

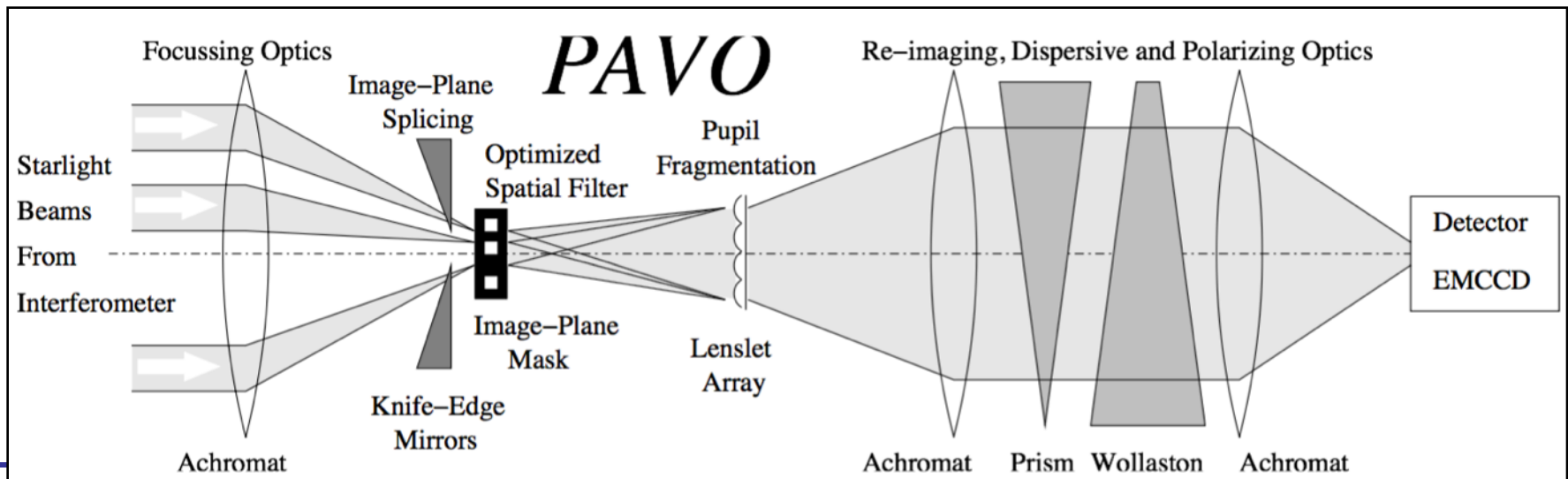


PAVO Science Update

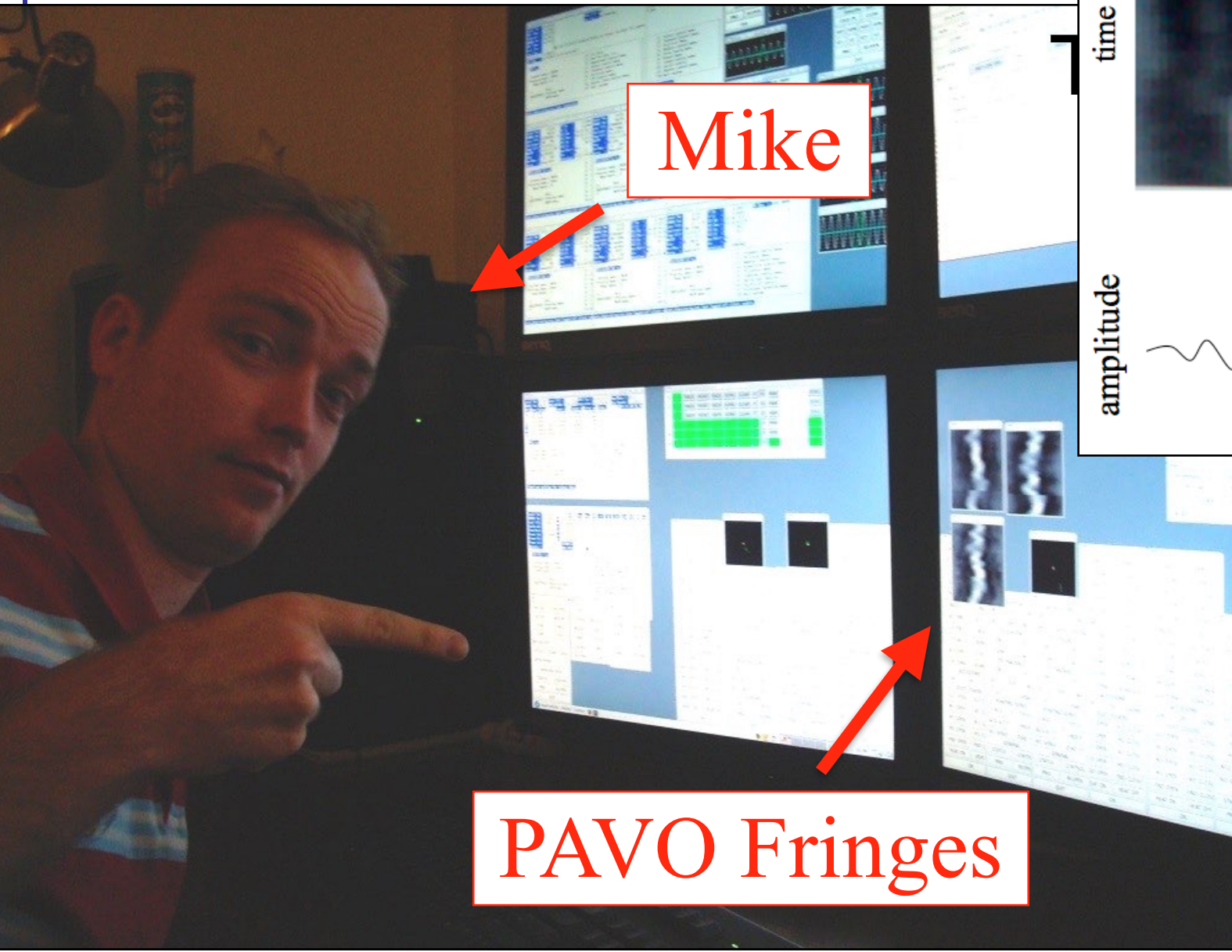
Daniel Huber (IfA Hawaii), Tim White
(Aarhus), Mike Ireland (ANU), Peter
Tuthill (Sydney), Iva Karovicova
(Heidelberg)

PAVO Basics

- 3-Telescope Beam Combiner
- $\lambda \sim 0.6\text{-}0.8\text{ }\mu\text{m}$ in ~ 20 channels
- Spatially modulated pupil-plane fringes
- Best performance: $R \sim 8$ mag
- No major hardware upgrade since ~ 2009



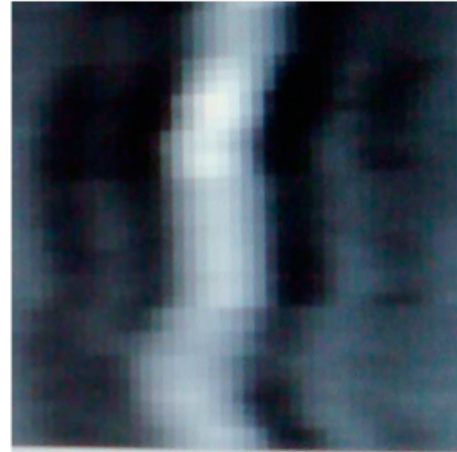
sometime in 2009 ...



Mike

PAVO Fringes

time



delay

amplitude





PAVO Software

- Reduction & analysis tools available (on cvs ... to be ported to Github soon)
- 2T: essentially the default operation mode
- 3T: bias reduction issues; *we welcome collaborators willing to contribute to reduction efforts (chopper data available)*

<http://pavo.wikispaces.com/>

2016

	Gordon	Gies, Schaefer	Fundamental Properties of O- and B- Type Stars
	Huber	White, Collet, Ireland, Tuthill, Bedding	Measuring Limb Darkening at visible wavelengths with PAVO
P3	Ireland	Karovicova, White, Gilmore, Jofre, Worley, Hourihane, Lind, Bergemann, Heiter, Wittkowski, Asplund, Chiavassa, Creevy, Thevenin	Interferometric Observations of Benchmark Stars for calibrating large stellar surveys of the Milky Way
P4	Quinn	Jones, White	Open Cluster Ages from Sizes of Giants and A Stars
P5/C4	Boyajian/vonBraun	ten Brummelaar, Farrington, McAlister, Gies, van Belle, White, Jones, Ireland, Huber, Fischer	Diameters and Temperatures of Main Sequence FG Stars (PAVO/Classic)
P6/C5	Huber	White, Ireland, Tuthill, Bedding, Stello, Boyajian, Aguirre, Creevy, Nardetto, Mourard	Paving the way for Galactic Archeology: Angular diameters of oscillating red giants (PAVO/Classic, VEGA/Classic)
P7/CL3	Jones	White, Boyajian, Schaefer, Baines, Ireland, Patience	How Old are the nearest A-stars?
P8/C6	Tuthill	Richichi, Schaefer, ten Brummelaar, Ridgway, Ireland	Pilot Study for Lunar Occultations at CHARA (PAVO/Classic)
P9/C7	vonBraun/Boyajian	van Belle, Henry, Kane, Schaefer, Giguere, Fischer, Brewer, Wana, Huber, Ireland, Pewett, Ciardi, Mann, Baron, Martens, Egland, Monnier, Roettenbacher, Jones	Radii of late type dwarf, exoplanet hosts, and exoplanet host candidates
P10/M8	White, R		Star Spots and Radii of Solar Analogues

2017A

	Gordon	Gies, Schaefer	Fundamental Properties of O- and B-type stars
P2	Huber	White, Collet, Ireland, Tuthill, Bedding	Measuring Limb-Darkening at Visible Wavelengths with PAVO
P3	Ireland	Karovicova, White, Gilmore, Jofre, Worley, Hourihane, Lind, Bergemann, Wittkowski, Asplund, Chivassa, Thevenin	Interferometric Observations of benchmark stars for calibrating large stellar surveys of the Milky Way
P4	Jones	White, Boyajian, Schaefer, Baines, Ireland	How old are the nearest A-stars
P5	Quinn	Jones, White	Open Cluster Ages from Sizes of Giants and A-stars
P6/C2	Tuthill	Richichi, Farrington, Schaefer, ten Brumelaar, Ridgway, Tasuya	Lunar Occultations at CHARA
P7/V10	Huber	White, Creevy, Boyajian, Ireland, Tuthill, Bedding, Stello, Aguirre, Nardetto, Mourard	Paving the way for Galactic Archeology: Angular diameters of Oscillating Red Giants
P8/C3	Boyajian/vonBraun	ten Brummelaar, Farrington, McAlister, Gies, van Belle, White, Jones, Ireland, Huber, Fischer	Diameters and Temperatures of Main-Sequence FG stars
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PAVO Science: Diameters for Galactic Archeology

White, Huber, Karovicova,
Ireland, Bedding + VEGA Team

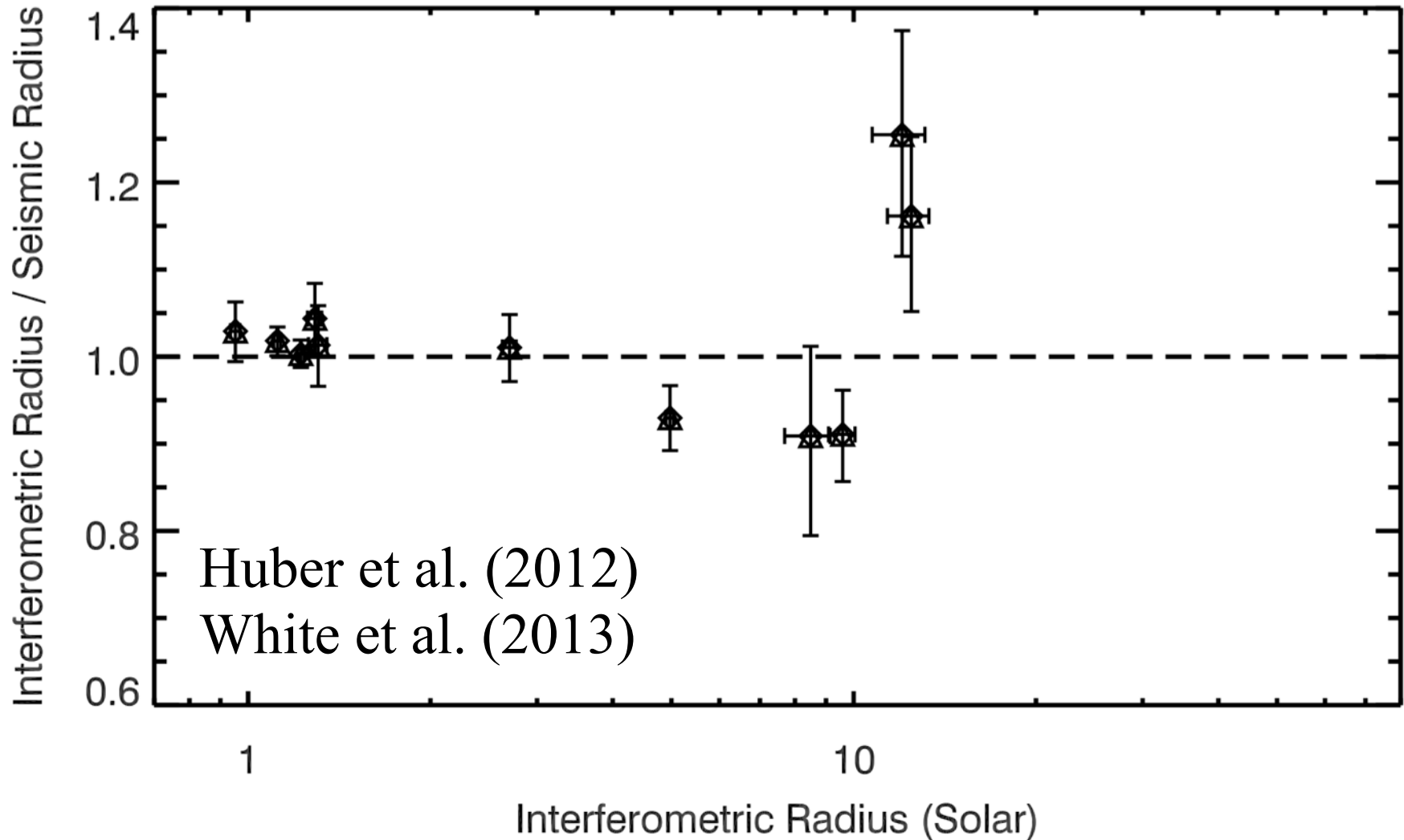
Galactic Archeology

→ Asteroseismology (Kepler/K2, TESS)

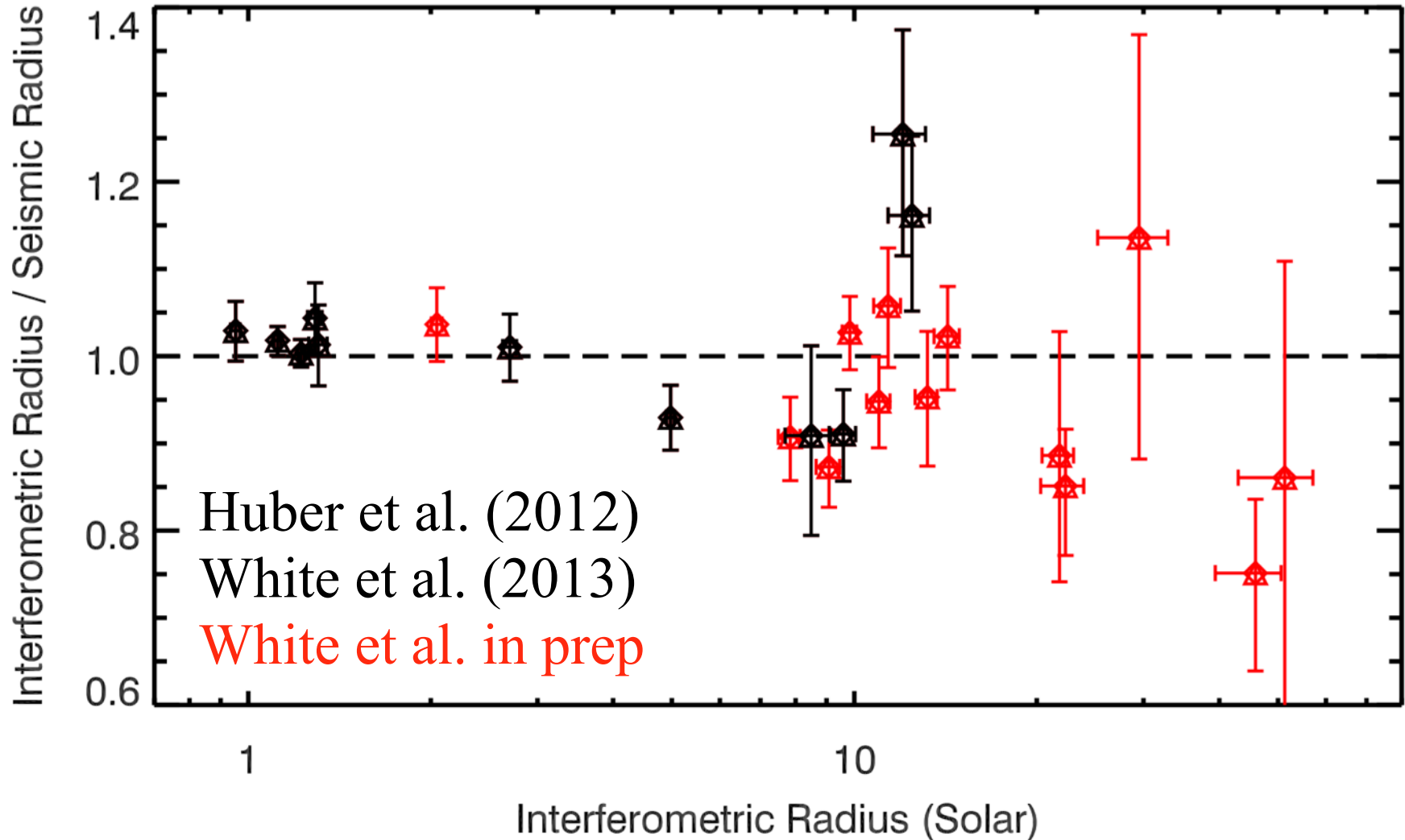
→ Spectroscopic surveys (APOGEE, GALAH, RAVE, Gaia-ESO)

but ... all hinges on fundamental
calibration: radii for asteroseismology,
 T_{eff} for spectroscopy!

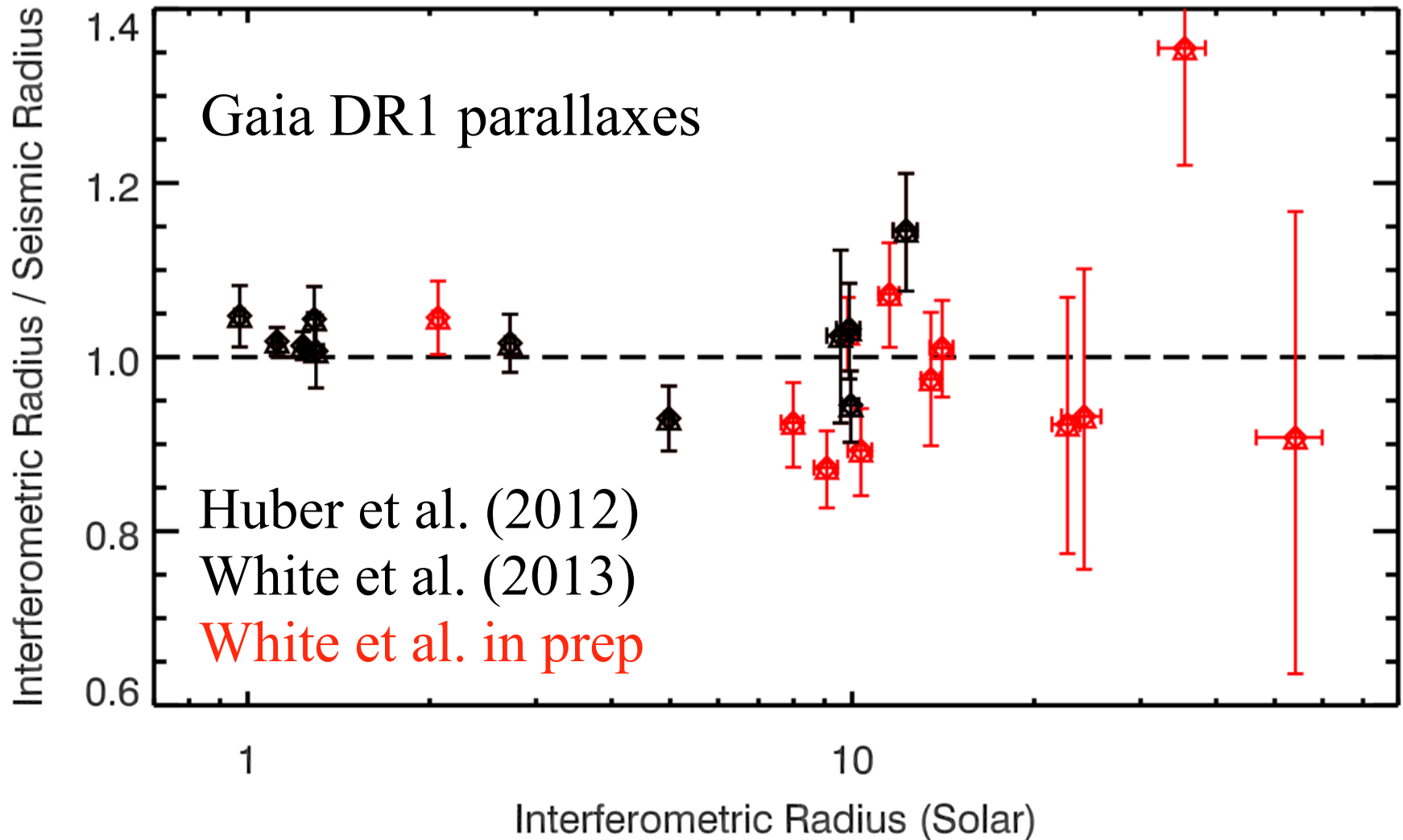
Asteroseismology Program



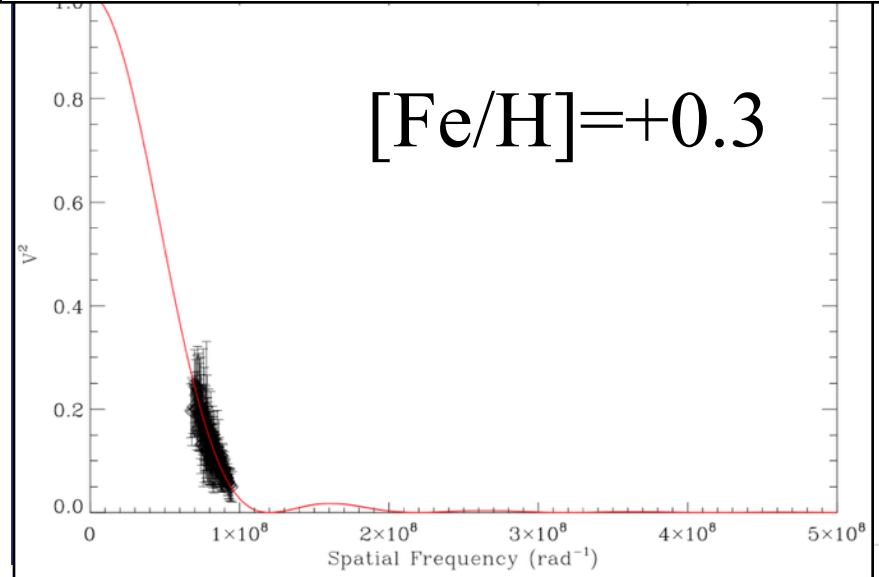
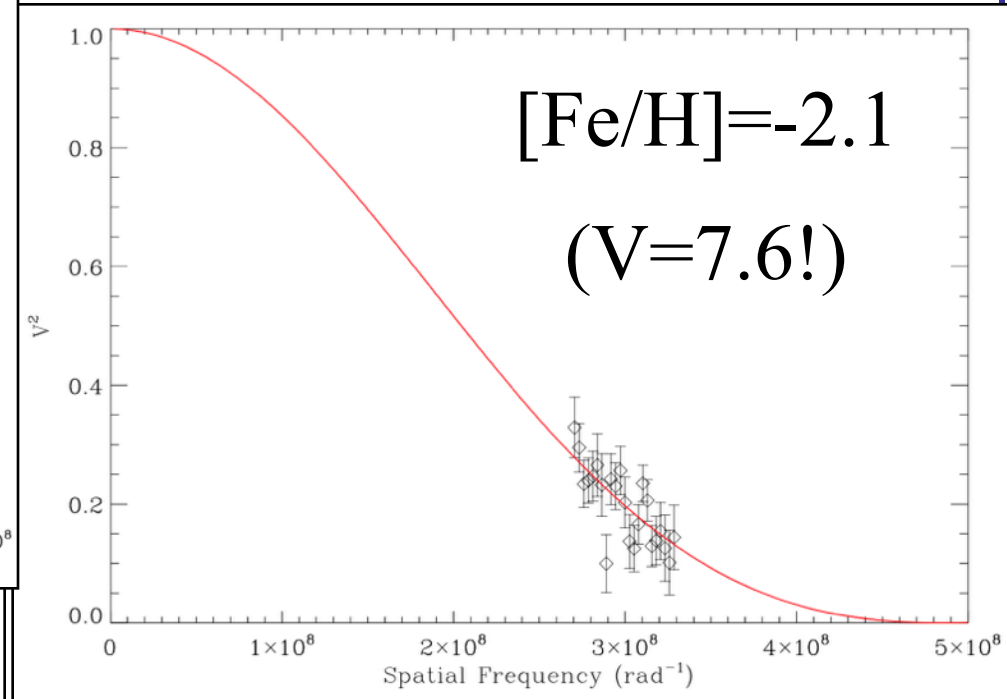
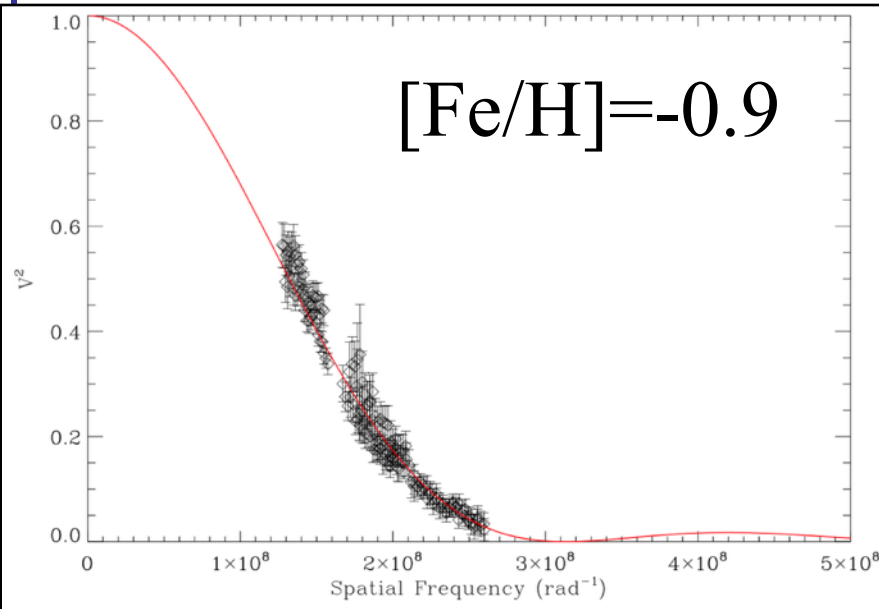
Asteroseismology Program



Asteroseismology Program

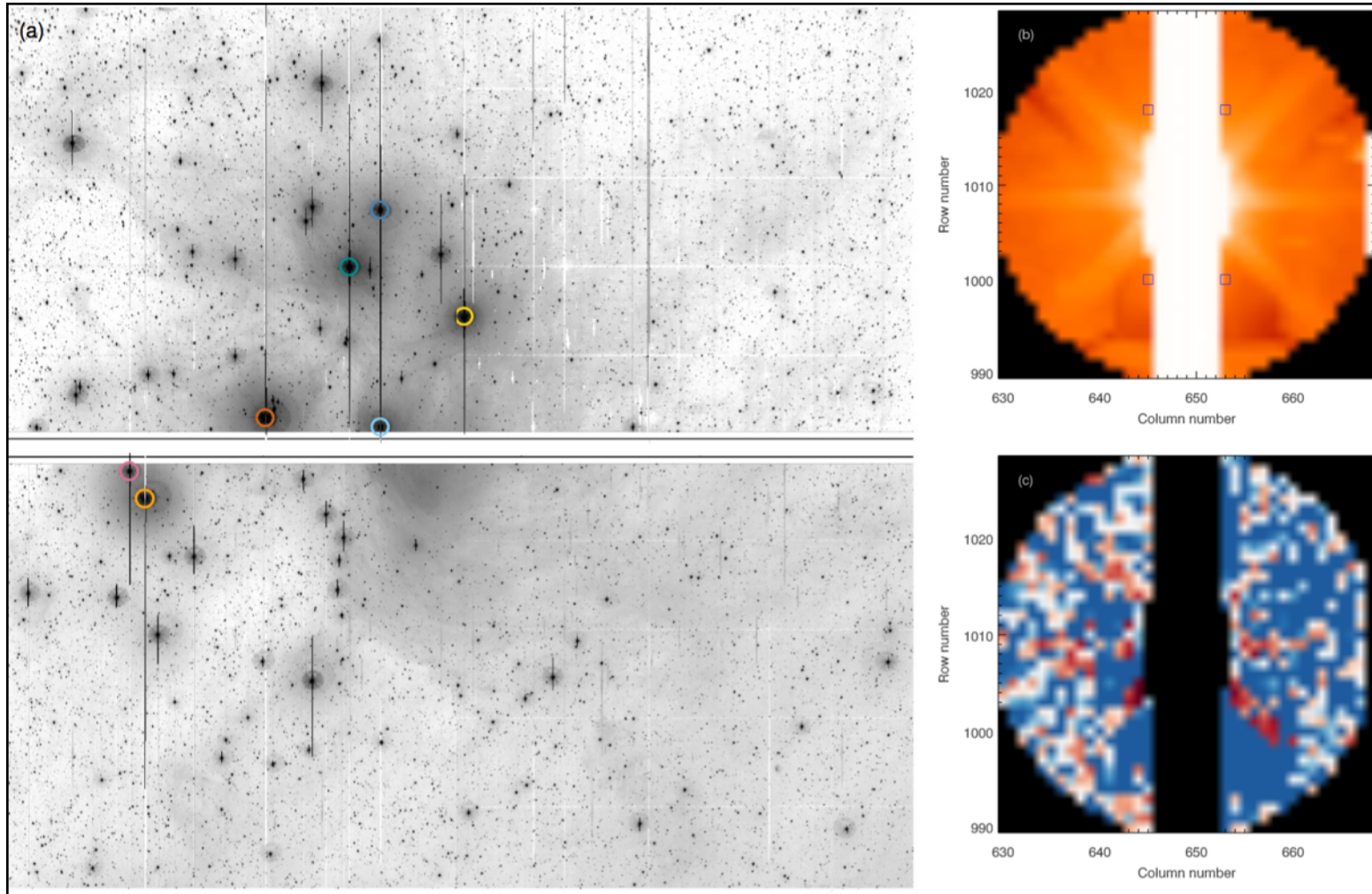


Gaia Benchmark Program

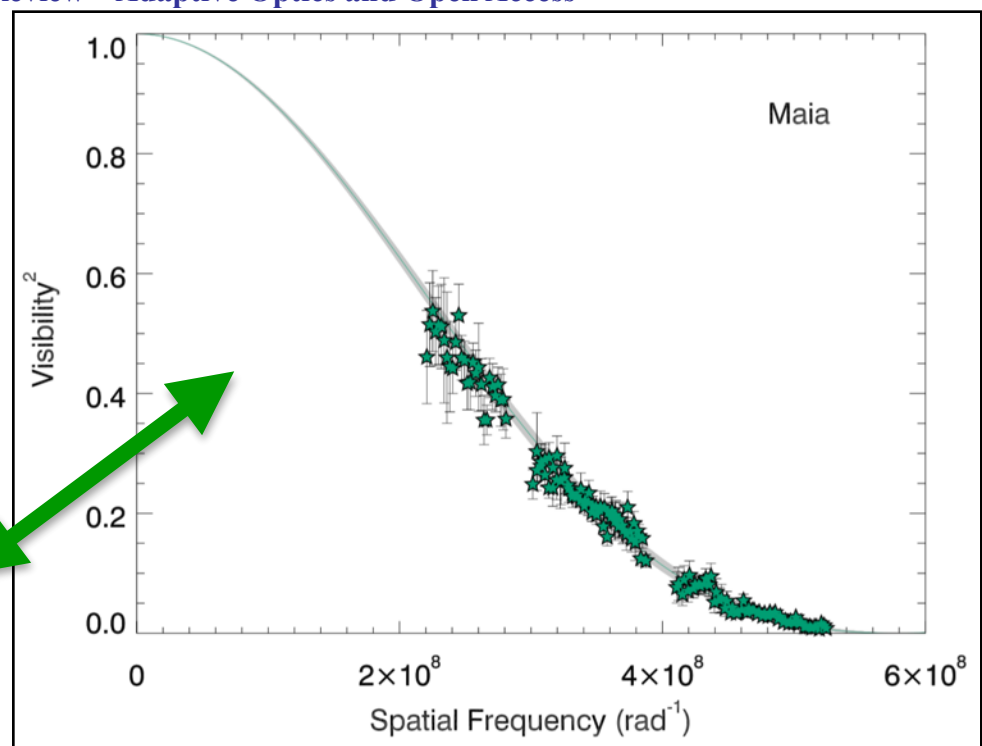
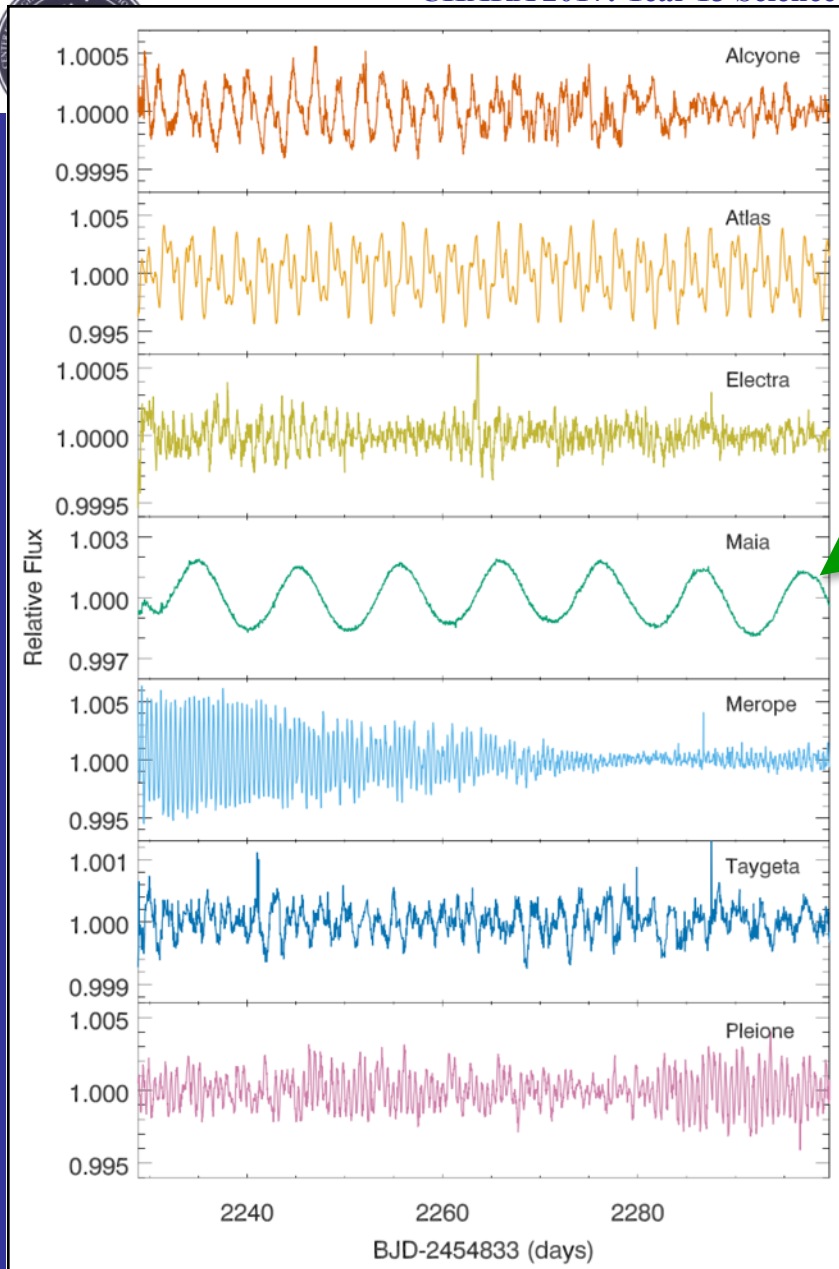


Karovicova et al., in prep

Bright Kepler/K2 Stars



White et al., nearly submitted

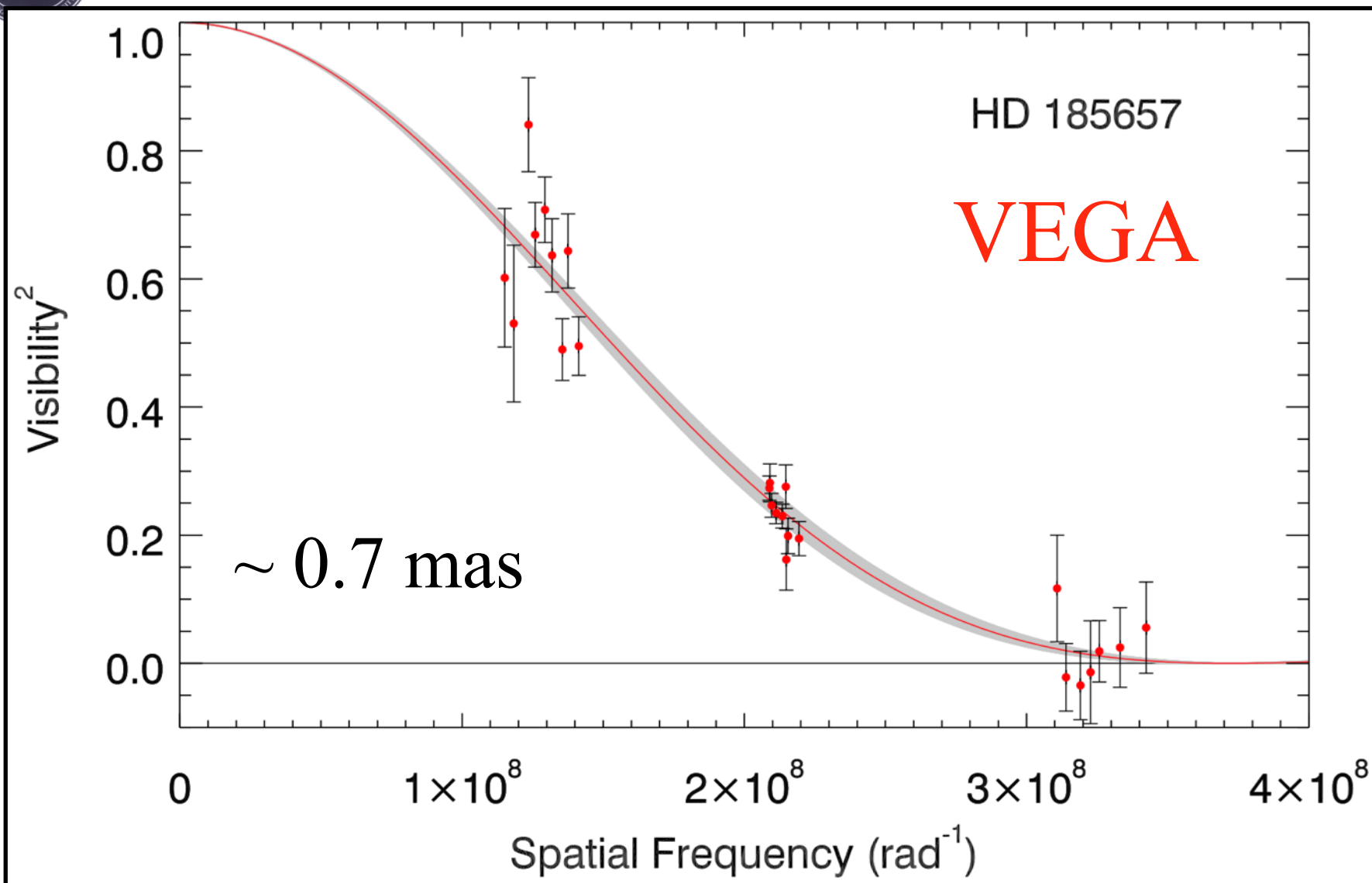


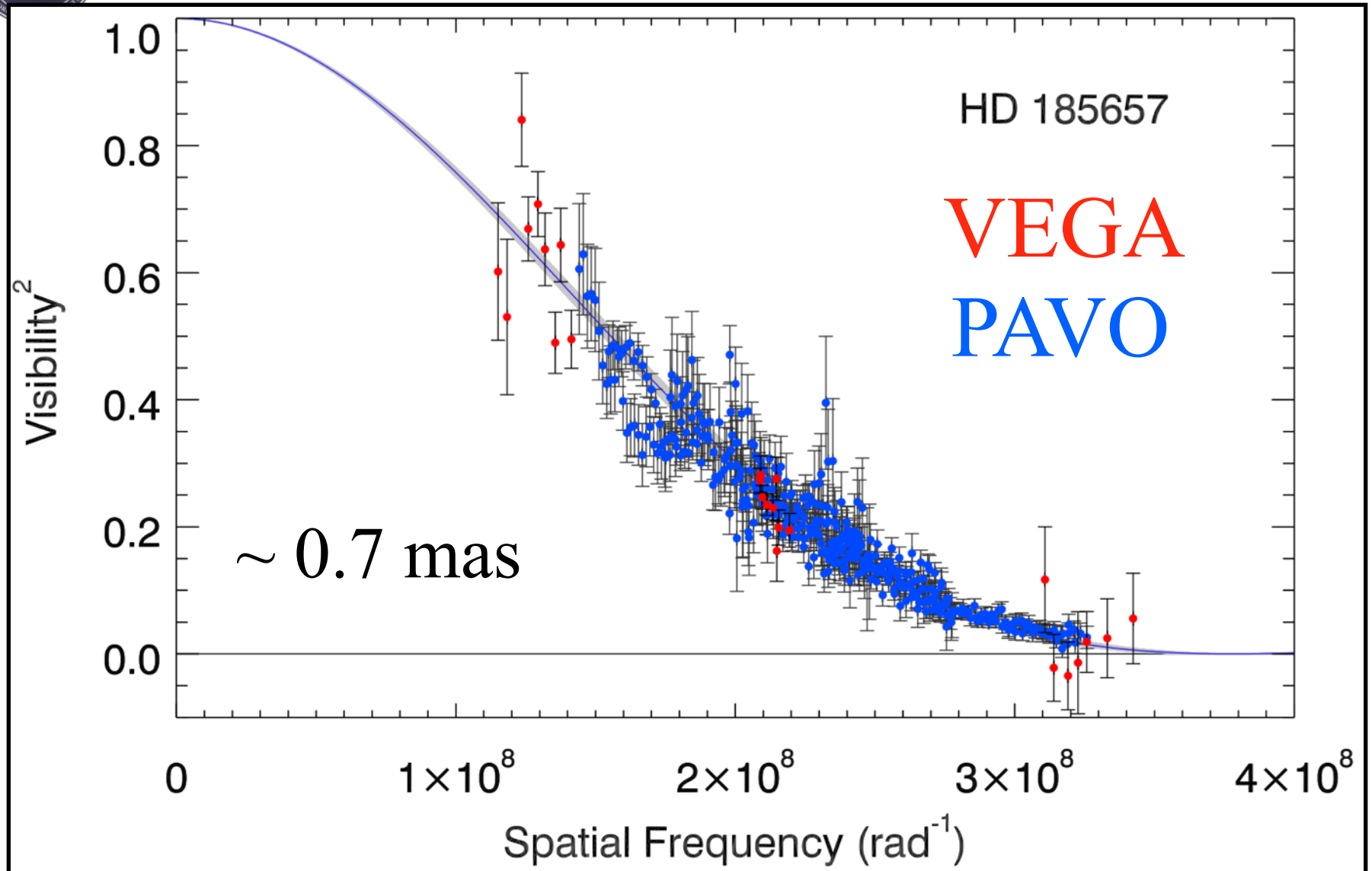
“Maia is variable, but
Maia is *not* a Maia
variable.”

White et al., nearly submitted

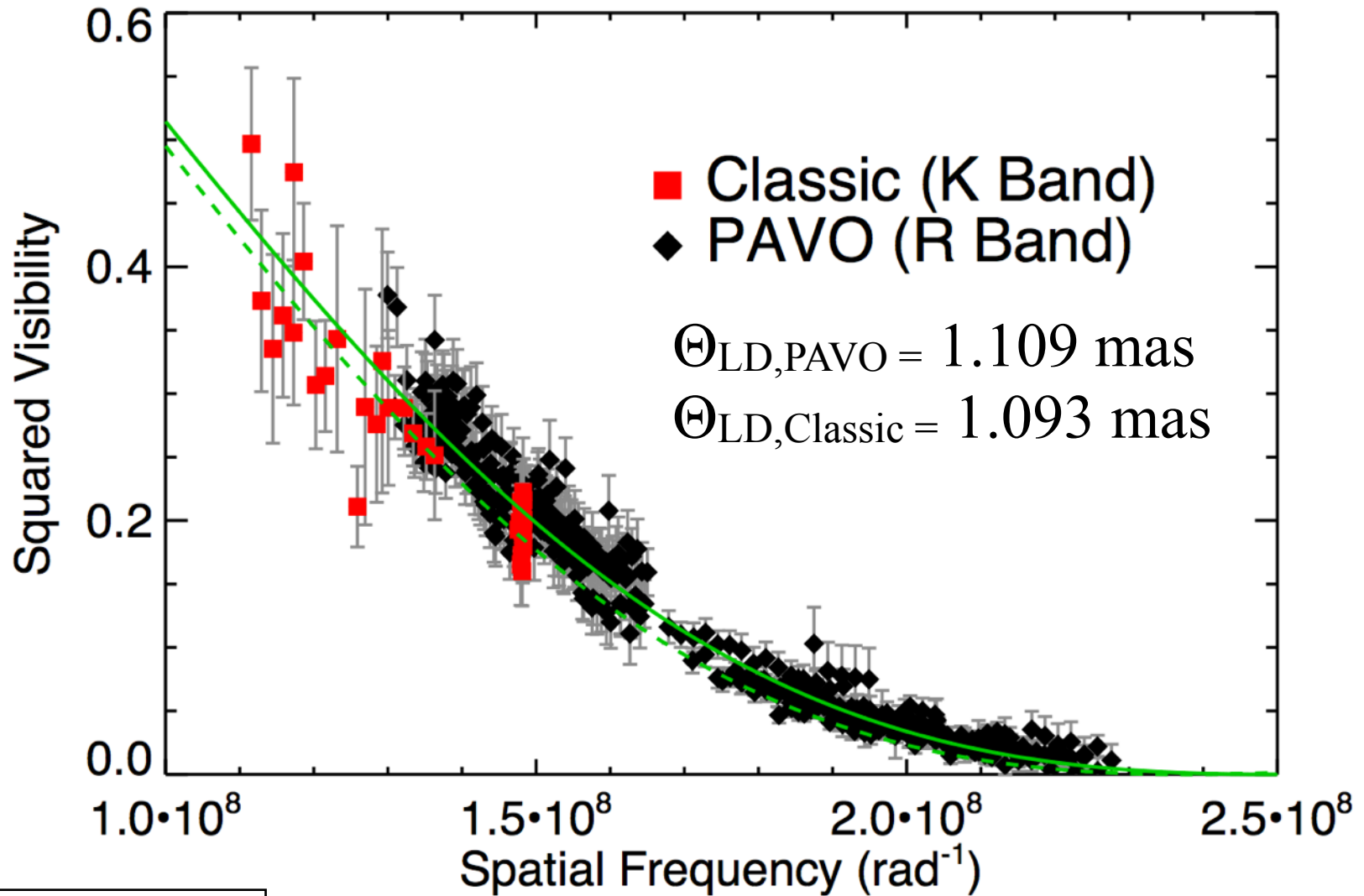


Interlude: Cross-Beam Combiner Calibrations



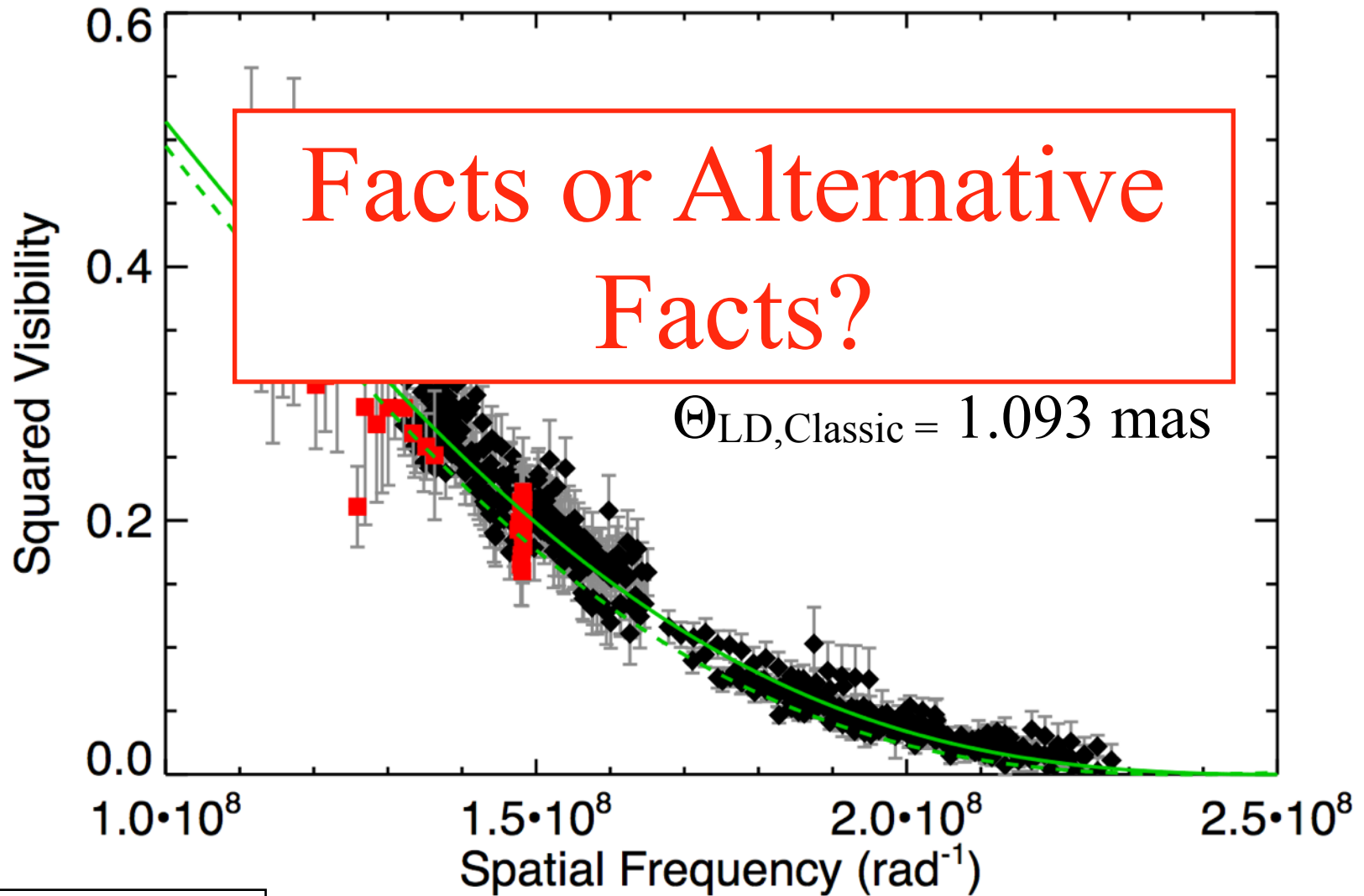


HD219134

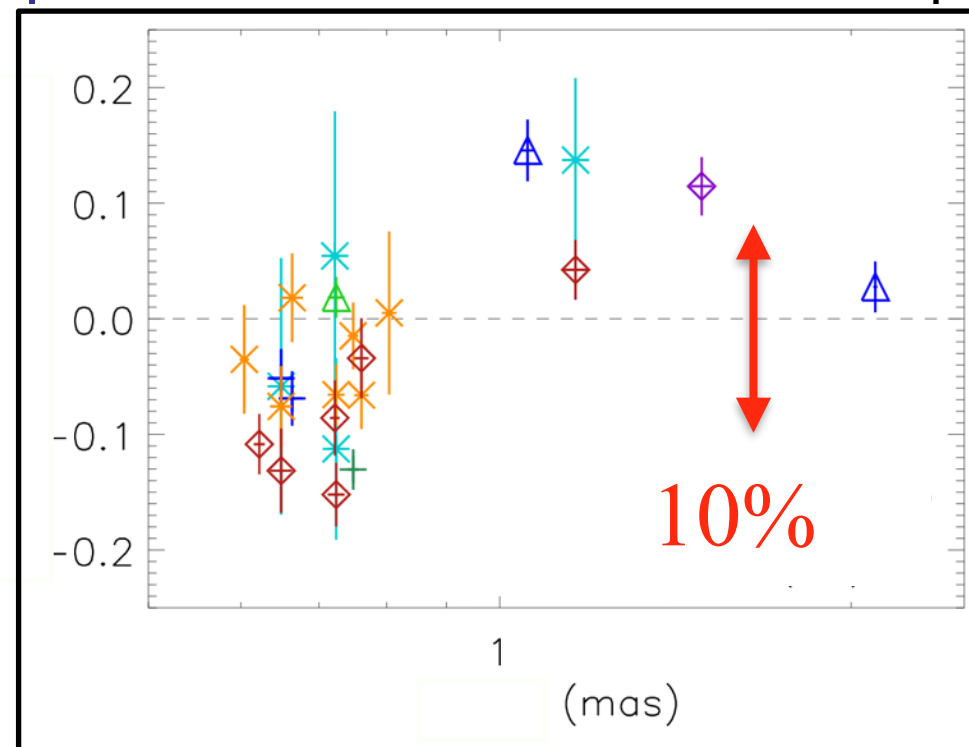
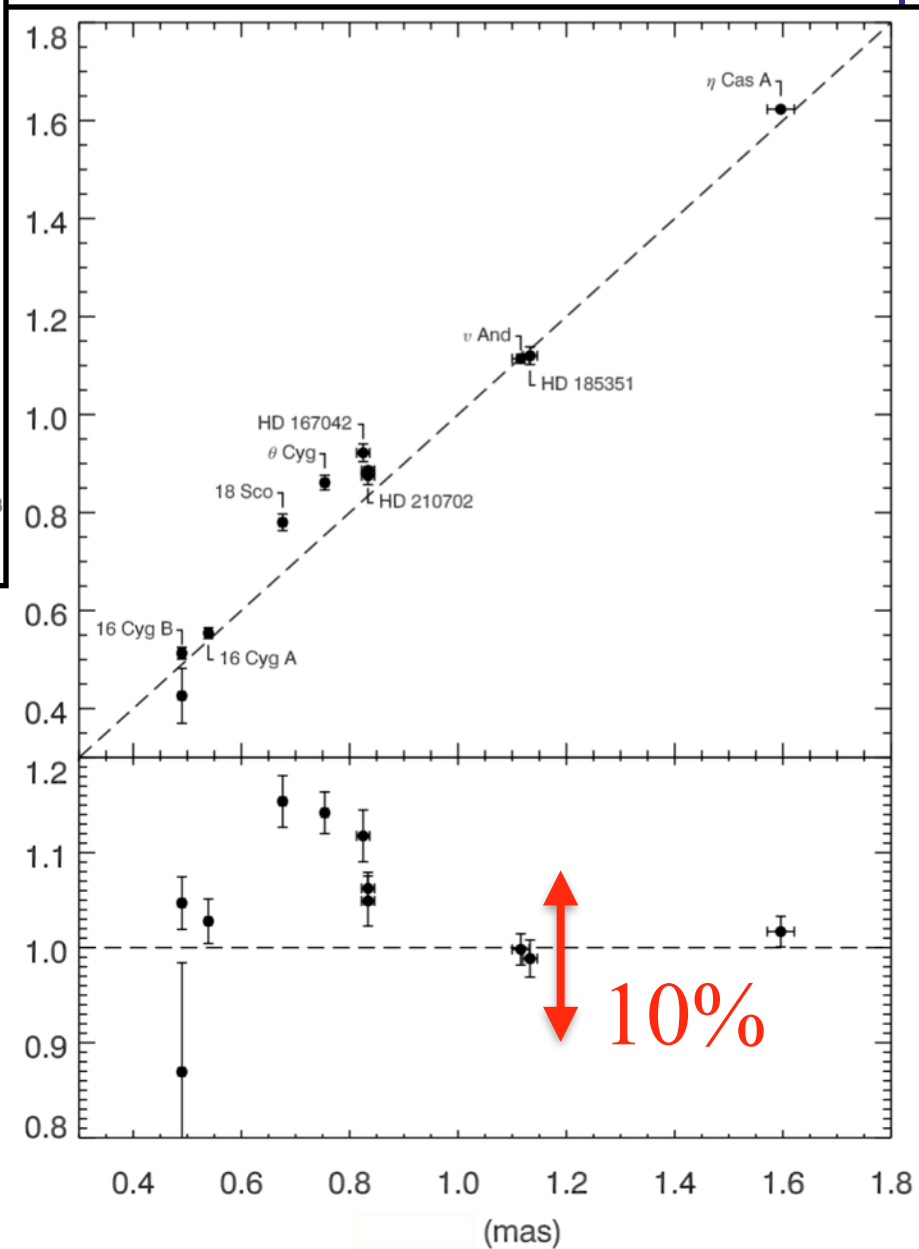
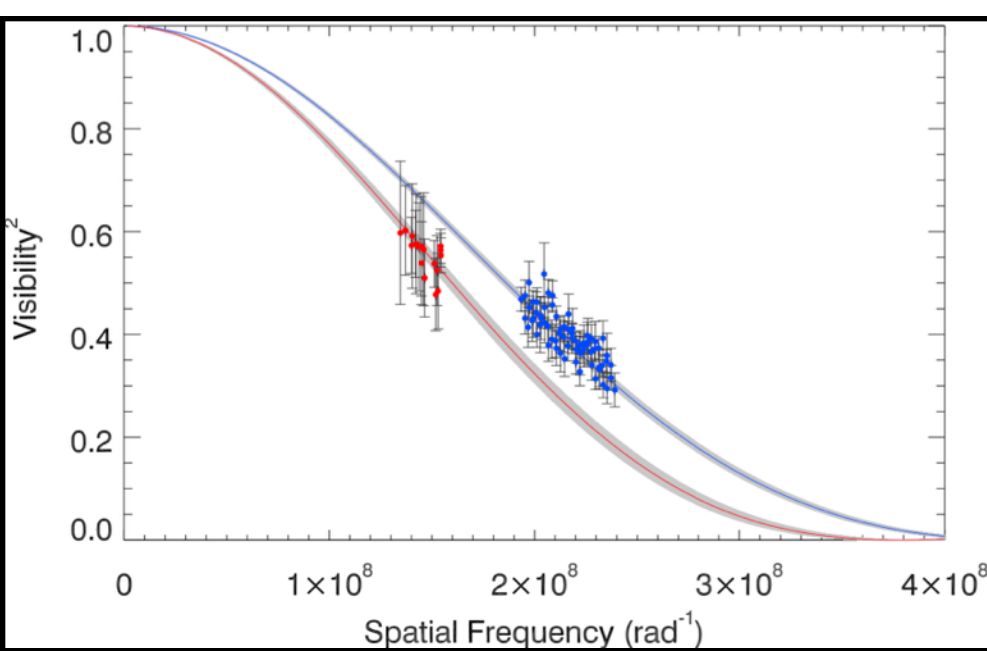


Huber 2016

HD219134

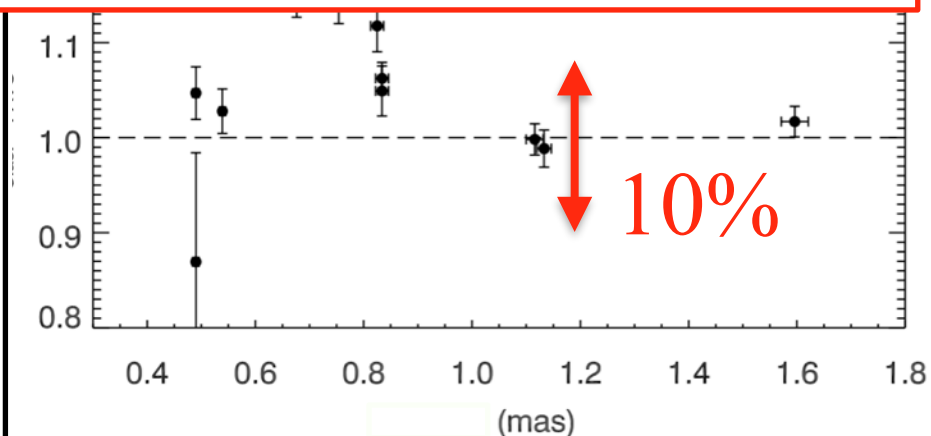
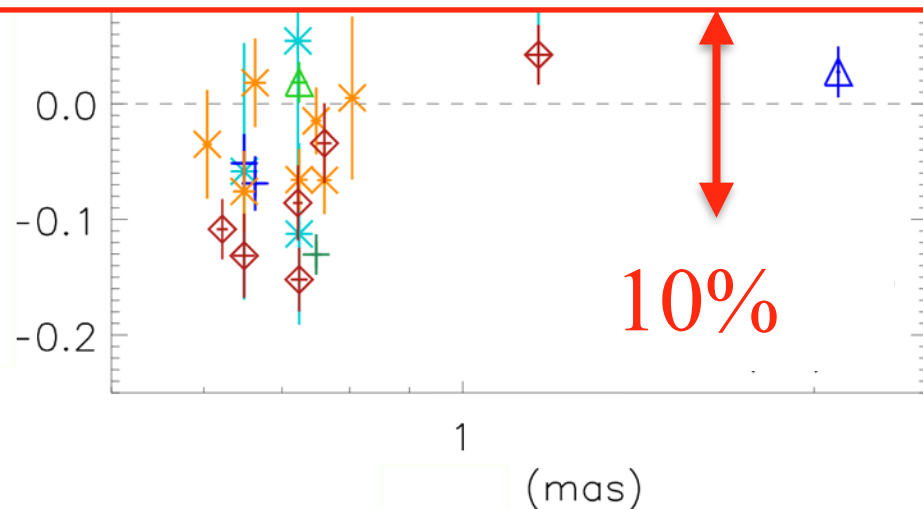


Huber 2016



Two massive rocky planets transiting a K-dwarf 6.5 parsecs away

Mass ($M_{\odot}$) [*]	0.81 ± 0.03	
Radius ($R_{\odot}$) [†]	0.778 ± 0.005	(0.6 %)
Effective temperature (K) [†]	$4,699 \pm 16$	(0.3 %)



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Solution: dedicated (simultaneous?), multi-beam combiner observations of the same target/calibrators?

1
(mas)

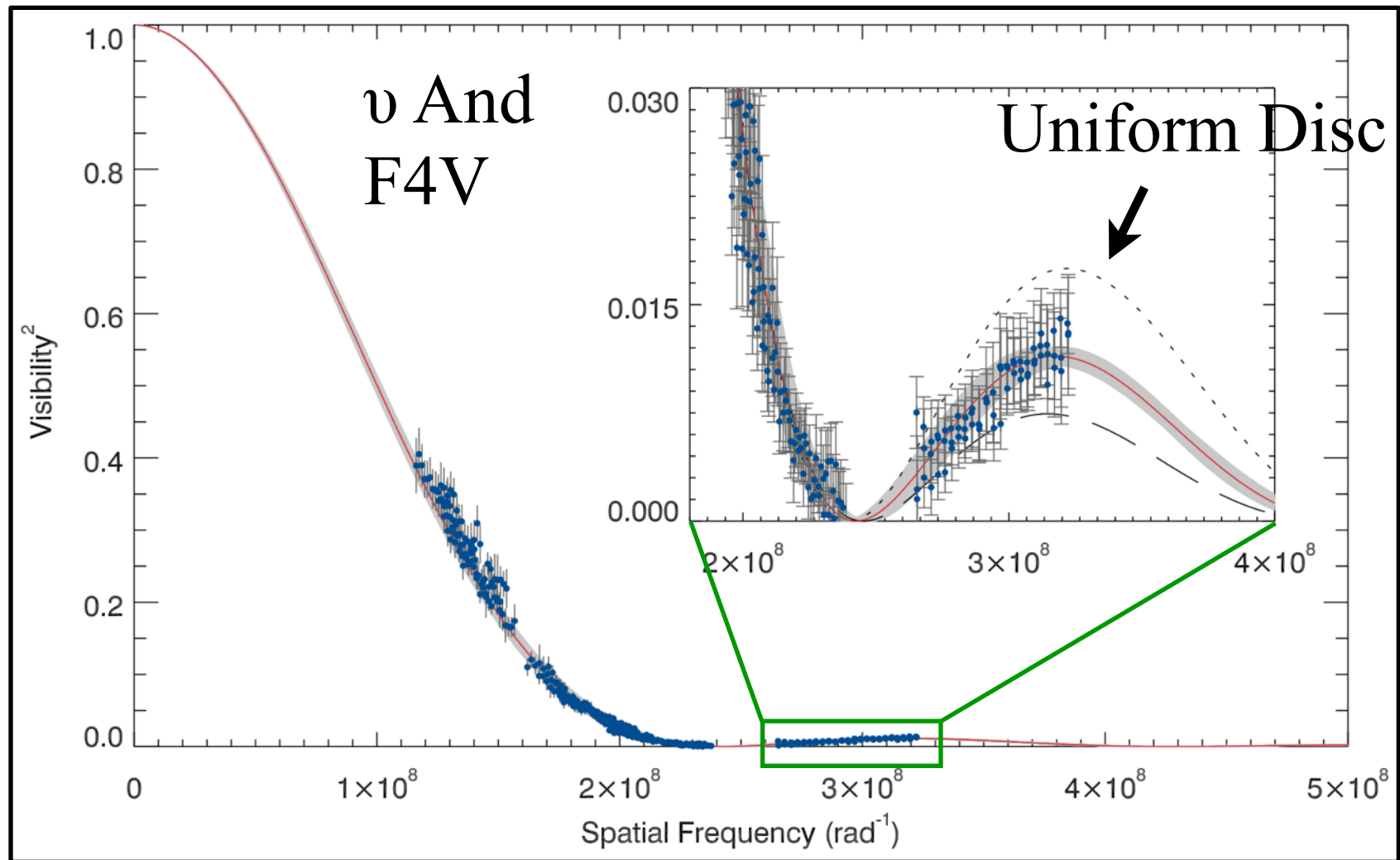
(mas)



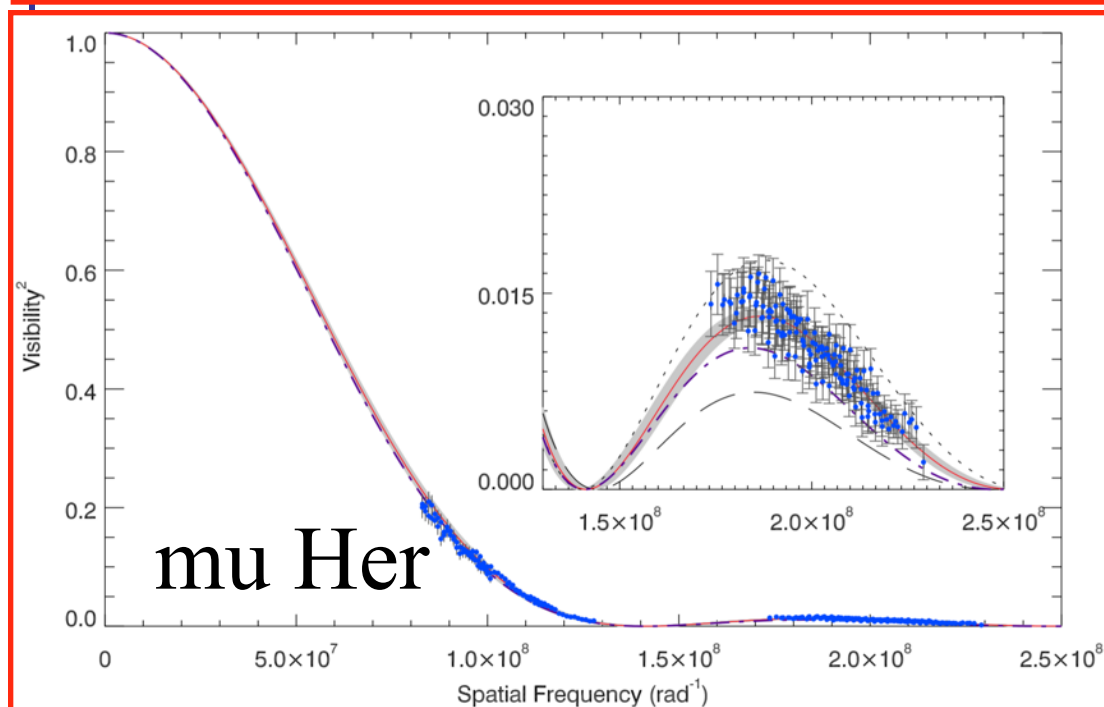
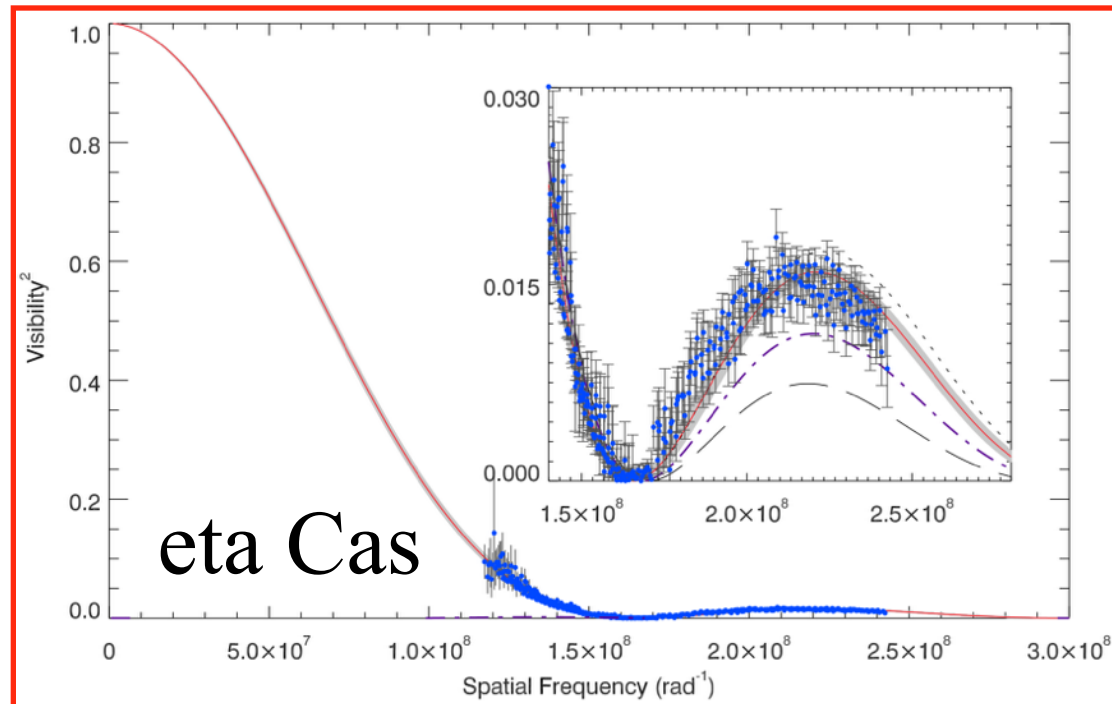
PAVO Science: Limb Darkening

White, Huber, Ireland, Tuthill,
Bedding

ups And (2T Data!)



White et al., submitted



- 4 solar-type stars with 2nd lobe 2T fringes
- systematically *lower* limb-darkening than expected from 1D atmospheres
- ...

White et al., in prep

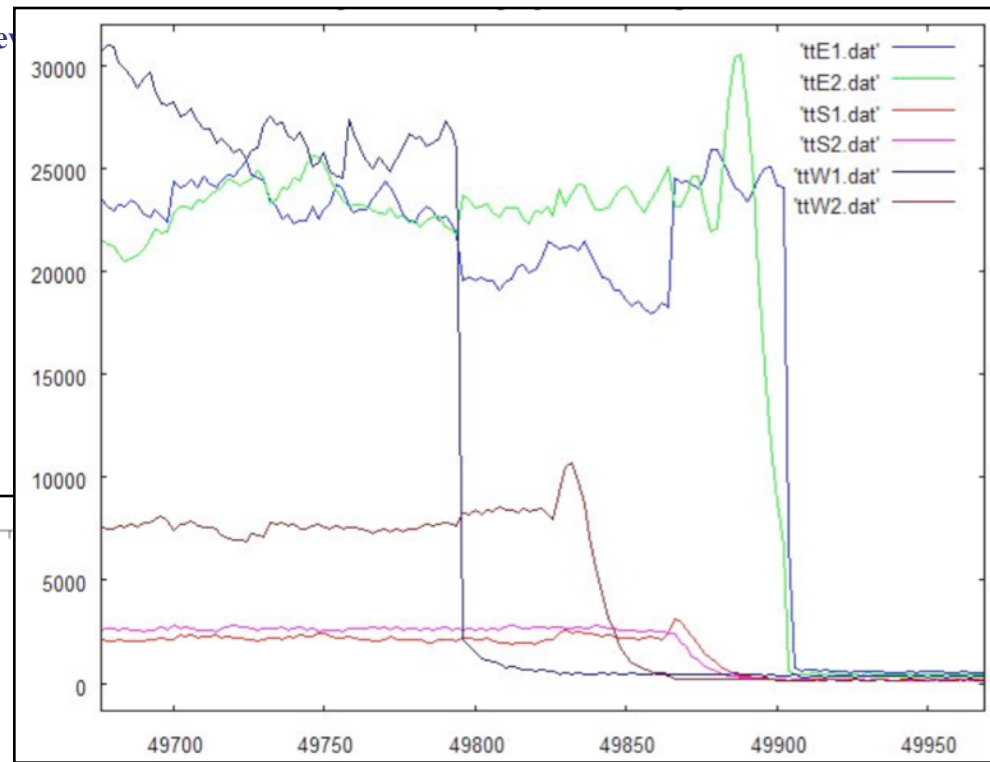
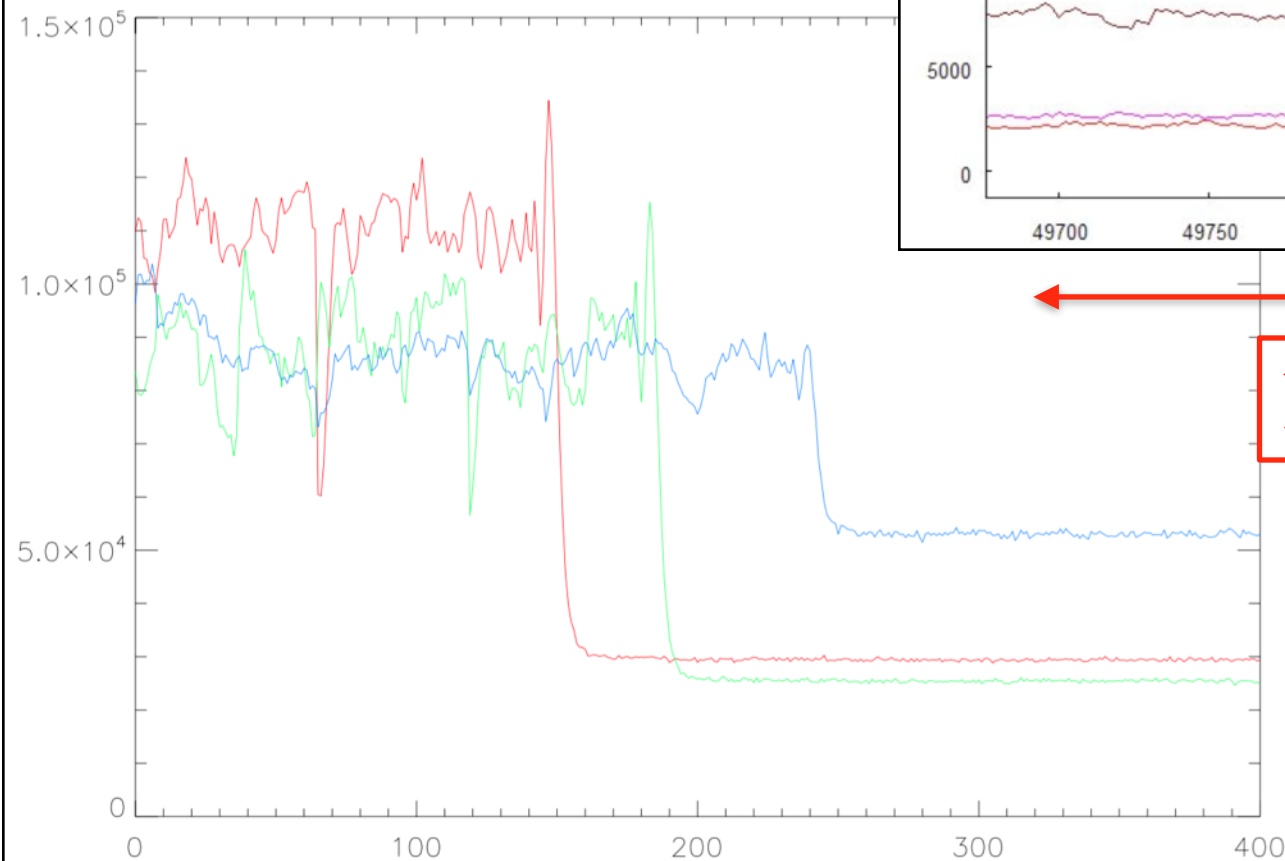
PAVO Science: Lunar Occultations

Tuthill, Richichi, Farrington, ten Brummelaar, ...



Tip-Tilt

PAVO



1 second



Detector T: -55.9A Status: run
ax: 493 Flux: 1.84e+05 Binning: 1x1 Exp Time (ns): 3.9
0.50N Late: 0 Size: 512x64 Count: 142, 338/ 200
n: 2032ople: OPEN/OFF Cosmic: 1.6 +/- 5.4
XY: -0.13 0.05Noff/on: 1.2 1.6 DTIME: 0.42
t Cnt V^2 V^2C Rat Disp Tel State Pos Vel TL S
0 338 3.716 3.772 1.015 0.0 V1 ACFF 0 0.0 0.0
0 338 1.234 1.221 0.990 -1.0 E2 ACFF 0 0.0 0.0
0 338 1.106 1.070 0.967 -3.0 W2 FIX 0 0.0 0.0

PAVO Image/Pupil Display

PAVO

GO/STOP SAVE AS

SEARCH LINEAR SHUTTER

VIDEO ACQUIRE

BACK FORE

MOVE: B1-M1

UP BIGGER

LEFT RIGHT step size: 100

DOWN SMALLER

X1[10]= 9437 X2[10]= 9437

Y1[9]= -33293 Y2[9]= -33293

B1 B2 B3

TARGETS LP02-568

DISPLAY NO DISPLAY

Gain: 120 Average: 10

IMAGE LENSLET PUPIL

ENG MASK OUT

STATUS DELAY PLOTS

REOPEN QUIT

Current Call

Gruplot



Summary

- 2T PAVO routine, 3T progress stalled by lack of (human) resources
- *Cross-Beam Combiner calibrations should become priority in open access CHARA era*
- Key Science (4+ papers in prep):
 - Asteroseismology (White/Huber)
 - Gaia Benchmarks (Karovicova/White)
 - Limb Darkening (White/Huber)
 - Lunar Occultations (Tuthill/Richichi)