

Watcher Monitoring of *V404 Cygni* in Outburst

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Image: *Martin Jelínek*



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What is Watcher?

- A Fully Robotic Telescope designed primarily for GRB prompt and afterglow observations.
- 40cm Primary Mirror.
- Andor iXon EMCCD.
- 10' × 10' Field of View.
- First Light: April 2006.
- Developed by UCD in collaboration with:
University of the Free State,
South Africa,
Instituto de Astrofisica de Andalucia,
Spain,
Astronomical Institute,
Czech Republic.



Watcher Components

Davis Weather Station



CaTeC Precipitation Sensor



Mrakoměr Cloud Meter

Microwave Transceiver



FLI Filter Wheel

RoboFocus



Paramount ME



Rolling Roof



Andor iXon EMCCD



UPS

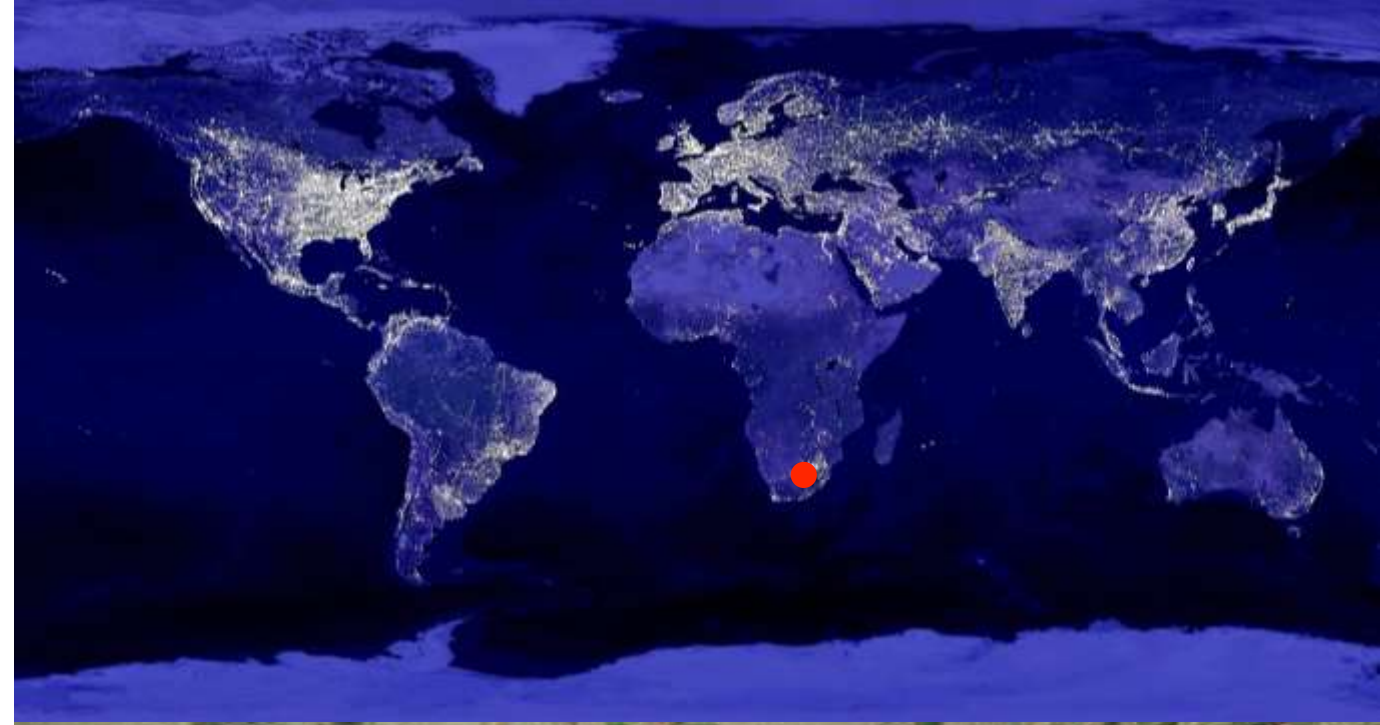


Zelio PLC Roof Controller



Where is Watcher?

- Boyden Observatory,
Maselspoort, South Africa.
- $29^{\circ} 02' 20''$ South,
 $26^{\circ} 24' 20''$ East,
Elevation: 1387m.
- Approx 200 observing nights
per year.
- Site chosen by Harvard in 1927
after extensive survey of
southern Africa.
- Operated by UFS since 1976.

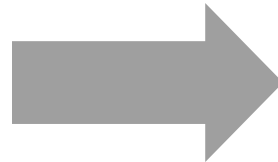




Archiving / Transfer to UCD

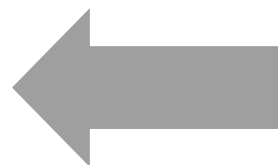
Watcher: RTS2

- Writes files to disk at observatory



Watcher: archiver.py

- python / watchdog (inotify)
- Detects filesystem changes
- Adds new FITS files to a priority queue
- GRB images are prioritised over all other images
- Images are transferred using Rsync

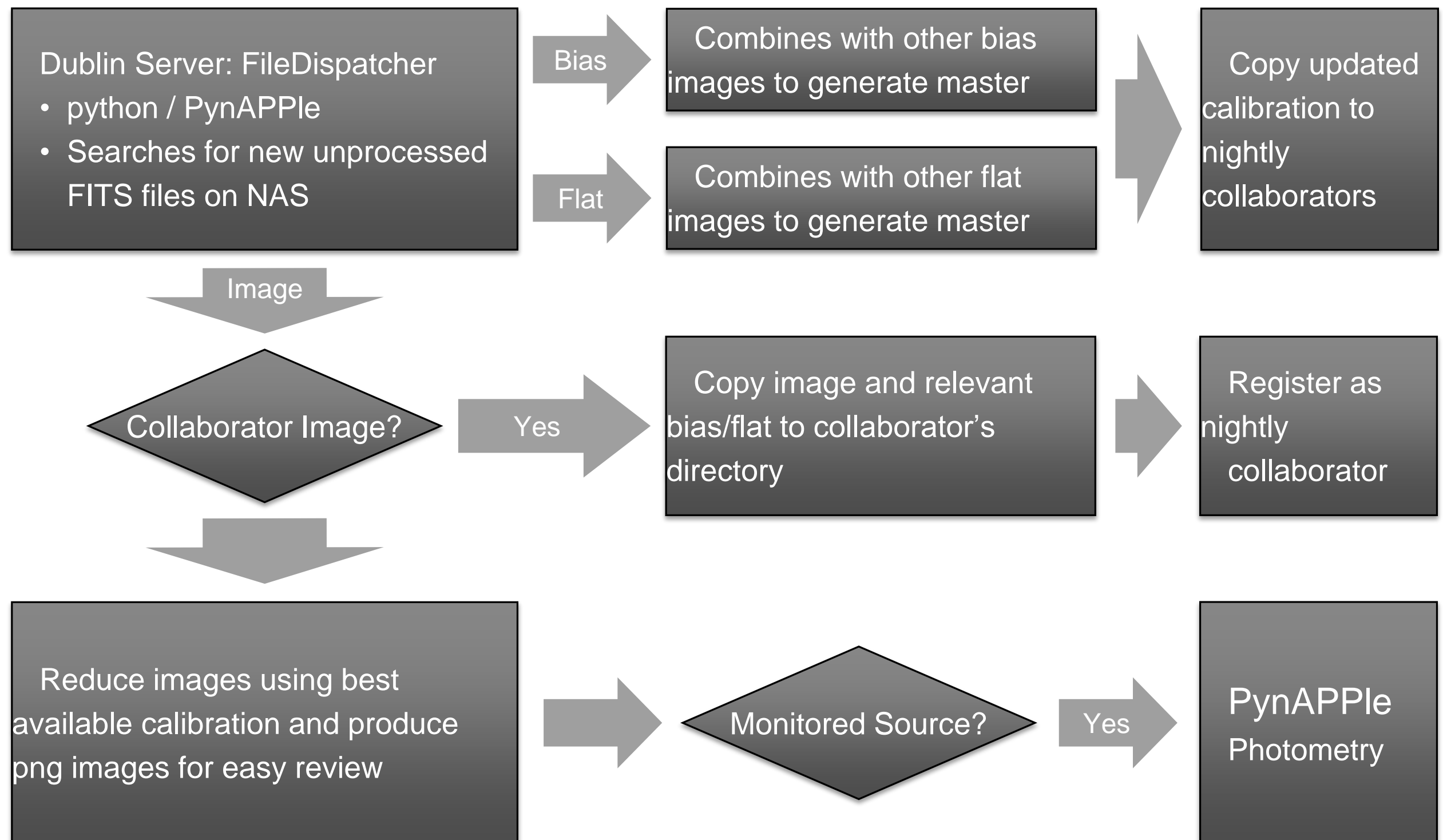


Dublin NAS: Rsync

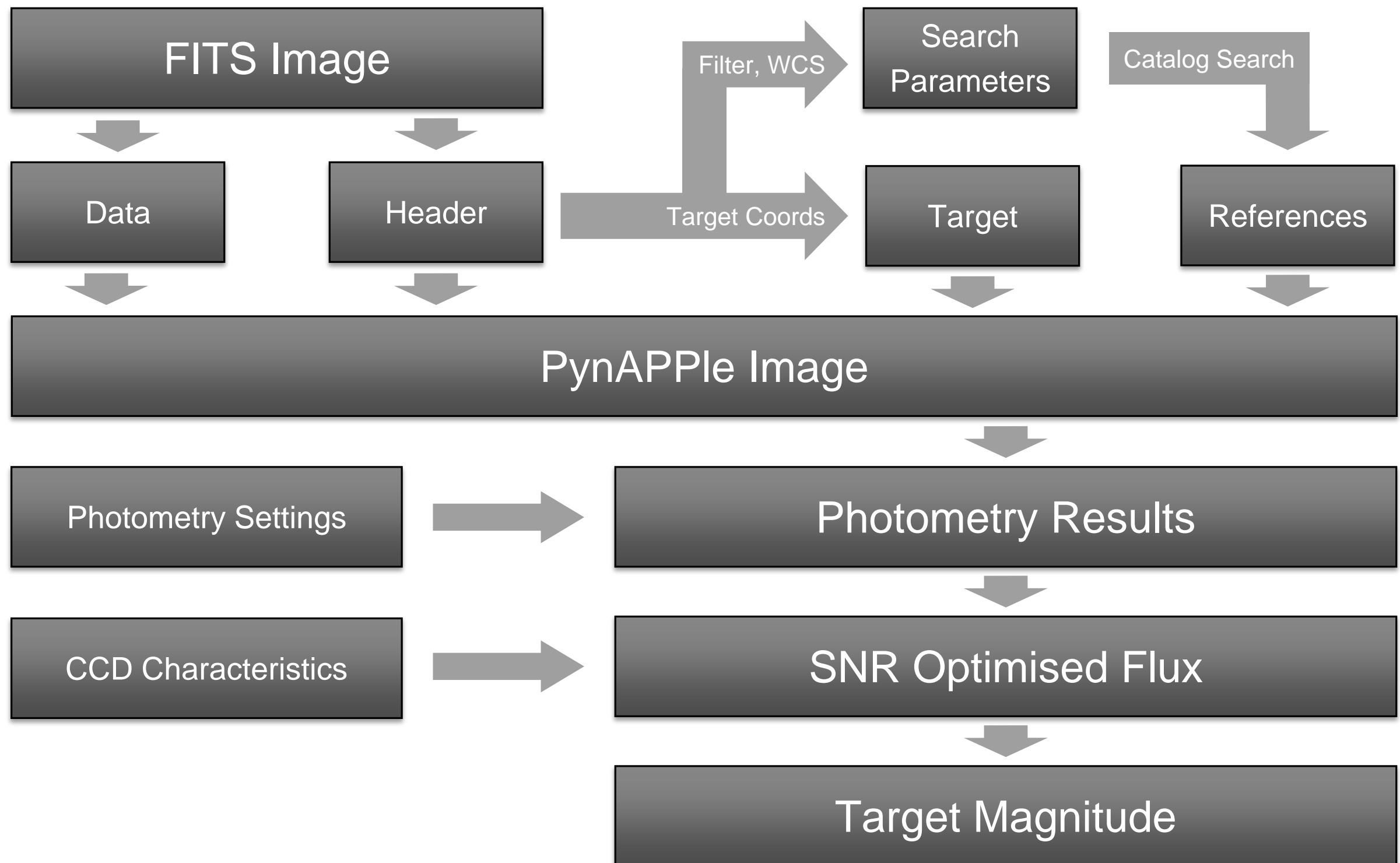
- Writes files to disk at laboratory



Data Management

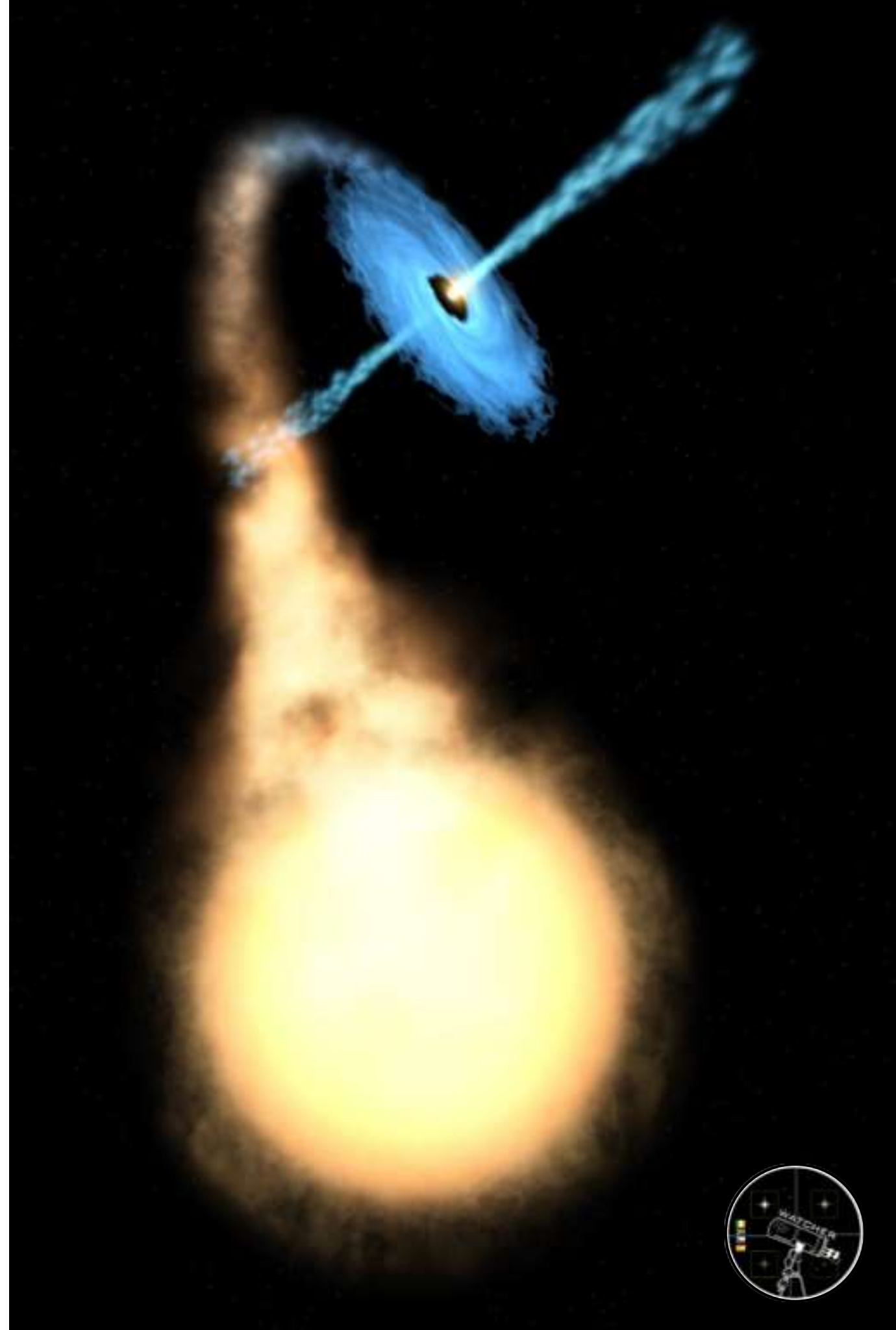


PynAPPlE Photometry



Low Mass X-ray Binaries

- Semidetached binary systems.
- Emit mostly in X-rays and appear as faint sources ($V \sim 17$) in optical.
- System consists of a low-mass late-type star that transfers gas on to a compact object i.e. neutron star or black hole.
- Mass transfer results in outburst periods.
 - Luminosity is dramatically increased.
 - Highly variable at all wavelengths from radio to γ -rays.





V404 Cygni

- An LMXB at a distance of ~ 3.5 kpc with a black hole of mass $\sim 12 M_{\odot}$ and a K0 IV companion [1].
- The orbital period of the system is ~ 6.5 days [2], which is among the longest for LMXBs.
- One of the most X-ray luminous sources while in quiescence ($L_x \sim 10^{33-34}$ erg s $^{-1}$ [3]).
- Optical quiescent magnitude is $R \sim 17.5$.
- Seen in outburst in 1989 [4] and has been in quiescence since then, showing elliptical modulations in the optical light curve of ~ 0.24 mag with fast, low amplitude variability (~ 0.07 mag) superimposed [5].

[1] Shahbaz et al., 1994, MNRAS, 271, L10

[2] Casares & Charles, 1992, MNRAS, 255,

[3] Garcia et al., 2001, ApJ, 533, L47

[4] Zycki et al., 1999, MNRAS, 309, 561

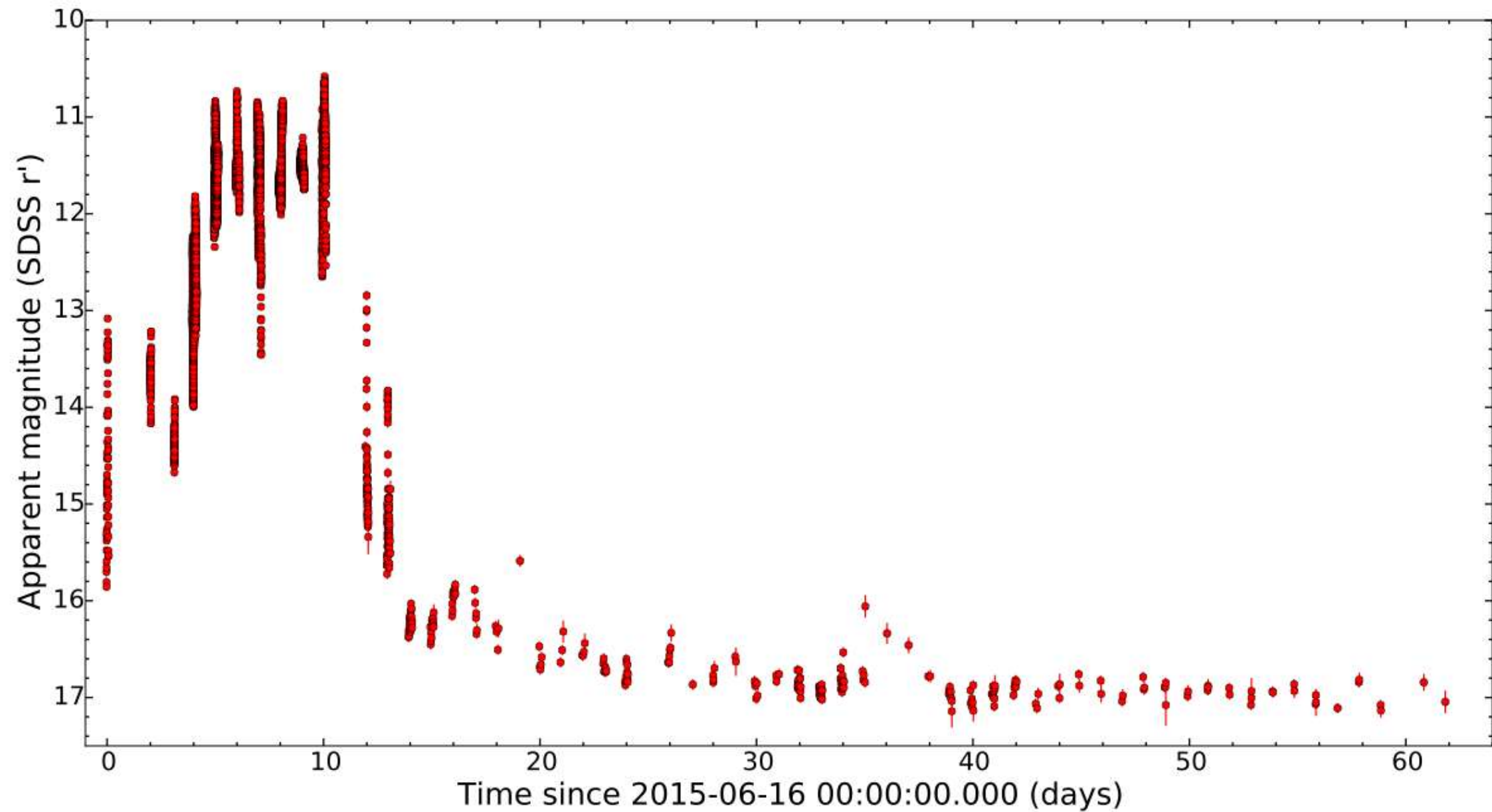
[5] Zurita et al., 2004, MNRAS, 352, 877



The Watcher *V404 Cygni* Campaign

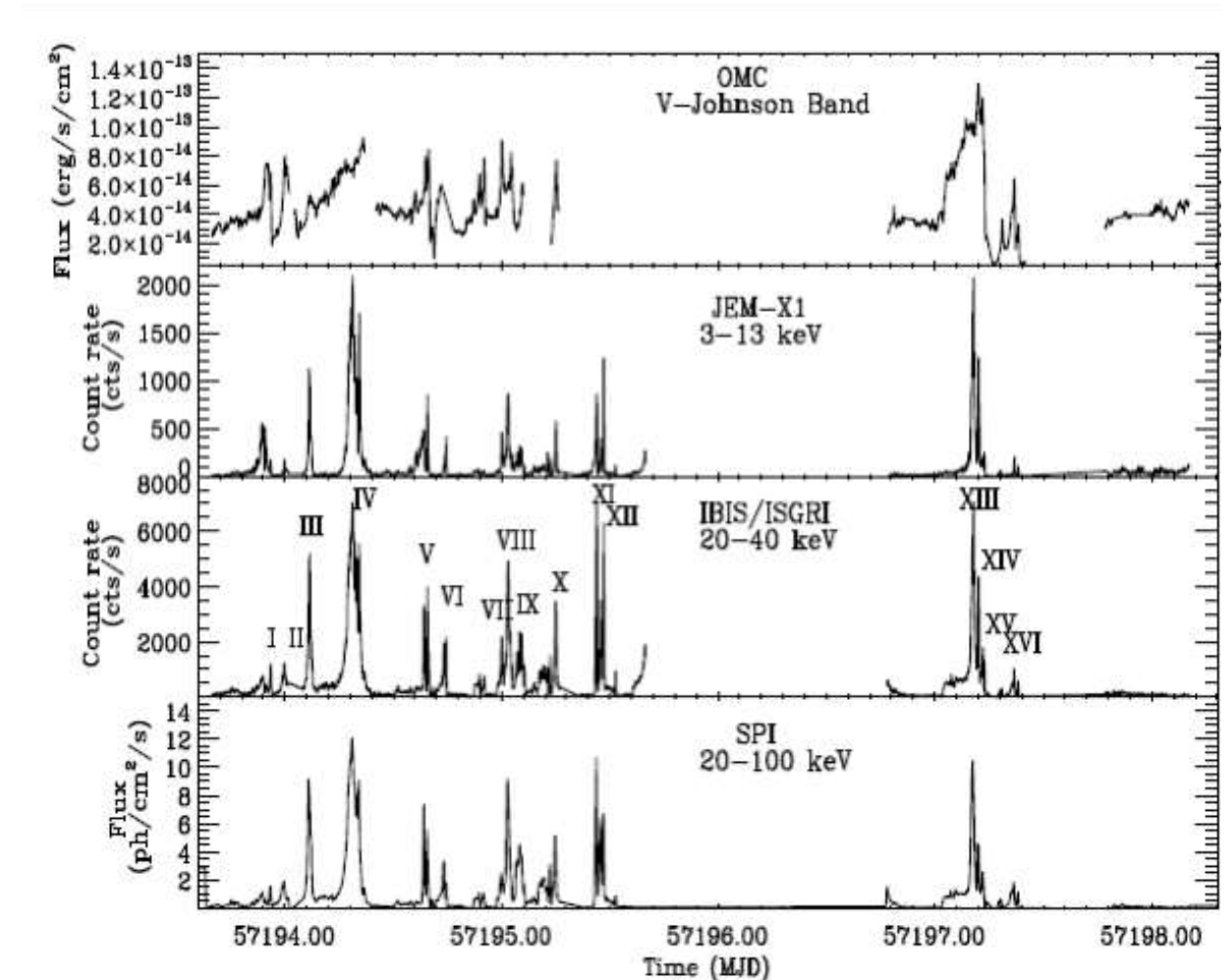
- First observation on June 15th at 23:15 UT in response to a *Swift* GCN alert.
- Following our standard automatic GRB response, observations were made in the SDSS r' band with exposures ranging from 0.5 to 120 seconds.
- Received 6 further GCNs from *Swift* and 110 from *INTEGRAL* over the following 2 weeks.
- Source was visible for ~3 hours each night around midnight.
- During the next 10 weeks we performed scheduled observations with exposures ranging from 5 to 120 sec.
- Observations are mainly in r' filter, but on some nights g' & i' filters were also used.
- Over 13,000 images giving more than 8 days of open shutter time.
- Also experimented with EM mode 0.5 s observations on two nights.

Light Curve - Complete

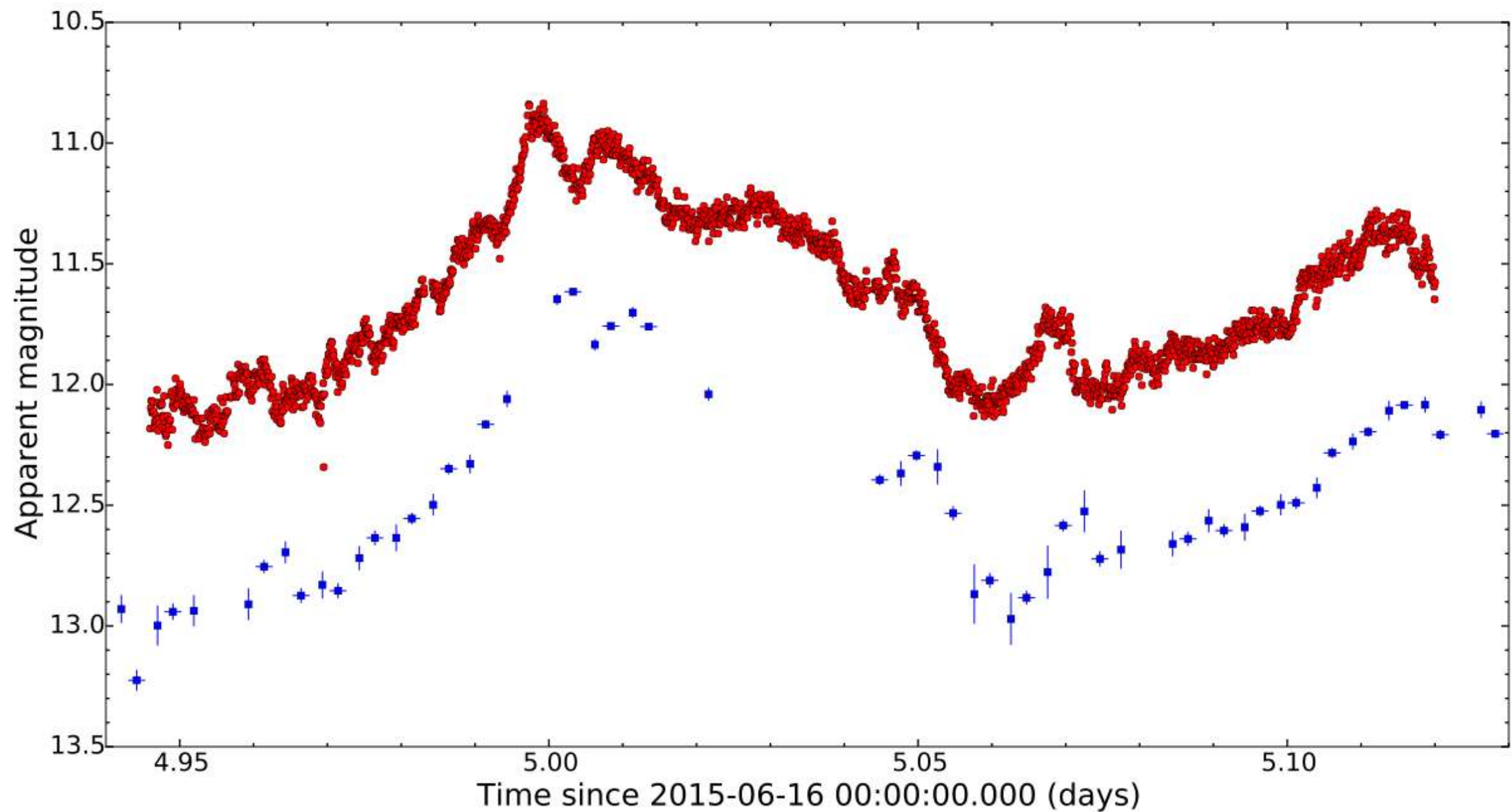


INTEGRAL Observations

- *INTEGRAL* monitored source from June 20th - 25th (days 4 - 9) with all four instruments.
- Optical flares lasted typically 0.25 - 2.5 hr with most showing fast rises (<1 hr).
- Optical & X-ray (*JEM-X*) flares in coincidence mostly, but in some cases with an optical lag of 30 mins.
- Rodriguez et al. (astro-ph/1507.06659v2) suggest the former arise from X-ray reprocessing by either an accretion disk or the companion star while the latter may be associated with plasma ejections, also seen in radio.
- *There will be a special day long V404 Cygni session at the Rome INTEGRAL workshop next week.*



Comparison to *INTEGRAL* OMC



Thank You

- The V404 outburst shows the capability of small autonomous telescopes to respond to and monitor transient sources.
- Such a large dataset could not be analysed without automated tools.
- Observations of this source are continuing.
- Correlation with high-energy light curves is being addressed.



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