Precursor science discussion summary; IROUV-exoplanet

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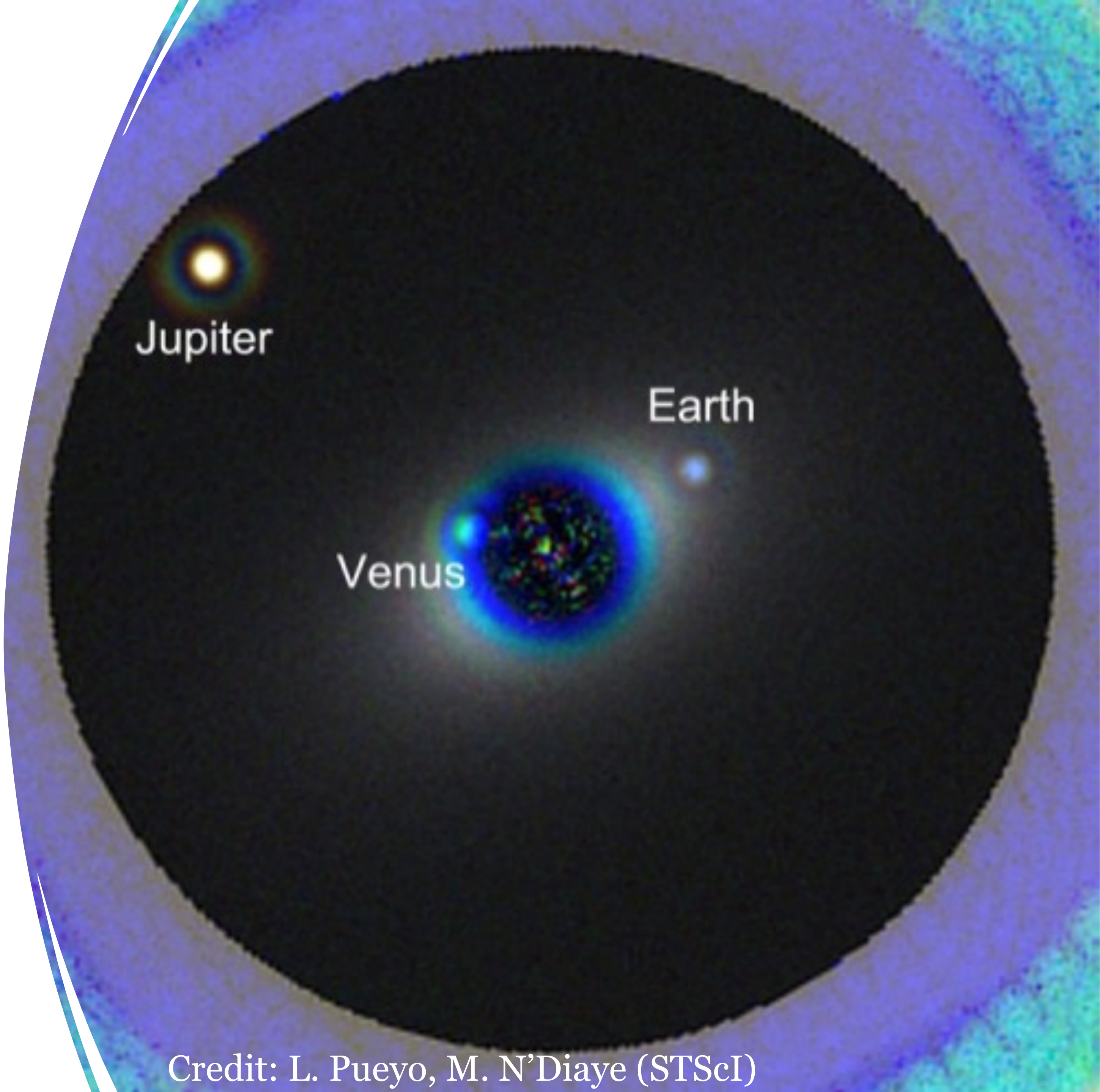

Credit: L. Pueyo, M. N’Diaye (STScI)

- Precursor science–drives design reference mission
  - *Example*: knowing the frequency of habitable-zone Earth-size planets around sun-like stars allows one to design the mission towards the Decadal survey recommendation of discovering ~25 such systems

- Preparatory science—science that is important to do in advance of mission, but does not drive design reference mission
  - *Example*: precise knowledge of target star ages can place important limits on biogenic vs abiogenic atmospheric biosignatures (and hence the spectra). But such knowledge would not exclude a habitable-zone planet from observation (eg, 0.5 Gyr is interesting, so is 10 Gyr), so would not drive the mission target list or design.

Overall summary

- ~30 science gaps proposed for precursor, whittled down to ~20 (remove solely preparatory science and duplicates)

- Several science gaps both preparatory and precursor, and were kept

- Will discuss several important* precursor science ideas that came up, under general themes

*own opinion, not in consultation with the broader exopag

eta-Earth

What is the frequency of Earth-like (similar radius or mass) planets in the habitable zone around Sun-like stars?

- Main driver of mission design
- Current uncertainties large: $37\%^{+48\%}_{-21\%}$ (Bryson et al. 2020)
- Precursor science to reduce this is highly valuable

eta-Earth

- Can anything be done observationally?
  - PLATO: Launch 2026, 4 year survey→2030
  - Roman microlensing (edge of HZ/iceline), launch 2026, survey done 2030?
- Theoretical modeling: How far can theory go?
  - what is the habitable zone? conservative? optimistic?
- Further analysis of Kepler and integration with TESS/RV/etc to reduce eta-Earth uncertainties
- Understanding of giant planet occurrence rate in HZ can also constrain this
- Understanding of “eta-Earth” around binaries, and comparative planetology around binaries in general

Accurate mission simulation

- Detailed modeling of telescope+instrument+universe
- Standardization of evaluations, exposure time, noise models, etc
- Standardized virtual population (from exoplanet demographics surveys) as input to mission simulators
- Understanding of the “gradient” of the design reference mission
  - Moving beyond “detect molecule X at SNR Y in Z hours”
  - what is the marginal science yield of an observation at one more filter? At one more point in time? With a resolution 50% higher?

Accurate mission simulation

- Detailed modeling of telescope+instrument+universe
- Standardization of evaluations, exposure time, noise models, etc

- “Photobombers”—how do blended planets affect science?
- Spectral and photometric extraction/coronagraphic performance in the presence of exozodi

Goal→optimizing mission design for maximum science yield

”Billion dollar questions”

Exozodi

- Exozodi can complicated direct imaging observations as it presents a surface brightness penalty to the imaging and spectroscopic data
- Higher exozodi levels drive aperture size/spectral resolution needs of the mission
- Needs: better measurements and predictions of the amount of **visible/nir** exozodi in target systems

- Direct visible-light observations of exozodiacal dust around at least a small number of targets
- Theoretical work to translate thermal ir exozodi to visible wavelengths
- Continued observational work from LBTI/VLT
- Theory and obs. of hot exozodi dust, further out (eg, w/JWST)
- Roman? probably not in time.

Extreme precision radial velocity

Knowing a partial planet census around the ~100 IROUV target stars hugely valuable

- Can identify habitable zone planets (earth or giant planets that preclude earth)
- Both can affect the design reference mission

Big opportunity here?

Unlike things like Roman and PLATO, there are several extreme precision RV spectrographs online ~**now** that show precisions near what is needed to detect HZ Earths. (ESPRESSO, EXPRES, HARPS(all), Maroon-X, NEID)

But need a focused, ~10 year observational push.

And need to solve stellar variability problem very soon (largest issue)

Conclusions

- Many precursor science opportunities in terms of mission simulation and theoretical modeling of planet spectra. These are very valuable in design trade studies, and we need to move beyond molecule/snr/time.
- If God could hand us one number ”for free,” we would all ask for eta-Earth, which is poorly constrained. But the timing does not seem right for an observational effort (Plato, Roman, final data products expected in 2030s)
- Exozodi characterization is one area where observational efforts can yield immediate, relevant results. Theoretical modeling here is also needed.
- There is an opportunity for an all-out RV effort—the instrumentation now exists--but it needs to start immediately and be a community effort.