Sensitivity analysis of the WFCAM Transit Survey 2

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Sensitivity analysis

- Insert transit signals into real data
  - Includes all the noise, systematics, detection difficulties
  - Monte Carlo approach:
    - pool of flat M dwarf lightcurves
    - drawing system parameters (Ic, period, offset, inclination)
    - calculate transit shape, add to lightcurve

Transit detections

- Expected number of detections:

$$N_{\rm det} = f\, N\, P_{\rm det}$$

- Detection probability:

$$P_{\rm det} = \iint P_{\rm r}\, P_{\rm t}\, \frac{{\rm d}^2 p}{{\rm d}\, R_p\, {\rm d}\, P}\, {\rm d}\, R_p\, {\rm d}\, P$$

- Prior assumption:
  - scale invariant, uniform, Kepler best-fit
- We can construct confidence intervals for *f*:

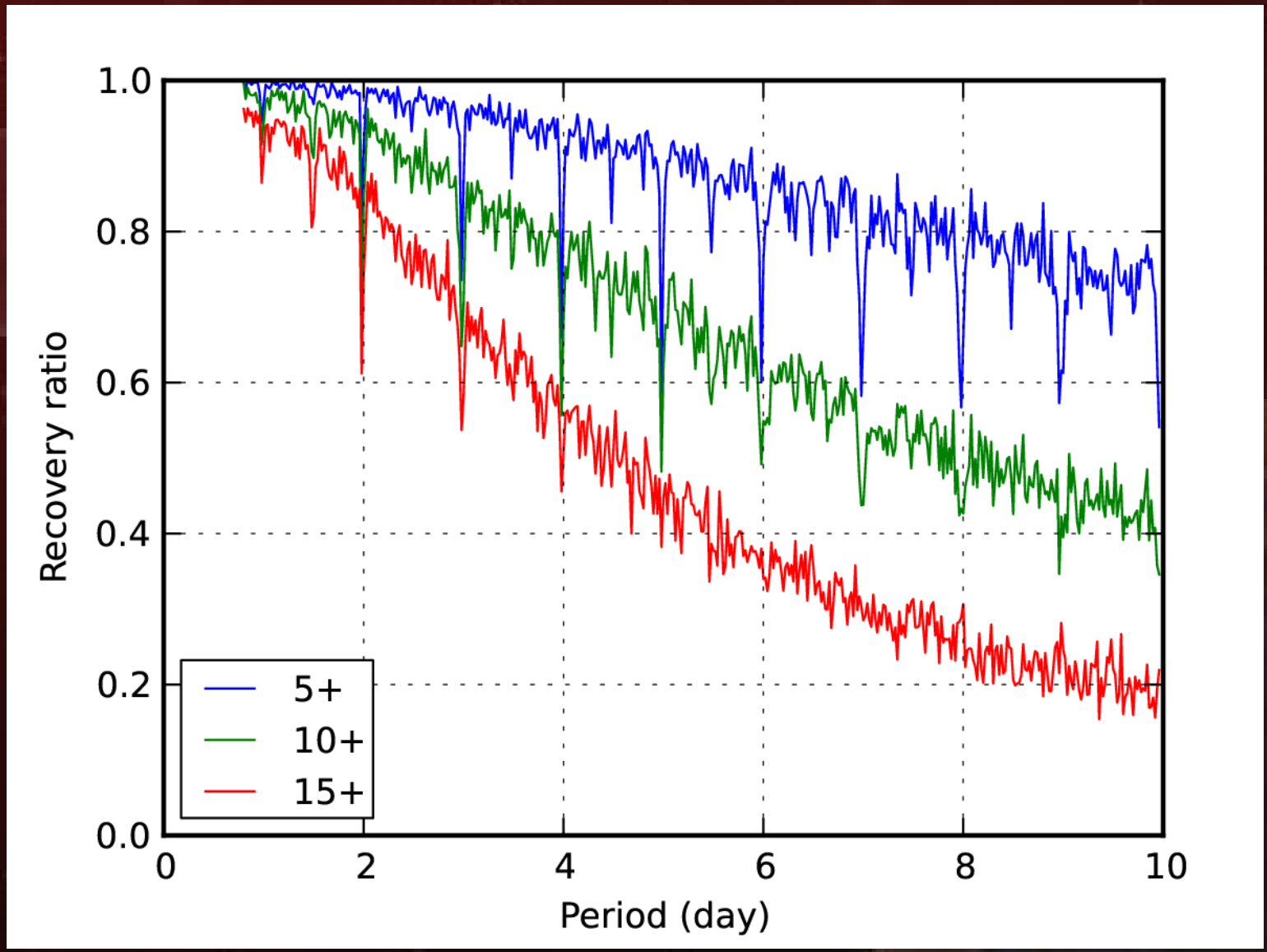
$$0 < f_{95\%} < 3 / (N P_{\rm det})$$

Recovery probability

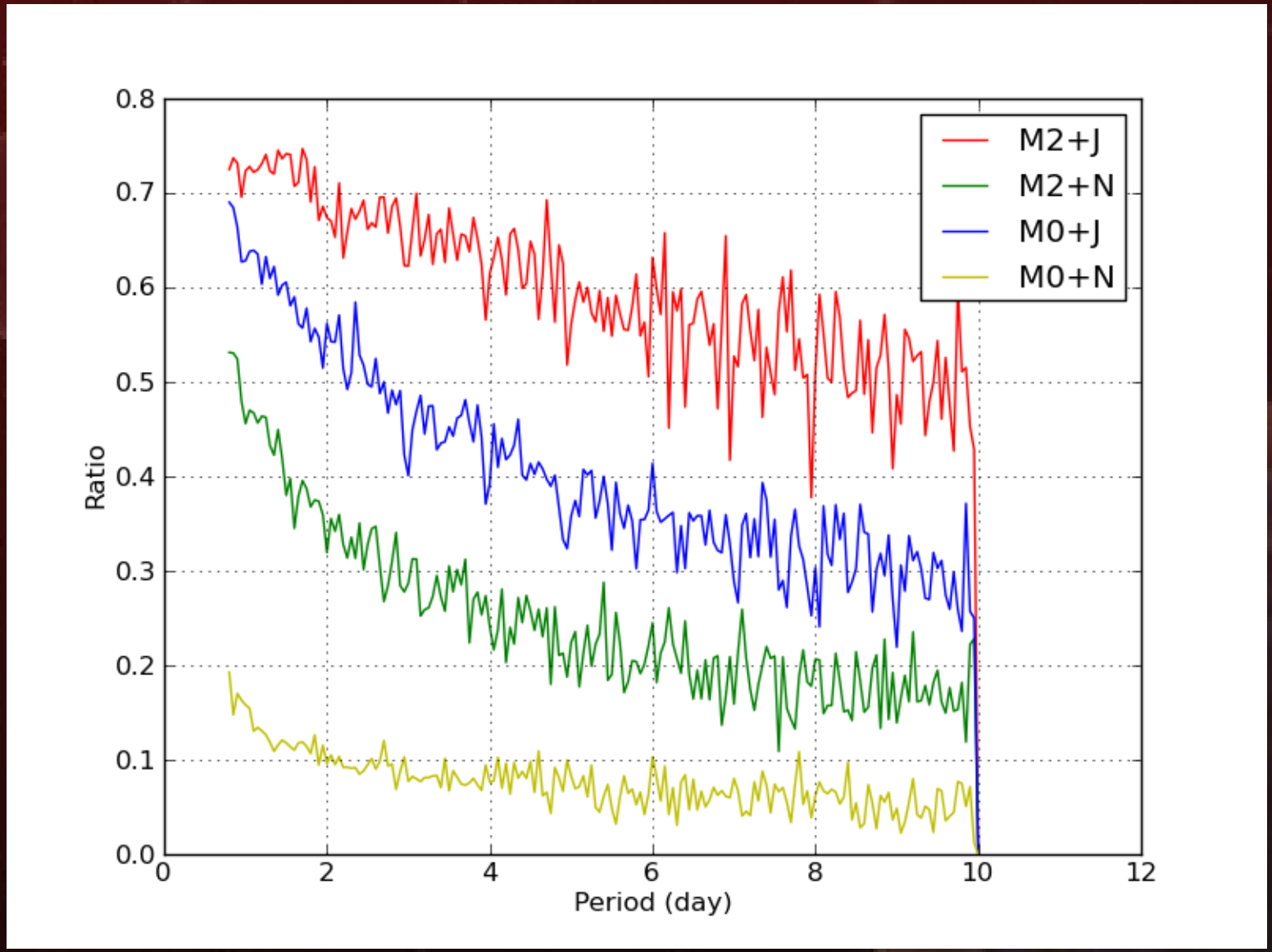
- When is a recovery attempt successful?
  - In transit data points (5,10,15)
  - S/N: detection threshold

- Detection algorithm/statistics:
  - optimistic: all our S/N positive detections are finally recovered
  - pessimistic: we need to get the period right. Quality of detections.

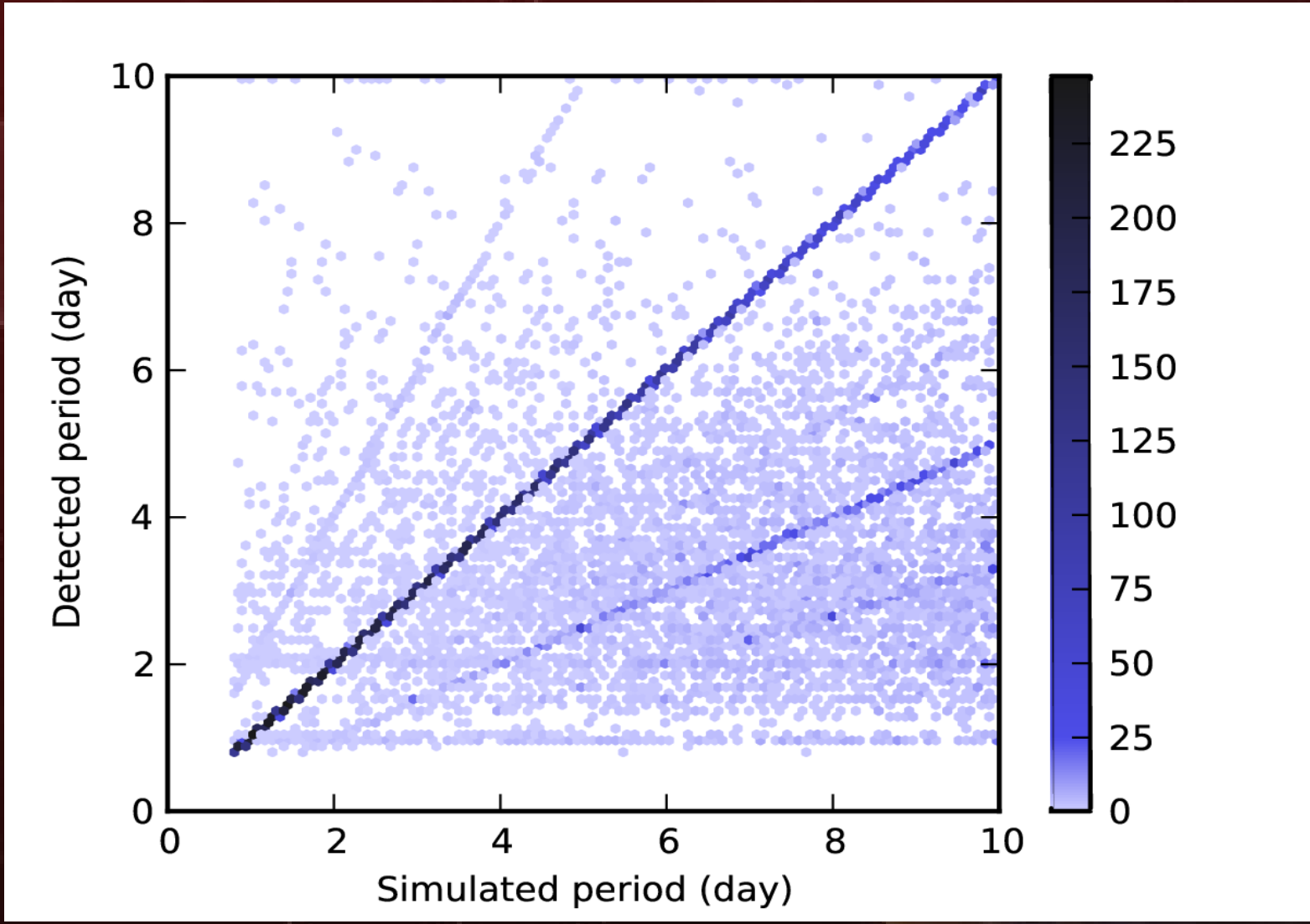
Effect of observation strategy



S/N threshold



Quality of significant detections



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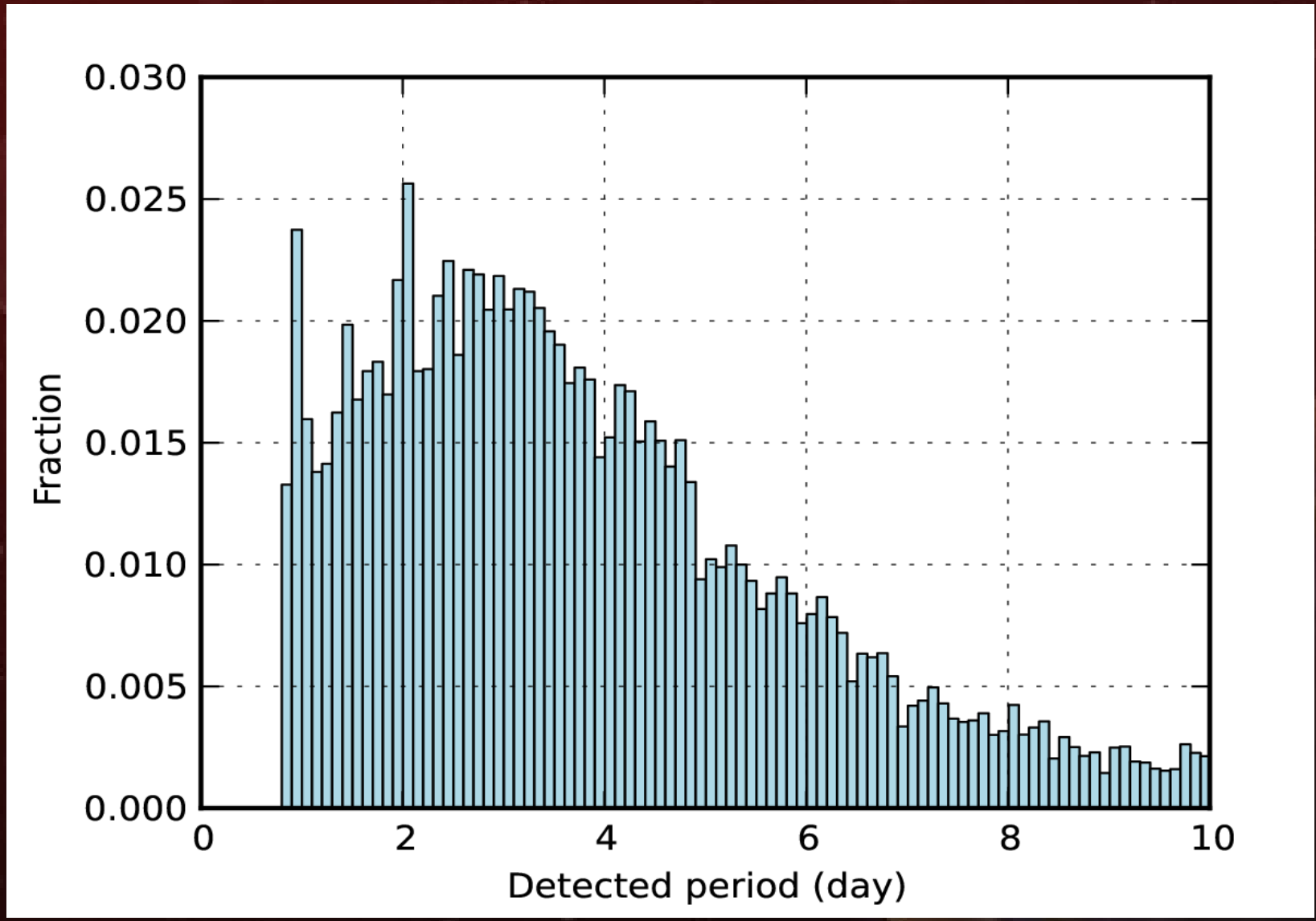

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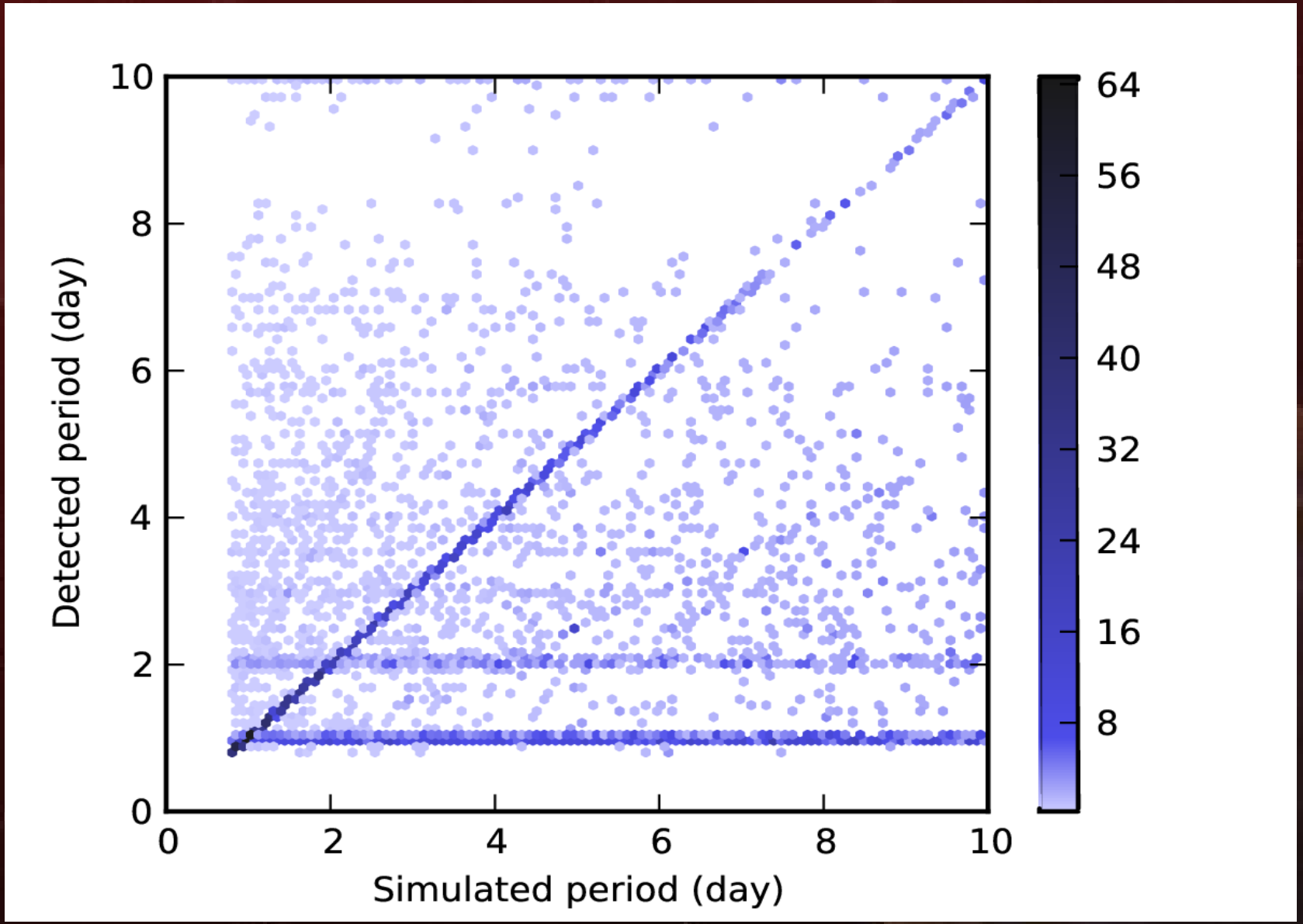

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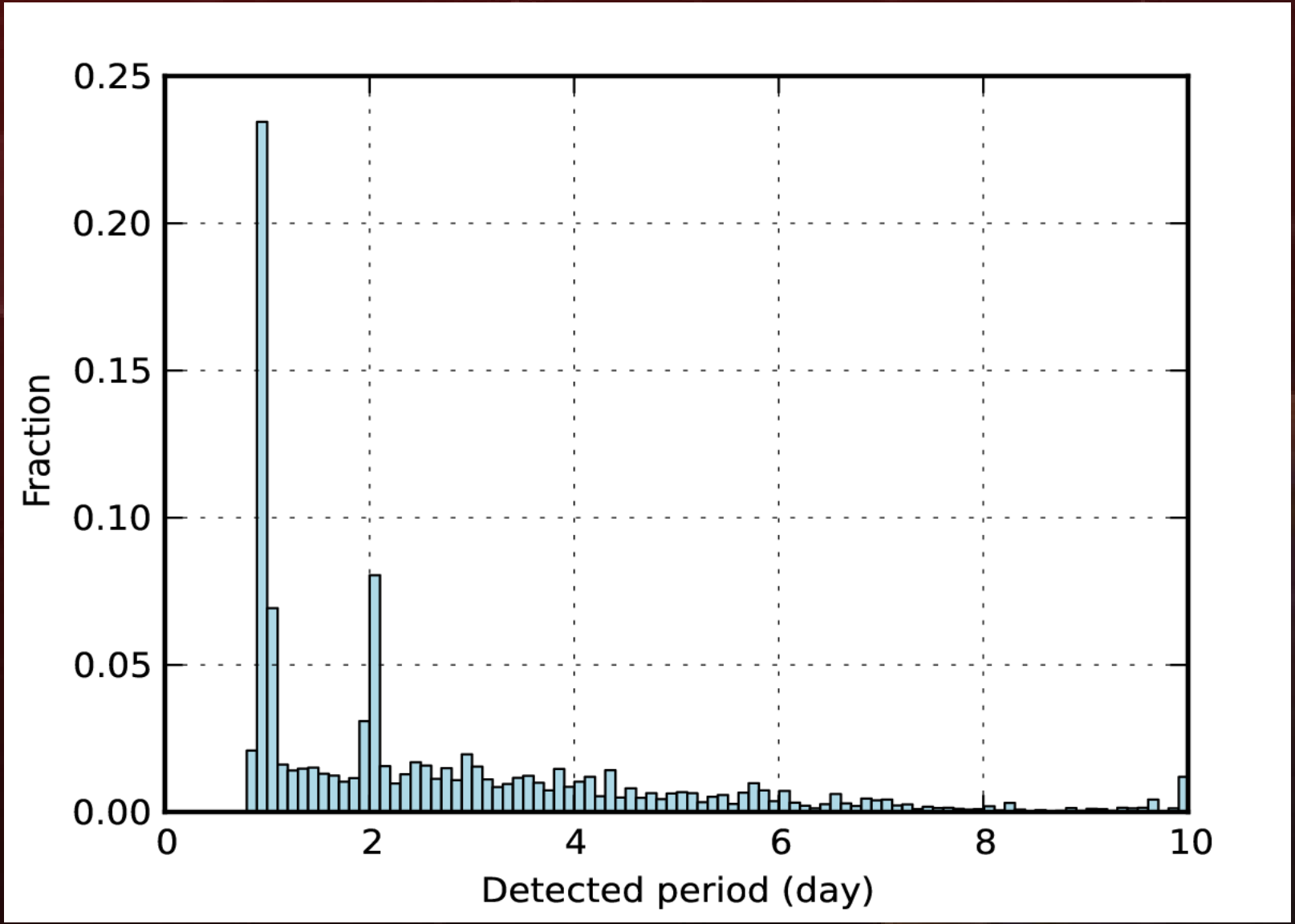
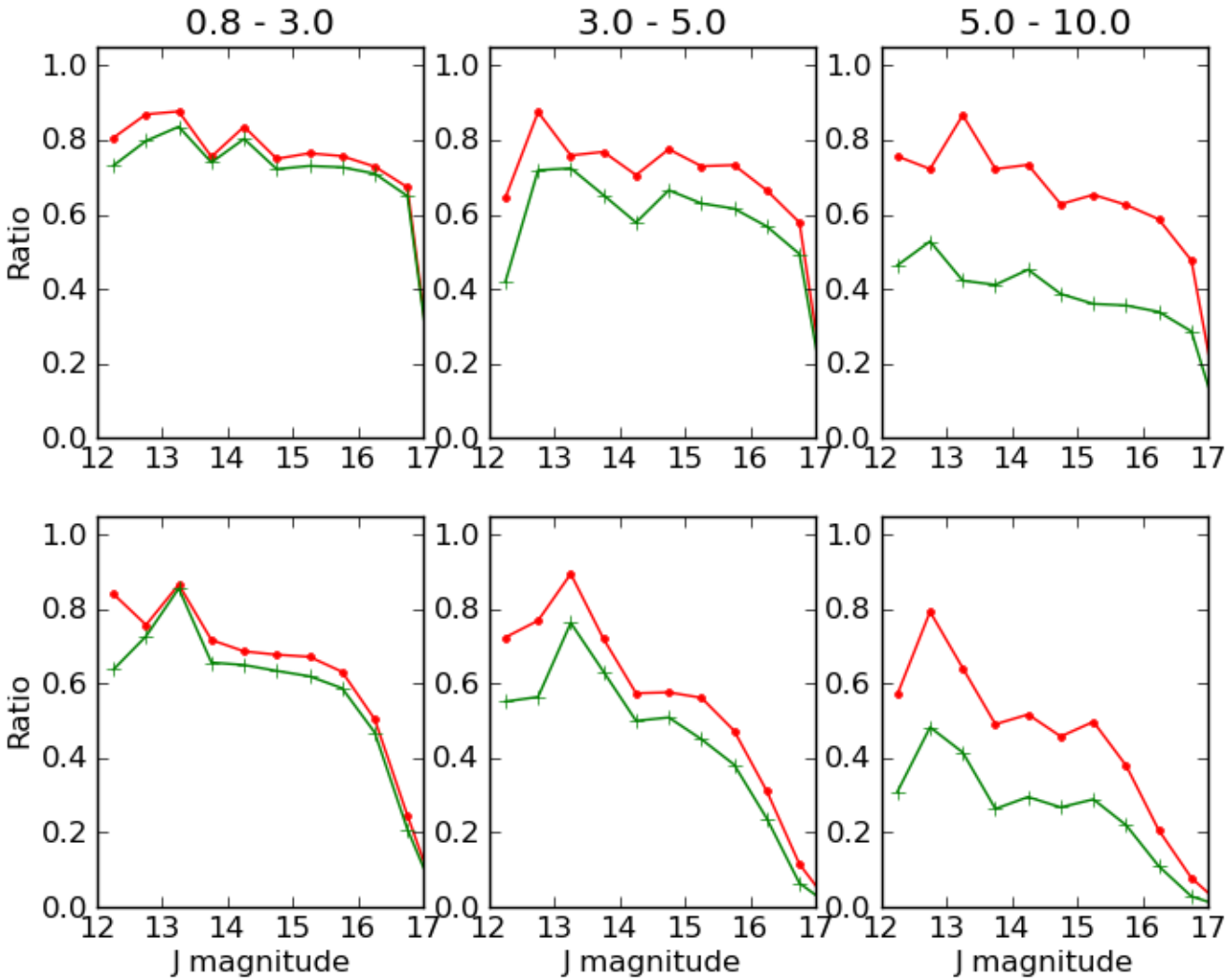


Recovery probabilities

M2 + J

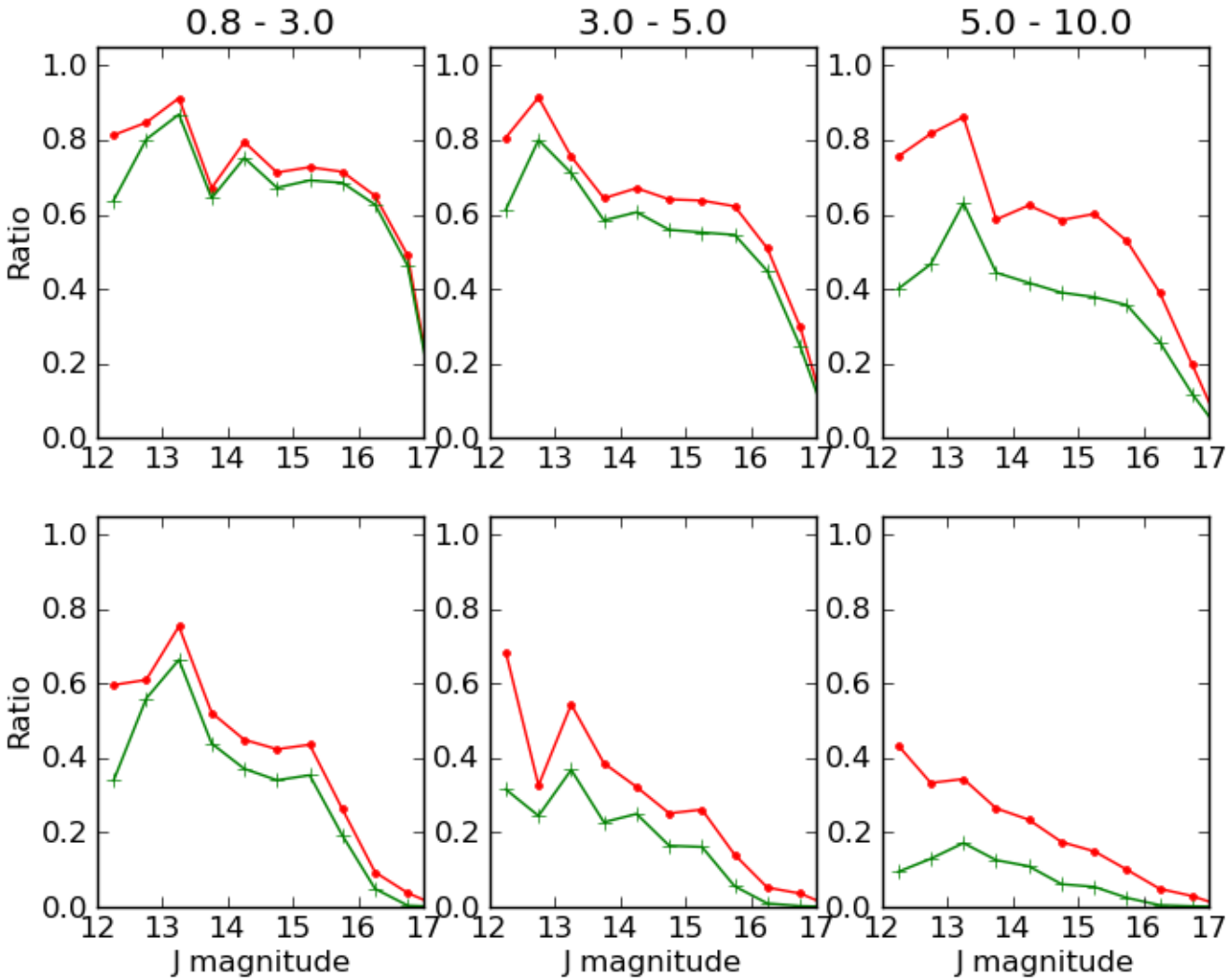
M2 + N



Recovery probabilities

M0 + J

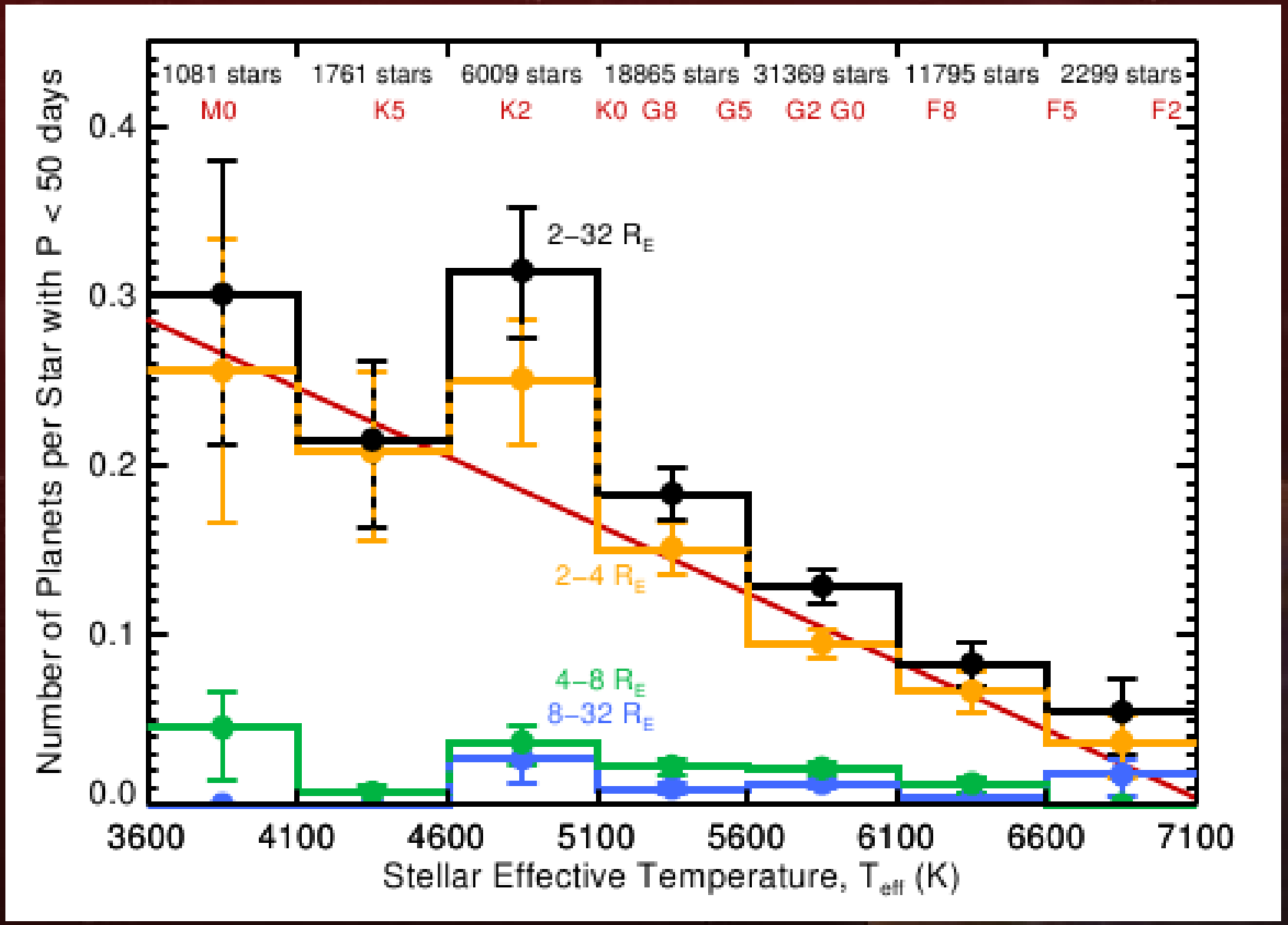
M0 + N



Comparison with a Kepler study

- Howard et. al. arXiv 1103.2541
- Calculates planetary fraction based on Kepler Q2 data release
- Period distribution of different planetary systems for GK stars (prior)
- High quality candidates over high quality stars:

$$f = \frac{\sum_{j=1}^{N_{pl}} 1/P_T}{n_{\text{stars},j}}$$



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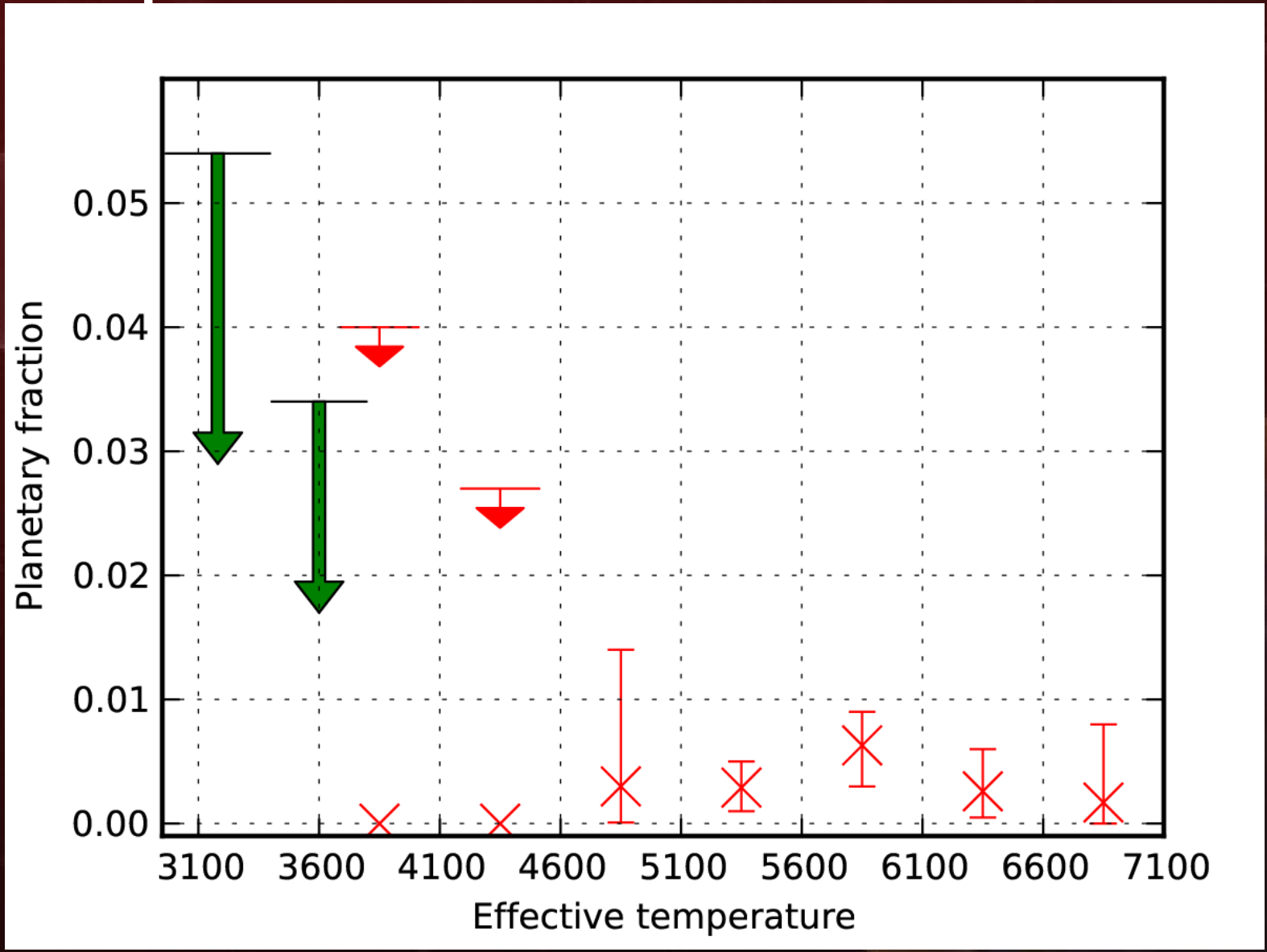
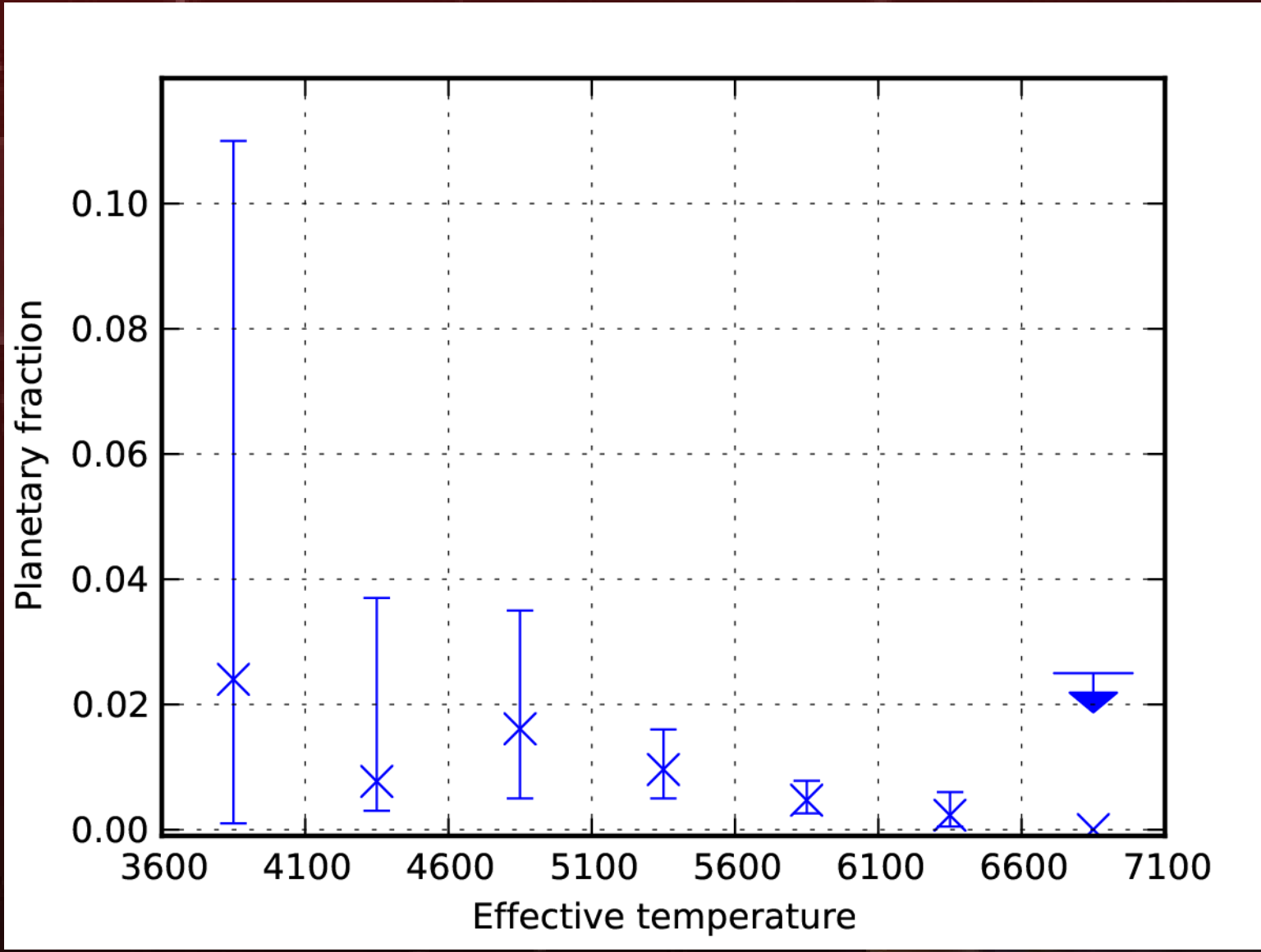
Jupiter occurrence fractions



Neptune occurrence fractions



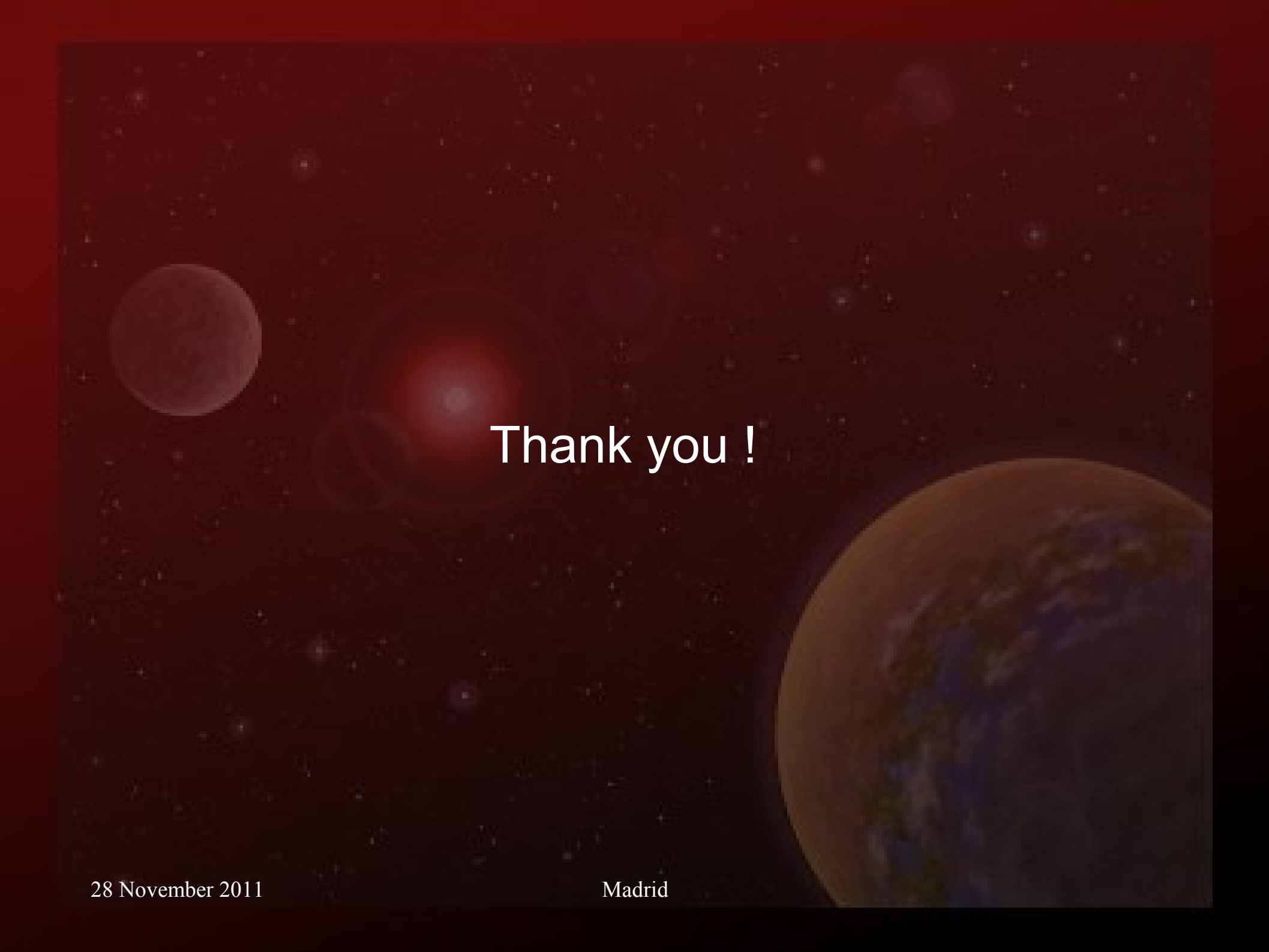
System	N	P_det	f_opt.	P_det.	f_pess
M0+J, 1/P	2844	0.061	2%	0.056	2%
M0+J, uni	2844	0.036	3%	0.031	3%
M0+J, Kep	2844	0.036	3%	0.031	3%
M0+N, 1/P	2844	0.012	9%	0.007	15%
M0+N, uni	2844	0.007	16%	0.003	35%
M0+N, Kep	2844	0.005	21%	0.002	53%
M2+J, 1/P	1679	0.062	3%	0.057	3%
M2+J, uni	1679	0.041	4%	0.033	5%
M2+J, Kep	1679	0.041	4%	0.034	5%
M2+N, 1/P	1679	0.031	6%	0.027	7%
M2+N, uni	1679	0.017	11%	0.014	13%
M2+N, Kep	1679	0.013	14%	0.009	20%

Number of Neptunes in WTS

System	0.001	0.024	0.11
M0	0.03	0.82	3.75
M2	0.05	1.20	5.72
Total	0.08	2.02	9.47
M0	0.01	0.14	0.63
M2	0.02	0.36	1.66
Total	0.03	0.50	2.29

Conclusions

- Sensitivity for Jupiters is robust, does not depend on prior, high quality detections.
- Jupiter constraint may be better than of other survey's, not restrictive enough for planet formation.
- Sensitivity for Neptunes depends on assumptions. Upper limit for null-detection are not restrictive. Expected number of Neptune detections is uncertain.


Thank you !

Field of view: 1.6 sq deg per field
Exposure: 10s
Cadence: 16min

M dwarfs J=16: 6000

exoplanets.org
exoplanet.eu

All: 540 planets,
Transiting: 118 planetary systems
M0_2 3400.0, 'Tul': 3800.0,
M2_4 'Tll': 2960.0 , 'Tul': 3400.0,
M4_9 'Tll': 1800.0, 'Tul': 2960.0,

False positives

- Detection statistic pass when no physical signal exists (or too weak)
  - fluctuations
  - systematics (1 day alias)
- Eclipsing binaries, variable stars
  - Mimic transit signal
- Selection criteria:
  - controls our follow-up needs, eyeballing burden

False positives 2

- In the simulation: No false positive
  - tells what we miss
- for false positive considerations:
  - we can use “external information”: good selection criteria should select the same systems as comparing detection to simulated parameters
  - our “pessimistic” approach uses simulated information: detection statistic looses the signal where different from optimistic

Release 3.0 notes

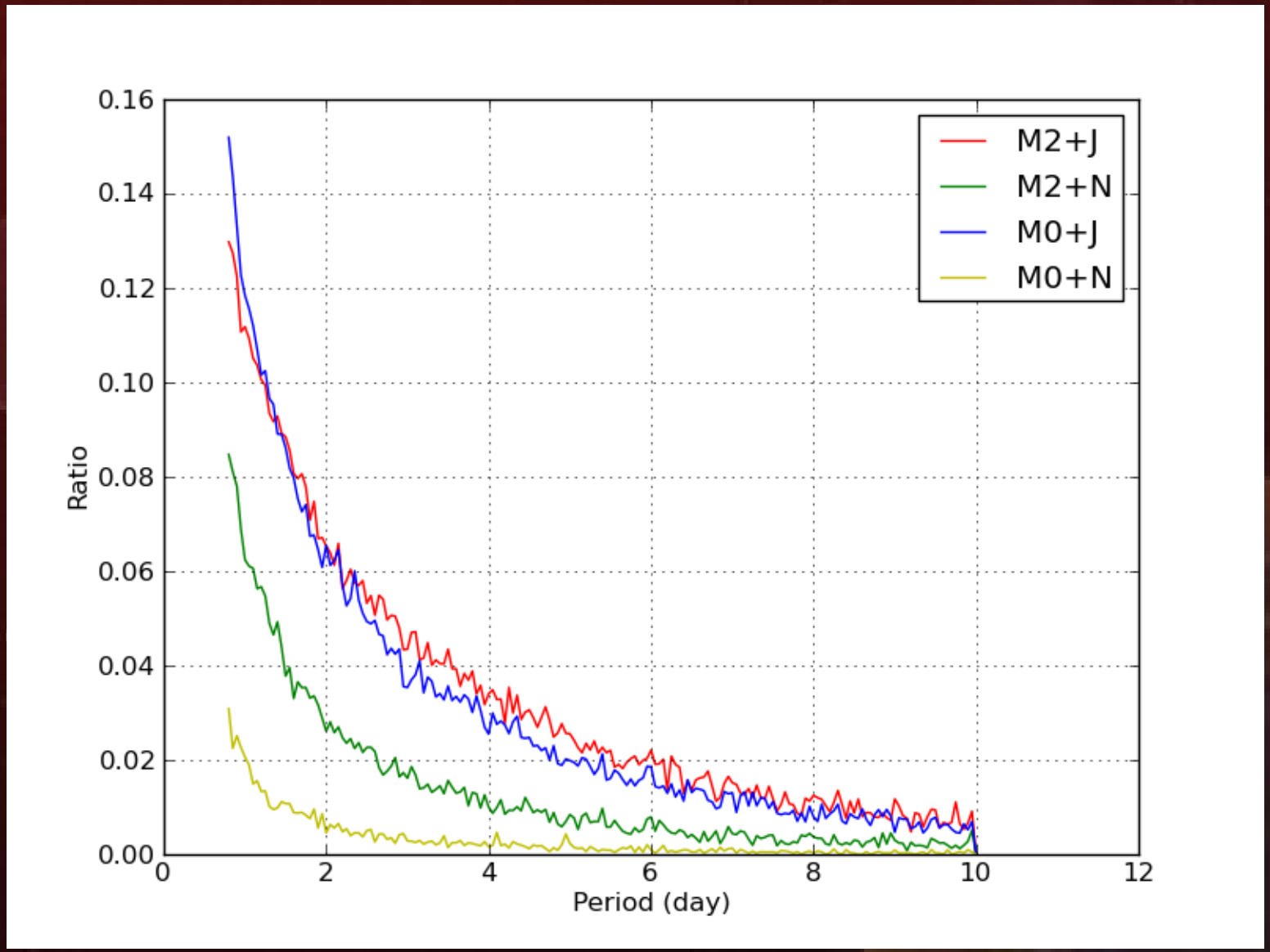
- Lightcurves generated in the same way
  - same catalogue, 3sigma filtering, seeing correction
  - crossed 2G limit: wget, IE, TopCat
  - new per-frame header keywords
- lc: restricted to J< 17, class == -1, all-finite values

Release 3.0 notes 2

- many column bls result file
  - not for humans – reference python script provided
  - 5 peaks in order (SR)
  - best inverse (“minus” - magnitudes) transit period and $\Delta\chi^2$ (negative)
  - 2nd run after best peak model removal
  - phase relative to first epoch in lc (exception: model in periodogram file)
- ascii lc file: includes model removed values after 1st and 2nd run

WFCAM Observation Strategy

- Project on UKIRT telescope
  - UKIRT is operated in queue mode, WTS is a bad weather fallback programme
  - Runs since 2007, till 2012
- Targets low mass stars, J band
  - 4 fields, observed usually at the beginning of nights, some epochs per night
- Long overall time range, few epochs with big gaps, faint objects
  - 03h: 343 07h: 533 17h: 617 19h: 1129


M2+J
M2+N
M0+J
M0+N
Ratio
Period (day)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0
2
4
6
8
10
12