Pulsating stars harboring planets

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Synergy

Noise

Characterization

Discovering

Future prospects

Guideline of the review

Why bother with asteroseismology while studying planets?

(Vauclair, S., EAS Publications Series, Volume 41, 2008)

1. Observations are done with the same instruments

SYNERGY

SYNERGY

Paradigmatic case of synergy

Astero → Exop: Most of the content of this talk

Exop → Astero: The presence of exoplanets can change stellar properties

More opportunities for space and ground-based projects

(alone you cannot, with friends… yes, you can!)

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"NOISE"

“NOISE”

Stellar variability (including pulsations) treated as noise by the exoplanet community

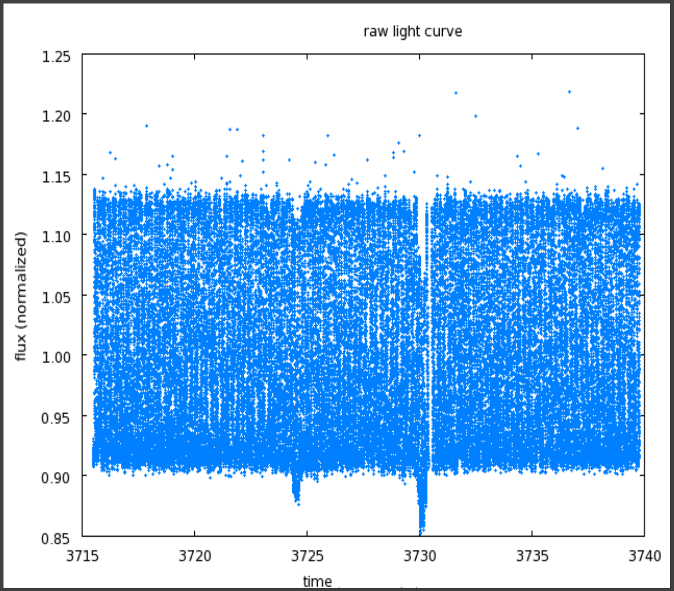
Dumusque, X., A&A, Volume 525, id.A140, 2011

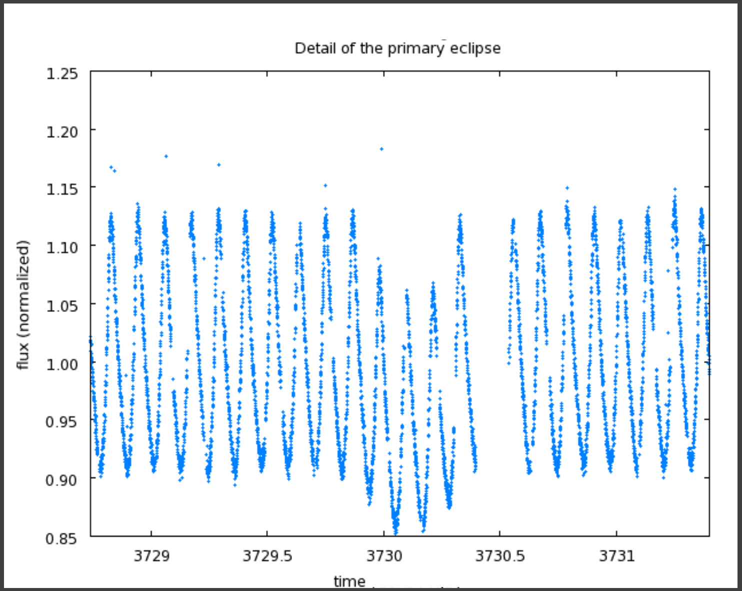
Title: Planetary detection limits taking into account stellar noise. I. Observational strategies to reduce stellar oscillation and granulation effects

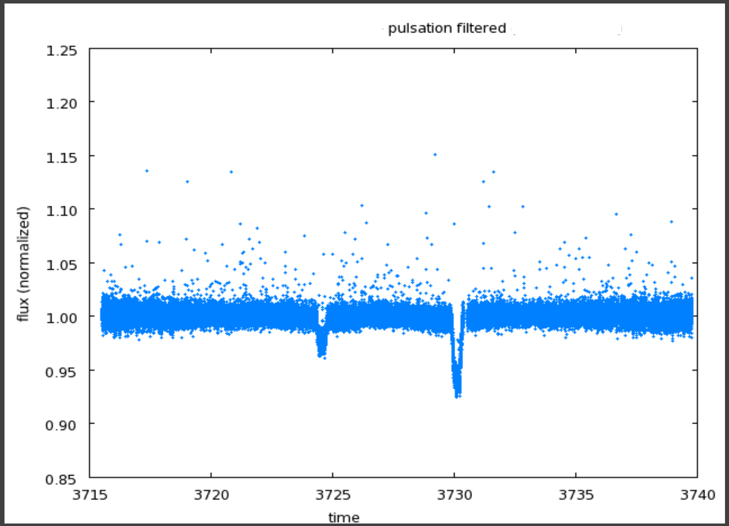
But this noise is information that helps characterize the host star

“NOISE”

The right understanding of pulsations increase the S/N for discovering planets







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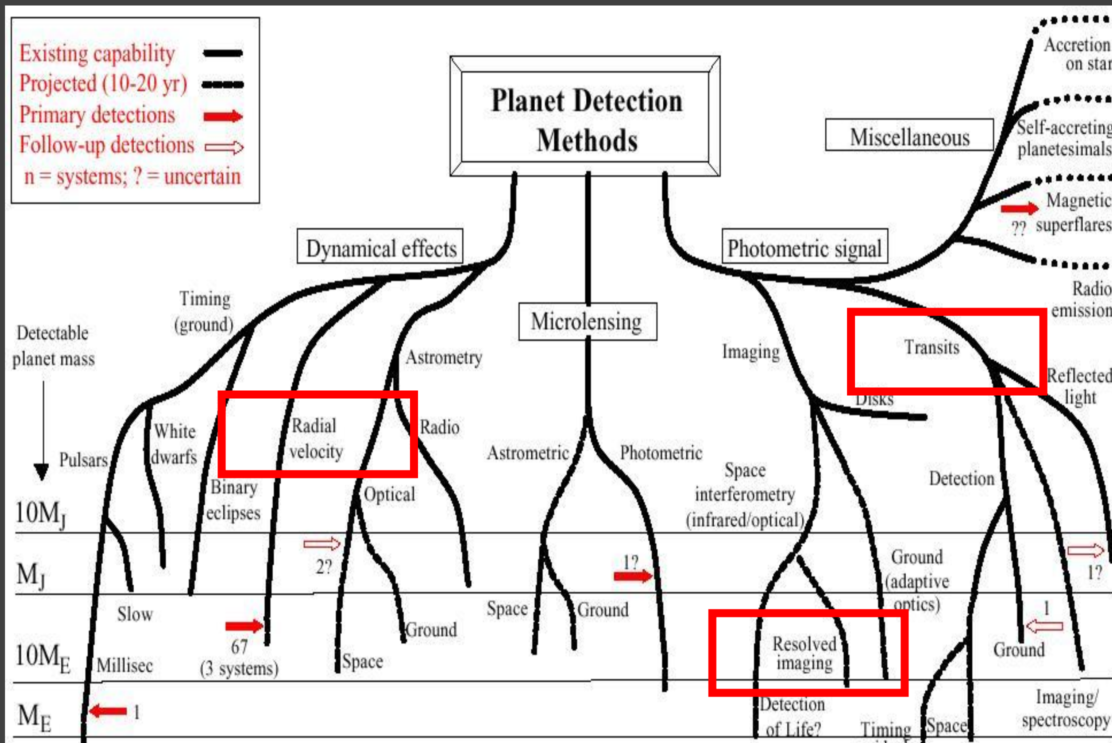
CHARACTERIZATION

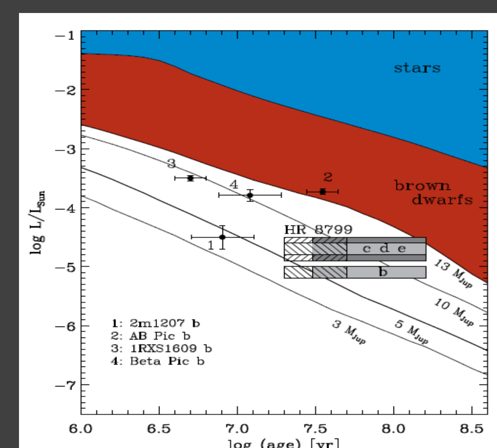
Current situation



Transits

$$\frac{\Delta F}{F} = \left(\frac{R_P}{R_*} \right)^2$$

Direct imaging (age)



Radial Velocity

$$RV = f\left(\frac{M_P}{M_*} \right)$$

Current situation

Homogeneous studies of transiting extrasolar planets. IV. Thirty systems with space-based light curves

Southworth, J., 2011, arXiv:1107.1235

Mean errors

M_*	R_*	ρ_*	Age	M_p	R_p
9,3%	7%	13.7%	150%	10.6%	7.1%

Errors of M_P and R_P dominated by errors of M_* and R_*

From asteroseismology

Precision obtained with Kepler

An uniform asteroseismic analysis of 22 solar-type stars observed with Kepler

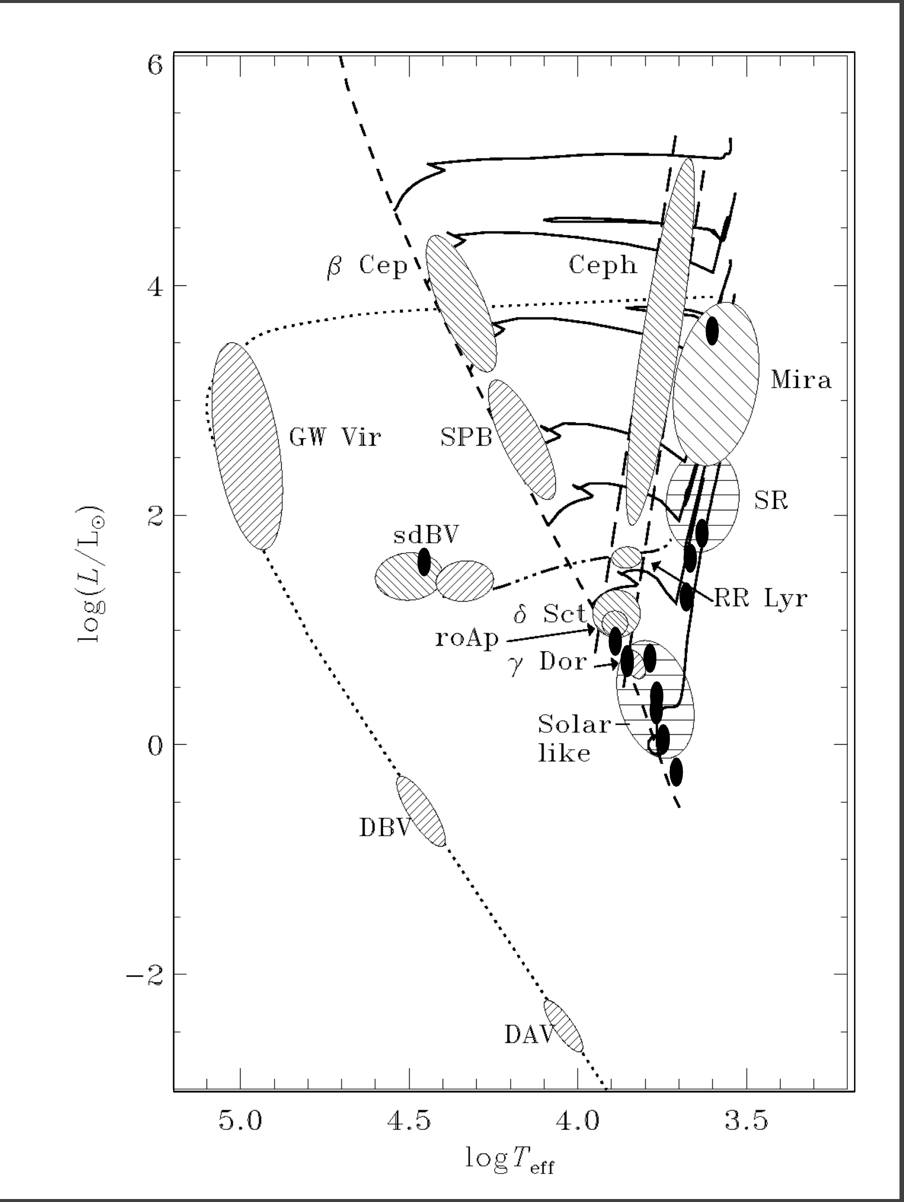
Mathur et al., 2012, A&A, in press

	Individual frequencies not resolved	**Individual frequencies resolved**
Mass	5%	1%
Radius	2%	1%
Age	10%	2.5%

CHARACTERIZING: Real cases

μ Arae: Bouchy et al. 2005; Bazot et al. 2005; Soriano & Vauclair 2008, 2010
i Horologii: Laymand & Vauclair, 2007; Vauclair et al., 2008
HD46375: Gaulme et al. 2010a,b
HAT-P-7: Christensen-Dalsgaard, 2010
TrES-2: Christensen-Dalsgaard, 2010
HAT-P-11: Christensen-Dalsgaard, 2010
HD52265: Soriano et al., 2007, 2008; Ballot et al., 2011
WASP-33: Herrero et al., 2011
HR8799: Zerbi et al., 1999; Moya et al., 2010a,b; Wright et al., 2011
β Pictoris: Koen et al., 2003
HD17156: Nutzman et al., 2010
KIC 9904059: Gilliland et al., 2010
V391 Pegasus: Silvotti et al., 2007
i Draconis: Hatzes & Zechmeister, 2008
HD13189: Hatzes & Zechmeister, 2008
β Geminorum: Hatzes & Zechmeister, 2007, 2008; Hatzes et al., 2006
Kepler-21: Howell, S. B., et al., 2012

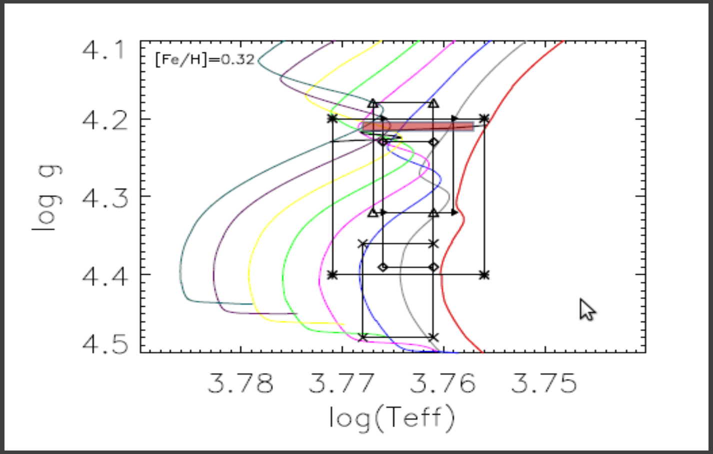
CHARACTERIZING: Real cases

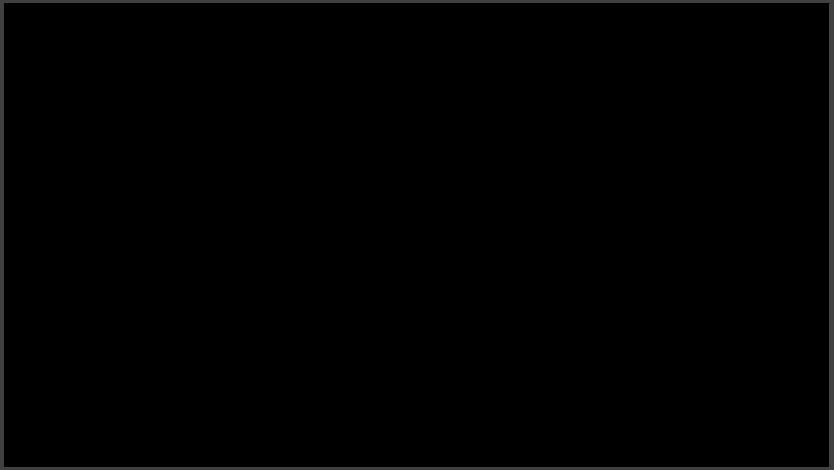


CHARACTERIZING: Real cases

μ Arae

	M_*	Log g	R_*	[Fe/H]	T_{eff}
Without Asteroseismology	4.6%	2.3%	23%	31%	1.7%
With Asteroseismology	1.8%	0.1%	4.4%	6.3%	0.9%



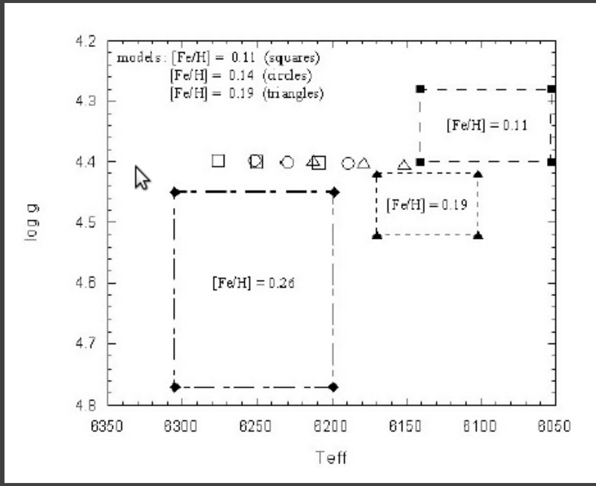


Very precise determination Y=0.30±0.01, Age=6.3±0.8 Gyr

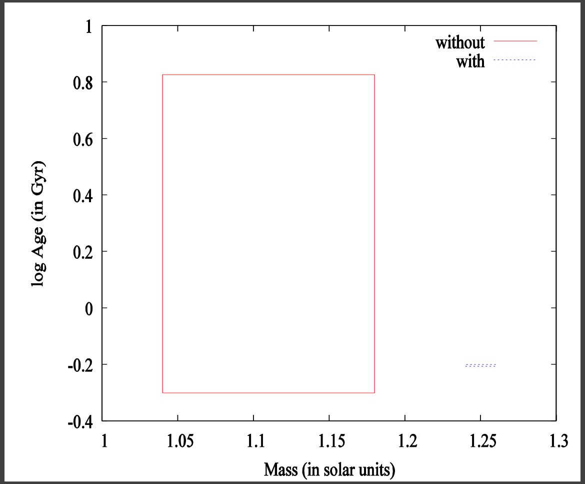
CHARACTERIZING: Real cases

ι Horologii

	M_*	Log g	M_p	[Fe/H]	Age
Without Asterosismology	6.3%	2%	8%	30%	86%
With Asteroseismology	0.8%	0.2%	0.7%	18%	0.8%



New determination mass of the planet: 2.26±0.18 →2.60±0.02



Y=0.255±0.015, Age and Fe/H compatible with Hyades cluster

CHARACTERIZING: Real cases

KIC 9904059

- [redacted]
- [redacted]
- [redacted]
- [redacted]

[redacted] provided a R_*

[redacted]

$\Delta\sigma$ (μHz)	σ_{max}(μHz)	ρ_*(g·cm^{-3})	M_*(M)	R_*(R)	$R_{¿P?}$ (R)
11.77±0.07	143±3	0.0113±0.0001	1.72±0.13	5.99±0.15	0.45+0.11-0.07

The planet is probably a companion star

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DISCOVERING

DISCOVERING: Timing

Timing method: “This method is based on the reflex motion of the parent star due to the companion, which changes periodically the star-observer distance, causing a delay (or advance) on the arrival time of the photons.” Silvotti et al., 2011

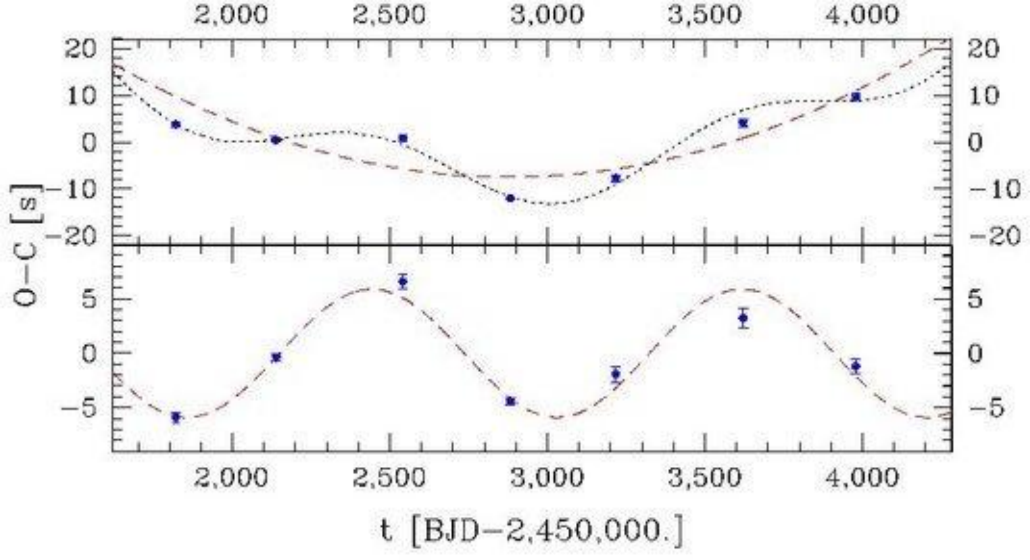
We need a precise astronomical clock:

1) Pulsars
2) EB’s
3) Pulsations

DISCOVERING: Timing

V391 Pegasus

SdB hybrid pulsator



Silvotti et al., 2007

$M_p$sin i [M_J]	a [A.U]	P [Yr]
3.2	1.7	3.2

The evolution of the star can be studied too

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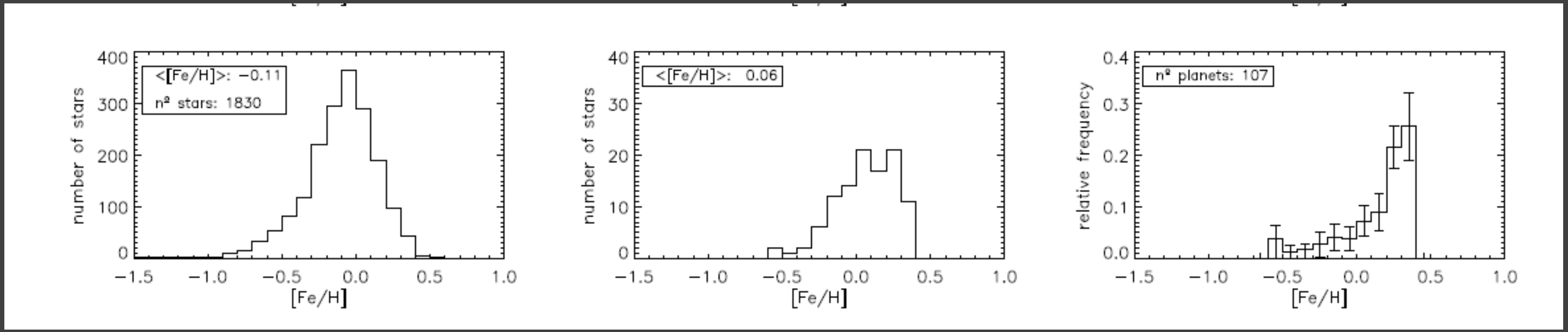
4. Links between asteroseismology and planet discoveries
5. Additional information about different physics (A. Moya)

BONUS TRACKS

BONUS TRACKS: Metallicities

Most of the exoplanet-host star are over-metallic



Sousa et al. 2011

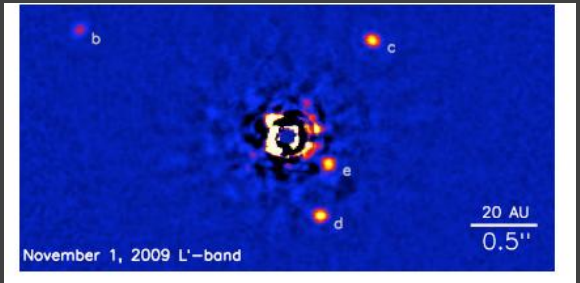
Is this metallicity internal or accreted? Motivation of the first works (μ Arae, i Horo)

BONUS TRACKS: Visual angle “i”

Having “v sin i”, R and the rotation period

LPV can accurately determine “i”

HR8799 (Wright et al. 2011)



Planets and debris disk i ≤ 25º (Su et al., 2009; Reidermeister et al., 2009)

Spectroscopic determination of i_{*}=65±25º (ℓ=1,m=1)

First reported misalignment between i_{*} and i_{debris}

BONUS TRACKS: False positives

Mentioned on Tingley et al., 2011 and Nutzman et al., 2010

Transits and asteroseismology offer independent measurement of the mean density

Star	Ec1	Ec2	Spect	Astroseis
HAT-P-7	0.29±0.06	$0.32^{+0.08}_{-0.07}$	$0.33^{+0.07}_{-0.01}$	0.2712±0.0032
HAT-P-11	3.36±0.78	$3.00^{+0.45}_{-0.10}$	2.69±0.24	2.5127±0.0009
TrES-2	-	1.38±0.07	1.38±0.17	1.3233±0.0027
HD17156	$0.45^{+0.20}_{-0.03}$	$0.50^{+0.16}_{-0.10}$	$0.59^{+0.09}_{-0.11}$	0.5208±0.0040

RVs show HAT-P-7b non-eccentric orbit

FUTURE PROSPECTS

1) Searching for life on other planets.
2) We need to find and study planets orbiting other stars
3) Roadmap already designed: Exoplanet search, accurate characterization of these exoplanets, searching for biomarkers on their atmospheres.

Taken from: An European roadmap for exoplanets (Exoplanet Roadmap Advisory Team, October 2010)

THANK YOU!!!!!!!