Liverpool Telescope

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Liverpool John Moores University

http://telescope.livjm.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

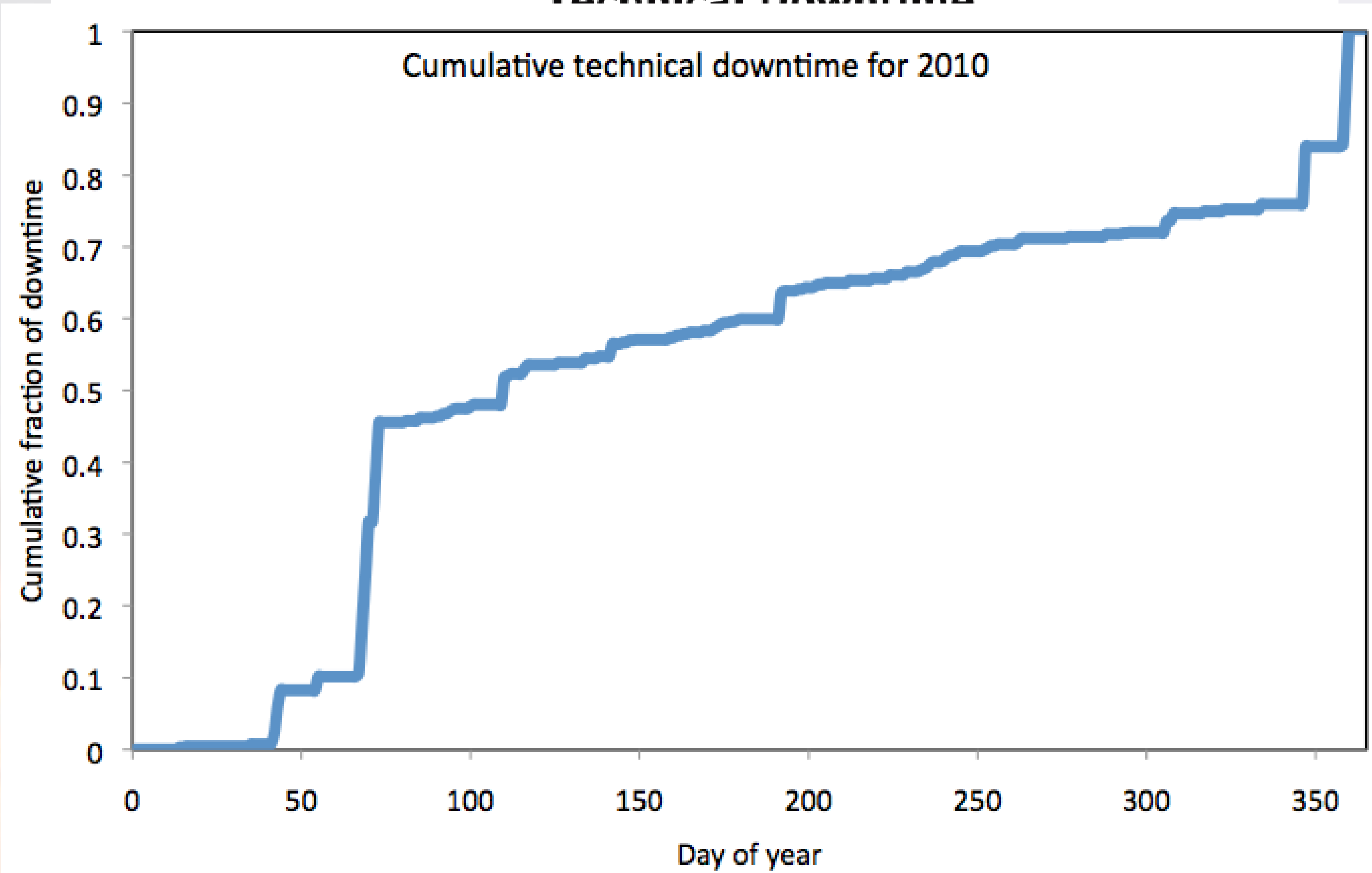
Advantages of Robotic (as opposed to remote)

- 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

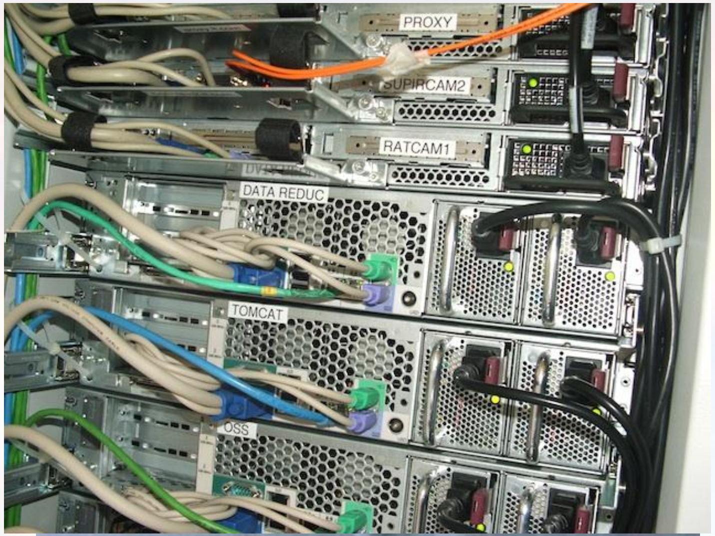
Requirements for an automatic telescope

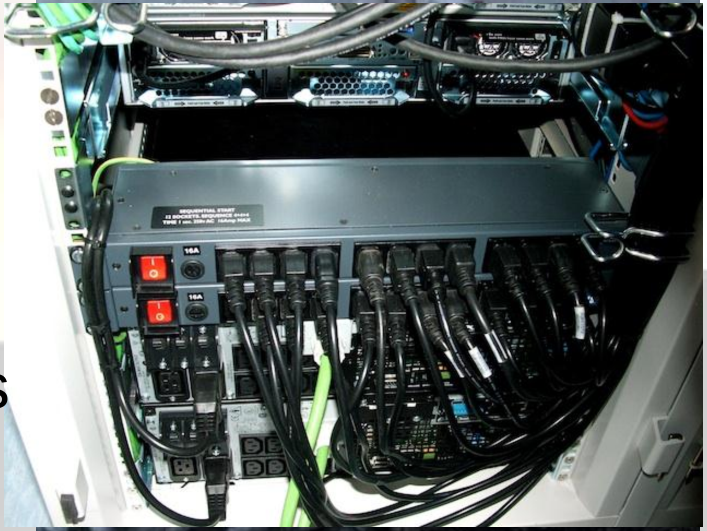
Remote & Robotic

- 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

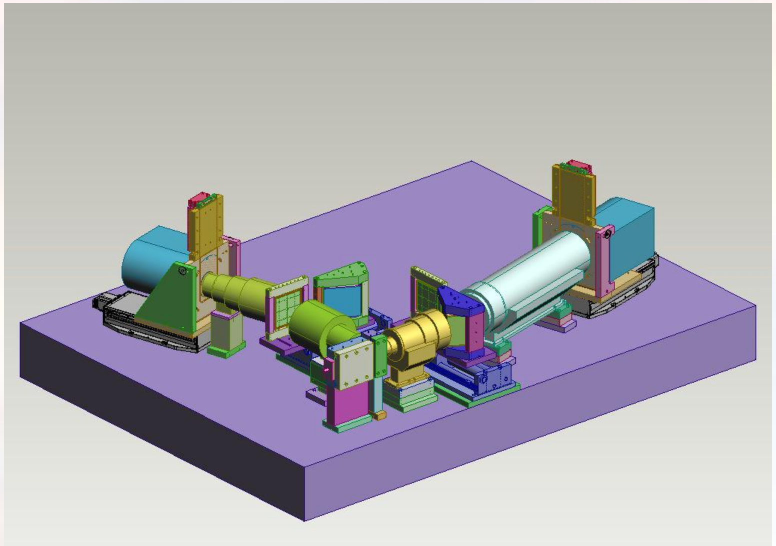
- Well defined sequence of observations including calibration observations.
- Autonomous scheduler for robotic operation.

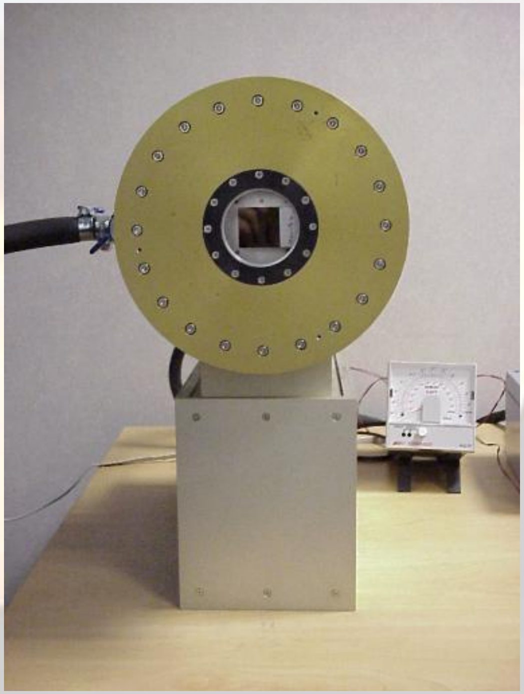


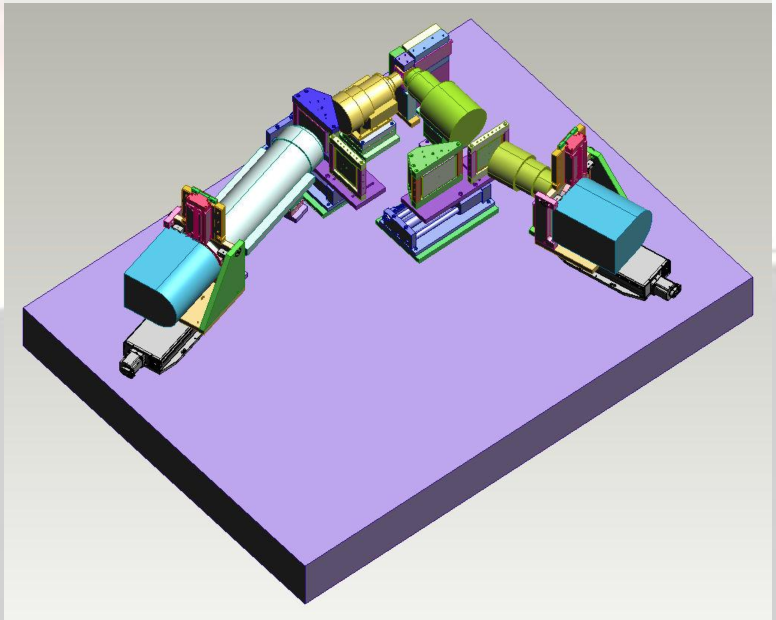


Instrumentation

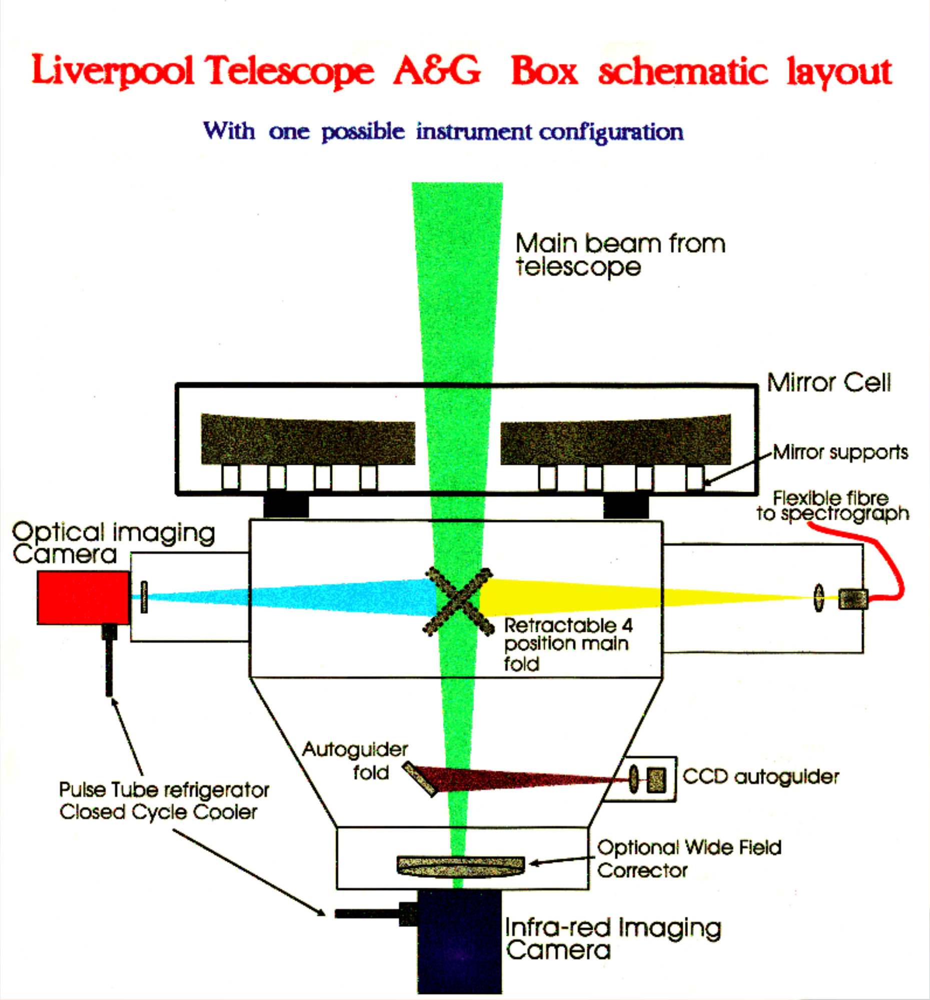
Iain Steele, Chris Mottram, Alan Scott, Stuart Bates, Steve Fraser, Robert Smith (JMU)
John Meaburn, Dan Harman (Manchester)
Phil Charles, Luisa Morales (Southampton)
Peter Meikle (ICSTM)
David Clarke (Glasgow)
Don Pollacco, Ian Todd (QUB)
Sue Worswick (Optical design)



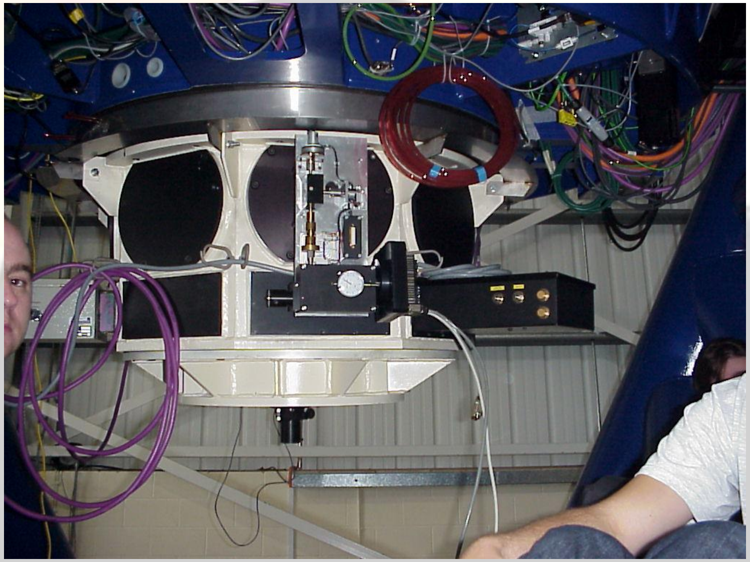




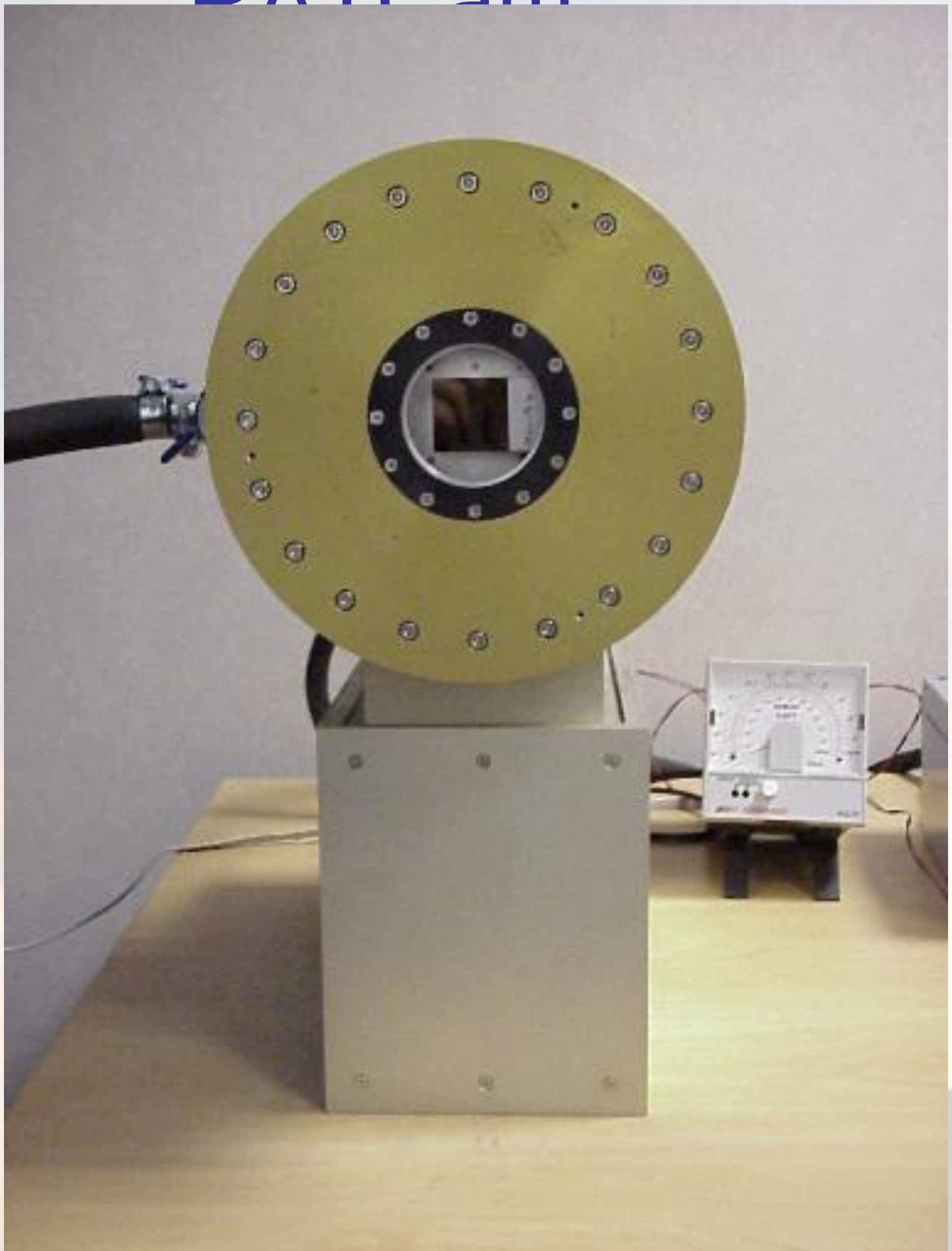
Acquisition & Guidance Box

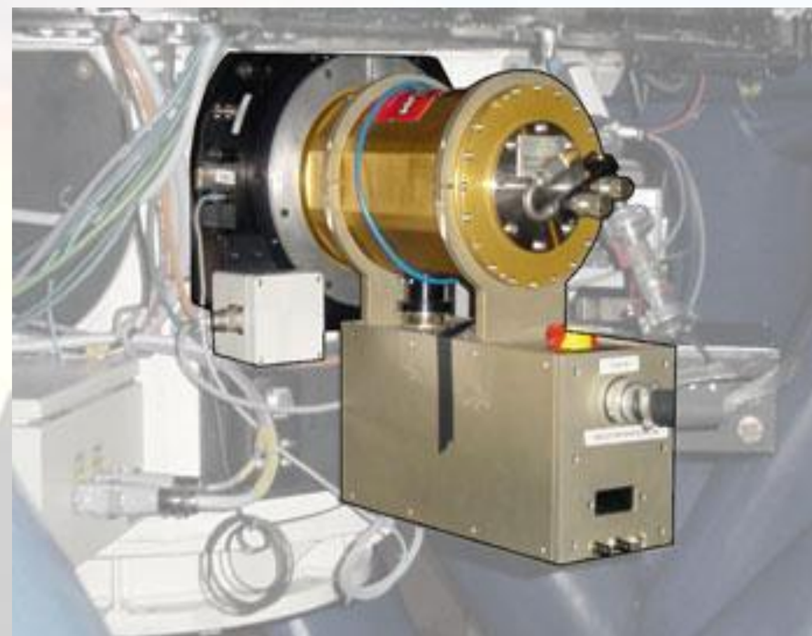


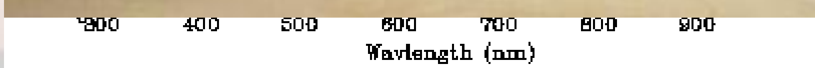
- 1 straight-through port
- 18 side ports
- Off axis frame transfer autoguider (limit V=17)
- Retractable, folding mirror gives instrument change time < 30 seconds



RATCam



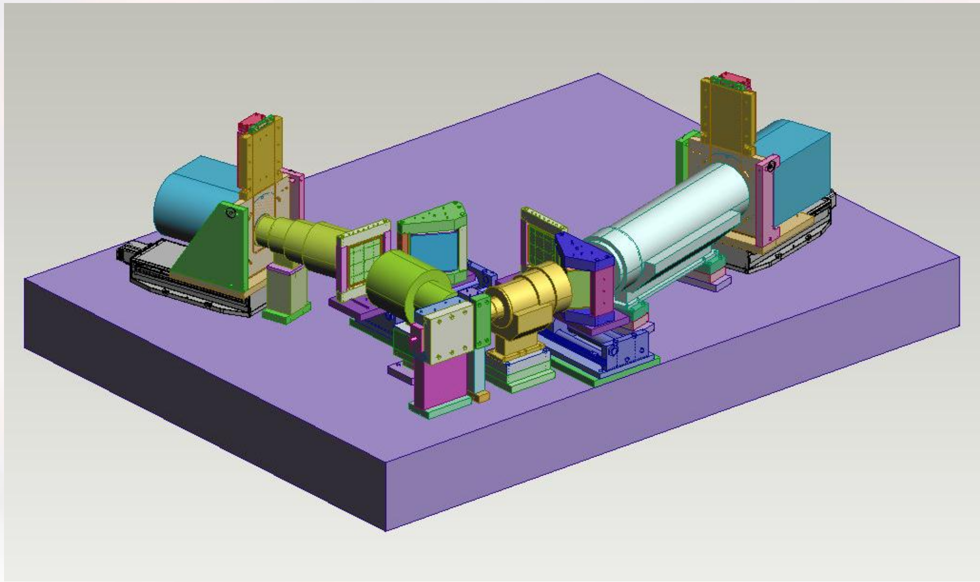




RATCam Calibrations & Pipeline

- 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

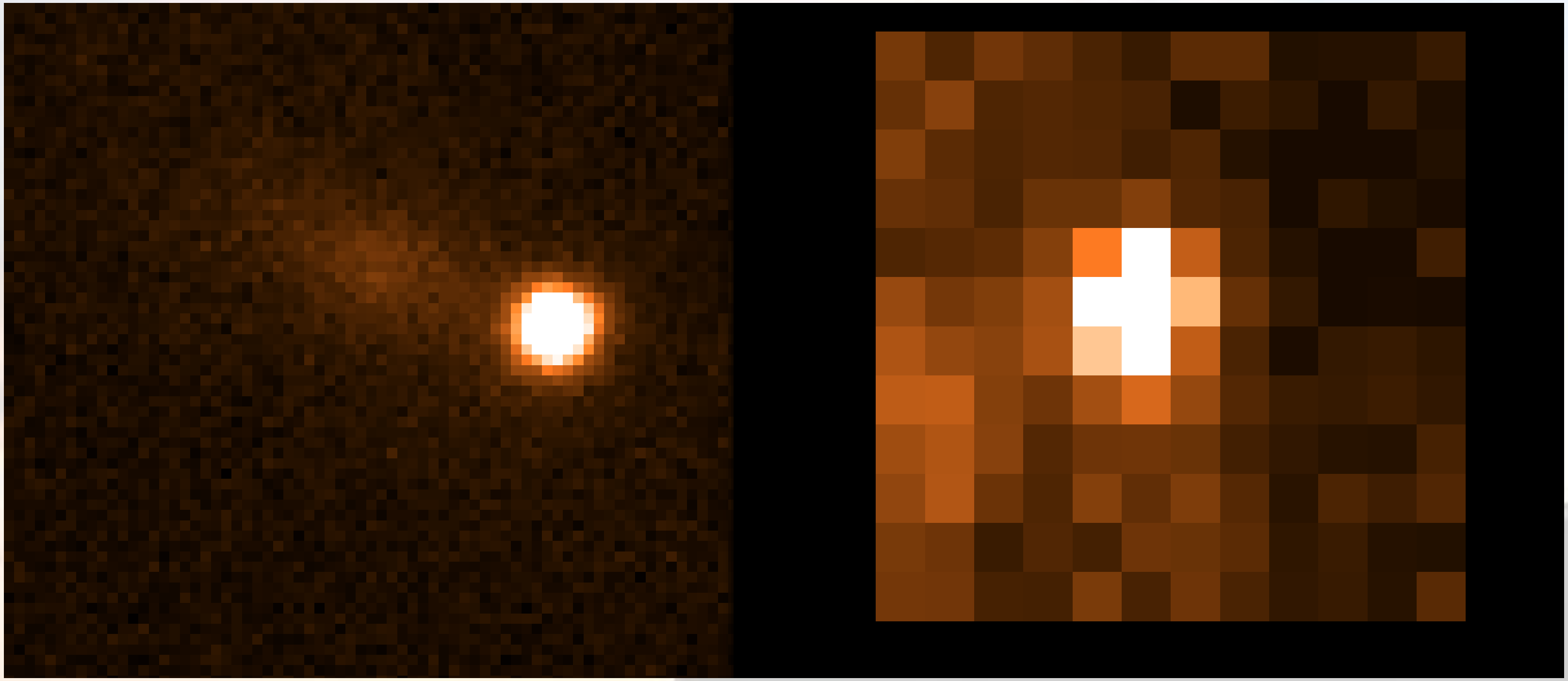
FRODOSpec



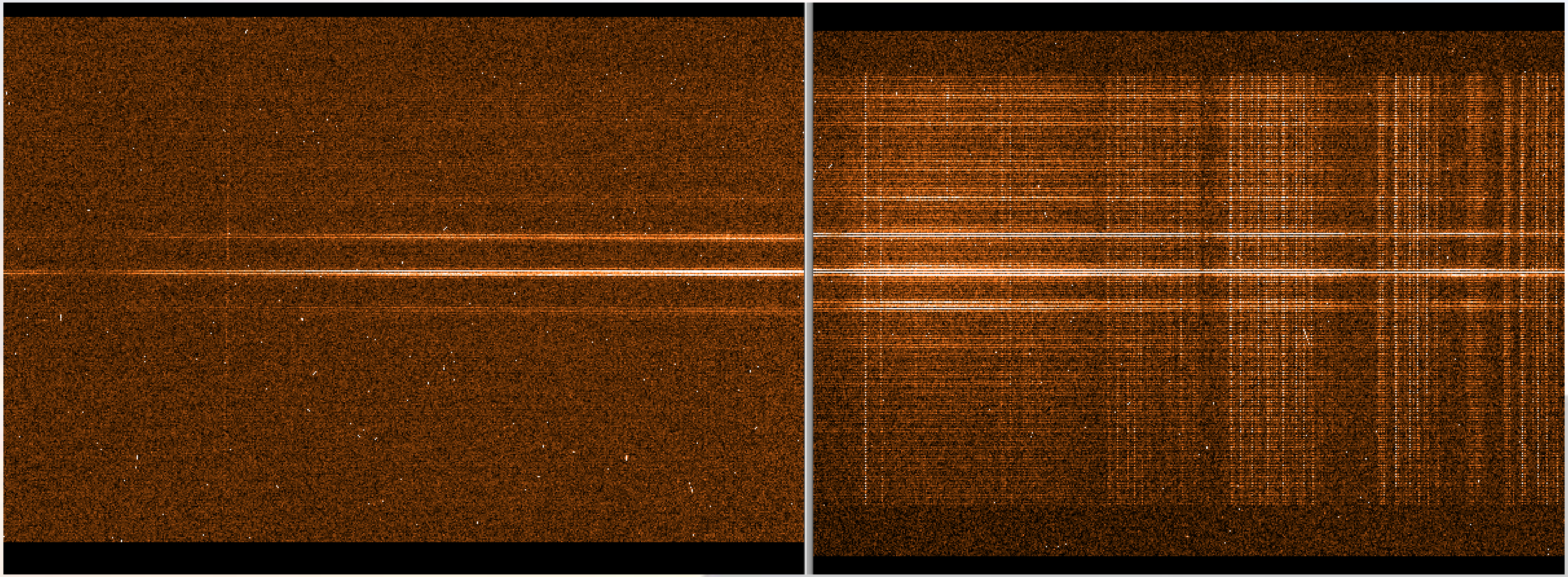
- Dual beam
  - Dichroic at 5750Å
  - Blue Arm 3800 – 5750Å
  - Red Arm 5750 – 9000Å
- Two gratings
  - VPH, R = 5500
  - Transmission grism, R = 2300
- IFU 11x11 lenslet array (0.9 arcsec “pixels”)
- Fixed central wavelengths
- Ar, Xe and W lamps
- 4k x 2k detectors cooled to -100 degC
- Commissioned Autumn 2008.

A big black box

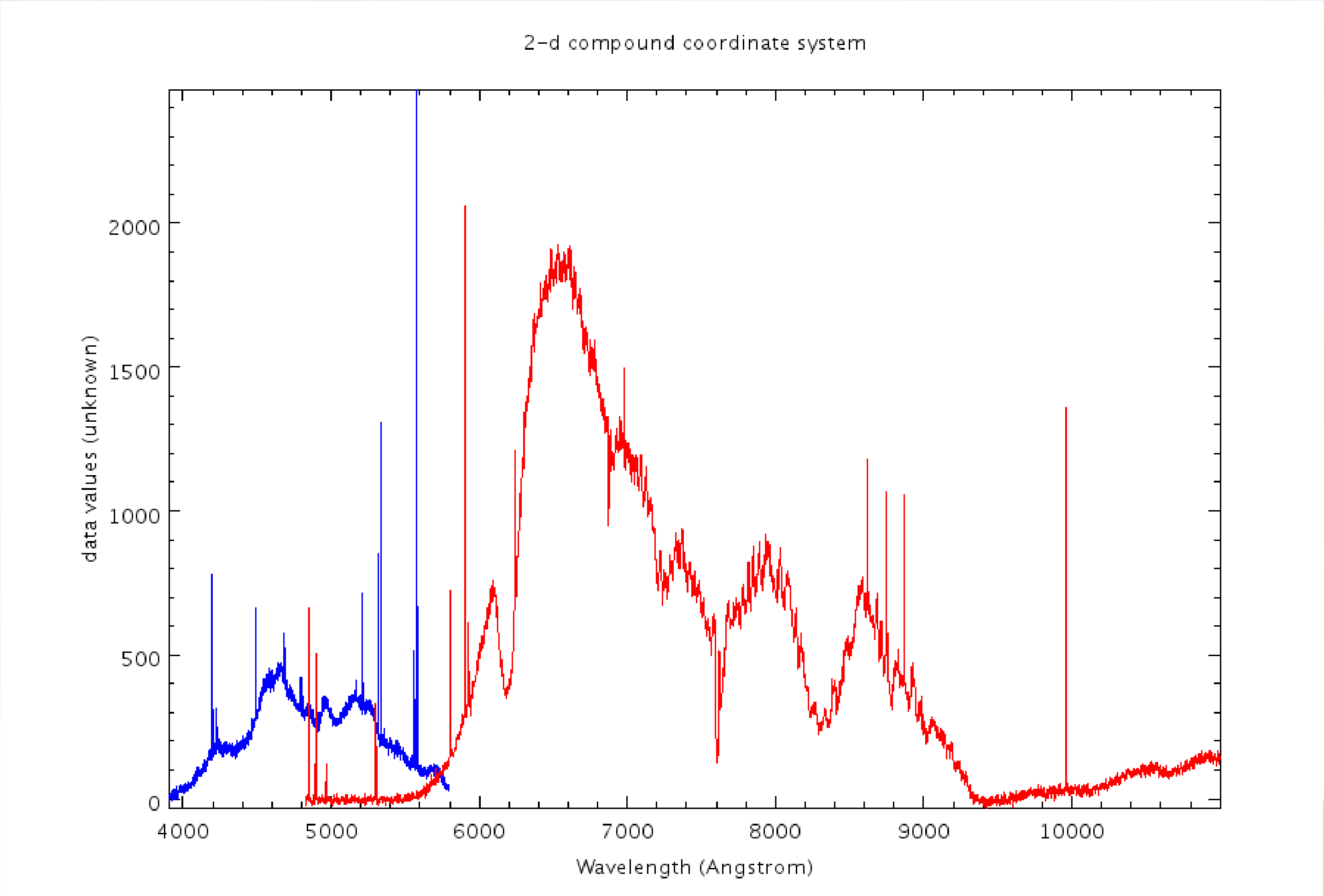
Example: A PTF supernova



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

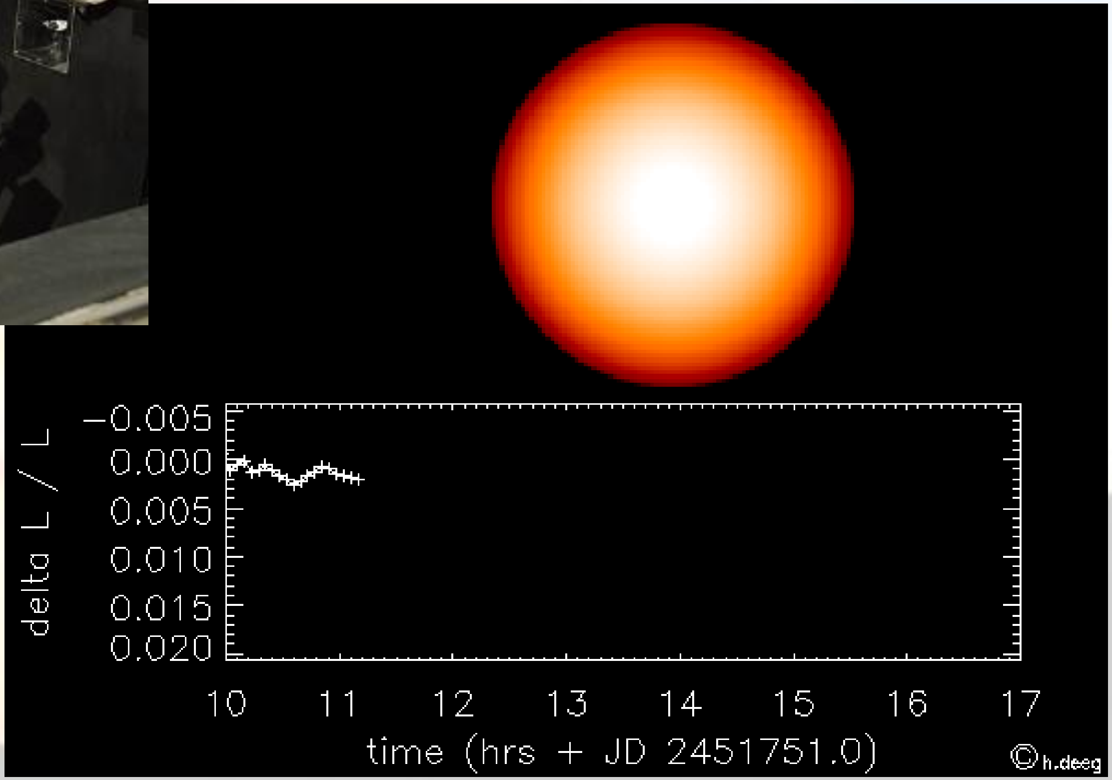
RISE
Fast imager / photometer

- 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

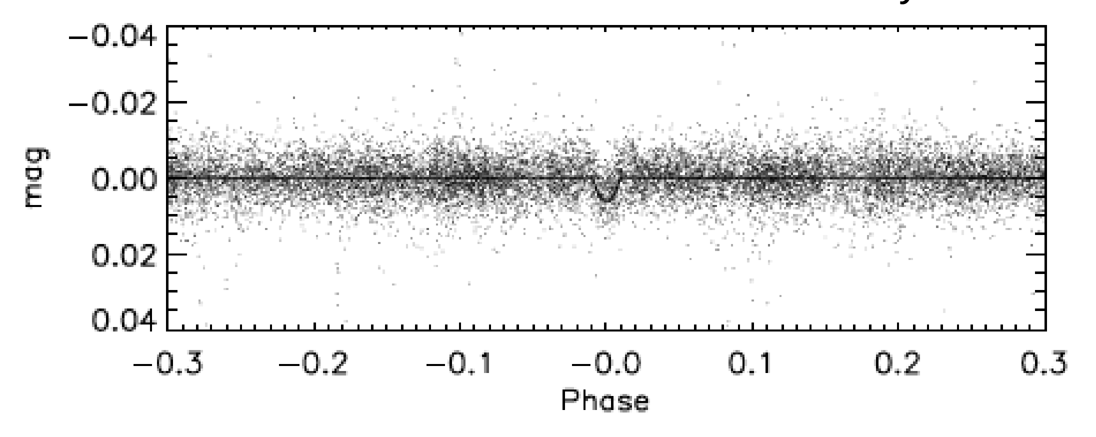
Exoplanets - Transit timing

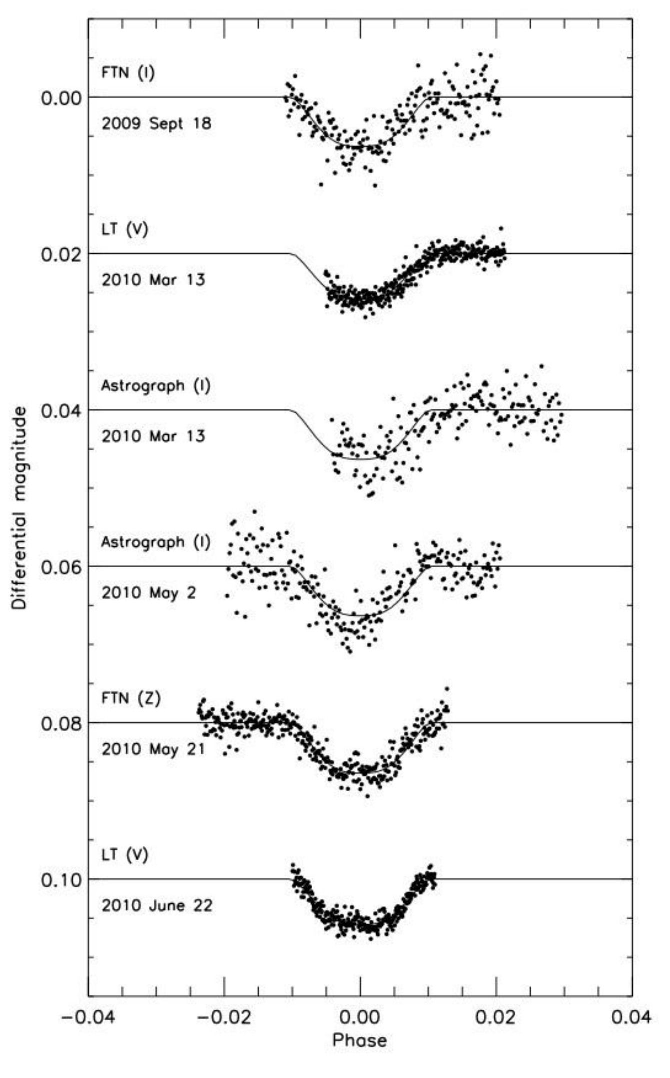
Routinely delivering few-millimag photometry for transit studies.

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



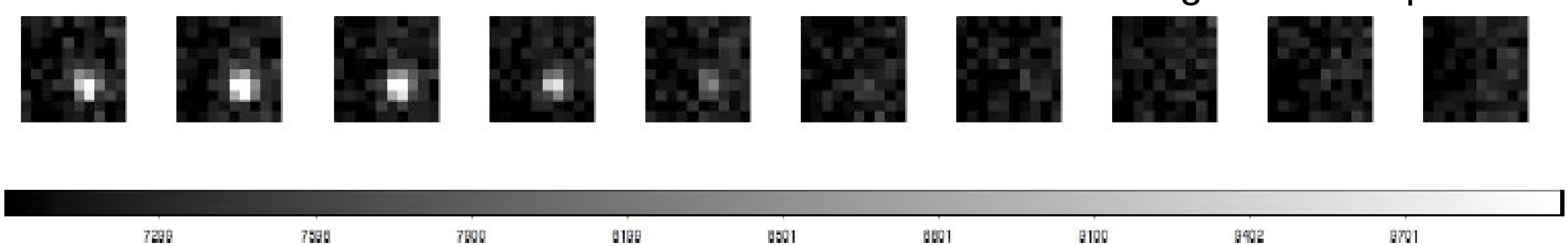


E. Simpson, S. Barros, QUB

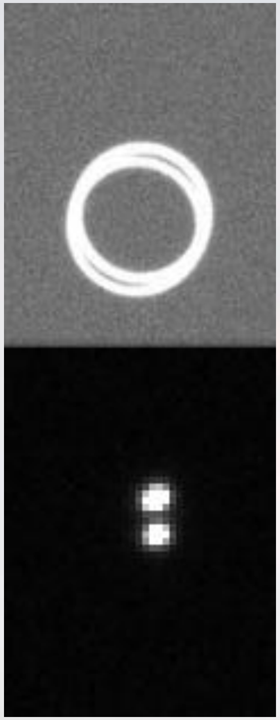
THOR
Even faster imager

- 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

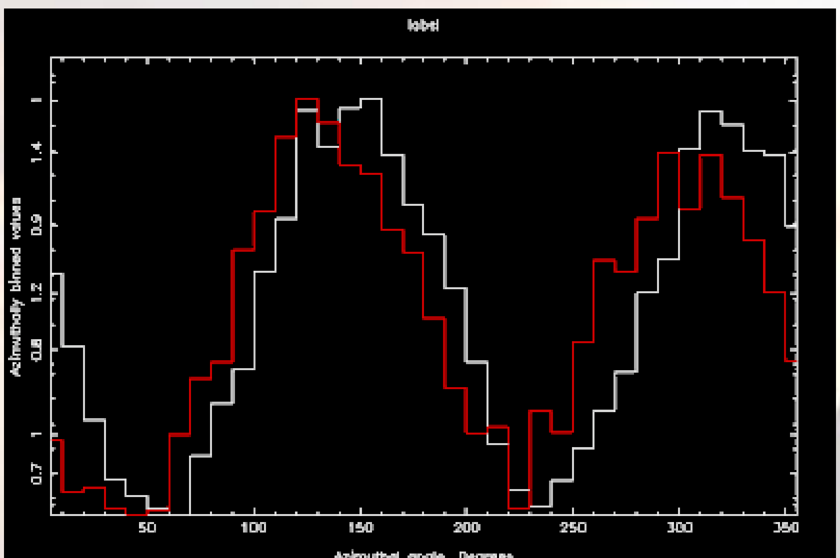
Lunar occultation timing. 6msec exposures



RINGO2

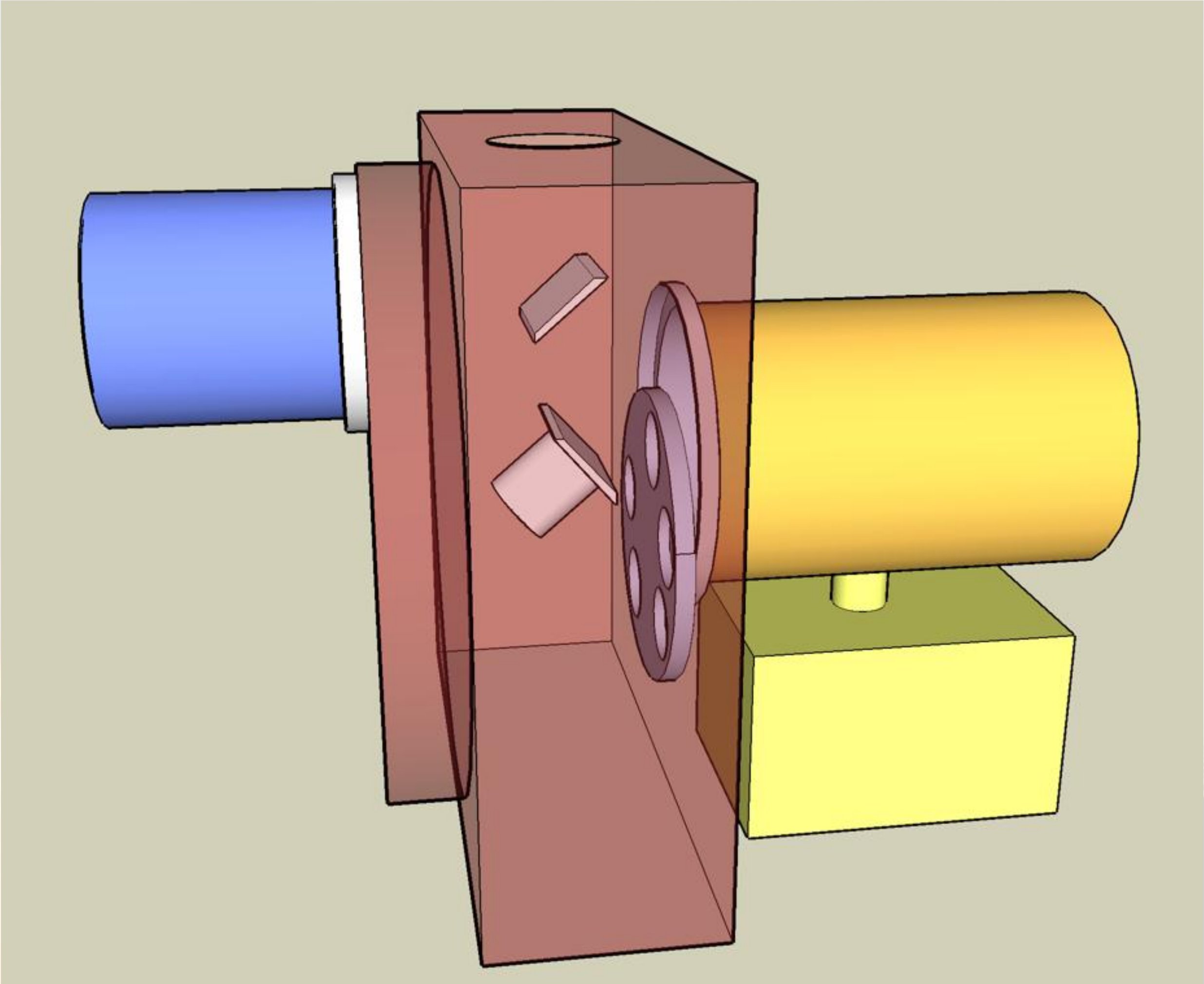


- Upgrade to RINGO polarimeter
- EMCCD has read-noise <1e$^-$ and read out approx. 8 fps.
- Gain 2 mag sensitivity
- Time resolution ~ 1sec



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

IO



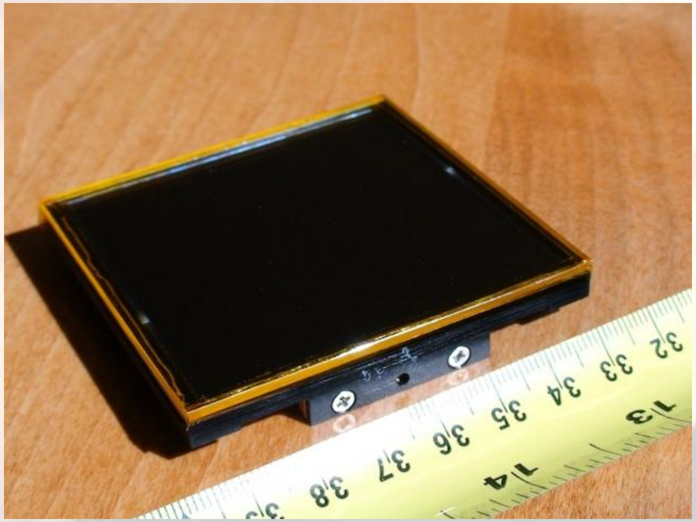
Instrument for 2011: IO (“Infrared-Optical”)

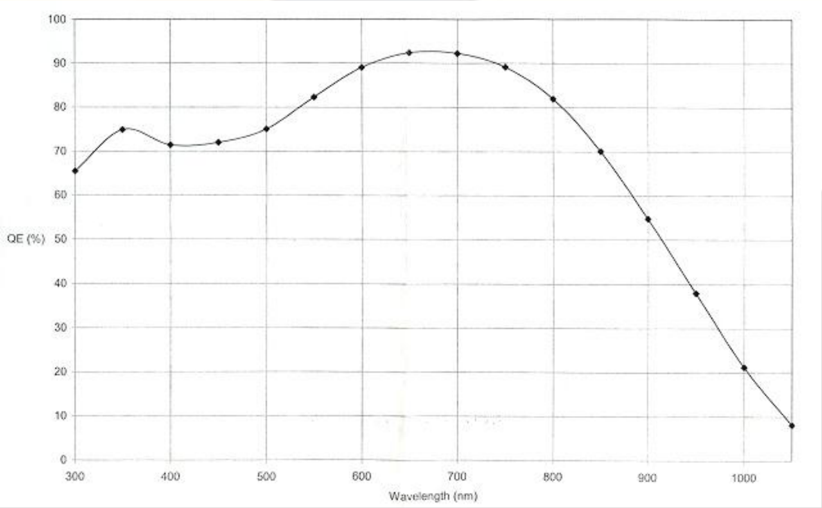
- Optical FOV 10 x 10 arcmin
- IR FOV 6 x 6 arcmin
- Tip-tilt feeds for both cameras
- Dichroic feed to both cameras
- Wavefront sensor (THOR) is EMCCD that can be used as very fast (10ms) timing camera and for lucky imaging.

O camera

- Fairchild CCD486 BI array
- 4096 x 4096 15 micron pixels
- Dark current < 0.02 e^- /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^- / sec
  - Guide window functionality to generate tip-tilt signal

Instrumentation

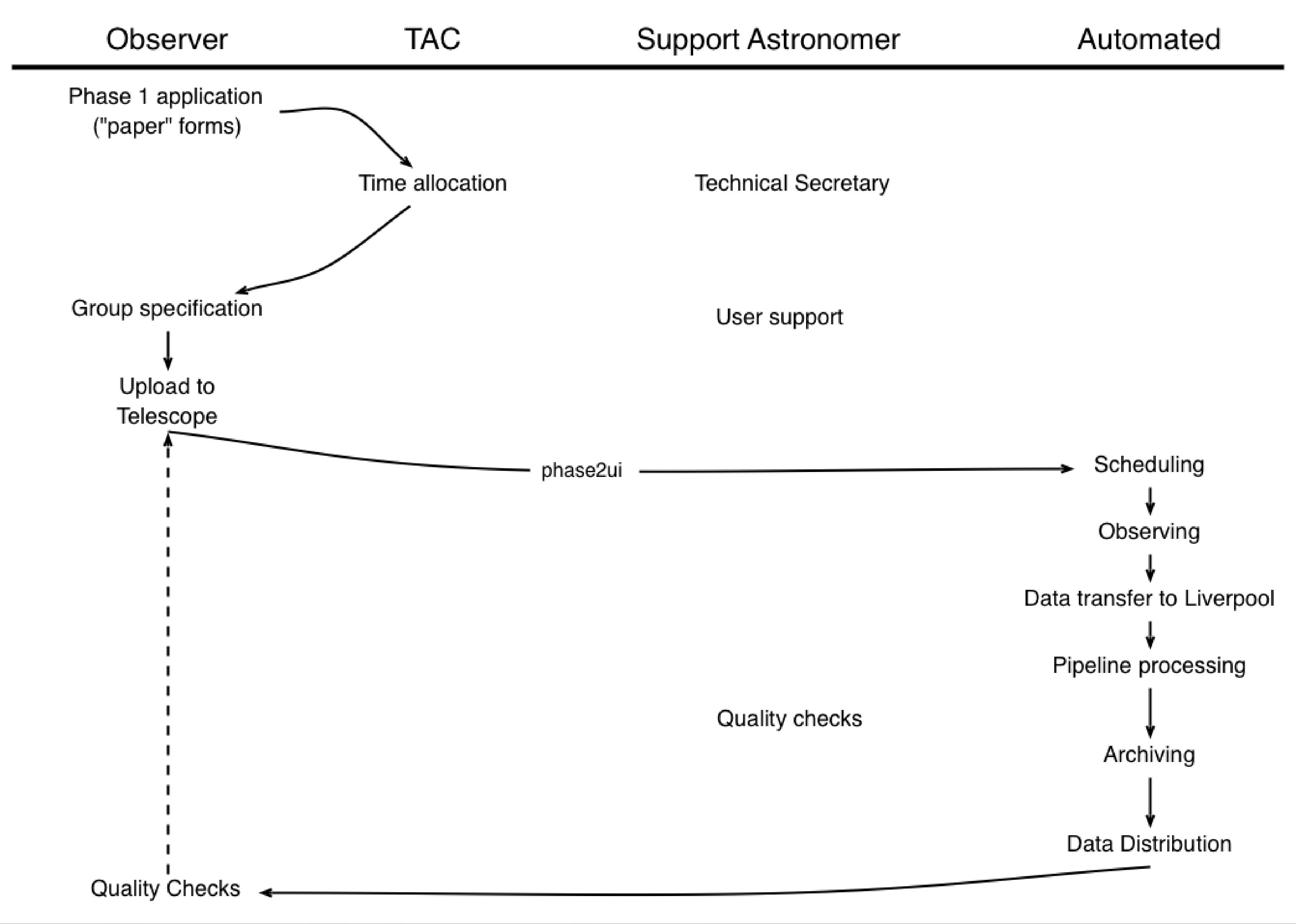
- Current
  - RATCam   CCD imager
  - RINGO2   Polarimeter
  - FrodoSpec   Spectrometer
  - RISE   Fast readout CCD
  - THOR   Very fast readout CCD
- Near Future (this year)
  - IO:O   CCD Imager
- Later
  - IO:I   NIR Imager
  - Tip-Tilt

- Decommissioned
  - SupIRCam   NIR imager
  - RINGO   Polarimeter
  - Meaburn(John)   Spectrometer

Common Features Between Instruments

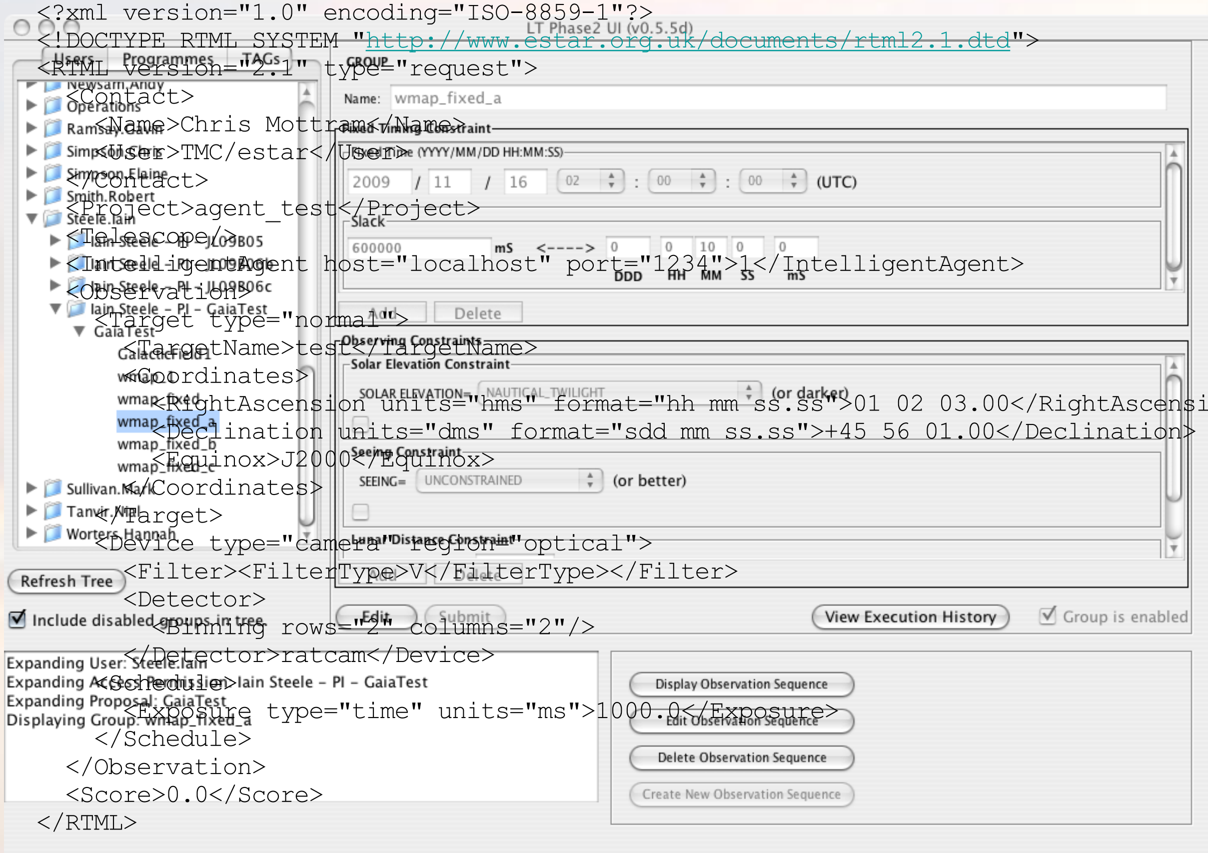
- Completely independent
- Common command set (e.g. CONFIG, DAY_CALIBRATE, NIGHT_CALIBRATE, TWILIGHT_CALIBRATE, WAVELENGTH_CALIBRATE, EXPOSE)
- Knowledge of calibration procedures built into the instrument control system
- Electrical power kept running 24/7
- Few servo mechanisms – obtain precision via 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.



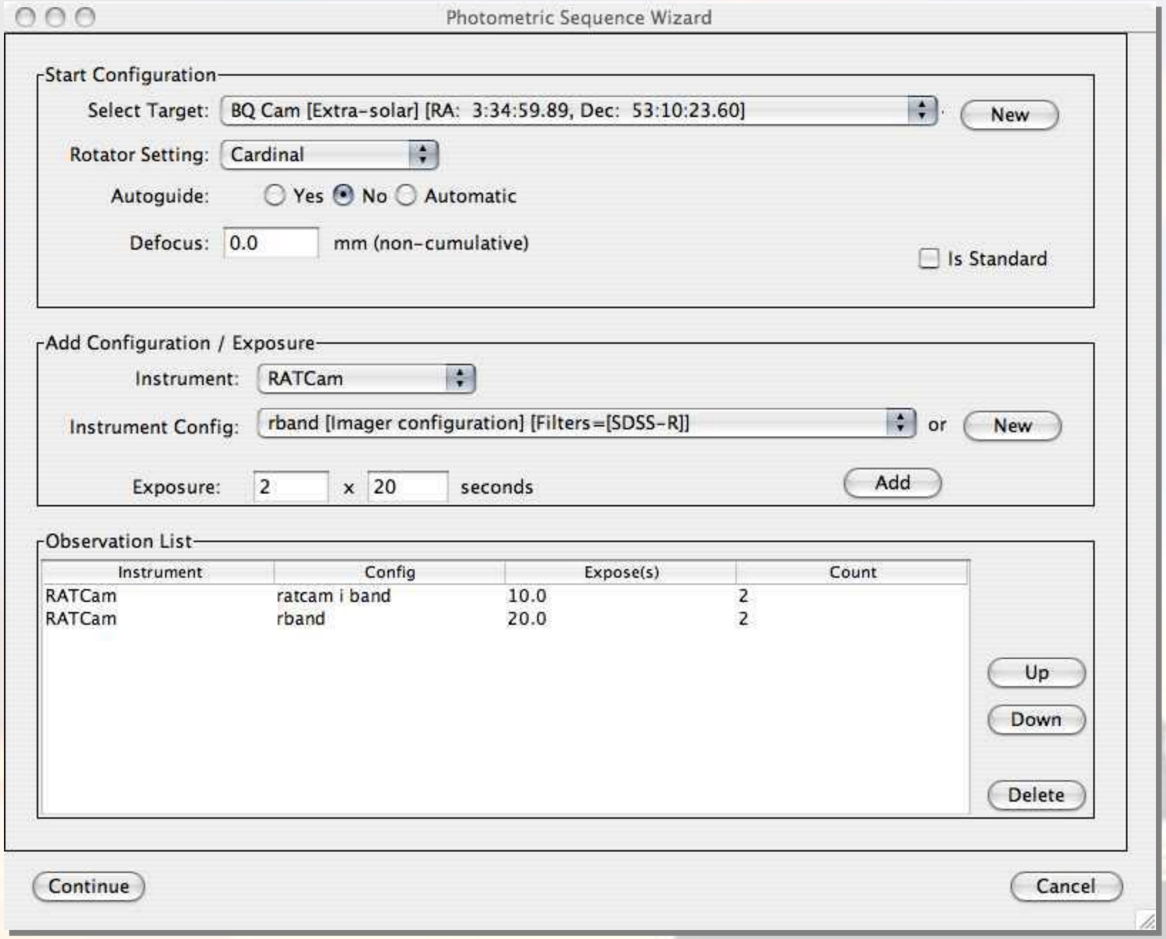

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<!DOCTYPE RTML SYSTEM "http://www.estar.org.uk/documents/rtml2.1.dtd">
<RTML version="2.1" type="request">
  <Contact>
    <Name>Chris Mottram</Name>
    <User>TMC/estar</User>
  </Contact>
  <Project>agent_test</Project>
  <Telescope/>
  <IntelligentAgent host="localhost" port="1234">1</IntelligentAgent>
  <Observation>
    <Target type="normal">
      <TargetName>test</TargetName>
      <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>
        <Equinox>J2000</Equinox>
      </Coordinates>
    </Target>
    <Device type="camera" region="optical">
      <Filter><FilterType>V</FilterType></Filter>
      <Detector>
        <Binning rows="2" columns="2"/>
      </Detector>ratcam</Device>
    <Schedule>
      <Exposure type="time" units="ms">1000.0</Exposure>
    </Schedule>
  </Observation>
  <Score>0.0</Score>
</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.

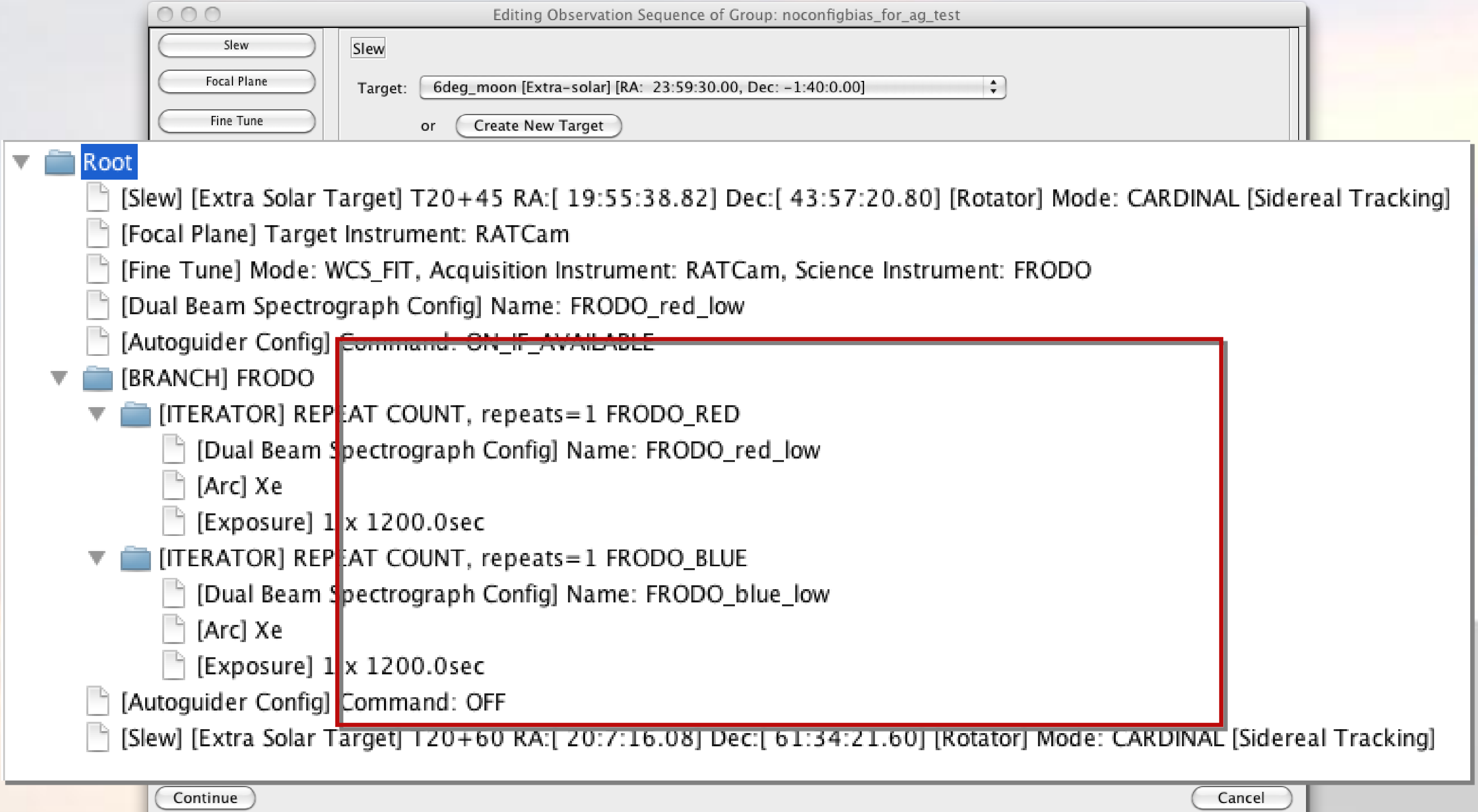
Observation Definition Wizard



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

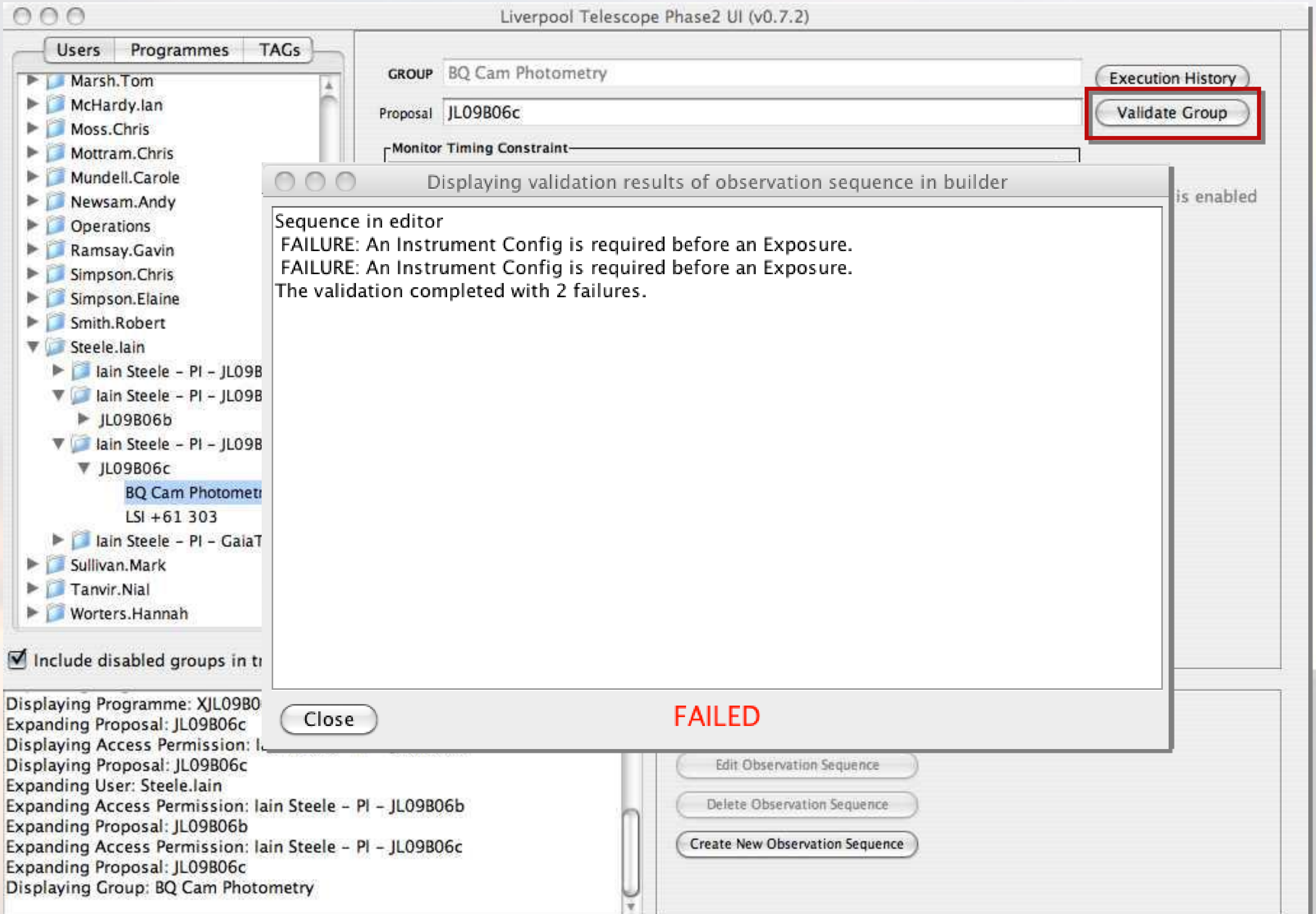
Specify **what** you want, not how.

Modular Definition of Sequences



User defines observation as an explicitly ordered list of commands

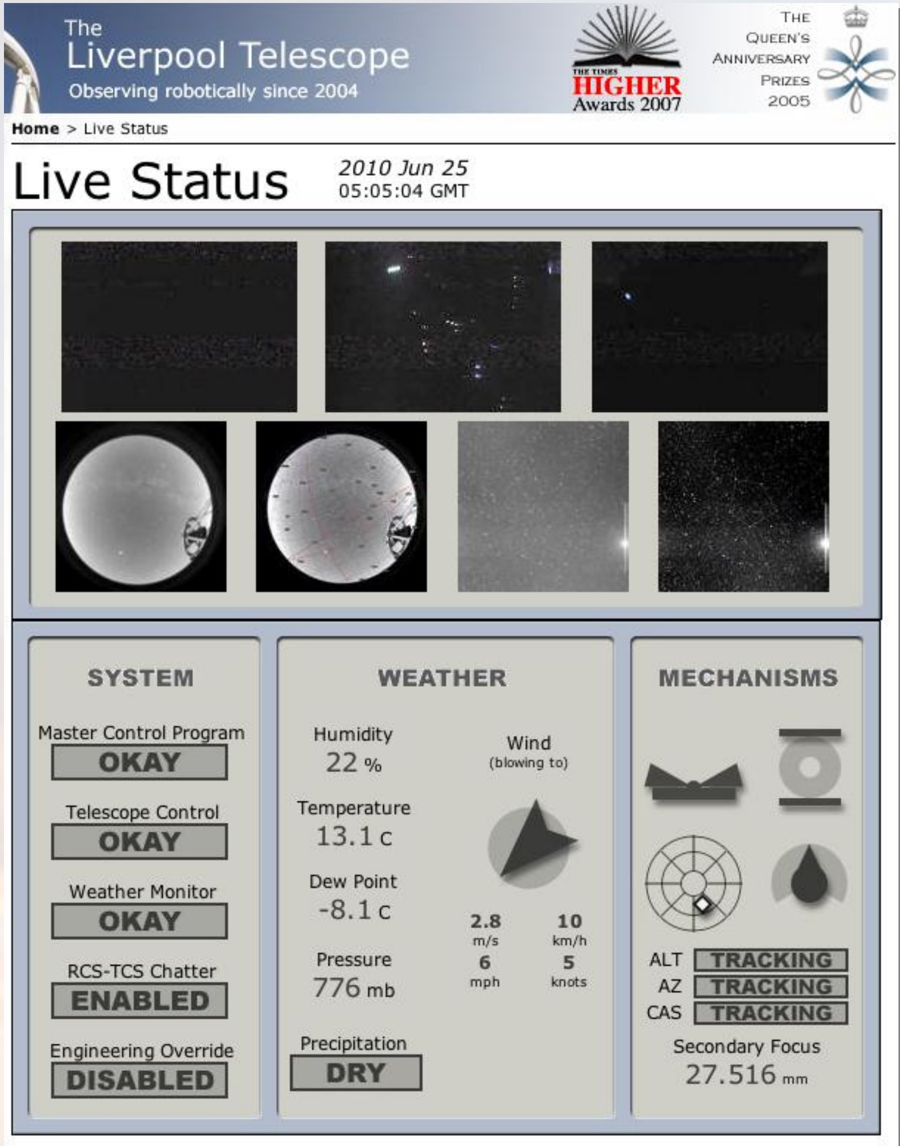
The Validator



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



Real time status of LT

Liverpool Telescope Quicklook Data

Proposal	User Name	24/06	23/06	22/06	21/06	20/06
JL09B03b	Matt Darnley	-	6	-	-	-
JL09B06b	Iain Steele	-	-	-	15	4
JL09B07	Ian McHardy	2	8	-	16	-
PL09B03	Mark Sullivan	-	12	6	15	-
PL10A01	Susana Barros	-	-	103	-	-
PL10A03	Tom Barclay	4	1	-	1	-
PL10A04	M.T. Botticella	-	13	-	-	-
PL10A05	Ian McHardy	1	-	1	-	-
PL10A07	Keith Horne	8	61	27	49	-
PL10A13	Tom Marsh	-	8	-	17	-
CL10A02	Luis Goicoechea	4	-	-	-	-
CL10A03	Nancy Elias	11	-	-	11	-
CL10A06	Francesc Salles	-	-	10	-	-
LTCollim	LTOps	2	-	-	-	-
NSOPrior1	Andy Newsam	-	-	-	-	3
NSO_Priority_1	Andy Newsam	6	3	3	1	-
NSO_Priority_3	Andy Newsam	-	-	1	-	-
NSO_Priority_4	Andy Newsam	-	-	-	-	4
RATStand	LTOps	18	66	48	72	-
RISEFocus	LTOps	-	-	20	-	-
Standards	BGCA	4	116	32	4	-
UNKNOWN	UNKNOWN	2	-	-	-	-

Pipeline reduced data within 2–3 minutes

Liverpool Telescope
Astrophysics Research Institute

liverpool JMU

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 | Resolve name now

Observational Criteria

Date ☑ | **Integration** (sec.) ☑

Seeing (pixels) ☐ | **Airmass** (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 (Å) ☐ | **Resolution** (Å) ☐

Dispersion ($Å\ pix^{-1}$) ☐

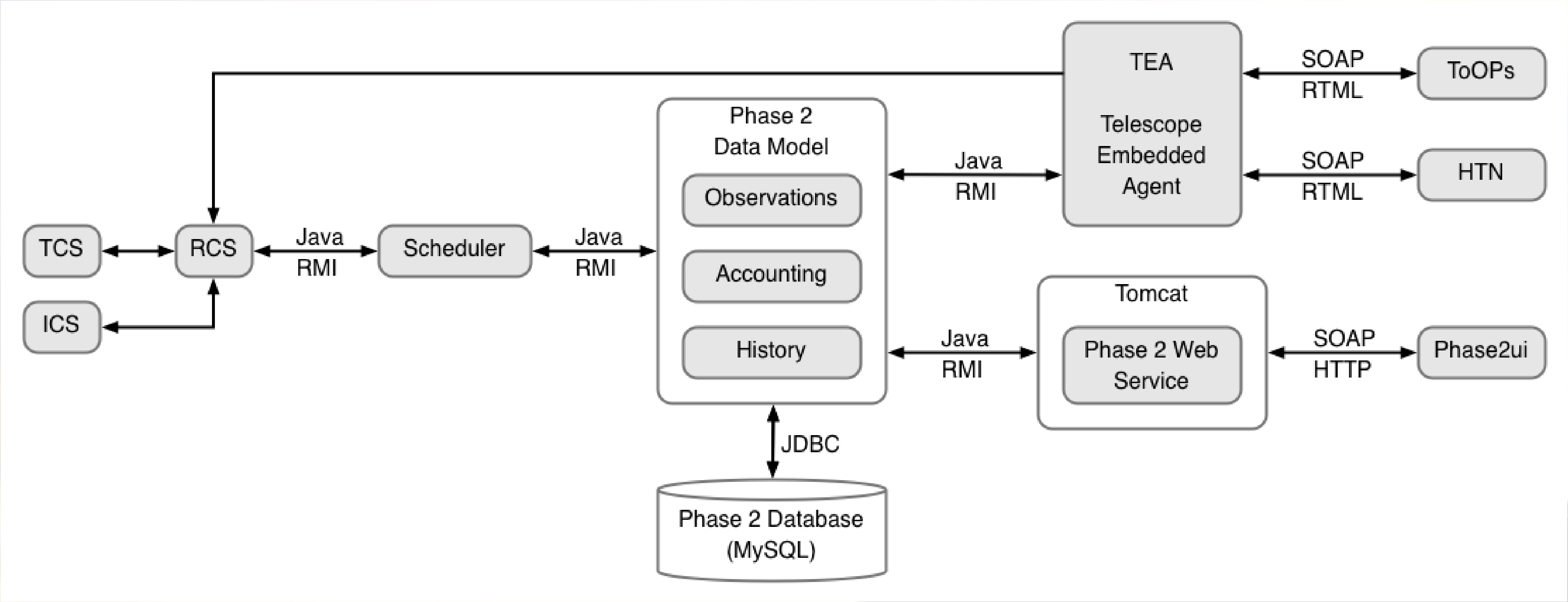
Timing Constraints

- 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

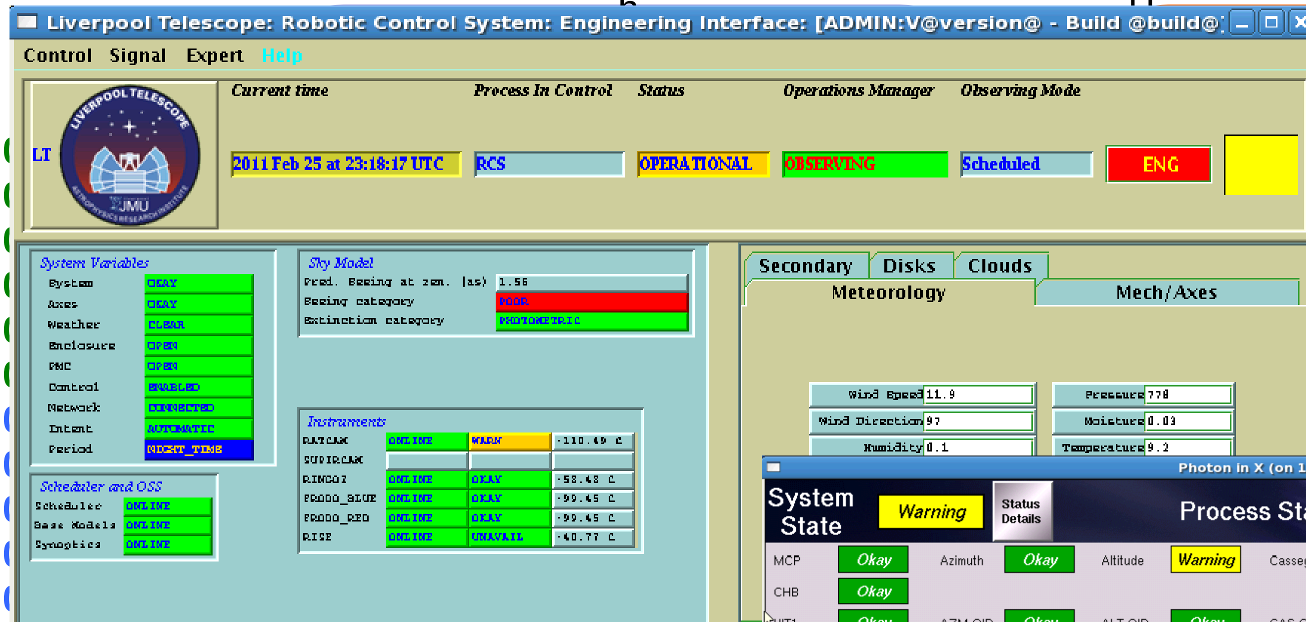
- Almost all staff on this rota.
- Reduces out-of-hours working by the classically “operations” staff (aka astronomers)
- Allows software engineers to see their own code running.
- One staff hour per day

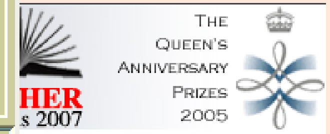
Normal office hours
Out-of-hours working

Staff

Software

Data Archive





12:0
13:0
14:0
15:0
16:0
17:0
18:0
19:0
20:0
21:0
22:0
23:00
00:00
01:00
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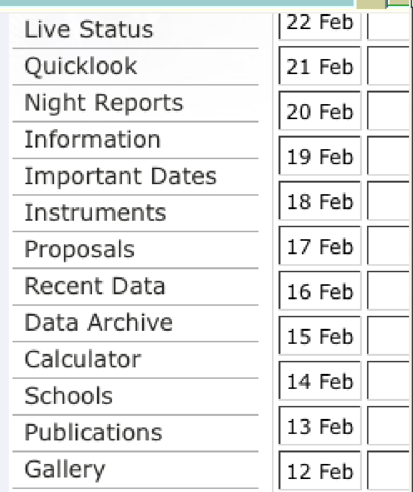
03:00
04:00
05:00
06:00
07:00 Sunrise
08:00
09:00
10:00
11:00
12:00

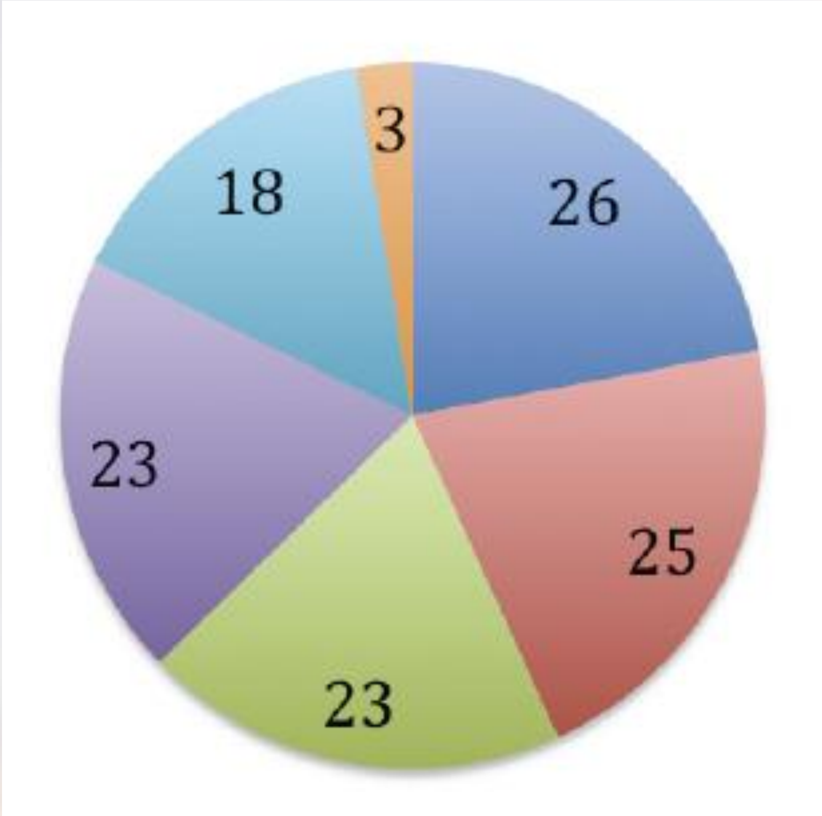


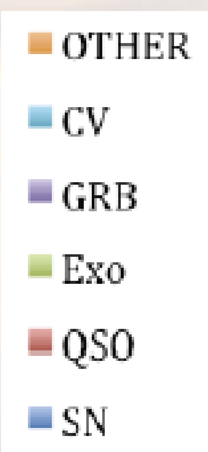
Q
A

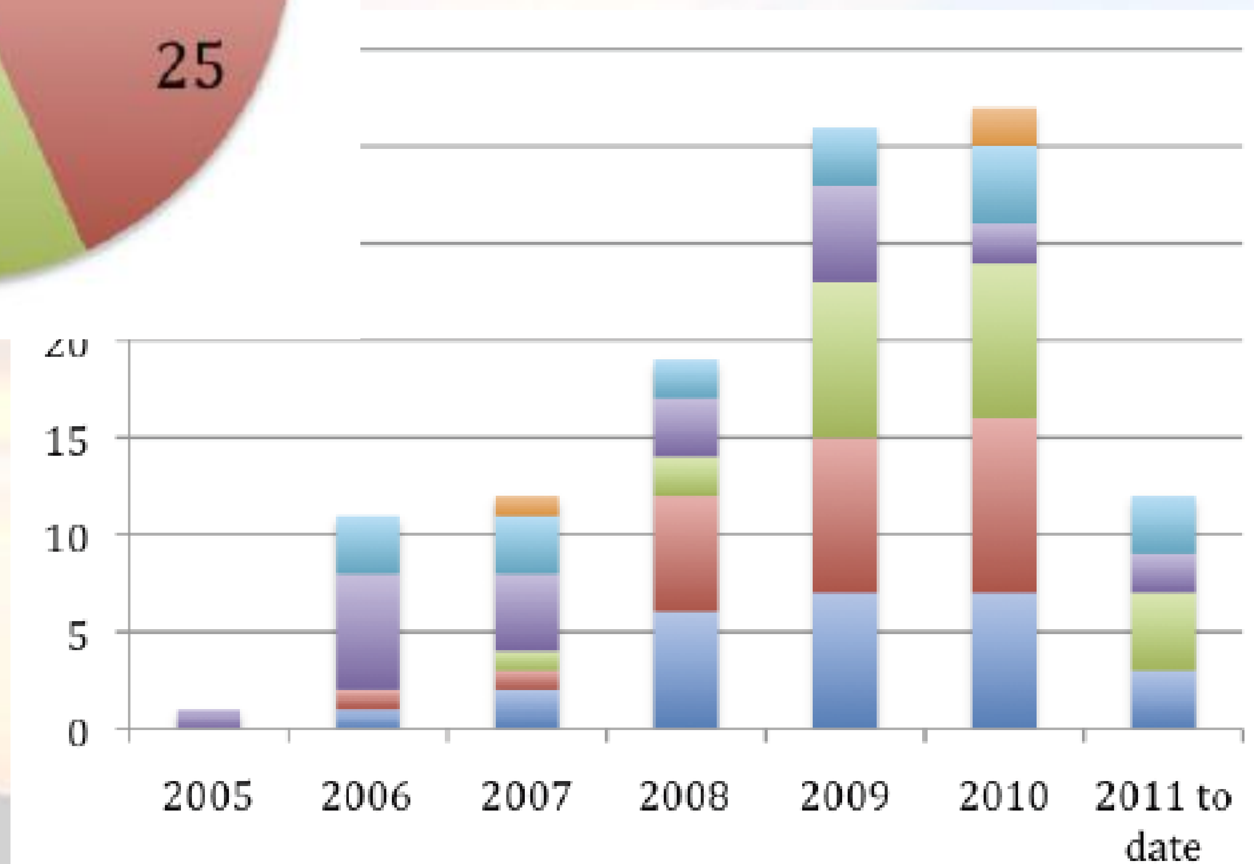
Science with the LT

- 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







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