# PAVO Follow-Up of Kepler Stars

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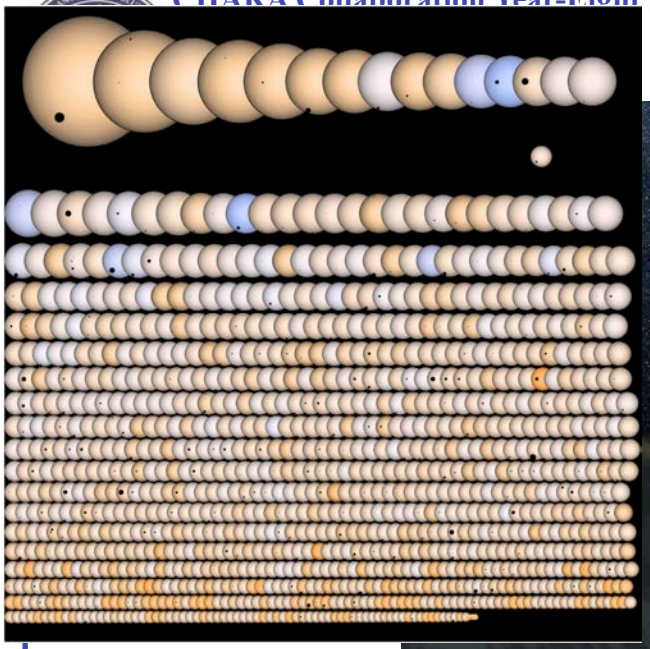
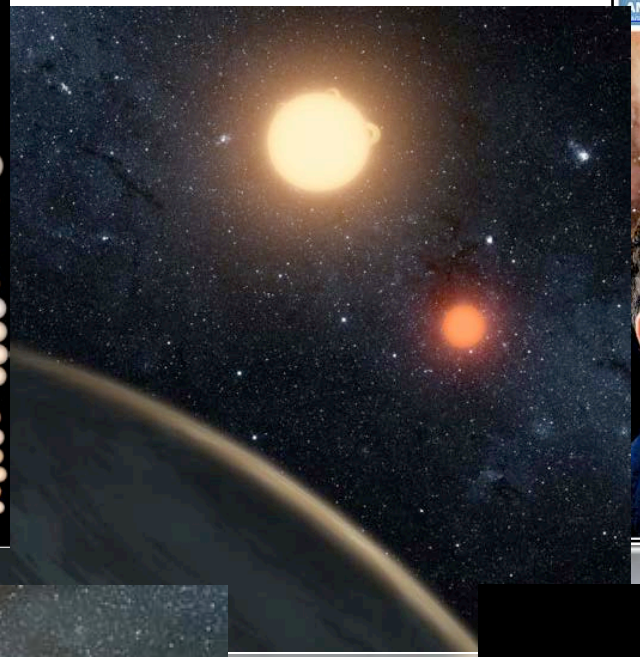
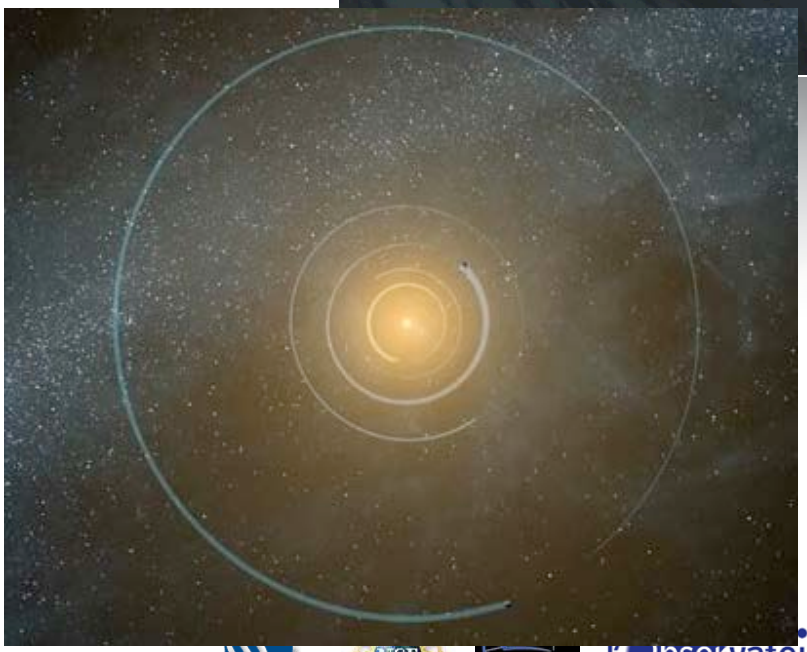
NASA Ames / Sydney Uni

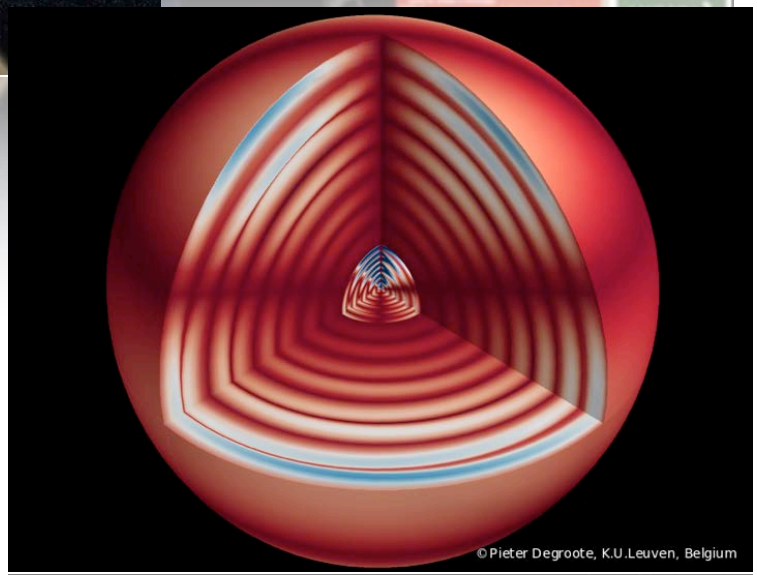
Mike Ireland, Vicente Maestro, Tim White, Tim Bedding, Peter Tuthill and the CHARA team






Inner West Courier
TUESDAY, APRIL 5, 2011
INNER CITY EDITION
$1.20 INCL. GST
Garage Sale Trail
FOLLOW THE PATH TO TREASURES AND BARGAINS
Sport
UNI DECLARED FIRST GRADE CHAMPIONS
Facebook
SIMPLY SEARCH ON "INNER WEST COURIER" FOR NEWS UPDATES AND FUN
UNIVERSAL STARS
Greens create Balmain history
Page 5

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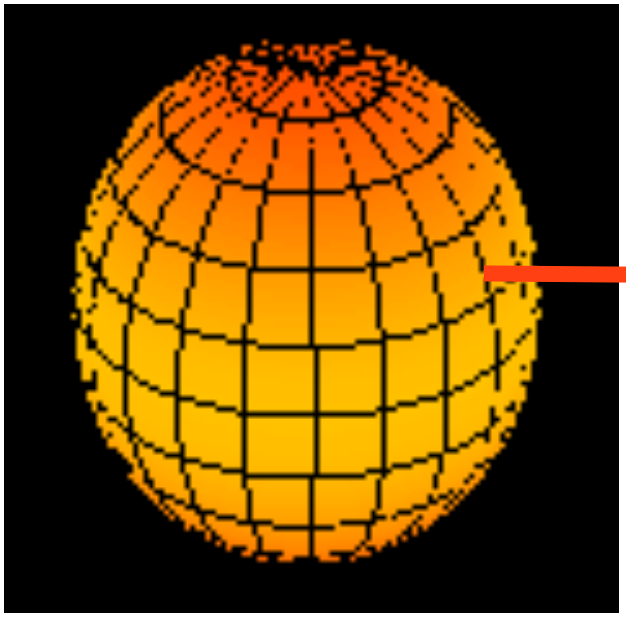
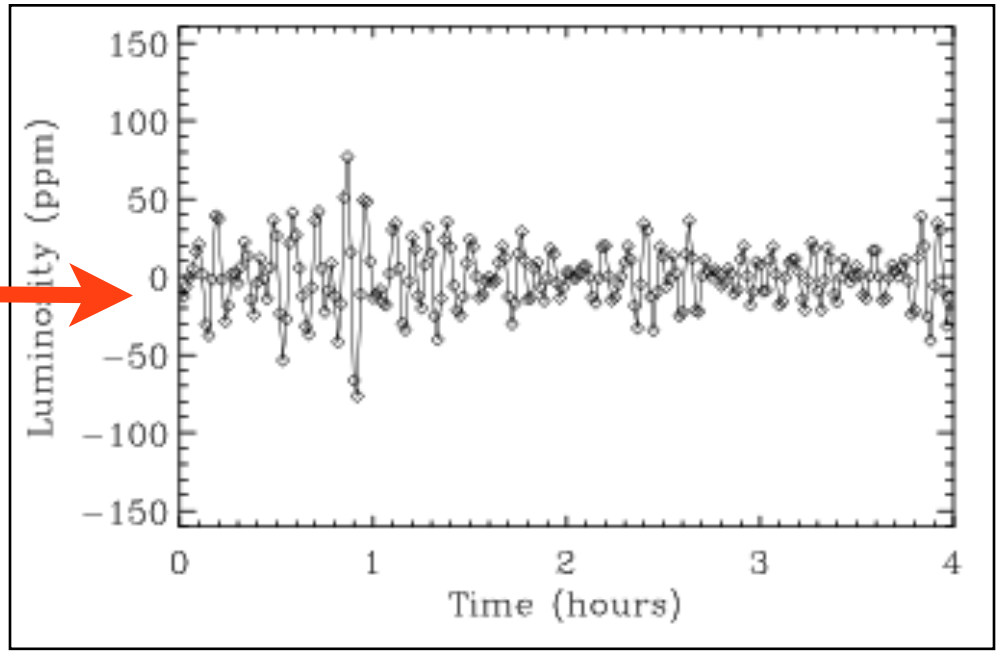
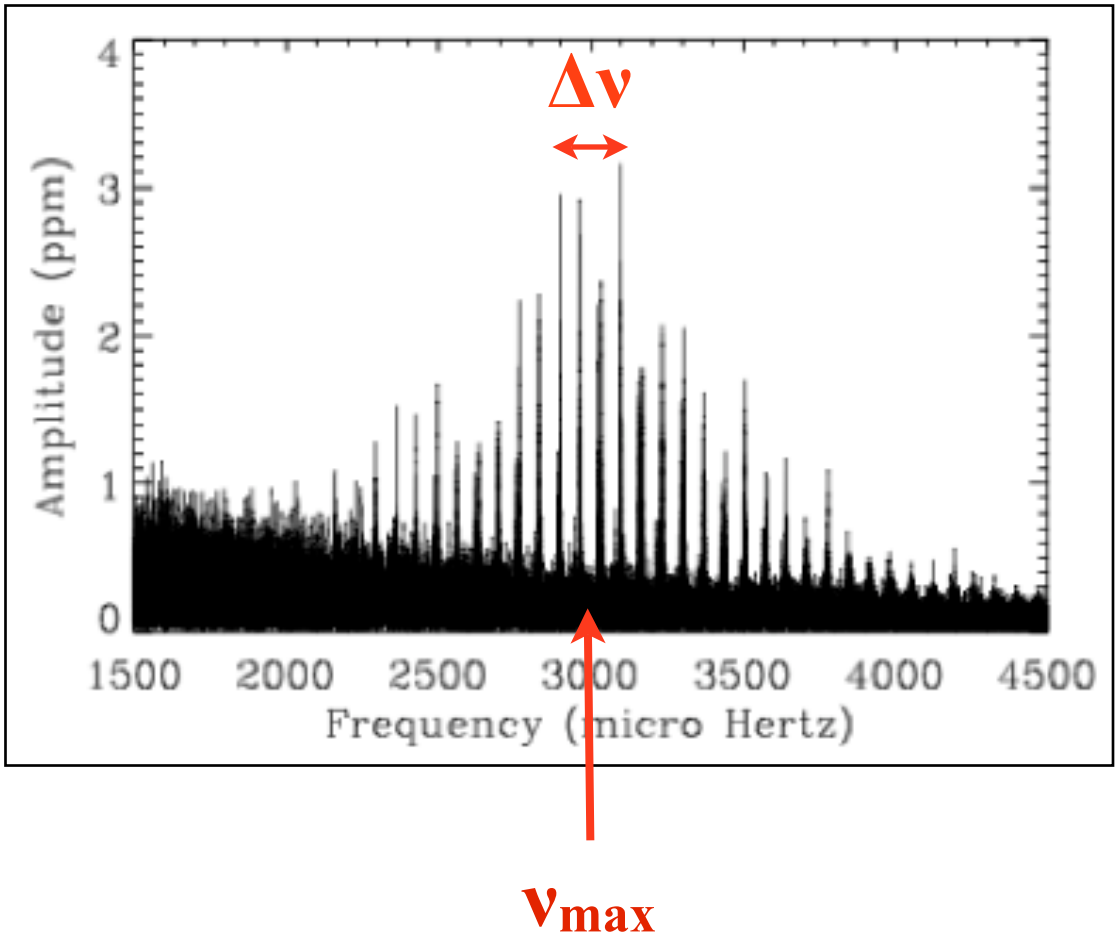
# Asteroseismology





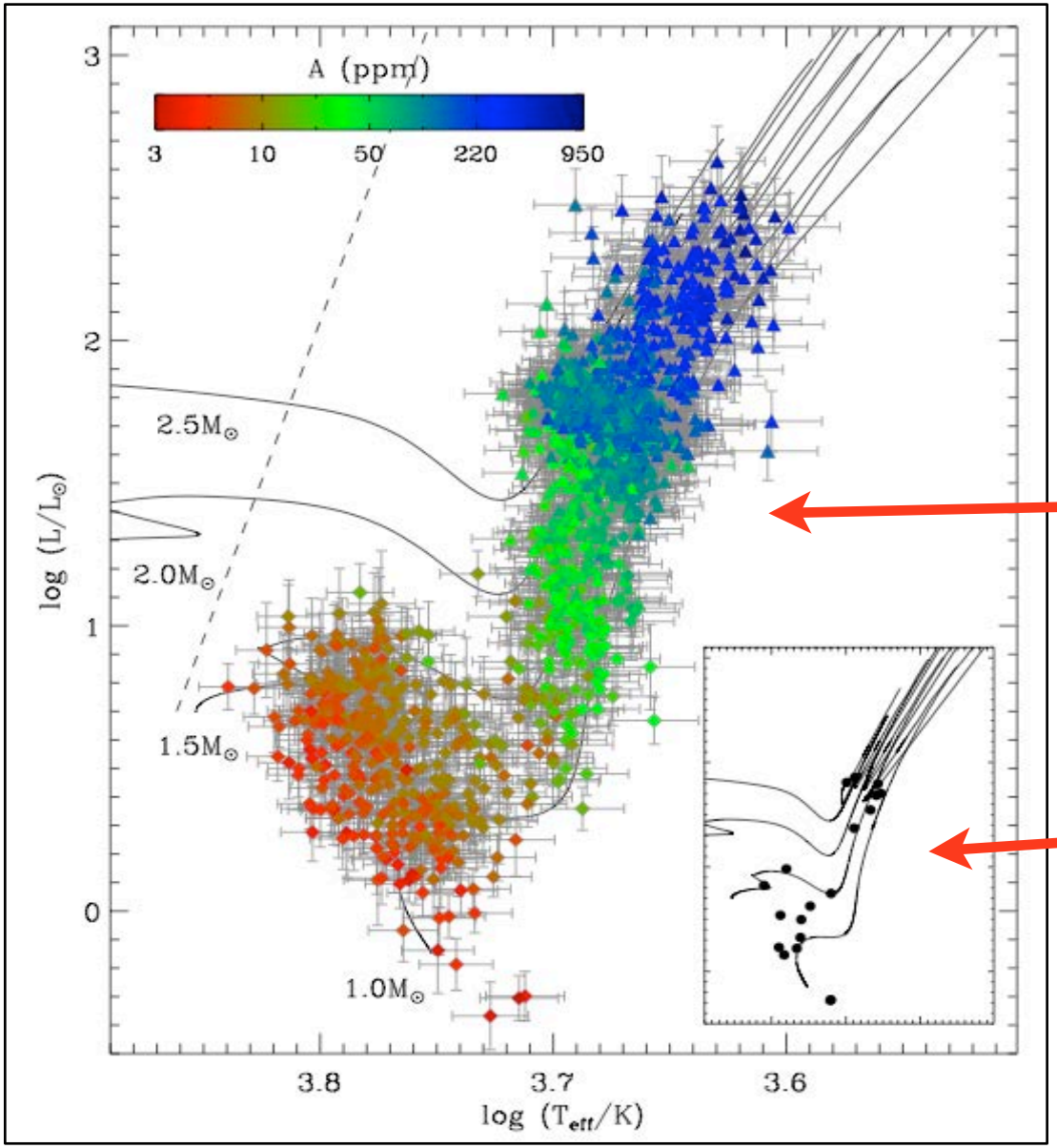

oscillations are standing sound waves excited by surface convection in low-mass stars

# Asteroseismology




**Δν ∝**
M^1/2 R^-3/2
**(mean density)**

**$\nu_{max}$ ∝** g Teff^1/2 ∝
M R^-2 Teff^1/2
**(mostly radius)**




# Known Oscillating Stars

Kepler

pre-2008

(not including CoRoT!)

# But Kepler Stars are hard to observe. Why bother?

# Photometry

$T_{eff}$

## Spectroscopy

$T_{eff}$, logg, [Fe/H]

ev. models

*$T_{eff}$, R, M, [Fe/H]*

typical Kepler stars (V>12)

**model dependent** → **measured**

**Photometry** → $T_{eff}$

**Asteroseismology** → density

**Spectroscopy** → $T_{eff}$, log(g), [Fe/H]

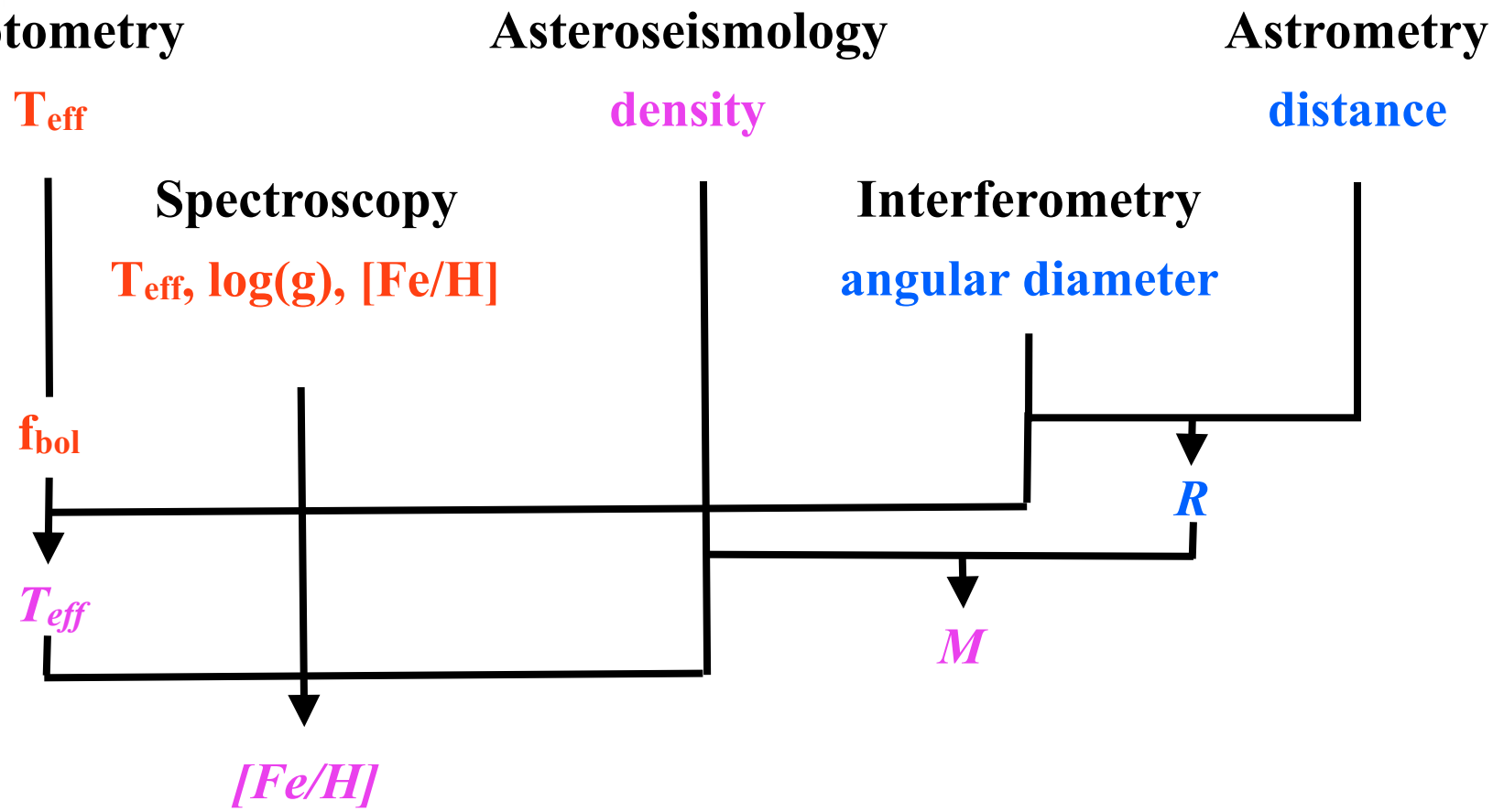
ev. models

*$T_{eff}$, R, M, [Fe/H]*

model dependent

bright'ish Kepler stars (V < 12)

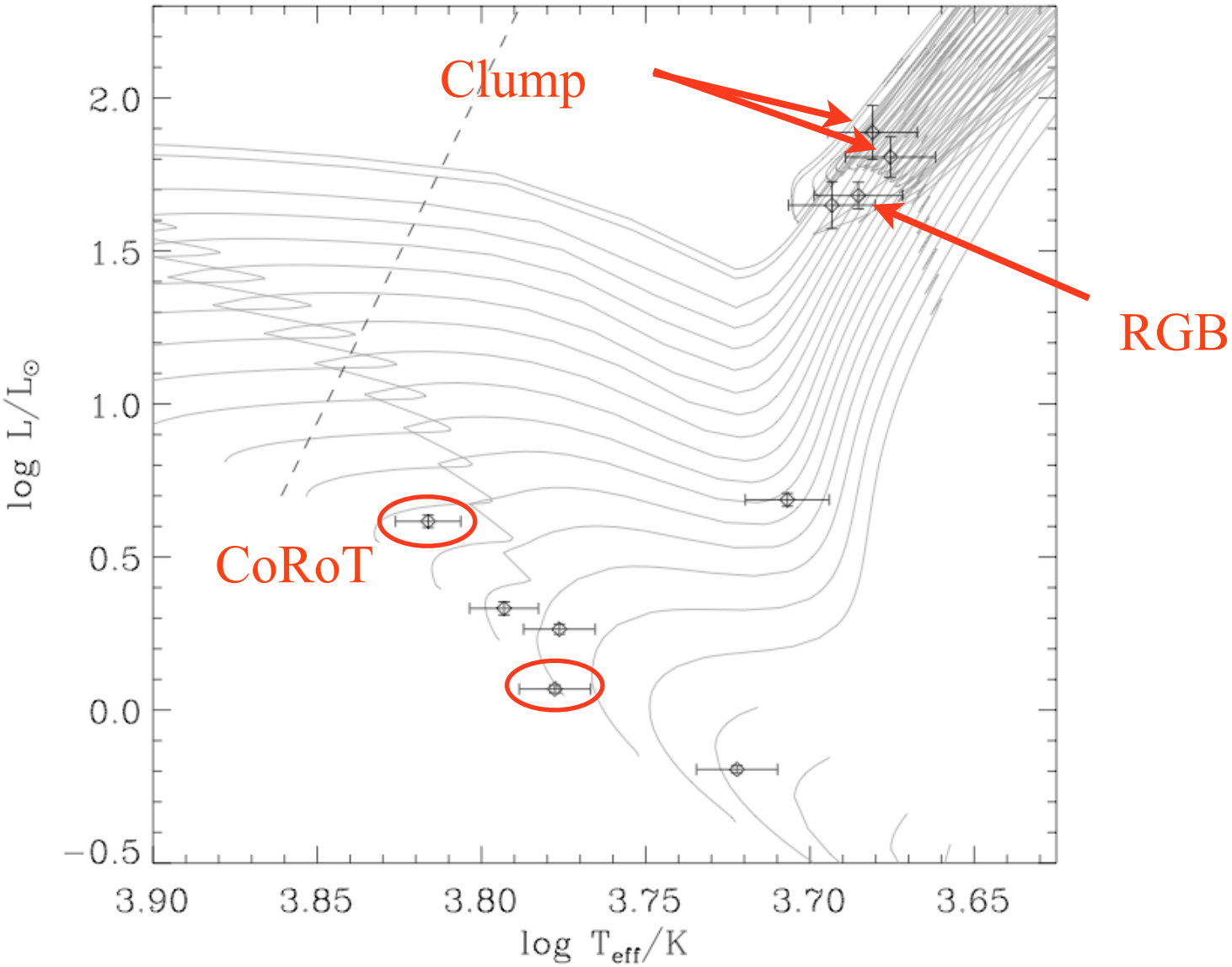
measured

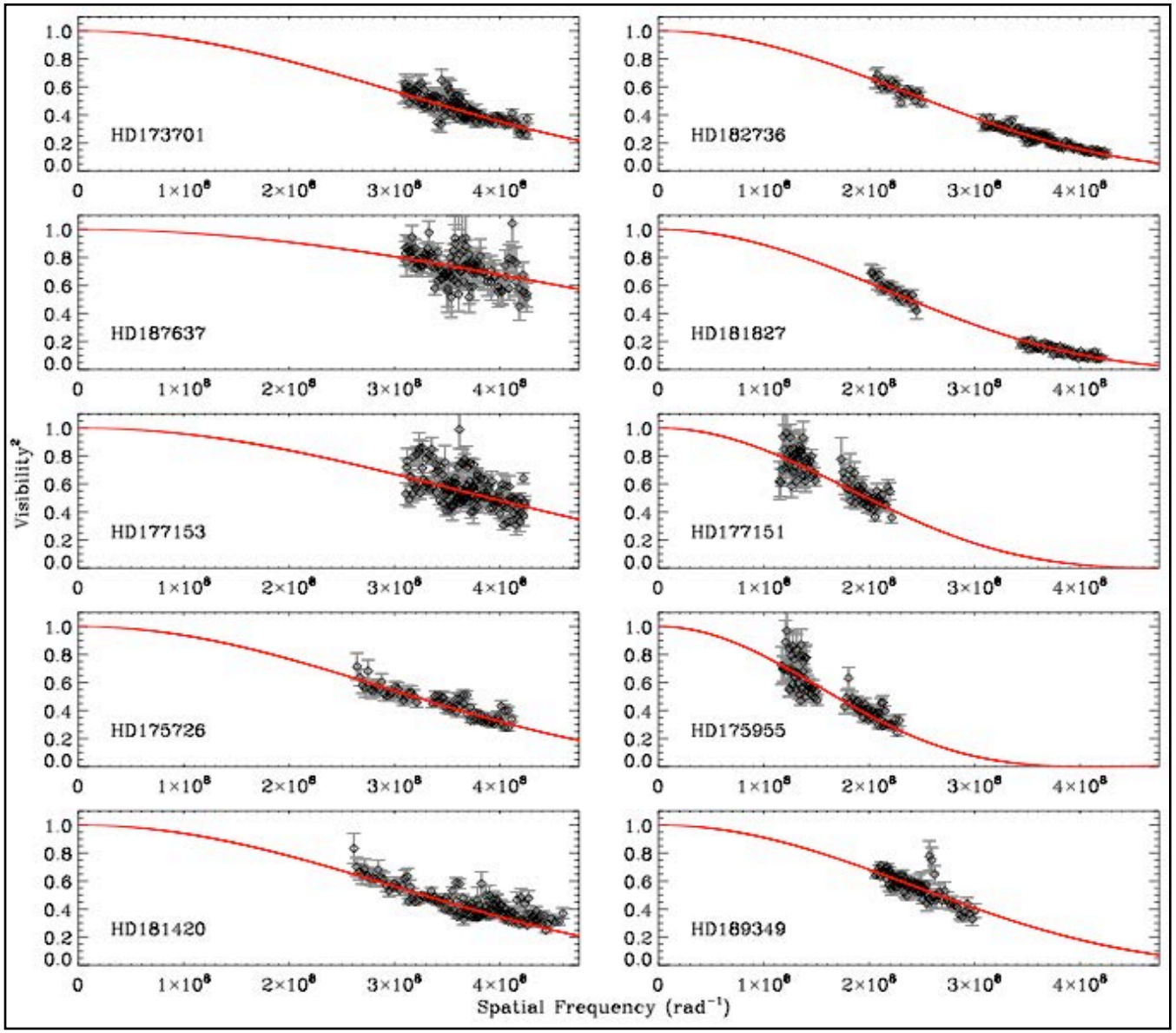


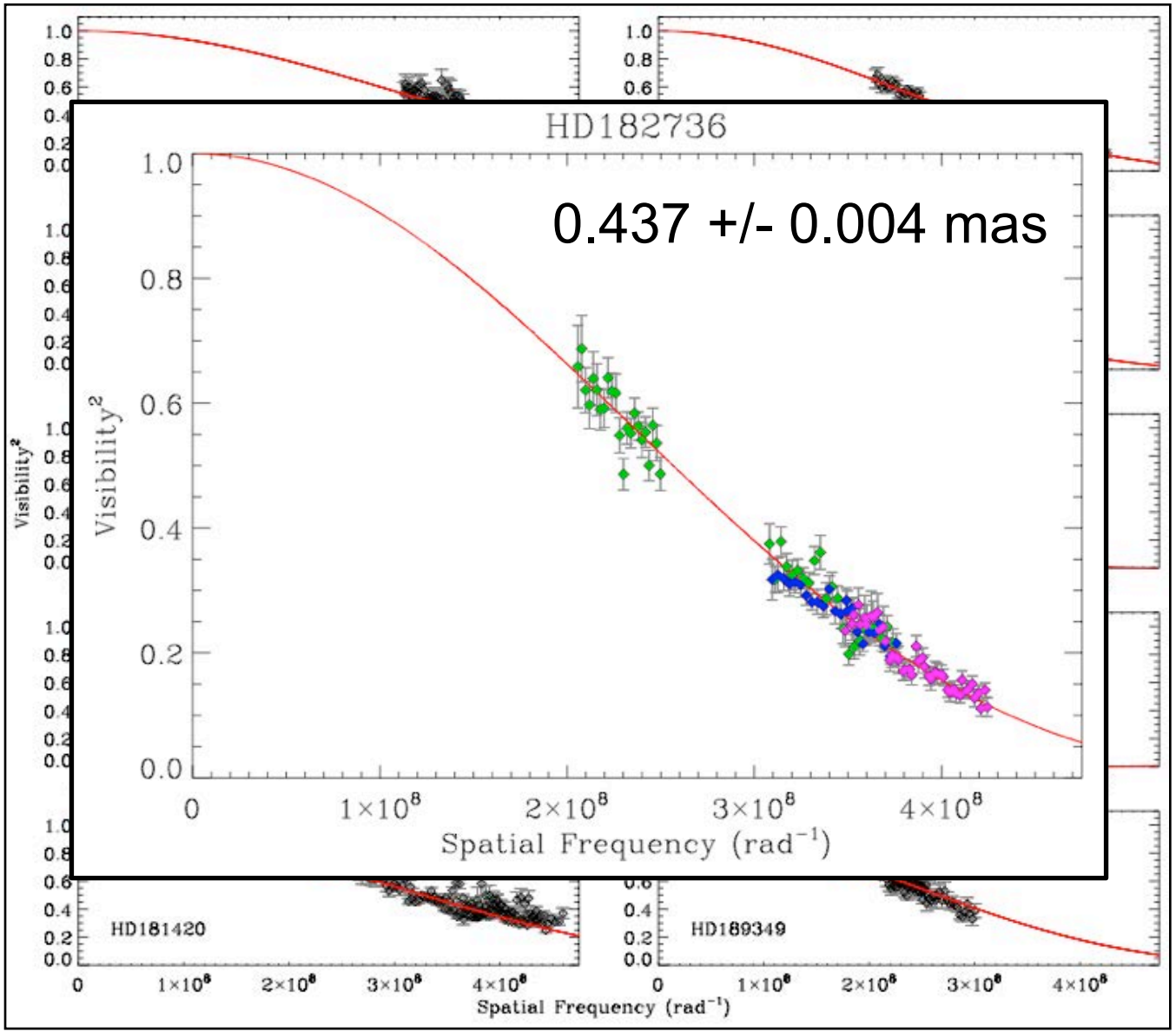

bright Kepler stars (V<7-8)

model dependent

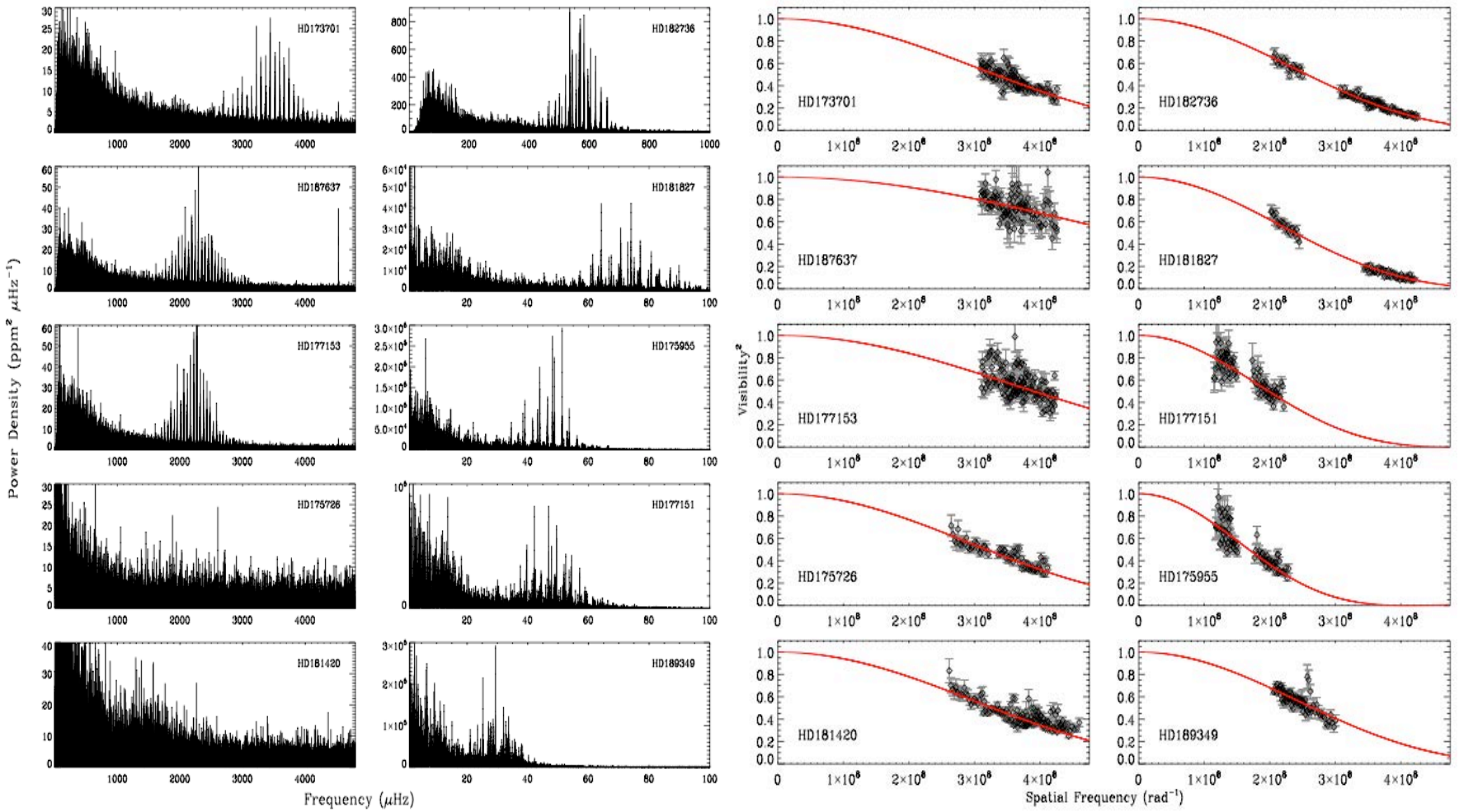
measured


Clump
RGB
CoRoT
2.0
1.5
1.0
0.5
0.0
−0.5
log L/L⊙
3.90
3.85
3.80
3.75
3.70
3.65
log T_eff/K


HD173701
HD182736
HD187637
HD181827
HD177153
HD177151
HD175726
HD175955
HD181420
HD189349
Visibility²
Spatial Frequency (rad⁻¹)
0
1×10⁸
2×10⁸
3×10⁸
4×10⁸
0.0
0.2
0.4
0.6
0.8
1.0


HD182736
0.437 +/- 0.004 mas
Visibility²
Spatial Frequency (rad⁻¹)
HD181420
HD189349

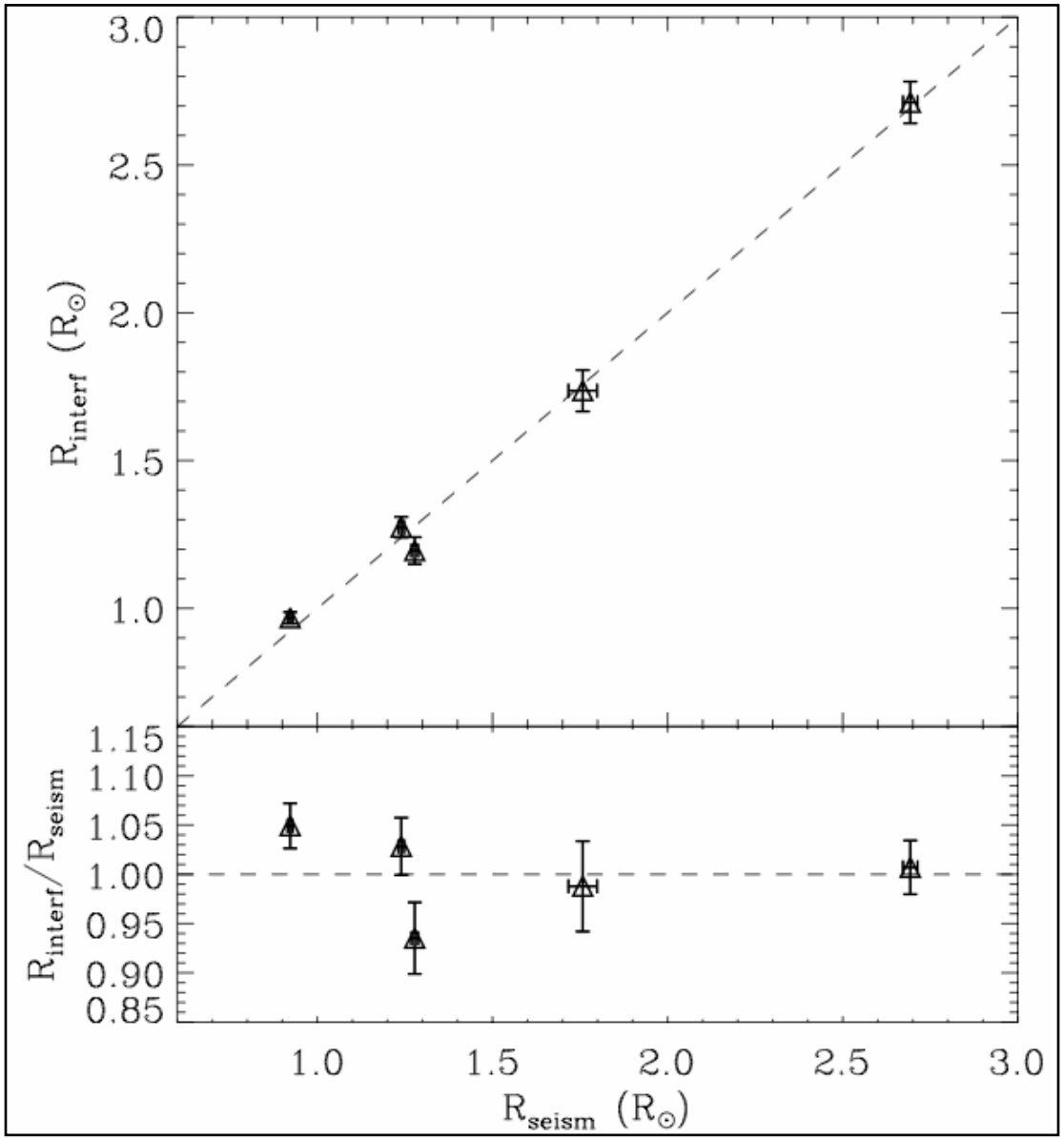
temporal FT ⟷ spatial FT

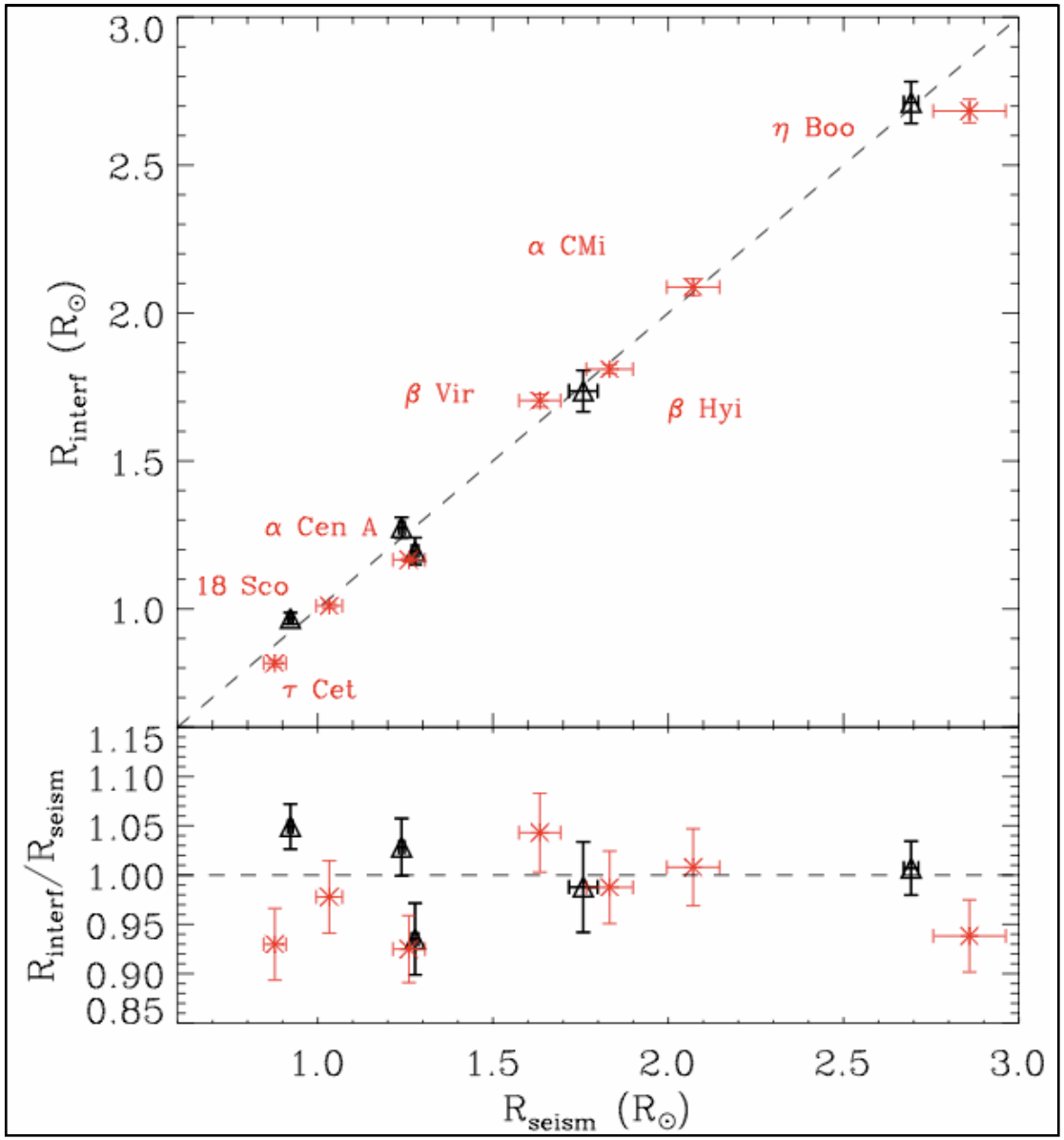


# How *accurate* are asteroseismic radii?

$$\Delta\nu \propto M^{1/2} R^{-3/2}$$

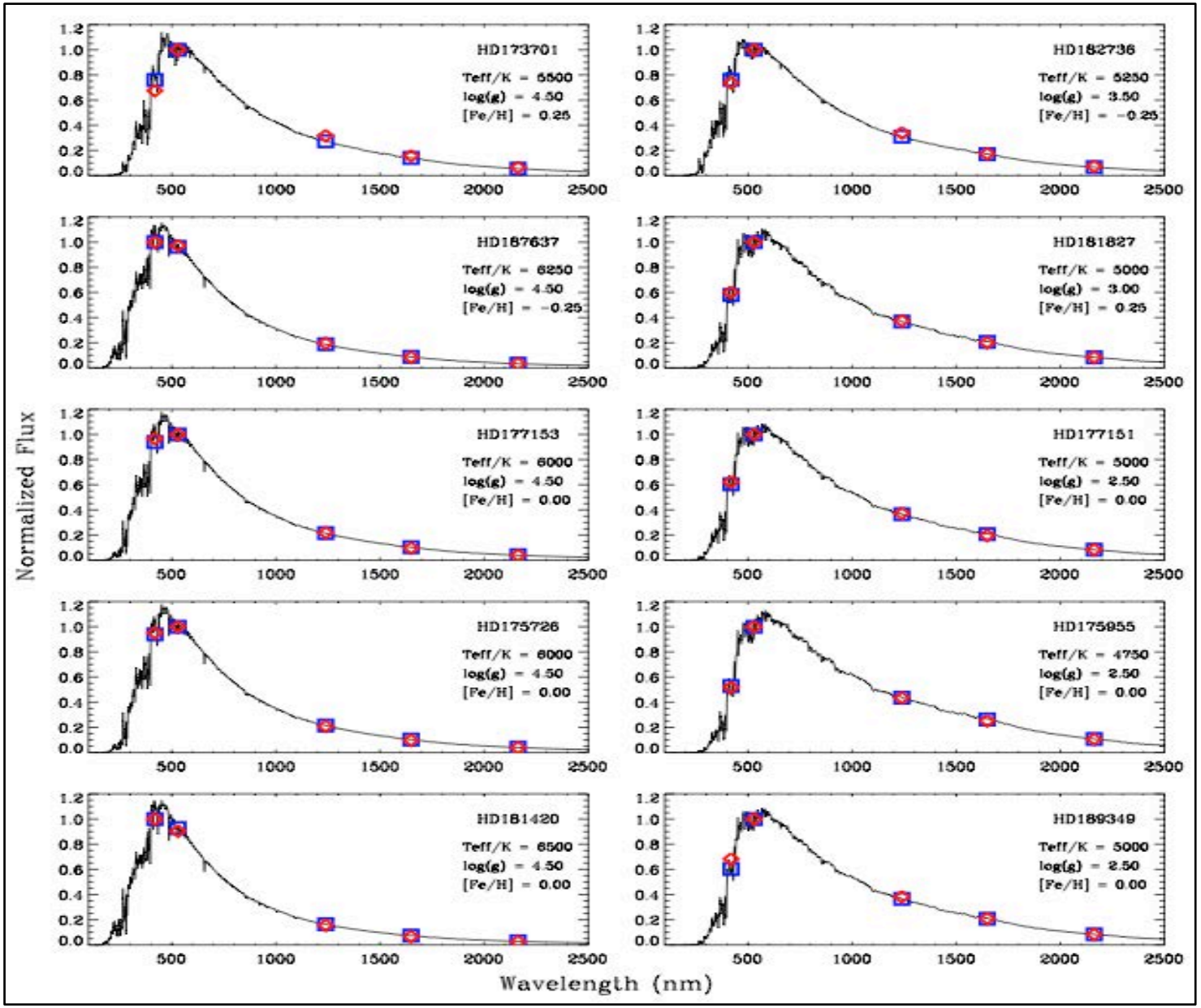
$$\nu_{max} \propto M R^{-2} T_{eff}^{-1/2}$$

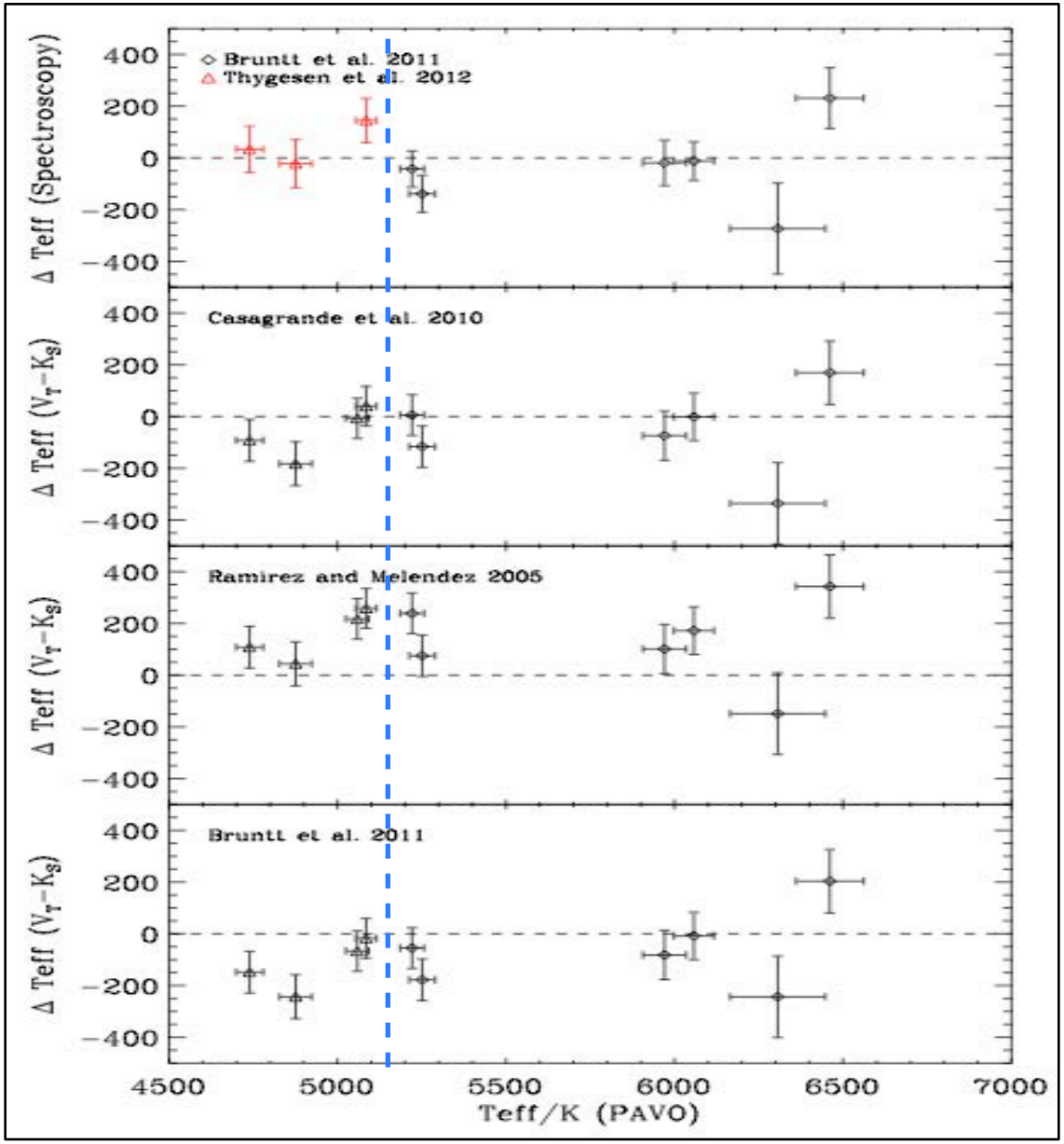

3.0
2.5
2.0
1.5
1.0
$R_{interf}$ ($R_\odot$)
1.15
1.10
1.05
1.00
0.95
0.90
0.85
$R_{interf}/R_{seism}$
1.0
1.5
2.0
2.5
3.0
$R_{seism}$ ($R_\odot$)


3.0
2.5
2.0
1.5
1.0
$R_{interf}$ ($R_\odot$)
η Boo
α CMi
β Vir
β Hyi
α Cen A
18 Sco
τ Cet
1.15
1.10
1.05
1.00
0.95
0.90
0.85
$R_{interf}/R_{seism}$
1.0
1.5
2.0
2.5
3.0
$R_{seism}$ ($R_\odot$)

4%

# How *accurate* are spectroscopic & photometric temperatures?


HD173701
Teff/K = 6500
log(g) = 4.50
[Fe/H] = 0.25
HD182736
Teff/K = 5250
log(g) = 3.50
[Fe/H] = −0.25
HD187637
Teff/K = 6250
log(g) = 4.50
[Fe/H] = −0.25
HD181827
Teff/K = 5000
log(g) = 3.00
[Fe/H] = 0.25
HD177153
Teff/K = 6000
log(g) = 4.50
[Fe/H] = 0.00
HD177151
Teff/K = 5000
log(g) = 2.50
[Fe/H] = 0.00
HD175726
Teff/K = 6000
log(g) = 4.50
[Fe/H] = 0.00
HD175955
Teff/K = 4750
log(g) = 2.50
[Fe/H] = 0.00
HD181420
Teff/K = 6500
log(g) = 4.50
[Fe/H] = 0.00
HD189349
Teff/K = 5000
log(g) = 2.50
[Fe/H] = 0.00
Normalized Flux
Wavelength (nm)


Bruntt et al. 2011
Thygesen et al. 2012
Δ Teff (Spectroscopy)
Casagrande et al. 2010
Δ Teff (V_T−K_S)
Ramirez and Melendez 2005
Δ Teff (V_T−K_S)
Bruntt et al. 2011
Δ Teff (V_T−K_S)
400
200
0
−200
−400
4500
5000
5500
6000
6500
7000
Teff/K (PAVO)

# How *accurate* are models?

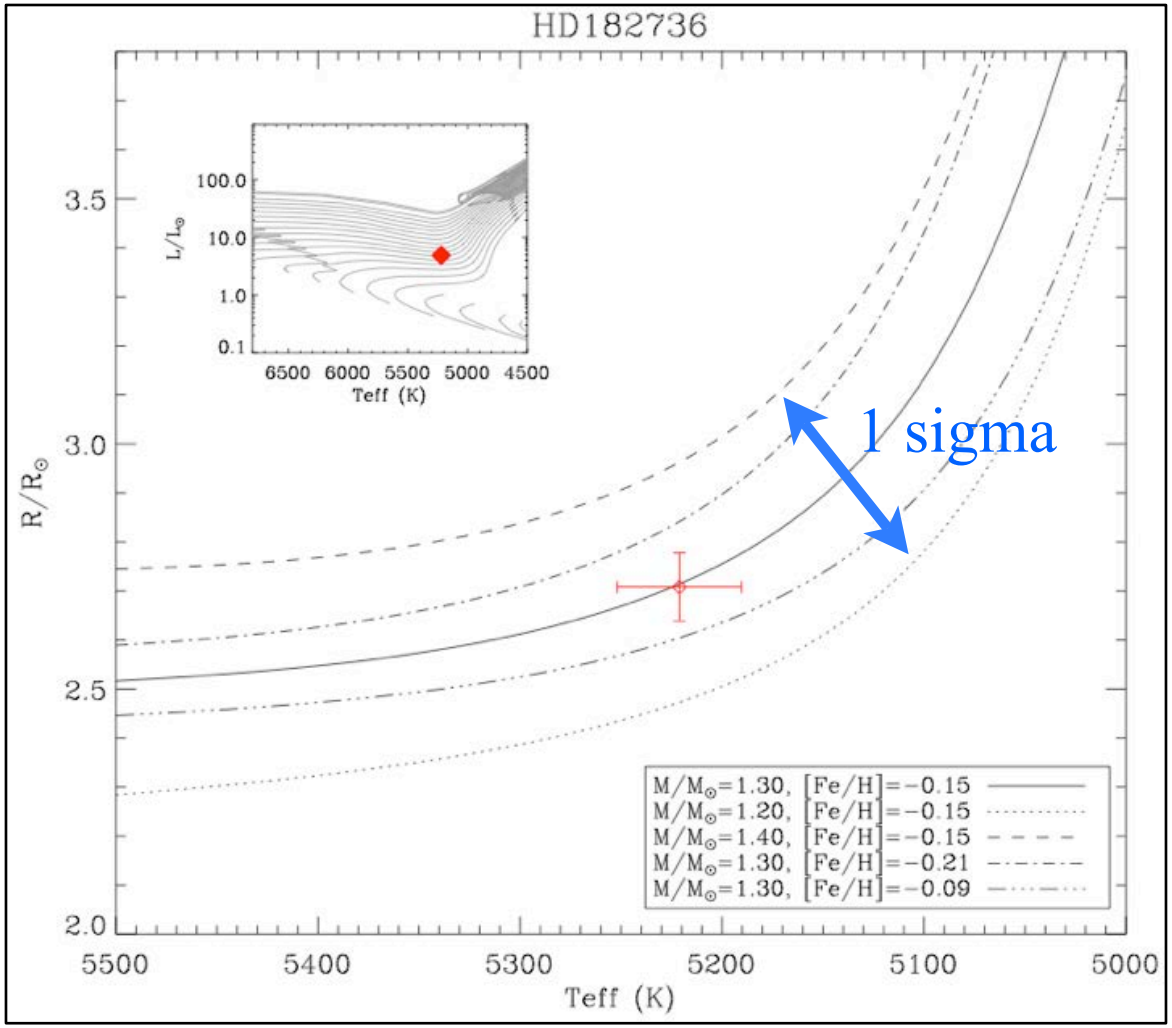
ang. diameter + parallax → **Radius**

interferometric radius + asteroseismic density → **Mass**

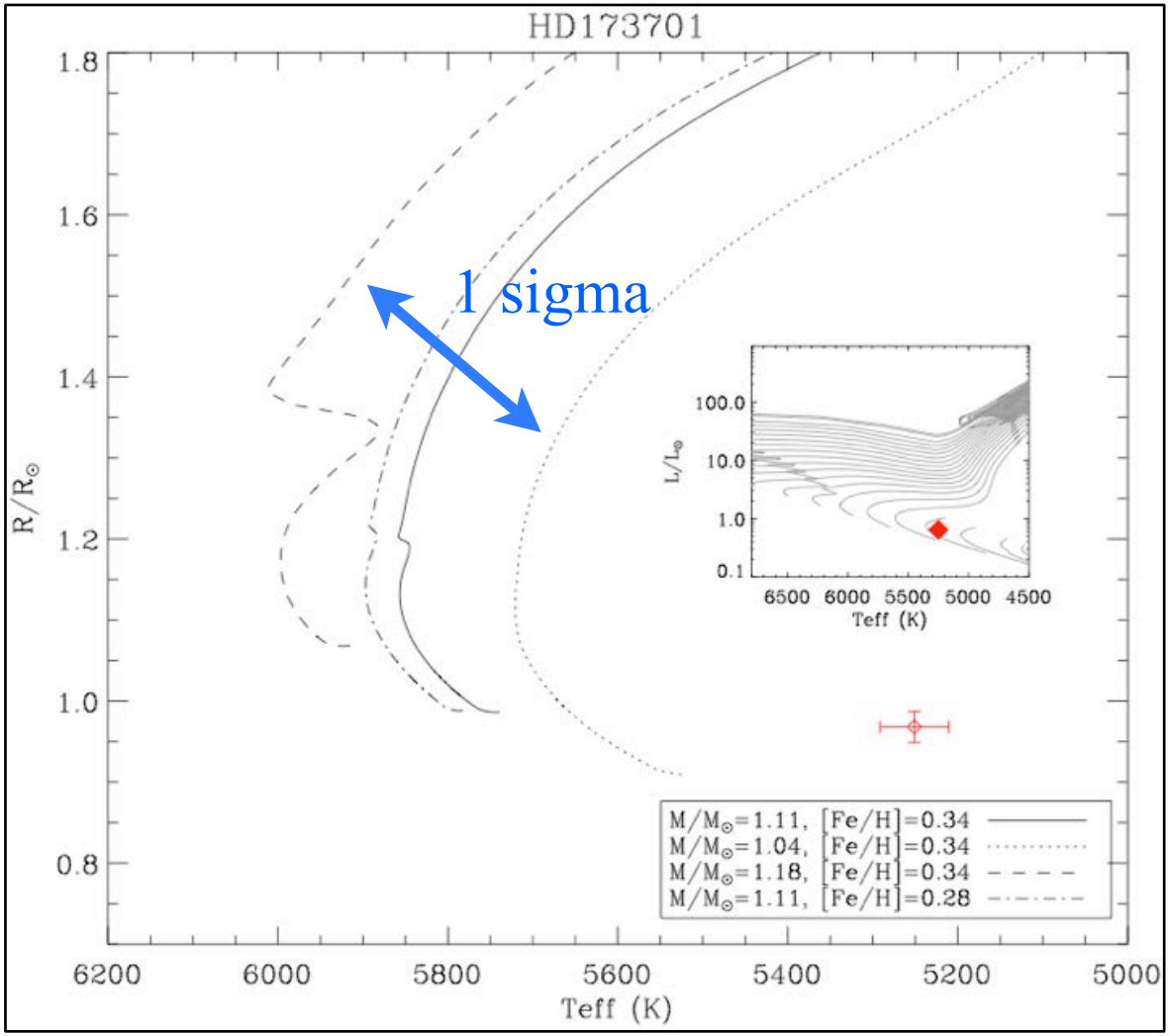
bol. flux + ang. diameter → **Teff**

spectroscopy (with asteroseism. constraints) → **[Fe/H]**

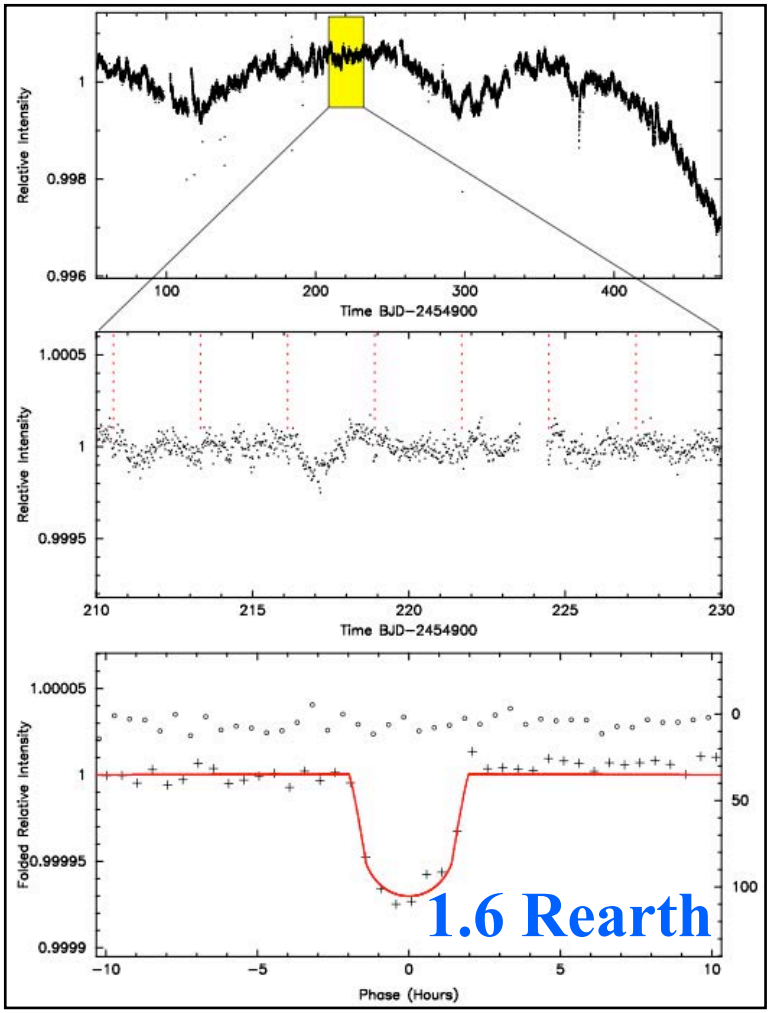
# Subgiant: Spot-on



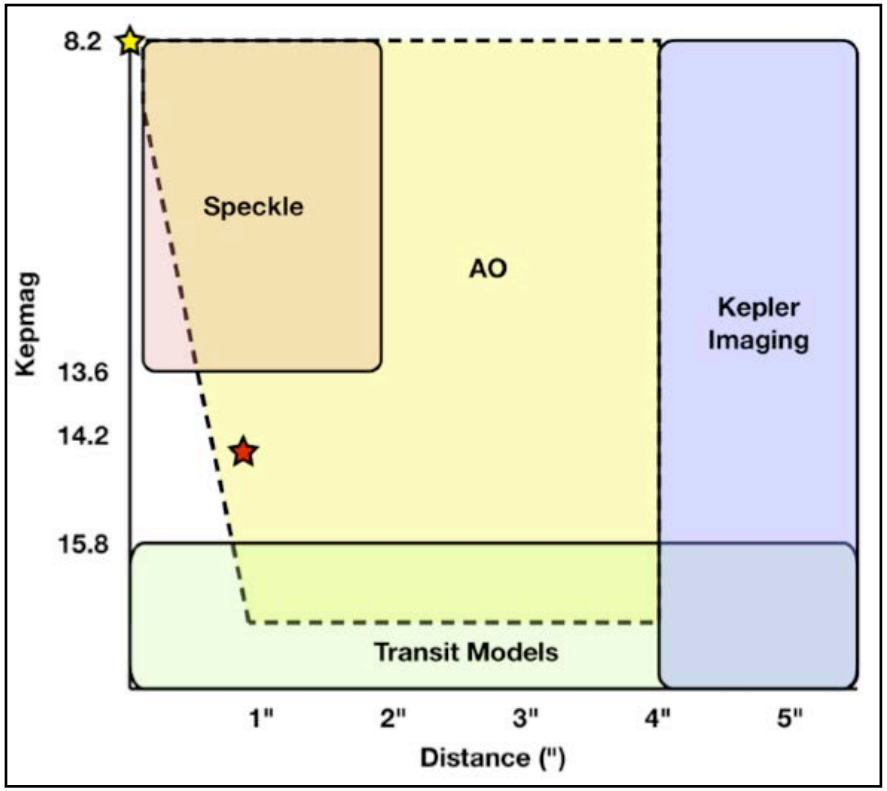
# Metal-rich K dwarf: Slightly Impossible



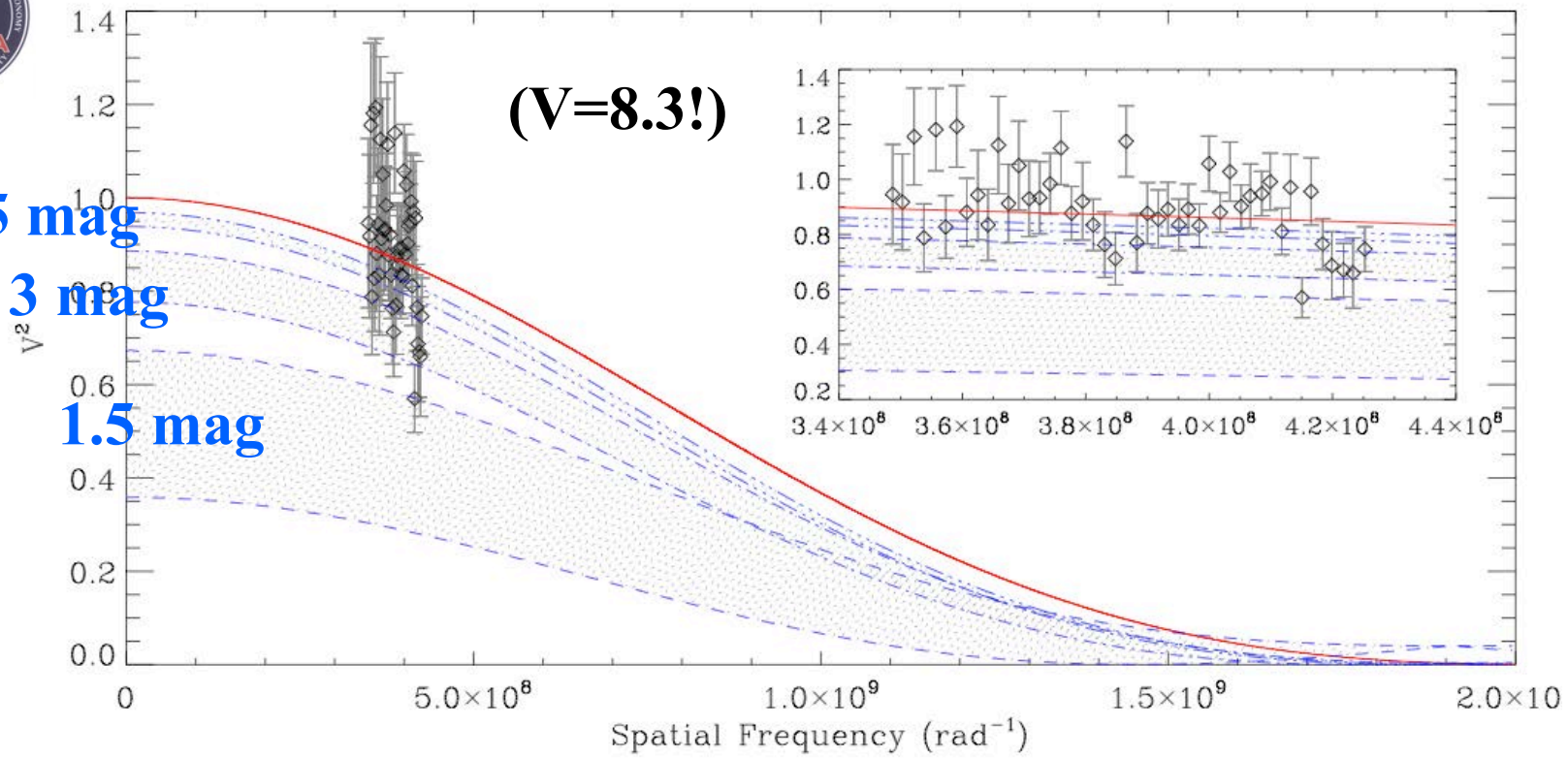
# Validating extrasolar planets with PAVO




## Kepler-21

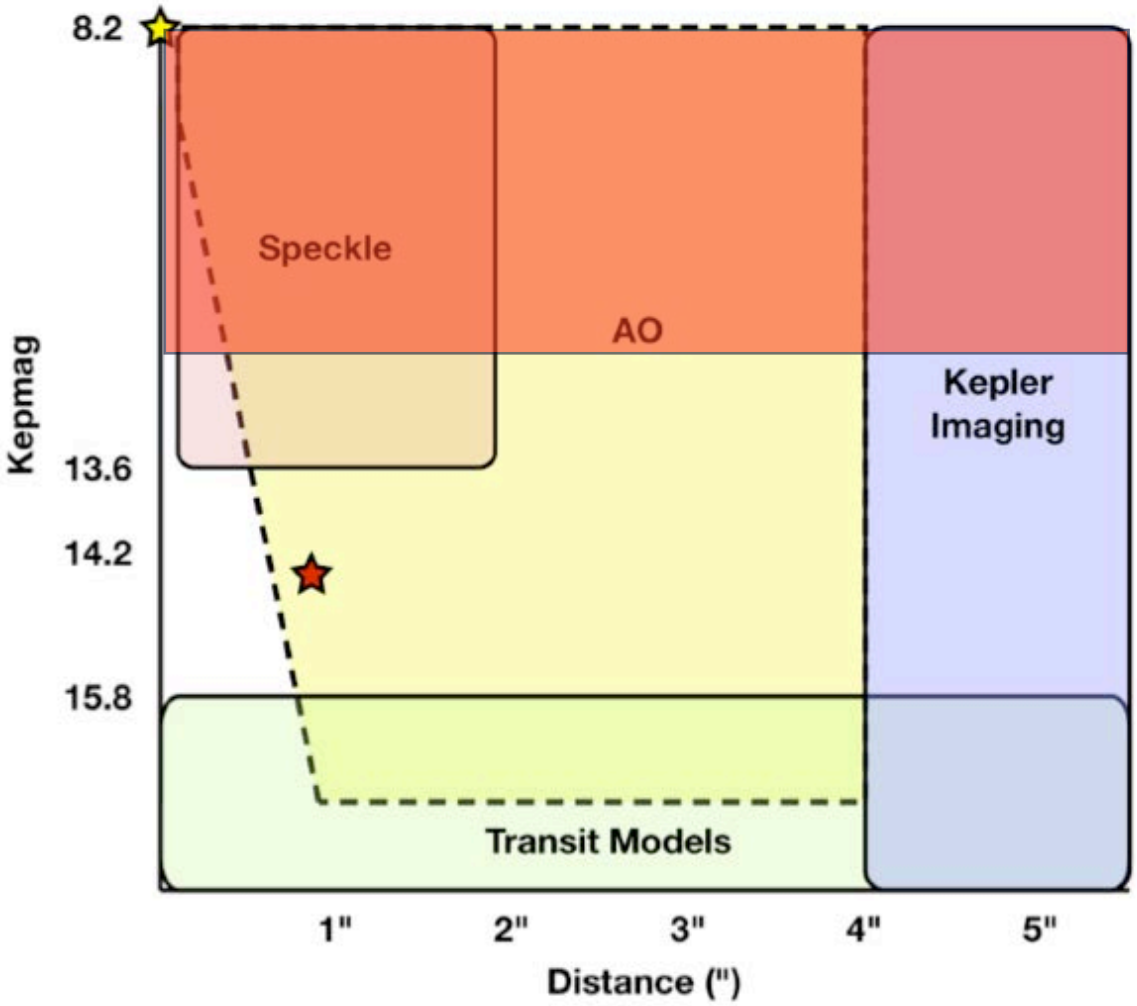



Howell et al. 2011




excludes any (physical and change-alignment) blends
at > 1 mas and < 3.5 mag

Huber et al. (2012)


8.2
Speckle
AO
Kepler
Imaging
13.6
14.2
15.8
Transit Models
Kepmag
1"
2"
3"
4"
5"
Distance (")

PAVO

# Summary: PAVO Asteroseismology / Kepler program

2009 Semester 1/2: 7/3 nights (100/0 % clear)
2010 Semester 1/2: 4/3 nights (100/0 % clear)
2011 Semester 1/2: 5/3 nights (90/0 % clear)

- ***18 Sco (Bazot et al. 2011, A&A)***
- ***Trinity (Derekas et al. 2011, Science)***
- ***Kepler-21 (Huber et al. 2012, MNRAS)***
- *Kepler ensemble (Huber et al., May 2012)*
- *16 Cyg A&B (White et al., late 2012)*