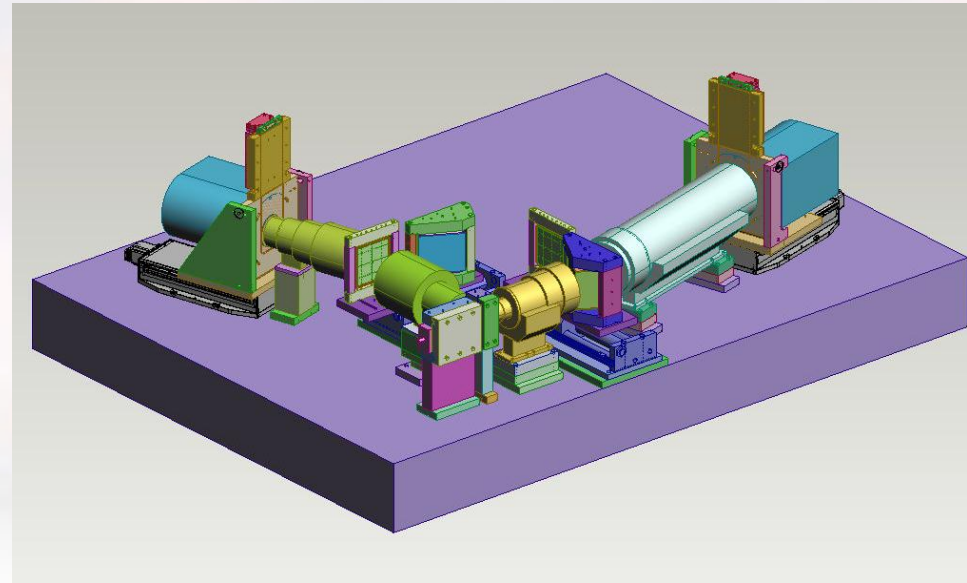
200 400 500 600 700 800 900  
Wavelength (nm)

# RATCam Calibrations & Pipeline

- Every night
  - Automated twilight flat fields
  - Photometric standards every 2 hours.
  - Quicklook reductions in 2 – 3 min
- End of night pipeline
  - Debiases and trims the overscan region
  - Flat fields based on latest flats
  - Solves WCS against catalogues
  - Data distributed following business day
- Data provided to allow user to
  - Defringe
  - Apply a bad pixel mask

# FRODOSpec

- Dual beam
  - Dichroic at  $5750\text{\AA}$
  - Blue Arm  $3800 - 5750\text{\AA}$
  - Red Arm  $5750 - 9000\text{\AA}$
- Two gratings
  - VPH,  $R = 5500$
  - Transmission grism,  $R = 2300$
- IFU  $11 \times 11$  lenslet array ( $0.9$  arcsec “pixels”)
- Fixed central wavelengths
- Ar, Xe and W lamps
- $4k \times 2k$  detectors cooled to  $-100$  degC
- Commissioned Autumn 2008.

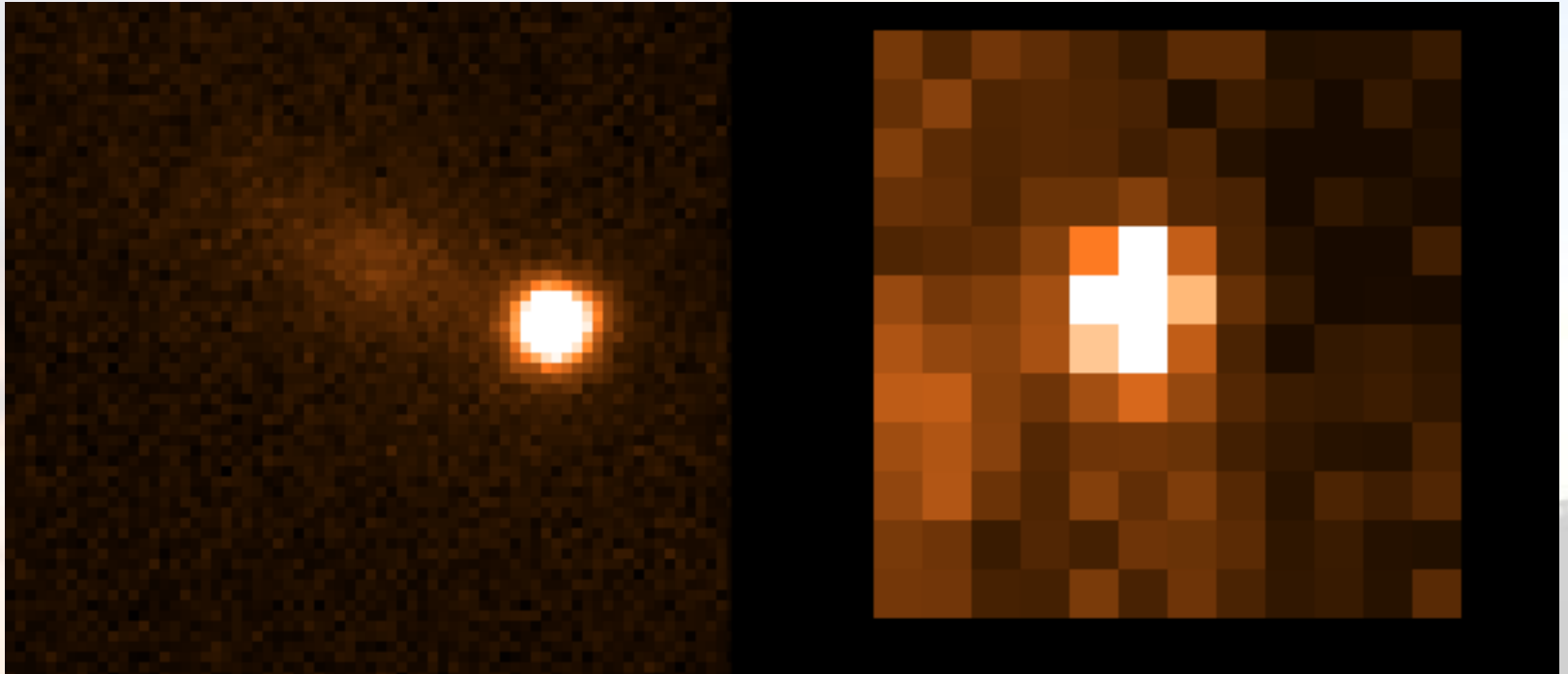


# A big black box

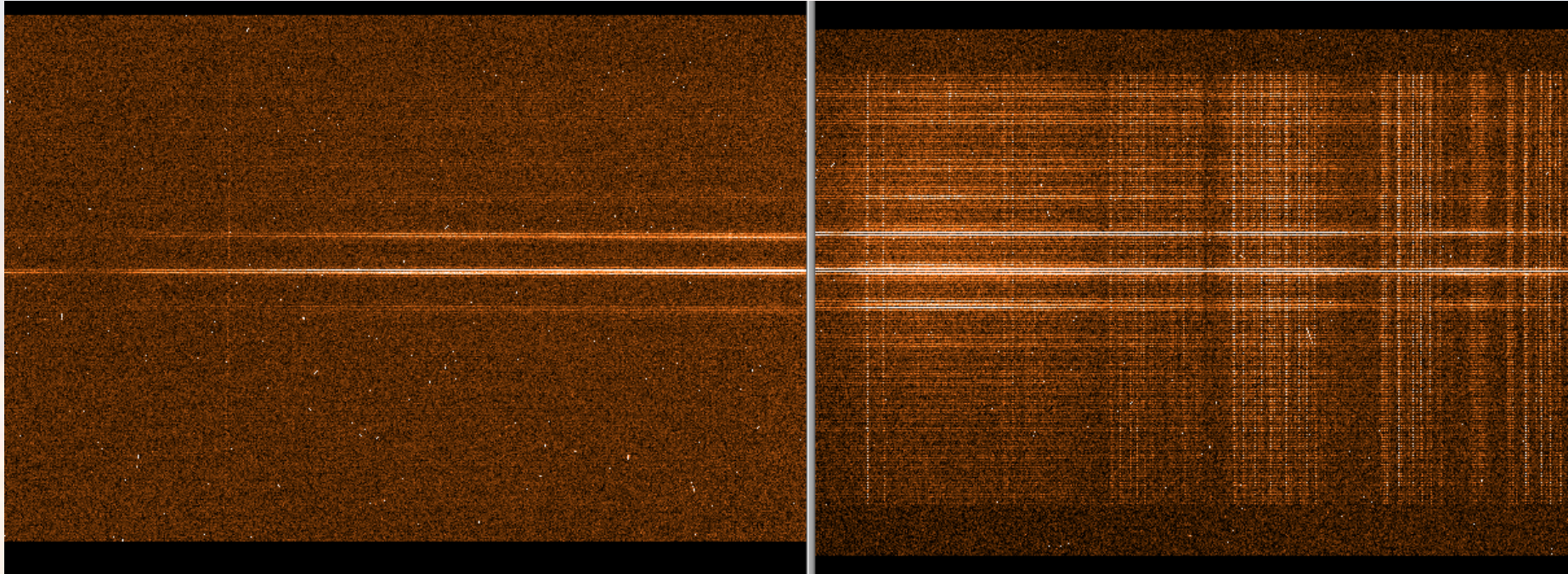




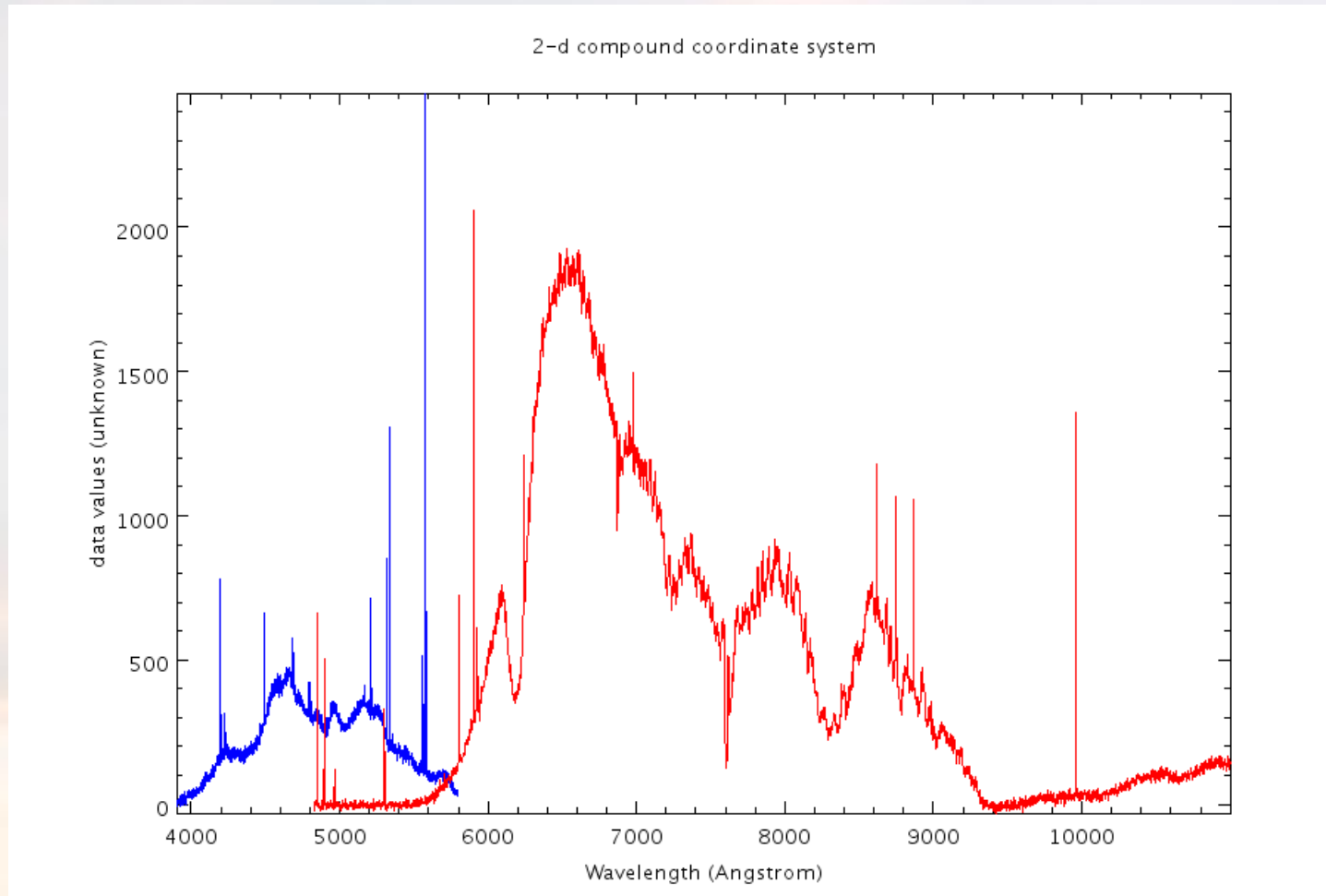
# Example: A PTF supernova



Unprocessed 2D spectra  
available within ~2 minutes.



# Pipeline extracted spectra



Currently available next day, but working on speeding up the software to allow inclusion in Quicklook

# RISE

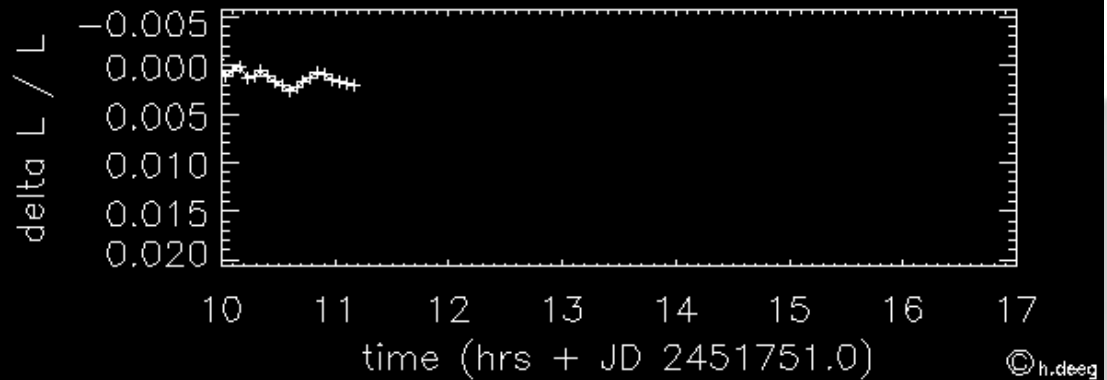
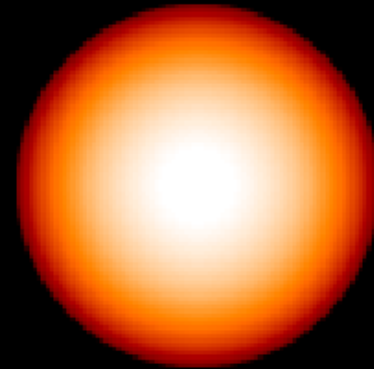
## Fast imager / photometer

- Rapid Imaging Search for Exoplanets
- Frame transfer CCD (no shutter) camera (Andor)
- 1024 x 1024 pixels
- Fore-optics give 10x10 arcmin FoV
- 0.6 seconds minimum exposure time
  
- Developed with QUB for specific project but available as a common user facility.

# Exoplanets - SuperWASP



SuperWASP telescope  
on La Palma



HS209458, Hans-Jörg Deeg

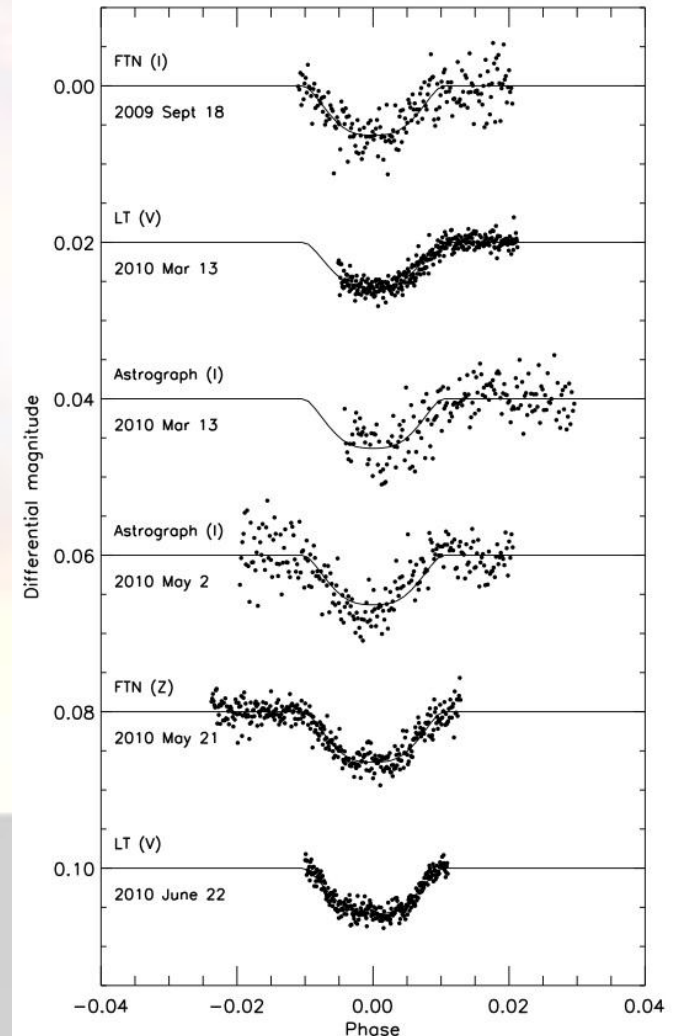
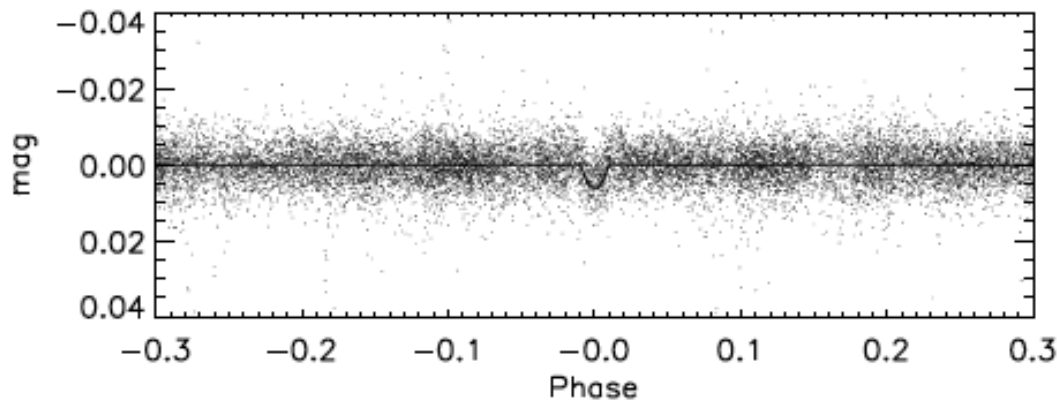
# Exoplanets - Transit timing

Routinely delivering few-millimag photometry for transit studies.

Typical depth of transit 0.01-0.03 magnitudes and duration 1-4 hours.

An “Earth” in the same system would perturb the orbit timing by about 10 seconds a year.

WASP discovery data

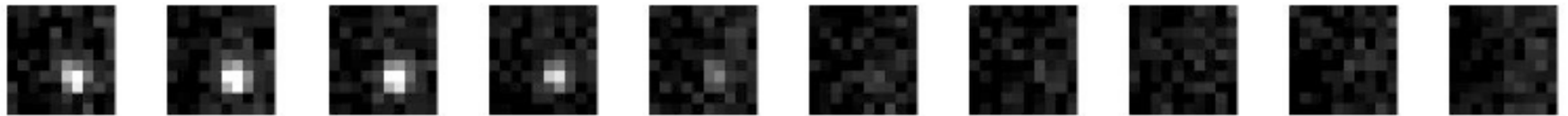


# THOR

## Even faster imager

- Primarily the tip-tilt camera but can be deployed scientifically too.
- Integrated into the user phase 2 system
- EMCCD (no shutter) camera (Andor)
- 512 x 512 pixels (but frequently windowed)
- ~5 msec minimum exposure time
- High time resolution or “lucky” shift-and-add

Lunar occultation timing. 6msec exposures



7239

7299

7800

8189

8501

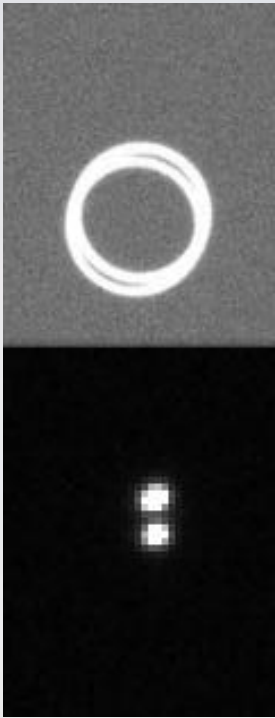
8801

9100

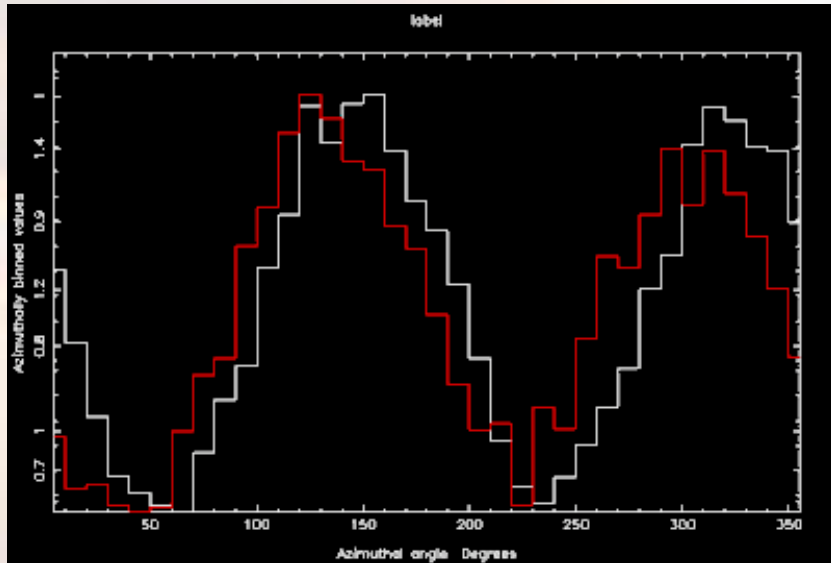
9402

9701

# RINGO2



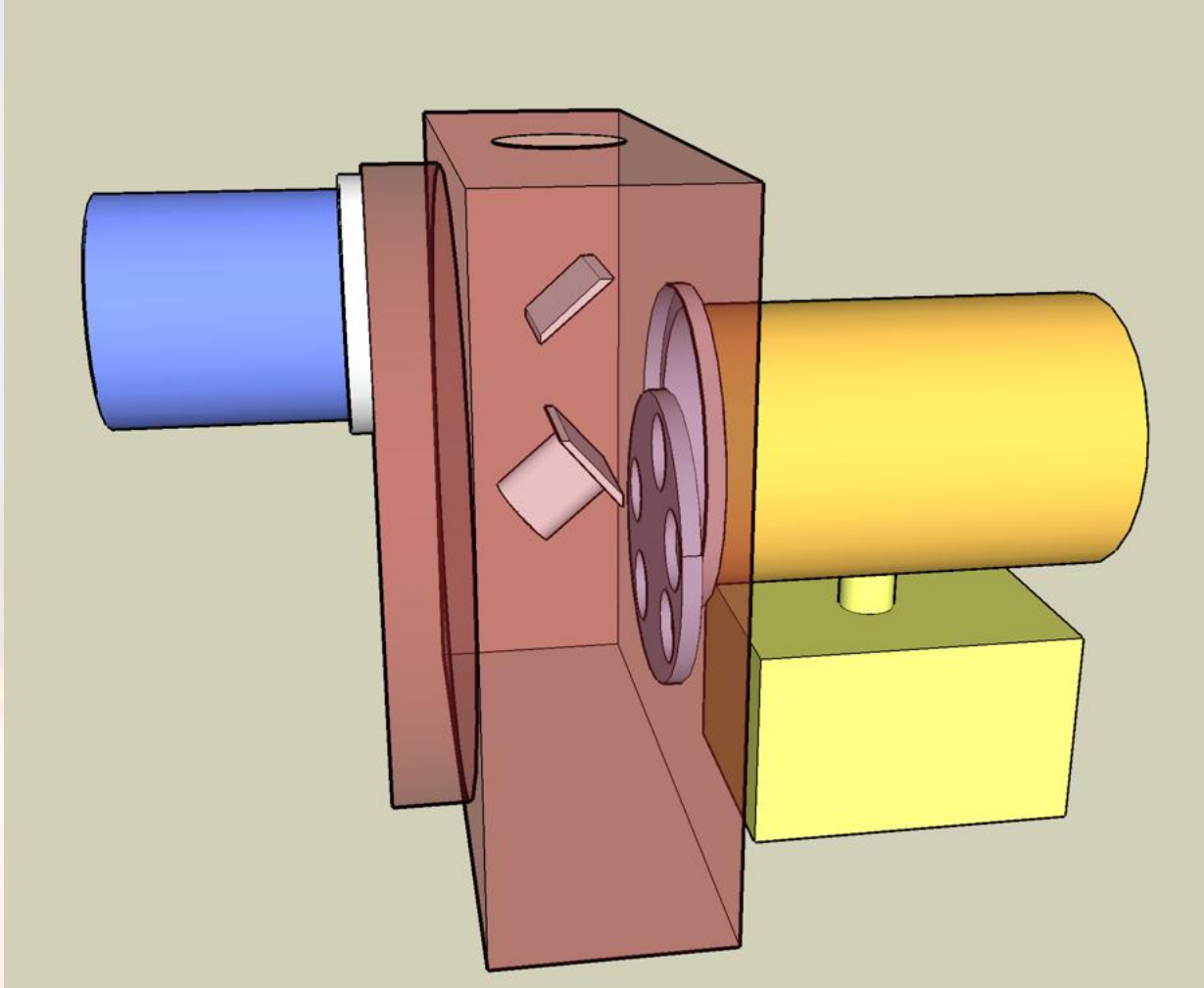
- Upgrade to RINGO polarimeter
- EMCCD has read-noise  $<1e^-$  and read out approx. 8 fps.
- Gain 2 mag sensitivity
- Time resolution  $\sim 1$ sec



Can stack data post acquisition to trade sensitivity vs. time resolution



10

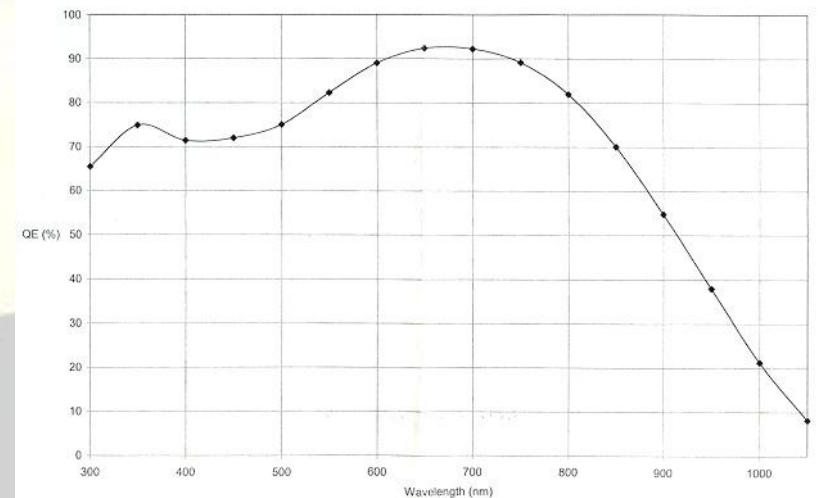
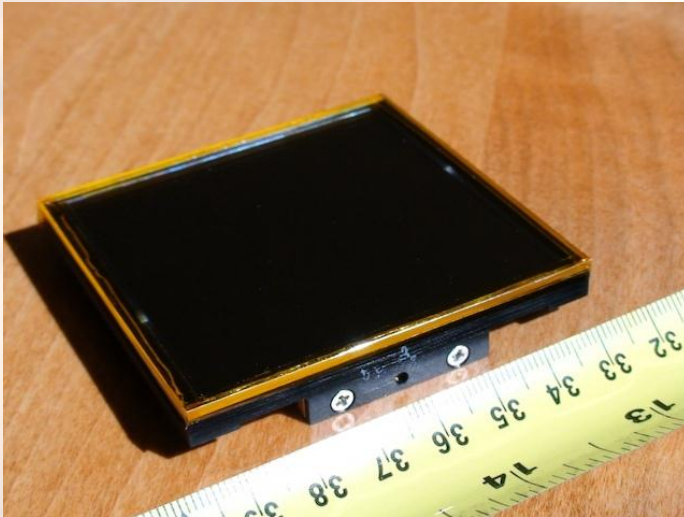


# Instrument for 2011: IO ("Infrared-Optical")

- Optical FOV 10 x 10 arcmin
- IR FOV 6 x 6 arcmin
- Tip-tilt feeds for both cameras
- Dichroic feed to both cameras
- Wavefront sensor (THOR) is EMCCD that can be used as very fast (10ms) timing camera and for lucky imaging.

# O camera

- Fairchild CCD486 BI array
- 4096 x 4096 15 micron pixels
- Dark current  $< 0.02 e^- / \text{sec}$
- Read noise  $< 10 e^-$
- Modifications to the telescope are complete
- Camera to be installed 2011



# I camera

- HAWAII-2RG
  - 2048 x 2048 18 micron pixels
  - 1.8 micron cutoff
  - Substrate removed
    - QE>70% 0.4 - 1.0 microns
    - QE>80% 1.0 - 1.8 microns
  - Dark current < 1 e<sup>-</sup> / sec
  - Guide window functionality to generate tip-tilt signal

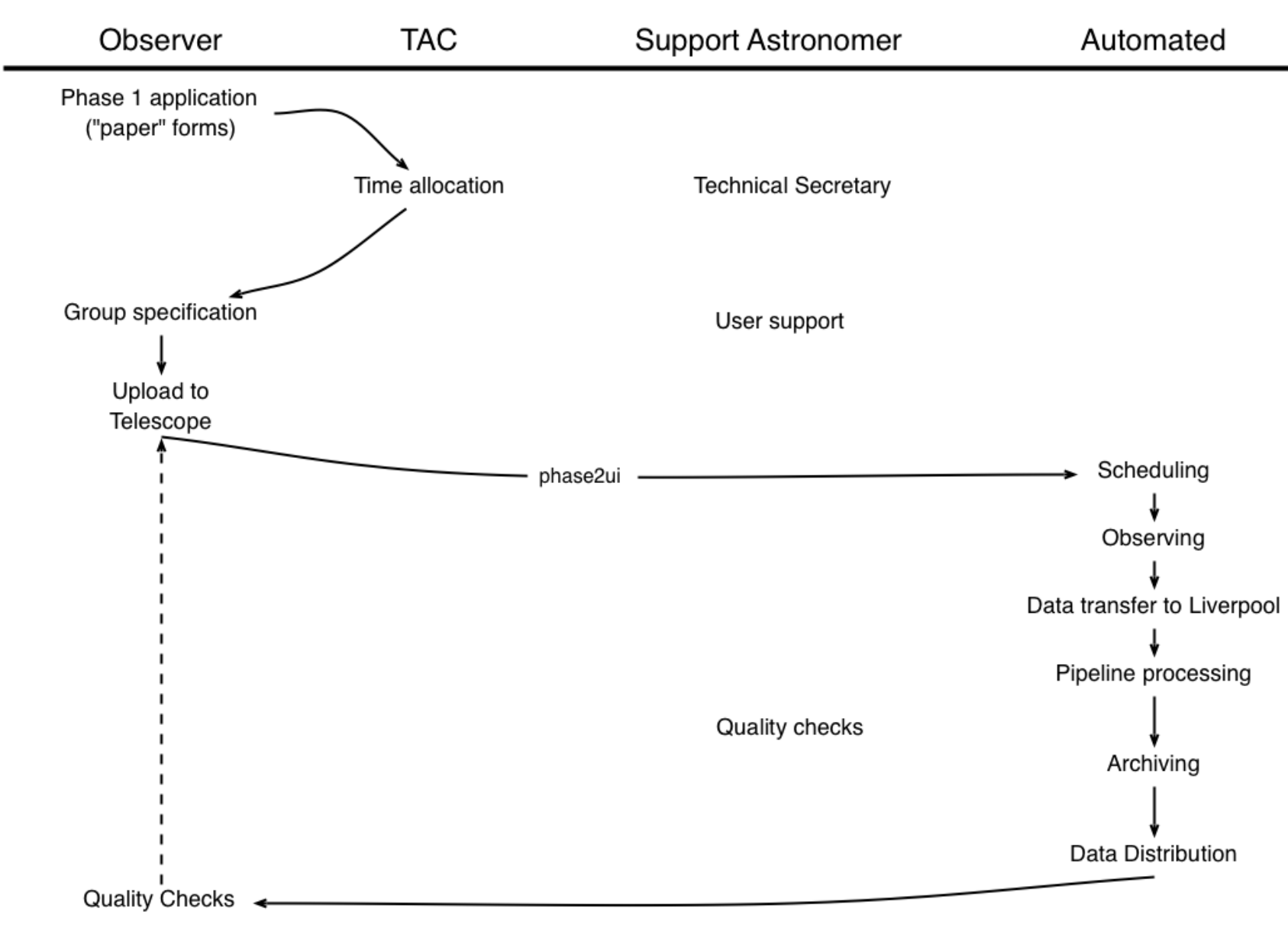
# Instrumentation

- Current
  - RATCam CCD imager
  - RINGO2 Polarimeter
  - FrodoSpec Spectrometer
  - RISE Fast readout CCD
  - THOR Very fast readout CCD
- Near Future (this year)
  - IO:O CCD Imager
- Later
  - IO:I NIR Imager
  - Tip-Tilt
- Decommissioned
  - SupIRCam NIR imager
  - RINGO Polarimeter
  - Meaburn(John) Spectrometer

# Common Features Between Instruments

- Completely independent
- Common command set (e.g. CONFIG, DAY\_CALIBRATE, NIGHT\_CALIBRATE, TWILIGHT\_CALIBRATE, WAVELENGTH\_CALIBRATE, EXPOSE)
- Knowledge of calibration procedures built into the instrument control system
- Electrical power kept running 24/7
- Few servo mechanisms – obtain precision via mechanical means
- Housekeeping: Single data transfer, reduction software, archiving
- Problems with cooling
- PSU failures are most common fault

# How Users See Robotic Operation



# Phase2 Data Entry

Observing Requests entered at any time.  
Available immediately to the scheduler.

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<!DOCTYPE RTML SYSTEM "http://www.estar.org.uk/documents/rtml2.1.dtd">
<RTML Version="2.1" type="request">
  <Users>
    <User>Chris Mottram</User>
  </Users>
  <Programmes>
    <Programme>TMC/estar</Programme>
  </Programmes>
  <ITAGs>
    <ITAG>agent_test</ITAG>
  </ITAGs>
  <Groups>
    <Group>
      <Name>wmap_fixed_a</Name>
      <Type>camera</Type>
      <Region>optical</Region>
      <Coordinates>
        <RightAscension units="hms" format="hh mm ss.ss">01 02 03.00</RightAscension>
        <Declination units="dms" format="sdd mm ss.ss">+45 56 01.00</Declination>
      </Coordinates>
      <Observing Constraints>
        <Solar Elevation Constraint>
          SOLAR ELEVATION="NAUTICAL TWILIGHT" (or darker)
        </Solar Elevation Constraint>
        <Seeing Constraint>
          SEEING="UNCONSTRAINED" (or better)
        </Seeing Constraint>
      </Observing Constraints>
      <Exposure>
        <Exposure type="time" units="ms">1000.0</Exposure>
      </Exposure>
      <Filter>
        <FilterType>V</FilterType>
      </Filter>
      <Detector>
        <Detector>ratcam</Detector>
      </Detector>
      <Schedule>
        <Schedule type="time" units="ms">1000.0</Schedule>
      </Schedule>
      <Score>0.0</Score>
    </Group>
  </Groups>
</RTML>
```

- Phase 2 GUI (for humans)
- RTML document (for software)



# Phase2ui

- A conventional menu driven GUI
- Java 5 and Swing executable runs locally at user
- Launched from browser by Java Webstart
- Accesses phase2 db at telescope via Web Services
  - SOAP (XML documents) over HTTP
  - Widespread compatibility and minimal system requirements. (Browser + JVM)
  - If web browser works, this should too.
- User has single sign-on for all their proposals
- When internet fails, requests cannot be changed. Observations continue using existing database.

# Observation Definition Wizard

Photometric Sequence Wizard

Start Configuration

Select Target: BQ Cam [Extra-solar] [RA: 3:34:59.89, Dec: 53:10:23.60] New

Rotator Setting: Cardinal

Autoguide:  Yes  No  Automatic

Defocus: 0.0 mm (non-cumulative)  Is Standard

Add Configuration / Exposure

Instrument: RATCam

Instrument Config: rband [Imager configuration] [Filters]=[SDSS-R] or New

Exposure: 2 x 20 seconds Add

Observation List

Instrument	Config	Expose(s)	Count
RATCam	ratcam i band	10.0	2
RATCam	rband	20.0	2

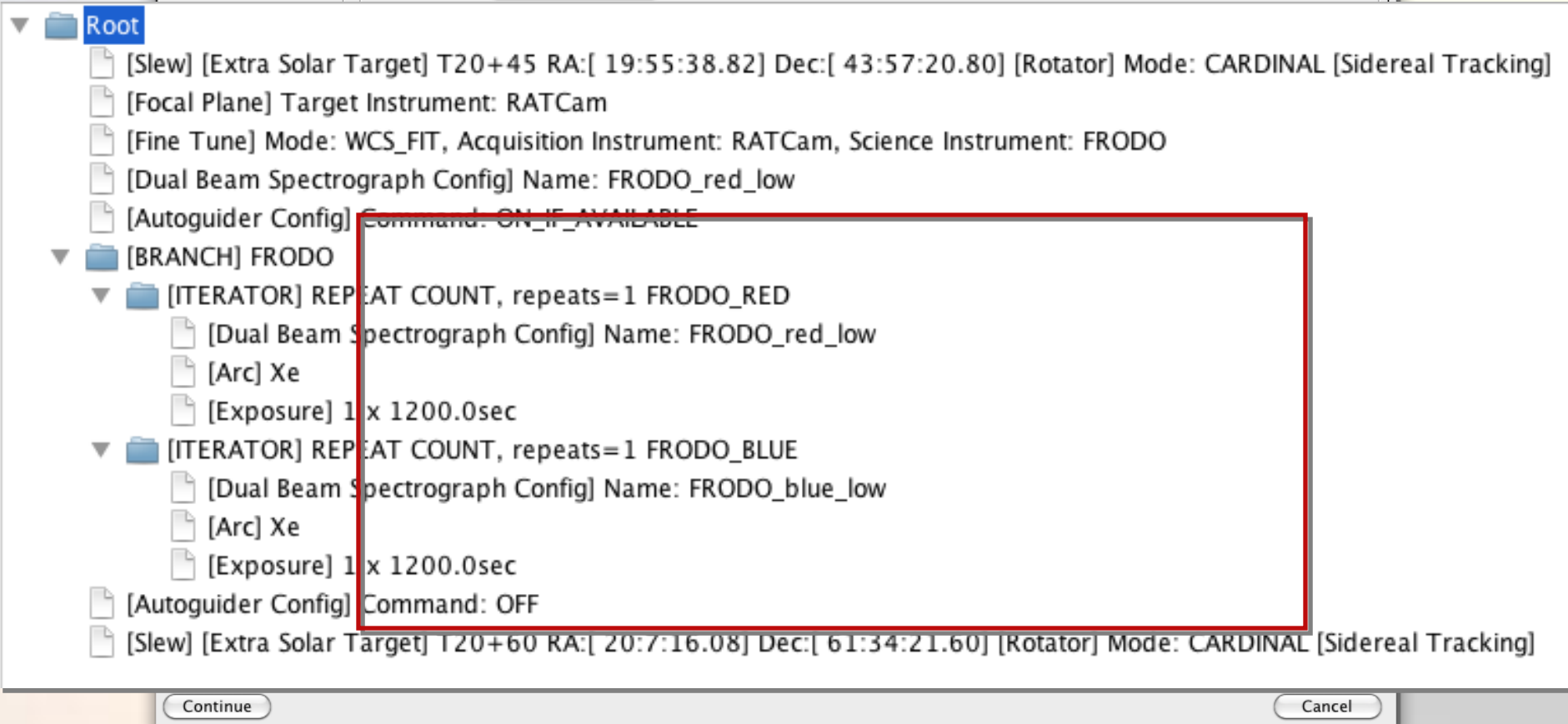
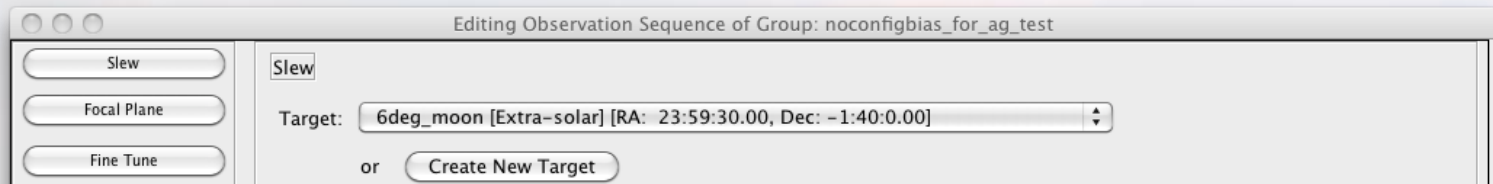
Up  
Down  
Delete

Continue Cancel

For straightforward observation groups. Most programs use the conventional pre-packaged sequences.

Specify **what** you want, not how.

# Modular Definition of Sequences



User defines observation as an explicitly ordered list of commands

# The Validator

The screenshot displays the Liverpool Telescope Phase2 UI (v0.7.2) with a validation failure dialog box open. The main window shows a tree view of users and programmes, with 'BQ Cam Photometry' selected under 'JL09B06c'. The 'Validate Group' button is highlighted with a red box. The dialog box, titled 'Displaying validation results of observation sequence in builder', contains the following text:

Sequence in editor  
FAILURE: An Instrument Config is required before an Exposure.  
FAILURE: An Instrument Config is required before an Exposure.  
The validation completed with 2 failures.

The dialog box also features a 'Close' button and a large red 'FAILED' status indicator. Below the dialog box, the main window shows a list of programmes and users, including 'JL09B06c' and 'BQ Cam Photometry'. The 'Include disabled groups in tree' checkbox is checked.

Displaying Programme: XJL09B0  
Expanding Proposal: JL09B06c  
Displaying Access Permission: JL09B06c  
Displaying Proposal: JL09B06c  
Expanding User: Steele.Iain  
Expanding Access Permission: Iain Steele - PI - JL09B06b  
Expanding Proposal: JL09B06b  
Expanding Access Permission: Iain Steele - PI - JL09B06c  
Expanding Proposal: JL09B06c  
Displaying Group: BQ Cam Photometry

Buttons in the dialog box: Close, Edit Observation Sequence, Delete Observation Sequence, Create New Observation Sequence.

# Validator Rules

- **DANGER** : “injury to life or equipment”
  - Cannot occur!
- **FAIL** : “telescope software will reject”
  - E.g., no PI, no TAC, no timing constraint, missing instrument config, sky PA specified but no target coordinates
- **WARN** : “telescope accepts, but it looks wrong”
  - Should almost never be ignored
  - E.g., missing focal plane configuration, no target
- No approval required by support astronomer
- No “mild warning” for uncommon configs

Live Status 2010 Jun 25  
05:05:04 GMT



SYSTEM	WEATHER	MECHANISMS
Master Control Program <b>OKAY</b>	Humidity 22 %	Wind (blowing to)
Telescope Control <b>OKAY</b>	Temperature 13.1 c	
Weather Monitor <b>OKAY</b>	Dew Point -8.1 c	
RCS-TCS Chatter <b>ENABLED</b>	Pressure 776 mb	ALT <b>TRACKING</b>
Engineering Override <b>DISABLED</b>	Precipitation <b>DRY</b>	AZ <b>TRACKING</b>
		CAS <b>TRACKING</b>
		Secondary Focus 27.516 mm

Real time status of LT

# Liverpool Telescope Quicklook Data

Proposal	User Name	24/06	23/06	22/06	21/06	20/06
<a href="#">JL09B03b</a>	Matt Darnley	-	<u>6</u>	-	-	-
<a href="#">JL09B06b</a>	Iain Steele	-	-	-	<u>15</u>	<u>4</u>
<a href="#">JL09B07</a>	Ian McHardy	<u>2</u>	<u>8</u>	-	<u>16</u>	-
<a href="#">PL09B03</a>	Mark Sullivan	-	<u>12</u>	<u>6</u>	<u>15</u>	-
<a href="#">PL10A01</a>	Susana Barros	-	-	<u>103</u>	-	-
<a href="#">PL10A03</a>	Tom Barclay	<u>4</u>	<u>1</u>	-	<u>1</u>	-
<a href="#">PL10A04</a>	M.T. Botticella	-	<u>13</u>	-	-	-
<a href="#">PL10A05</a>	Ian McHardy	<u>1</u>	-	<u>1</u>	-	-
<a href="#">PL10A07</a>	Keith Horne	<u>8</u>	<u>61</u>	<u>27</u>	<u>49</u>	-
<a href="#">PL10A13</a>	Tom Marsh	-	<u>8</u>	-	<u>17</u>	-
<a href="#">CL10A02</a>	Luis Goicoechea	<u>4</u>	-	-	-	-
<a href="#">CL10A03</a>	Nancy Elias	<u>11</u>	-	-	<u>11</u>	-
<a href="#">CL10A06</a>	Francesc Salles	-	-	<u>10</u>	-	-
<a href="#">LTCollim</a>	LTOPs	<u>2</u>	-	-	-	-
<a href="#">NSOPrior1</a>	Andy Newsam	-	-	-	-	<u>3</u>
<a href="#">NSO Priority 1</a>	Andy Newsam	<u>6</u>	<u>3</u>	<u>3</u>	<u>1</u>	-
<a href="#">NSO Priority 3</a>	Andy Newsam	-	-	<u>1</u>	-	-
<a href="#">NSO Priority 4</a>	Andy Newsam	-	-	-	-	<u>4</u>
<a href="#">RATStand</a>	LTOPs	<u>18</u>	<u>66</u>	<u>48</u>	<u>72</u>	-
<a href="#">RISEFocus</a>	LTOPs	-	-	<u>20</u>	-	-
<a href="#">Standards</a>	BGCA	<u>4</u>	<u>116</u>	<u>32</u>	<u>4</u>	-
<a href="#">UNKNOWN</a>	UNKNOWN	<u>2</u>	-	-	-	-

Pipeline reduced data within 2-3 minutes



# DATA ARCHIVE

If you have javascript available on your browser, we strongly recommend turning it on.  
Should you decide not to, the 'Refresh form' button can be used to force the dynamic updates which would have been automated by javascript.  
[Instructions for using this form](#)

### TARGET POSITION

**Target Name**    
**Right Ascension**   **Declination**   J2000   
 Radial search mode:  Circle  00 10 00  
**Resolve name**  **using resolver**  NED

### OBSERVATIONAL CRITERIA

**Date**   **Integration**    
(sec.)  
**Seeing**   **Airmass**    
(pixels) (sec z)  
**Instrument**    
 RATCam  
 Ringo  
 SupIRCam  
 Meaburn

### IMAGING CONFIGURATIONS

Any  of these filters   
 Optical: Clear, Sloan u', Sloan g', Sloan r', Sloan i', Sloan z', Bessell B  
 IR: J, H, -ANY-  
 Binning

### SPECTROSCOPIC CONFIGURATIONS

**Wavelength** ( $\text{\AA}$ )   **Resolution** ( $\text{\AA}$ )    
**Dispersion** ( $\text{\AA pix}^{-1}$ )

# Timing Constraints

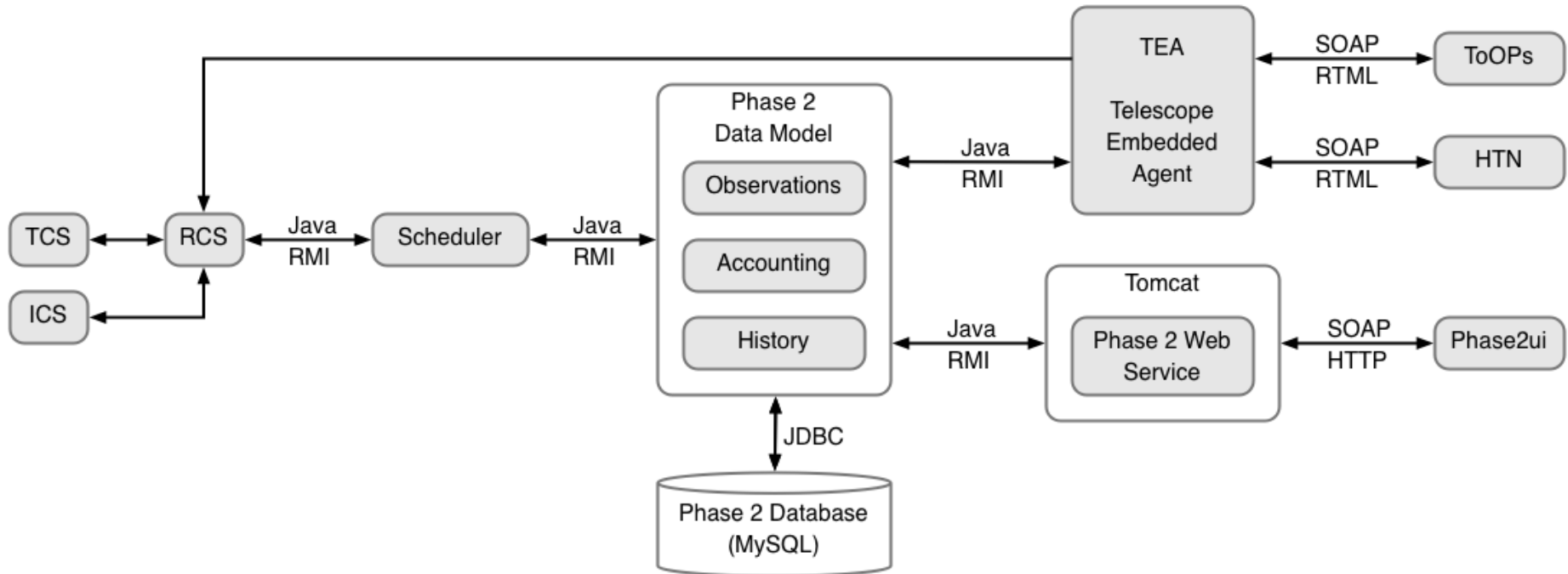
- Flexible
  - Any time after a start date the conditions are met. Once only.
- Monitor
  - Repeat at an interval with regularity precision defined by a window fraction. Interval typically hours to months.
- Ephemeris
  - Once only, at a specified phase.
- Interval
  - Observe repeatedly with a fixed minimum interval.
- Fixed
  - At a specific time (e.g. occultation or simultaneous with a spacecraft)
- Target of Opportunity modes...



# Targets of Opportunity

- Client script running at the telescope (e.g., GRB followup)
- Intelligent agent submitting Robotic Telescope Markup Language with the appropriate priority flag (e.g., exoplanet microlensing)
- Make it as simple or as complex as you like...

# Software Processes



# Night Operations Staffing

- Capable of totally unsupervised operations.
- Duty Officer on rota doing one week shifts.
- Principally role is coordinating safety officer
  - Always someone on call at a single phone number.
- Can prevent operations at their discretion.
- Most errors occur at start-up, so frequently helpful to have a witness even if the automated fault recovery fixes things for itself.
- No observers means no observer support

# Night Operations Staffing

- Almost all staff on this rota.
- Reduces out-of-hours working by the classically “operations” staff (aka astronomers)
- Allows software engineers to see their own code running.
- One staff hour per day



Normal office hours  
Out-of-hours working

Staff

Software

Data Archive

12:00  
13:00  
14:00  
15:00  
16:00  
17:00  
18:00  
19:00  
20:00  
21:00  
22:00  
23:00  
00:00  
01:00  
02:00  
03:00  
04:00  
05:00  
06:00  
07:00 Sunrise  
08:00  
09:00  
10:00  
11:00  
12:00

**Liverpool Telescope: Robotic Control System: Engineering Interface: [ADMIN:V@version@ - Build @build@]**

Control Signal Expert Help

Current time: 2011 Feb 25 at 23:18:17 UTC  
Process in Control: RCS  
Status: OPERATIONAL  
Observing Mode: OBSERVED AG  
Scheduled: Scheduled  
ENG

**System Variables**

System	OKAY
Access	OKAY
Weather	CLEAR
Enclosure	OPEN
PWC	OPEN
Control	ENABLED
Network	CONNECTED
Intent	ACTIVATED
Period	MEASUREMENT

**Sky Model**

Pred. Seeing at zen. (arc) 1.56  
Seeing category **POOR**  
Extinction category **INSUFFICIENT**

**Instruments**

NAME	STATUS	WASH	TEMP
RATCAM	ONLINE	WASH	-110.49 C
SUPIDCAM	ONLINE	OKAY	
RINGO2	ONLINE	OKAY	-52.42 C
FRONO_BUTE	ONLINE	OKAY	-99.45 C
FRONO_PFD	ONLINE	OKAY	-99.45 C
RISE	ONLINE	UNAVAILABLE	-40.77 C

**Secondary Disks Clouds**

**Meteorology**

Wind Speed 11.9  
Wind Direction 97  
Humidity 0.1  
Pressure 778  
Moisture 0.03  
Temperature 9.2

**Mech/Axes**



**Photon in X (on 1)**

System State: **Warning** Status Details

Process States: 25/02/11 23:16:59 Control LT MONITOR E11 v0.108

MCP	Okay	Azimuth	Okay	Altitude	Warning	Cassegrain	Okay	Aux.Mech.	Okay	Prim.Mirror	Okay
CHB	Okay										
SUIT1	Okay	AZM OID	Okay	ALT OID	Okay	CAS OID	Okay	AMN OID	Okay	PMS OID	Okay
UIT2	Okay	AZM NCI	Okay	ALT NCI	Okay	CAS NCI	Okay	AMN NCI	Okay	PMS NCI	Okay
AIT1	Okay	AZM NCO	Okay	ALT NCO	Okay	CAS NCO	Okay	AMN NCO	Okay	PMS NCO	Okay
AIT2	Okay	AZM REP	Okay	ALT REP	Okay	CAS REP	Okay	AMN REP	Okay	PMS REP	Okay
AIT3	Okay	AZM NSC	Okay	ALT NSC	Warning	CAS NSC	Okay	AMN AMS	Okay	PMS AMS	Okay
MCB	Okay	AZM AES	Okay	ALT AES	Okay	CAS AES	Okay	AMN CAN	Okay	PMS CAN	Okay
SDB	Okay	AZM AMC	Okay	ALT AMC	Okay	CAS AMC	Okay	AMN MBS	Okay	PMS SIF	Okay
SPT	Okay	AZM ASC	Okay	ALT ASC	Okay	CAS ASC	Okay	AMN AGD	Okay	PMS ACM	Okay
EPT	Okay	AZM MIF	Okay	ALT MIF	Okay	CAS MIF	Okay	AMN AGF	Okay		
WMS	Okay	AZM NMC	Okay	ALT NMC	Okay	CAS NMC	Okay	AMN SFD	Okay		
TCS	Okay	AZM TFP	Okay	ALT TFP	Okay	CAS TFP	Okay	AMN SFP	Okay	EC10	Okay
AGS	Okay	AZM VEN	Okay	ALT VEN	Warning	CAS VEN	Okay	AMN SMF	Okay	EC11	Okay
										EC12	Time Out
										EC13	Time Out
										EC14	Time Out
CCT-SVS	Time Out	CCT-SCC	Okay	CCT-AZM	Okay	CCT-CAS	Okay	CCT-TCC	Okay		
CMT-SYS	Time Out	CMT-SCC	Okay	CMT-AZM	Okay	CMT-CAS	Okay	CMT-TCC	Okay		
CCT-MCC	Okay	CCT-ACC	Time Out	CCT-ALT	Okay	CCT-AMN	Okay	CCT-OCC	Time Out		
CMT-MCC	Okay	CMT-ACC	Time Out	CMT-ALT	Okay	CMT-AMN	Okay	CMT-OCC	Time Out		

EXIT MODE System Request

Live Status	22 Feb
Quicklook	21 Feb
Night Reports	20 Feb
Information	19 Feb
Important Dates	18 Feb
Instruments	17 Feb
Proposals	16 Feb
Recent Data	15 Feb
Data Archive	14 Feb
Calculator	13 Feb
Schools	12 Feb
Publications	
Gallery	

Q  
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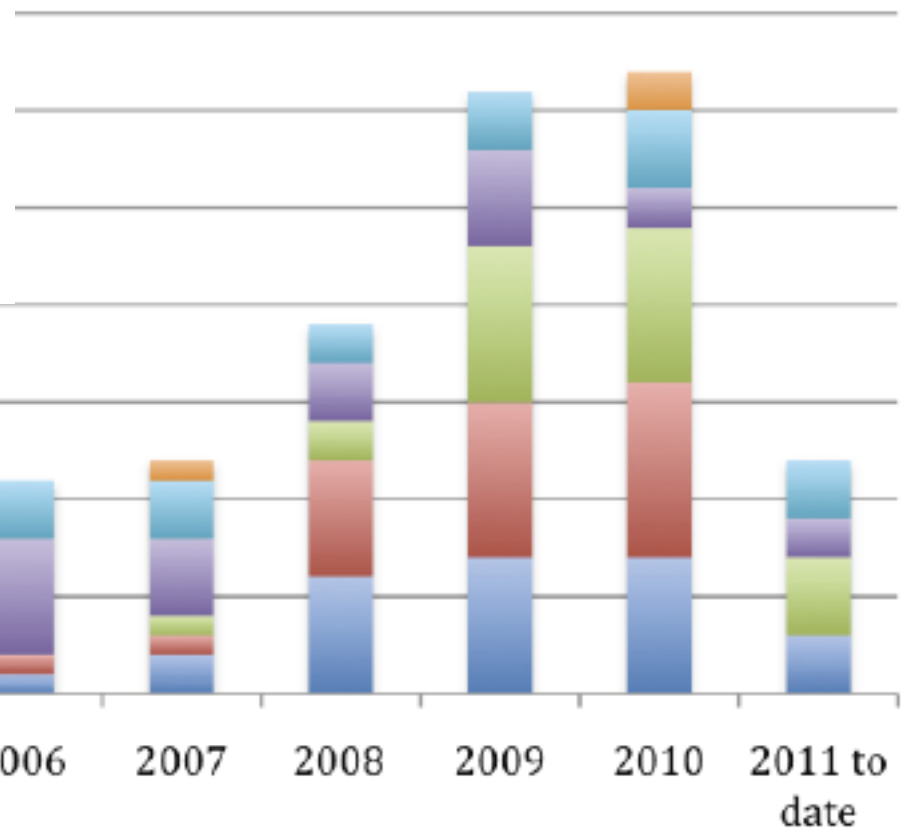
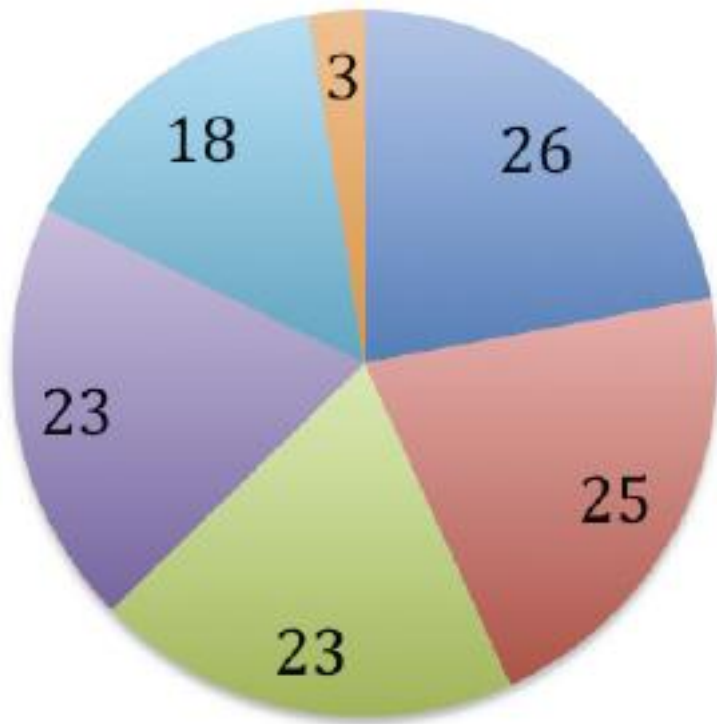
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A

Q  
A

# Science with the LT

- Target of Opportunity follow-up
  - GRBs
  - Extragalactic Supernovae
  - Novae
  - Solar system objects – Comets and asteroids
- Regular monitoring
  - Variable stars: CVs, YSOs
  - AGN and Quasars
  - Doppler mapping with a spectroscopic capability
  - Gravitational lensing
  - Solar system objects – Comet orbits

# Science Publications



- OTHER
- CV
- GRB
- Exo
- QSO
- SN

# Current Time Allocations

- PATT (UK) 40%
- Liverpool JMU 30%
- CAT (Spain) 20%
- CCI (International) 5%
- Schools/Education (UK) 5%
- OPTICON (International) up to 2%
- LT has 40-50 observing programs from 30 different institutes, allocated by 6 TACs



# Summary

- Common User Facility – adds cost!
- Comprehensive instrumentation suite
- Can react to triggers (manually or automatically) within seconds
- Data products available promptly
- Always happy to work with people to make “special” modes and/or instrumentation to enable new science

<http://telescope.livjm.ac.uk/>