Terrestrial Planet Finder - Coronagraphs and Interferometers

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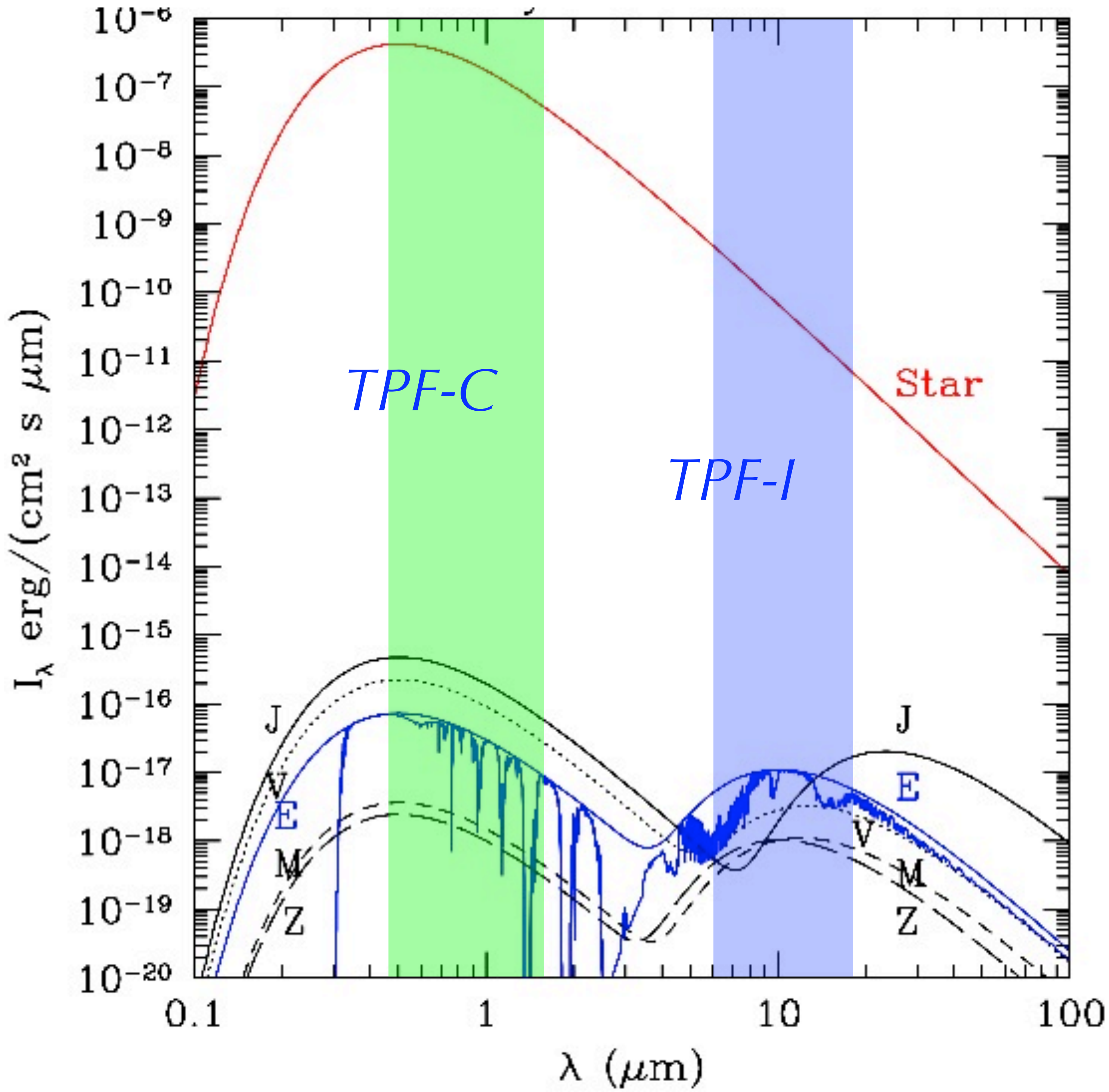
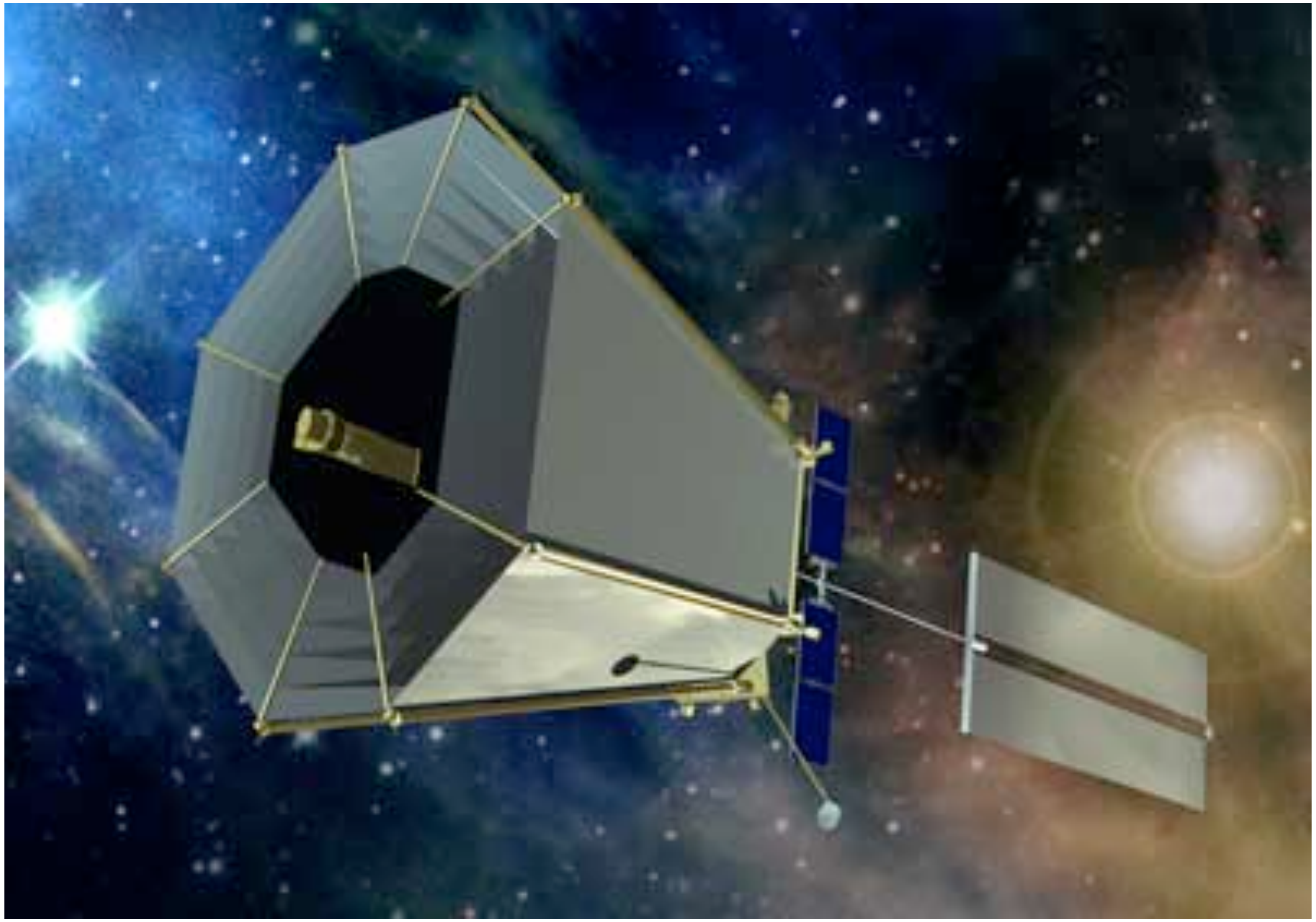
The fundamental challenge



Terrestrial Planet Finder - Coronagraph



Terrestrial Planets

- *Directly detect terrestrial planets within the habitable zones around nearby stars, or show they are not present.*
- *Measure orbital parameters and brightnesses for any terrestrial planets that are discovered.*
- *Distinguish among planets, and between planets and other objects, through measurements of planet color.*
- *Characterize at least some terrestrial planets spectroscopically, for O_2, O_3, H_2O, and possibly CO_2 & CH_4.*

Giant Planets

- *Directly detect giant planets of Jupiter's size and albedo at a minimum of 5 AU around solar type stars, and determine orbits for such giant planets when possible*
- *Obtain photometry for the majority of detected giant planets, to an accuracy of 10% in at least three broad spectral bands, and in additional bands for the brightest or well-placed giants.*
- *Characterize detected giant planets spectroscopically, searching for the absorption features of CH4 and H2O.*

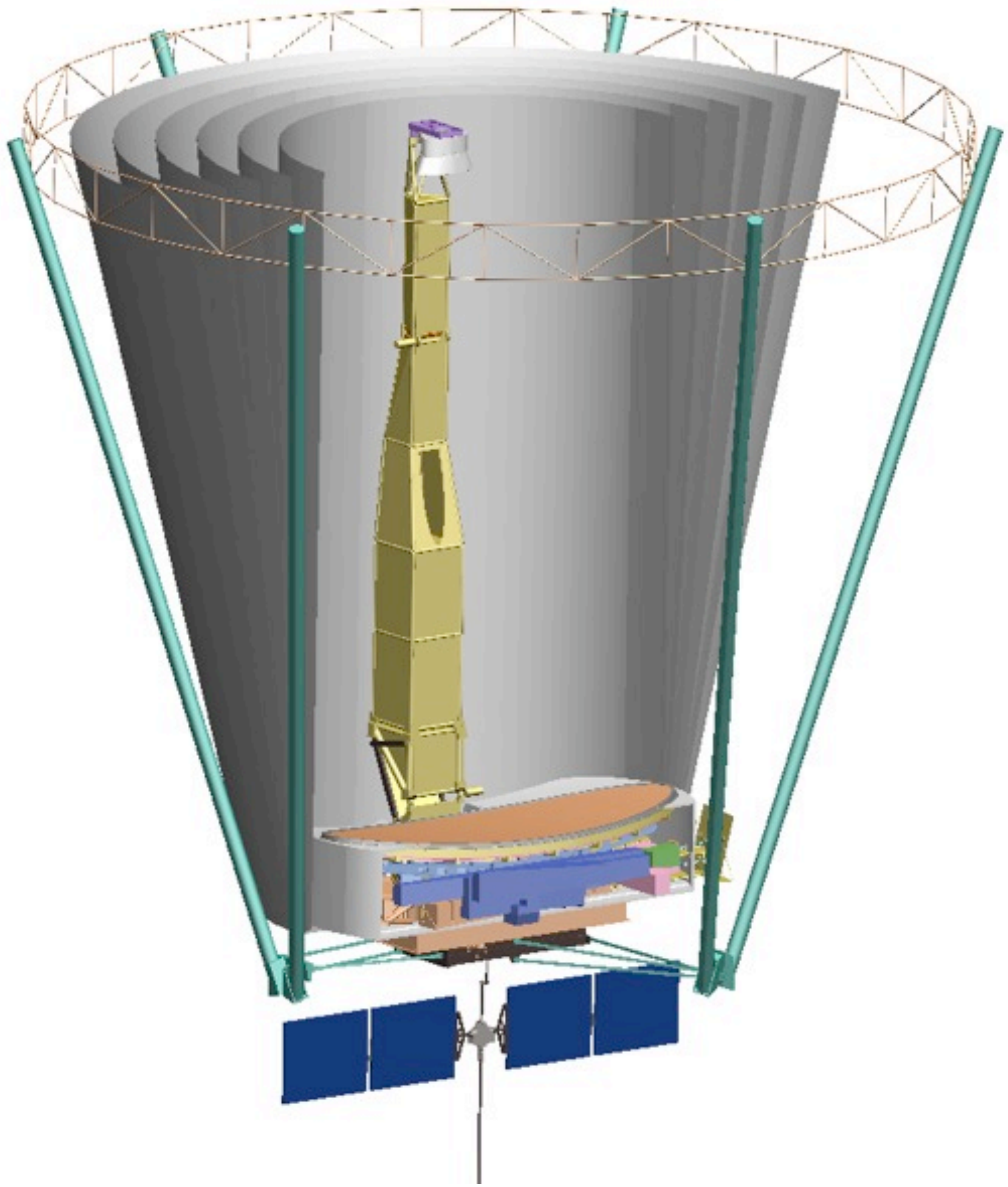
Disks and Planet Formation

- *Measure the location, density, and extent of dust particles around nearby stars for the purpose of comparing to, and understanding, the asteroid and Kuiper belts in the Solar System.*
- *Characterize disk-planet interactions with the goal of understanding how substructures within dusty debris disks and inferring the presence of planets.*
- *Study the time evolution of circumstellar disks, from early protoplanetary stages through mature main sequence debris disks. measurements of planet color.*

General Astrophysics, including ...

- *Constrain the nature of Dark Energy via precise measurements of the Hubble constant and the angular-diameter vs. redshift relation.*
- *Use the fossil record of ancient stars in the Milky Way and nearby galaxies to measure the time between the Big Bang and the first major episodes of star formation.*
- *Determine what sources of energy reionized the universe and study how galaxies form within dark-matter halos, through a program of low-resolution spectroscopy of large statistical samples, gathered in parallel with the TPF-C planet search program.*
- *Carry out a diverse General Observer program in the tradition of the Hubble, Chandra, Spitzer, & JWST observatories.*

TPF-C Design



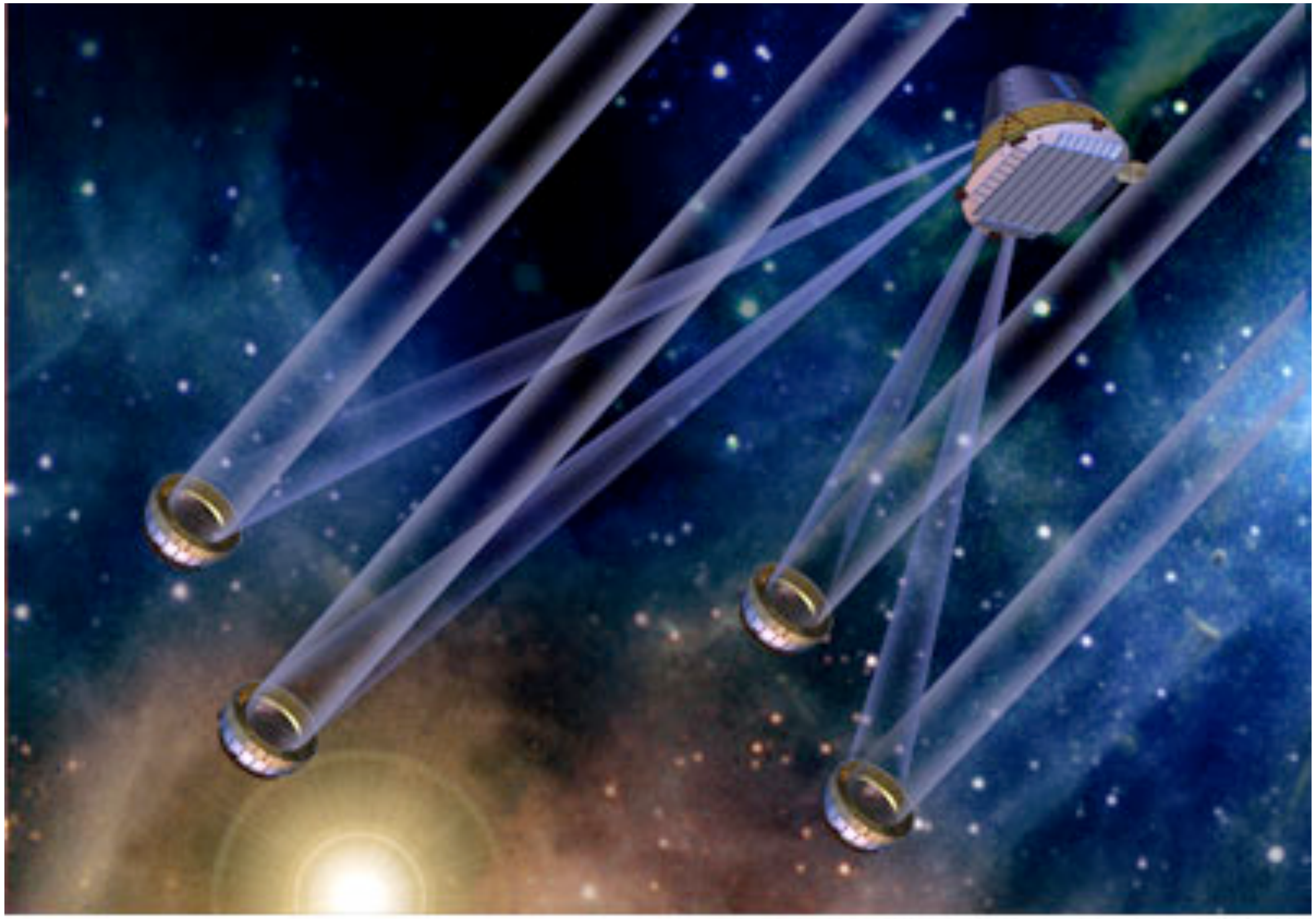
TPF-C Science Performance Requirements

- *Search habitable zones in at least 32 Systems with ability to detect an Earth twin at 10 pc, and*
- *Detect at least one habitable zone planet with 95% confidence, assuming 10% of target stars have planets*
- *Spectroscopically detect atmospheric O2 and H2O*
- *High-level performance requirements:*
    - *Earth is 25 magnitudes fainter than the central star in reflected starlight at visible wavelengths (400-1000 nm)*
    - *Starlight suppression better than 25 mag at an IWA of 65 milliarcsec*
    - *Contrast stability better than 28 mags*

TPF-C Engineering Requirements

- *TPF-C Flight Baseline 1 design:*
    - *3.5m x 8m elliptical telescope aperture*
    - *Starlight suppression with 4 lambda/D, 8th order Band Limited mask*
    - *1 picometer wavefront stability per Zernike mode*
    - *1 mK temperature stability for primary mirror and coronagraph*
    - *0.3 mas image jitter: 4 mas body pointing plus internal fine steering mirror*
    - *Integral field spectrograph with R > 70*
    - *Roll angles sweep narrow-beam axis*
    - *Roll angle dithers remove instrument noise*

Terrestrial Planet Finder - Interferometer



SPACECRAFT IMAGE BY T. HERBST (MPIA)

TPF-I Science Objectives

- *Detect Earth-like planets in the habitable zones of the nearby stars*
- *Study planets of all types within 5 AU of the parent stars (to 10 pc)*
- *Spectroscopically characterize Earth-like planets*
- *Carry out a program of general astrophysics*

TPF-I Science Performance Requirements

- *Search habitable zones in at least 150 systems within 30 pc, with ability to detect an Earth with 90% confidence*
- *Spectroscopically detect atmospheric biomarkers, including the combined detection of O_3, H_2O, and CO_2.*
- *Determine orbital positions to within 10% of the planet's semi-major axis*
- *High-level performance requirements:*
    - *Earth-like planet is ~17 magnitudes fainter than the central star at mid-IR wavelengths (6.5 - 18 microns)*
    - *Starlight suppression by 15 mags*
    - *Spectral resolution of 25-50*

TPF-I Design

- *Four formation-flying telescopes, each of 4 meter aperture, plus a beam combiner spacecraft, Emma layout (as shown) is one possibility*
- *Telescope array rotates about the line-of-sight to the star, with interferometric baselines up to 200 meters*
- *Fringe trackers and delay lines stabilize the location of the null on the star*
- *Imaging in the interferometric nulling mode dims the central star by 15 magnitudes*
- *Spectroscopy at R = 25-50 in the mid infrared (6.5-18 microns)*

TPF Status ...

- *Lots of information on TPF can be found at http://planetquest.jpl.nasa.gov*
- *TPF-C and TPF-I are currently supported by NASA for technology development and milestone demonstrations.*
- *The Astro2010 Decadal Survey by the National Academies is now evaluating astronomy program priorities for the coming decade, with a report to be released next year. A high priority for a medium-class exoplanet mission in the coming decade is one possible outcome.*
- *As we await the Astro2010 recommendations, NASA has announced a competitive program for the advancement of planet-finding technologies.*
- *We expect significant advancements and opportunities for the exploration of exoplanetary systems in the coming years.*

End