Exoplanet Task Force

A Strategy for the Detection and Characterization of Exoplanets

Preliminary Findings Briefing

Presented to NASA Astrophysics Subcommittee, 28 January 2008

"Do there exist many worlds, or is there but a single world? This is one of the most noble and exalted questions in the study of Nature."

-Albertus Magnus (1193-1280)

Outline

- Introduction to the Taskforce
- Recent Exoplanet Highlights
- Major Recommendations
- Recommended Strategy

Task Force Formed

DEC 19 2006

Dear Dr. Illingworth:

This letter is to request that the Astronomy and Astrophysics Advisory Committee (AAAC) establish an Exo-Planet Task Force (ExoPTF) as a subcommittee to advise NSF and NASA on the future of the ground-based and space-based search for and study of exo-planets, planetary systems, Earth-like planets and habitable environments around other stars.

Task Force Charge

The ExoPTF is asked to recommend a 15-year strategy to detect and characterize exo-planets and planetary systems, and their formation and evolution, including specifically the identification of nearby candidate Earth-like planets and study of their habitability. The strategy may include planning and preparation for facilities and missions beyond the 15-year horizon. Since future funding levels are uncertain, and project costs are difficult to establish at an early stage, it is important to develop an efficient and adaptable plan. To the extent possible, the recommendations should accommodate a range of funding levels representing conservative and aggressive programs. The ExoPTF will work in cooperation with agency efforts to advance the justification, specification and optimization of planet finding and characterizing opportunities.

Task Force Membership

Chair: Jonathan Lunine (LPL/University of Arizona)

Debra Fischer (San Francisco State)	Gary Melnick (CFA)
Heidi Hammel (Space Science Institute)	David Monet (USNO)
Lynne Hillenbrand (Cal Tech)	Charley Noecker (Ball)
James Kasting (Penn State)	Stan Peale (UCSB)
Greg Laughlin (UCSC)	Andreas Quirrenbach (Landes. Heidelberg)
Bruce Macintosh (Lawrence Livermore)	Sara Seager (MIT)
Mark Marley (NASA Ames)	Josh Winn (MIT)

Thomas Henning - MPI (ESA liaison)

Task Force Process

- Five Task Force meetings in 2007
- Public Input
  - 18 external presentations
  - 84 exoplanet white papers contributed from the community
  - Open sessions during the first 4 meetings
  - 7 external readers
- Report is being completed
- Final step: present to AAAC in February 2008

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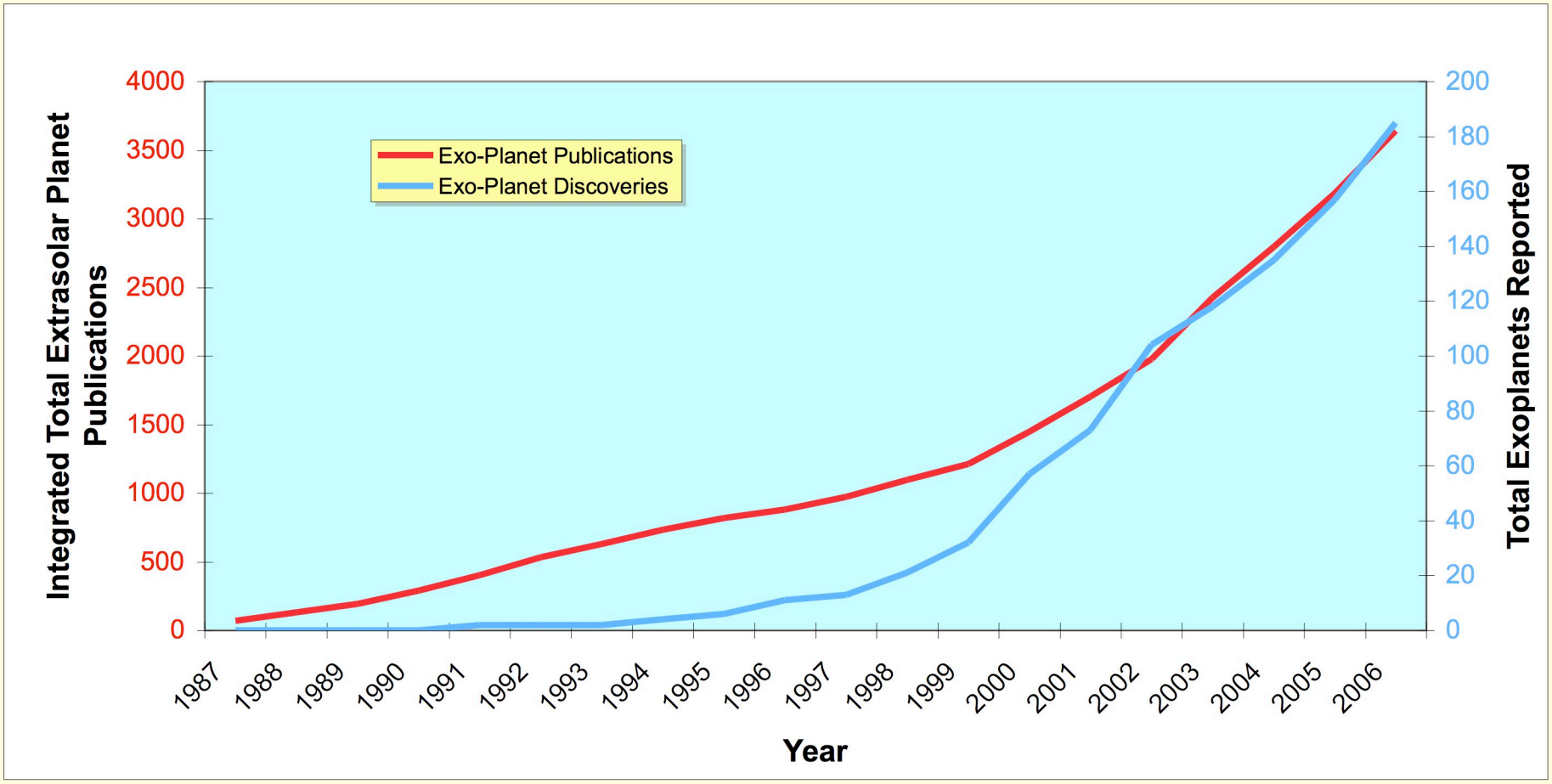
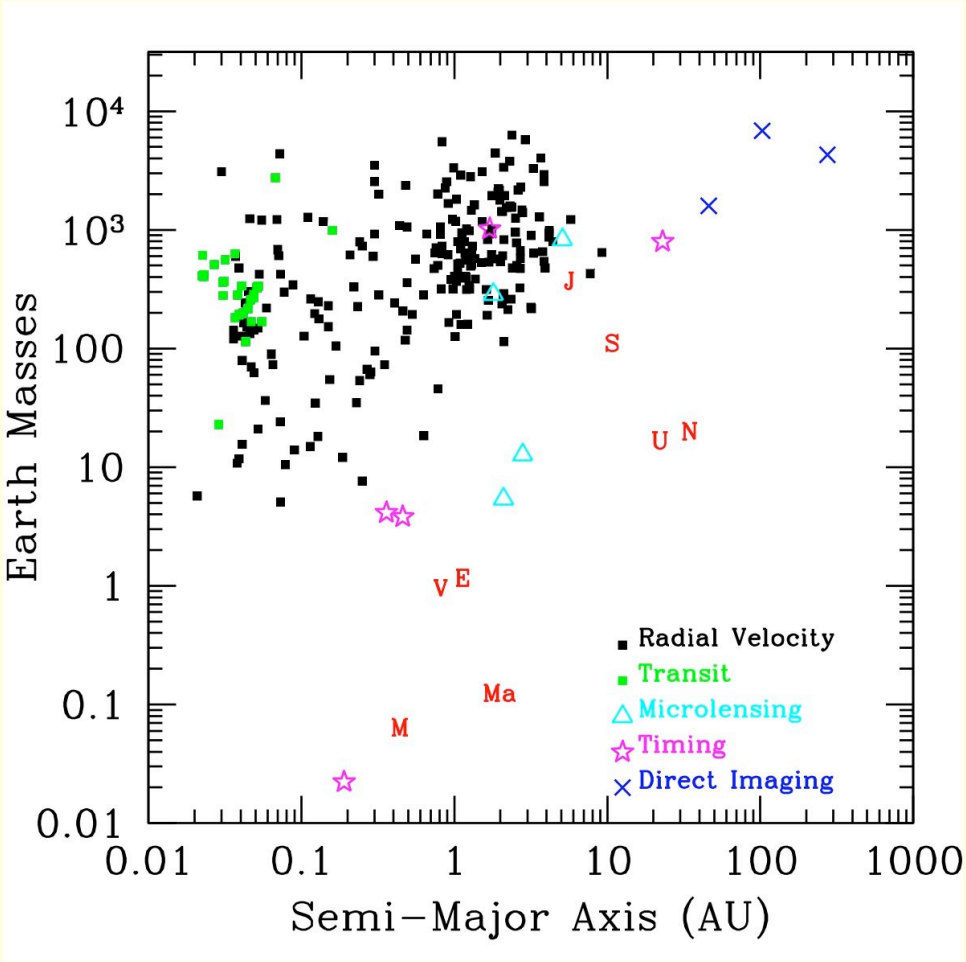
Publications and Planets



Recent Exoplanet Highlights



- Many detections with different techniques
- Rich variety of exosystems
- Multi-planet systems
- Closer to solar system analogs
- Lower masses
- Super Earths orbiting M stars may be common
- Atmosphere studies with Spitzer

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Compelling Questions Identified by the Task Force

1. What are the characteristics of Earth-mass/Earth-size planets in the habitable zone around nearby, bright stars?

"Towards Earths"

2. What is the architecture of planetary systems?
3. How do planets and planetary systems form?

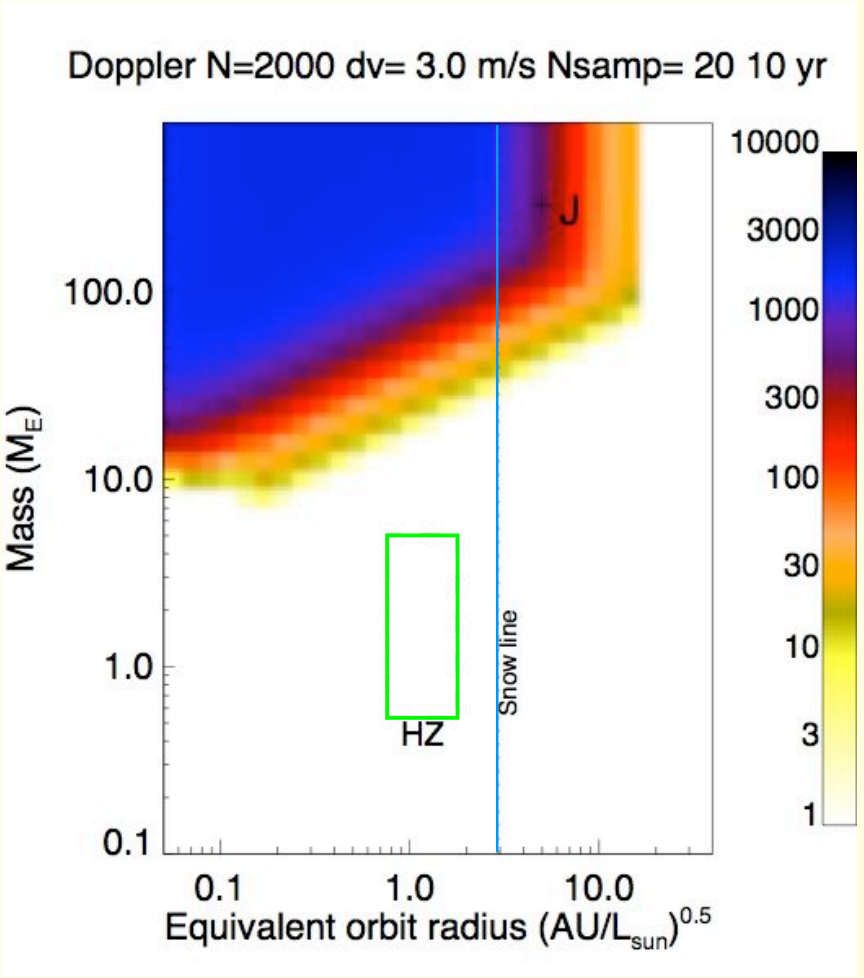
"Planetary Architecture/Evolution"

Recommendations: Towards Earths

- **Intensify RV studies to reach down to (several) Earth-mass planets around bright stars**
  - More telescope time/higher precision
  - Invest in IR spectrograph development for late M stars
- **Search for transiting terrestrial-size exoplanets around nearby M dwarfs and characterize with Warm Spitzer and JWST**

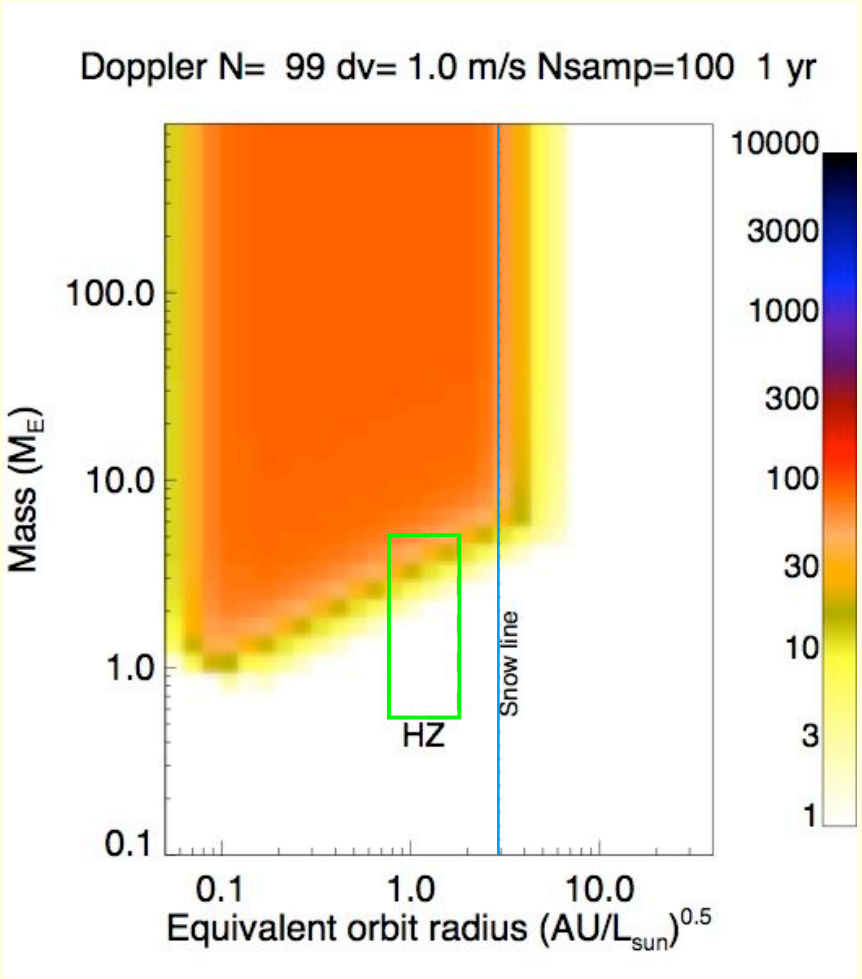
"Depth of Search" Figures

- The number of detectable planets assuming every star to be examined has a planet of the given mass and semi-major axis
- No assumptions need be made about planet distributions
- No imposed mission lifetime
- Scaled x-axis allows all star types on the same plot
- Both x- and y-axes are on a log scale

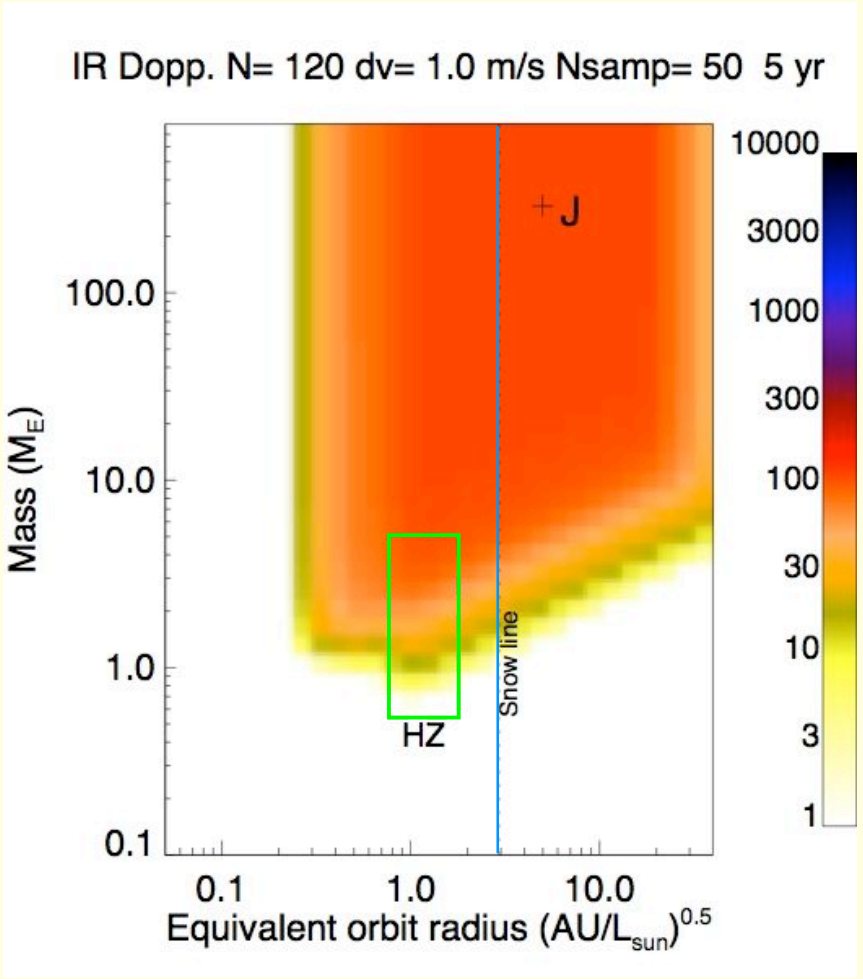


Figures should read: Equivalent orbit radius $AU/(L_{Sun})^{0.5}$

RV Studies

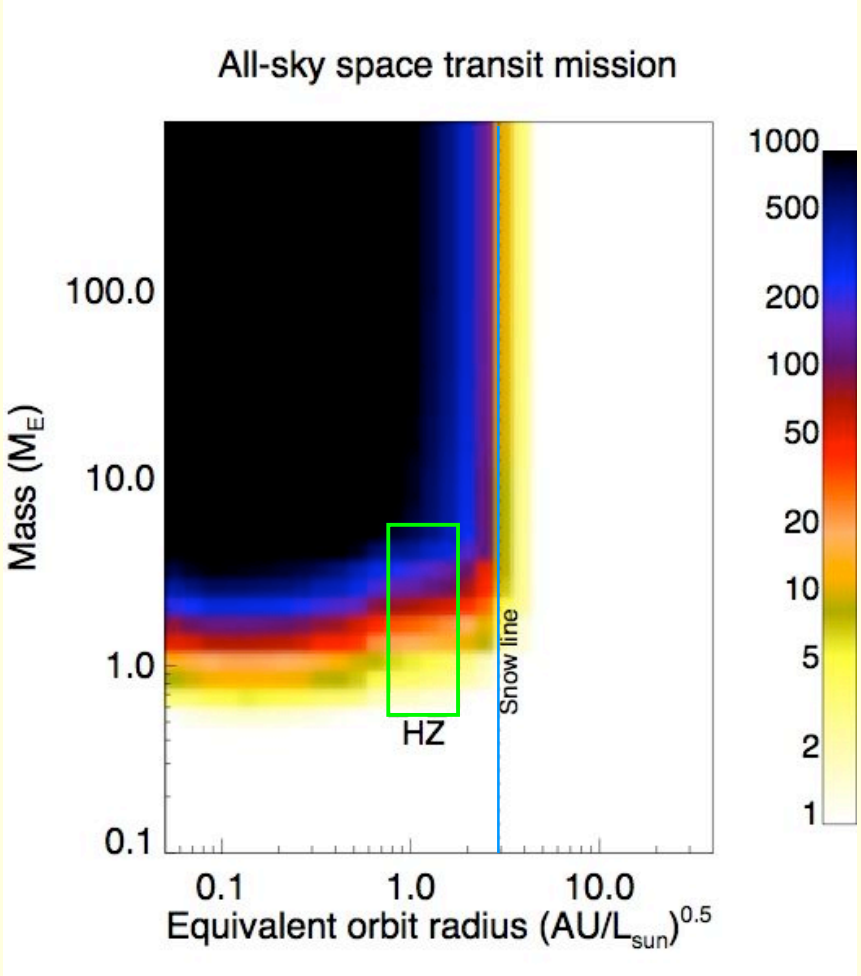


Optical

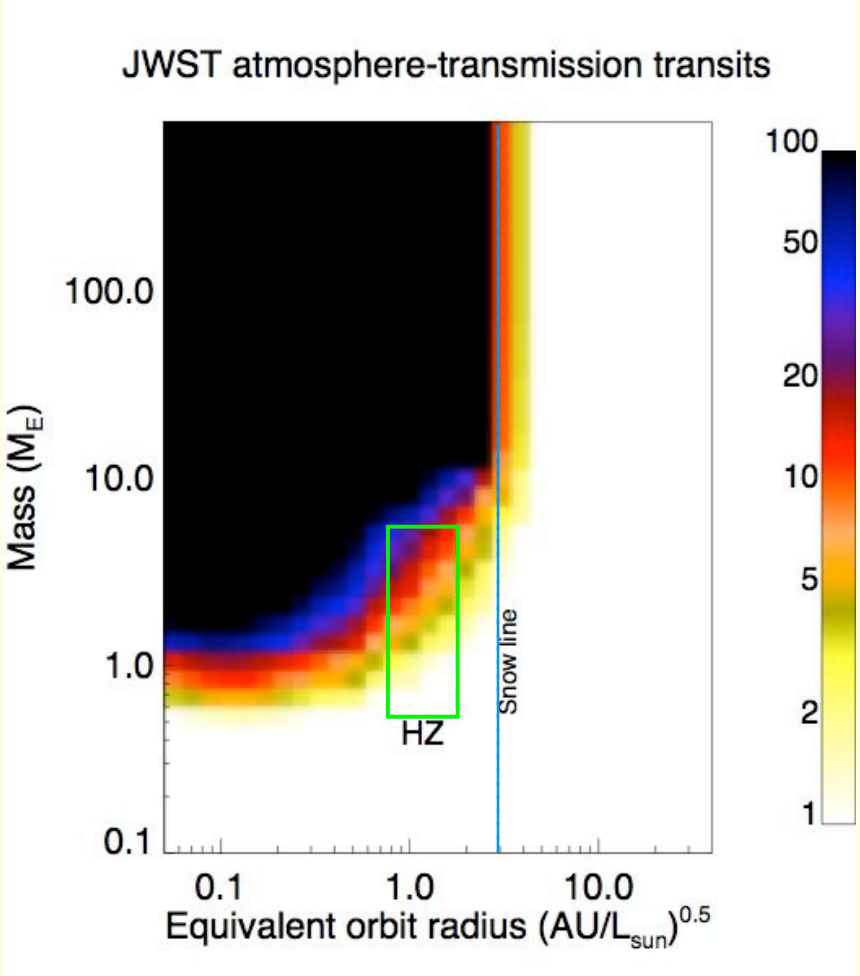


Near IR

Terrestrial Transits for Characterization



Transits from space



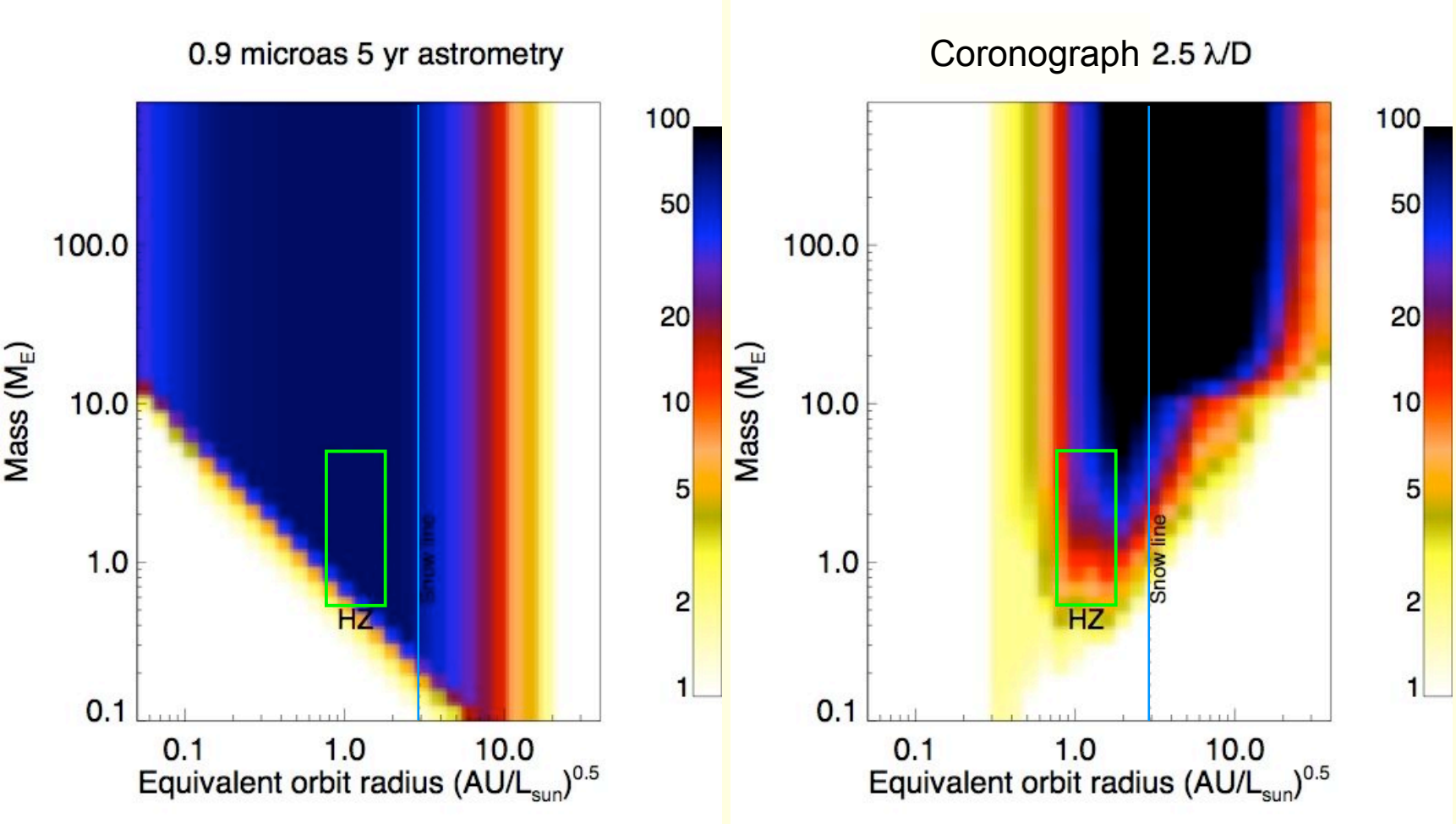
Atmospheres with JWST

Recommendations: Towards Earths

- **Develop a space-borne astrometric planet search mission**
  - Mass and orbits are required to understand habitability
  - Find the Earth-mass exoplanets in habitable zones of nearby sun-like stars and get their orbits
  - Sub microarcsecond astrometric signatures on order of 100 stars
  - Study planetary architectures whether or not Earth-mass planets are common, whether or not zodi is large

- **Prepare for space-based direct imaging characterization mission**
  - Ongoing development to be ready for launch after some targets are known
  - Exozodi measurements down to 10 zodi around nearby stars

Space Astrometry and Direct Imaging

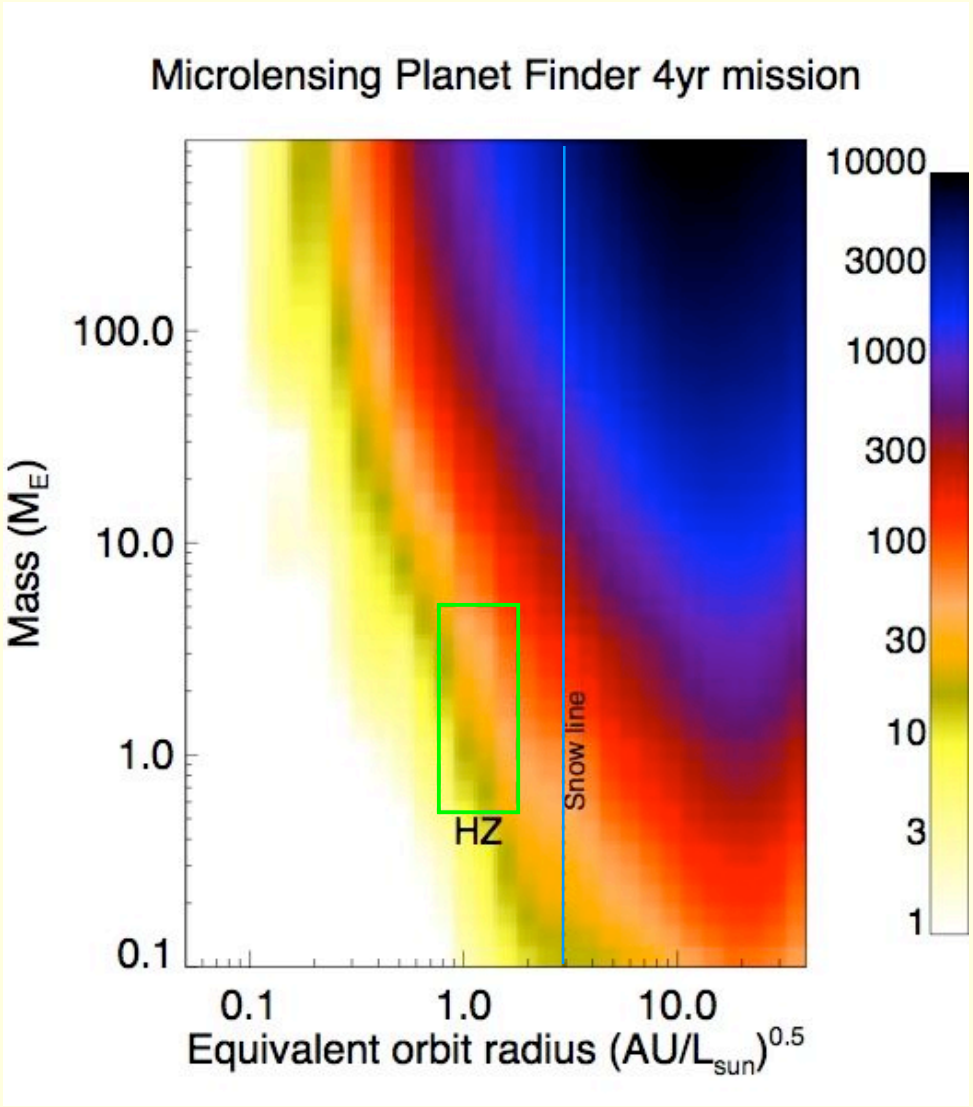


Recommendations: Planetary Architectures/Formation

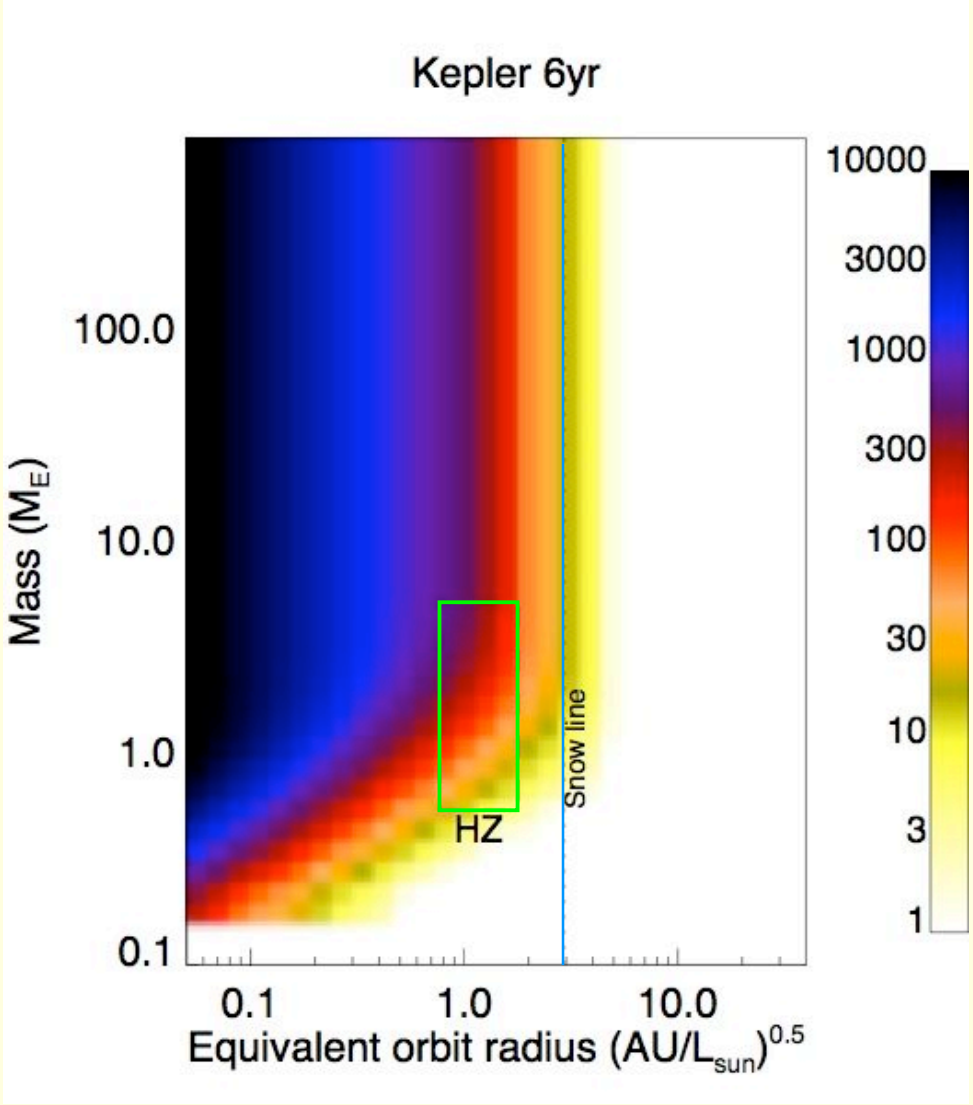
- **Microlensing for planetary masses and separations**
  - Augment ground-based facilities
  - Space-based mission if possible at Discovery level or below, AND if it does not affect the astrometric and direct imaging missions

- **Ground-based direct imaging**
  - Develop and implement extreme AO
  - Support construction of a 30-m telescope with extreme AO

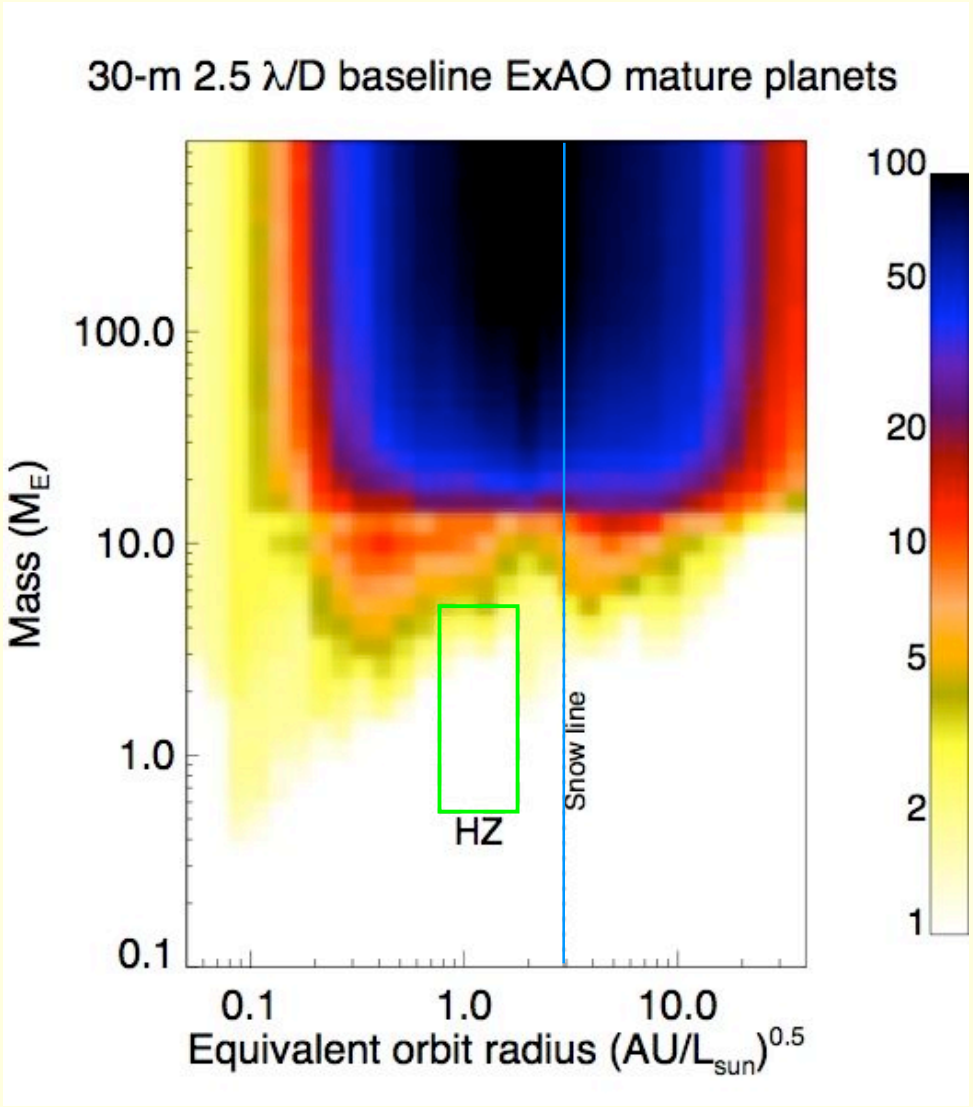
Space-Based Microlensing



Kepler


Kepler 6yr
Mass (M_E)
100.0
10.0
1.0
0.1
HZ
Snow line
0.1
1.0
10.0
Equivalent orbit radius $(AU/L_{sun})^{0.5}$
10000
3000
1000
300
100
30
10
3
1

Ground-Based Direct Imaging



Recommendations: Planetary Architectures/Formation

- **Circumstellar Disk Science**
  - Maintain US involvement in Herschel and ALMA
  - Archival analysis for relevant Spitzer, Chandra, Hubble, and ground-based data
  - Invest in appropriate instrumentation on large-aperture telescopes

- **Support for activities that maximize the knowledge return from data and train new scientists in the field**
  - Theoretical studies
  - Stellar property surveys
  - Competitive fellowships for young researchers

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Definition of $\eta_{\oplus}$

From TPF-STDT report 2005:

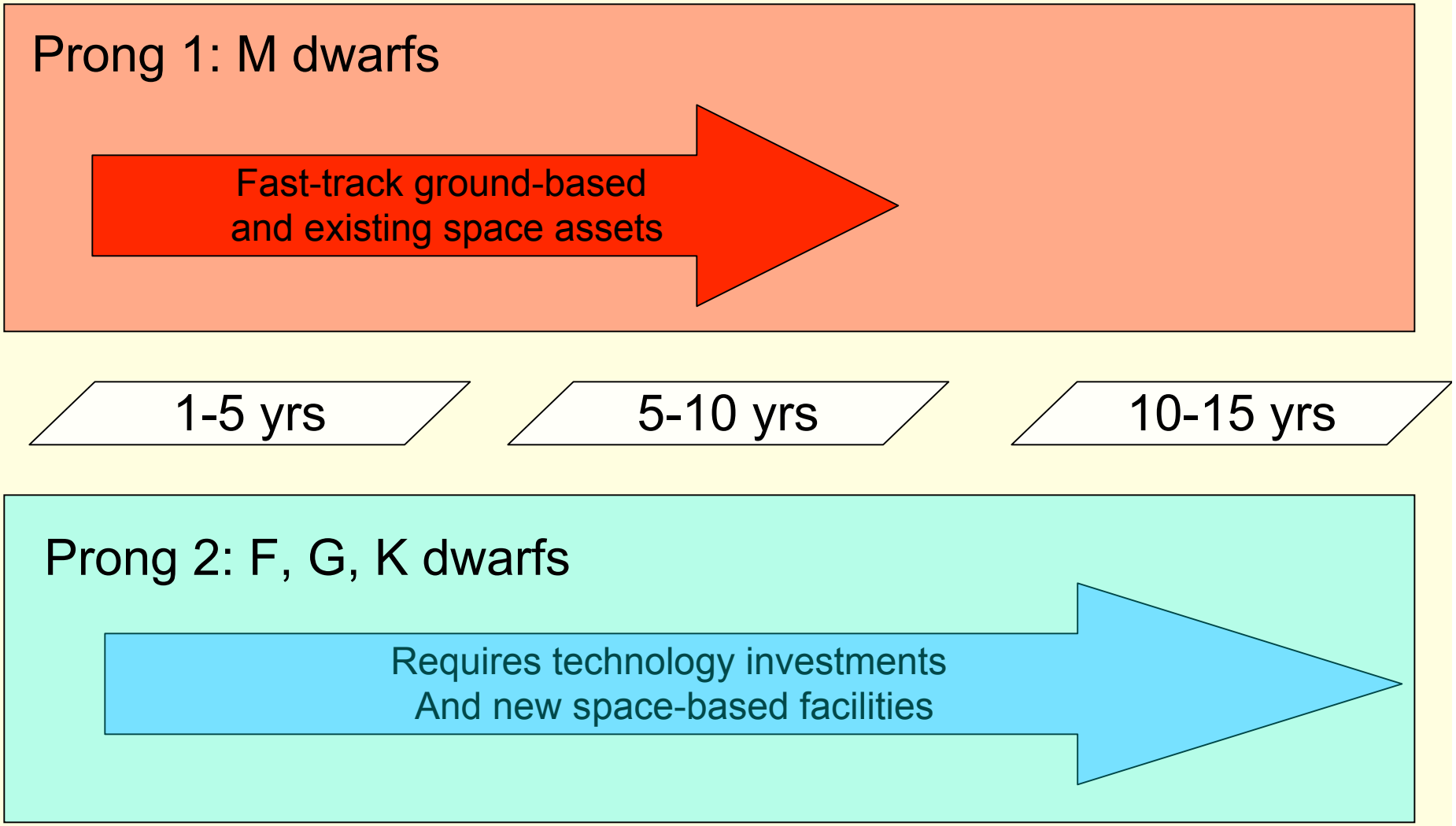
- The fraction of stars that have at least one potentially habitable planet
- I.e., at least one planet in the habitable zone
- For our sun, $\eta_{\oplus} = 1$

Strategic Goals

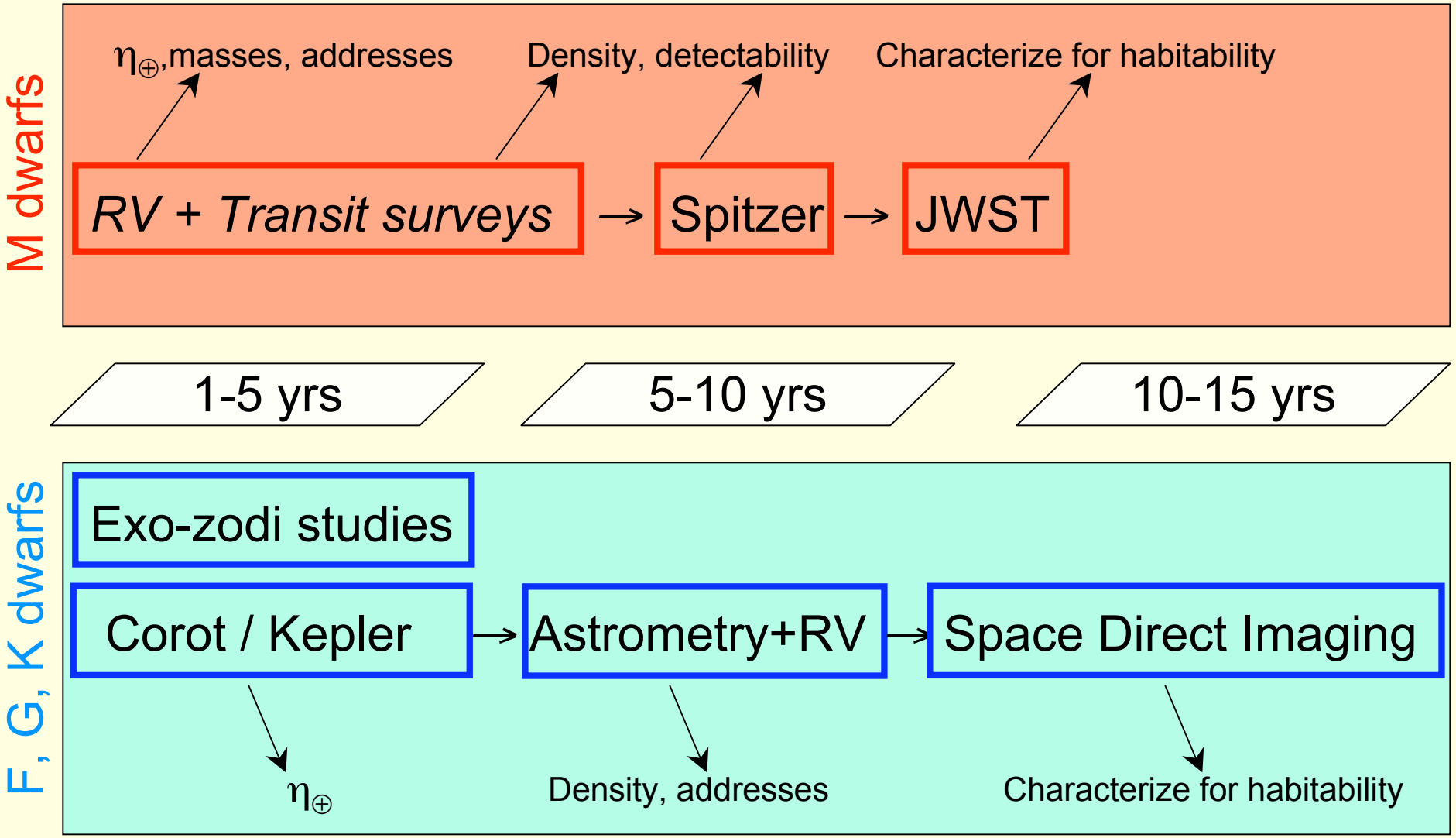
1. Determine $\eta_{\oplus}$ to a high degree of statistical significance around a broad range of main sequence stellar types
2. Constrain the architectures of planetary systems down to sub-Earth masses for semi-major axes out to several AU (for G-dwarfs), both in the nearby solar neighborhood of order 10^6 cubic pc and in the larger galactic bulge
3. Provided $\eta_{\oplus}$ is large (at least 0.1), characterize at least one Earth-sized planet for mass and basic atmospheric composition

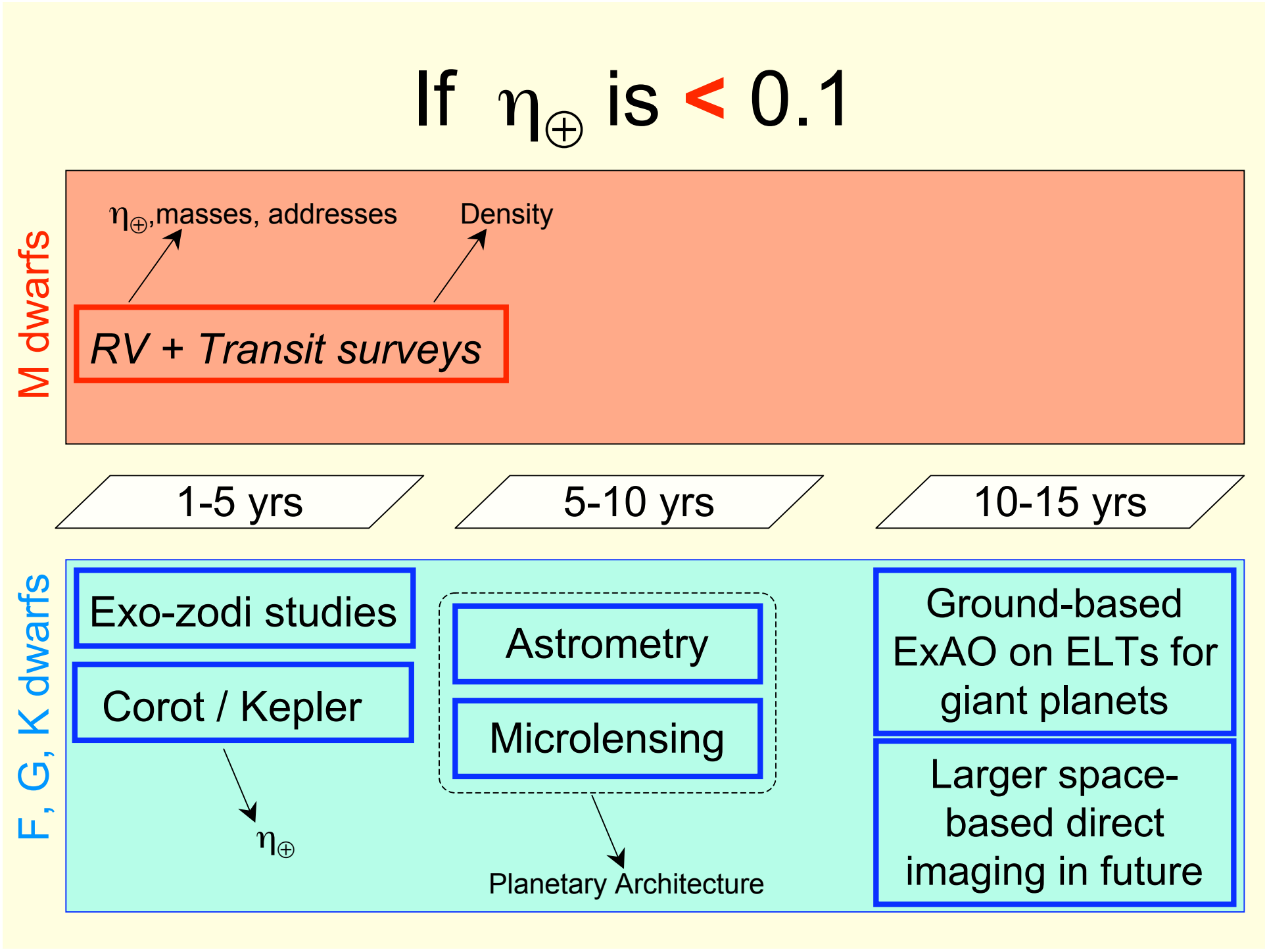
Divide into three time periods: 1-5, 5-10, 10-15 years from now

Two-Pronged Strategy

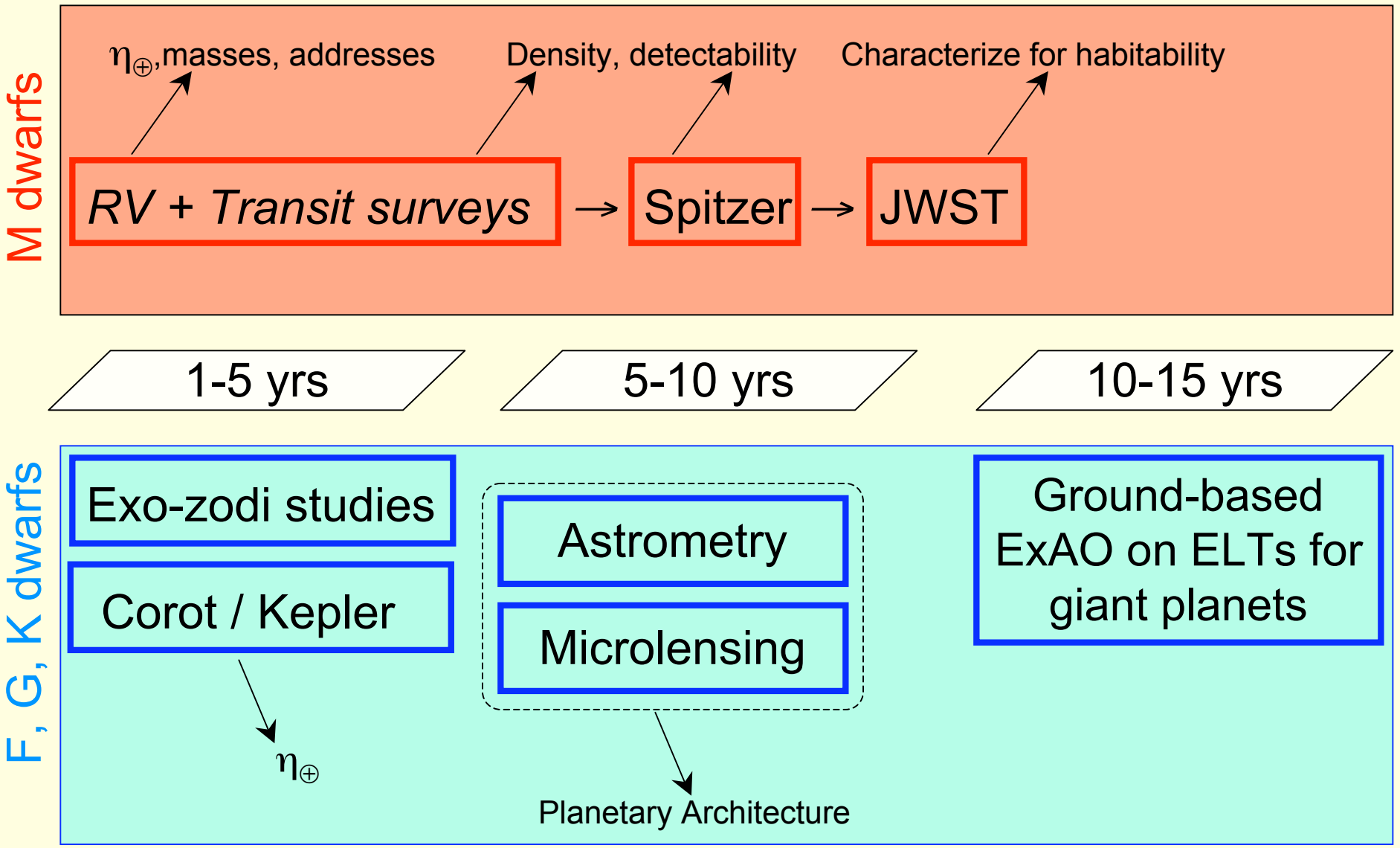


If $\eta_\oplus$ is > 0.1

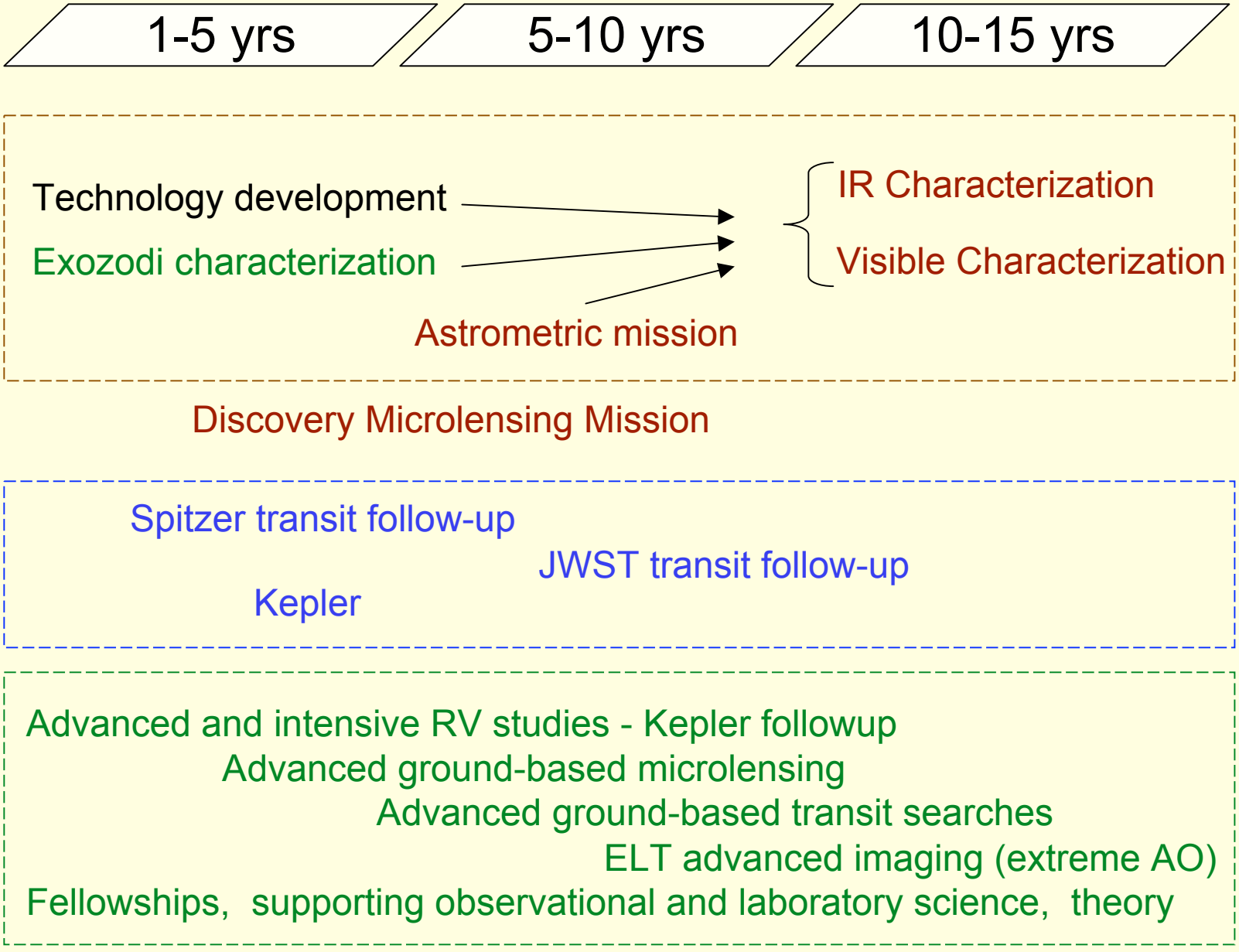



If $\eta_\oplus$ is < 0.1
M dwarfs
$\eta_\oplus$,masses, addresses
Density
RV + Transit surveys
1-5 yrs
5-10 yrs
10-15 yrs
F, G, K dwarfs
Exo-zodi studies
Corot / Kepler
$\eta_\oplus$
Astrometry
Microlensing
Planetary Architecture
Ground-based ExAO on ELTs for giant planets
Larger space-based direct imaging in future

If Exozodi > 10 Earth Zodi



Recommended Programs, Missions, & Activities



Strategy Summary

- **Two-pronged approach**
  - Potential for early results on Earth-sized planets orbiting M stars
  - Astrometric search is insensitive to zodi and background objects; ensures significant results on planetary architectures and Earth-mass planets
  - Known targets simplify the space-based direct detection mission
- **Flexibility**
  - Decision points occur early enough in the strategy to shift focus toward the end, contingent on $\eta_{\oplus}$ and zodi
  - Individual elements can be delayed or stretched out while the overall program still provides exciting discoveries

Conclusions

1. **Plan addresses key questions in exoplanet research**
   Are there habitable planets around other stars?
   What is the architecture of planetary systems?
   How do planets fit into the process of star formation?

2. **Plan provides opportunity for early discoveries and risk reduction; space-borne direct imaging is significantly simplified**

3. **Plan depends on a balance of ground vs space assets, as well as existing vs future assets**

4. **Plan is flexible to surprises, failures, and new discoveries**

5. **Plan is streamlined in cost but can be stretched out**