HST/FGS Astrometry of Nearby Stars

Exoplanet Masses and Exoplanetary System Architecture

Fritz Benedict & Barbara McArthur

McDonald Observatory

University of Texas

Rory Barnes

University of Washington

Astrometry of Exoplanet Host Stars

•HST/FGS Astrometry (but RV essential!)

•Exoplanetary Masses and System Architecture for Nearby Systems

υ And

HD 128311

HD 33636

•Future of HST Astrometry

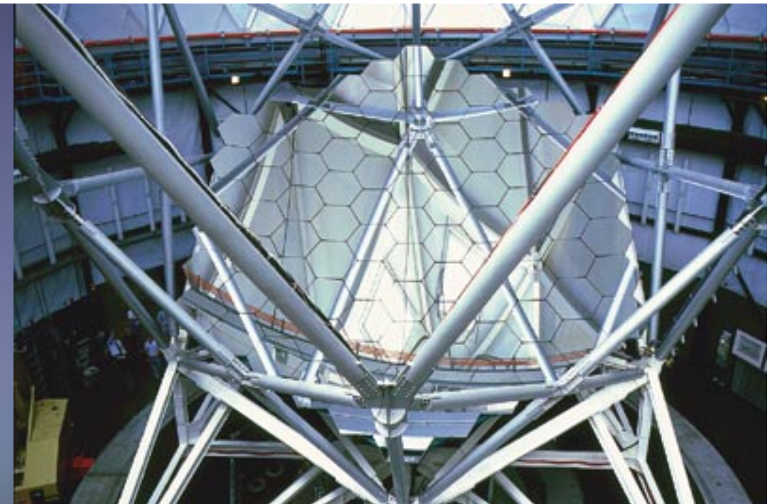
More architectures

M star masses

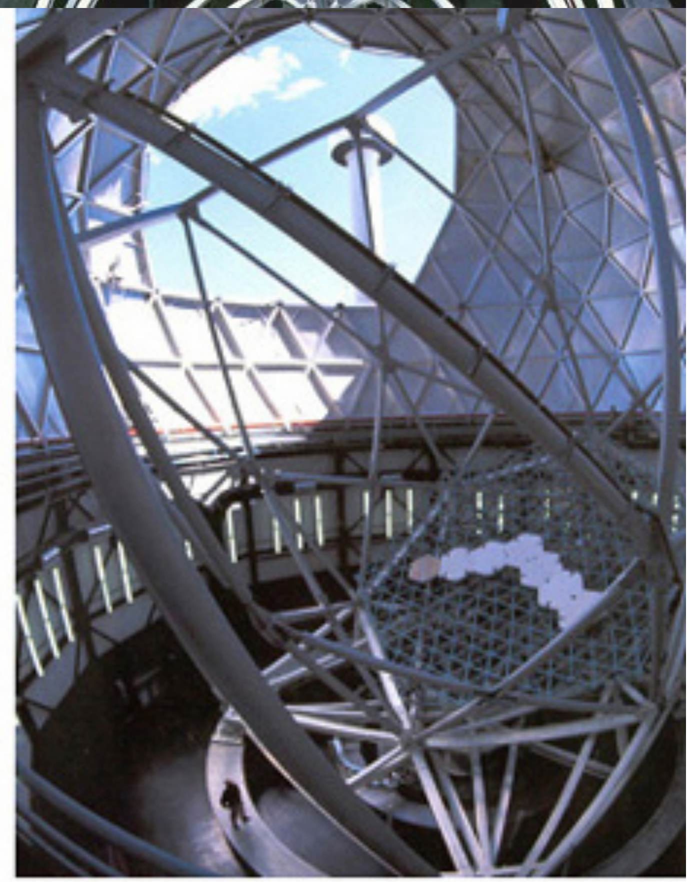
Things Gaia can't do

Typical response to the word ‘astrometry’

But stay awake – there is some RV stuff, too.



The queue-scheduled Hobby Eberly Telescope gives us high cadence and lots of epochs, which we desperately need because we don't get much coverage with HST.

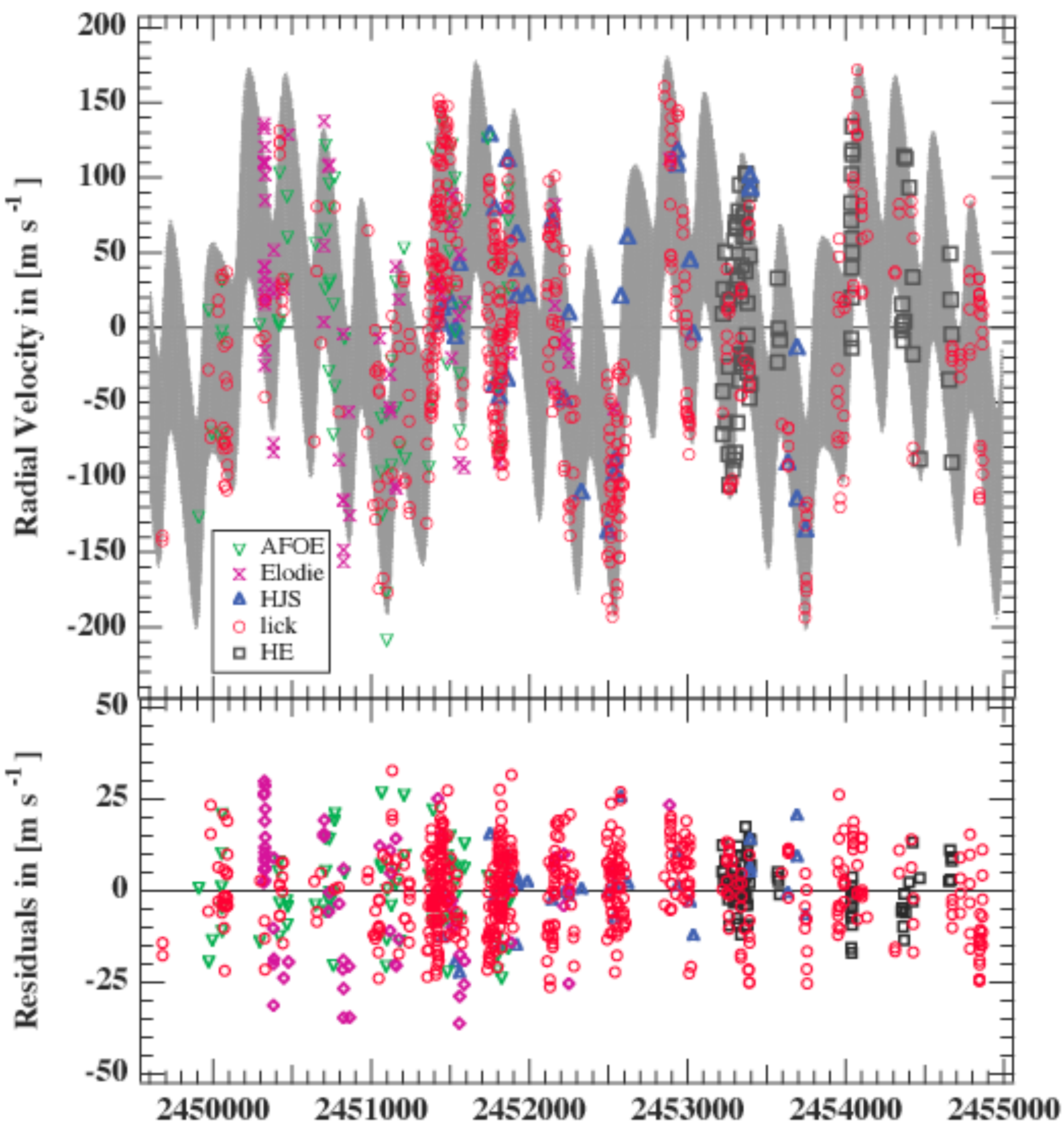


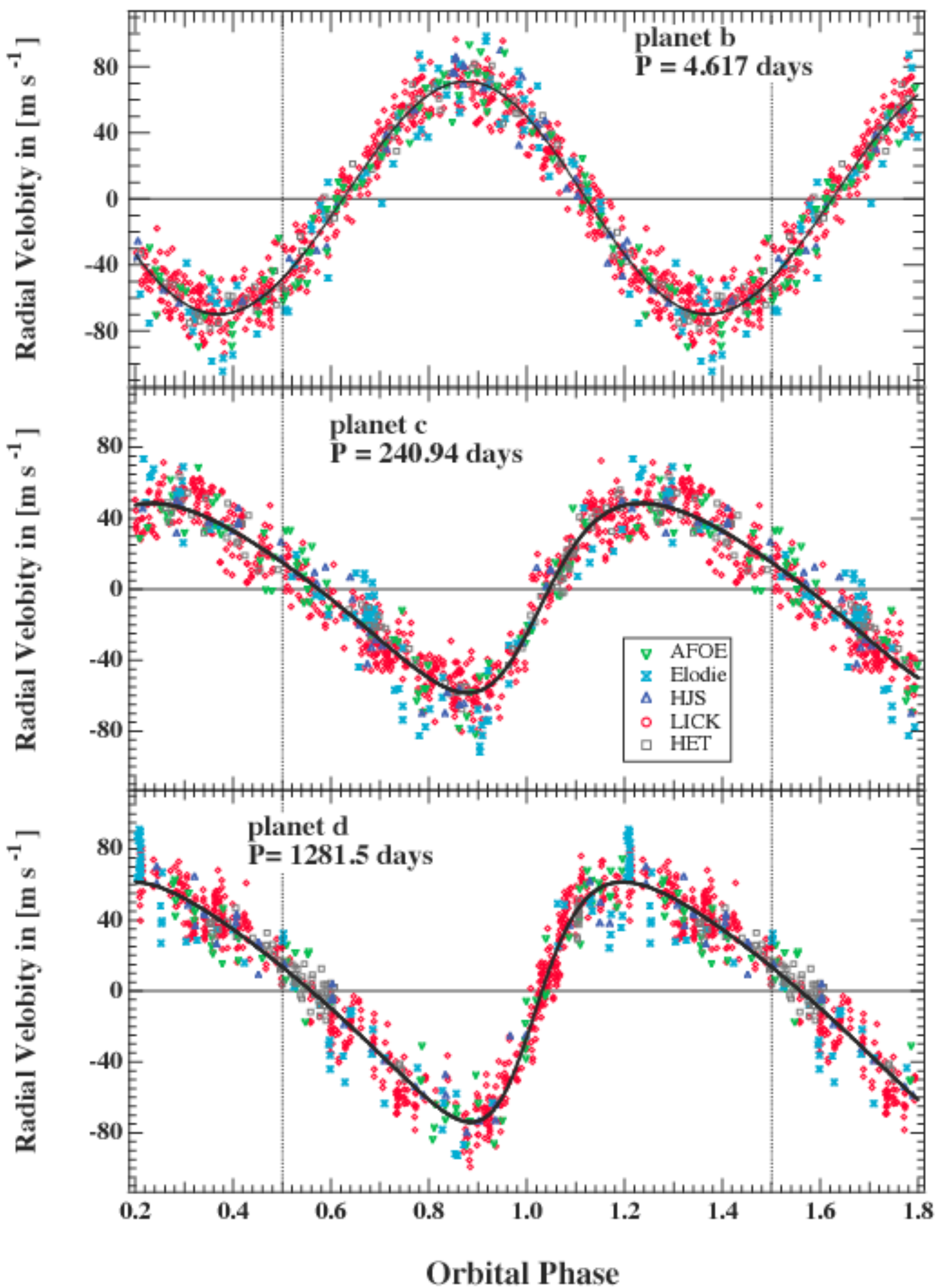
A sense of scale: A man stands next to the HET

A recent example of architecture determination

McArthur+, ApJ, 715, 1203

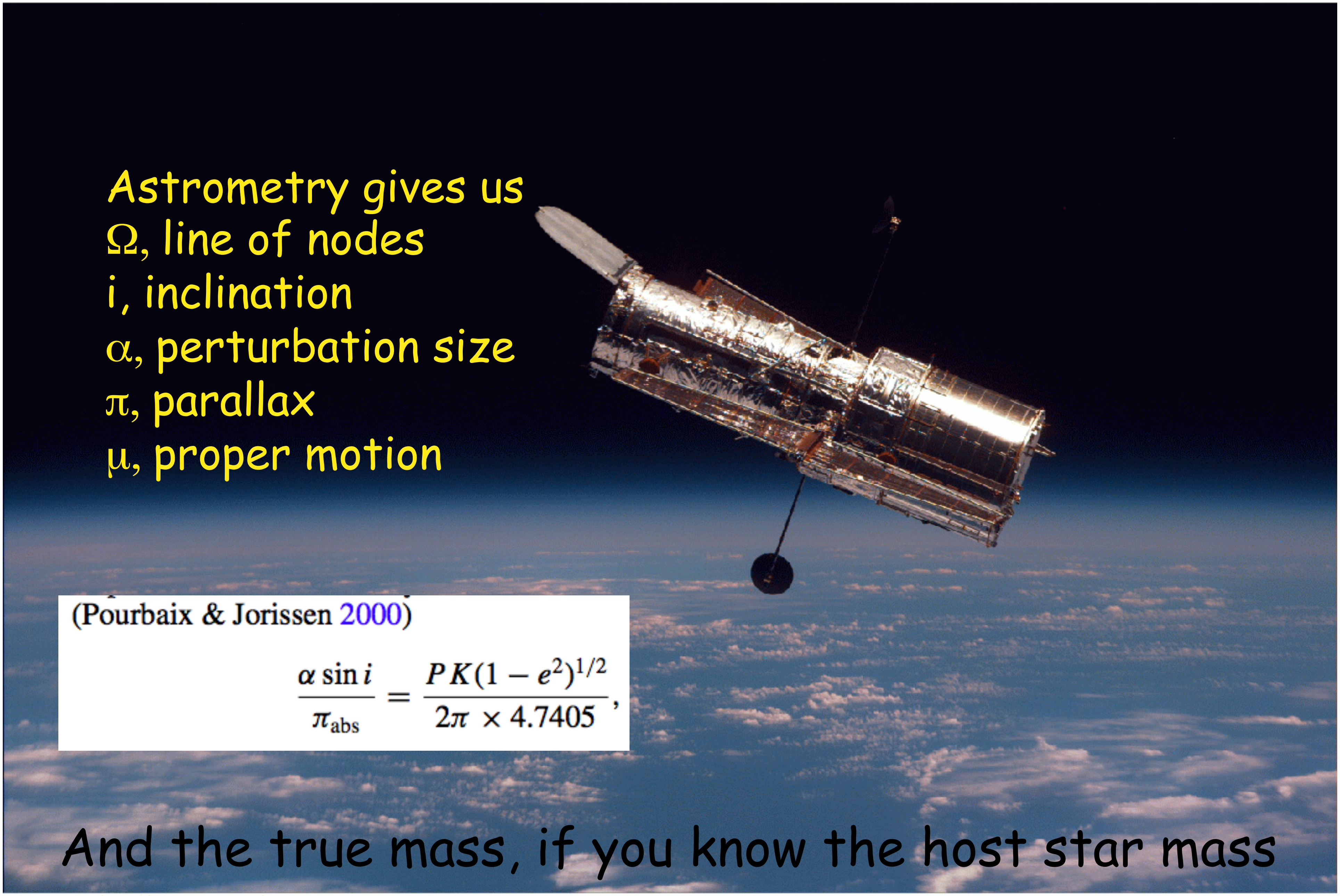
υ Andromeda, a star a little hotter, a little more massive, and a little richer in heavy elements than the Sun





RV gives us
K, RV amplitude
P, period
ε, eccentricity
ω, periastron ∠
T_0, time of ω

(long-term trend due to component e removed)



S82E5937 1997:02:19 07:06:57

Astrometry gives us

- Ω, line of nodes
- i, inclination
- α, perturbation size
- π, parallax
- μ, proper motion

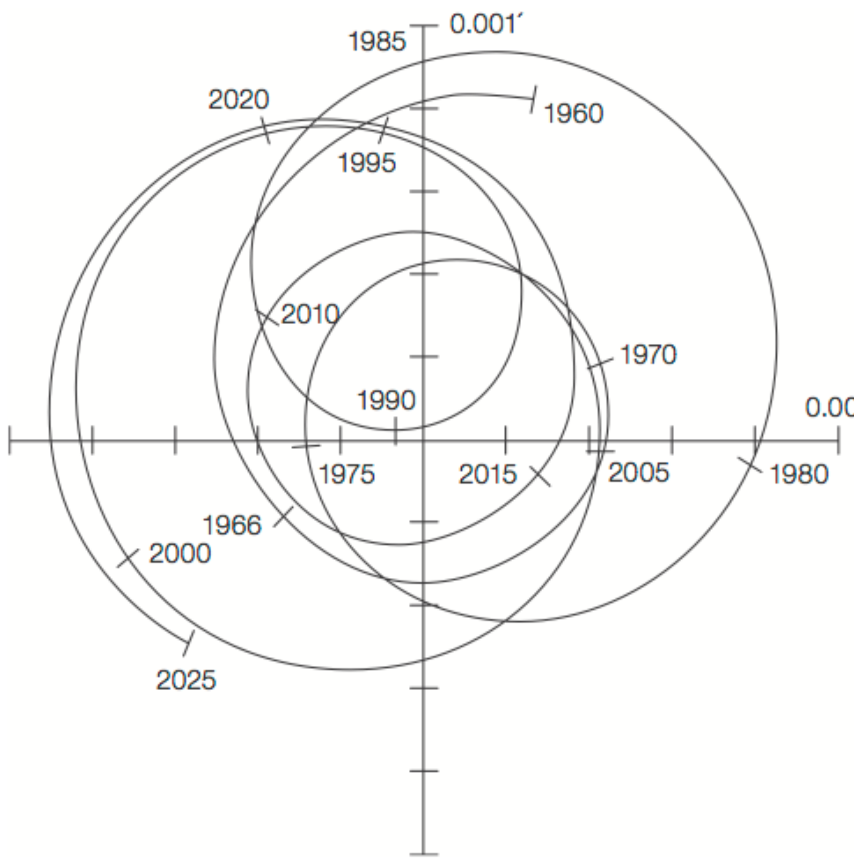
(Pourbaix & Jorissen 2000)

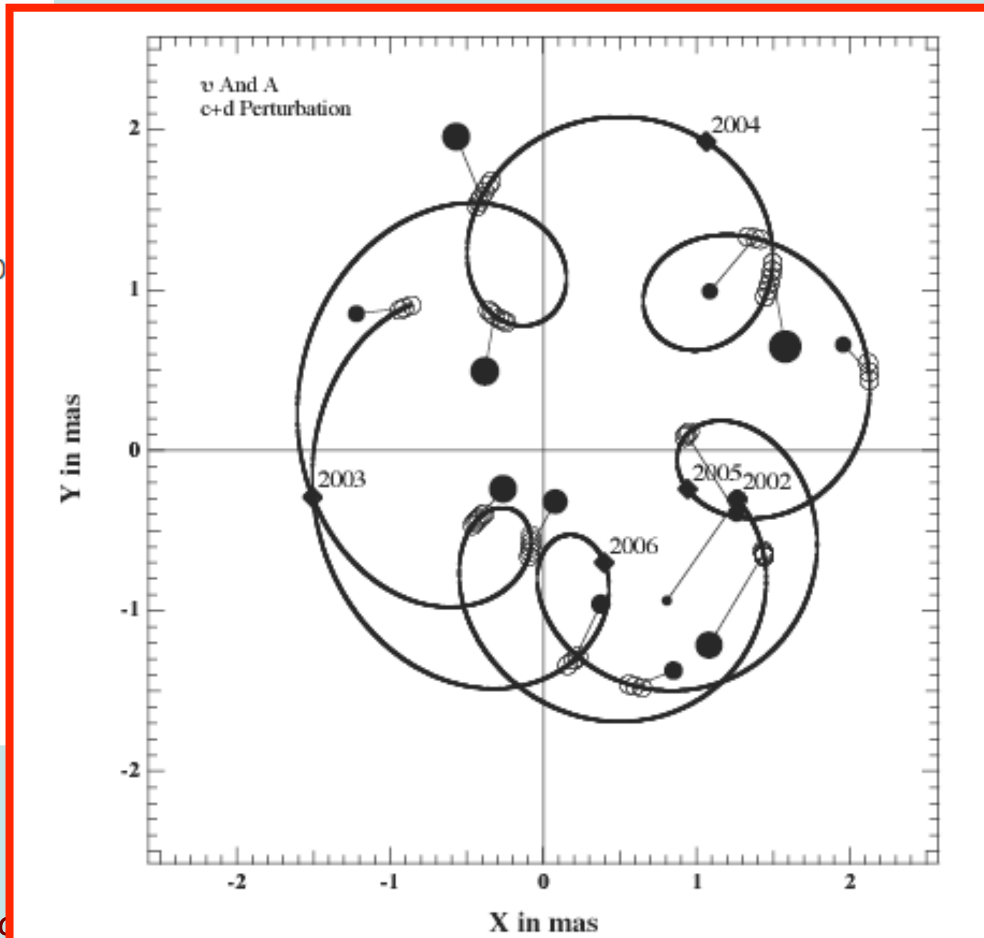
$$\frac{\alpha \sin i}{\pi_{\text{abs}}} = \frac{P K (1 - e^2)^{1/2}}{2\pi \times 4.7405},$$

And the true mass, if you know the host star mass

The Architecture of the υ And System (Analysis by Barbara McArthur)

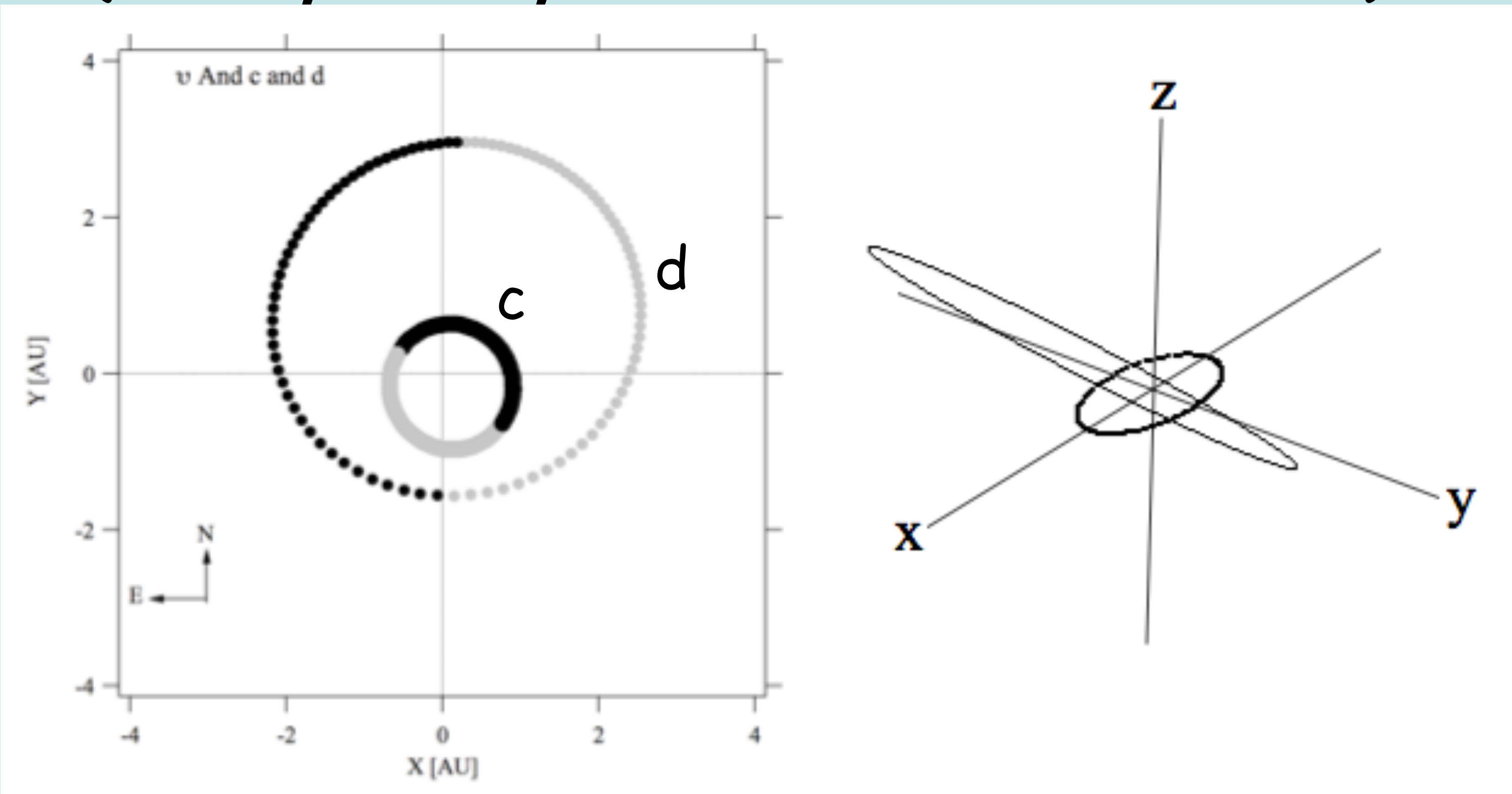
D=13pc





D=10pc

The Architecture of the υ And System (Analysis by Barbara McArthur)



Two suprises:

M_c = 14M_{Jup} M_d = 10M_{Jup} (mass magnitude switched from Msini)

$\phi = 35^\circ$ (mutual inclination)

υ And, the Movie

http://mcdonaldobservatory.org/news/releases/2010/0524-video.html

4.5 y span of data
to characterize
P_c=0.66y, P_d=3.5y

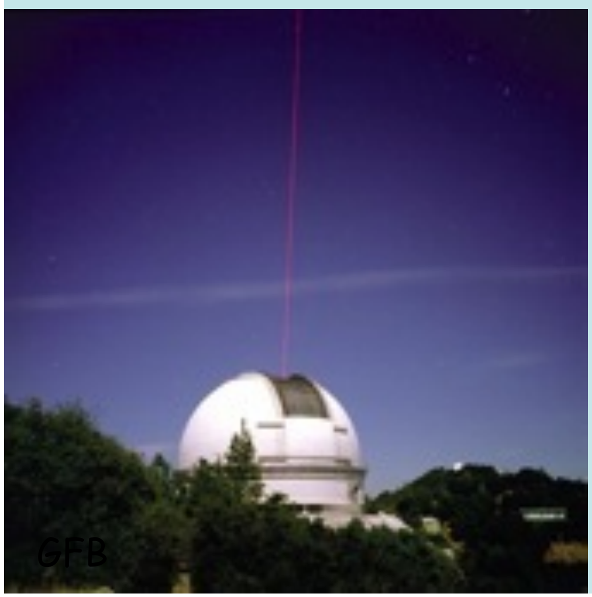
Why this mutual inclination?
Planet-planet scattering? (promiscuous planet formation)
Migration? (component b = Hot Jupiter)
M dwarf companion? (sep~9kAU, ε?)

HD 128311 b, c Perturbation Orbits

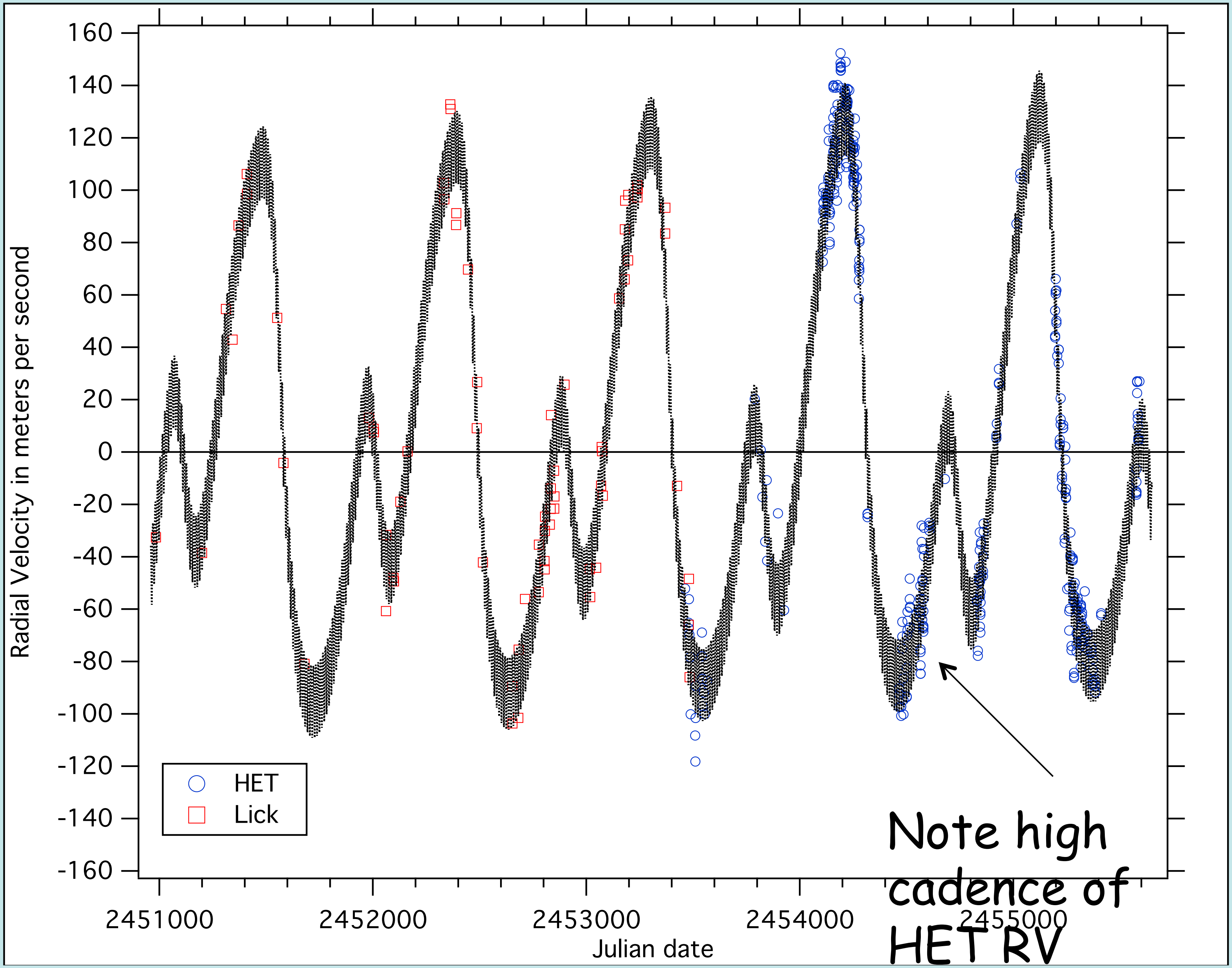
27 astrometric epochs in two clumps spanning only 1.6 years

P_b = 1.23y, α=0.11 mas
P_c = 2.52y, α=0.38 mas
(α predicted), D=16.6pc

12.6y RV Lick + HET



HD 128311 b, c, d(?) RV

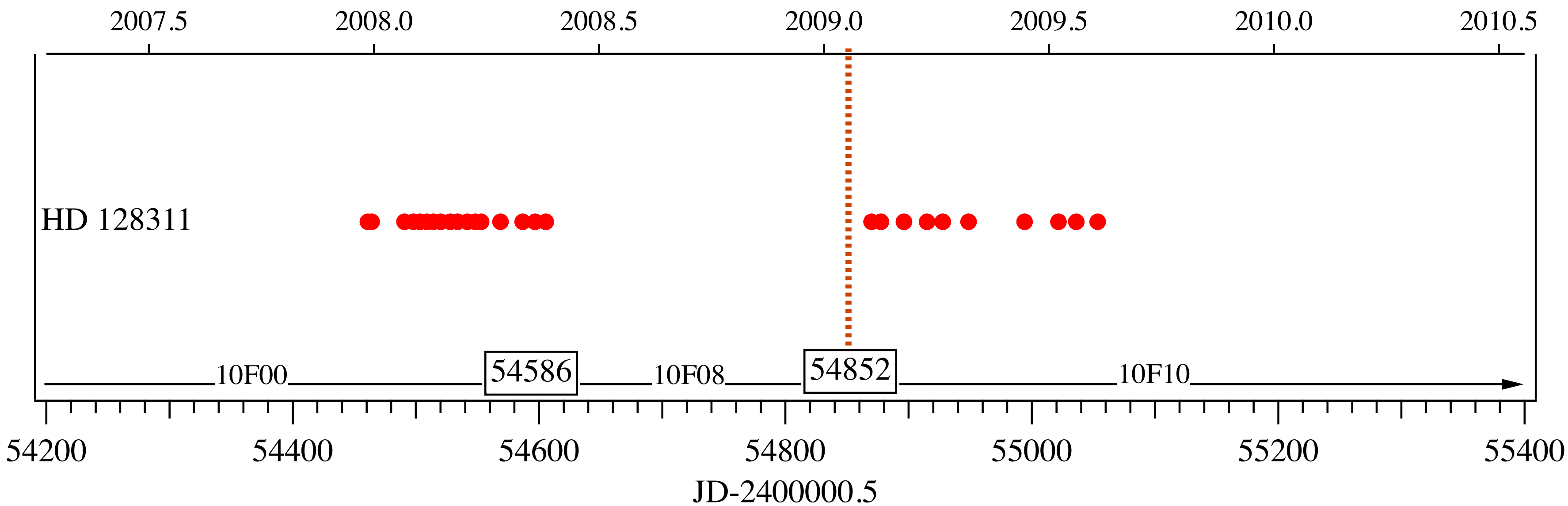


GFB

HD 128311 is an Active Star

- Activity introduces noise in RV signals
- HET RV preened using Bisector Analysis
- The signal of RV component d remains after preening
- Rules out activity/spots/rotation as generator of RV component d signal (K_d=13m s^{-1})
- Preening results in significant improvement in HET RV residuals (dropped rms by 5 m s^{-1})
- Dynamical modeling of our new RV orbital elements suggest that b and c components are not in mean motion resonance
- Paper (McArthur+ 2011) in preparation

Why HD 128311 is 'difficult'



Peculiar temporal distribution of astrometric observational epochs due to HST two gyro guiding constraints

Phase coverage of component c orbit not optimal

We don't yet 'see' component b, so no measure of mutual inclination

Exoplanet Masses with HST Astrometry

HST/FGS Astrometric Results									
Companion	M_* ($M_\odot$)	[Fe/H]	Sp.T.	d(pc)	ecc	M (M_{Jup})	α (mas)	inc(°)	P(d)
GJ 876 b	0.32	-0.12	M4 V	4.7	0.1	1.9±0.5	0.25	84±6	61
55 Cnc d	1.21	0.32	G8V	12.5	0.33	4.9±1.1	1.9	53±7	4517
ε Eri b	0.83	-0.03	K2 V	3.2	0.7	1.6±0.2	1.9	30±4	2502
υ And d	1.31	0.1	F8V	13.6	0.32	10±2	1.4	24±1	1282
HD 128311 c	0.79	0.08	K0V	16.6	0.29	4.2±1	0.6	50±10	911
υ And c	1.31	0.1	F8V	13.6	0.25	14±3	0.6	8±1	241
HD 136118 b	1.25	-0.05	F8V	51.7	0.35	42±15	1.5	163±3	1191
HD 38529 b	1.48	0.27	G4IV	40	0.35	17.8±2	0.9	57±14	2139

HD 128311 b inclination (mass) likely out of reach, unless we get more HST data

HD 33636

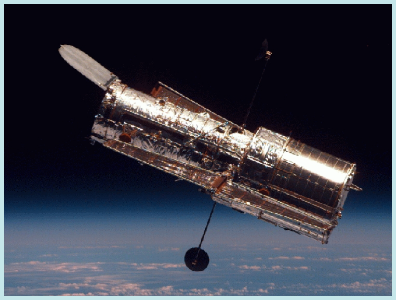
Additional HST/FGS data secured in November 2008, extending the time baseline from 1.2 y to 3.26 y. P_b=5.8y.

Proper motion and orbit remain severely entangled. Even with high-precision measurements, for this object it is difficult to establish an orbit with only fractional phase coverage.

HD 33636 b now more likely a brown dwarf, not an M dwarf, agreeing with Reffert & Quirrenbach (2011) Hipparcos result (but, again, only partial orbit).

More data are required, and have been requested (a fraction of a Cycle 19 HST proposal).

The Near-term Future

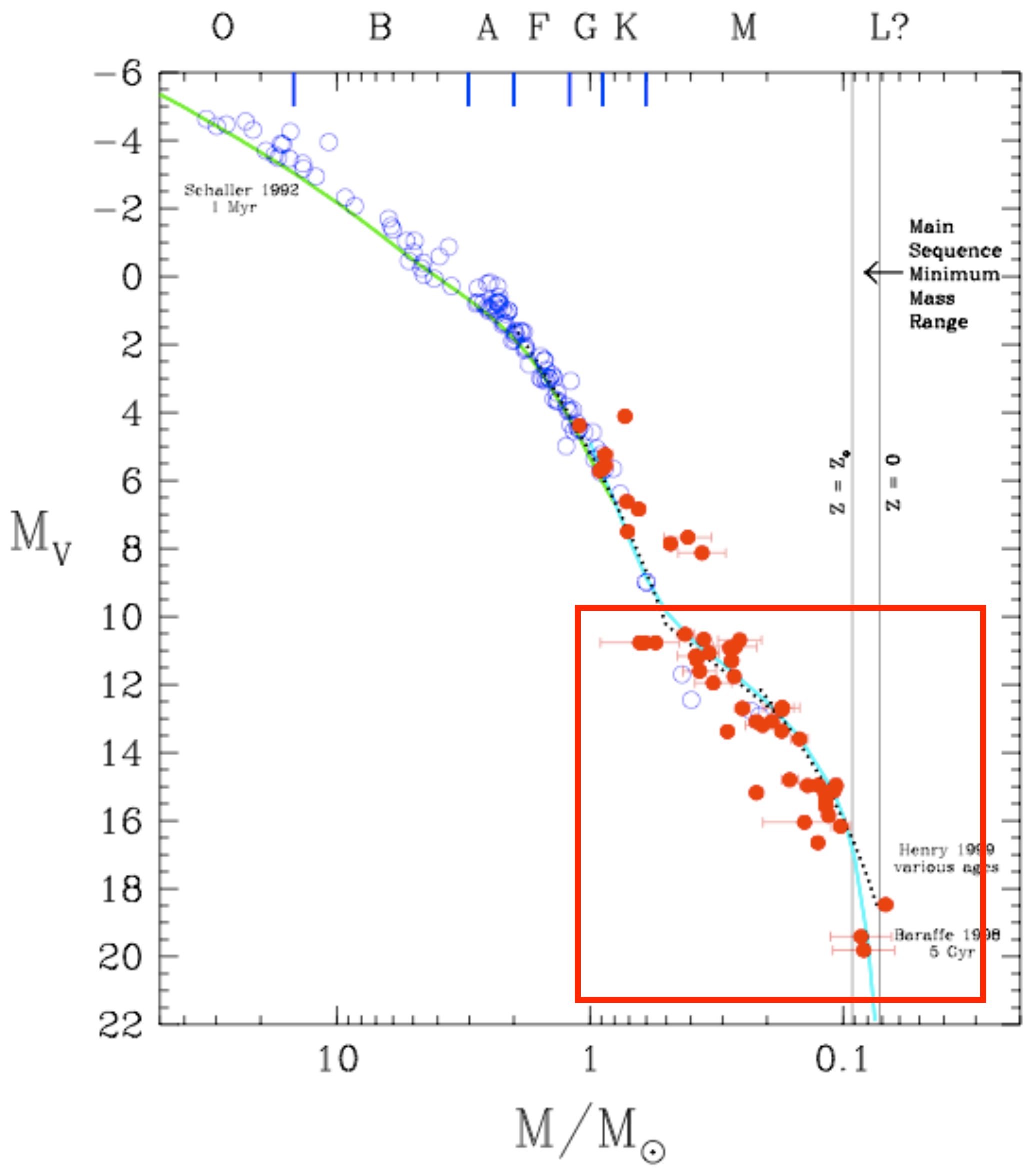
 + 

Mass Targets							
Companion	M_* ($M_\odot$)	Sp.T.	d(pc)	ecc	Msini (M_{Jup})	αsini (mas)	P(d)
HD 47536 b	1.1	K1 III	12.1	0.2	7	0.8	712
HD 168443 c	1.05	G6 IV	37.9	0.2	17.4	1.3	1739
Coplanarity Targets							
HD 202206 b	0.90	G6 V	46.3	0.44	17.4	0.5	256
HD 202206 c	0.90	G6 V	46.3	0.27	2.4	0.2	1383
μ Ara b	1.15	G3 IV	15.3	0.31	1.7	0.3	630
μ Ara c	1.15	G3 IV	15.3	0.57	3.1	0.5	2490
γ Cep Ab	1.18	K1IV+M4V	13.7	0.11	1.4	0.8	2207

Exoplanet mass accuracy depends on stellar mass accuracy.

M star masses, not well characterized…

M star masses "Yesterday"



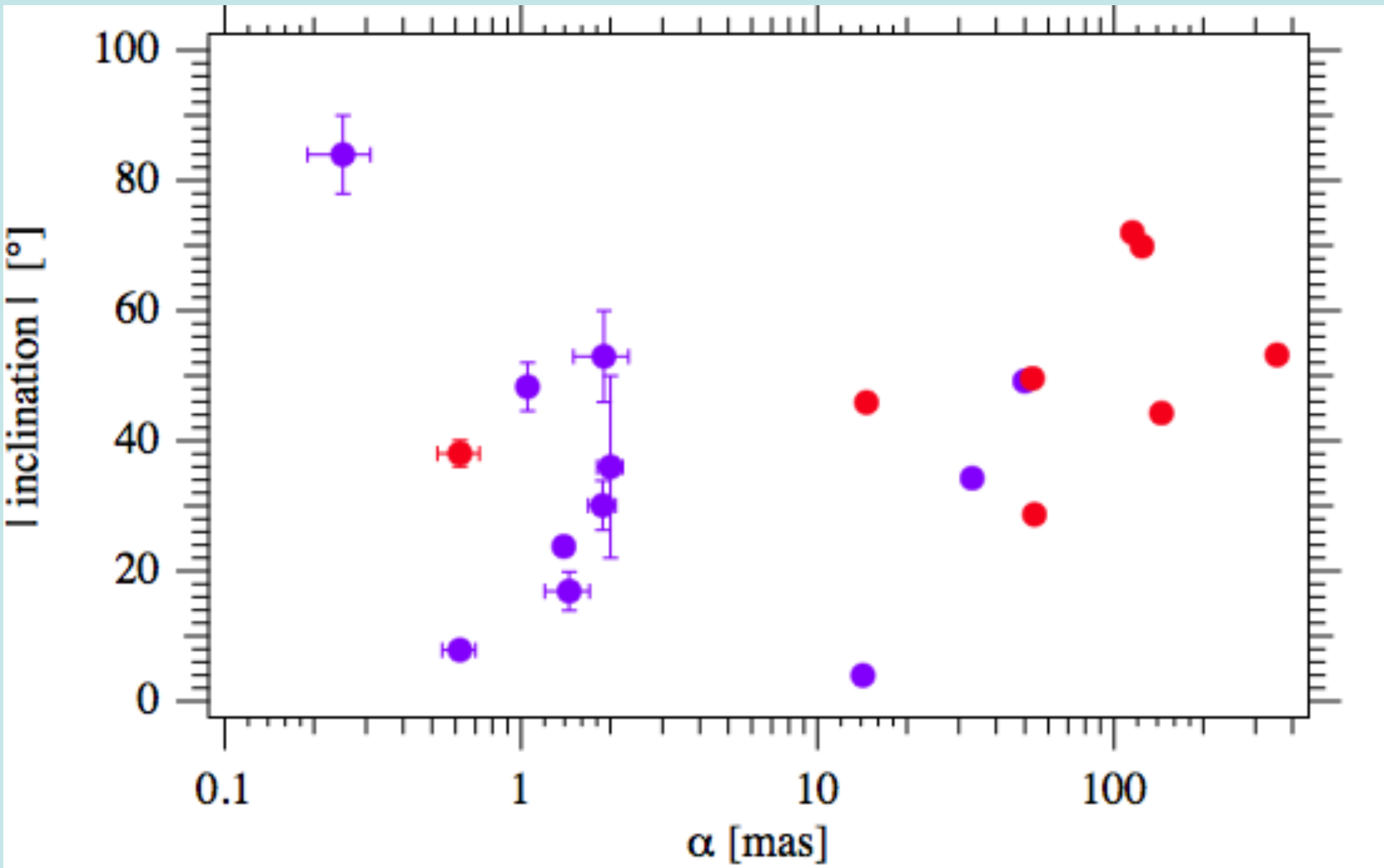
M star masses
better "tomorrow"

Preliminary and incomplete

HST/FGS astrometry of and masses for M star binary components,

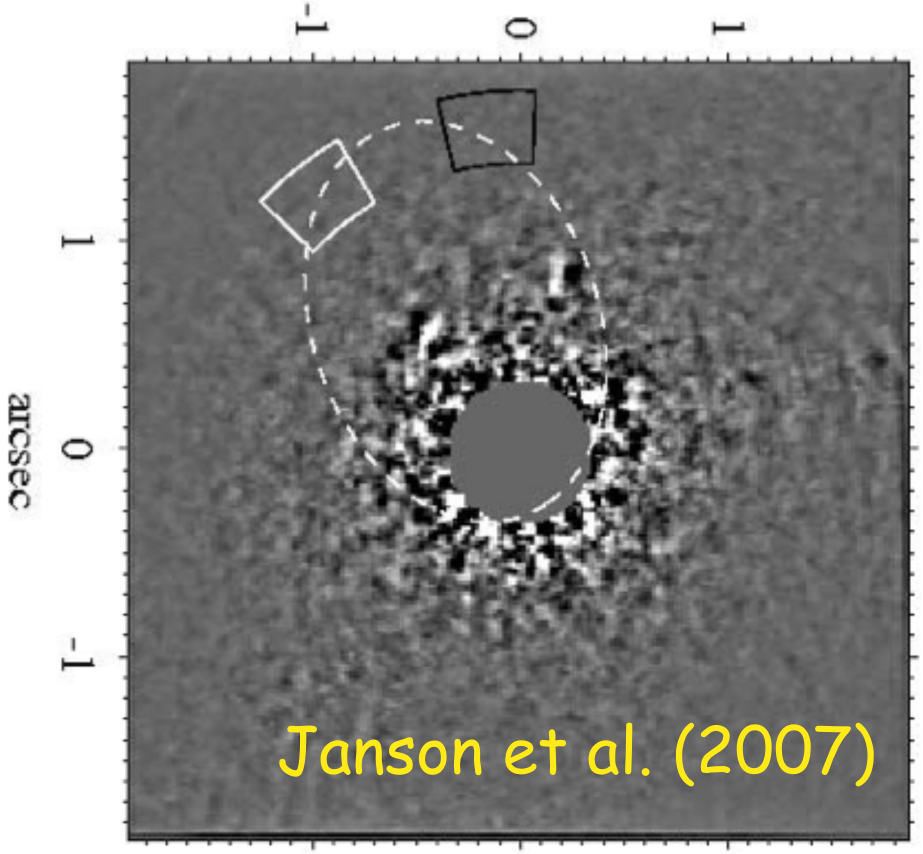
Henry et al. 2011, in preparation

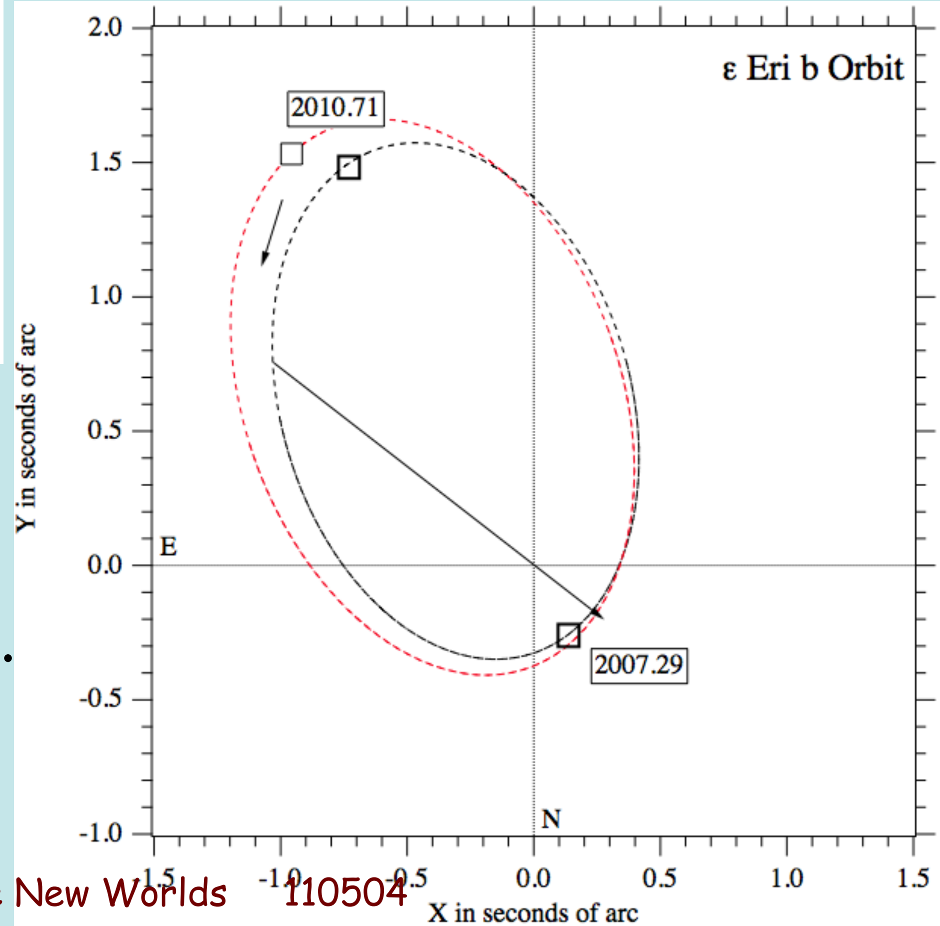
HST/FGS astrometry to date has produced 19 inclinations, some published (most exoplanets), some not published (most M dwarf binaries)



Motivation for another Cycle 19 HST proposal

ε Eri b, a prime direct imaging candidate, D=3.2pc





Ephemeris run-out errors

HST can improve ephemerides.
Gaia cannot (V=3.73).

Conclusions

- Architecture for nearby systems is difficult but not impossible to establish. As much orbital phase coverage as possible; valuable.
- HST will shortly contribute to improved M star mass accuracy.
- Gaia will blow the lid off this field, but will not contribute to our knowledge of components of the nearby (bright) systems.