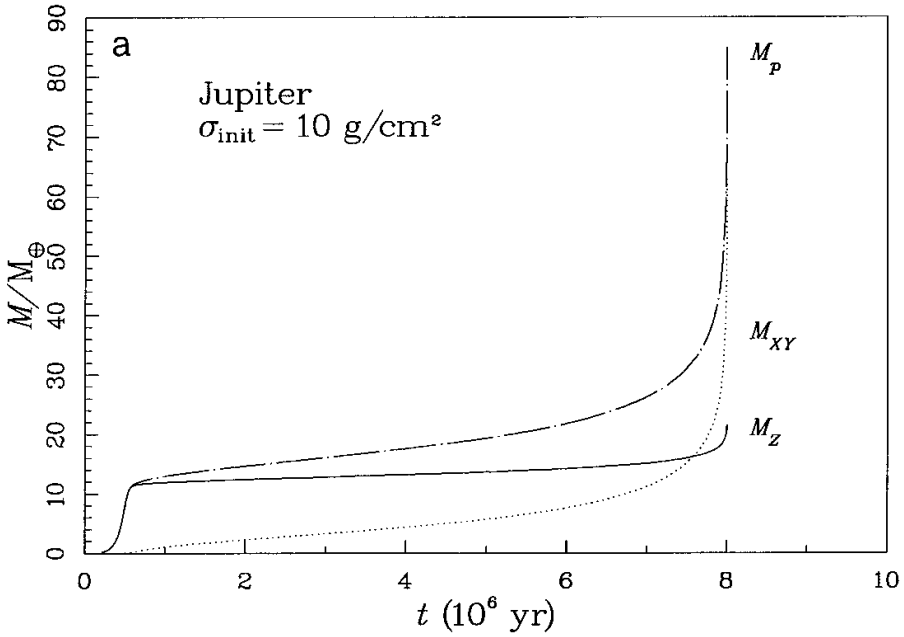
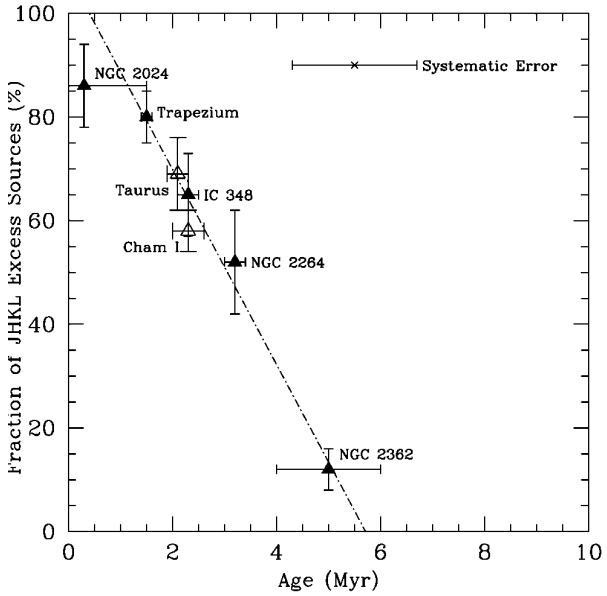
The Monitor project – Searching for low-mass eclipsing binaries and transiting planets in young open clusters

Jonathan Irwin
and the Monitor project team

Motivation - I

- Planet formation
  - Core accretion (Pollack et al. 1996 standard case model)

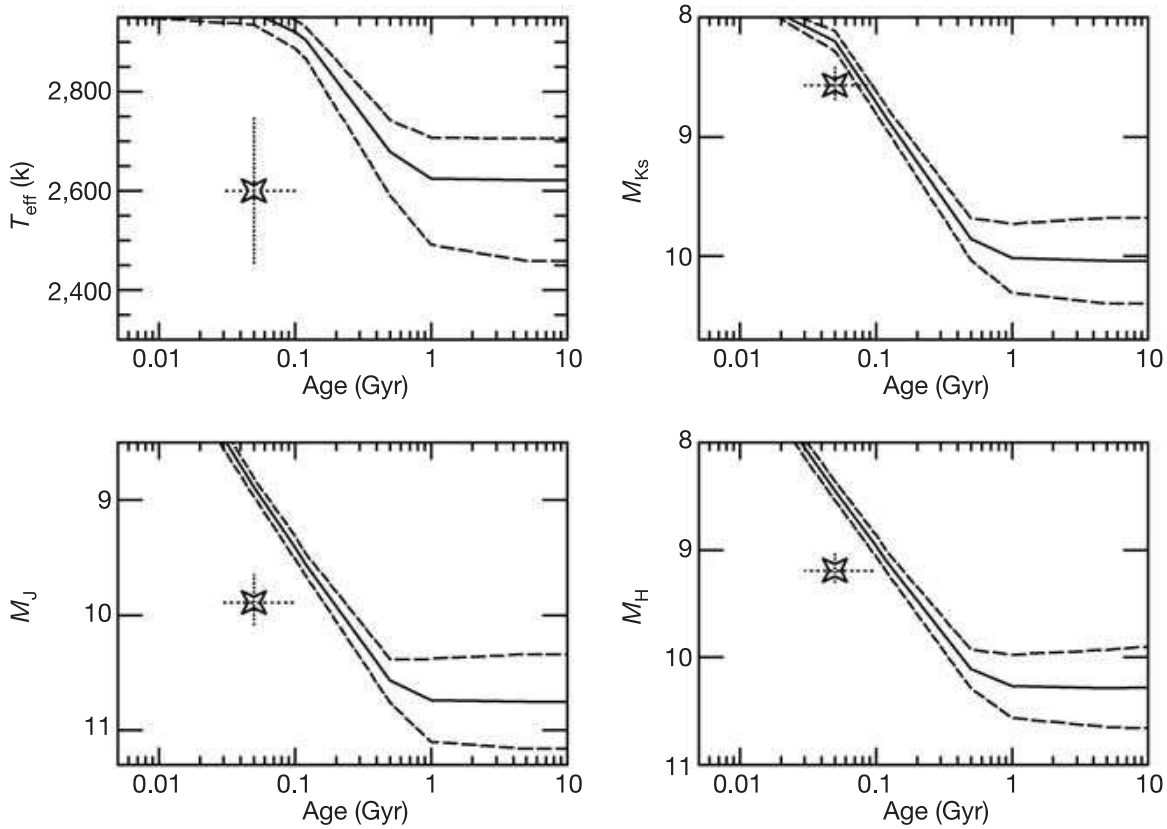




  - ∗ Core masses seem too high
  - ∗ Timescales too long (eg. Haisch et al. 2001 for disc dissipation)

Motivation - II

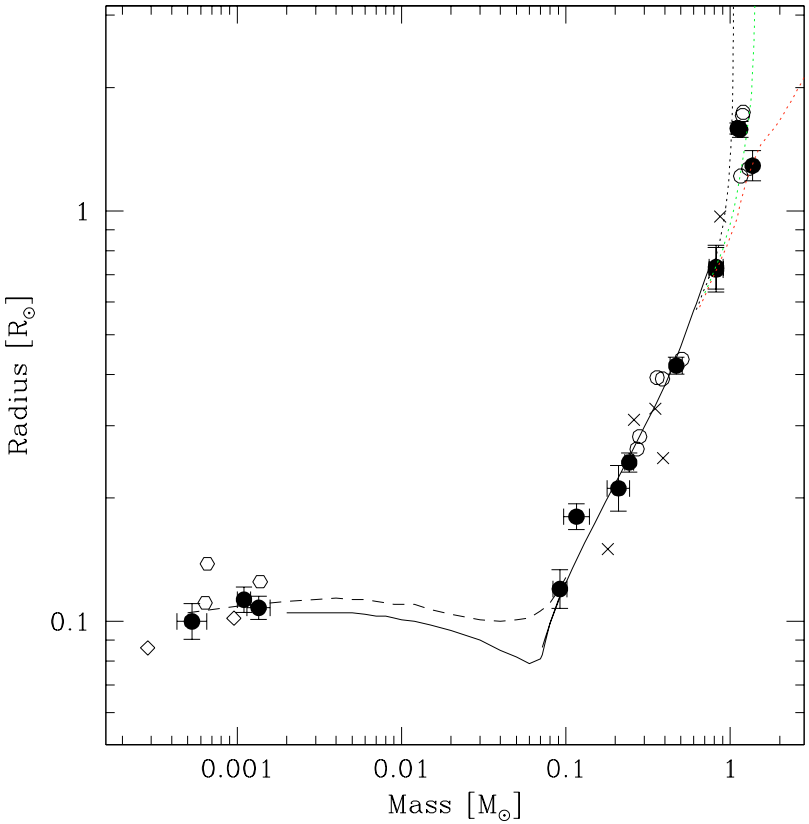
- How bright and large are young planets and BDs?
  - Measurements and models do not seem to agree (Close et al. 2005)

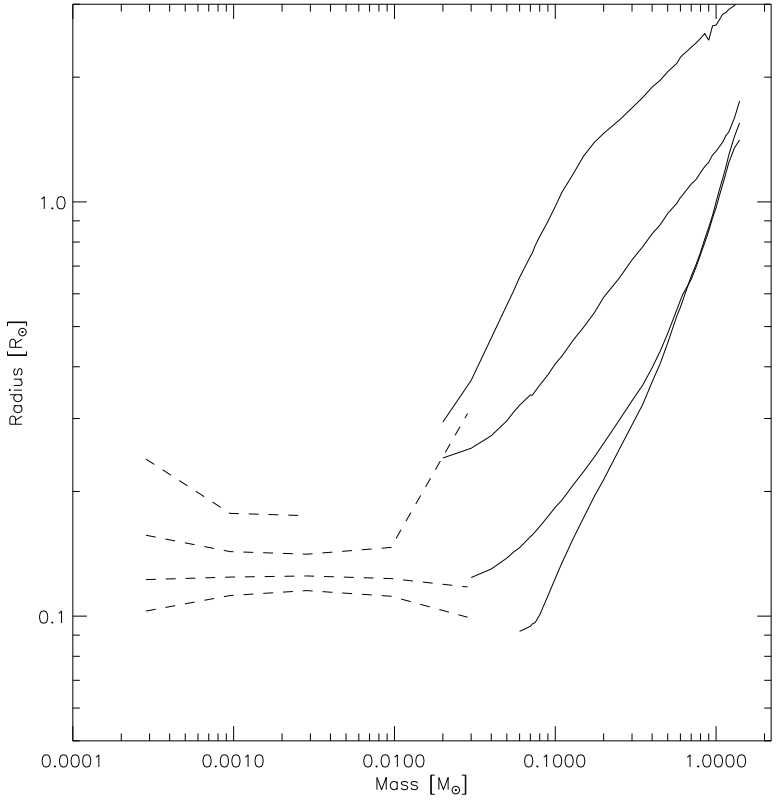


  - Uncertainties at early ages (eg. Baraffe et al. 2003)

Motivation - III

– Mass-radius relation (Pont et al. 2005)





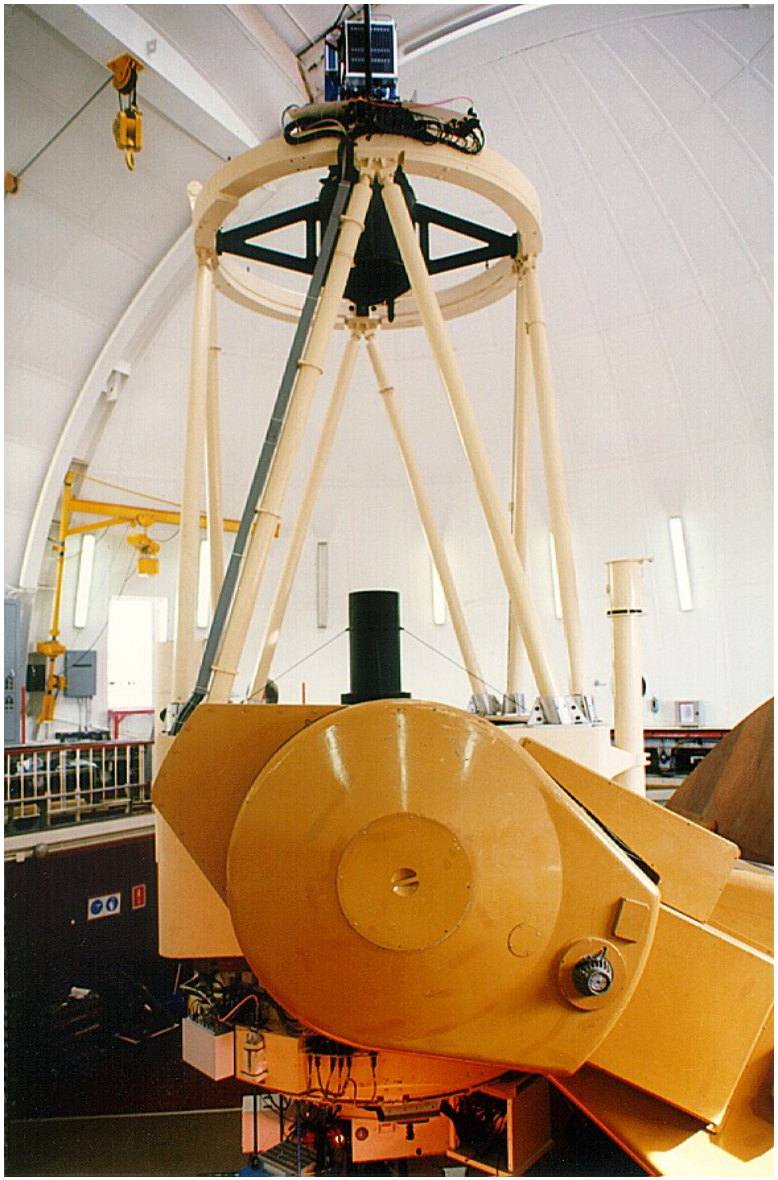
∗ Lack of objects with M, R in the BD regime

∗ Those found so far have uncertain (and mostly old) ages

$\Rightarrow$ Look for low-mass EBs in young open clusters

$\longrightarrow$ Empirical mass determination (one of most accurate methods)

The Monitor project



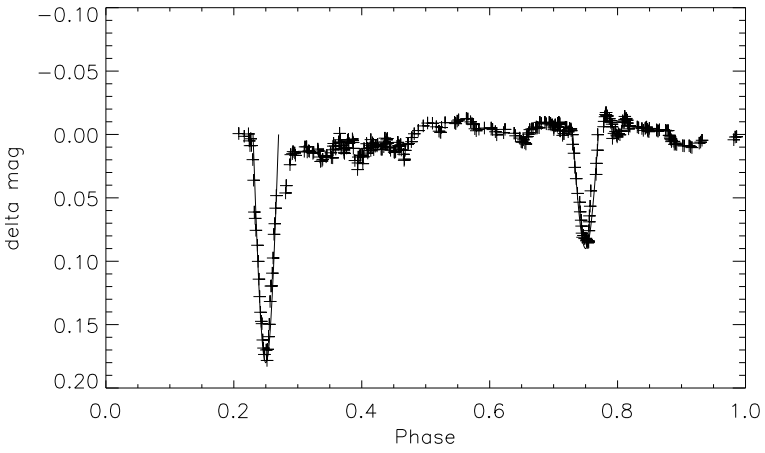
- Transit survey
  - Wide-field optical mosaics
  - $2 - 4$ m telescopes
  - Monitor 1000s of stars
  - RV followup $\rightarrow M$, R
- In young open clusters and SFRs
  - Known age (and metallicity)
  - Bloated primaries $\rightarrow$ improved alignment probability
- Concentrating on low- and very low-mass primaries
  - Deeper transits
  - Larger RV amplitudes make follow-up easier

Problems

- Strong bias toward short periods (eg. Gaudi et al. 2005)
- Contamination from (background) blends
- Requires a large number of observations per field
  - Can be partly mitigated by observing strategy
- Activity and accretion-related variability impede detection
  - Variability filters
  - Simultaneous V and I monitoring (transits achromatic whereas variability tends not to be)
- Faint stars and RV jitter may impede RV follow-up
  - $0.03\ \mathrm{M}_\odot$ BD in $3\ \mathrm{day}$ orbit around $\mathrm{M}_\odot$ star $\rightarrow$ RV amplitude $3\ \mathrm{km\ s^{-1}}$
  - $1\ \mathrm{M_{Jup}}$ planet in $3\ \mathrm{day}$ orbit around $\mathrm{M}_\odot$ star $\rightarrow$ RV amplitude $140\ \mathrm{m\ s^{-1}}$
  - Expect jitter $\sim 60\ \mathrm{m\ s^{-1}}$ at $3\ \mathrm{Myr}$

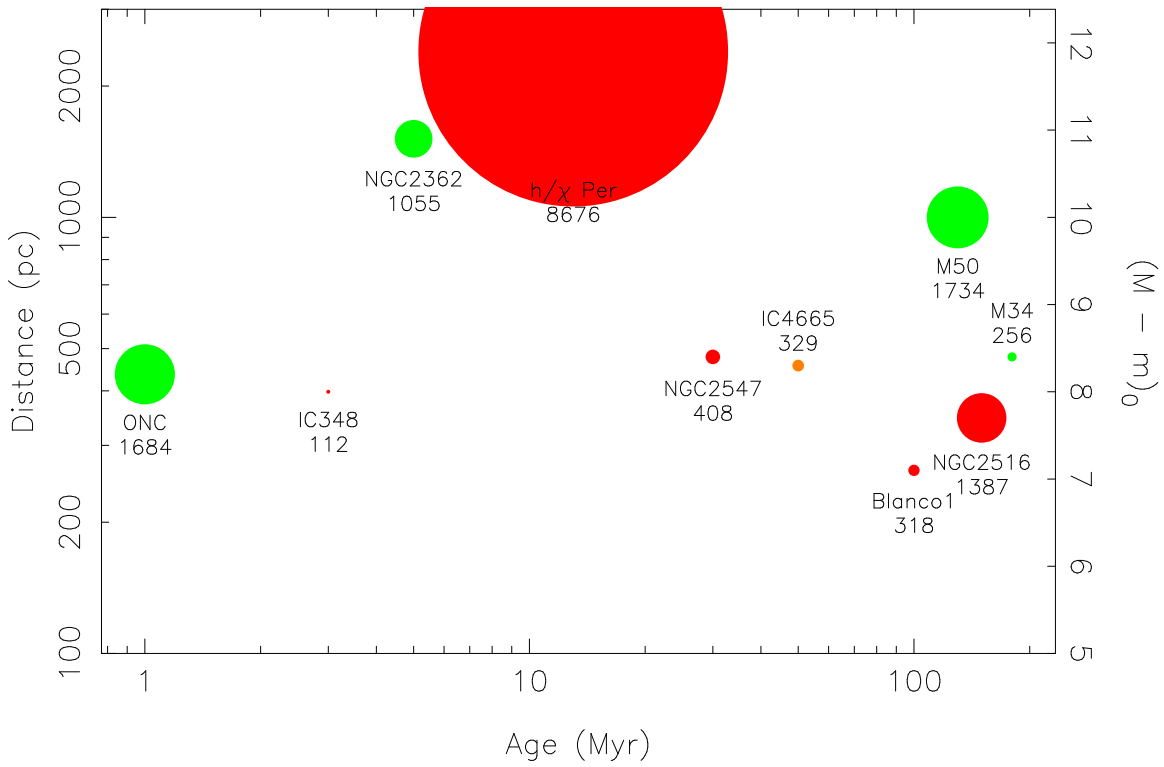
Related work

- Including:
  - EXPLORE-OC (von Braun et al. 2004)
  - St Andrews Open Cluster Planet Search (Street et al. 2003, Bramich et al. 2005)
  - PISCES (Mochejska et al. 2002, 2004, 2005)
- No detections so far
- Hebb et al. 2004



  - Survey of mid-age open clusters ($180\ \mathrm{Myr} - 1\ \mathrm{Gyr}$)
  - M-dwarf EB candidate in M35
  - Secondary eclipse detected in original INT/KPNO survey
  - Primary eclipse detected during Monitor Jan 2005 INT run!

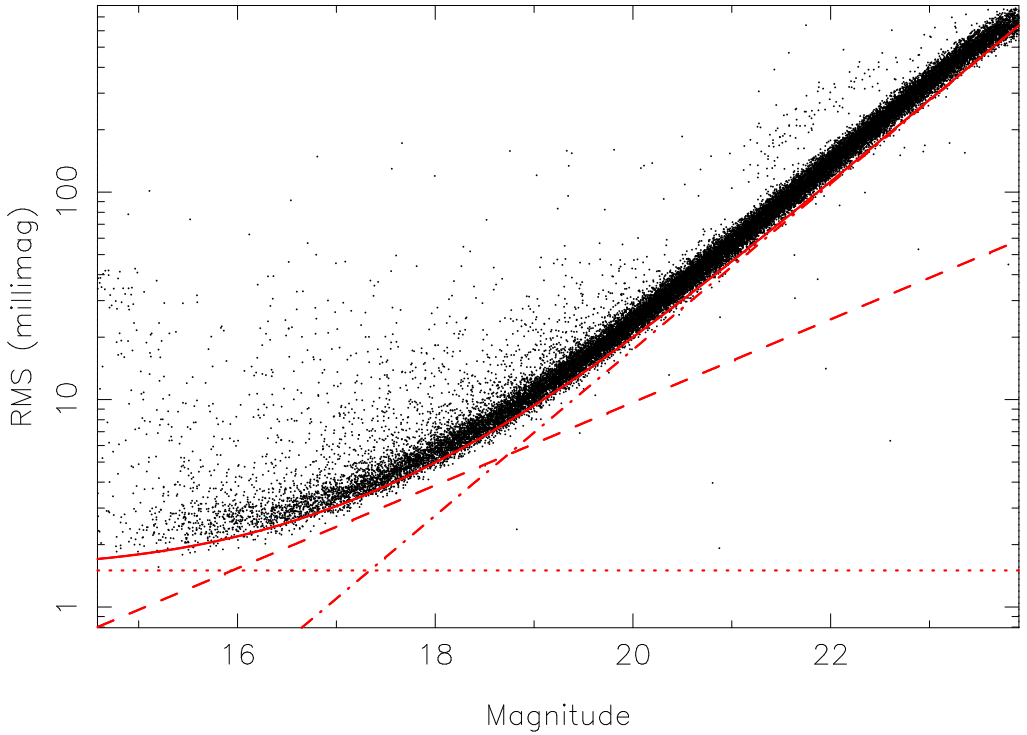
Targets



- Ages up to ~ 200 Myr
- Need to be relatively rich and compact
- Small distance modulus to reach low-mass

Photometric precision

- We can reach peak precision of ~ 2 mmag
- Better than 1% to $i \sim 19$ (CTIO), $i \sim 17$ (INT)



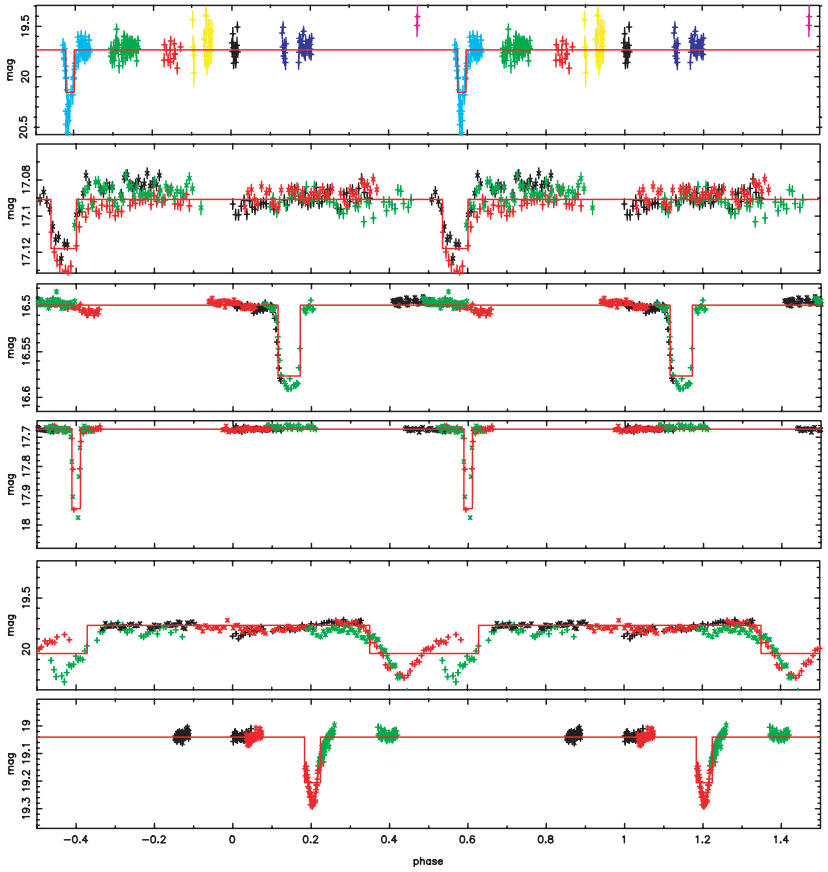
- Eclipse depths due to hot Jupiters $\sim 1\%$, EBs $1 - 10\%$

Eclipse candidate selection

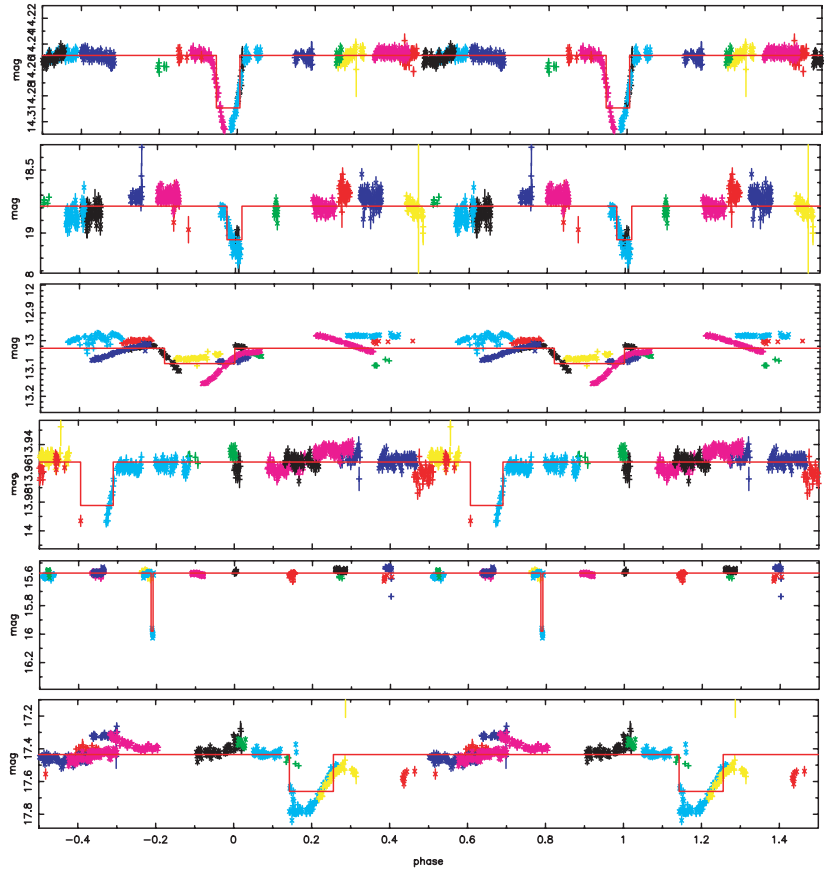
- Search lightcurves of unblended stars
  - Uses transit search algorithm of Aigrain & Irwin (2004)
  - ONC there is too much variability – so do by eyeball instead
- Remove any rotational modulation where necessary
- Determine eclipse parameters
  - Check duty cycle (duration / period) consistent with eclipses
  - Obtain approximate primary M, R from colours and models
  - Transit depth gives estimate of minimum secondary radius
  - Transit duration gives estimate of minimum secondary mass
  - See Seager & Mallén-Ornelas 2003 for much more detail

Candidates

- 12 high-quality candidates, 4 lower-quality



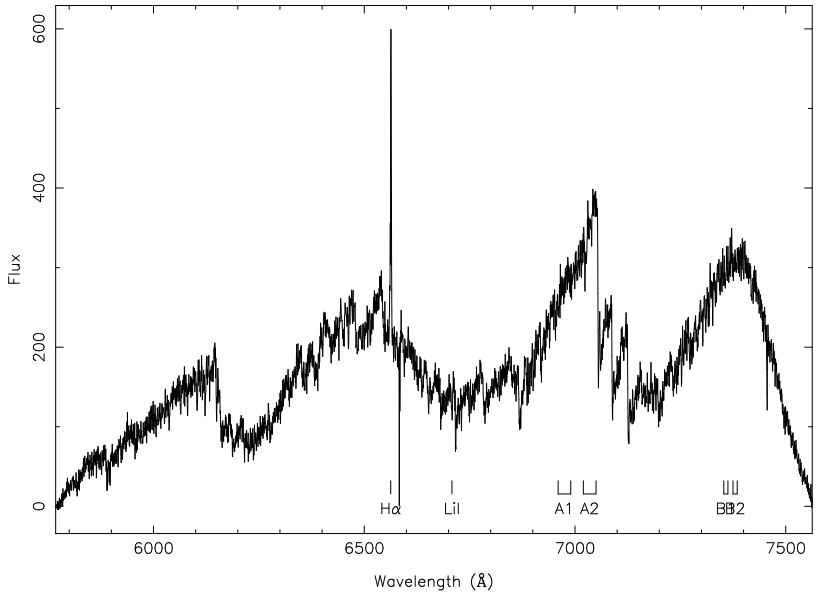
M34, M50, NGC 2362



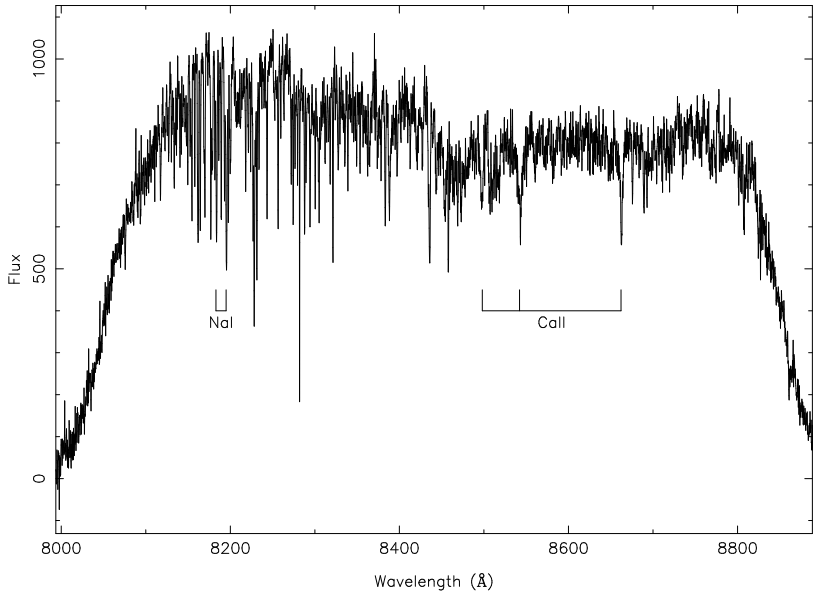
ONC

Spectroscopic follow-up

- Establish membership and spectral type of primary
- Multi-epoch RV measurements to constrain secondary mass
- WHT ISIS December 2005
  - Single-epoch RV (to $4\ \mathrm{km\ s^{-1}}$) + classification (bright targets)
  - More epochs via collaboration

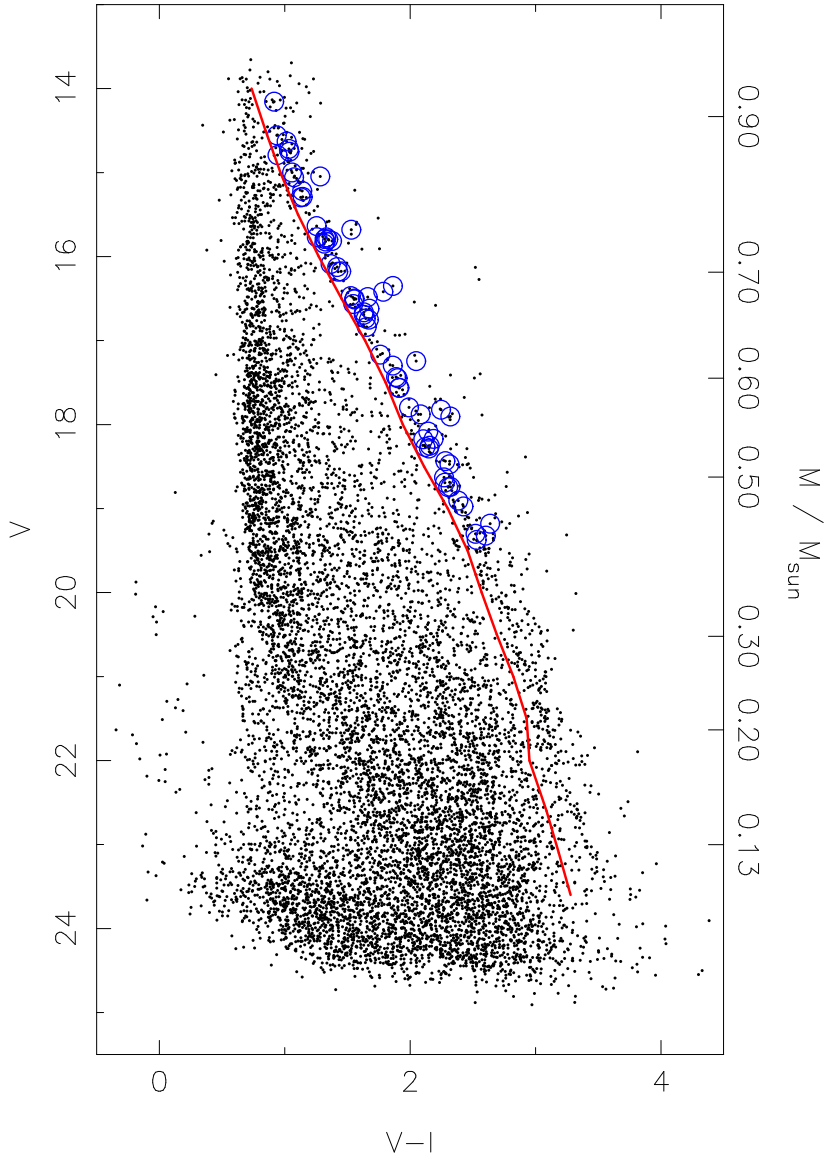


Candidate ONC-1-290 blue arm spectrum: M4-M5

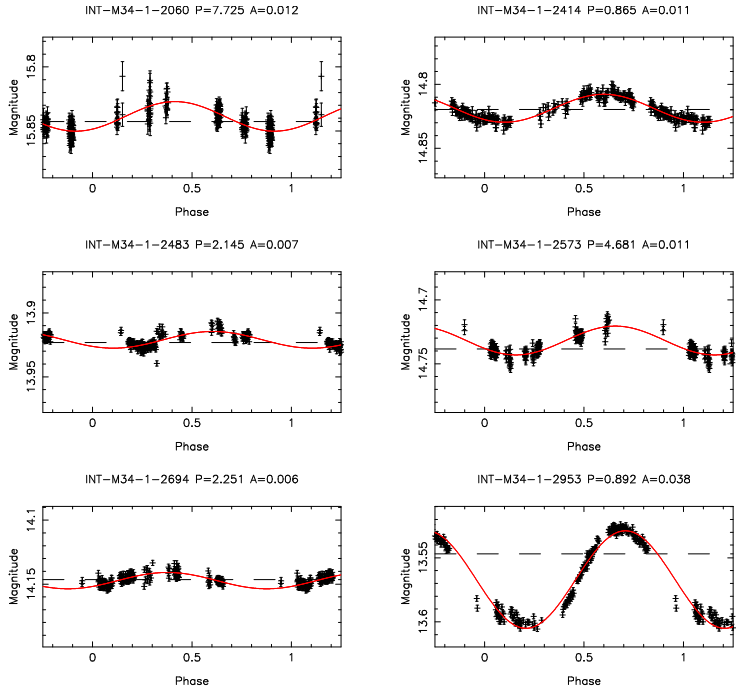


Candidate ONC-1-290 red arm spectrum

Rotation periods – M34



- 67 members show periodic variations (rotational modulation)
- 8 nights data in V and i
- Sensitive out to 16 days



- Can constrain rotational evolution $1 - 200$ Myr

Conclusions and future work

- Working to obtain a sample of young low-mass EBs
- Could discover first young transiting planet in an open cluster
- All at well-known ages
- We have a number of candidates requiring follow-up
  - First follow-up from WHT ISIS looks promising
  - Spectroscopic time very hard to come by
- More photometry and spectroscopy to come...
  - Including WFCAM survey (near-IR photometric monitoring)
- Secondary science:
  - Rotation period studies in all clusters (where possible)
  - Flares in ONC (and possibly others)
  - X-ray – optical connection in ONC with COUP

Thanks

- **Simon Hodgkin** – my supervisor
- **Suzanne Aigrain** – original proposal and a lot of help
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- **Dan Bramich** – for observing (INT)
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- **Leslie Hebb** – for observing (CTIO)
- **Mike Irwin** – for observing (INT) and much of the pipeline
- **Patricia Verrier** – for observing (INT)

More information:

`http://www.ast.cam.ac.uk/~suz/monitor/monitor.php`