Long term multicolour photometry of Luhman-16

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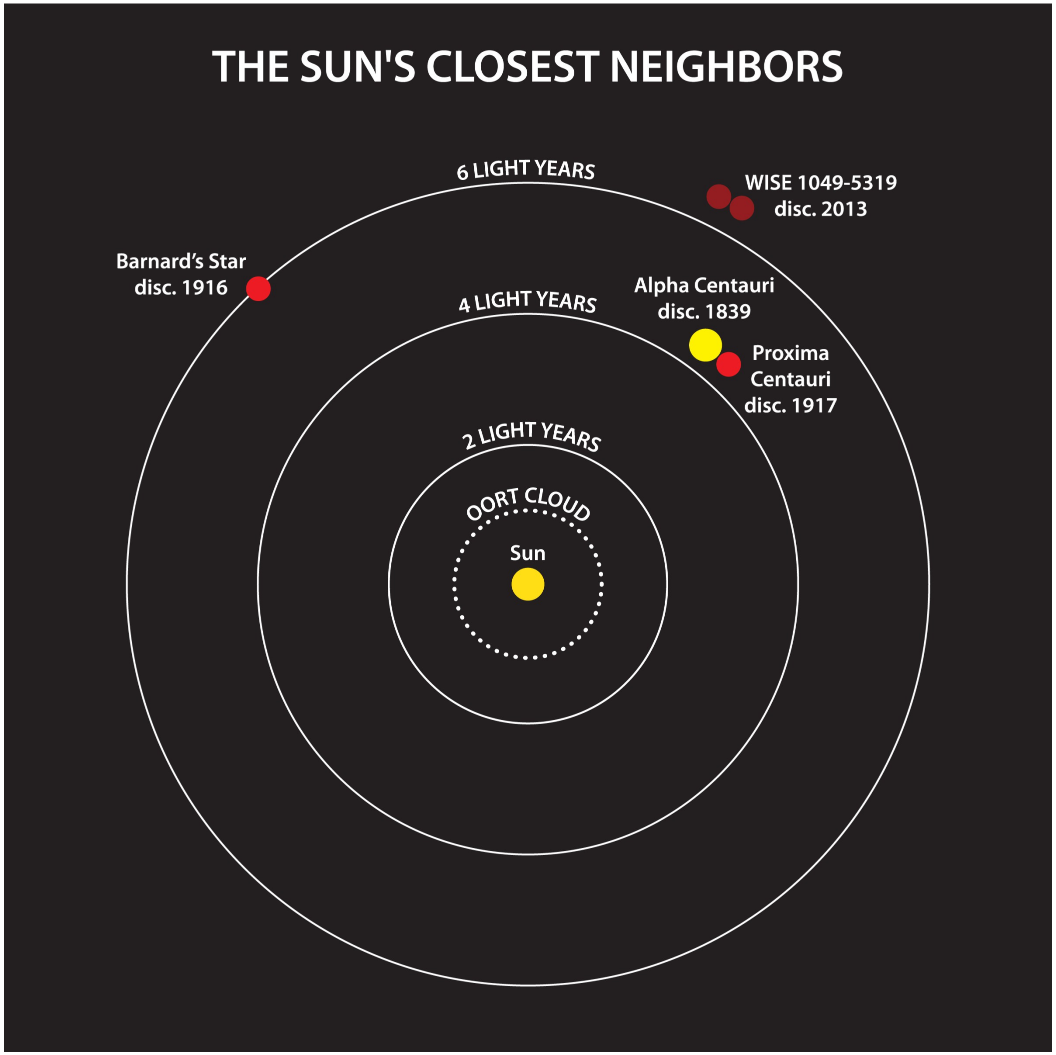
Brown Dwarf Binary in the Solar Neighbourhood



- WISE J1049-0053=Luhman16
  [Cutri et al. 2012]

- L7.5 primary + T0.5 secondary, close to the L/T transition
  [Luhman et al. 2013]
  [Burgasser et al. 2013]

- Quasi-periodic variability in IR photometry
  Amp ~11%
  P=4.87 hrs
  [Gillon et al. 2013]

Weather?

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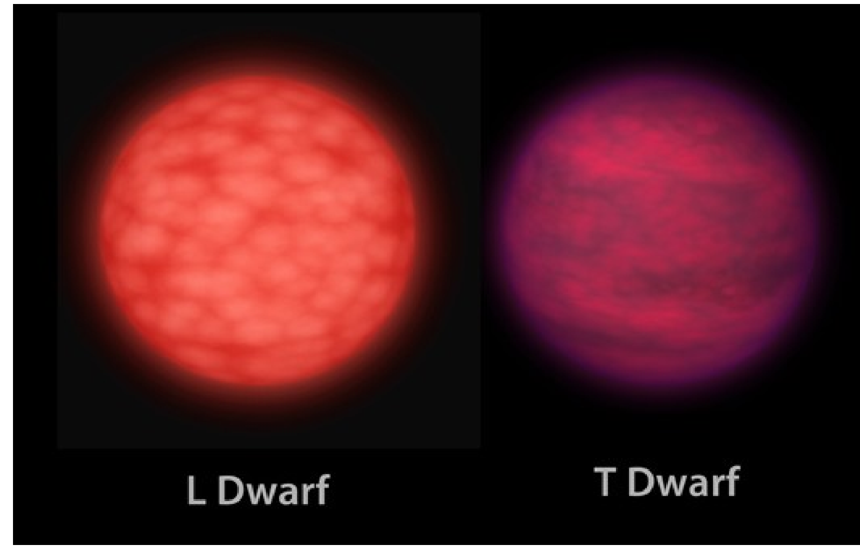
Variability in Brown Dwarfs

Convection in troposphere drives break-up of clouds, leading to depletion of condensates

→ Predicted IR photometric variability observed in several cases

Variability in optical bands less commonly observed (fainter) but can place limits on models of condensates in atmosphere.



→ Need for optical timeseries photometry

→ Short quasi-periodicity necessitates continuous monitoring ideally over a few rotation cycles ~15hrs or more

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Global Robotic Telescope Network (Southern hemisphere branch)

Cerro Tololo
Chile
3 x 1m telescopes

Sutherland,
South Africa
3 x 1m telescopes

Siding Spring
Australia
2 x 1m telescopes
1 x 2m telescope

Clusters of telescopes
All 1ms equipped with 15'x15' SBIG imager
Identical set of 15 filters

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LCOGT.net Observations

Coordinated observations:
Multiple telescopes at same site: simultaneous SDSS-i and Pan-STARRS-z
Multiple sites: extended timeseries photometry up to ~15hrs at a stretch

Began 2013 April 11, continued until target set
Included several intensive stints ~2-3days.

Data from 6 cameras, two colours
Overlapping but not precisely simultaneous
12 datasets reduced with aperture photometry separately to apply correct gain/read noise characteristics.

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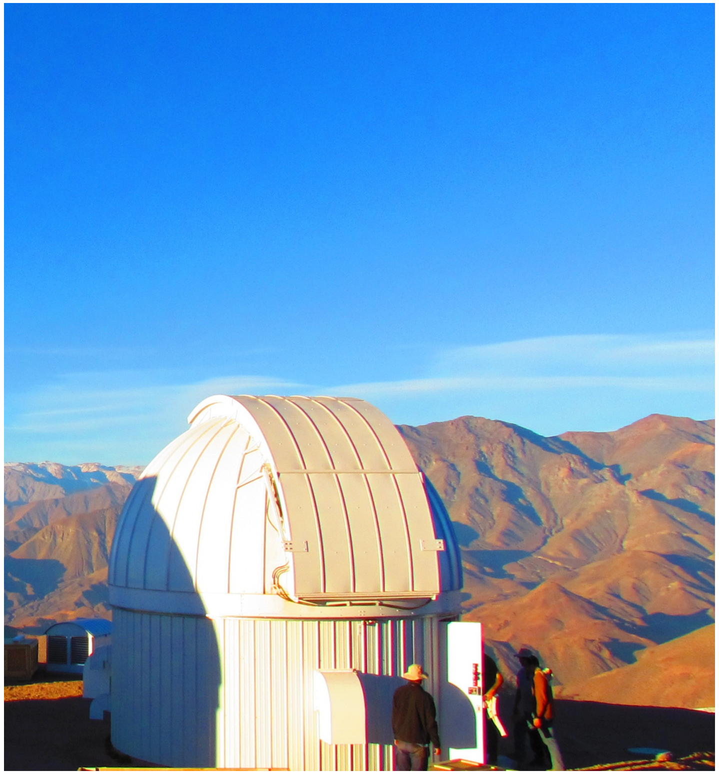
Combining Lightcurves

Combining data from different telescopes non-trivial
Typical approaches:
* Supernovae: low cadence (1/d) observations, plenty of time for standards
* Microlensing: high cadence obs fit to initial model, then iterated



Luhman 16:
Intensive observations
– no/limited time for calibration standards
Quasi-periodic, unknown variability
– no model to fit
Simultaneous observations from multiple telescopes at the same site and different sites

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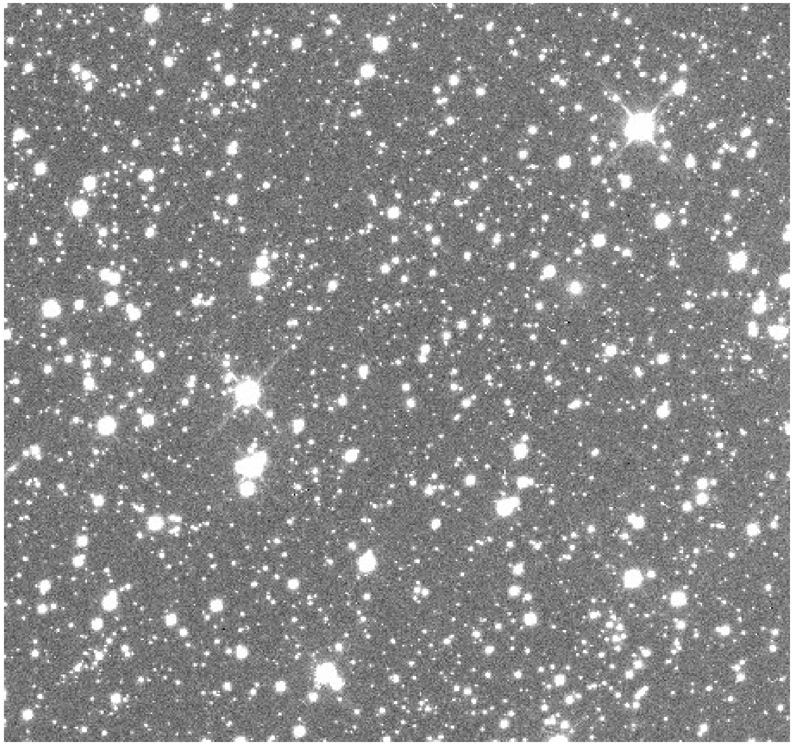
Combining Lightcurves

Explored a number of techniques for deriving differential photometry, e.g.:

Kepler Presearch Data Conditioning	[Stumpe et al. 2012, Smith et al. 2012]
Trend Filtering	[Kovacs et al. 2005]
Sys-Rem Detrending	[Mazeh et al. 2007]

Concerns:

- Work best with wide fields and a very large sample of stars
- Care required to avoid suppression of amplitude of target variability



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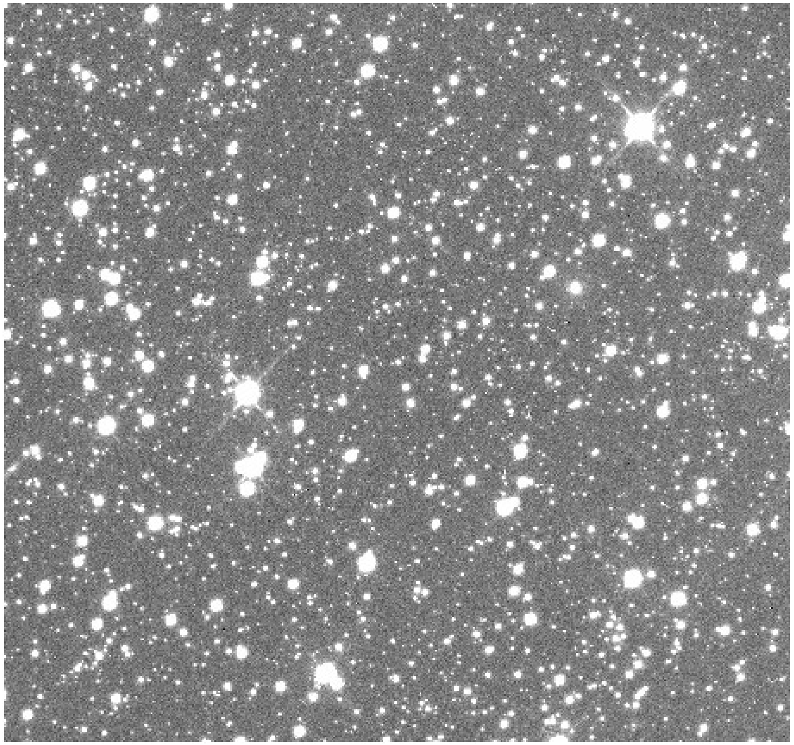
Solution:

- Two independent reductions
- Combined ensemble photometry derived from independently written algorithms
- Extensive cross-checking performed to confirm lightcurve features and exclude instrumental artifacts.



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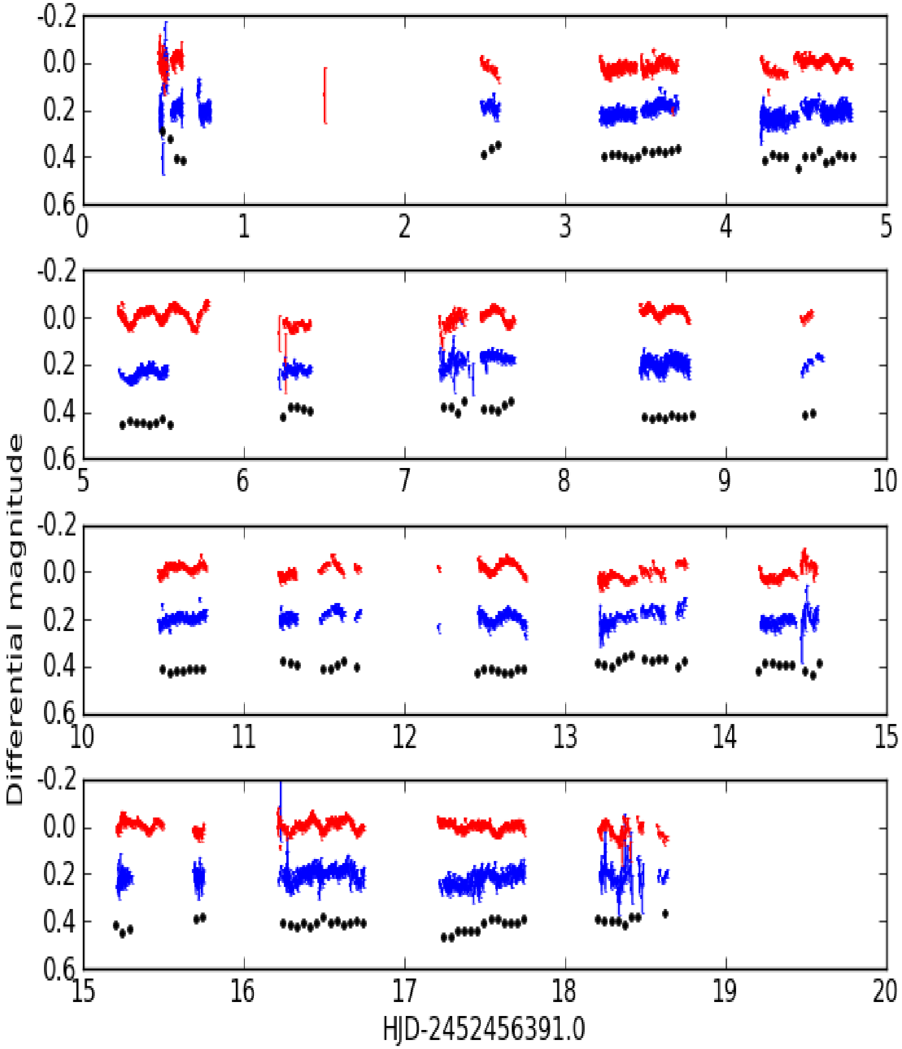
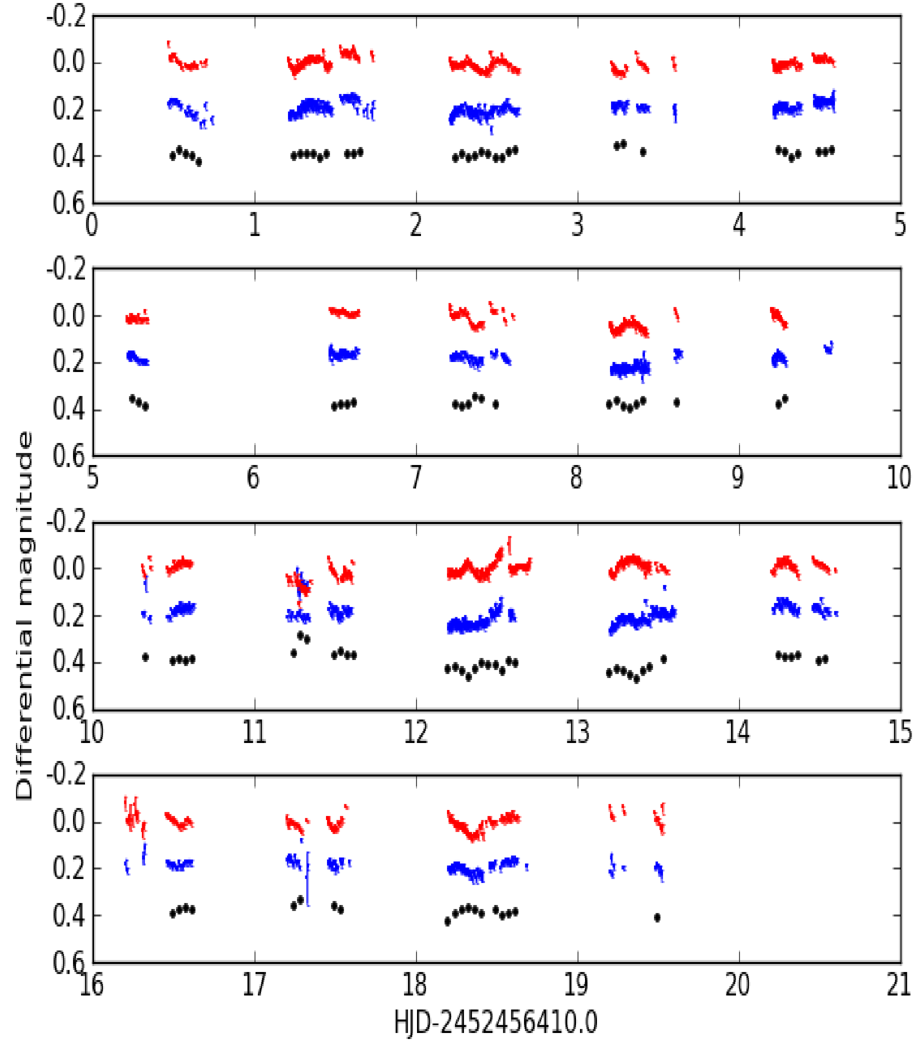
Final Lightcurve

2013 April 11 – May 1



2013 May 1 - 19



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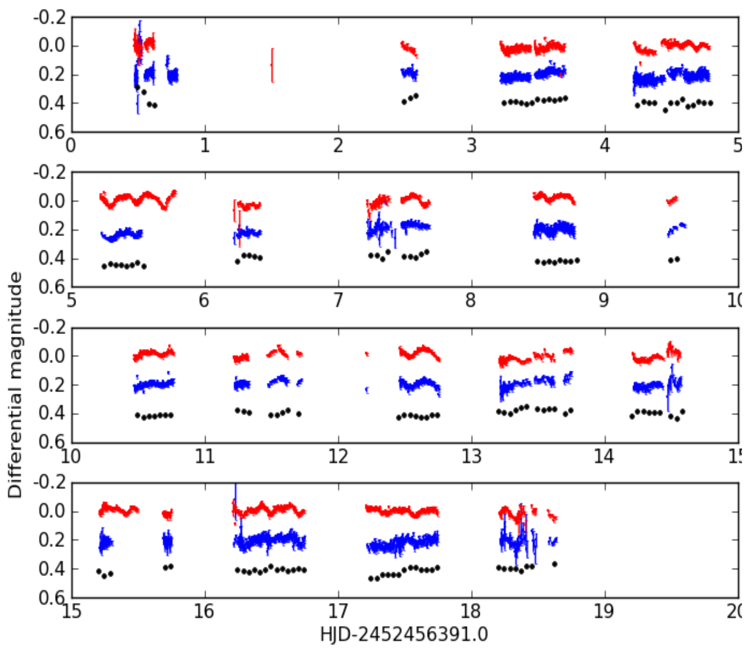
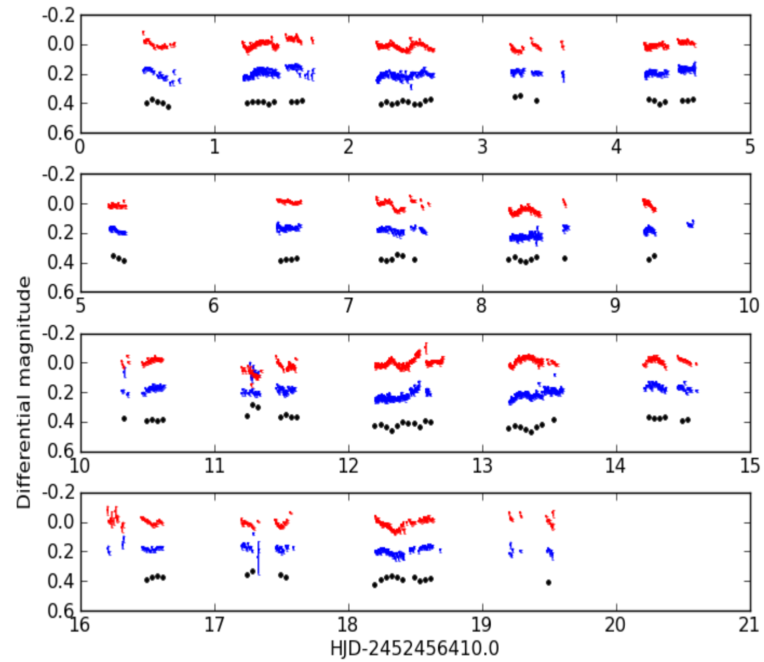
Final Lightcurve

2013 April 11 – May 1



2013 May 1 - 19



Amplitude range: 0.1mag in SDSS-i and Pan-Starrs-Z

Little phase offset observed

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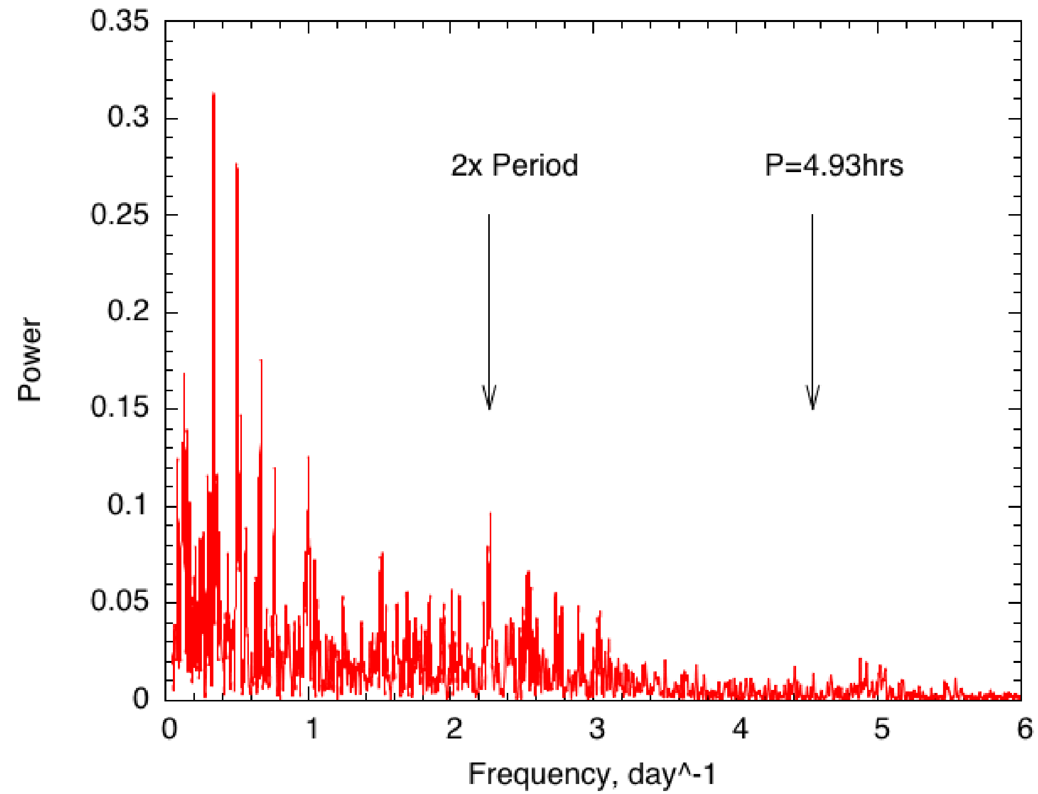
Periodicity Analysis

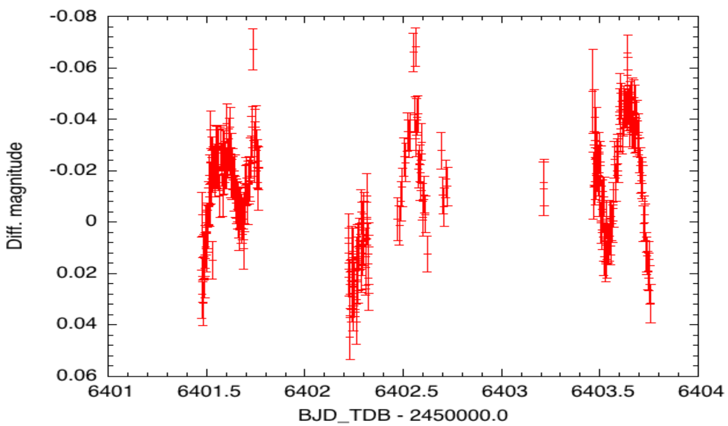
- ANVOA algorithm [Schwarzenberg-Czerny 1999]

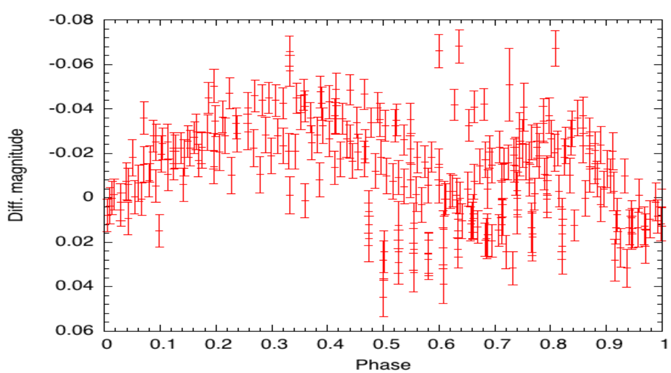
- Applied to whole Pan-STARRS-Z lightcurve
  → P=4.93±0.008hrs

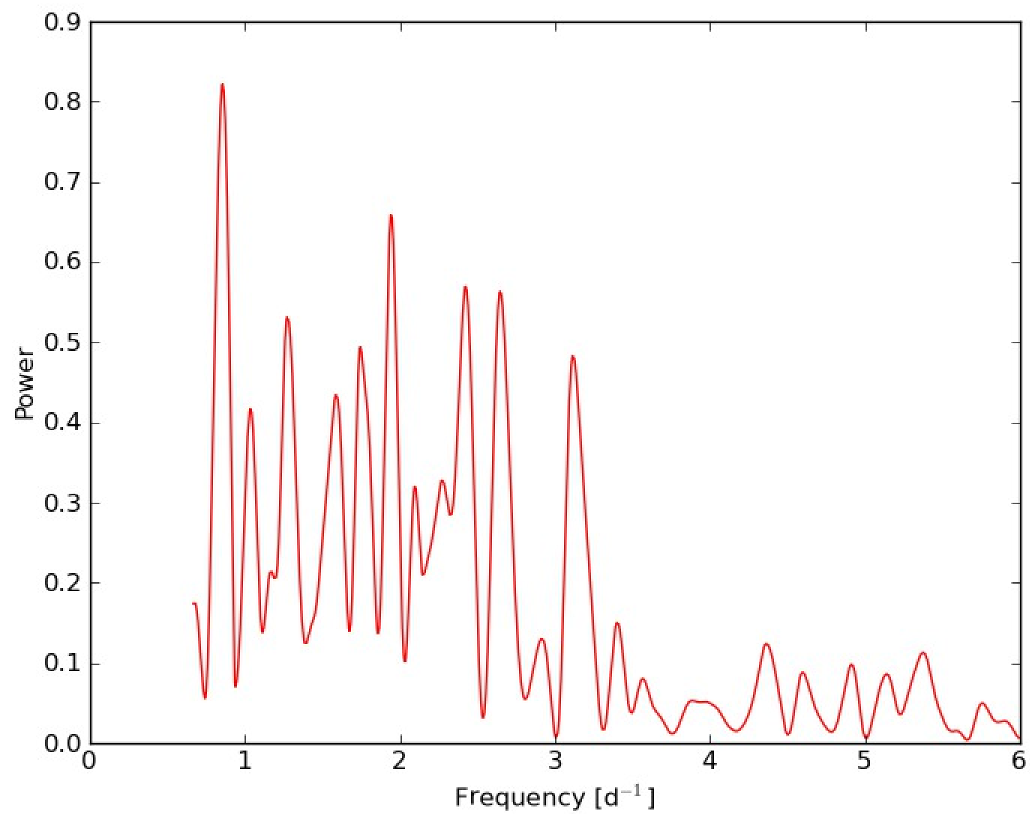


Changes in Periodicity

- Applied to longest continguous lightcurve sections
  Section 1: 2013 April 18-21
  P = 7.0 ± 1.6 hrs

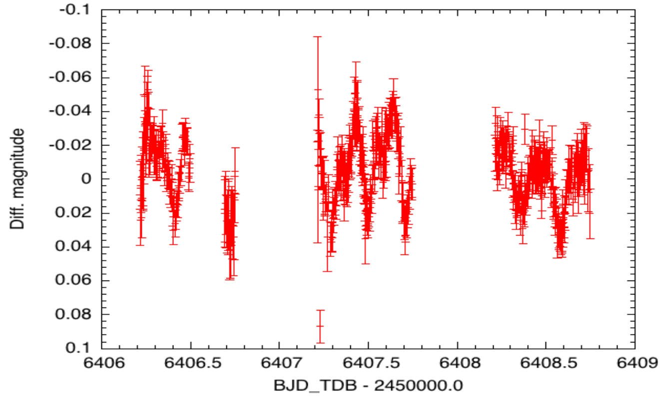


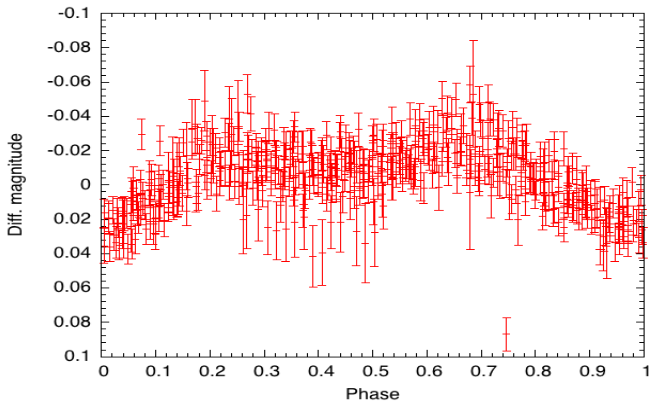


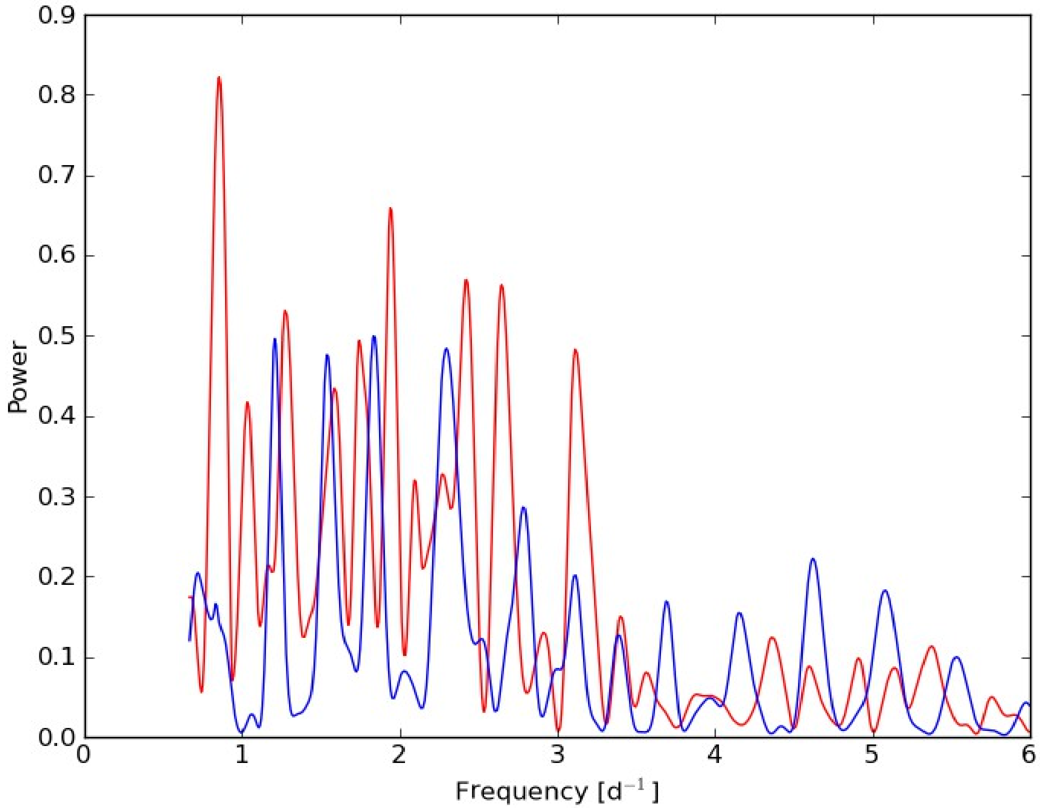


Changes in Periodicity

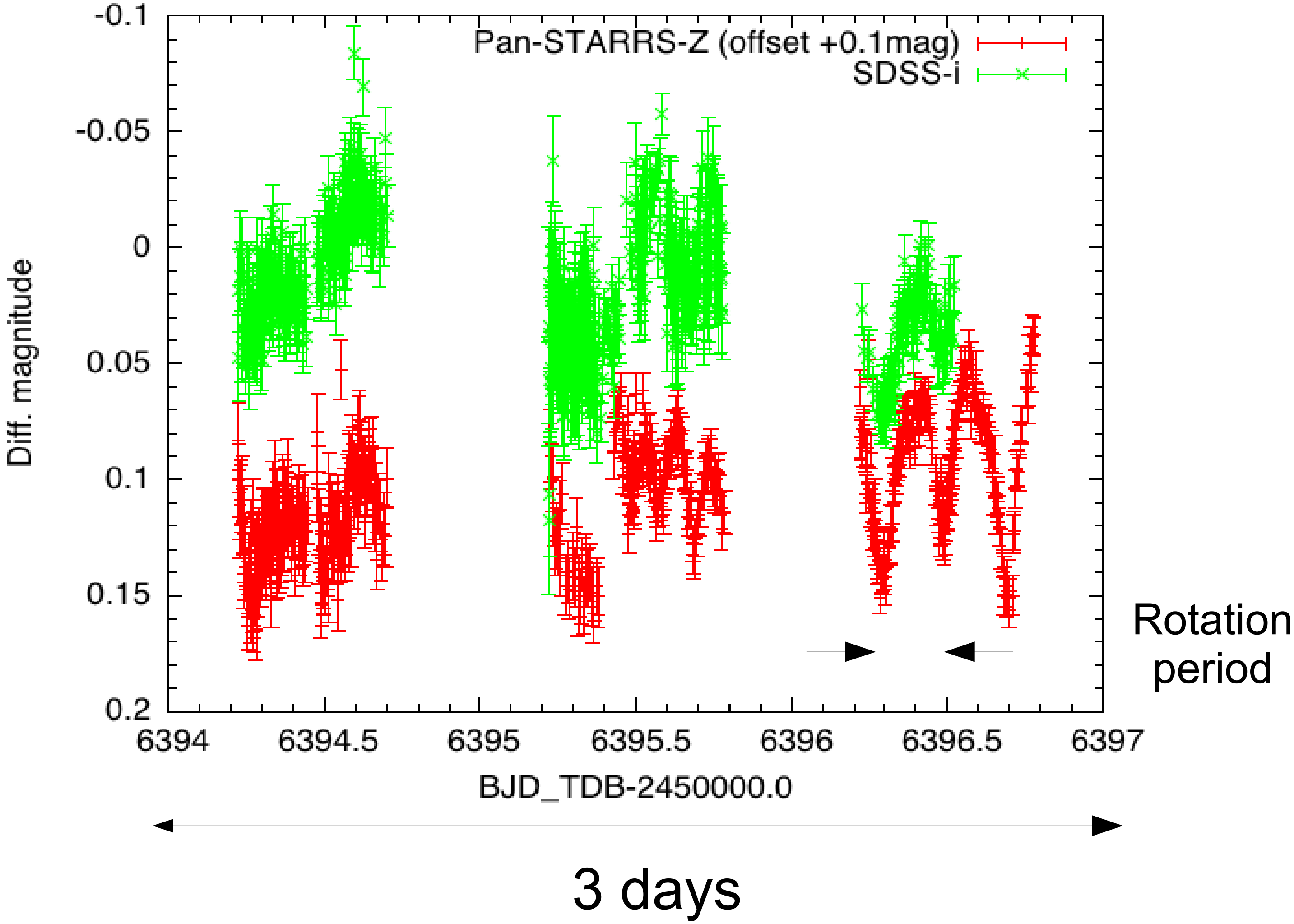
- Applied to longest continguous lightcurve sections
- Section 2: 2013 April 24-26
  P = 5.20±0.14hrs   Consistent over ~day timescales







Changes in Morphology



Summary and Future Work

Extended timeseries in SDSS-I, Pan-STARRS-Z – 41days

Amplitude of variation ~0.1mag in both bands, similar to IR
Little phase difference between the bands

Changes in morphology can occur rapidly, τ~rotation period.

Average period 4.93±0.008hrs but can be up to ~7hrs.

→ suggests cloud-like features, evolving rapidly.
→ changing latitude?

LCOGT Southern Ring 1m network now complete: 24hr coverage

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