What Robo-AO can do for *Kepler*

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IUCAA Robo-AO Workshop

Kepler:
A Revolution and a Challenge

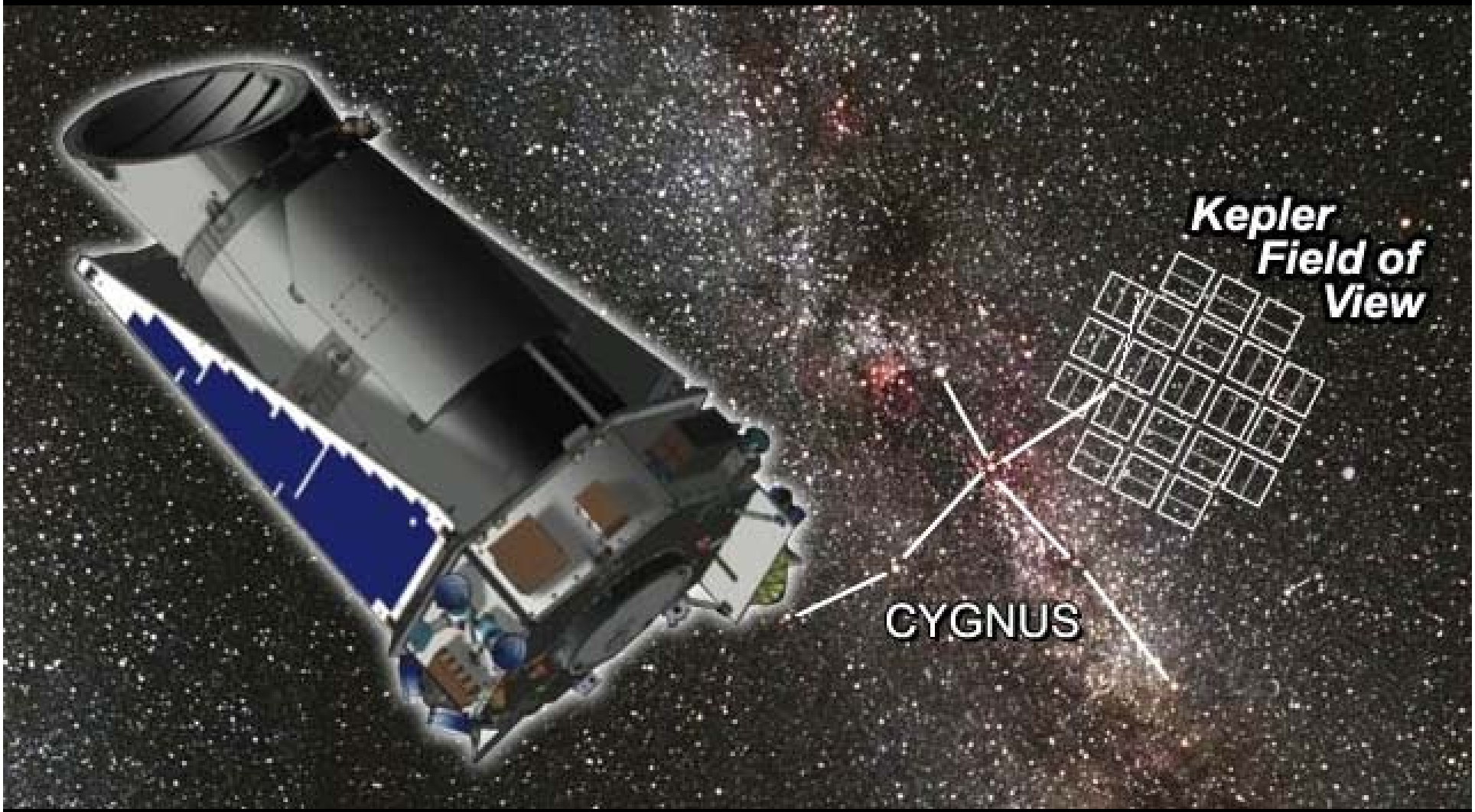
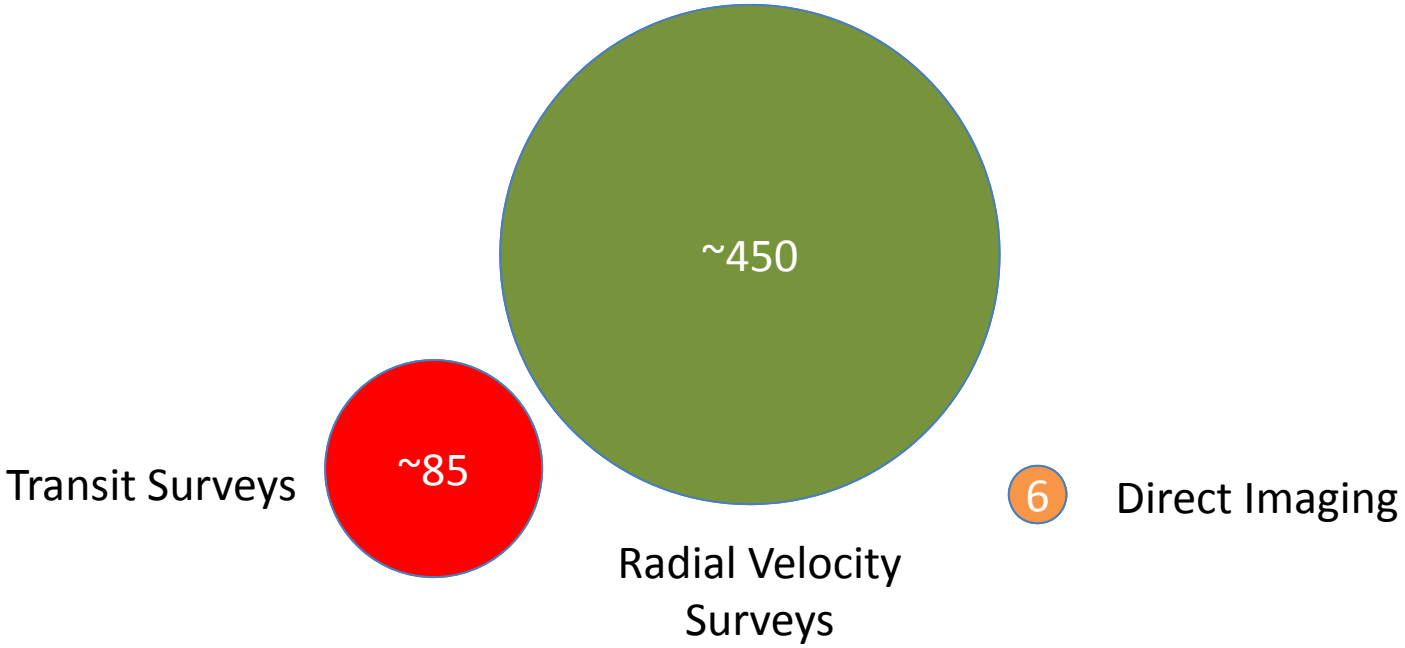


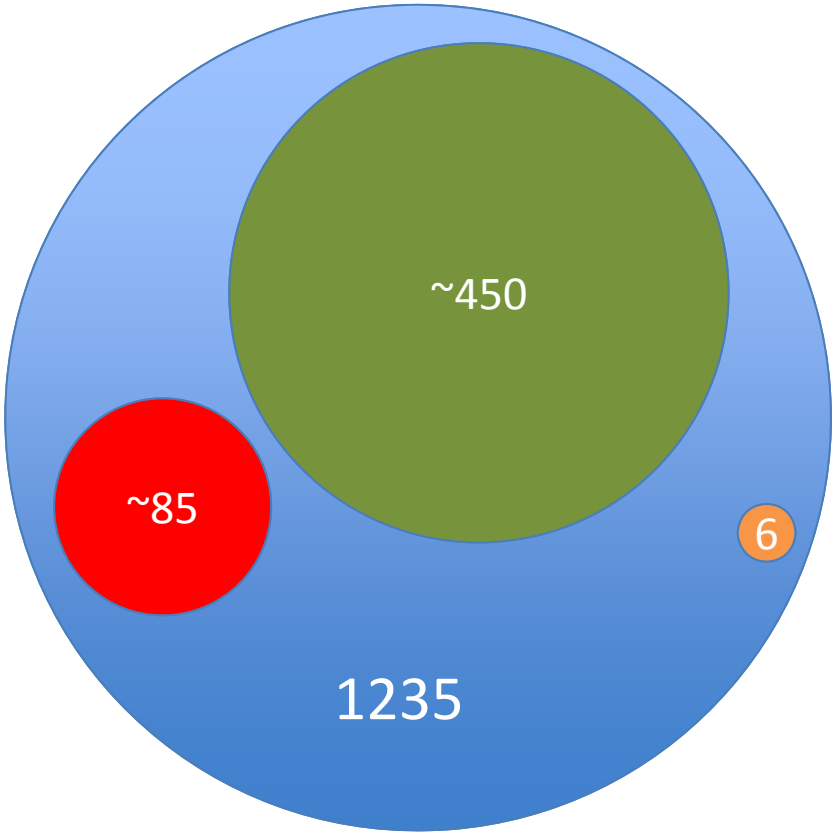
Image credit: *Kepler* team

Kepler:
A Revolution and a Challenge



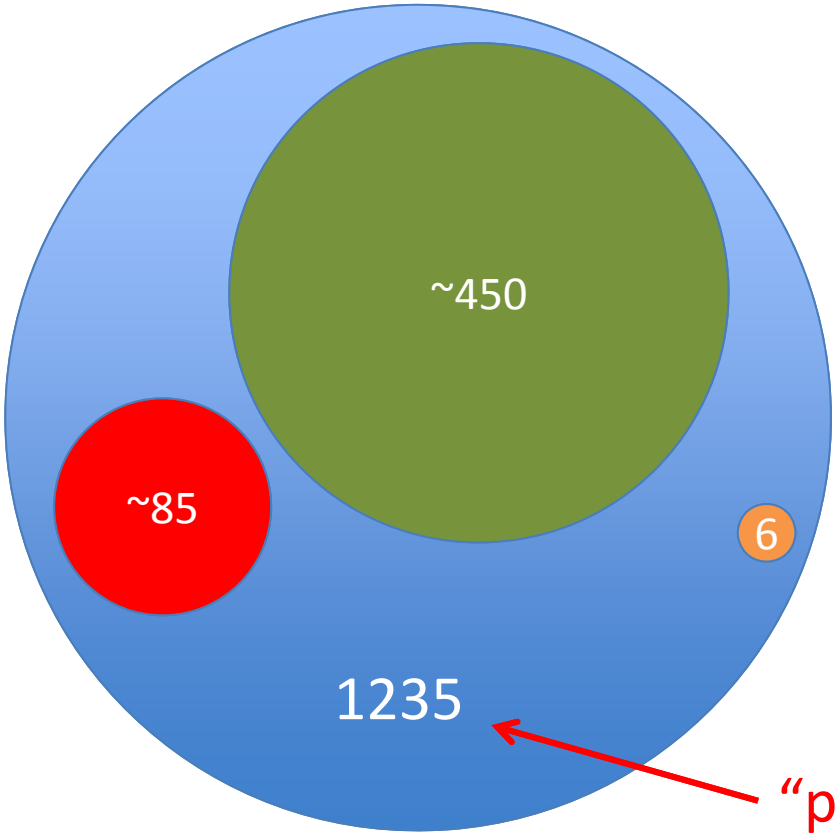
A pre-*Kepler* Exoplanet Census

Kepler:
A Revolution and a Challenge



Kepler as of Feb 2010!

Kepler:
A Revolution and a Challenge

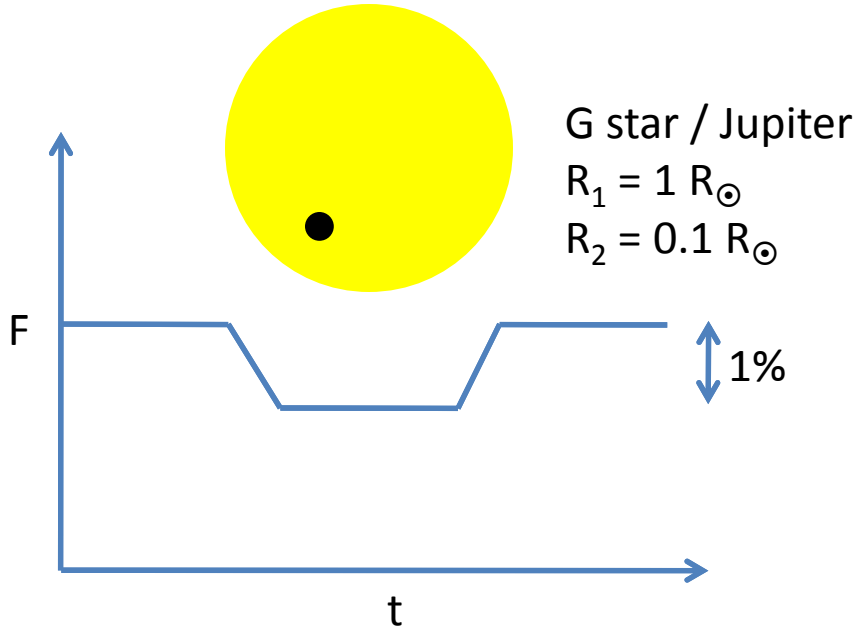


Kepler as of Feb 2010!

(only 18 confirmed!)

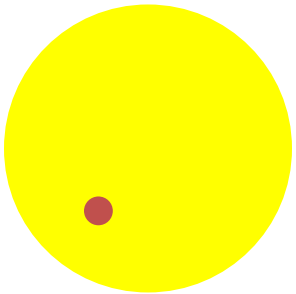
Transit False Positives

Transit:



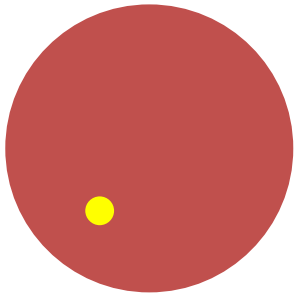
Transit imposters:

Eclipsing M-dwarf



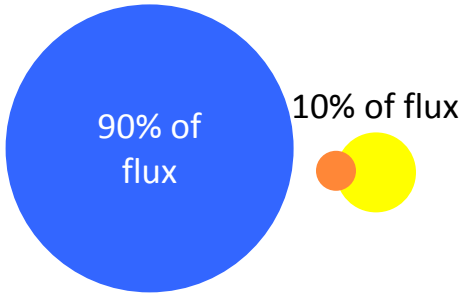
A star / M dwarf
$R_1 = 3\ R_\odot$
$R_2 = 0.3\ R_\odot$

Eclipsed Giant



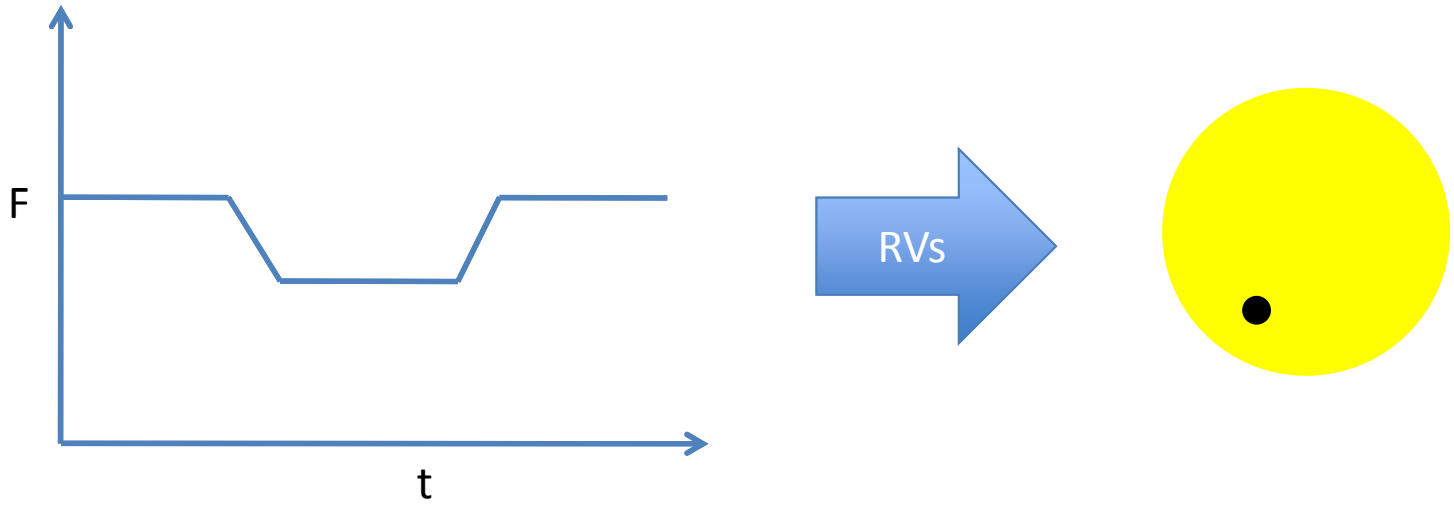
Giant / A star
$R_1 = 30\ R_\odot$
$R_2 = 3\ R_\odot$

Blended Eclipsing Binary



0.9 × (anything)
+ 0.1 × (G star / M dwarf)
$R_1 = 1\ R_\odot$
$R_2 = 0.3\ R_\odot$

Traditional planet confirmation: radial velocity follow-up

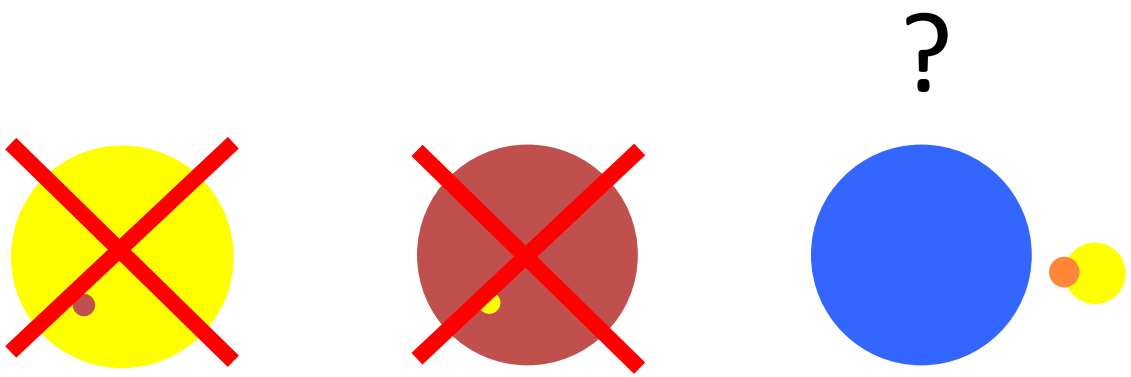


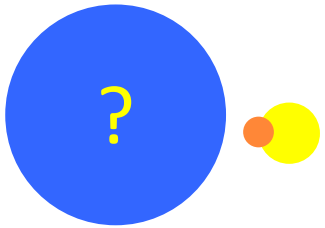
The *Kepler* Challenge

- Most host stars are faint (V > 14); typical high-precision RV targets are V < 10
- The expected RV amplitude of most of the candidates is below 1 m/s (many small candidates)
- Sheer numbers!

But:

(Kepler Input Catalog)





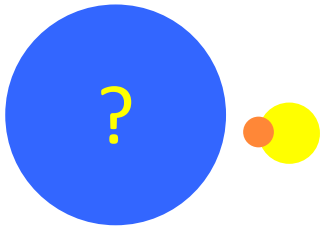
Another Approach: Probabilistic Validation

$$P_{planet} > 0.99$$

e.g. Kepler-9d, Kepler-11g, Kepler-10c

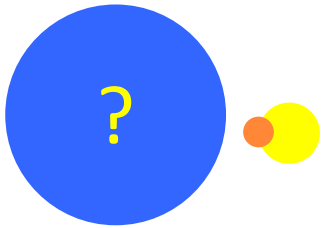
Kepler team's validation procedure:

- Extensive light curve modeling
- Multiple follow-up observations (spectroscopic and photometric)
- Takes weeks/months/$$ per candidate



A Simpler Way:
a priori
False Positive Probability (FPP)

$$P_{planet} = \frac{\pi_{planet}}{\pi_{planet} + \pi_{FP}} > 0.99$$



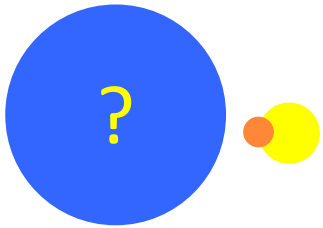
A Simpler Way:
a priori
False Positive Probability (FPP)

$$P_{FP} = \frac{\pi_{FP}}{\pi_{planet} + \pi_{FP}} < 0.01$$

π_{planet} = Pr(planet) × Pr(transit)

assumed (~20%) known

π_{FP} = Pr(blend) × Pr("appropriate" eclipsing binary) calculated…



Calculating false positive rate

π_{FP} = Pr(blend) × Pr("appropriate" eclipsing binary)

Sky density of stars of given magnitude range towards *Kepler* field. (stellar pop. synthesis + Galactic structure code)

×

Potential blend area (worst case = aperture size, best case ~2'' radius from centroid analysis)

Binary Fraction

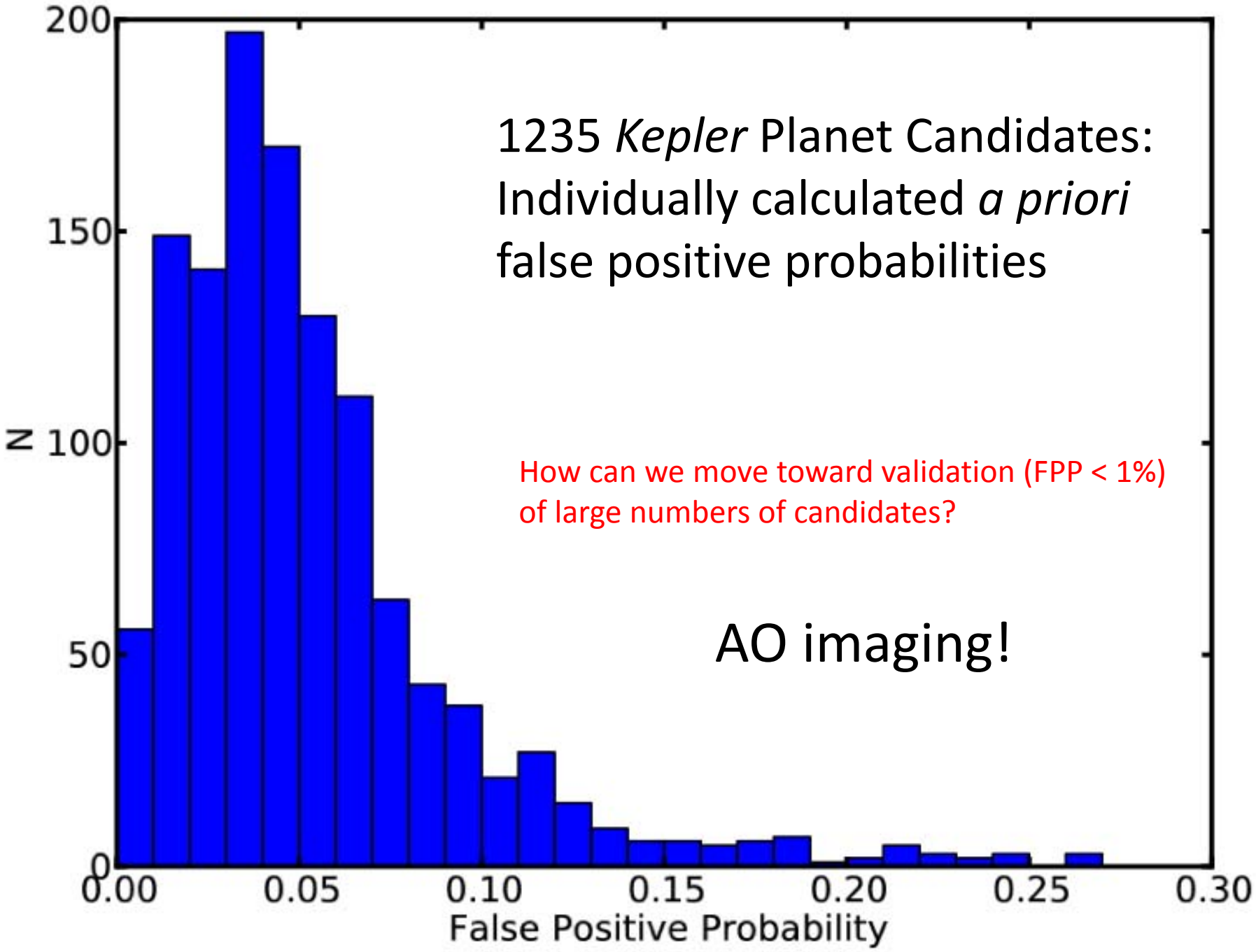
×

Fraction of binaries that undergo non-grazing eclipse (assume flat mass ratio distribution, secondary radii according to models)

×

Fraction of eclipsing binaries with a diluted eclipse of "planetary" depth, but whose secondary eclipse is not observable by *Kepler*.

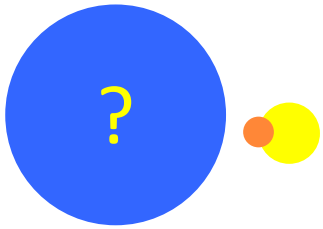
(+ repeat similar analysis for hierarchical triple blend scenarios)



1235 *Kepler* Planet Candidates:
Individually calculated *a priori*
false positive probabilities

How can we move toward validation (FPP < 1%)
of large numbers of candidates?

AO imaging!



Calculating false positive rates

π_{FP} = Pr(blend) × Pr("appropriate" eclipsing binary)

Binary Fraction

×

Sky density of stars

×

Fraction of binaries that undergo non-grazing eclipse

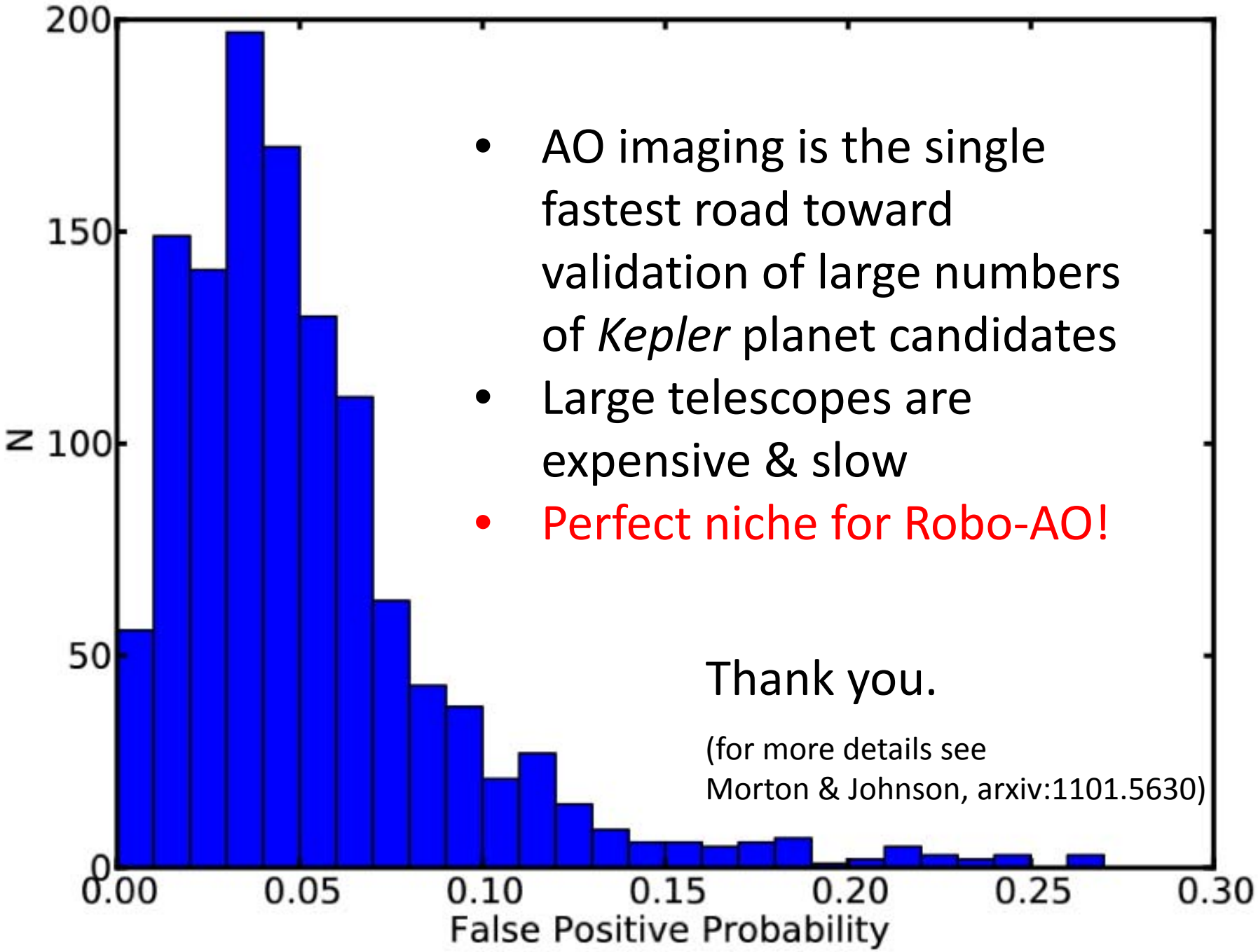
×

Potential blend area

Fraction of eclipsing binaries with a diluted eclipse of "planetary" depth, but whose secondary eclipse is not observable by *Kepler*.

Can be reduced with AO imaging!

Reducing "blend radius" by a factor of ~3 can reduce FPP by a factor of ~10!



- AO imaging is the single fastest road toward validation of large numbers of *Kepler* planet candidates
- Large telescopes are expensive & slow
- Perfect niche for Robo-AO!

Thank you.

(for more details see Morton & Johnson, arxiv:1101.5630)