η_{Earth}: Current guesses & Future constraints

Jack J. Lissauer

NASA Ames

Navigator Forum - 2007, May 17

Why do we care?

Why we care!

- The value of η_{Earth} drives the sizes and costs of TPF space missions

Determining η_{Earth}

- Current exoplanet data

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- Expected constraints from SIM
- Expected constraints from *Kepler*

Extrasolar Planets: Key Findings

- ~ 1% of sunlike stars have planets more massive than Saturn within 0.1 AU
  - Most if not all are gas giants
  - Models suggest these planets migrated inwards
- ~ 7% of sunlike stars have planets more massive than Jupiter within 2 AU
  - Some of these planets have very eccentric orbits
- At least a few % of sunlike stars have Jupiter-like (0.5 - 2 M_J, 4 AU < a < 10 AU) companions, but > 20% do not
- Small planets are more common than more massive ones
- More (giant) planets around stars with more metals

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- **Note: Key findings relate to planets quite different from Earth.**

What do we require to consider a planet **Earthlike**?

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

NASA/JPL-Caltech/R. Hurt (SSC)

Gliese 581 c

The first habitable exoplanet?

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TIFF (Uncompressed) decompressor
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Properties of GJ 581 c

- $M \sin i$ ~ 5 - 6 M_{Earth}, so M ~ 6 - 9 M_{Earth}
- Composition unknown
  - Local growth requires dense disk, yields few volatiles
  - Migration suggests gas-rich (especially because of more massive GJ 581 b orbiting interior)
- Stellar radiation very red
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- Observational issue: Small angular separation

Planets around M dwarfs may be Hellish places

Anticipated constraints from Doppler RV

Planets down to a few M_{Earth} in HZ's of M dwarfs

~ 10 M_{Earth} in HZ's of sunlike stars

Anticipated constraints from Microlensing

Planets down to ~ M_{Earth} orbiting a few AU from (in most cases) M dwarfs

Might do better from space

Anticipated constraints from Imaging

Outer giant planets from the ground

Capabilities from space depend on technology advances and $$

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Space imaging most promising for characterizing exoearths; not a cost-effective way to determine η_{Earth}

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A few true Earth analogs (1 M_{Earth} in Habitable Zones of sunlike stars) if $\eta_{Earth} \sim 1$

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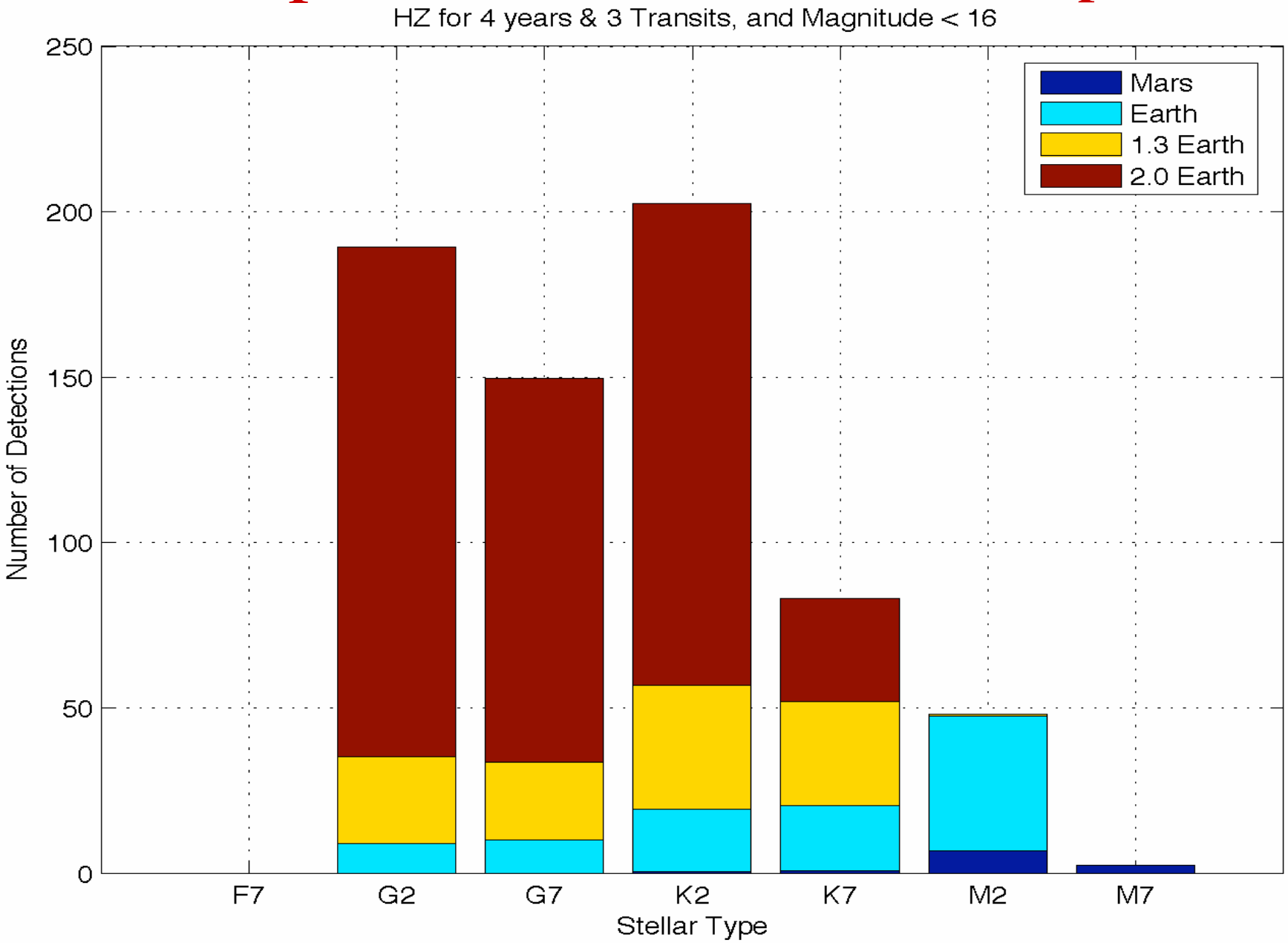
But timeframe bad news for TPF.

Anticipated constraints from *Kepler*



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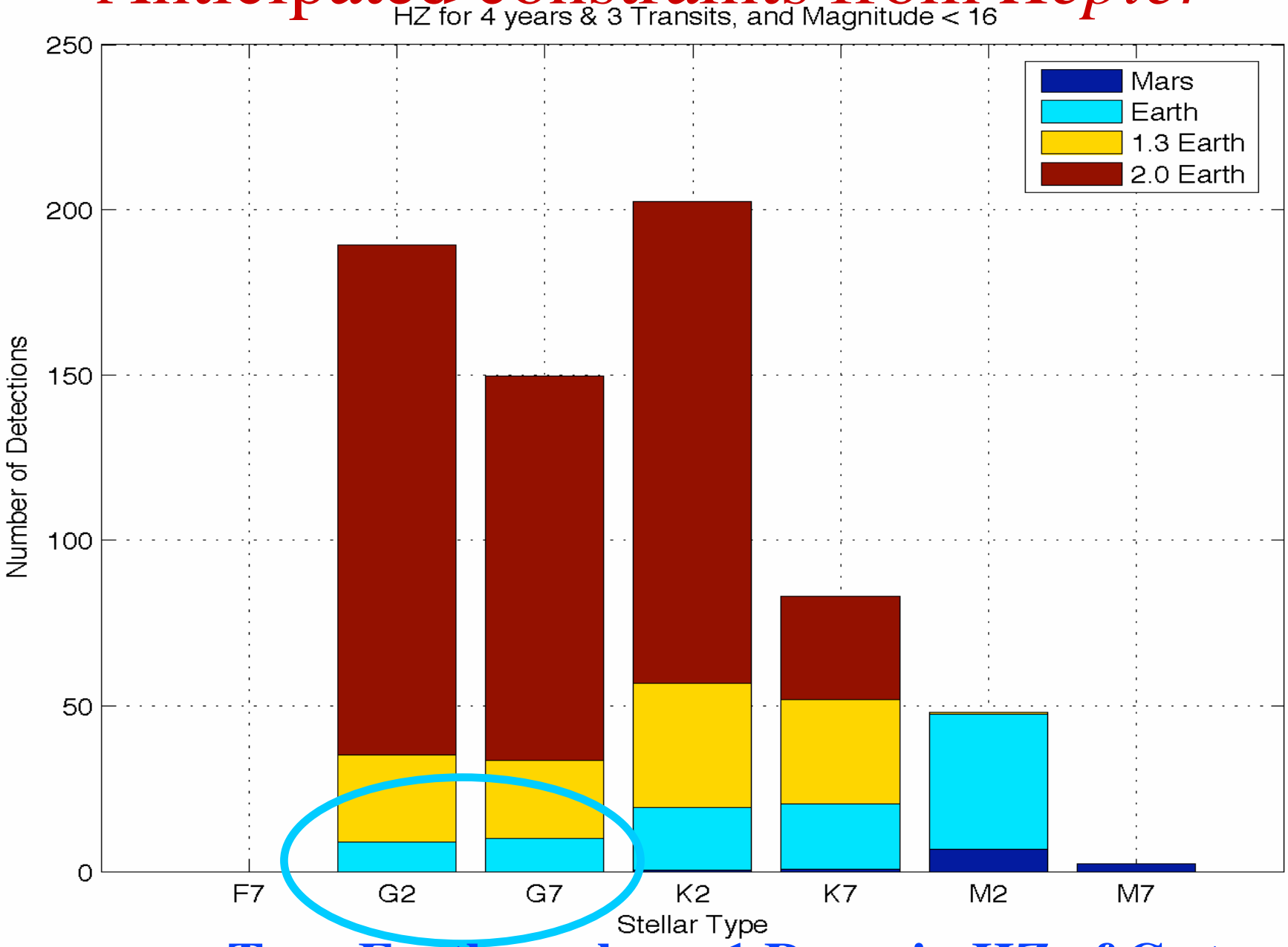
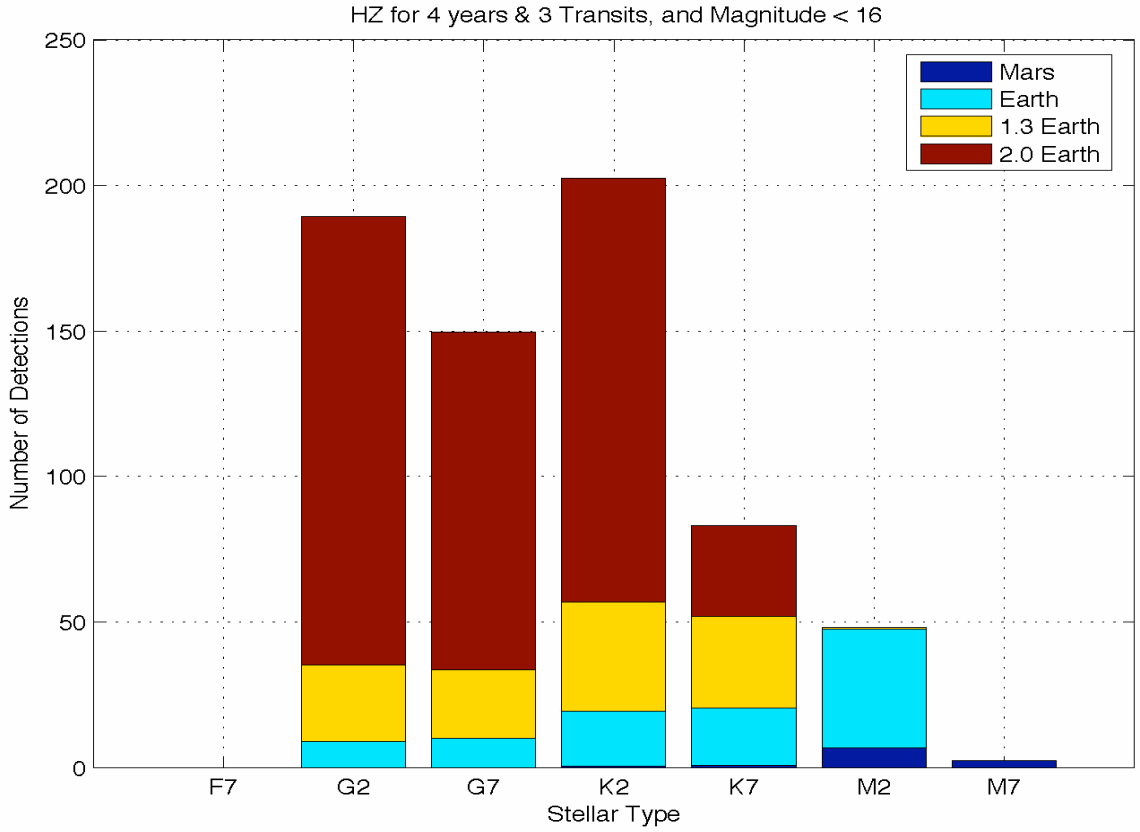
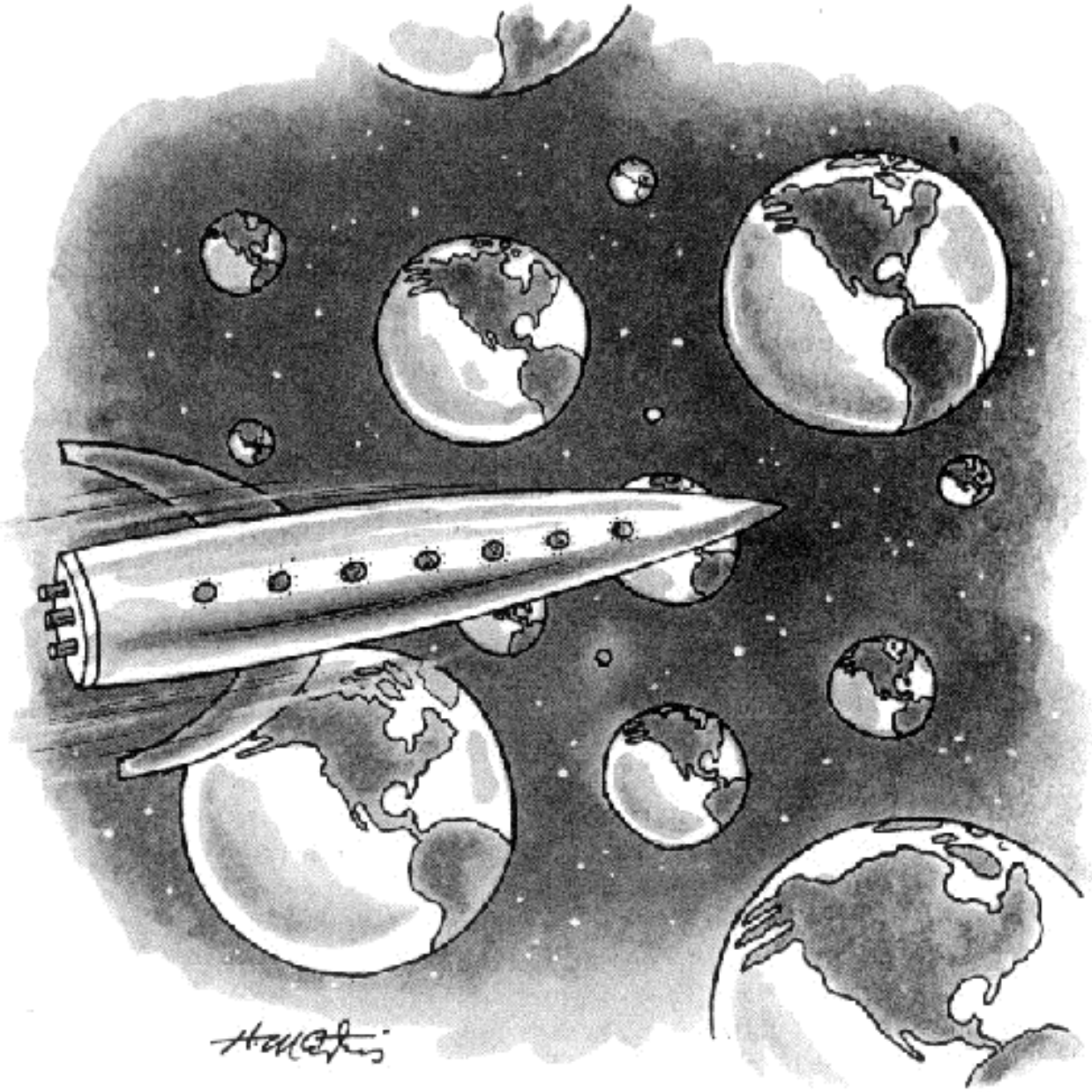


True Earth analogs: 1 R_{Earth} in HZ of G star

KEPLER EXPECTED TO DETECT TRUE EARTH ANALOGS



- Two dozen 1 R_{Earth} planets orbiting 1 AU from G stars will be detected if such planets are the norm. More if *Kepler* lasts 6 years.
- More Earth-sized planets can be found in HZ's of K and M stars than of G stars.
- Numbers for G and K stars increase substantially if 1.3 R_{Earth} planets are common.



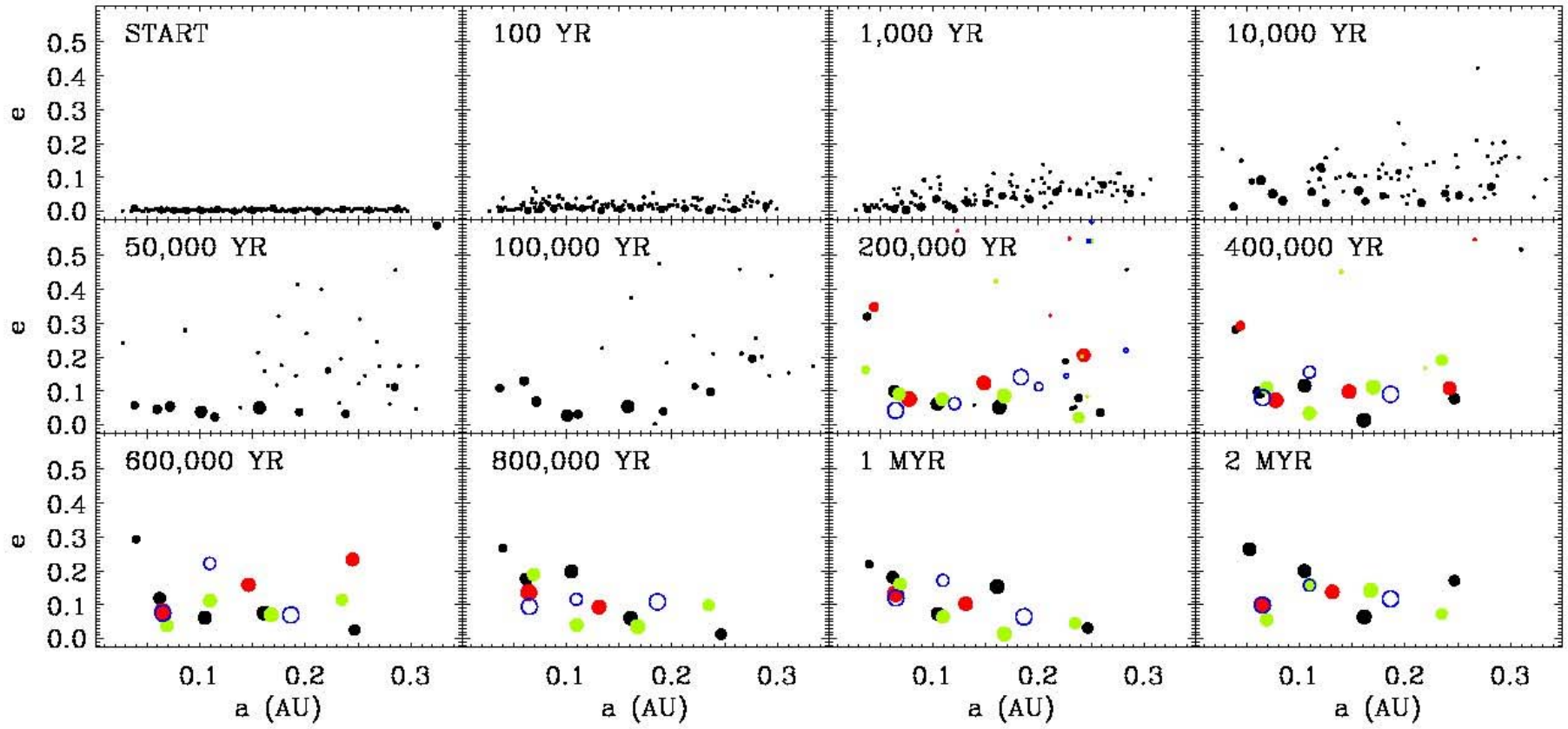
"Well, this mission answers at least one big question: Are there other planets like ours in the universe?"

Drawing by H. M
The New Yorker

η_{Earth}: Current guesses & Future constraints

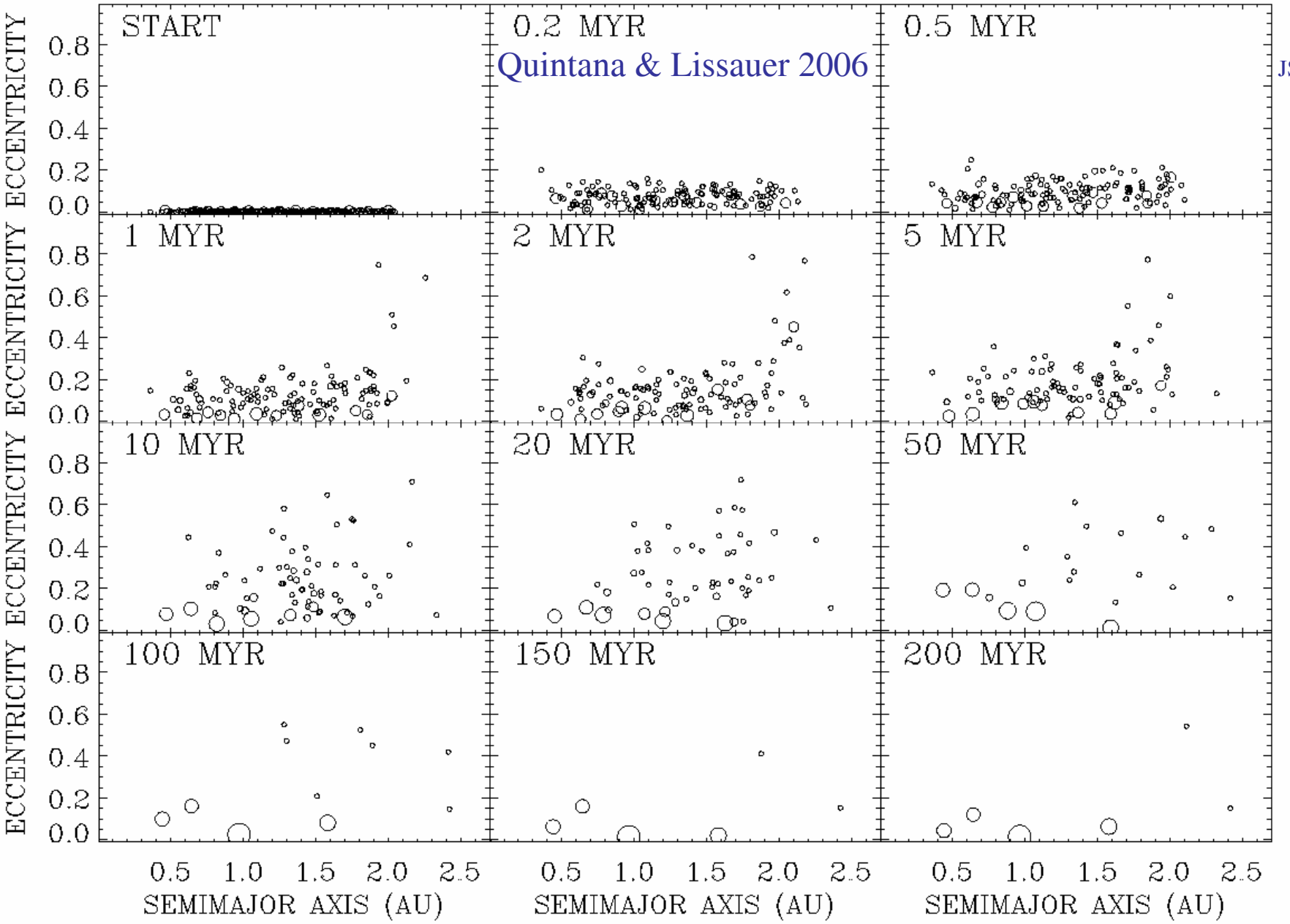
- Observations don't yet constrain η_{Earth}; not even close
- Theoretical uncertainties: Initial conditions, migration, … (Theory is far better for interpolation than extrapolation)
- *Kepler* should provide estimate of η_{Earth}, and give even better numbers for larger terrestrial planets in HZ

Disk around 1/3 M_{Sun} Star with Giant Planets



4 Runs (Lissauer 2007, *Ap.J.Lett.*)

Terrestrial Planet Growth Sun-Jupiter-Saturn



Quintana & Lissauer 2006

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