

Exo-Planet Task Force (ExoPTF)

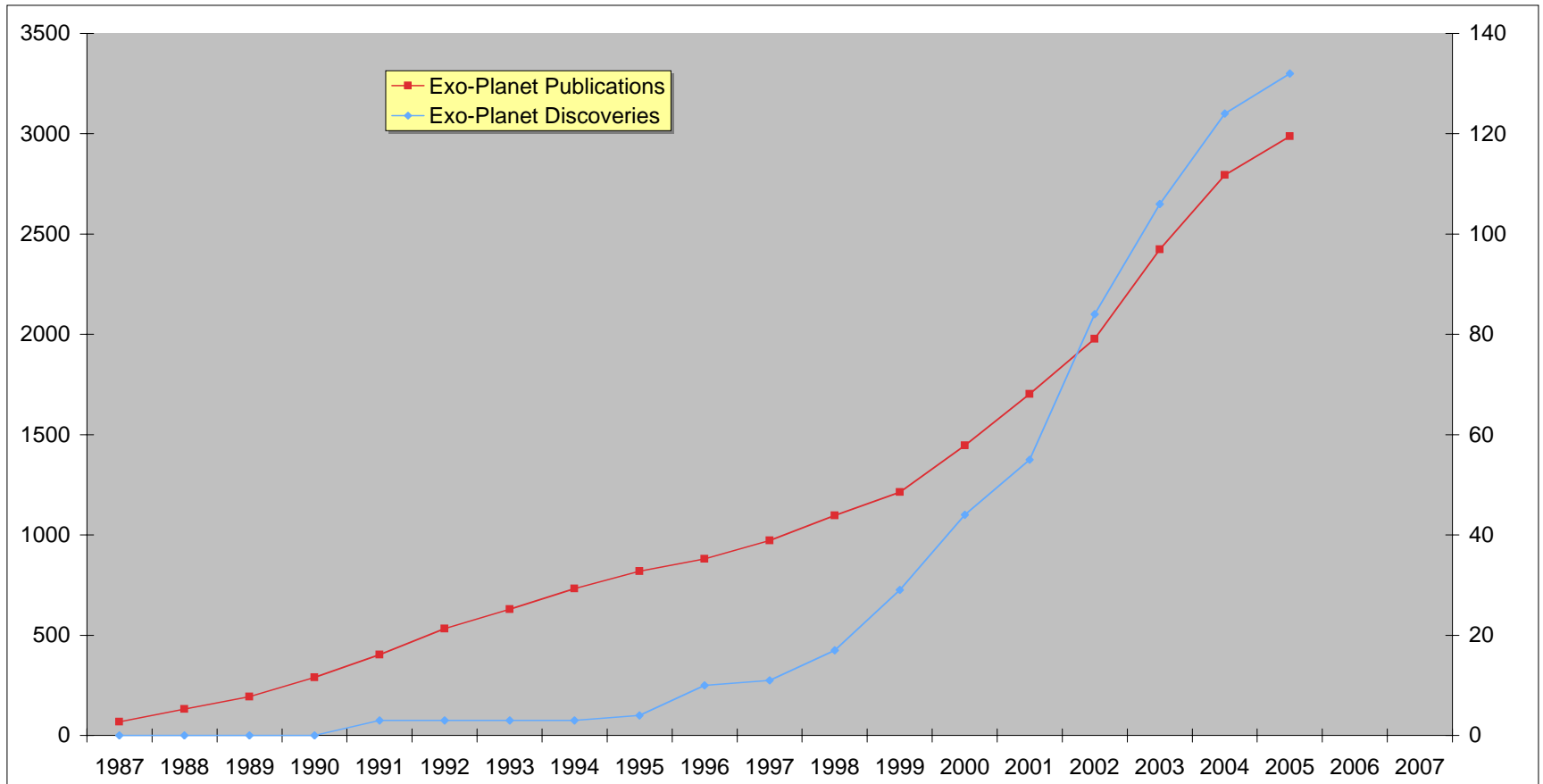
A Strategy for the Detection and
Characterization of Exoplanets

Preliminary Findings Briefing

“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

Publications and Planets



Recent Results for ExoSystems

- Many detections
- Rich variety of exosystems
- Multi-planet systems
- Lower masses
- Closer to solar system analogues
- Potentially Earth-like planets may be common

AAAC ExoPlanet Task Force
2006 - 2007



Astronomy and Astrophysics
Decade Review
2007 - 2010

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.



Charge to the Task Force

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.

The ExoPTF is asked to address the following specific areas:

1. The key scientific questions and issues, in the context of recent developments in exo-planet science and planet formation;
2. Measurement techniques, their enabling technologies and their implications for future survey and measurement directions and priorities;
3. Specific types of experiments (e.g., radial velocity measurements, transit searches, microlensing, adaptive optics, coronagraphy) with respect to their expected scientific return and contributions;
4. The potential and complementary science return from measurements at different wavelengths;
5. The role of theoretical investigations in defining needed capabilities, constraining measurement requirements, and interpreting results in terms of the overarching scientific questions;
6. Major decision points in the exo-planet study process;
7. Identification of key technologies relevant to the scientific goals of the program;
8. Important steps in the development of instrumentation, R&D, and other work required in preparation for or in support of, these and related experiments and missions;
9. The complementary ground-based and space-based research opportunities, coordination between funding agencies and possible synergistic advances;
10. Opportunities for cooperation, coordination or synergy with international programs.

Task Force Membership

| | |
|---|--|
| 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 Landessternwarte Heidelberg |
| Bruce Macintosh Lawrence Livermore | Sara Seager MIT |
| Mark Marley NASA Ames | Josh Winn MIT |

Meetings and Invited Briefings

March 20-21 (Washington - NSF and NASA HQ)

- Debra Fischer - Status of exoplanet detections
- Doug Lin - Jovian exoplanets
- Vicki Meadows/ Jim Kasting - Terrestrial exoplanets
- Wes Traub - Exoplanet detection approaches I
- David Charbonneau - Exoplanet detection approaches II

April 10-11 (Cambridge):

- Michael Perryman - European exoplanet detection and study programs
- Jamie Lloyd - RV measurements in the IR
- Mark Clampin - JWST potential
- Scott Gaudi - Microlensing techniques

May 2-3 (Tucson)

- Dave Latham - Kepler and Kepler follow-up
- Phil Pinto - LSST capabilities
- Phil Hinz - Imaging of exoplanet disk systems
- Shri Kulkarni - SIM
- Dan Coulter - TPF
- Greg Laughlin - Testing planet formation models
- Bruce Macintosh - Imaging with ELT's

August 14-15 (San Francisco)

- James Marr--Astrometric Planet Hunter
- Pete Worden--Mission costs

September 11-12 (Washington-NSF)--report preparation

Contributed Exoplanet White Papers

84 papers

308 distinct contributors

48 institutions

23 states

13 countries

The most compelling questions and how to answer them

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

- RV measurements
- Spitzer/JWST transit photometry
- Astrometric measurements
- Visible/IR Characterization

What is the architecture of planetary systems?

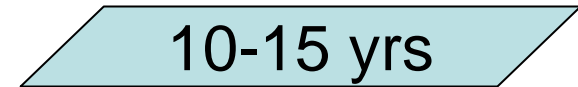
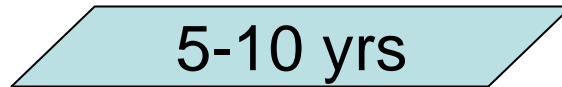
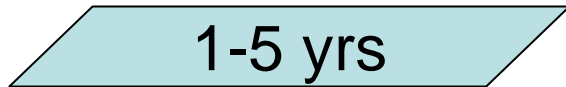
- Microlensing photometry and follow-up
- Kepler transit studies
- Astrometric measurements

Recommendations

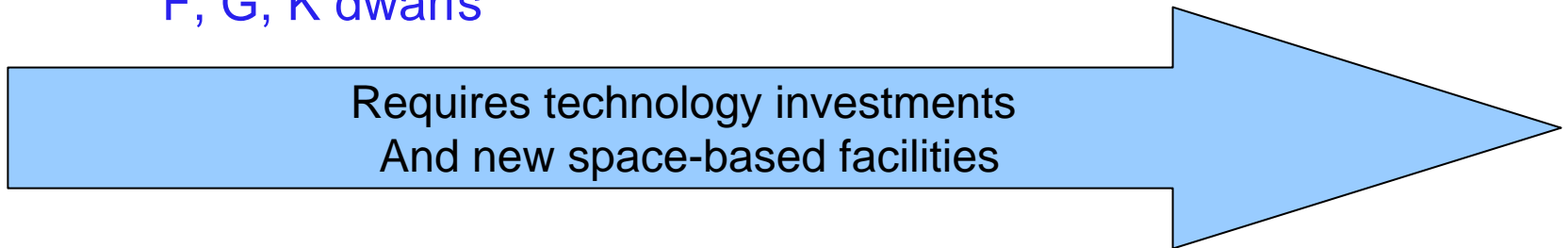
- Intensify RV studies to reach lower mass planets (more time/precision).
- Search for transiting terrestrial exo-planets around nearby M dwarfs, characterize with Warm Spitzer and JWST
- Prepare for a characterization mission around Sun-like stars - need actual earth-like targets with known orbits
 - Technology: sub m/s RV, sub micro-arcsec astrometry, spaceborne coronagraphy
 - Exozodi--need measurements down to 10 zodiac around nearby stars
 - An astrometric mission does not need to wait for Kepler's η_{\oplus}
- A characterization mission--coronagraphy/occultor first, then interferometry
 - Once stars are known from astrometry, mission is simplified
- Microlensing for large-scale architectures
 - Augment ground-based facilities
 - Spaceborne mission - if possible at Discovery level or below.
- Flexibility of approach
 - Adjust timing: Could slow astrometry/coronagraphy
 - Adjust ambition of characterization effort
 - Maintain pace on the M-dwarfs

Two-pronged strategy:

M dwarfs



F, G, K dwarfs



If η_{\oplus} is > 0.1 :

M
d
w
a
r
f
s

η_{\oplus} , masses, addresses Density, detectability Characterize for habitability

RV + Transit surveys --> Spitzer --> JWST

1-5 yrs

5-10 yrs

10-15 yrs

F Exo-zodi studies

G Corot/ Kepler --> Astrometry+RV -->

Coronagraphy/
occulter

K

η_{\oplus}

Density, addresses

Characterize for habitability

If exo-zodis are large (> 10 zodis):

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η_{\oplus} , masses, addresses Density, detectability

RV + Transit surveys --> Spitzer --> JWST

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5-10 yrs

10-15 yrs

F Exo-zodi studies

G Corot/ Kepler Astrometry+Microlensing

K

η_{\oplus}

Planetary architecture

Nearby stars:
Ground-based
extreme AO on
ELT for giant
planets

If η_{\oplus} is < 0.1 :

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η_{\oplus} , masses, addresses Density, detectability

RV + Transit surveys

1-5 yrs

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F Exo-zodi studies

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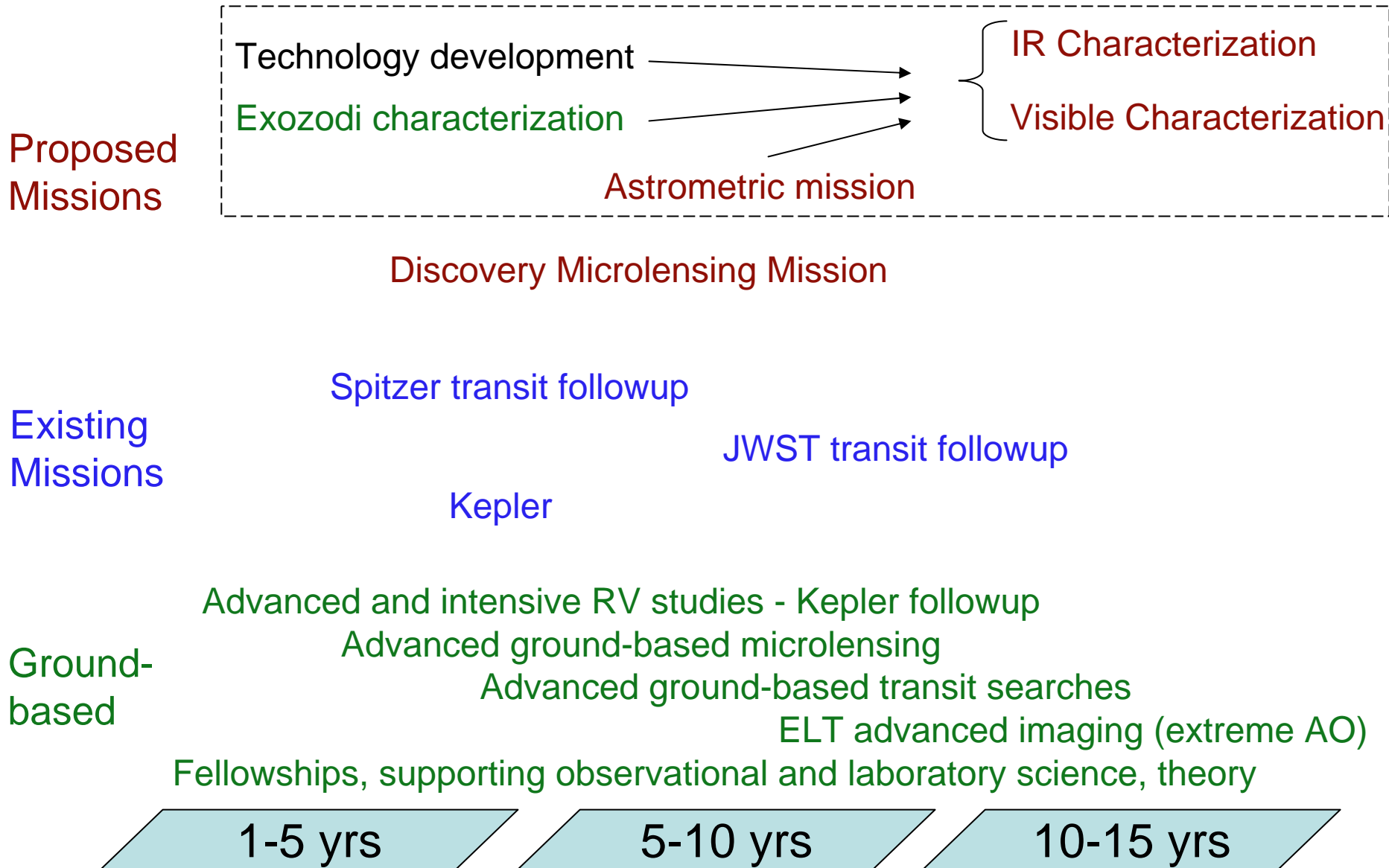
η_{\oplus}

Planetary architecture

Nearby stars:
Ground-based
extreme AO for
giant planets.

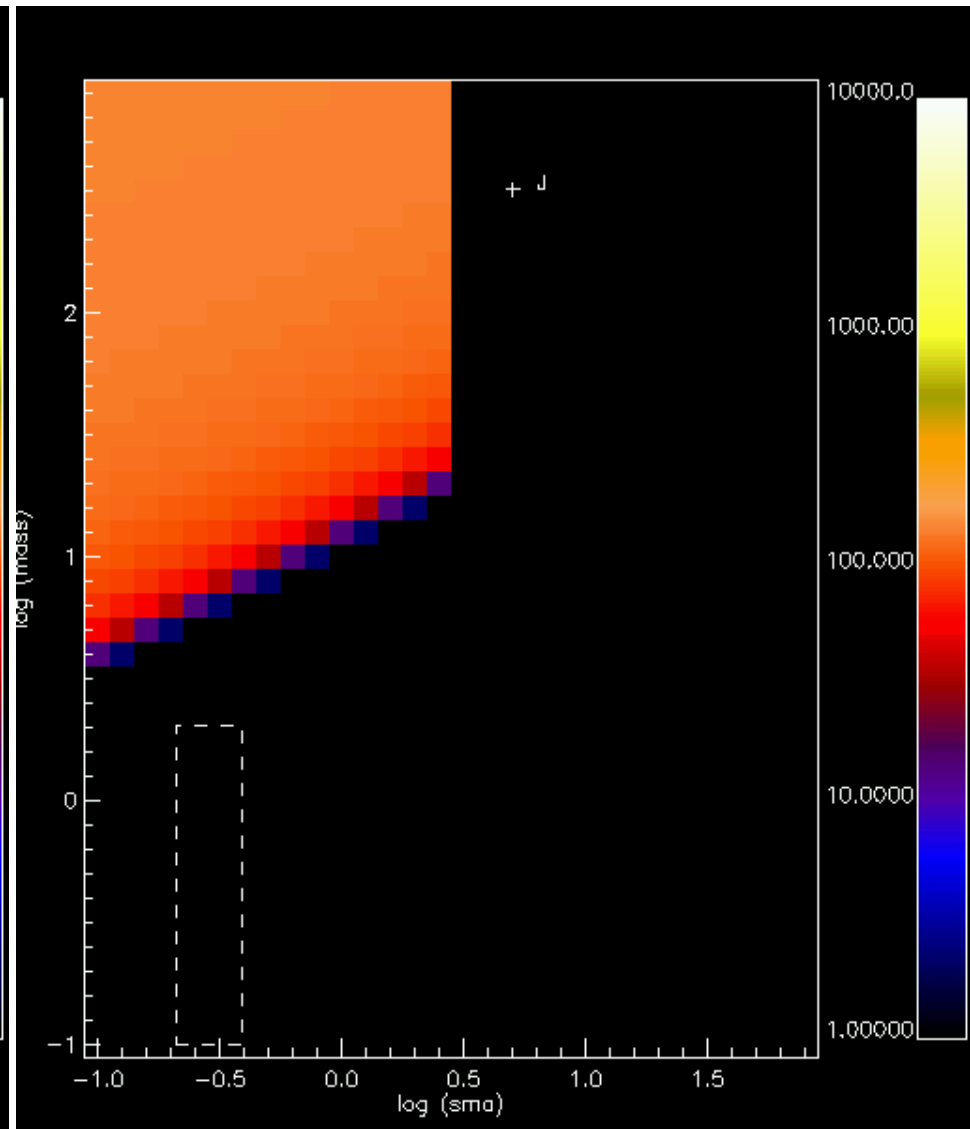
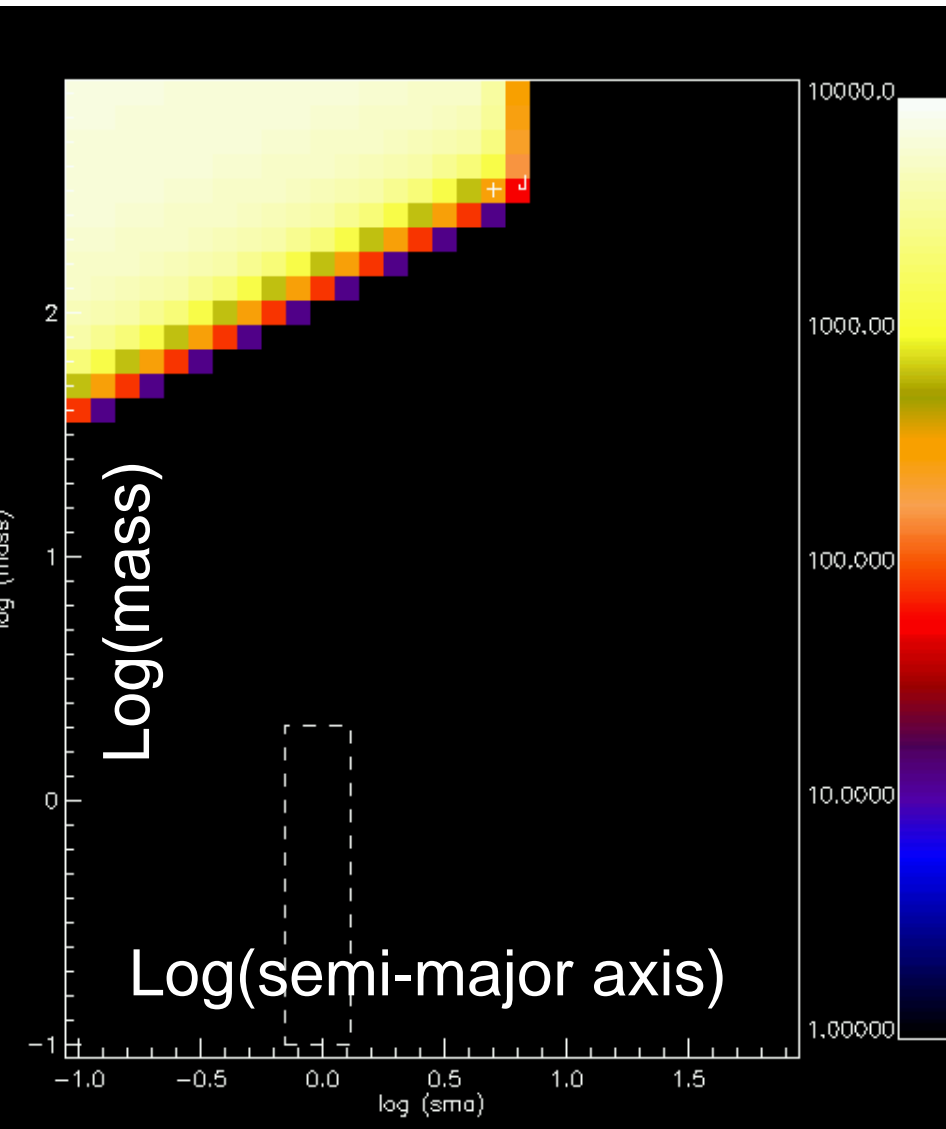
Possible
participation in
Darwin

Recommended Programs, Missions and Activities

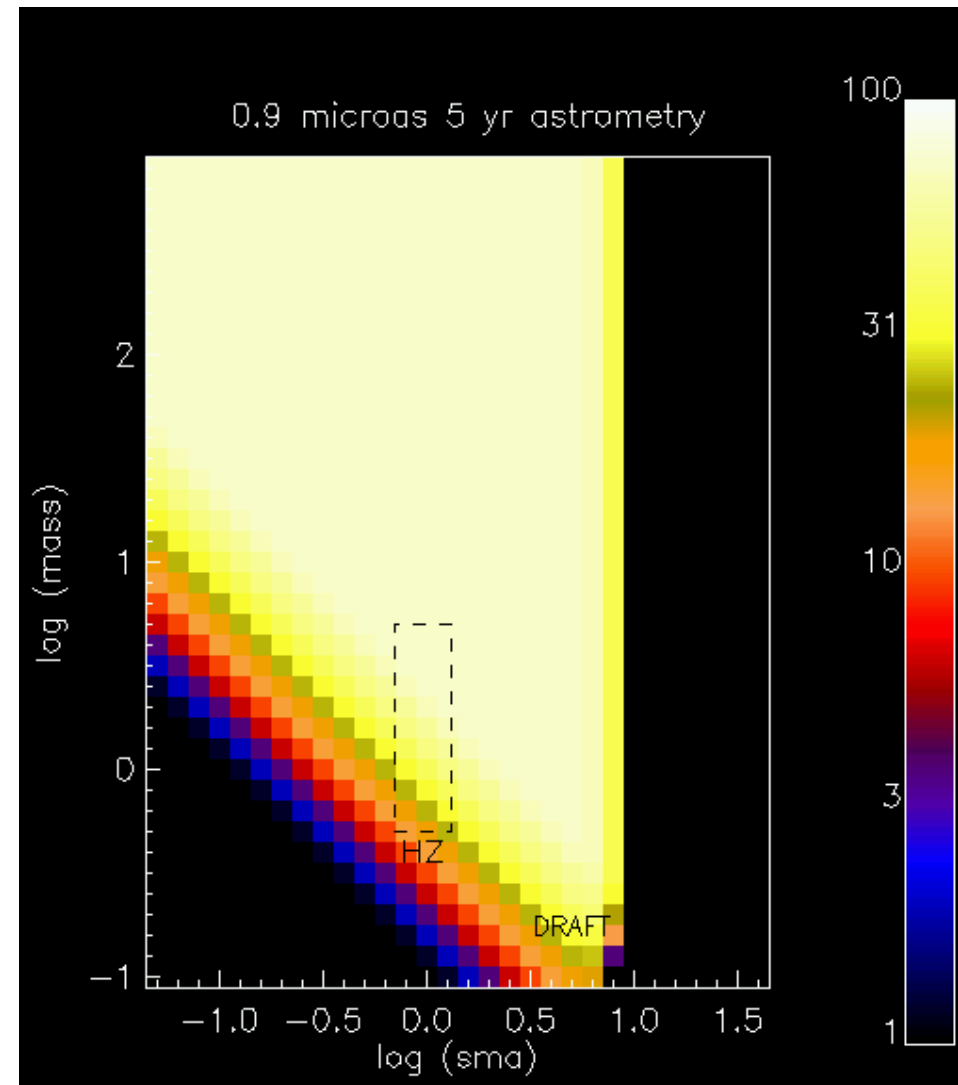
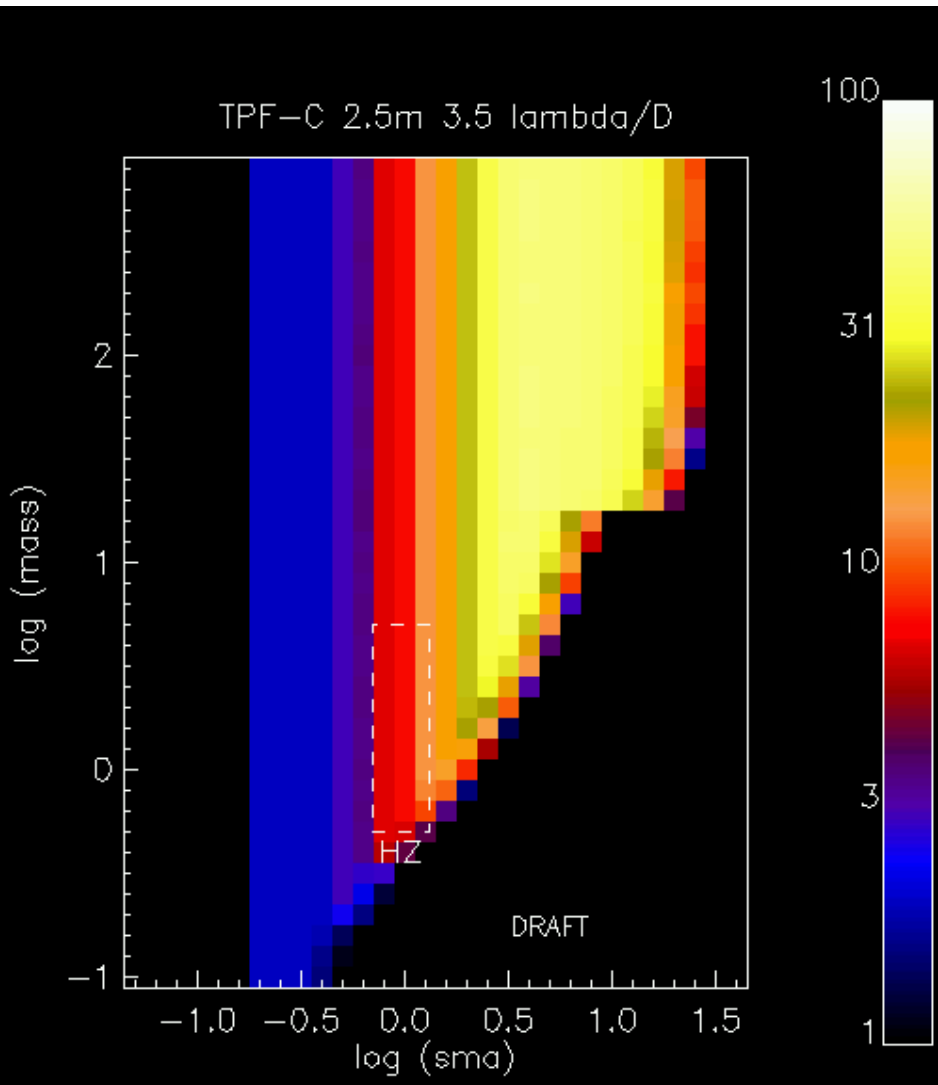


Constructing figures of merit for different techniques: example

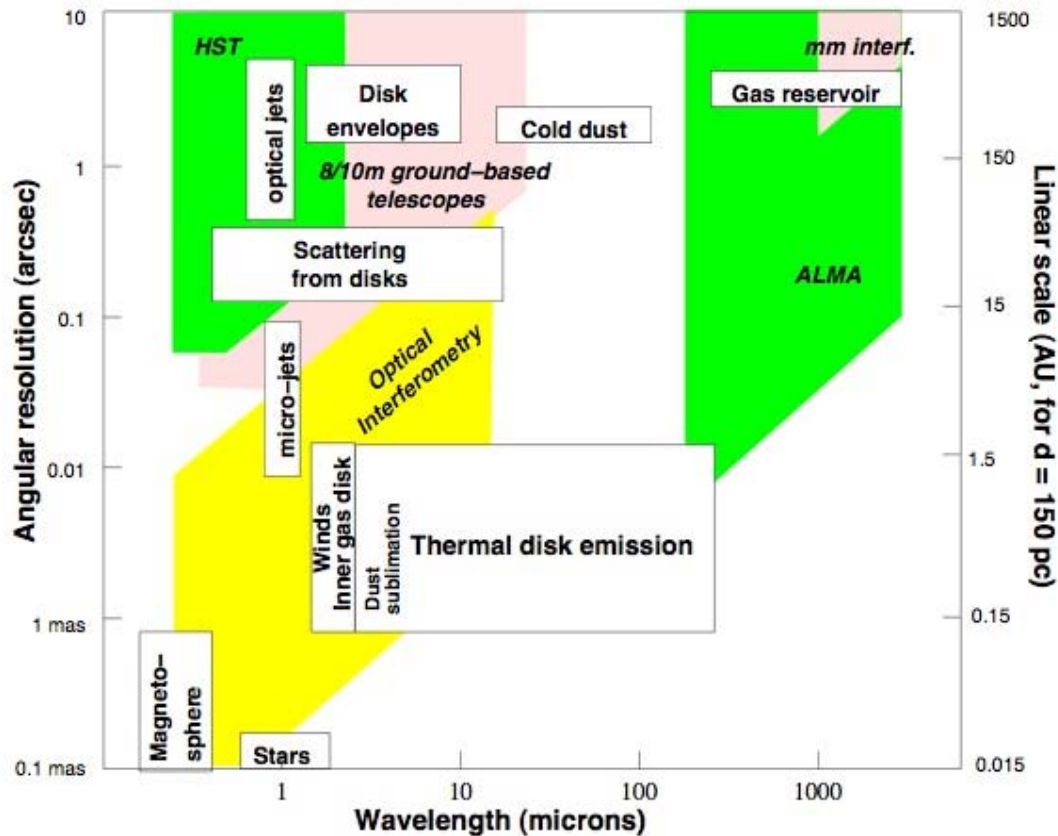
General doppler vs eta_e



Completeness figures for a probe-sized near-term TPF (2.5m with a 3.5 λ/D coronagraph) compared to a 0.9 microarcsec per visit astrometry mission ala Planet Hunter.



Observations of planet-forming and debris disks



Structure of the Report

- 1. Executive Summary
- 2. The scientific and philosophical significance of detecting other Earths
- 3. Goals and Methodologies for detecting and characterizing extrasolar planets
- 4. Findings of the Exoplanet Task Force
- 5. Exoplanet detection scenarios from the present to detect/char other Earths
- 6. Recommendations of the Exoplanet Task Force
- 7. State of knowledge of extrasolar planets
- 8. Figures of merit for exoplanet detection/characterization
- 9. Technique performance projections...(0-5), (6-10), (11-15) years
 - A. RV
 - B. Astrometry
 - C. Transit
 - D. Microlensing
 - E. Coronagraphy
 - F. Interferometry
 - G. Indirect inference via debris disk properties
- 10. Laboratory, theory, and technology investments required
- 11. References
- 12. Acknowledgments
- 13. Technical Appendix

Conclusions

1. The plan addresses the key questions in exoplanet research:
Are there habitable planets around other stars?
What is the architecture of planetary systems?
How do planets fit in to the process of star formation?
2. The plan provides the opportunity for early discoveries and risk reduction; spaceborne coronagraphy is significantly simplified.
3. Plan depends on a balance of ground- and space; existing and future assets
4. Plan is flexible to surprises, failures and new discoveries.
4. Plan is already streamlined in cost but can be stretched out