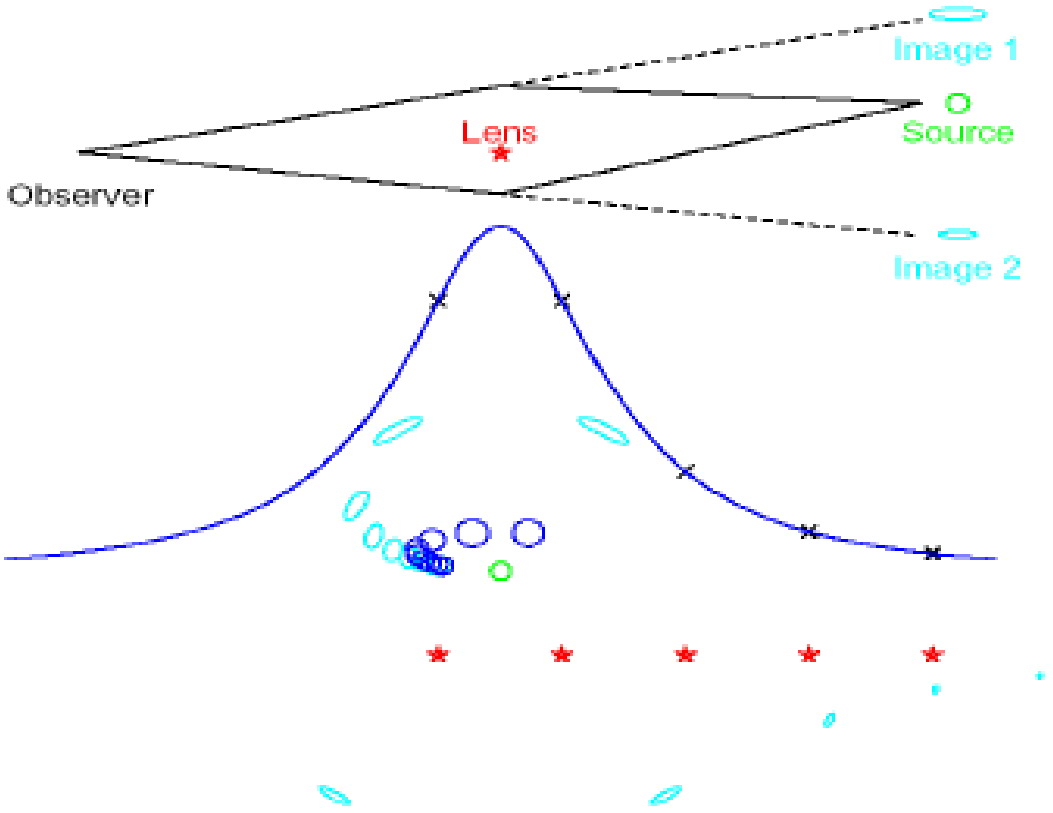
Precision CMDs in the Gaia Era

Andy Gould (OSU)



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Clusters

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- “Weird-looking” star ==>
  - Really “weird”
  - Not in cluster

Gaia: 6 phase-space coordinates

- Proper motions
  - Limit: scatter ~ 0.5 km/s
  - vs. ~25 km/s field star dispersion
  - 99% of cluster stars $\Delta v < 1.5$ km/s
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- RVs – roughly 10% discriminant

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- Blue Stragglers
- “Loop” stars
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- D < 7 kpc

Available Volume I: A-F stars Comparison to Present Sample

- Hyades ~ excellent (σ(v) ~ 1 km/s)
- Pleiades ~ good (σ(v) ~ 0.5 km/s)
- Few others

Available Volume II: K stars

- $M_V \sim 6$
- $\sigma(\mu) = 13\ \mu as/yr\ 10^{(V-15)/5}$
- $\sigma(\mu) = 20\ \mu as/yr\ (D/kpc)$ [Gaia]
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- $D < 2.2$ kpc

More Generally

- $M_V \sim 6$
- $\sigma(\mu) = 13\ \mu as/yr\ 10^{(V-15)/5}$
- $\sigma(\mu) = 20\ \mu as/yr\ (D/kpc)$ [Gaia]
- $\sigma(\mu) < 100\ \mu as/yr\ (kpc/D)$ [Required]
- $D < 2.2\ kpc\ \ (M_V = 6)$
- $D < 2.2\ kpc * 10^{-(M_V-6)/10}$

Available Volume I: K stars Comparison to Present Sample

- Hyades ~ very good (σ(v) ~ 1.5 km/s)

Field stars: Parallax Important (Rather Than Proper Motion)

- Similar calculation (but 40X less forgiving)
- $D < 2.2$ kpc * $10^{-(M_V-6)/10}$ (proper motions)
- $D < 0.3$ kpc * $10^{-(M_V-6)/10}$ (parallaxes)
- Disk G dwarfs within 0.3 kpc
  - $n \sim 0.01$ pc^{-3}
  - $4\pi/3(300 \text{ pc})^2 * n = 1*10^7$
- Halo G dwarfs within 300 kpc ~ $2*10^4$

Galactic Bulge?

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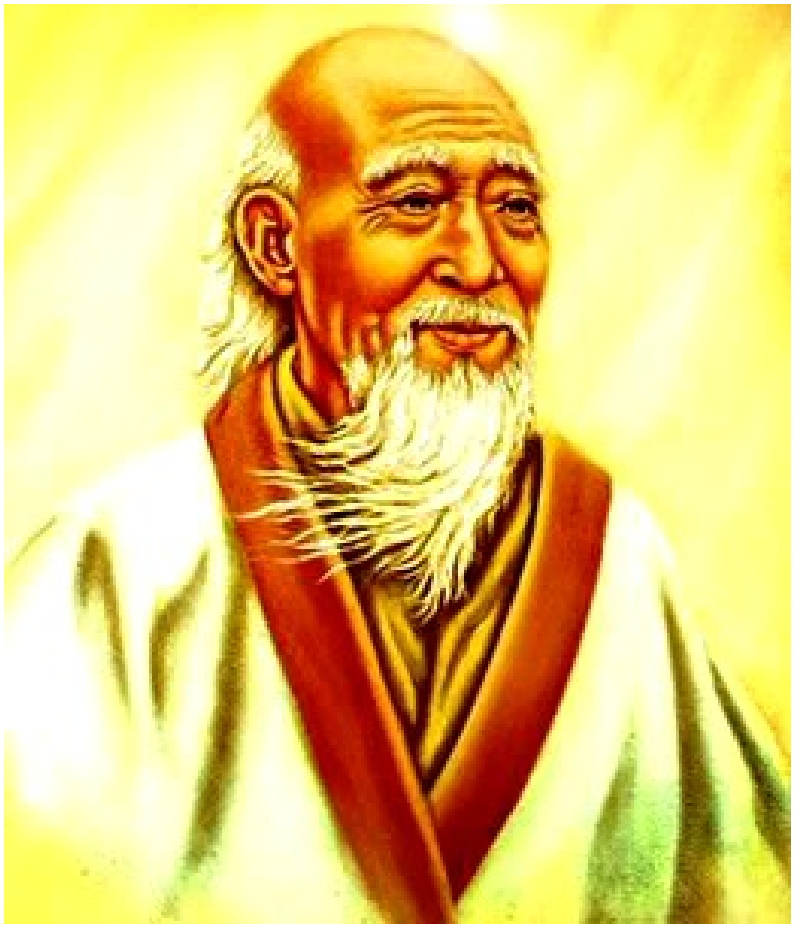
- Gaia useless! (Modulo Lao Tzu)

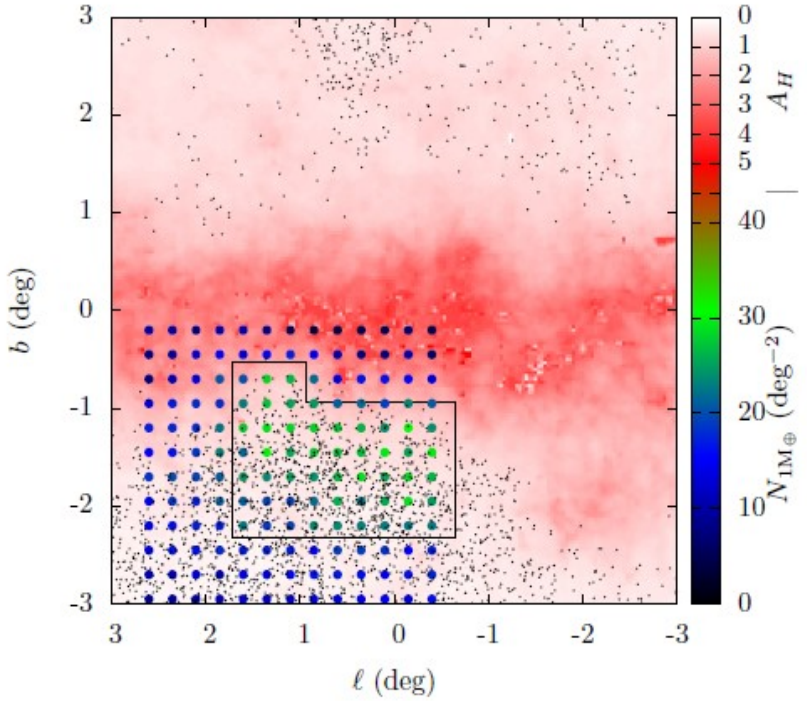
Lao Tzu

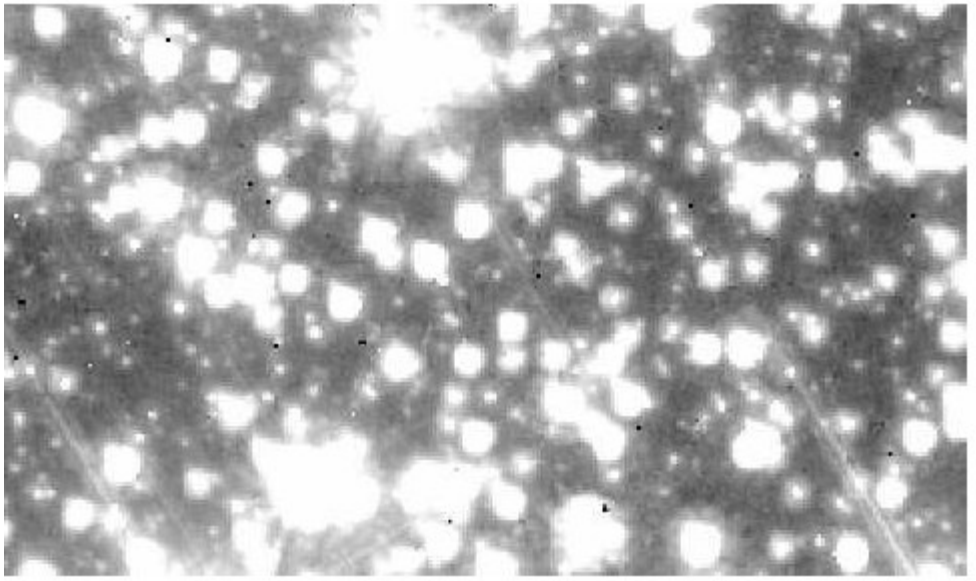


- “Any man knows the use of the useful, but it takes a wise man to know the use of the useless.”

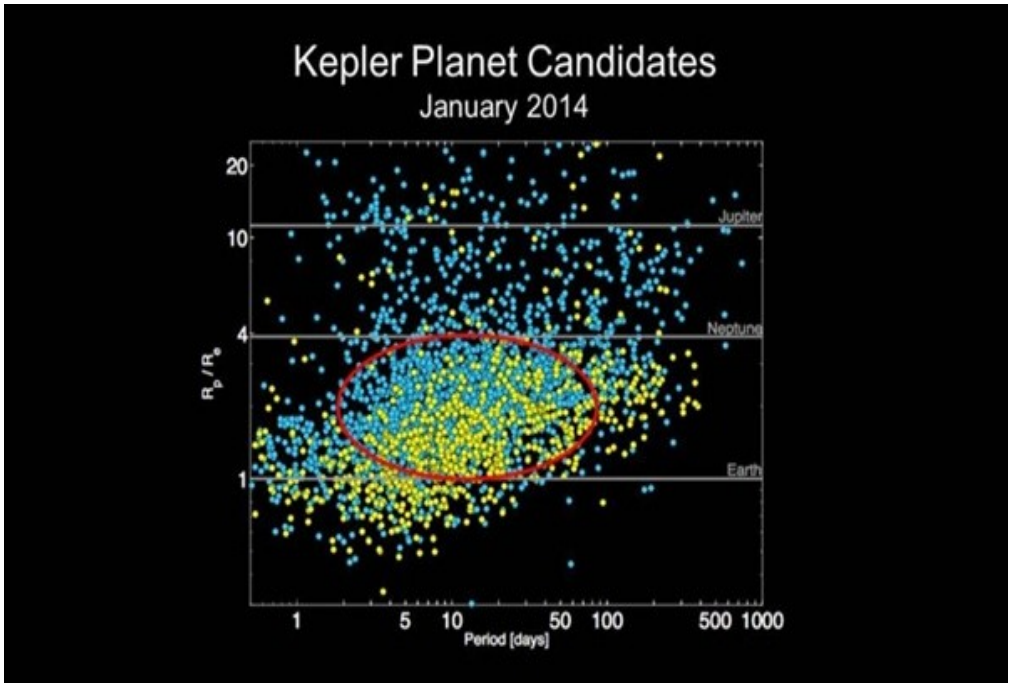
WFIRST Bulge Astrometry

- $\sigma(\pi) = 4\mu as$ for 4e7 stars (H<19.6)
- Precision Ages for 7e6 stars from Sun to GC
- Precision orbits for 5000 KBOs (R<30)
- BH and NS companions P<5 years of 1e8 stars
- Census of isolated BHs
- Neptune transit sensitivity a<10 R_* for 3e7 stars



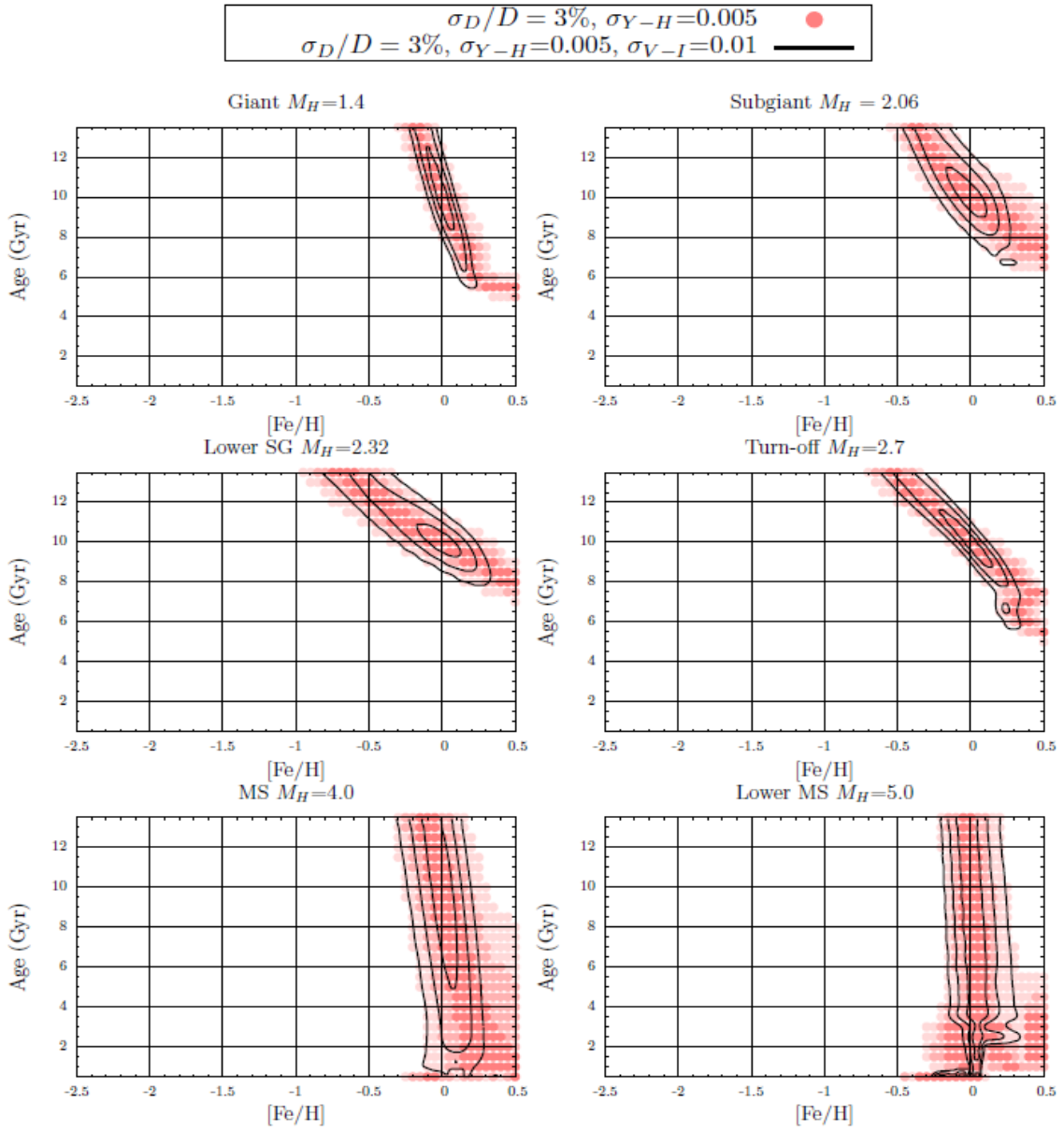


- 40,000 epochs, 110 mas pxl, σ(psf)=75mas
- S/N=100 => σ(pos) = 750 μas
- σ(π) = σ(pos)/sqrt(40,000) = 4 μas
- Systematics? Don't worry! exc. subpxl charact
- Blending? $\Delta\pi = f\,\pi_{rel} < 0.1\ (\pi/10) = \pi/100$



- 40,000 epochs, 1% phot
- $a/R_* < 10 \Rightarrow 1200$ transits
- $\chi^2 = 150\,[(r/R^*)/0.036]^2$
- (18,9,1)e6 (G,K,M)dwarfs
- $N_{try} = 5e5 \times 3e7 = 1e13$
- $\chi^2_{min} = 2*\ln(N_{try}) = 60$
- G dwarf => 2.5 R_{earth}
- K dwarf=> 2 R_{earth}
- M dwarf=> 1.2 R_{earth}

HST Optical Survey Needed



Non-Microlensing WFIRST Science: Ultra-precise Parallaxes

- H<14.0; $\sigma(\pi) < 0.3$ μas; 1,000,000 stars
- H<19.6; $\sigma(\pi) < 3.7$ μas; 40,000,000 stars
- H<21.6; $\sigma(\pi) < 10$ μas; 120,000,000 stars

Gould, Huber, Penny, Stello, 2015 JKAS, in press

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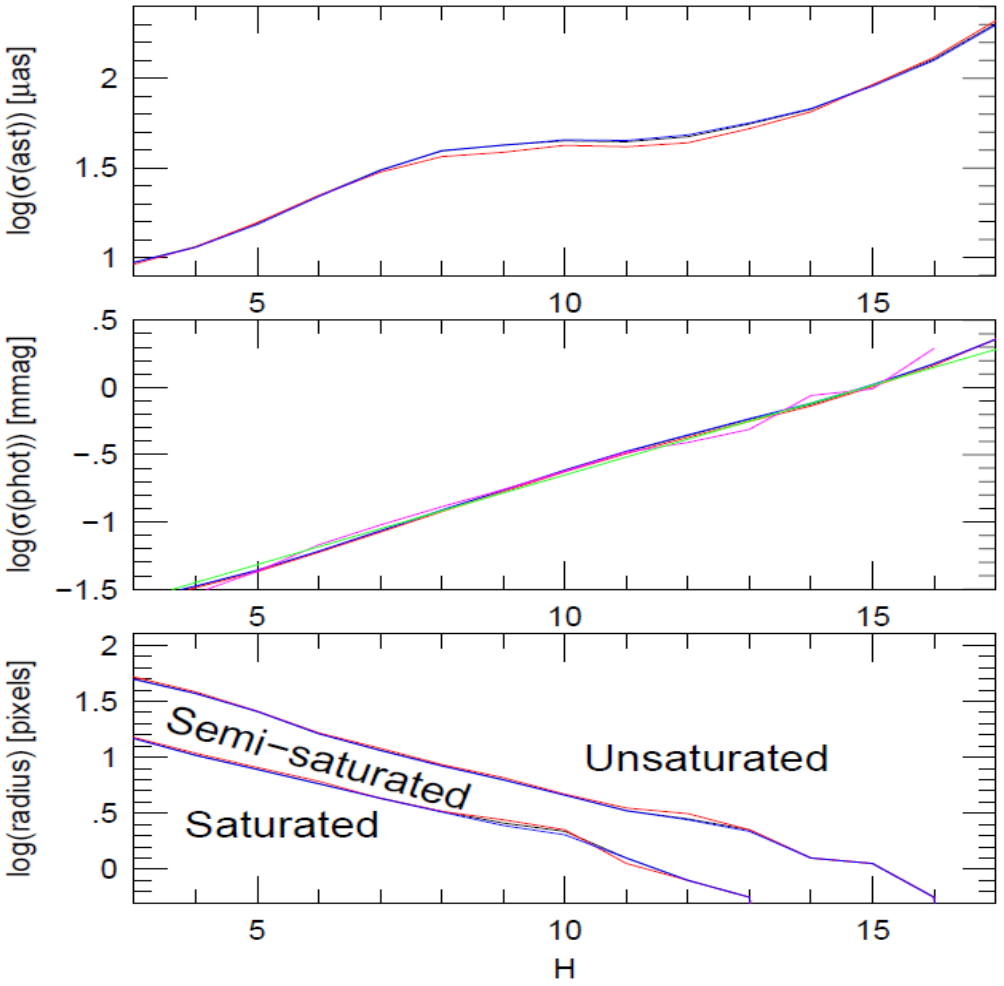
Ultra-precise Parallaxes



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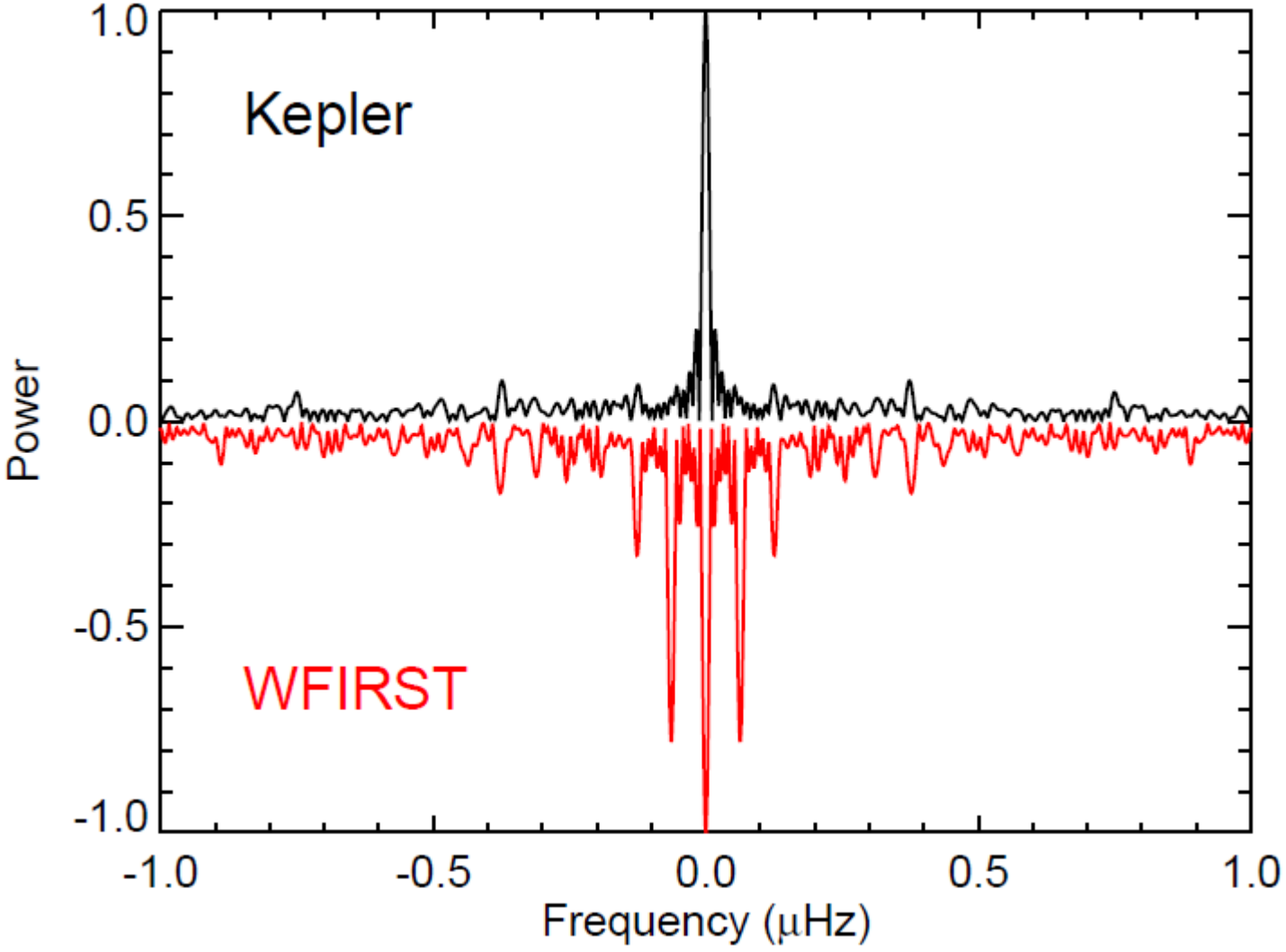
Non-Microlensing WFIRST Science:

Asteroseismic Window Function



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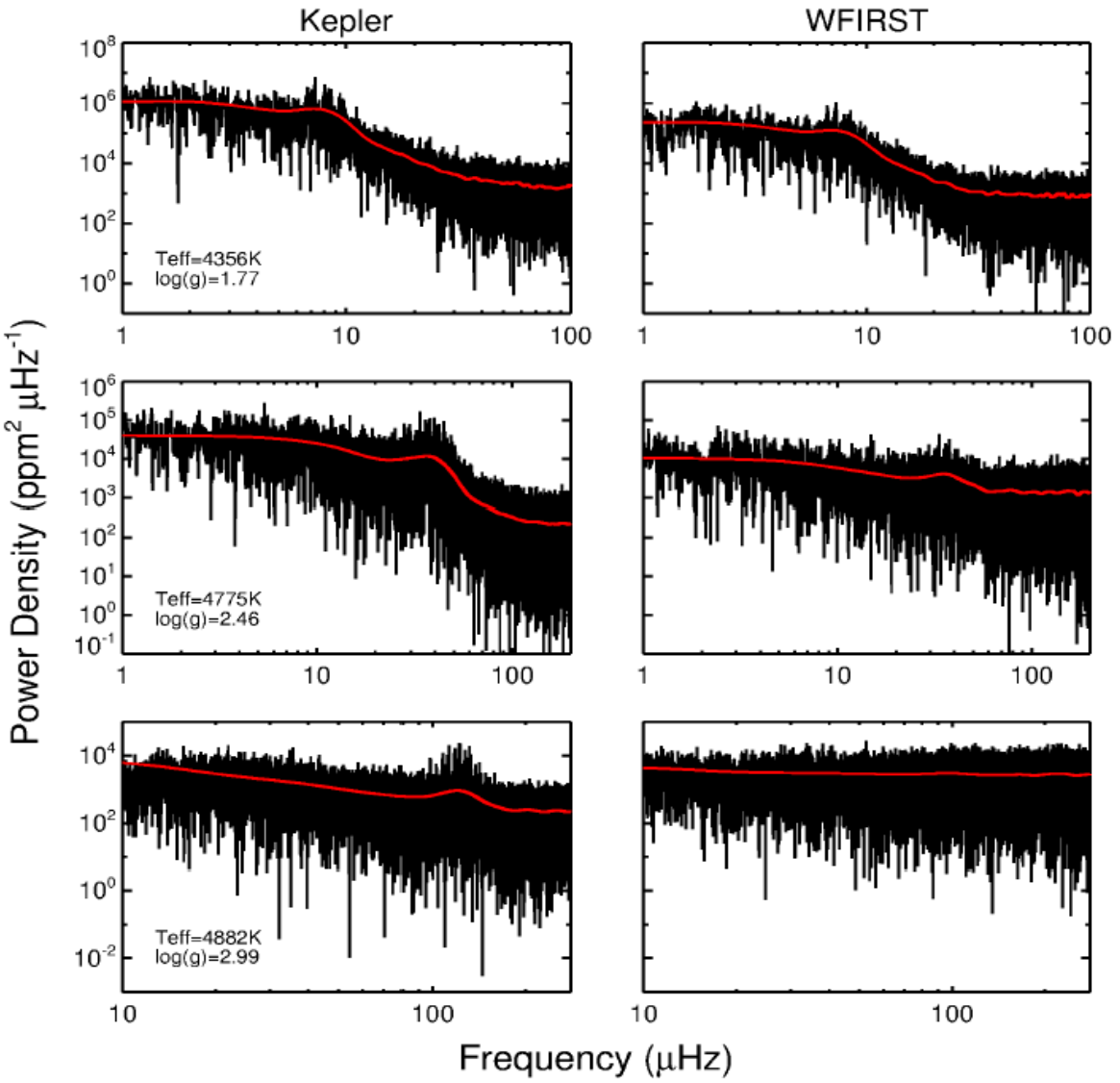

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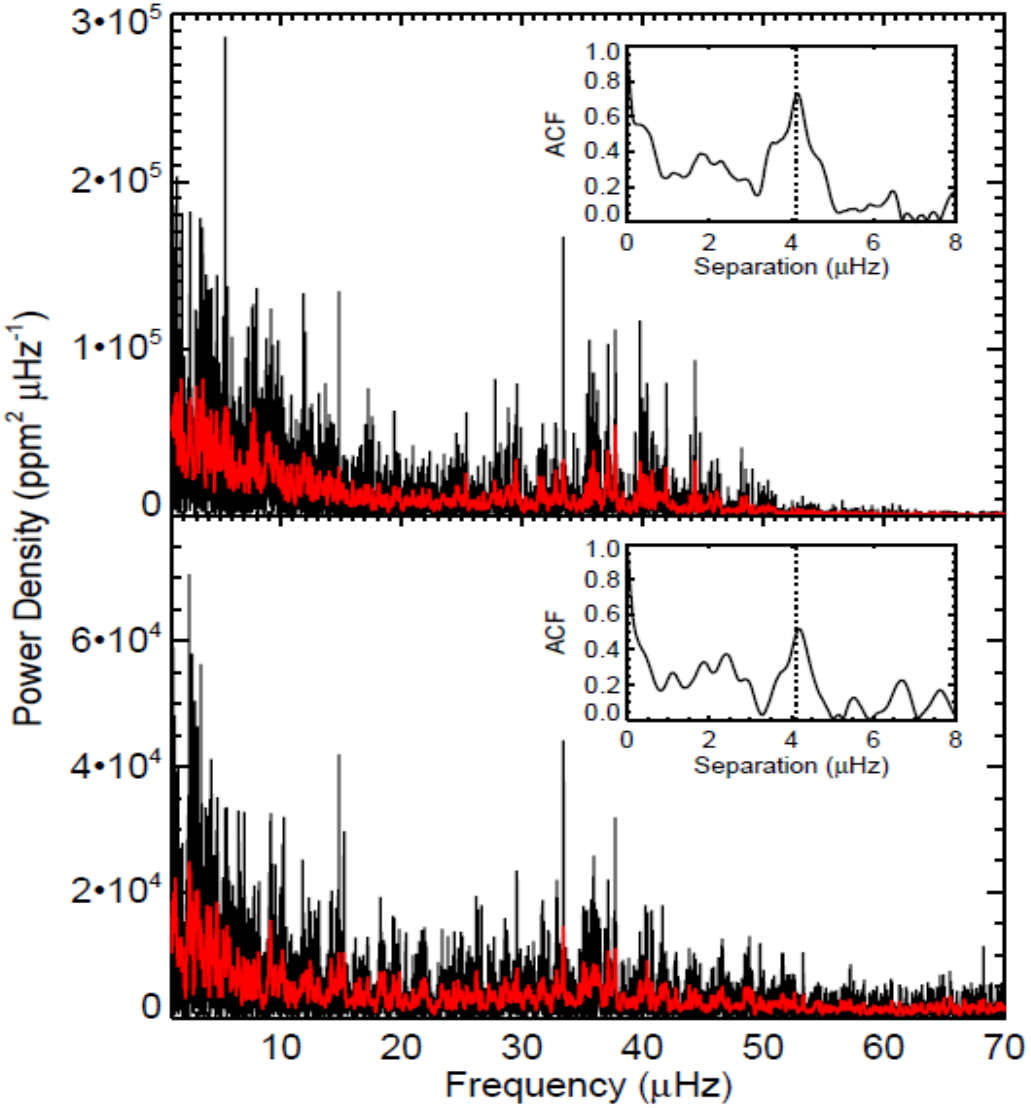

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Ask me about Euclid!

How can we make use of Gaia?

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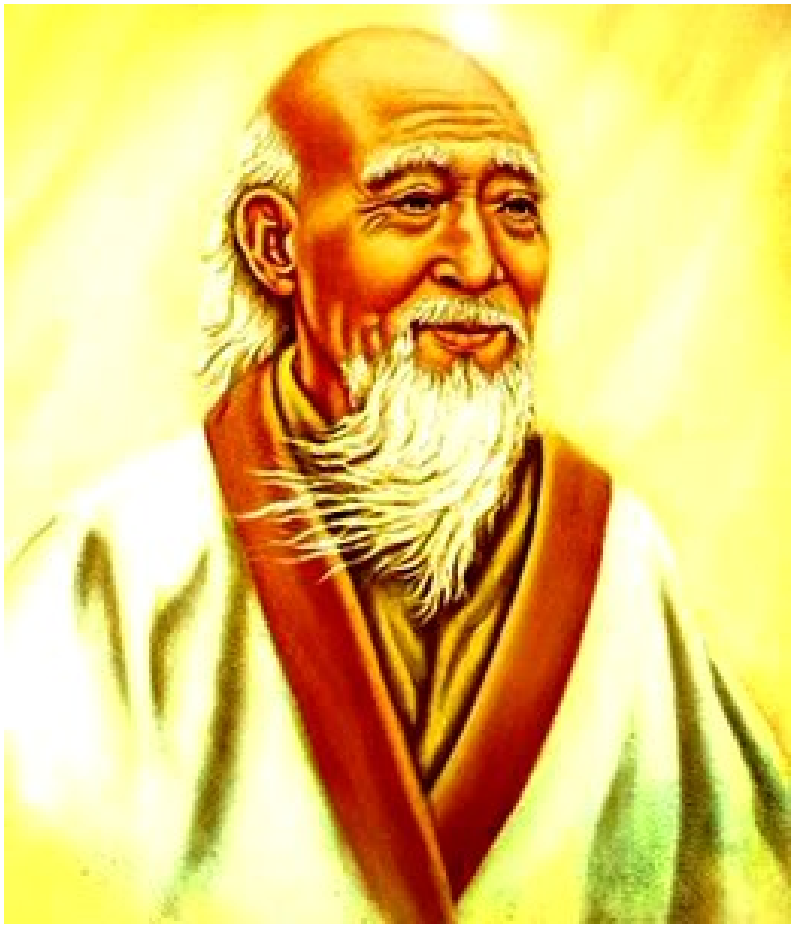
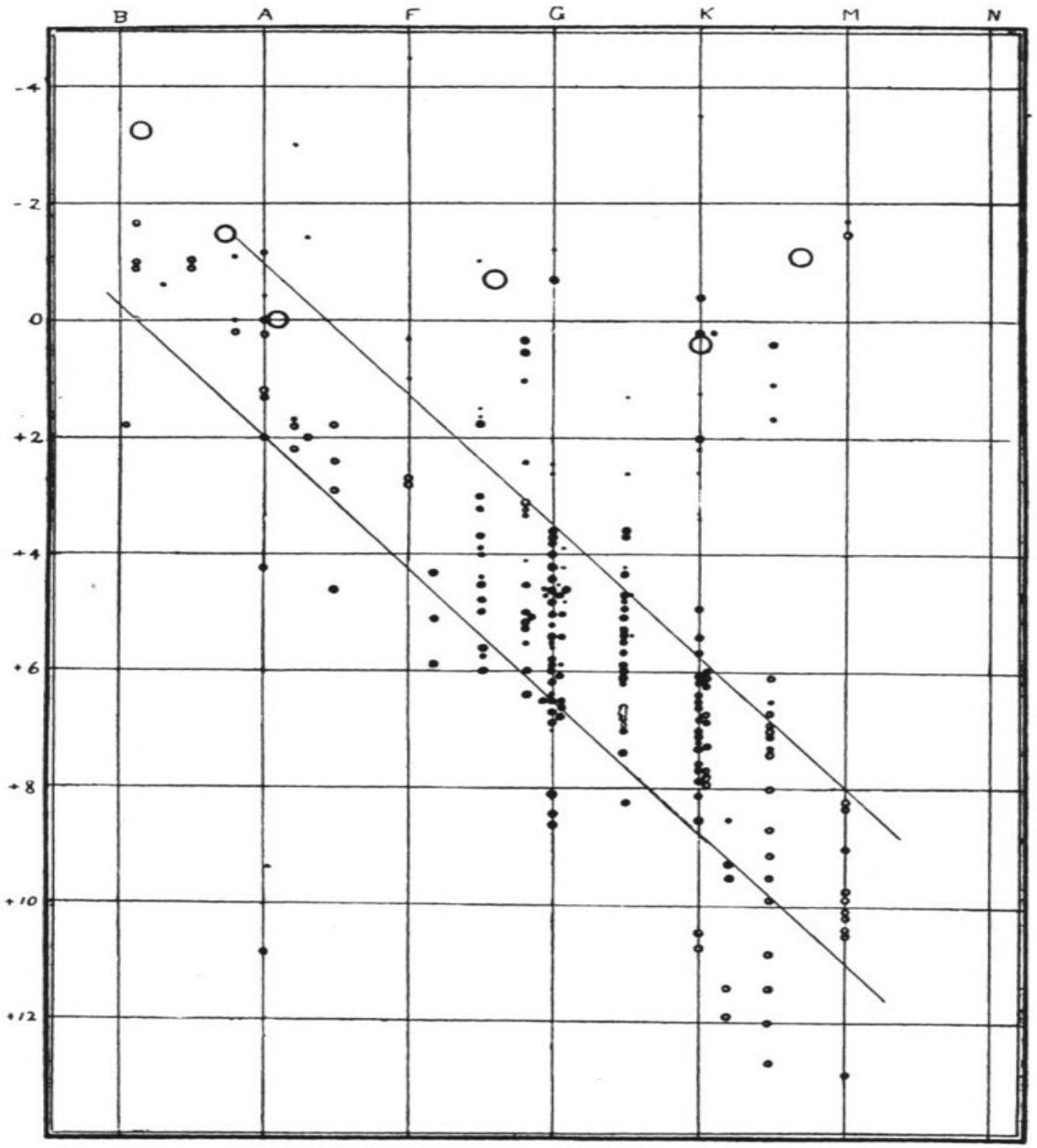
- Turn WFIRST relative parallaxes into absolute parallaxes

?

Lao Tzu



- "WFIRST is indeed a wise investment."


B
A
F
G
K
M
N
-4
-2
0
+2
+4
+6
+8
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