WTS: Hot Jupiters around M dwarfs

A sensitivity analysis

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Outline

- Background: Jupiters around M dwarfs
- WTS: Sensitivity Analysis
- Conclusions

Why giant planets around M dwarfs?

- Core accretion planet formation theories:
  - low mass host → low mass disk
    - time scale considerations
    - migration
    - Laughlin, 2004; Ida & Lin, 2005, 2008; Kennedy 2008; Thommes, 2008
  - predicting the lack / lower frequency of gas giants, lots of Earth + Neptune size planets
- Gravitational instability:
  - giant formation may be as efficient as around more massive stars

(Hot) Jupiter rates (G,K)

Table 2
Hot Jupiter Rate from Previous Works

Work	Rate (per thousand)	Sample
Gould et al. (2006)	$3.1^{+4.3}_{-1.8}$	OGLE-III Transits (90% confidence limits, $P < 5$ d)
Howard et al. (2011)	5 ± 1	Kepler Transits
Marcy et al. (2005)	12 ± 1	Keck, Lick, and AAT RVs
Cumming et al. (2008)	15 ± 6	Keck RVs (entire target list)
Mayor et al. (2011)	8.9 ± 3.6	HARPS and CORALIE RVs
This work	12.0 ± 3.8	Keck and Lick RVs

- F,G,K stars, P< 10 days, Wright, 2012
- Transit rates are systematically lower (2x factor), considered to be real; difference in stellar sample
- Hot Jupiters are rare – detections are biased

WTS Sensitivity Analysis

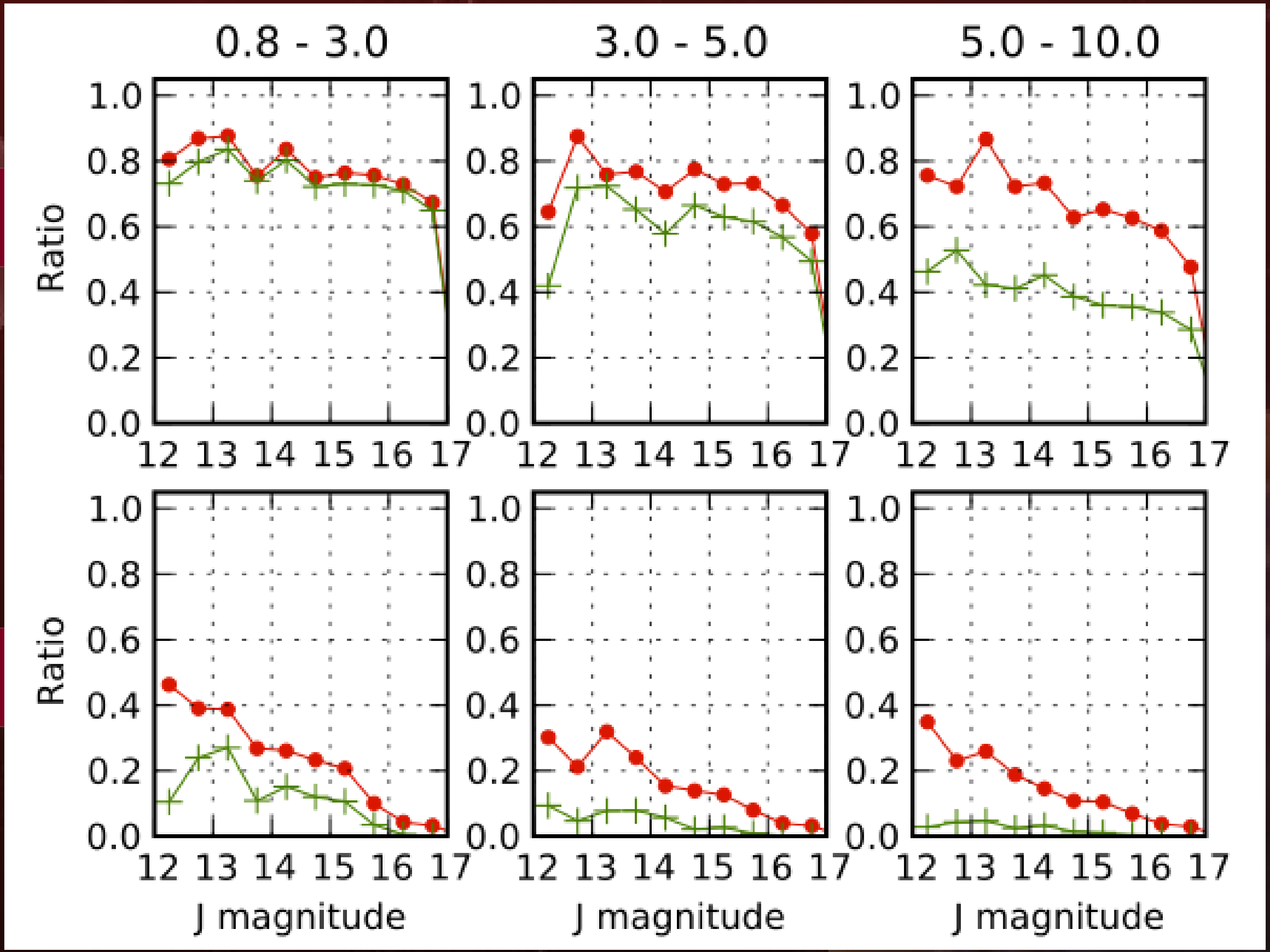
- Determine transit recovery probabilities
  - Fraction of successful BLS detections if every lightcurve has a transiting system

- Insert transit signals into real data
  - Includes all the noise, systematics
  - Monte Carlo approach:
    - Sample of quiet M dwarf lightcurves
    - Drawing system parameters (lc, period, offset, inclination)
    - Calculate transit shape, add to lightcurve

Recovery probabilities

M2 + J

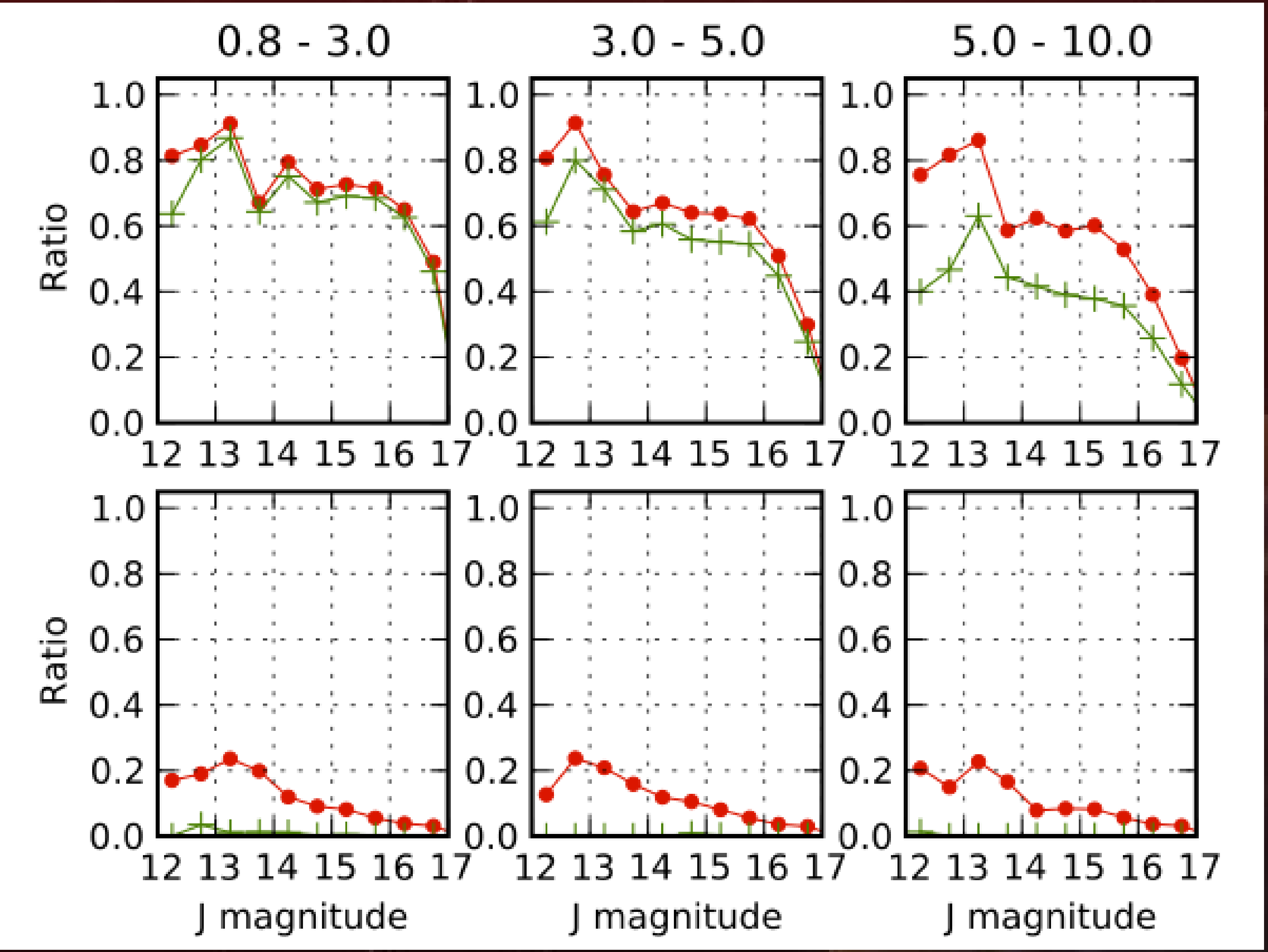
M2 + N



Recovery probabilities

M0 + J

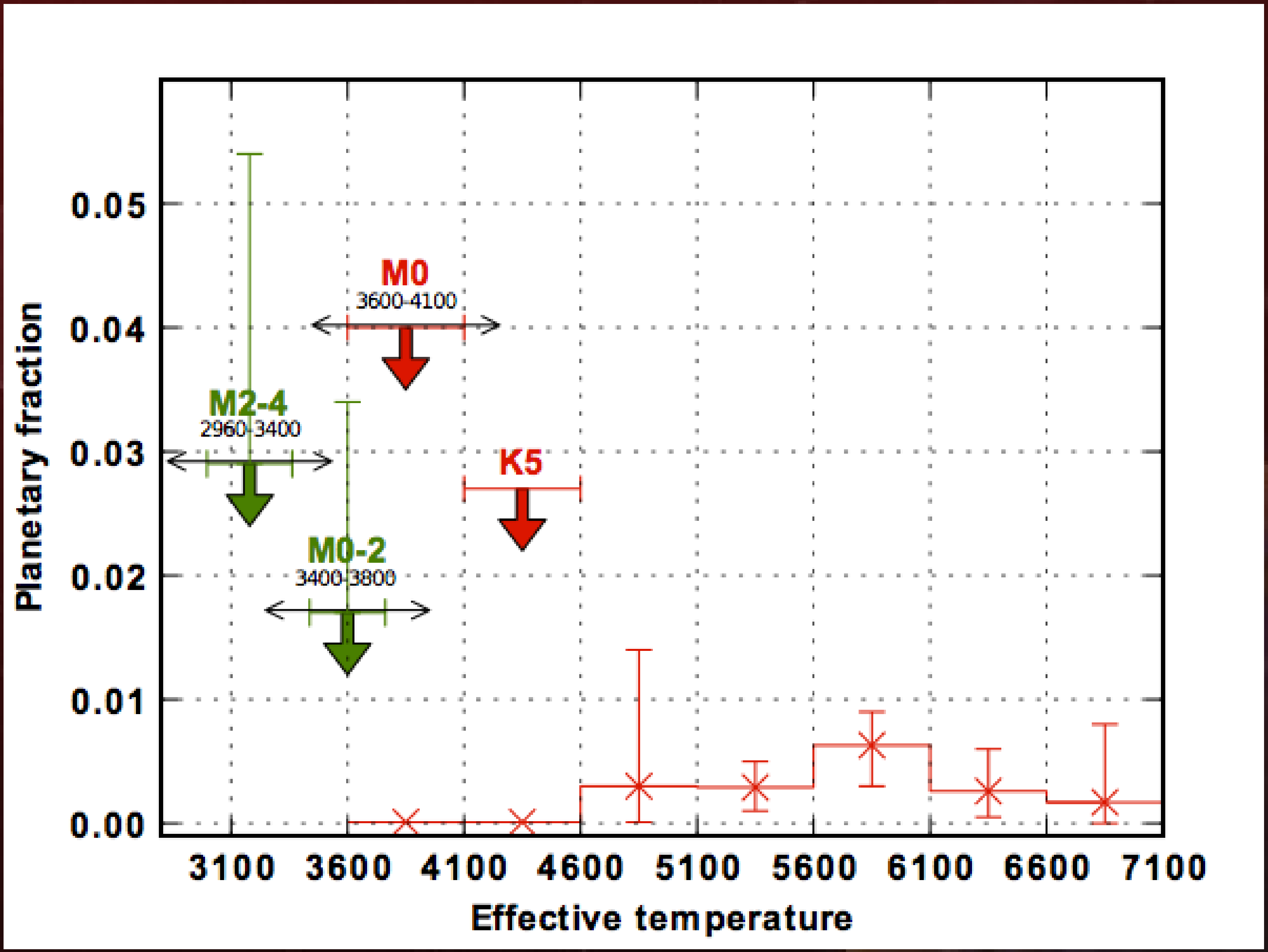
M0 + N



Upper limits

- Recovery probabilities + priors+ geom. factors →
  - Detection probability
- Null detection → statistical upper limit
- Howard, 2012 study: P<10 days sample recalculation

System type	prior	N_{stars}	P_{det} sn	$f_{95\%}$ sn	P_{det} pm	$f_{95\%}$ pm
M0+Jupiter	inv.	2844	0.061	2%	0.056	2%
M0+Jupiter	uni.	2844	0.036	3%	0.031	3%
M0+Jupiter	Kep.	2844	0.036	3%	0.031	3%
M2+Jupiter	inv.	1679	0.062	3%	0.057	3%
M2+Jupiter	uni.	1679	0.041	4%	0.033	5%
M2+Jupiter	Kep.	1679	0.041	4%	0.034	5%
M0+Neptune	inv.	2844	0.0044	24%	0.0001	100%
M0+Neptune	uni.	2844	0.0031	34%	0.0001	100%
M0+Neptune	Kep.	2844	0.0027	39%	0.0001	100%
M2+Neptune	inv.	1679	0.0052	34%	0.0016	100%
M2+Neptune	uni.	1679	0.0032	56%	0.0006	100%
M2+Neptune	Kep.	1679	0.0025	71%	0.0003	100%


Planetary fraction
0.05
0.04
0.03
0.02
0.01
0.00
M0
3600-4100
M2-4
2960-3400
K5
M0-2
3400-3800
3100
3600
4100
4600
5100
5600
6100
6600
7100
Effective temperature

(Hot) Jupiter rates (M)

- P years:
  - (Johnson,2007) 1.8% : smaller than around G,K (4.2%, 8.9%)
  - Microlensing (Gould,2010): rescaling compatible relation with RV (Cumming,2008)

- P<10 days (hot), null detections, upper limits
  - (Bonfils, 2011): 2% (95%)
  - Kepler, based on (Howard,2012): 4%
  - WTS: 2-3% or 3-5%

Hot Jupiter occurrences

- WTS Hot Jupiter limits agree well with other surveys
  - Slightly better than current Kepler limit
    - + KOI-254: agrees → 1% greater than zero

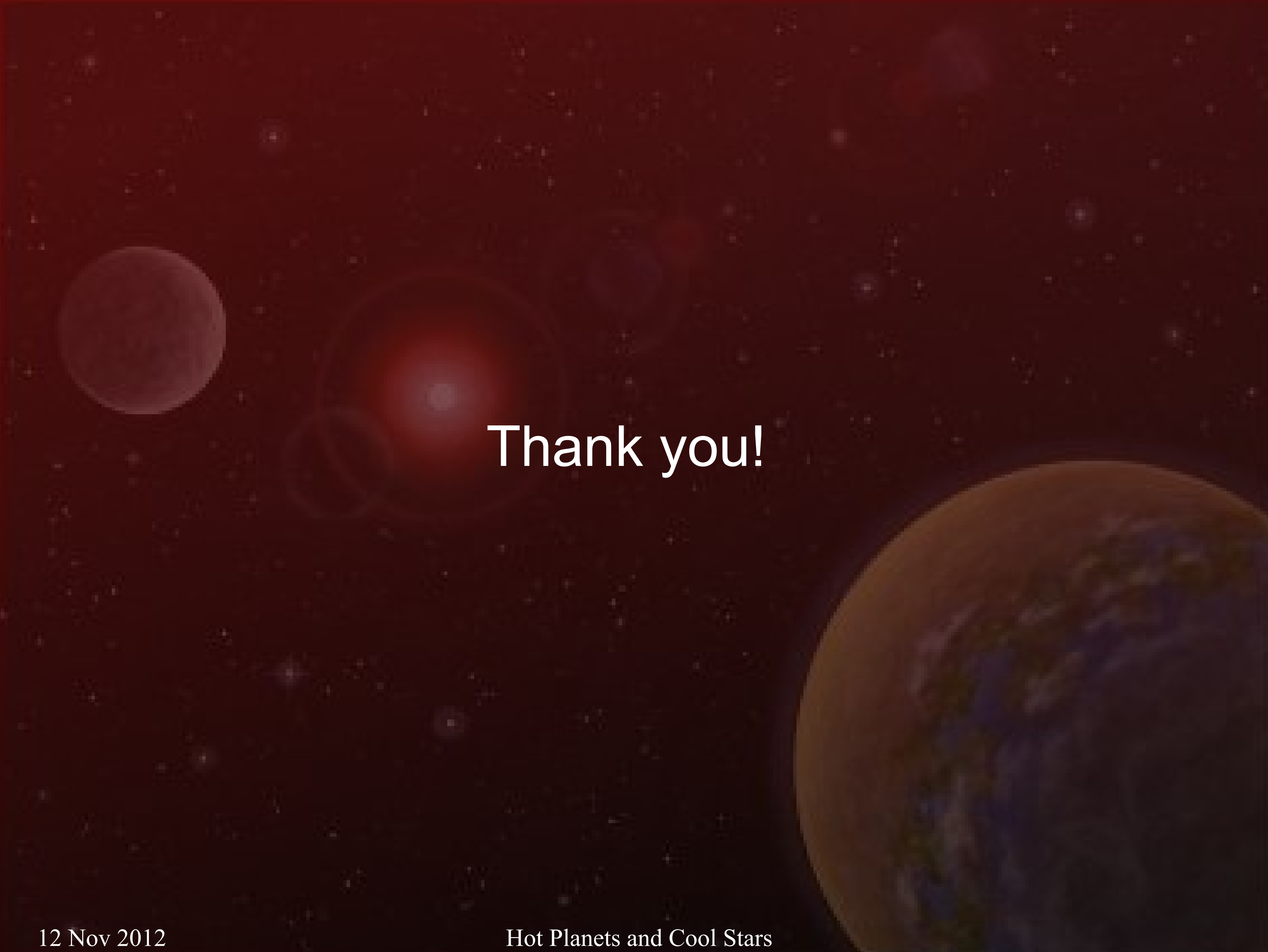
- No observational evidence that hot Jupiters are less common around early-mid M dwarfs

Conclusions (Jupiters)

- Detections: limit is not noise
  - Cadence: 2x factor
- WTS: considerable M dwarf sample
  - 19h: 4600, complete survey: 3x
  - Improvement: more fields
  - Upcoming surveys:
    - PTF, Panplanets, NGTS

Conclusions (Neptunes)

- Beyond the WTS sensitivity
  - Limited by noise in lightcurves
  - Hard to reach 3-4mmag precision in NIR
  - Small sample reaches this level
- Strategy leads to faint candidates to get a large sample
  - Upcoming surveys may do better



Thank you!