Building SOFIA's Instrument Roadmap

Exoplanet Science Potential

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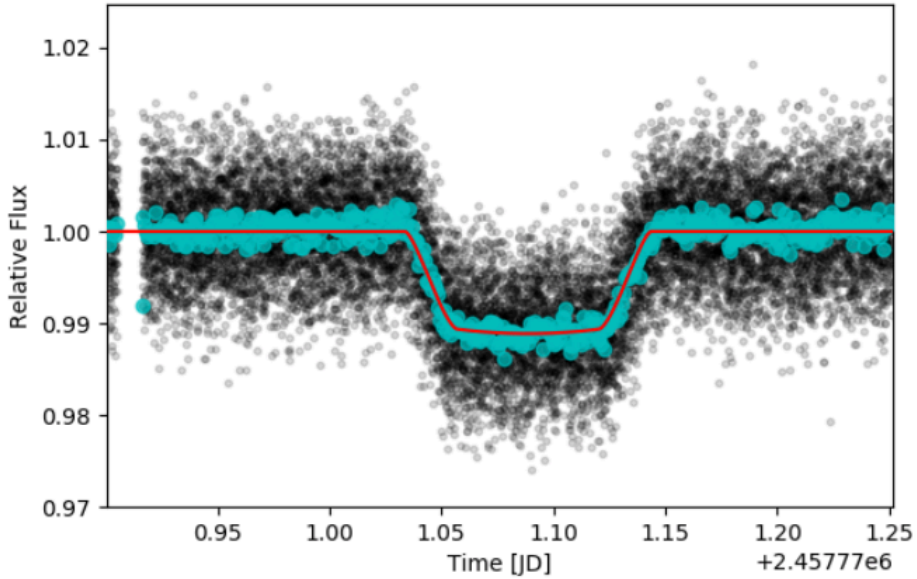
What Method Should SOFIA Use to Study Exoplanets?

- **Radial Velocity:** RV type detections well done already from the ground
- **Microlensing:** ground-based optical observing networks working well
- **Direct Imaging:** SOFIA wavefront quality and aperture diameter not competitive for direct imaging
- **Transits:** maybe an opportunity for SOFIA

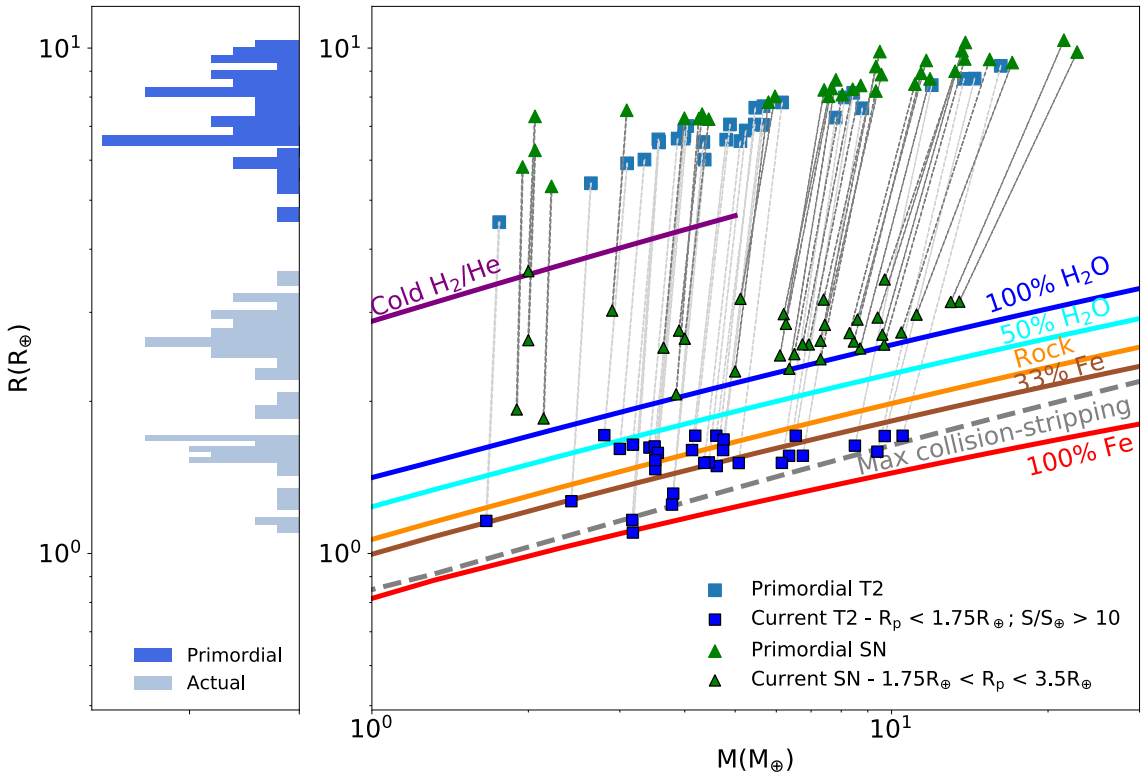


Spitzer/IRAC channel 2 transit
Pearson et al in preparation

Transit observations are the most promising exoplanet science area for SOFIA.

Exoplanet Transit Observations: Discovery and Bulk Density Characterization

- Kepler/K2 legacy
- TESS
- CHEOPS
- Ground-based transit surveys
- Ground-based precision RV surveys

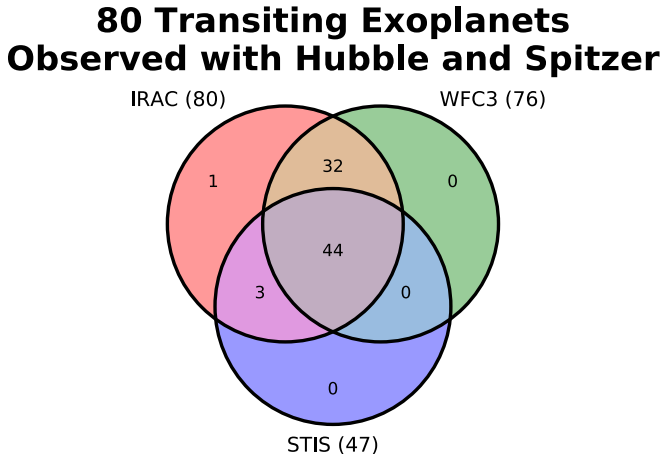


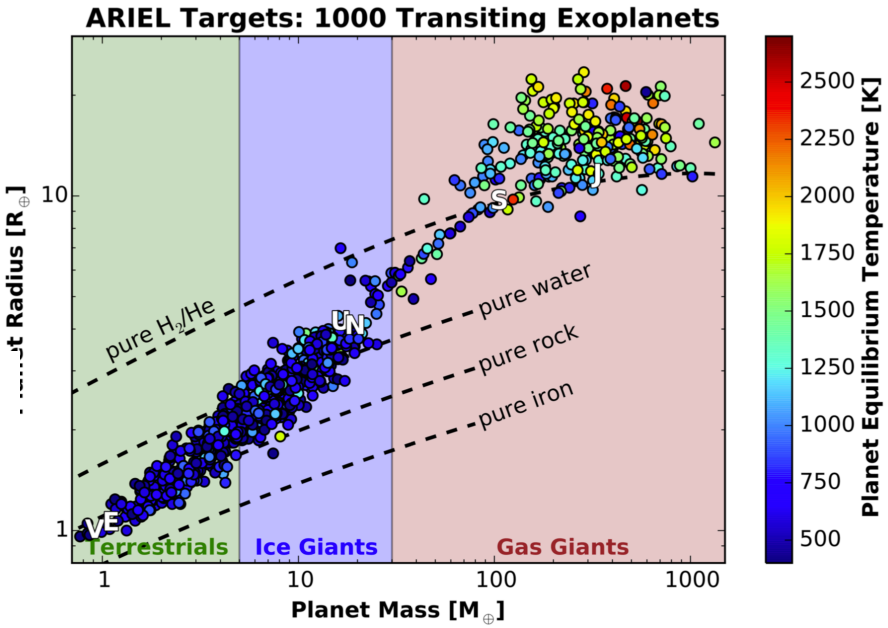
Envelope evolution Estrela et al. 2020

Bulk density characterization is now a statistical area so not well matched to SOFIA.

Exoplanet Transit Observations: Atmospheric Characterization

- HST/Spitzer
  - ~80 planets
- Ground
  - ~lots of planets
- JWST
  - ~29 GTO/ERS planets
- ARIEL
  - ~1000 planets



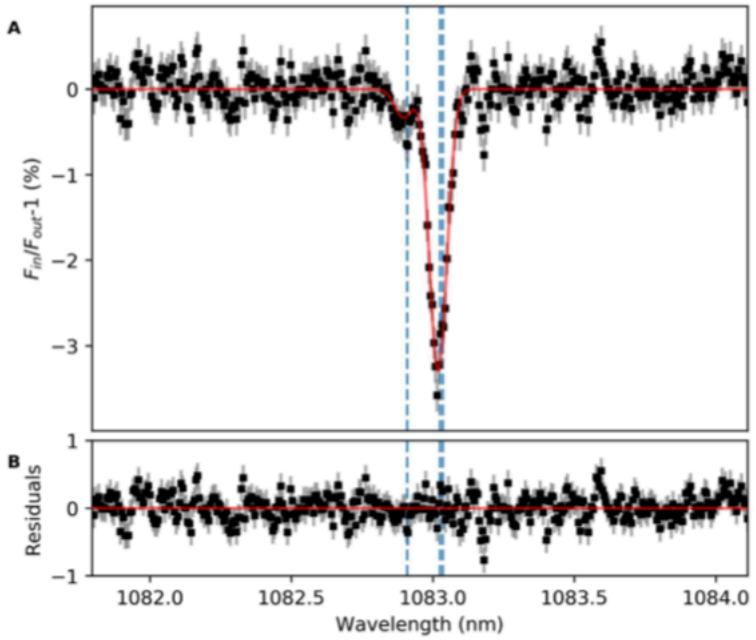


Simulated targets Zellem et al. 2019

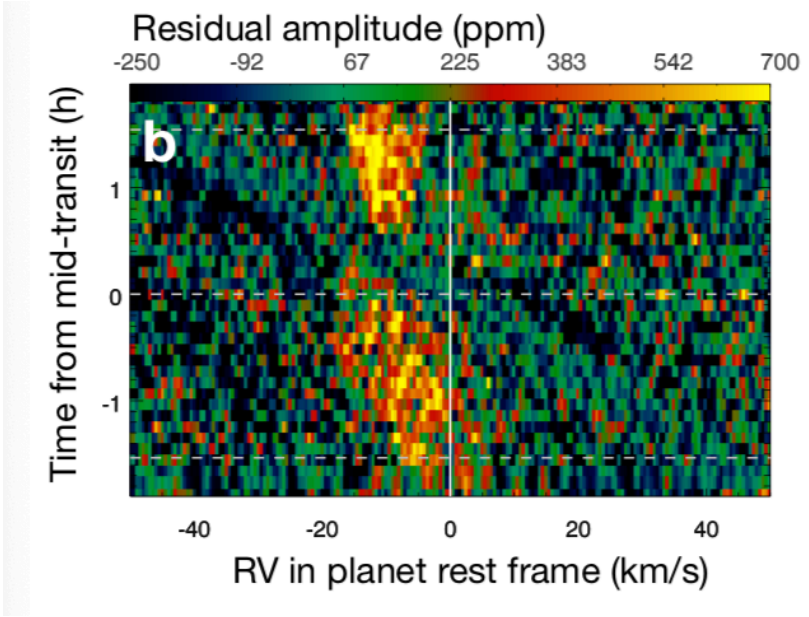
Atmospheric characterization becoming a statistical area.

Selected Ground-based R~100,000 class stabilized spectrometers

- CARMENES
- CRIRES+
- ESPRESSO
- EXPRES
- HARPS
- HARPS-N
- MAROONX
- NEID
- PARVI



CARMENES detection of He in WASP-69 b Nortmann et al. 2020

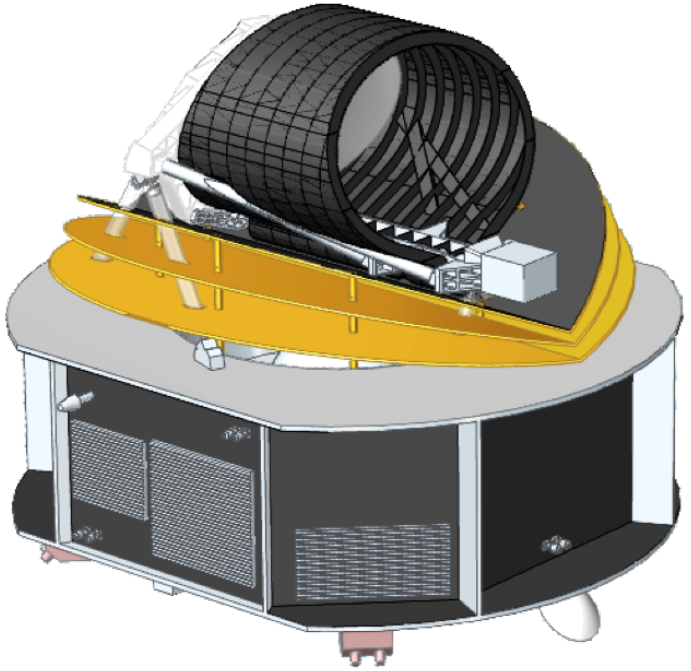


ESPRESSO detection of Fe in WASP-76 b Ehrenreich et al. 2020

Ground-based studies will be numerous and impactful.

Key Takeaways

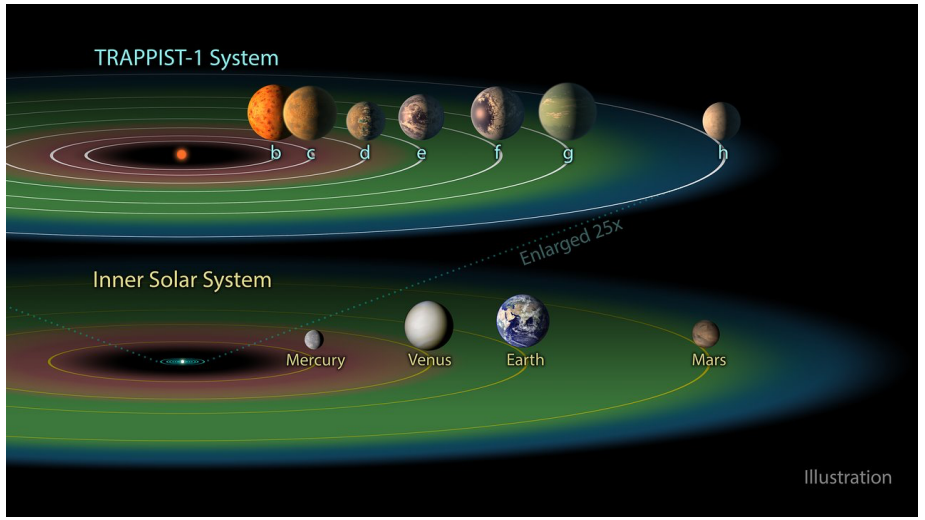
- Exoplanets is becoming a statistical field (although spectacular individual planet results are important)
- JWST will have an enormous impact and will observe ~50-100 planets
- High resolution spectroscopy (R~100,000) for atmospheric characterization is a rapidly growing area
- ARIEL will observe ~1000 planets



ARIEL spacecraft and payload
Credit: ESA/ARIEL Consortium

What is left for SOFIA?

- Transit observations
  - SOFIA not competitive for other observing methods
- High value singe targets
  - SOFIA not competitive for statistical studies
- Observing constraints
  - 4 hr observing limitation for return to base flight plans
  - Limits transit to 2 hr 1st to 4th contact
  - Implies planets in short period orbits
- Leverage SOFIA mid-IR to far-IR wavelength capability



TRAPPIST-1 system
Credit: NASA/JPL/Caltech

Notional Concept

- Focus on a few small temperate planets
- For short period orbits, they will be around M dwarfs
- Select a key molecule that only has strong opacity in mid-IR to far-IR
  - Key molecule must resolve important question such as eliminating an abiotic hypothesis for atmospheric composition
  - More than one key molecule would good but perhaps not essential
- Partner with other missions/programs to find the targets