Searching for occultations in young open clusters

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M-R relation at low masses

Isochrones:

Baraffe et al. (1998) — solid line
Chabrier et al. (2000) — dash-dot-dot line
Baraffe et al (2003) — dashed line
Burrows et al. (1997) — dotted line

Ages:

1, 10, 150, 1000 Myr

Constraints:

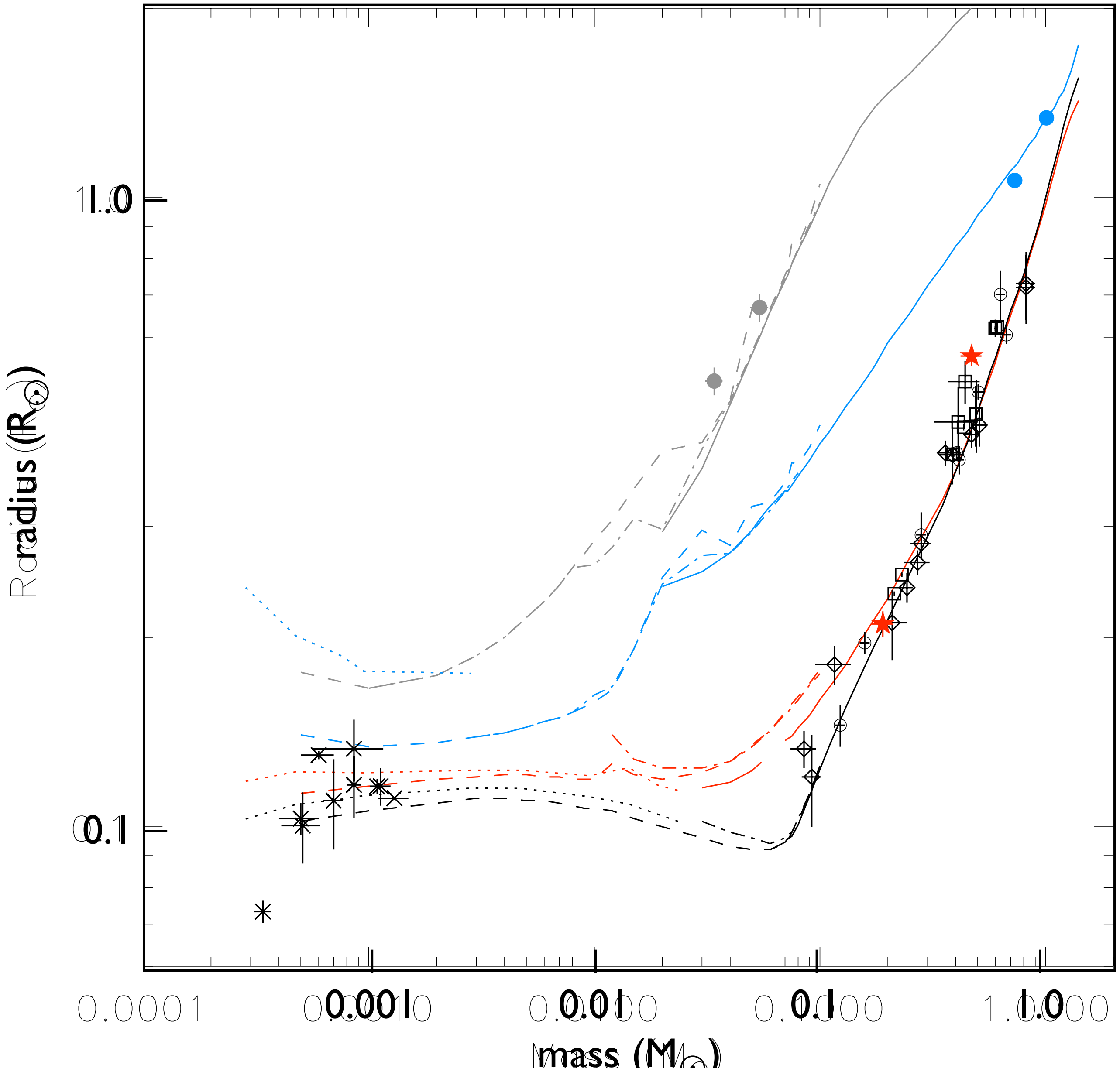
- *Field systems:*

interferometry, OGLE, M-M EBs
transiting planets

- *PMS systems:*

Stassun et al. (2004, Ori 1c)
Stassun et al. (2006, ONC)
Hebb et al. (2004, NGC1647)

global agreement with models, but significant discrepancies



Motivation

Noticeable features:

importance of age

BD desert

few PMS M-dwarf systems

no young (transiting) planets

Monitor goals:

- Populate the PMS relation

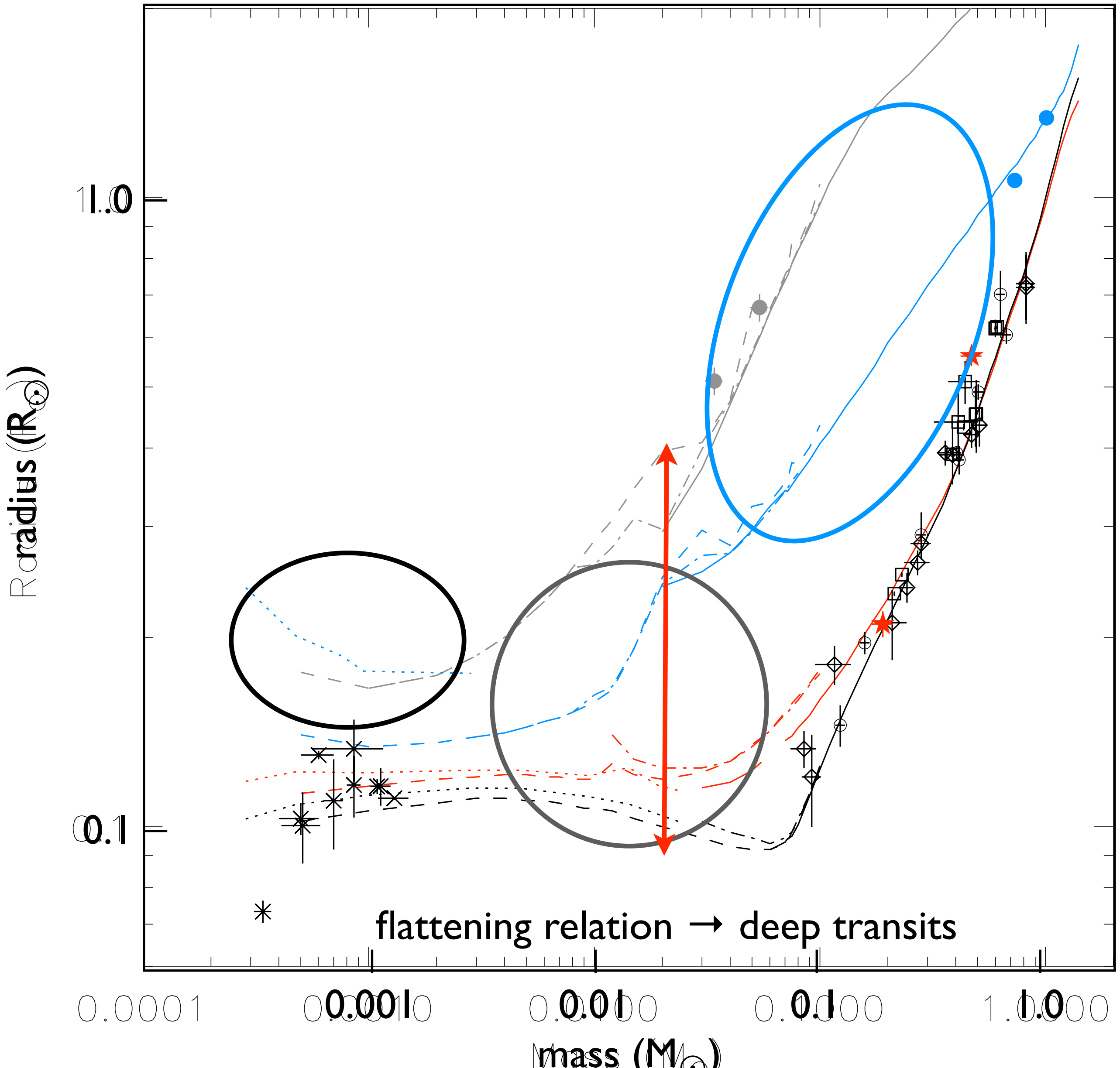
constrain evolutionary models

- Statistics of young low-mass binaries

constrain star formation scenarios

- first young planets

constrain planet formation timescales



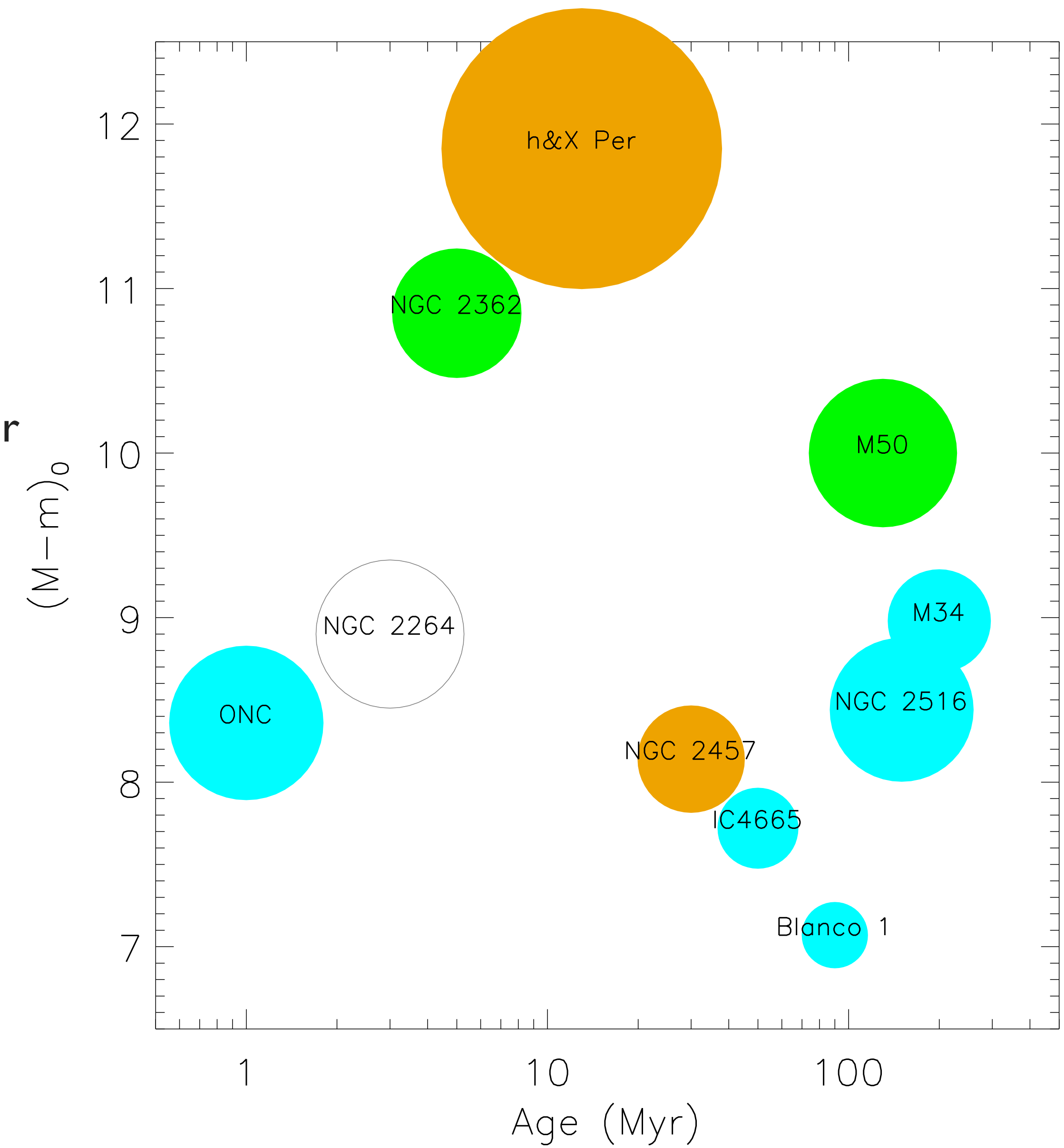
OC transit surveys

- Existing surveys
  - EXPLORE-OC, UStAPS, PISCES, STEPSS: focussed on planets
    - No detections so far (some candidates)
  - Hebb et al.: focussed on low-mass EBs
    - 1 confirmed detection, 2 candidates
  - All target older open clusters (mostly >1 Gyr)
- Pros
  - Known parameters: ages, [Fe/H], (rough) mass
  - Less contamination (membership selection)
- Cons (for planets)
  - Too few target stars
  - Faint targets: difficult RV follow-up

See Pepper & Gaudi (2005)
for (single transit, white noise only) scaling laws

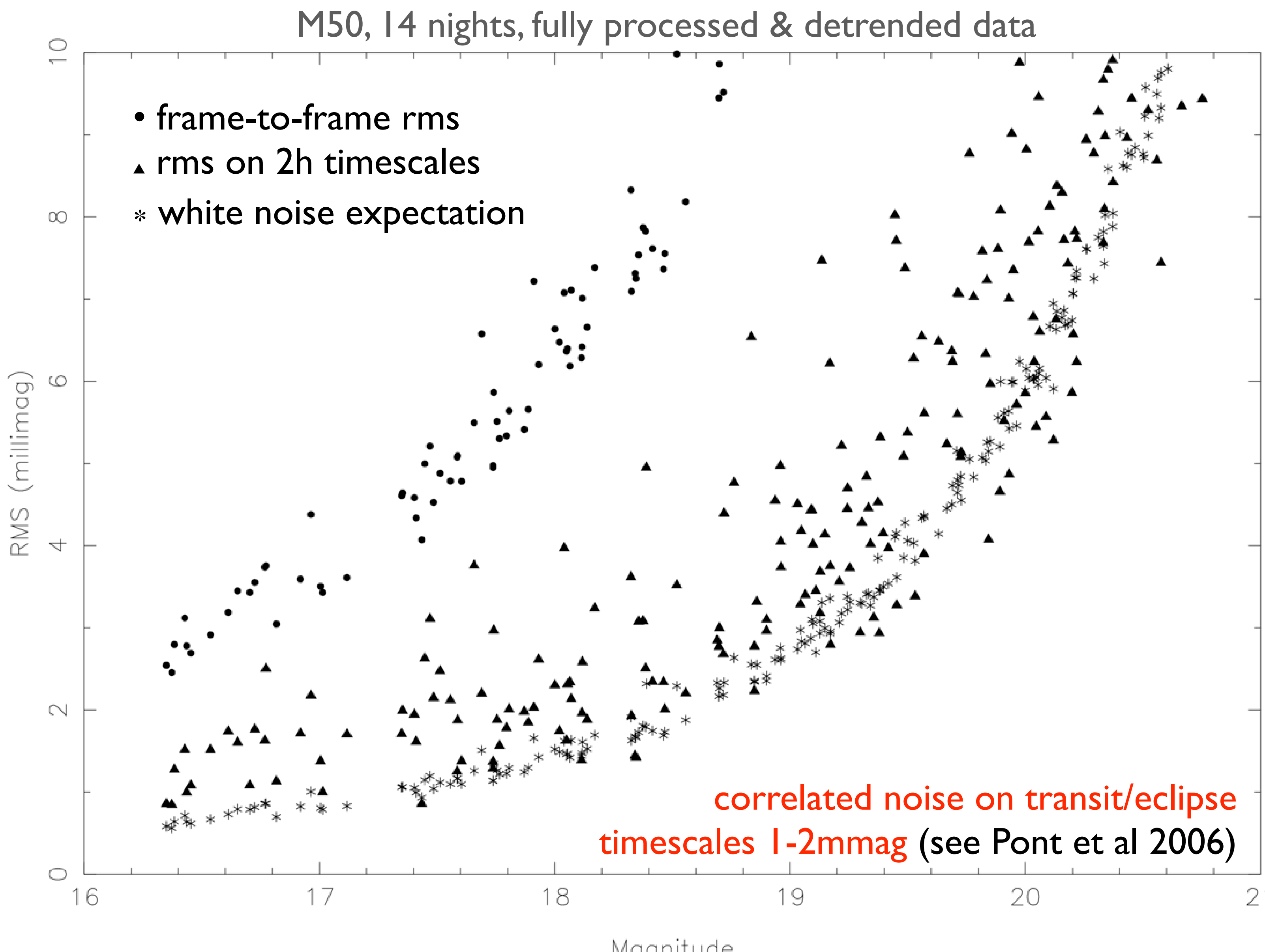
Monitor:YOC transit survey

- Pros:
  - More & deeper eclipses
  - Lower mass primaries
  - Even less contamination
- Cons
  - More photometric variability and RV jitter
  - Even fainter targets (2-4m telescopes)
- Observations (ongoing)
  - 2-4m telescopes
  - >=100h/target
  - up to 2yr baseline
  - <15min sampling
  - I-band



Photometric performance

See Monitor data processing paper (Irwin et al in prep) for details



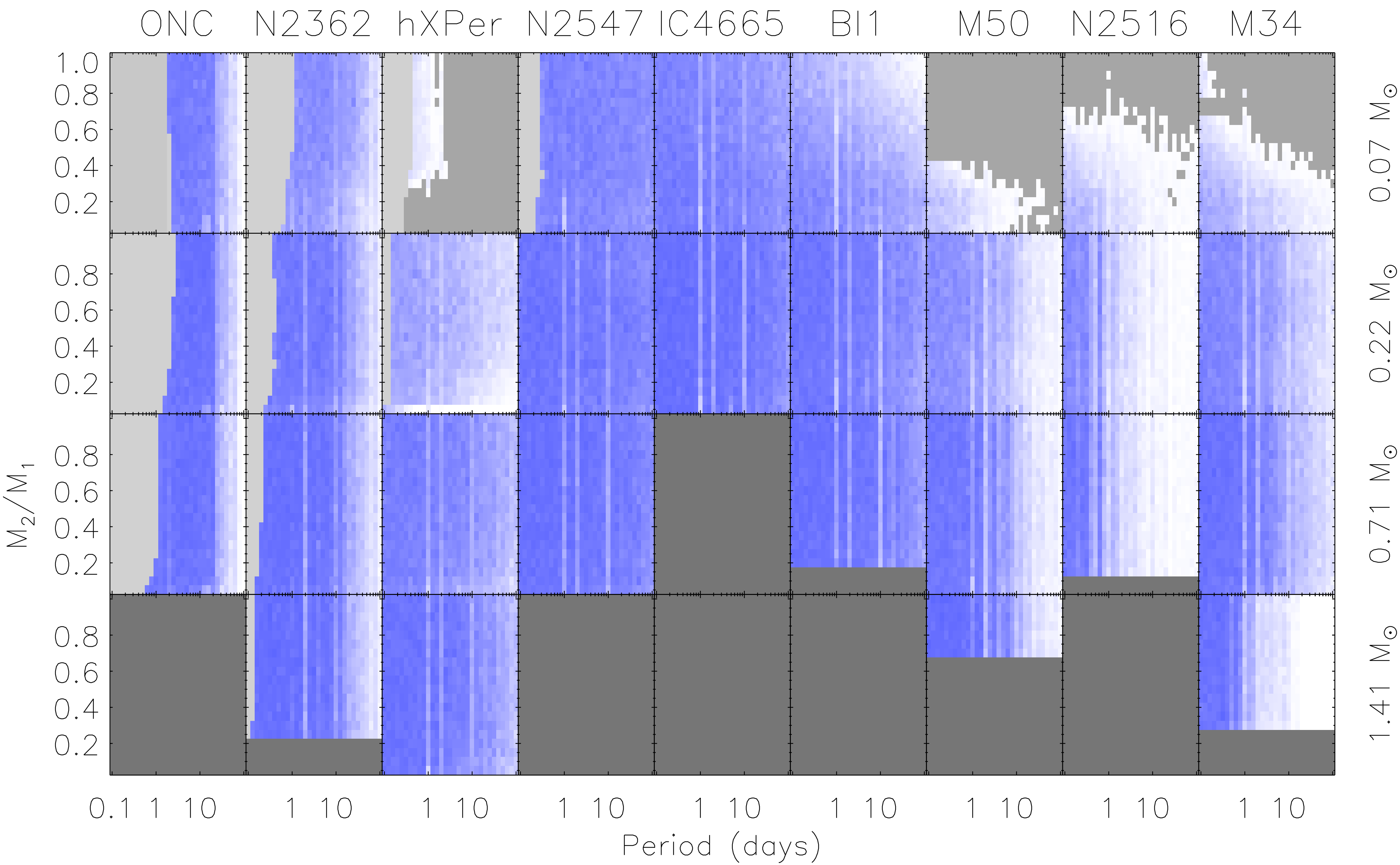
Detection estimates

Aigrain et al. (submitted to MNRAS)

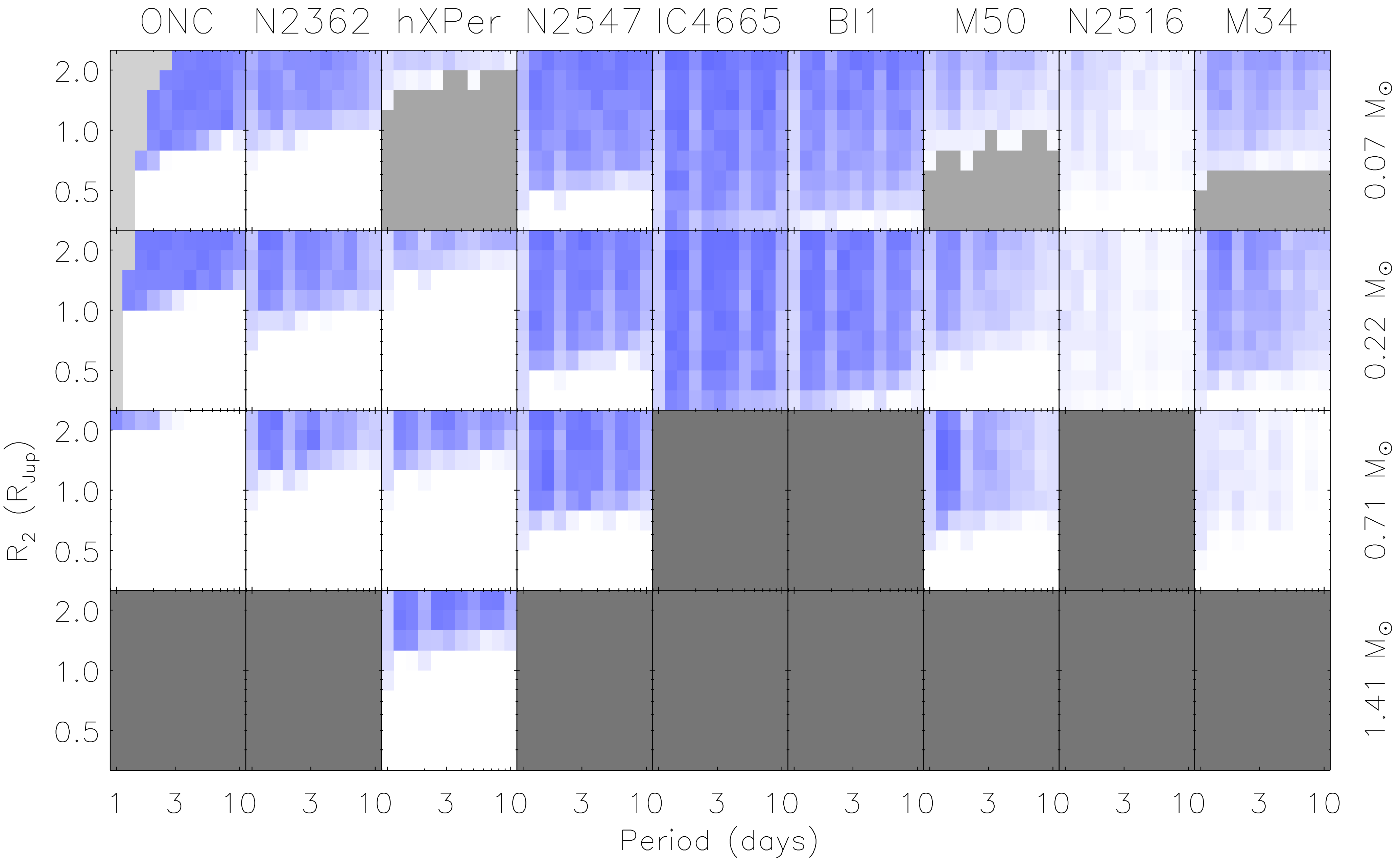
- Follow concept of Pepper & Gaudi (2005)
- $$\frac{d^3 N_{\rm det}}{dM\,dr\,dP} = N_* f_p \frac{d^2 p}{dr\,dP} \mathcal{P}_{\rm tot}(M,\ P,\ r) \frac{dn}{dM}\,.$$
- ... BUT:
  - replace planet radius r with mass ratio q for binaries
  - include grazing eclipses & mass of secondary
  - use mass function and companion probabilities appropriate for M-type primaries
  - use double-trapezoid extension of BLS (Aigrain, Mazeh & Tamuz in prep.)
  - account for correlated noise in detection (Pont, Zucker & Queloz 2006)
  - use real (observed) time sampling and noise budget versus magnitude
  - require Sred>8, >2 observed eclipses, >8 in-eclipse points for detection
  - incorporate a term representing the feasibility of RV follow-up

→ try to be as realist as possible while keeping workload manageable

Sensitivity to eclipses



Sensitivity to transits



Expected detections

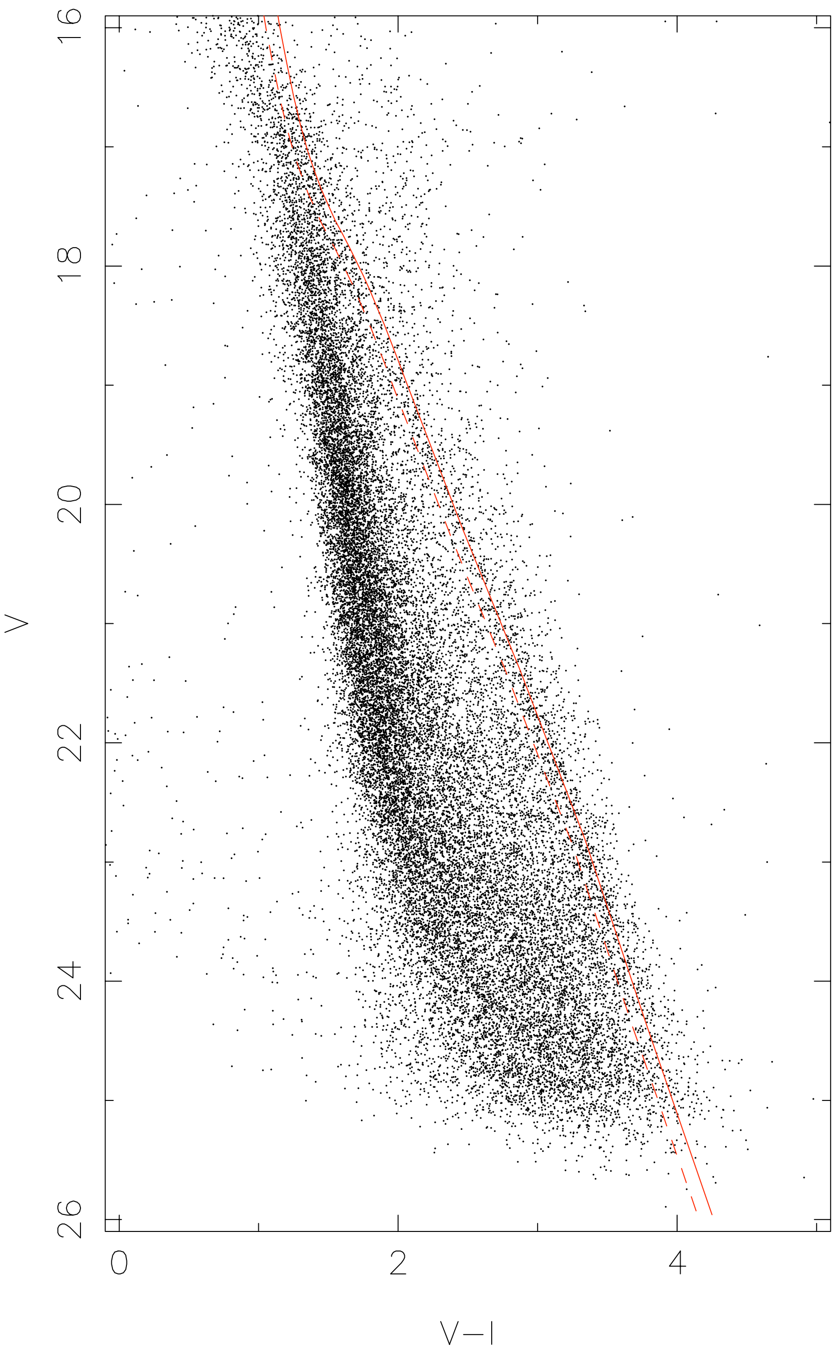
eclipse/transit detectability

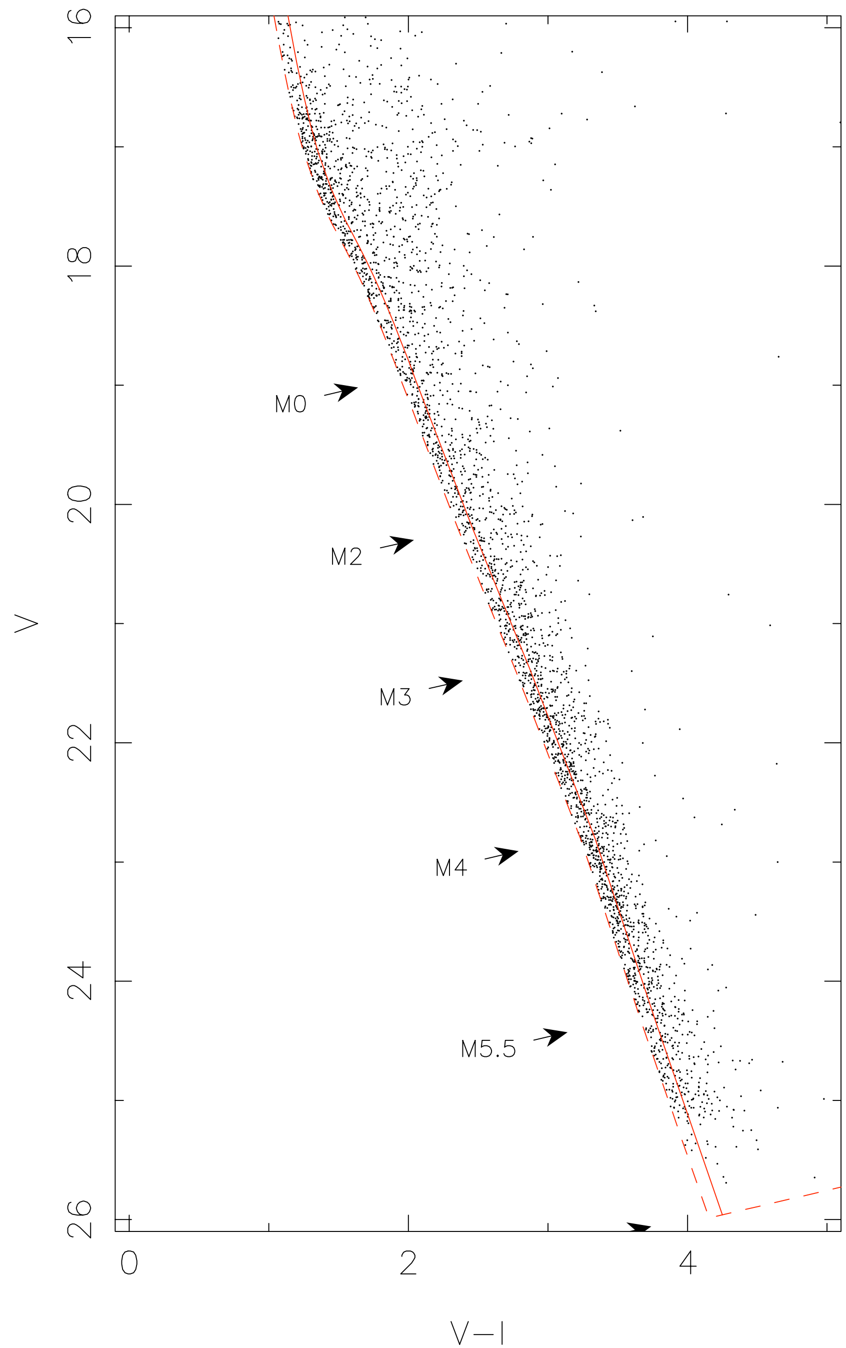
	Binaries			Planets		
Name	N_c	N_o	N_d	N_c	N_o	N_d
ONC	152.9	53.5	35.9	78.8	33.5	2.6
NGC 2362	96.9	25.7	15.9	40.8	10.7	0.9
h&χ Per	2590.3	560.1	201.2	515.7	82.4	4.2
NGC 2457	59.9	11.2	8.4	24.1	4.0	0.9
IC 4665	28.3	4.4	2.9	9.2	1.2	0.7
Blanco 1	12.6	1.5	0.9	4.3	0.5	0.2
M50	245.0	24.7	8.5	64.0	5.9	0.6
NGC 2516	154.8	15.5	3.1	54.5	5.2	0.3
M34	59.4	5.9	2.2	20.6	1.6	0.3
Total	3400.2	702.5	278.9	812.0	144.9	10.9

Table 4. Expected number of binaries, eclipsing binaries and detectabl eclipsing binaries, and of planets, transiting planets and detectable transi ing planets, for each cluster and for the survey as a whole, under the a: sumptions described in the text.

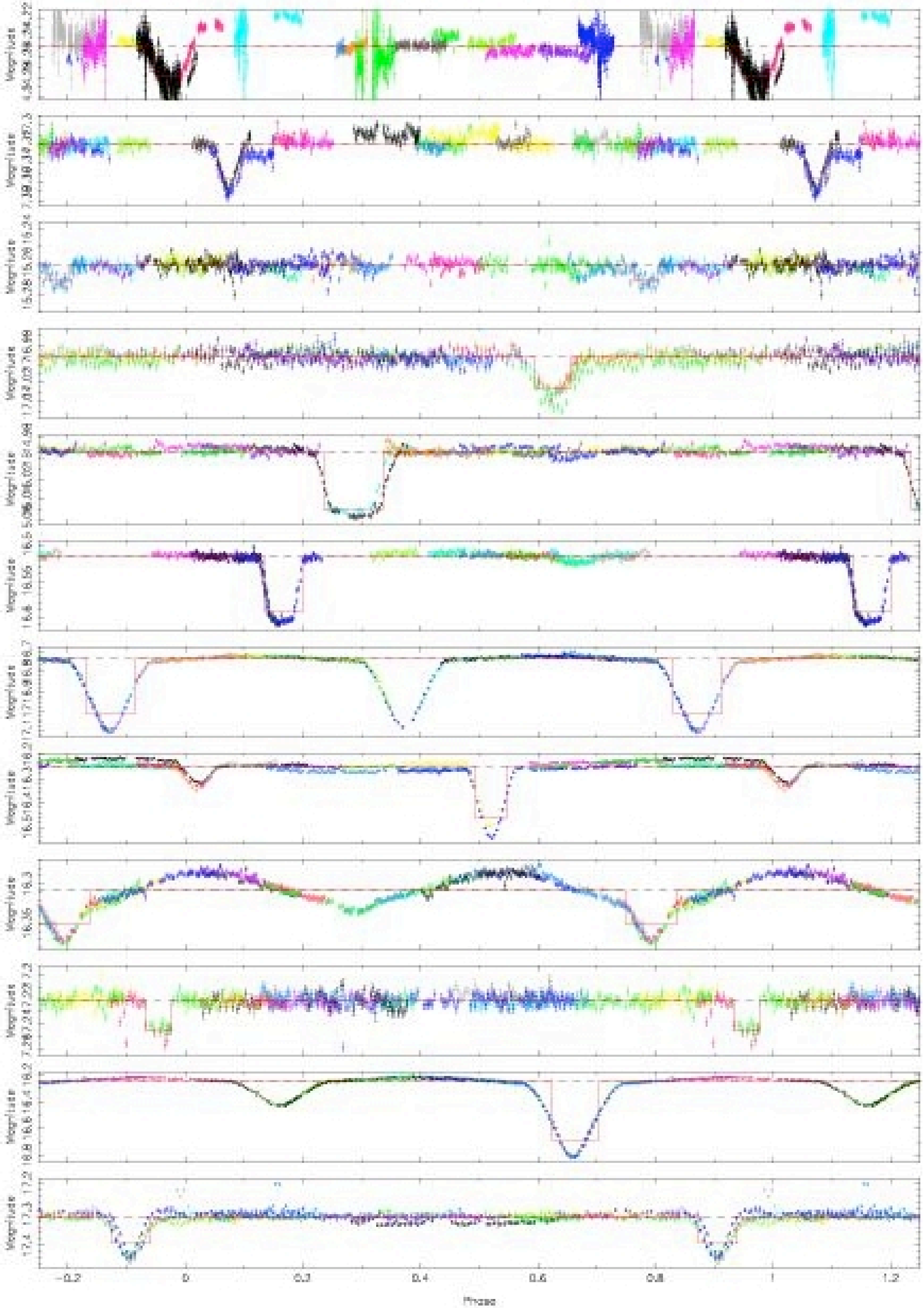
- RV follow-up:
  - 100% of the EBs whose eclipses can be detected also produce RV modulations detectable with VLT +FLAMES
  - 25% can be detected from a 4m
  - Only 29% of the planets in the ONC, and 10% of those in NGC2547, produce a detectable RV signal

Membership selection





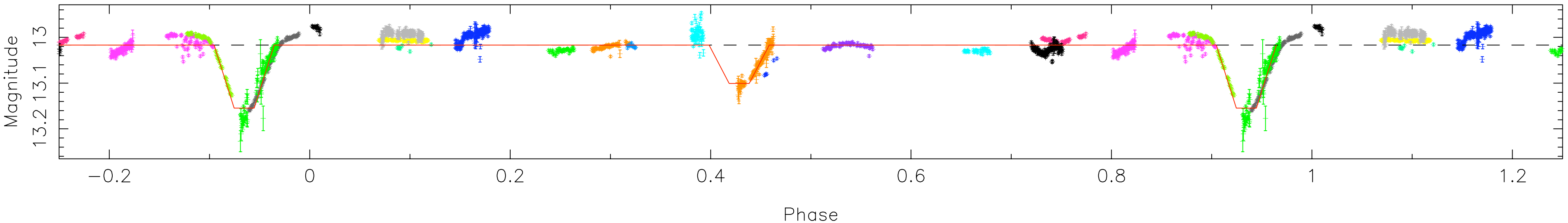
M50



Candidates

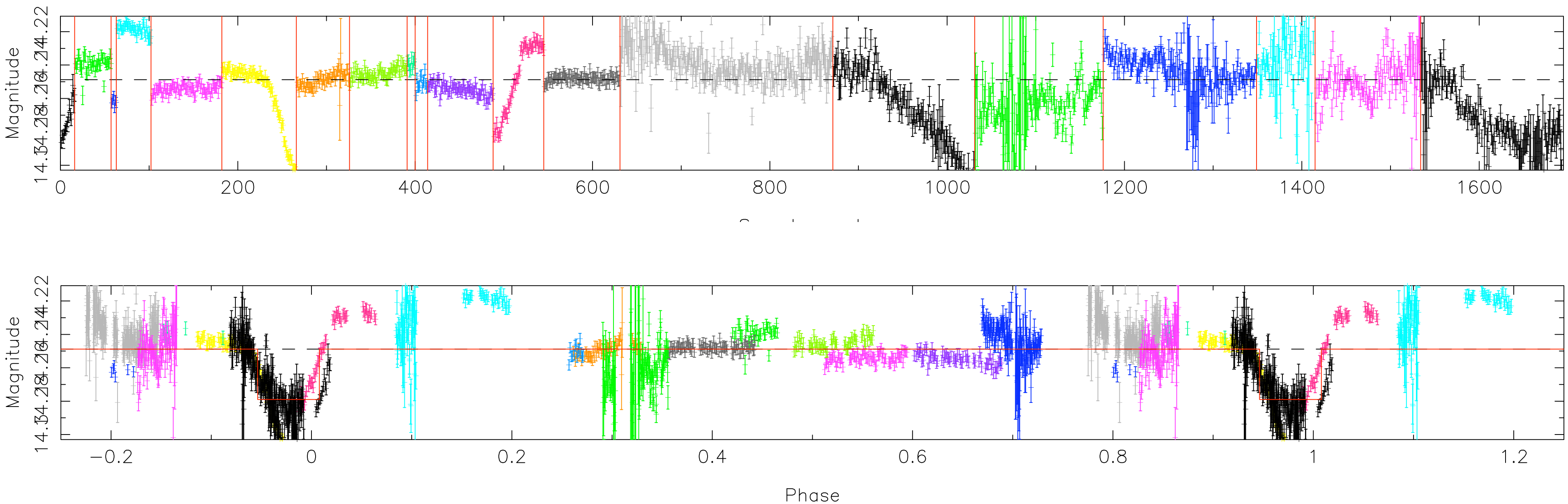
- 25 priority 1 candidates in 4 clusters so far
- ages 1 - 130 Myr
- 10 with depths compatible with planet
- completely unprecedented sample
- spectroscopy needed to
  - confirm cluster membership
  - measure companion masses
- follow-up strategy
  - start with medium res from 4m
  - move to high res from 8m
    - optical fro precision RV
    - IR to resolve both sets of lines

ONC 1-295



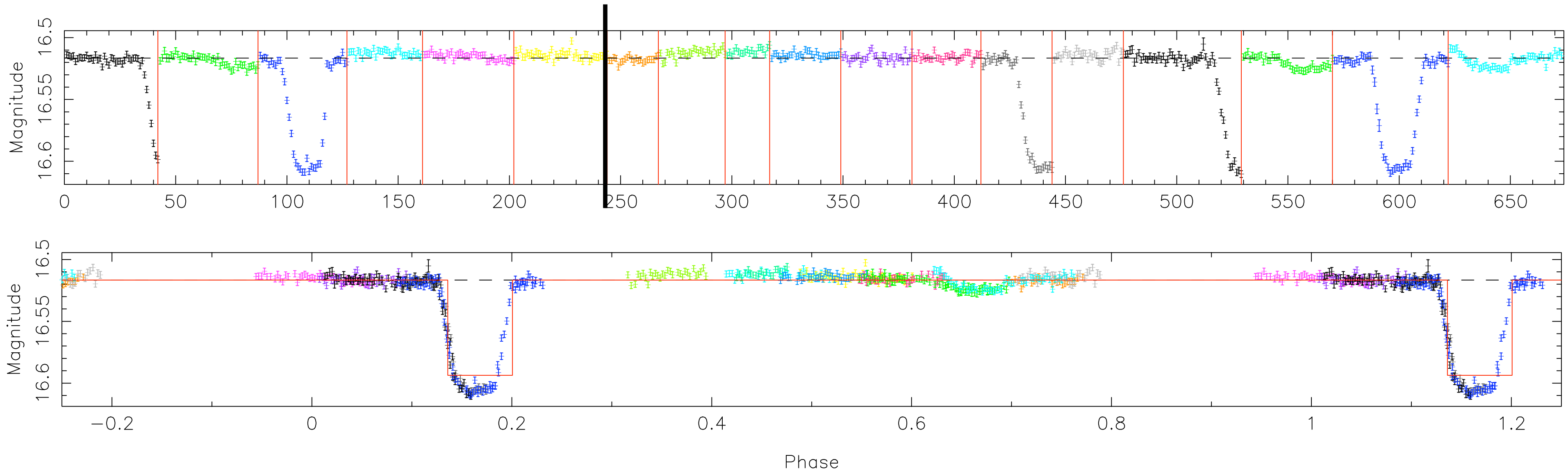
- bright (I=12.65), likely member (proper motion, Hillenbrand 1997), M2V, M~0.2$M_\odot$
- 3 partial primary eclipses + 1 partial primary eclipse in 2004B INT data + 2006A NMSU 1m data (courtesy J. Holzman)
- sine fit to remove out-of-eclipse variations (rotational modulation, p=0.78d)
- double trapeze fit: period=4.674d, depths=13.8% & 8.4%
- spectroscopy (WHT+ISIS, Magellan+MIKE, VLT+ISAAC): M4-M5V, RV amplitude > 50km/s (few km/s precision)
- independently discovered by Stassun et al.
- full double-lined orbital solution + multi-band light curve fits to be published soon

ONC 1-290



- likely member (Hillenbrand 1997)
- 5 partial eclipses observed in 2004B INT + 2006A NMSU 1m data
- no detrending applied (variability irregular)
- box fit: period=2.65d, depth=4%
- spectroscopy: M1V, no RV variations at the 3-4km/s level: v low mass
- single high resolution spectrum (courtesy K. Stassun) shows it's an SB2
- more data coming this season

M50 2-3089



- I = 16.41, V=17.64
- 3 partial + 2 full primary eclipses & 1 secondary eclipse in 2005A/B CTIO data
- Secondary eclipse (as well as more primaries) seen in second season
- I = 16.41, V = 17.64, P = 1.350 days, dur = 0.09 days, depths = 9 / 1.5%
- First guess at component masses from relative eclipse depths and apparent magnitudes: $M_1 \sim 0.7\ M_\odot$, $M_2 \sim 0.2\ M_\odot$ (Baraffe et al. 1998, 130 Myr).
- That would lead to K ~ 41 km/s.

What can we say already?

- ONC-1-290
  - $0.15 \leq M_1 \leq 0.25\ M_\odot$
  - $1.6 \leq R_1 \leq 1.8\ R_\odot$ (from T_{eff} & L)
  - $M_2 \leq 0.04\ M_\odot$
  - $0.39 \leq R_2 \leq 0.44\ R_\odot$
- ONC-1-295
  - $0.35 \leq M_1 \leq 0.9\ M_\odot$
  - $2.3 \leq R_1 \leq 2.6\ R_\odot$
  - $M_2 \geq 0.1\ M_\odot$
  - $R_2 \geq 0.7\ R_\odot$
- M50-2-3089
  - $M_1 \sim 0.7\ M_\odot$
  - $R_1 \sim 0.6\ R_\odot$
  - $M_2 \sim 0.2\ M_\odot$
  - $R_2 \sim 0.18\ R_\odot$