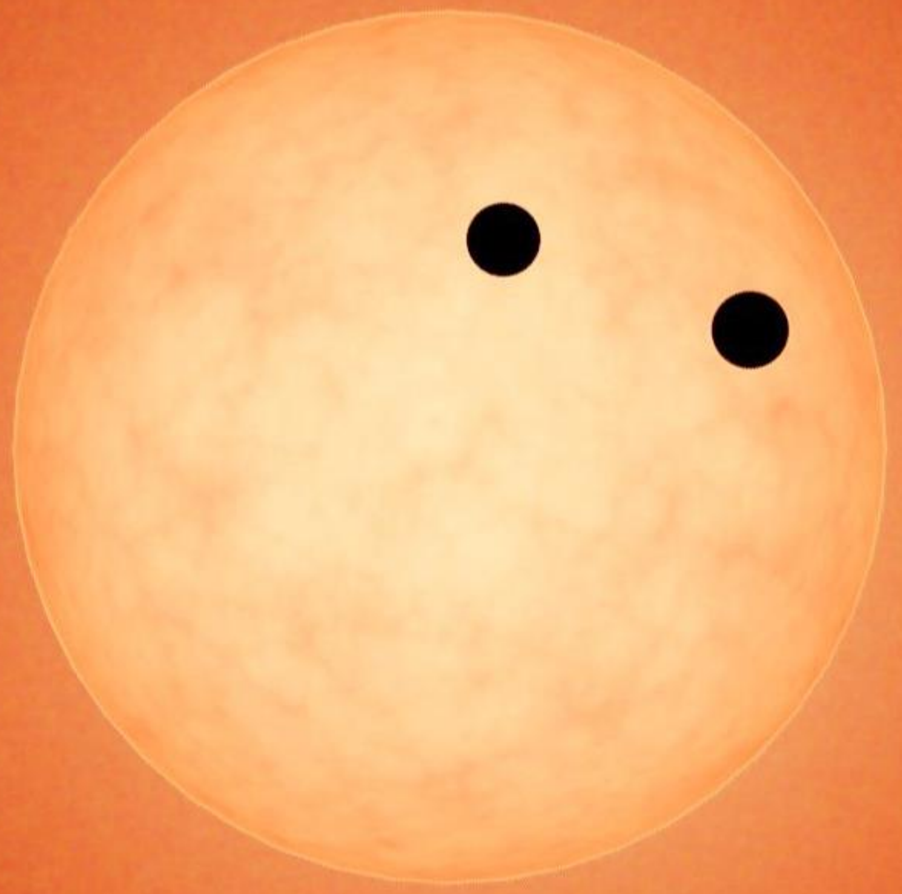


Exoplanet search and characterization with the proposed POET Canadian space mission

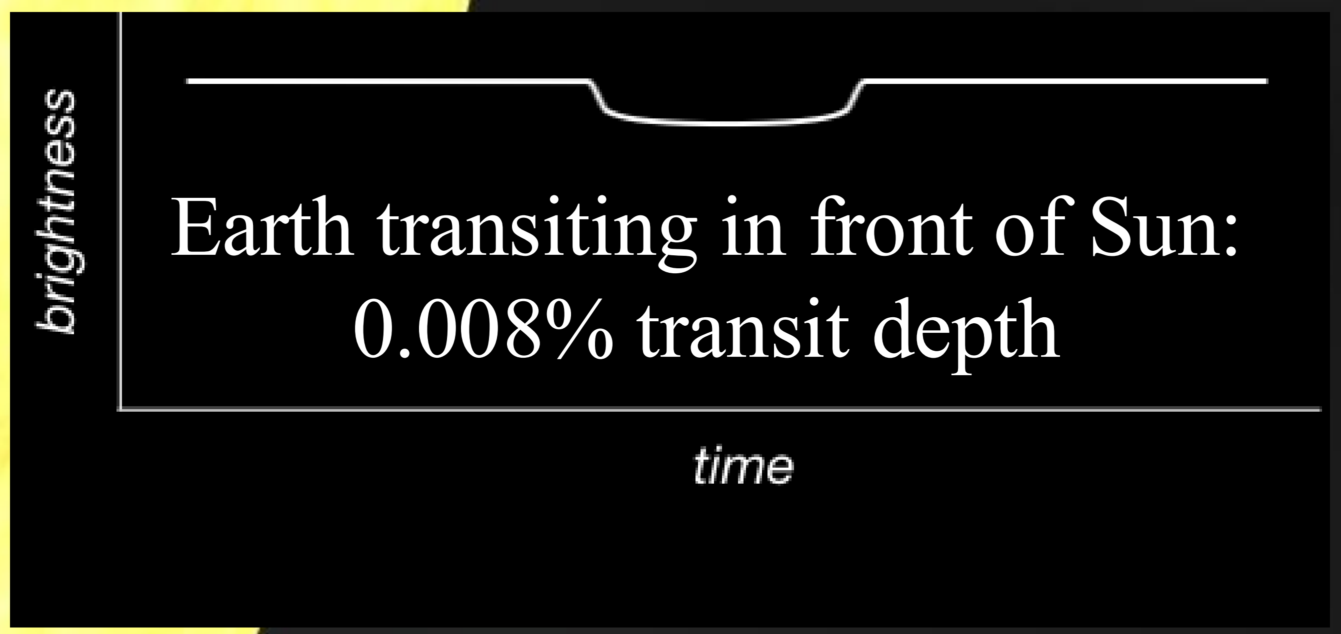
Stanimir Metchev
(The University of Western Ontario, Canada)

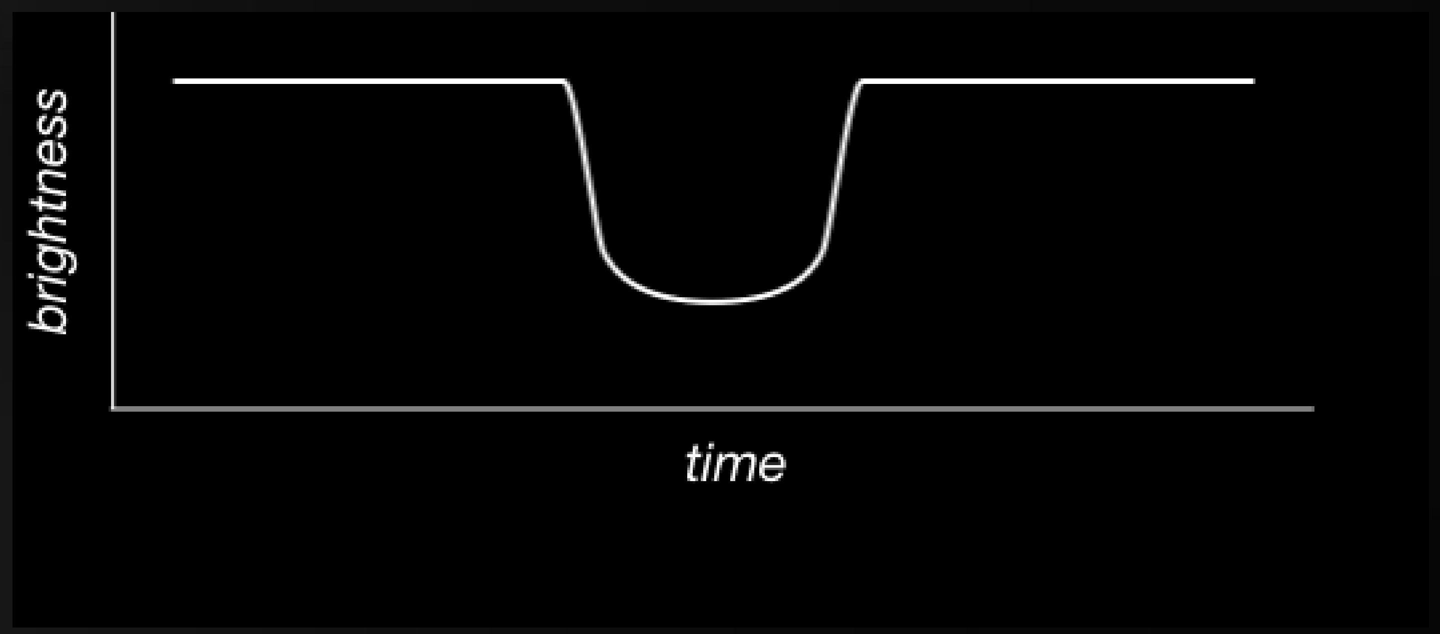
Collaboration:

J. Rowe, K. Hoffman, P. Miles-Páez, S. Lambier, R. Cloutier, H. Ishikawa, JJ Kavelaars, M. Kunimoto, D. Lafrenière, C. Lovekin, E. Pilles, J. Ruan, J. Sabarinathan, G. Wade, P. Wieger, F. Grandmont, A.-S. Poulin-Girard, S. Grocott, R. Zee, J. Dupuis, P. Langlois, J. Roediger

Small stars offer the best opportunity for rocky planet transit detection

Earth transiting in front of red / brown dwarf :
1% transit depth



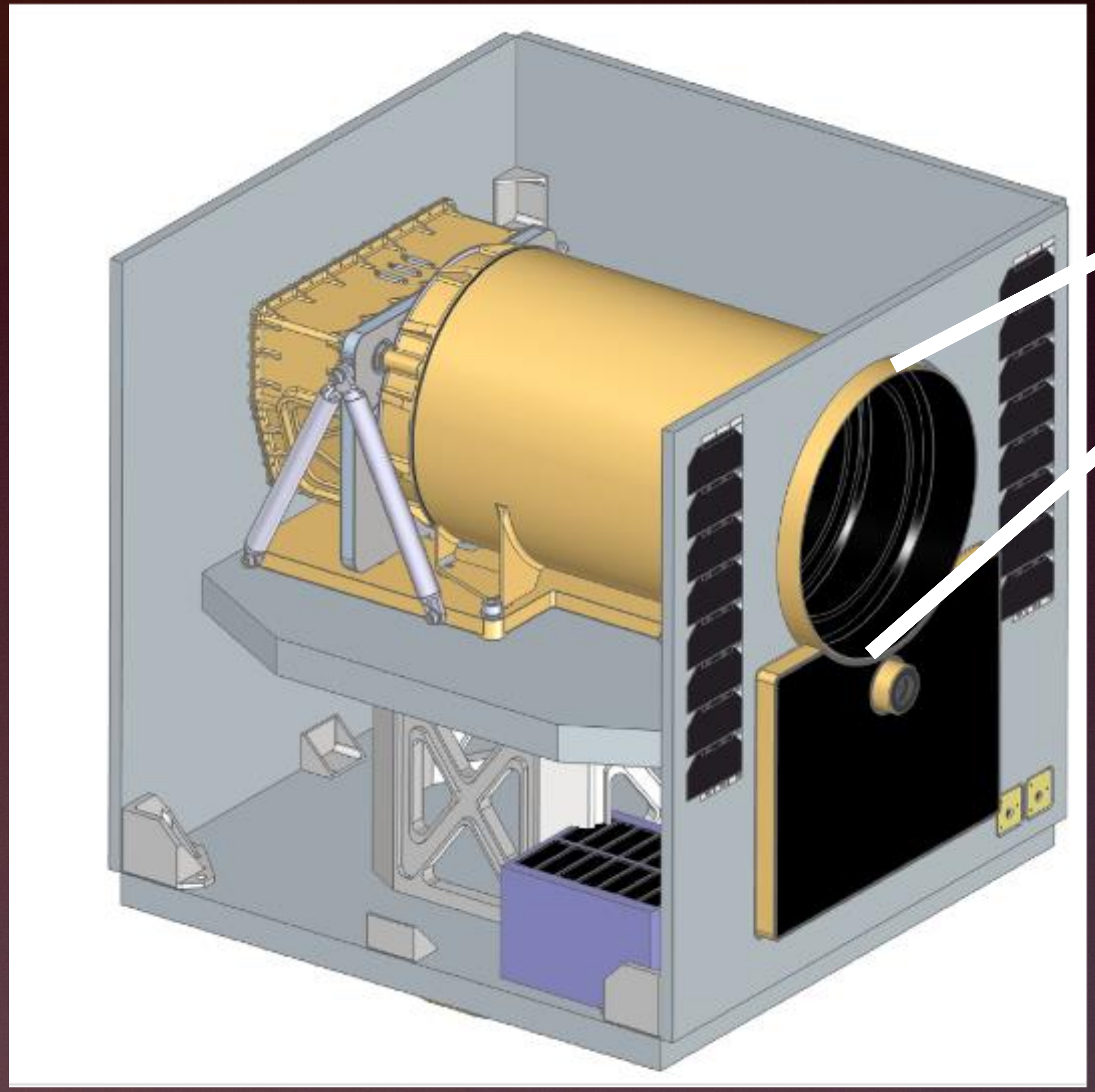


- Red / brown dwarfs make up 75% of all stars in the Milky Way.
- However, their intrinsic faintness makes them challenging.

Solution: POET

A space telescope for exoplanets around small stars

- POET: Photometric Observations of Exoplanet Transits
- Aperture: 20 cm, off-axis, 1 deg FOV
- Simultaneous imaging:
  - nUV (300–400 nm; CMOS)
  - VNIR (400–900 nm; CMOS)
  - SWIR (900-1700 nm; InGaAs)
- Science:
  - 80% dedicated to exoplanets
  - 20% general astrophysics
- Anticipated launch: 2029; 2+ year mission
- A top-ranked priority in the Canadian Astronomy Long Range Plan 2020–2030



telescope (D = 20 cm)

spacecraft bus (60 x 60 x 60 cm) with telescope

sun-synchronous low-Earth (~600 km) orbit

POET: equipment and infrastructure

Dauntless spacecraft bus
(shown: LEO 2 communications satellite)

Telescope prototype
(see paper 13602-6, Pelletier-Ouellet et al.)

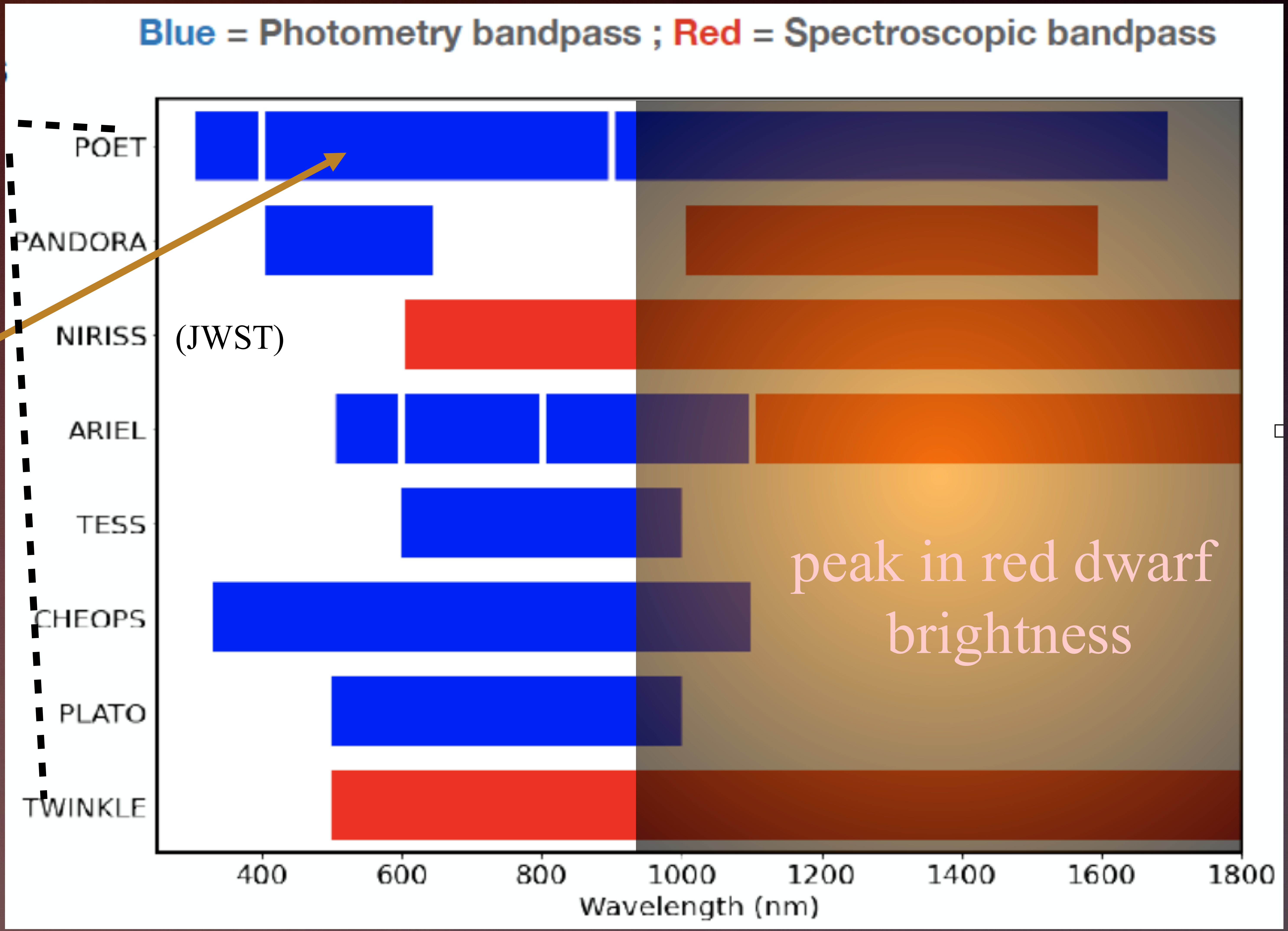
Satellite communications

At Western University (London, Ontario):

- Western Space Institute satellite communications upgrade
- Small-satellite lab upgrade (Engineering)
- Infrared remote-sensing lab (Engineering / Science)

POET:
optimized for red dwarf exoplanets

Exoplanet space missions
2025 – 2030



POET Optimization:

- photometric-only observations: maximum sensitivity
- 900 nm – 1700 nm band pass: peak in red dwarf brightness
- 80% focus on exoplanets: dedicated resource

POET: Science Goals

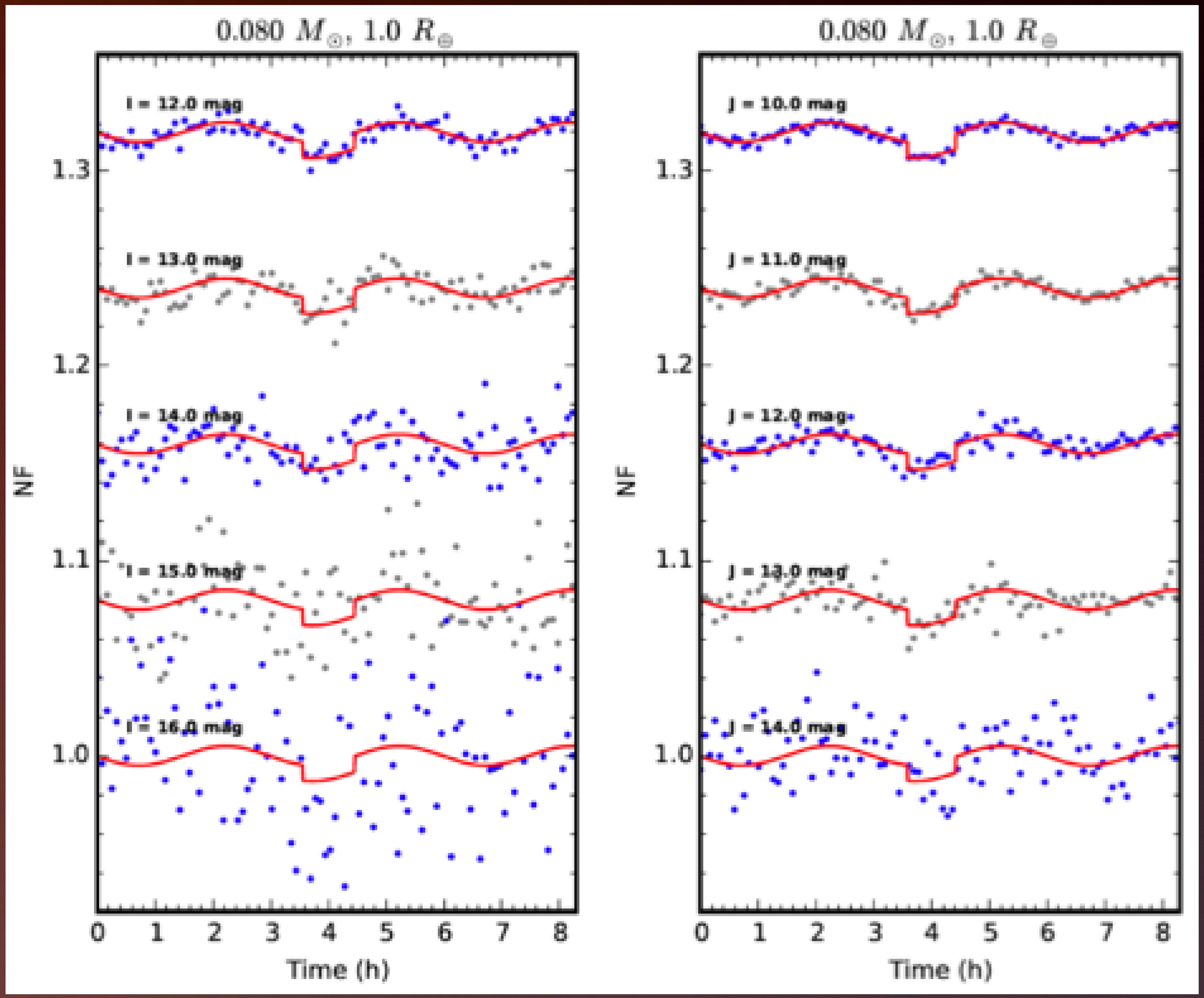
1. Atmospheric characterization of known transiting planets:
   - from super-Earths to Jupiters
   - nUV (300 – 400 nm) photometry complements longer-wavelength HST, JWST observations
2. Discovery of rocky exoplanets around ultracool dwarfs:
   - some the nearest transiting Earth-sized planets
   - planets in <2-week orbits, potentially in the habitable zone
   - could yield the best prospects for atmospheric and biosignature characterization with JWST

POET Science Goal 2: Exoplanet Discovery

- **SWIR** (900 nm – 1700 nm) channel
- Single transits of an Earth-sized planet are detectable for $I < 13$ mag or $J < 13$ mag stars.
- However, >M6 ultra-cool dwarfs have colors of $I - J > 2.6$ mag.
- Observing at J band (1.2 micron) could allow >2x more targets.

VNIR: star intrinsically dimmer

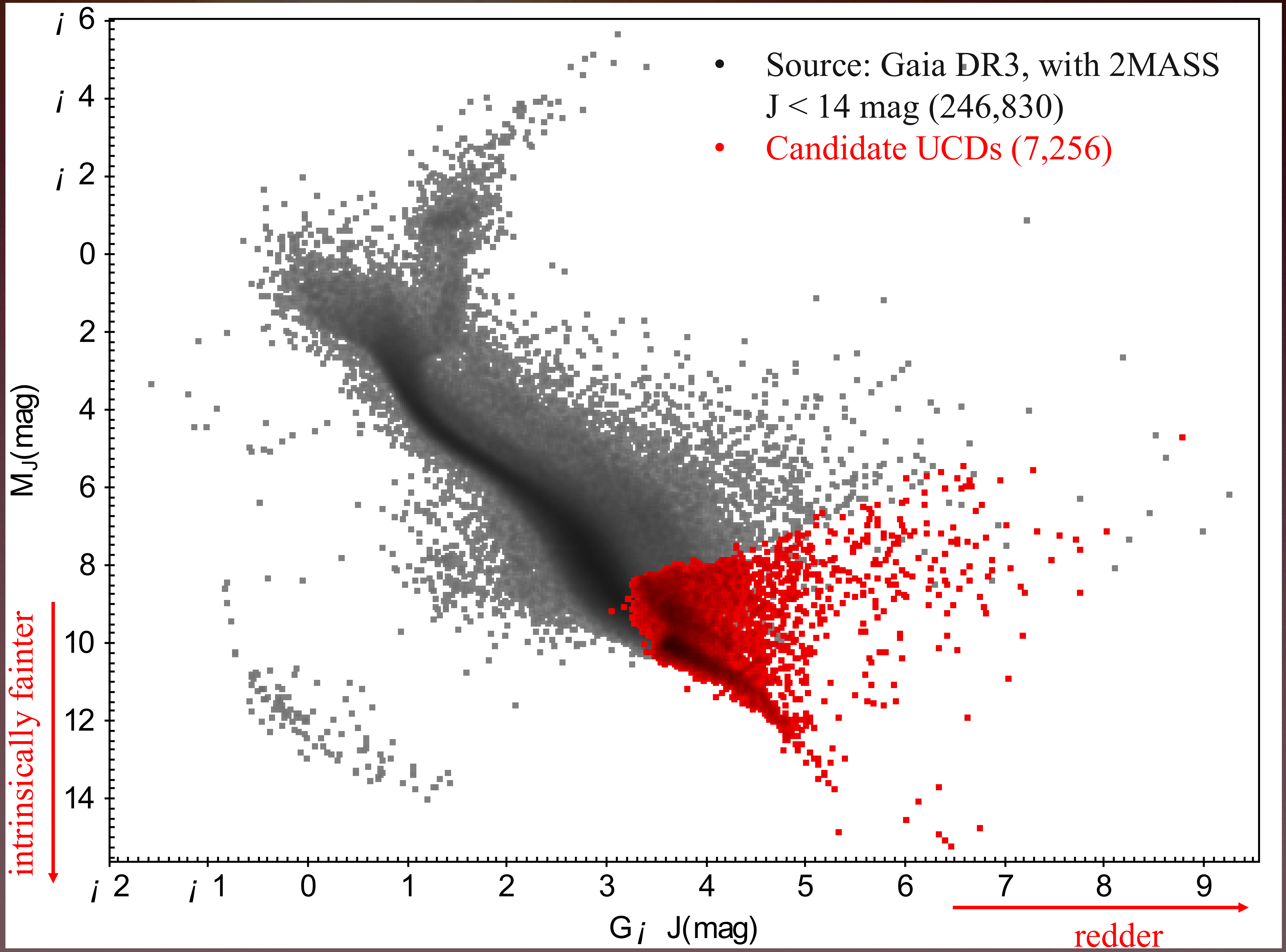
SWIR: star intrinsically brighter



Credit: Paulo Miles-Páez (CAB)

Simulated Earth-sized planet transits around a 0.08 M_{Sun} star. Transits are detectable with POET on sufficiently bright ultra-cool stars. SWIR wavelengths provide a 2x better sensitivity and planet yield.

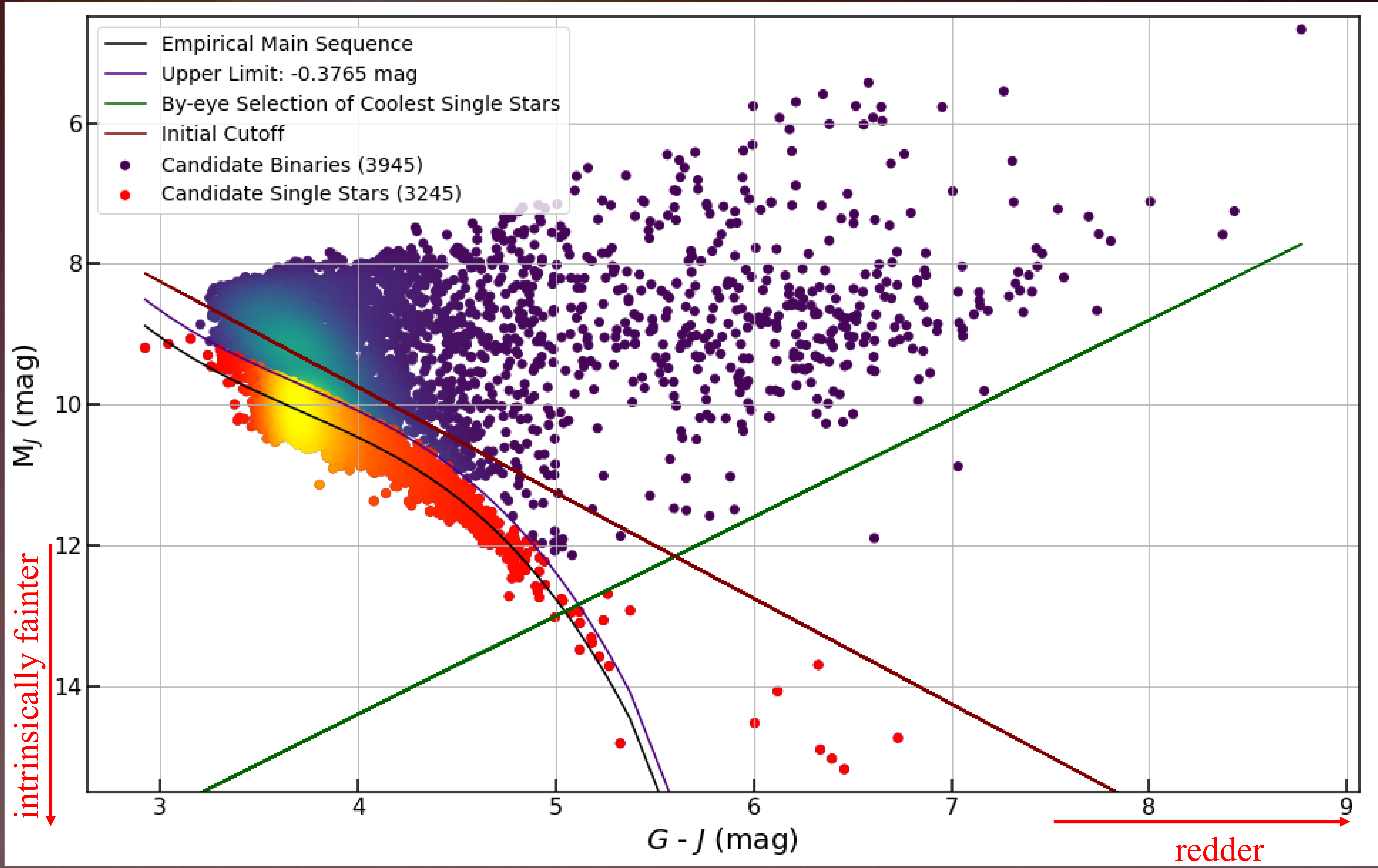
The POET input catalog of ultra-cool dwarfs: selecting the dimmest, closest and reddest stars



- bright enough for POET
- nearby (< 100 pc)
- ultra-cool: spectral type M6 or later
  - using $G - G_{RP}$ and $G - J$ colors as a proxy for spectral type
  - $T_{eff} < 2700$ K (Sun is 5700 K)

Lambier et al. (2025)

The POET input catalog of ultra-cool dwarfs: validation – remove unresolved binaries

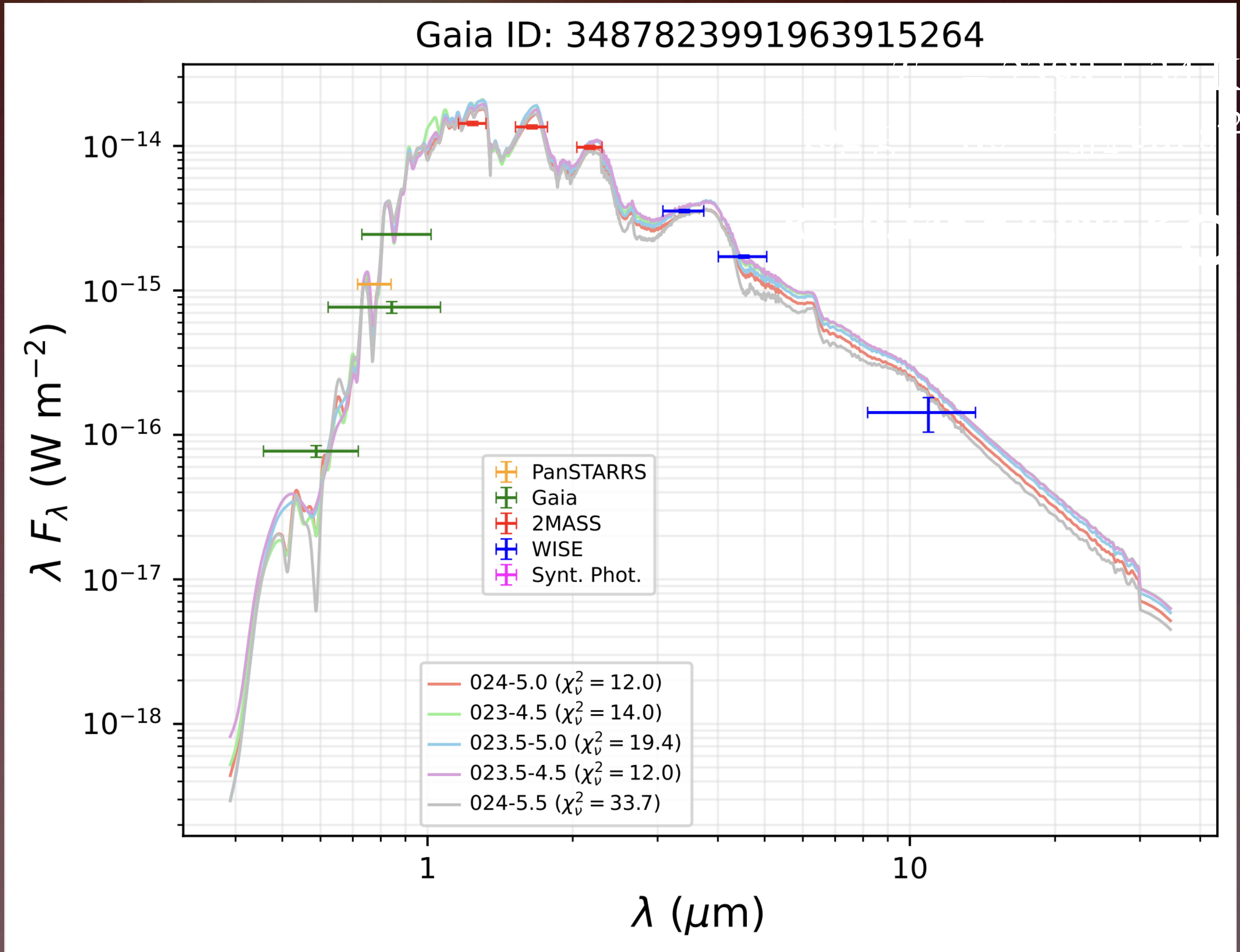


- **Validation**
  - remove likely binary stars that are spatially unresolved in Gaia
  - >3200 candidate POET targets
- **Transit geometry optimization**
  - seek targets seen nearly equator-on ($i \sim 90$ deg)

$$\sin(i) = \frac{v \sin(i)}{P/(2\pi R)}$$

Lambier et al. (2025)

POET input catalog of ultra-cool dwarfs: physical parameters of candidate host stars



- Stellar radius ***R***

$$\chi_r^2 = \frac{1}{N-2}\sum_{i=1}^{N}\left[\frac{(O_i - MY_i)^2}{\sigma_i^2 + \sigma_M^2}\right]$$

N = # of photometric points

O_i = observed flux

M = free-parameter multiplicative factor

Y_i = theoretical flux predicted by the model

σ_i = uncertainty of the data

σ_M = a systemic uncertainty

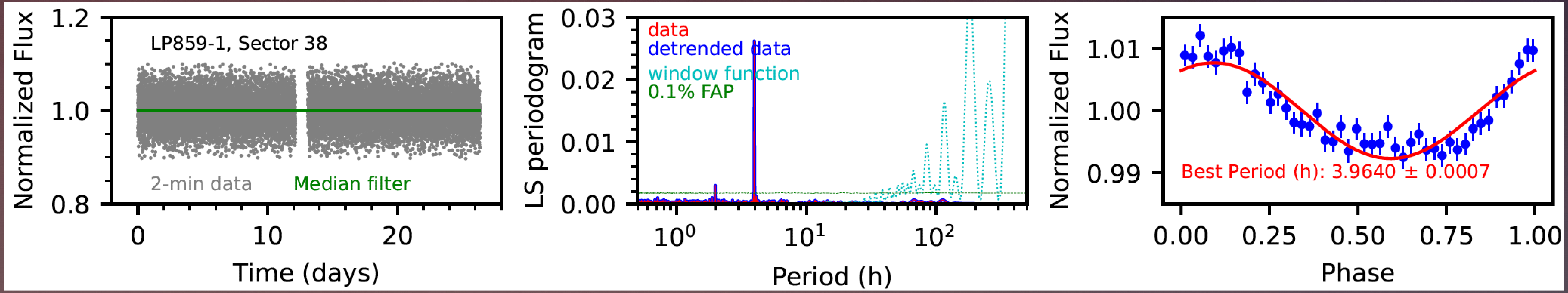
$$M = \left(\frac{R}{D}\right)^2$$

Credit: Genaro Suárez (AMNH)

POET input catalog of ultra-cool dwarfs: physical parameters of candidate host stars

- Stellar radius ***R***
- Rotation period ***P***
  - using TESS, Kepler, K2 or ground-based telescope photometry

TESS light curve of an optically faint (T = 14.4, G = 16.2) ultra-cool dwarf.



Miles-Páez et al. (2023)

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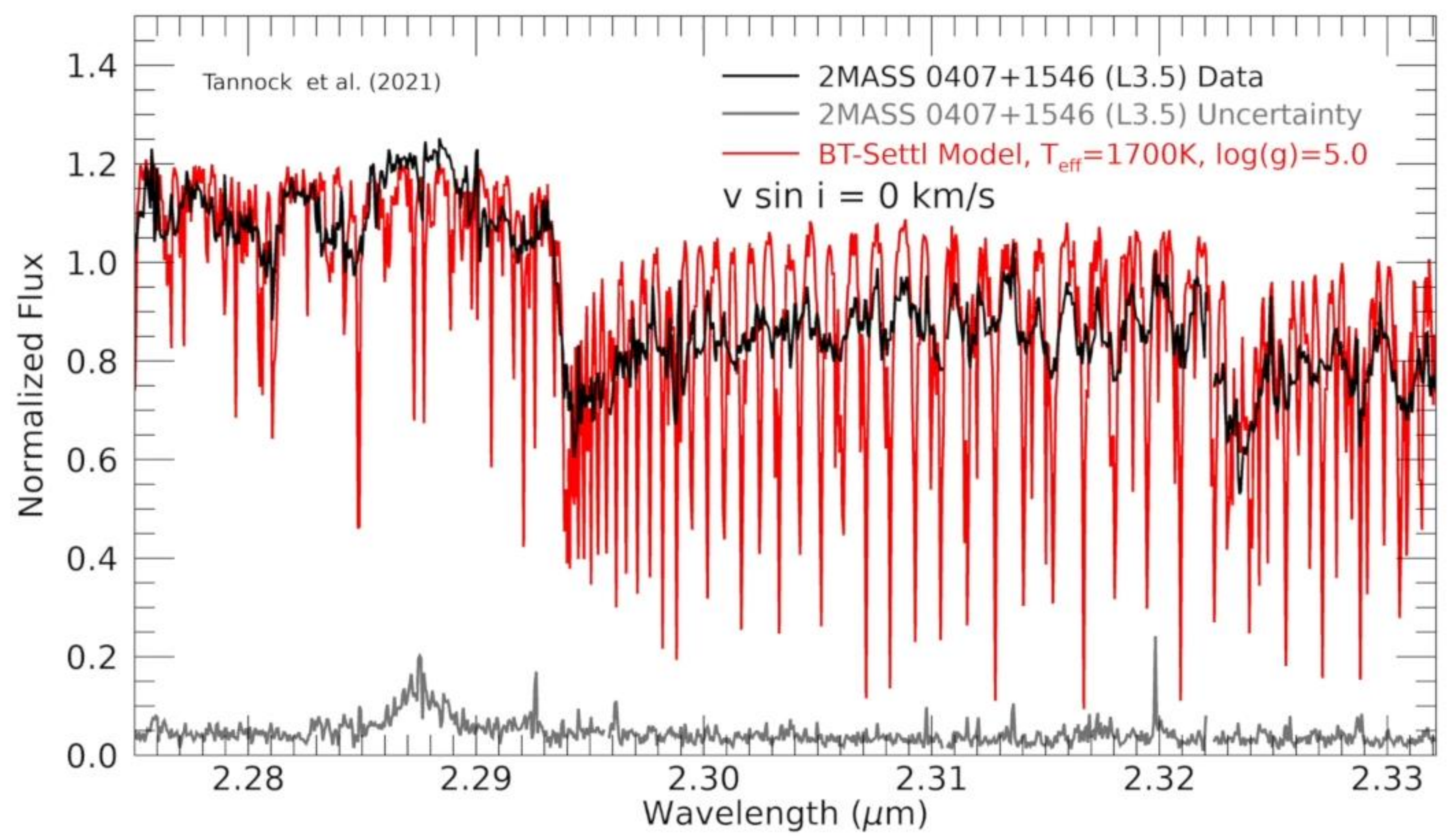


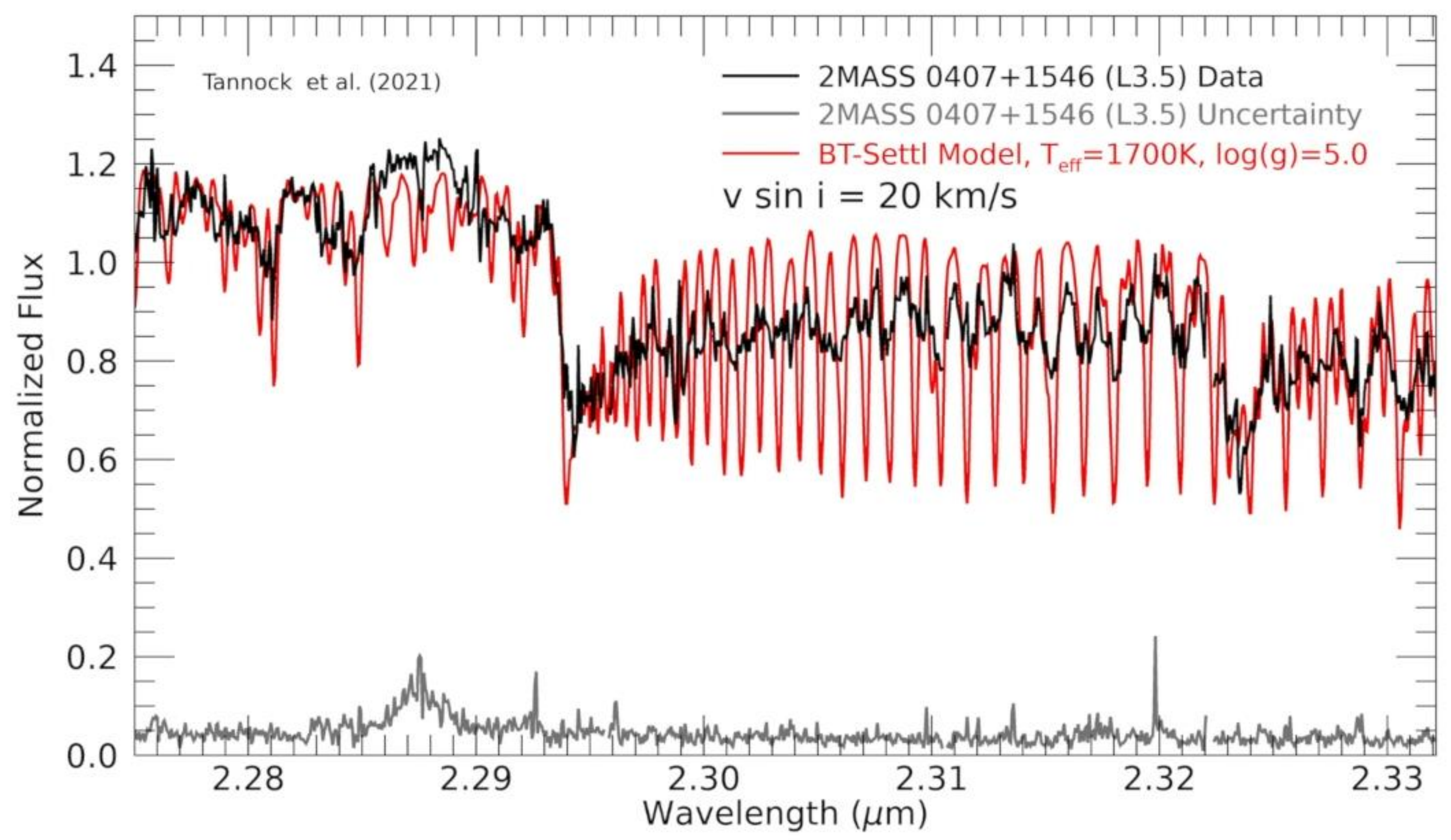
- Stellar radius ***R***
- Rotation period ***P***
- Projected rotational velocity ***v* sin(*i*)** (high-dispersion spectroscopy)
  - required to determine stellar inclination ***i***

$$\sin(i) = \frac{v\ \sin(i)}{P/(2\pi R)}$$

  - inclinations $i > 70$ deg required for POET UCD targets to maximize probability of transiting geometry

Tannock et al. (2021)

POET input catalog of ultra-cool dwarfs: physical parameters of candidate host stars



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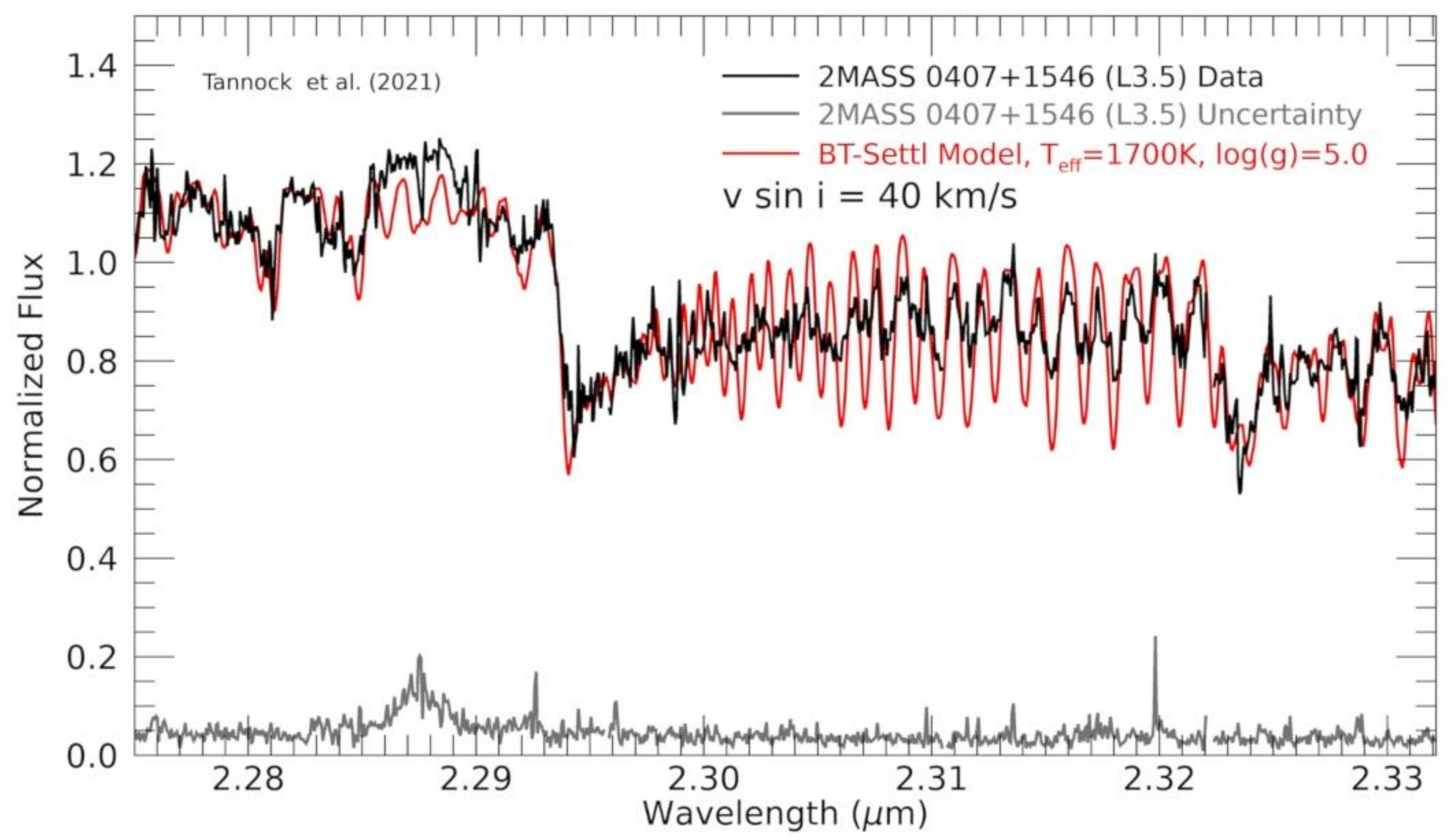

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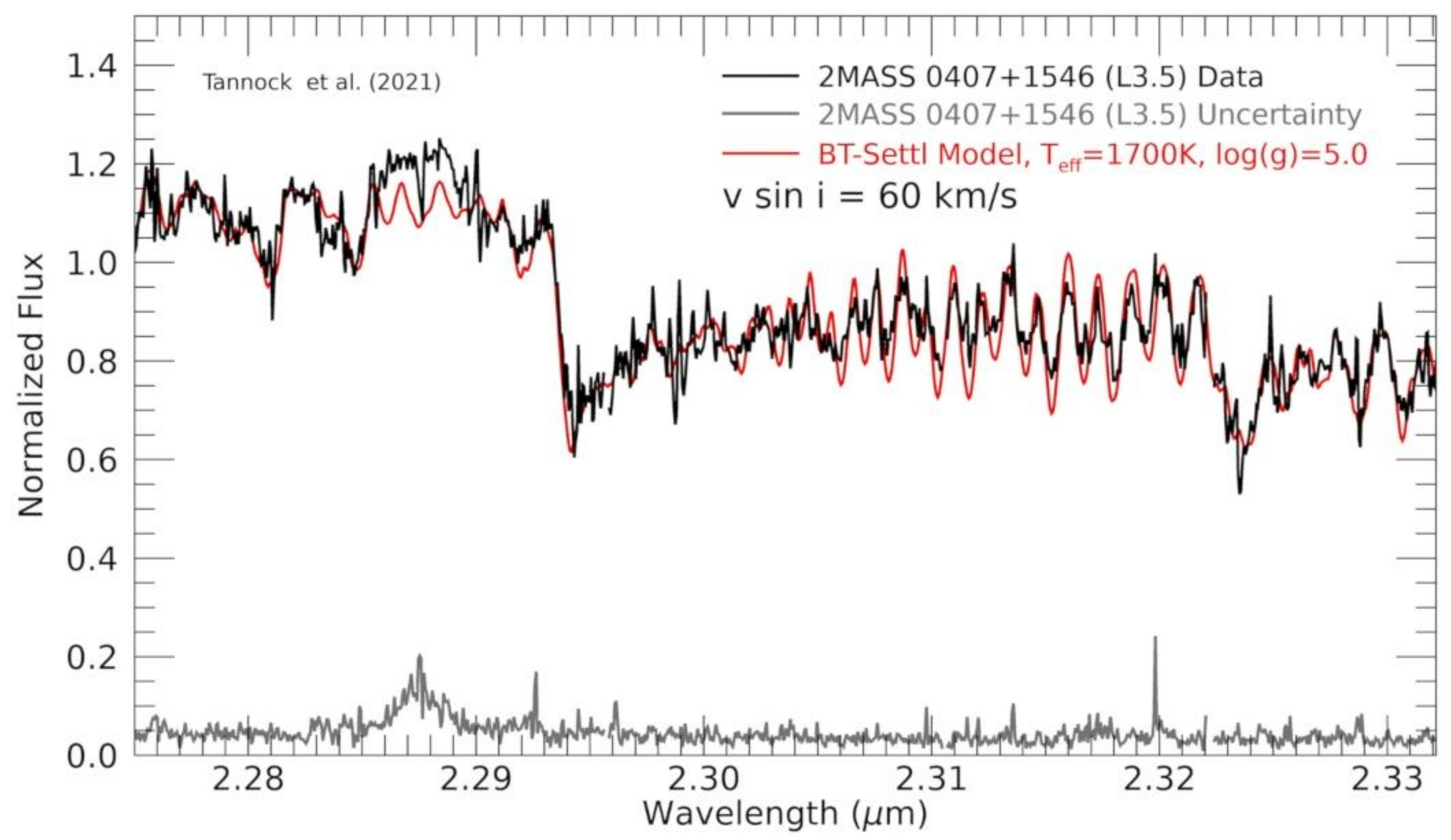

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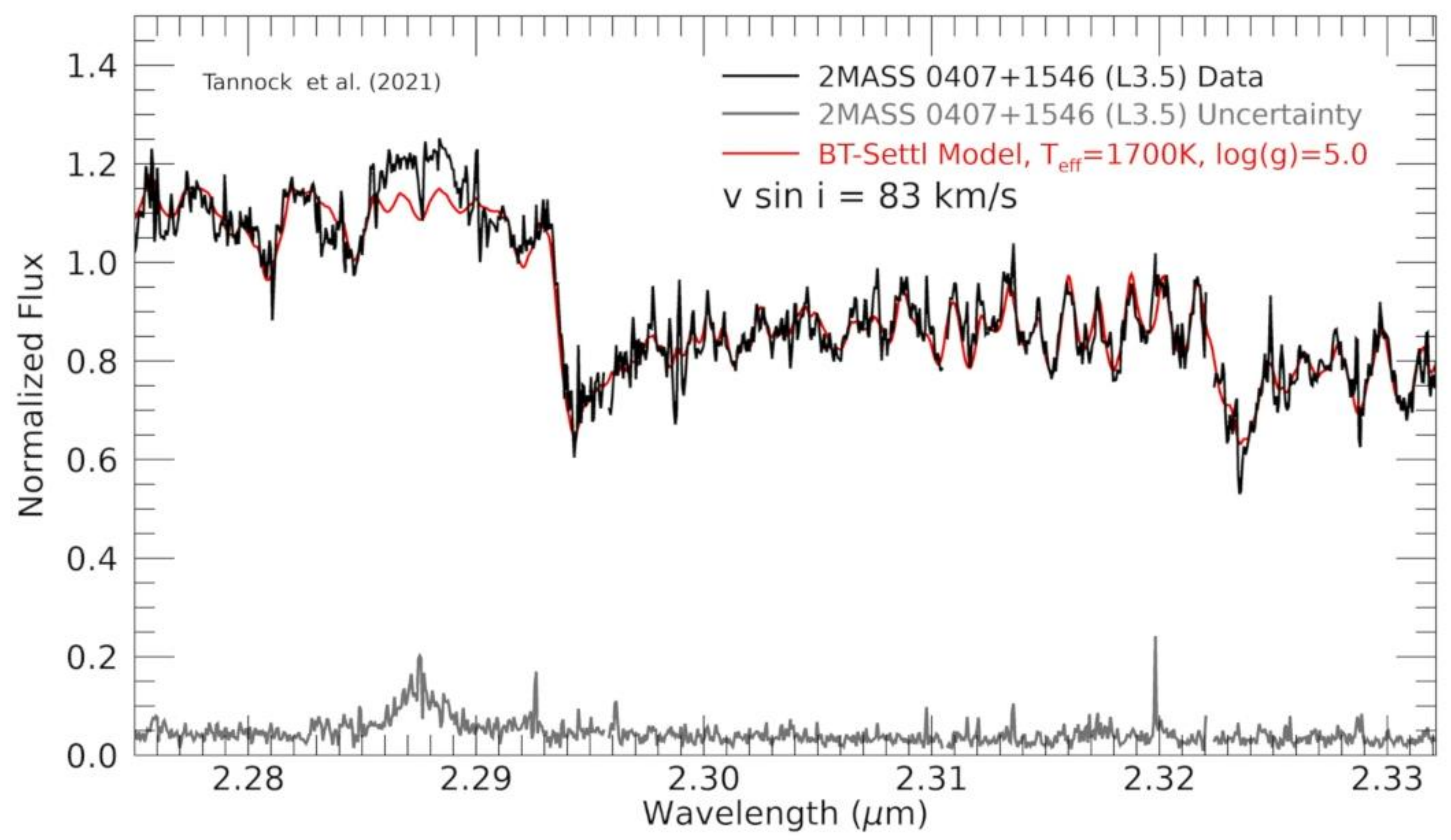

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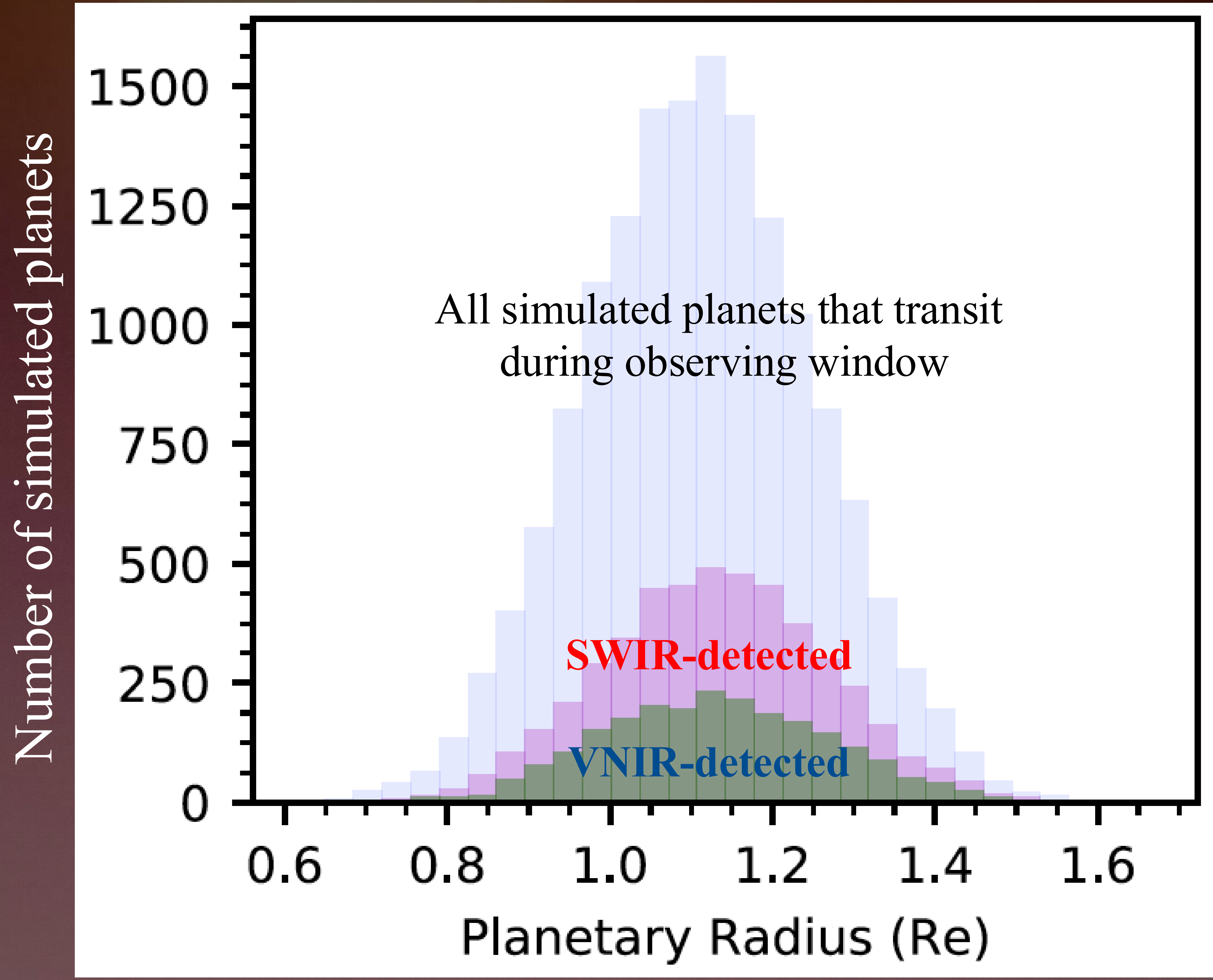
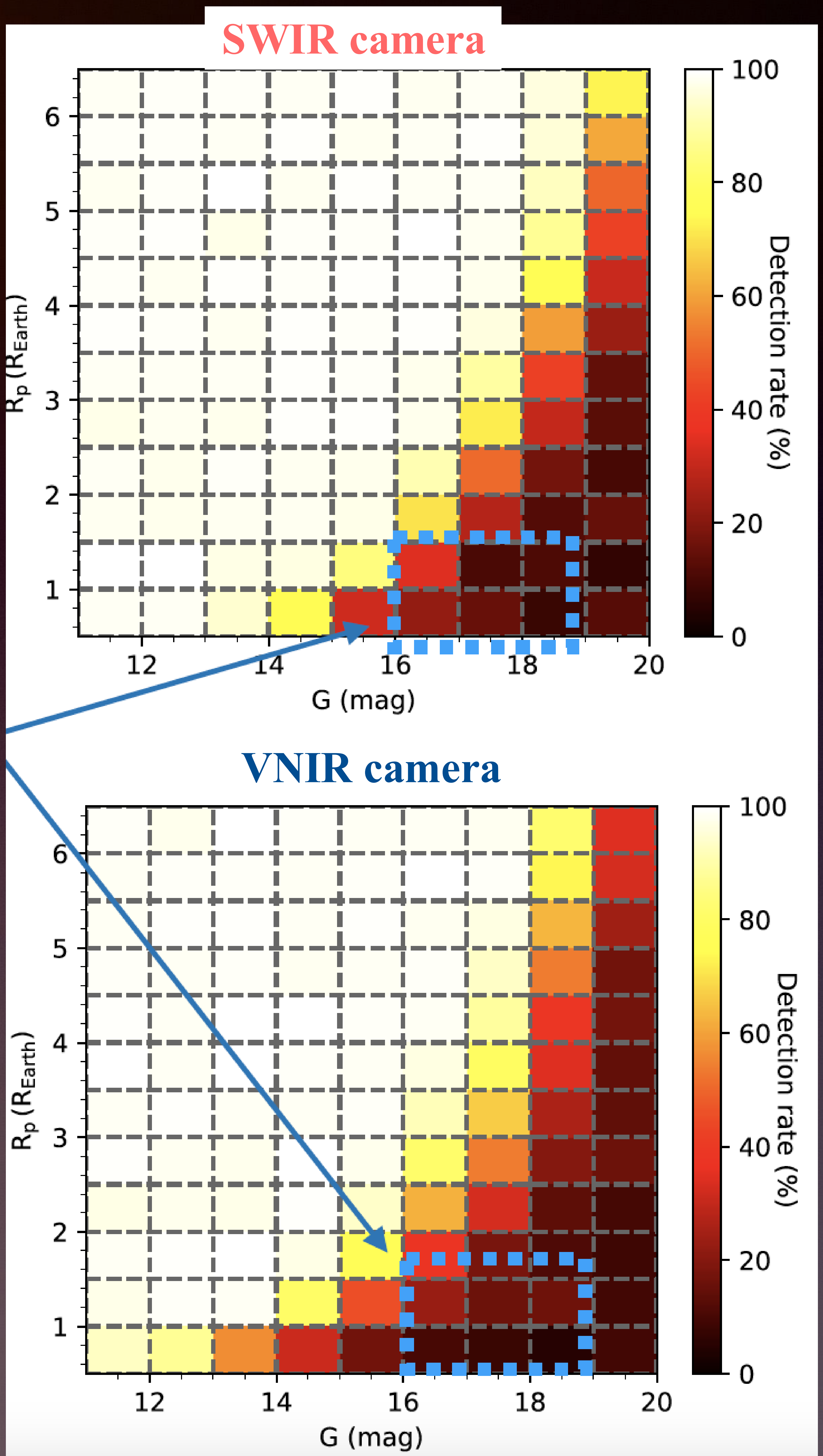
Tannock et al. (2021)

The SWIR advantage for POET



Simulation results: **100% higher yield of 0.5–1.5 Earth-radius planets in SWIR vs. VNIR.**

Magnitude distribution of host stars and radius distribution of simulated planets



Credit: Paulo Miles-Páez (CAB)

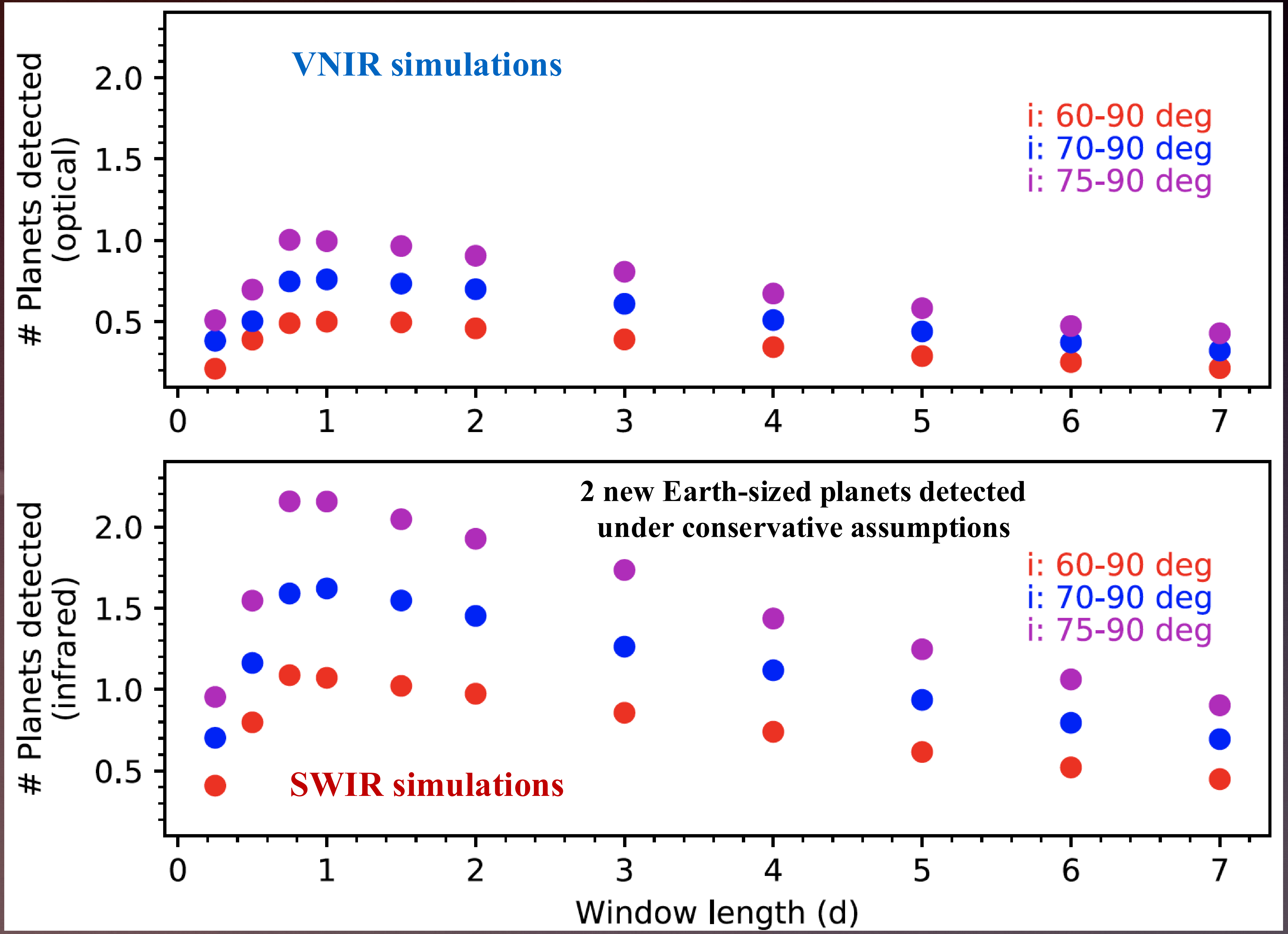
POET's rocky planet yield over one year of observations: 2 – 10 new Earth-sized planets

- **Could be the best targets for seeking life-supporting atmospheres**
  - similar to or more suitable than Trappist-1 planets

- Assumptions
  - SWIR observations (2 x lower yield for VNIR)
  - 80% duty cycle and 25% GO time (i.e., 220 days of observations over a year-long campaign)
  - sample of 110–220 high-inclination ultra-cool stars, continuously observed for 2–1 days.

- Caveats:
  - conservative planet-size distribution, centered on 1.1 Earth radii (Ment & Charbonneau 2023)
  - conservative duty cycle and GO time assumptions
  - uncertainties in VNIR and SWIR detector sensitivity.
  - single-planet systems, while transiting planets around cool stars are most often in >2x multiple systems.

- **Factor of 3 – 5 higher yields (6 – 10 planets) anticipated given above caveats.**



Credit: Paulo Miles-Páez (CAB)

POET collaboration

Pan-Canadian partnership (ON, QC, BC, NB):
academia (7 universities), industry, government

POET:
science team expertise

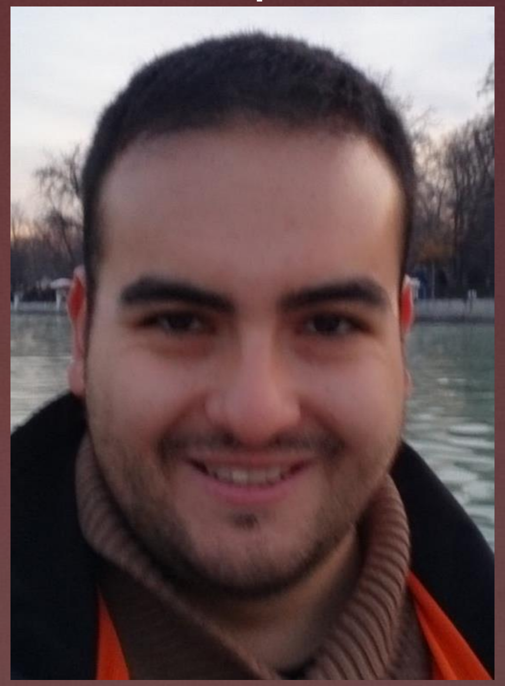
Metchev, Co-PI
red / brown dwarfs
Western Institute for Earth & Space Exploration

Rowe, Co-PI
exoplanets
Université Bishop's University

Cloutier
exoplanets, theory
McMaster University

Lafrenière
exoplanets, instrumentation
Université de Montréal

Kunimoto
exoplanets
UBC



Miles-Páez
red / brown dwarfs
Centro de Astrobiología, Asociado al NASA Astrobiology Institute, CSIC, INTA

Kavelaars
solar system, data management
NRC-CNRC Canada

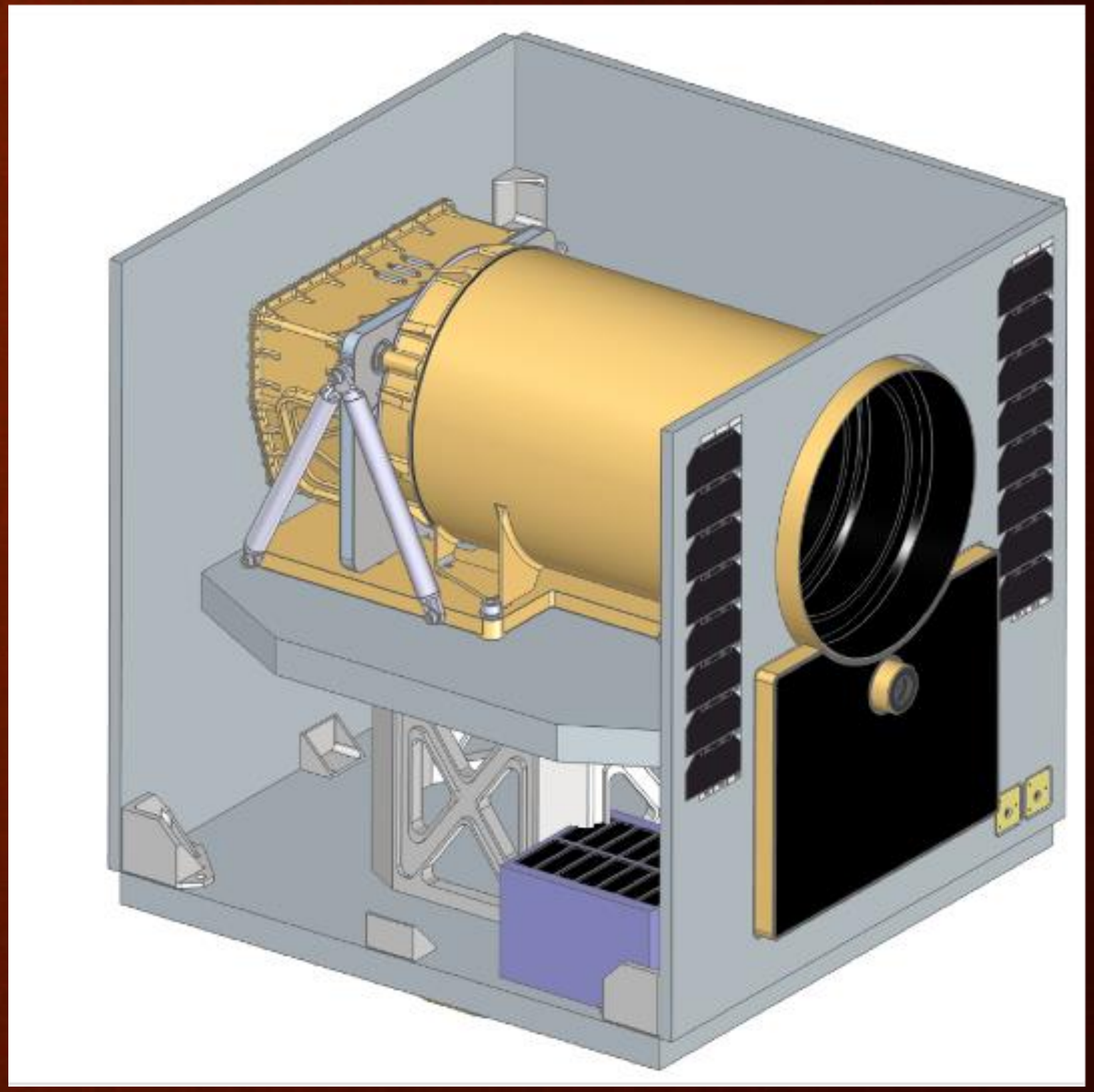
Wade
white dwarfs
RMC

Lovekin
massive stars
Mount Allison University

Sabarinathan
satellite engineering
Western Institute for Earth & Space Exploration

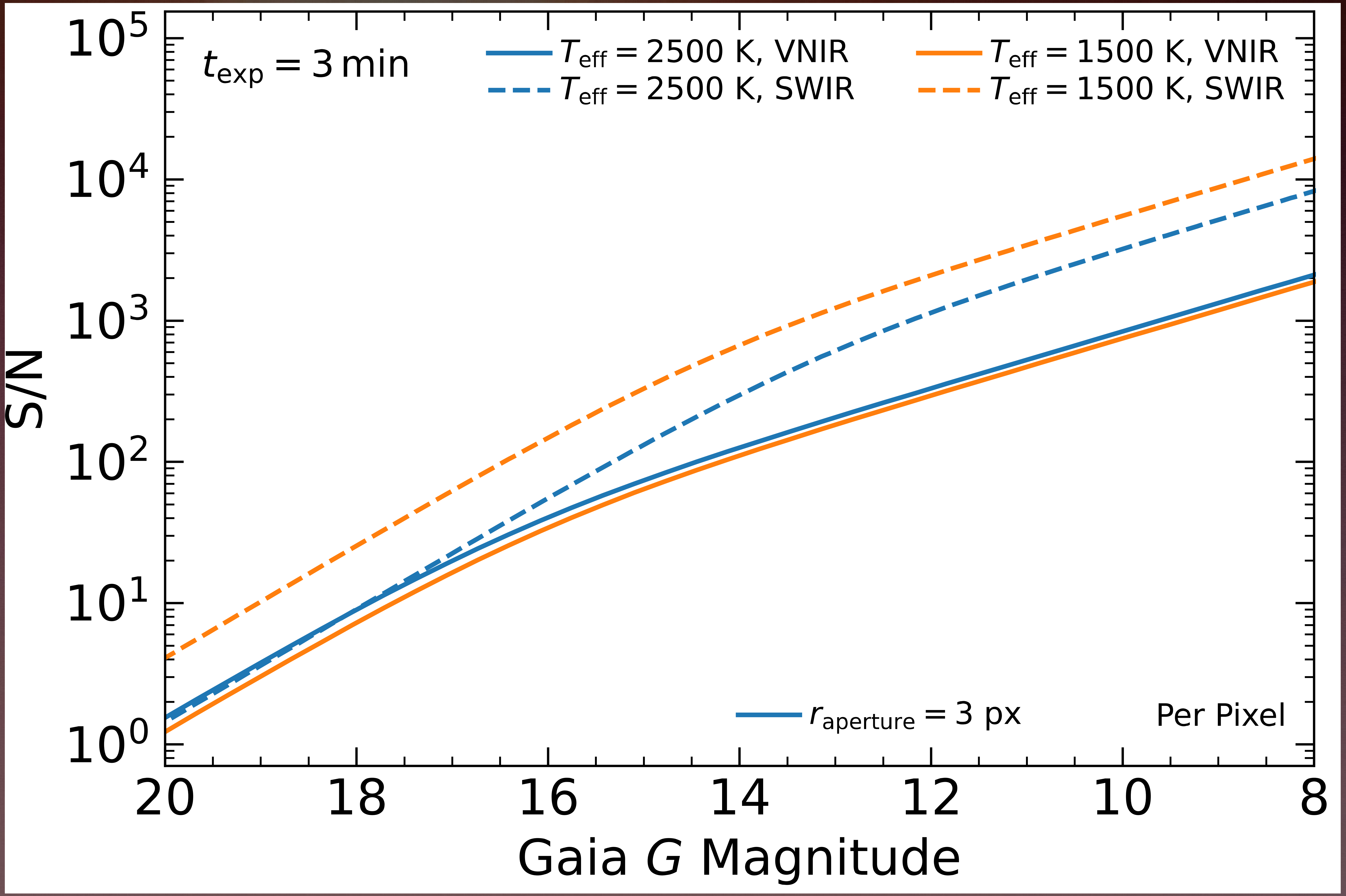
Exoplanet search and characterization with the proposed POET Canadian space mission

- D = 20 cm, 1 deg FOV
- Simultaneous imaging:
  - nUV (300–400 nm; CMOS)
  - VNIR (400–900 nm; CMOS)
  - SWIR (900-1700 nm; InGaAs)
- Transiting exoplanet focus
- Proposed launch: 2029



Extra slides

The SWIR advantage for POET



- Realistic S/N simulations for the POET input catalog of ultra-cool dwarfs in the VNIR and SWIR bands:
  - >3x higher SWIR S/N for 1500 K brown dwarfs
  - higher SWIR S/N for 2500 K ultra-cool dwarfs at $G < 17$ mag.

Credit: James Sikora (Lowell Observatory)

POET: equipment and infrastructure

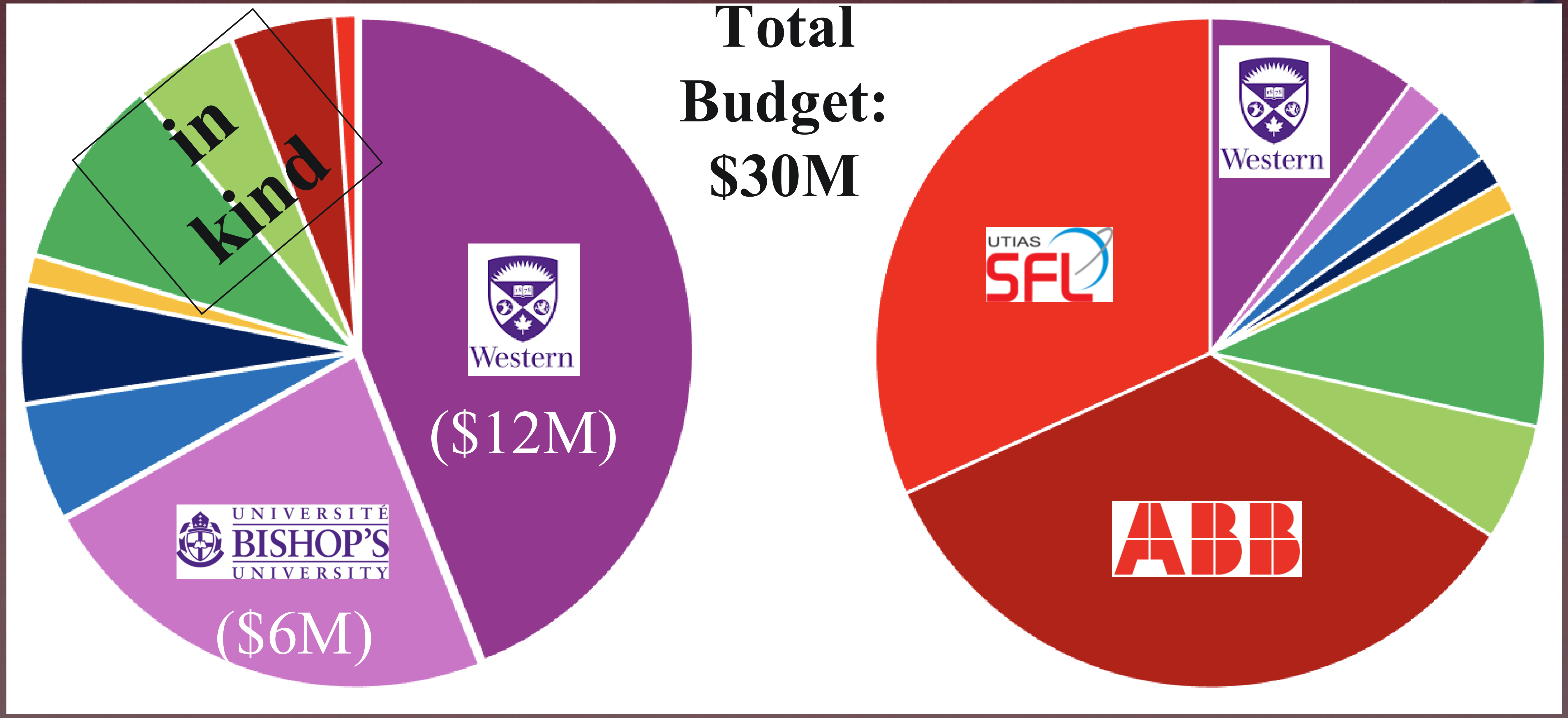
Spacecraft

Telescope

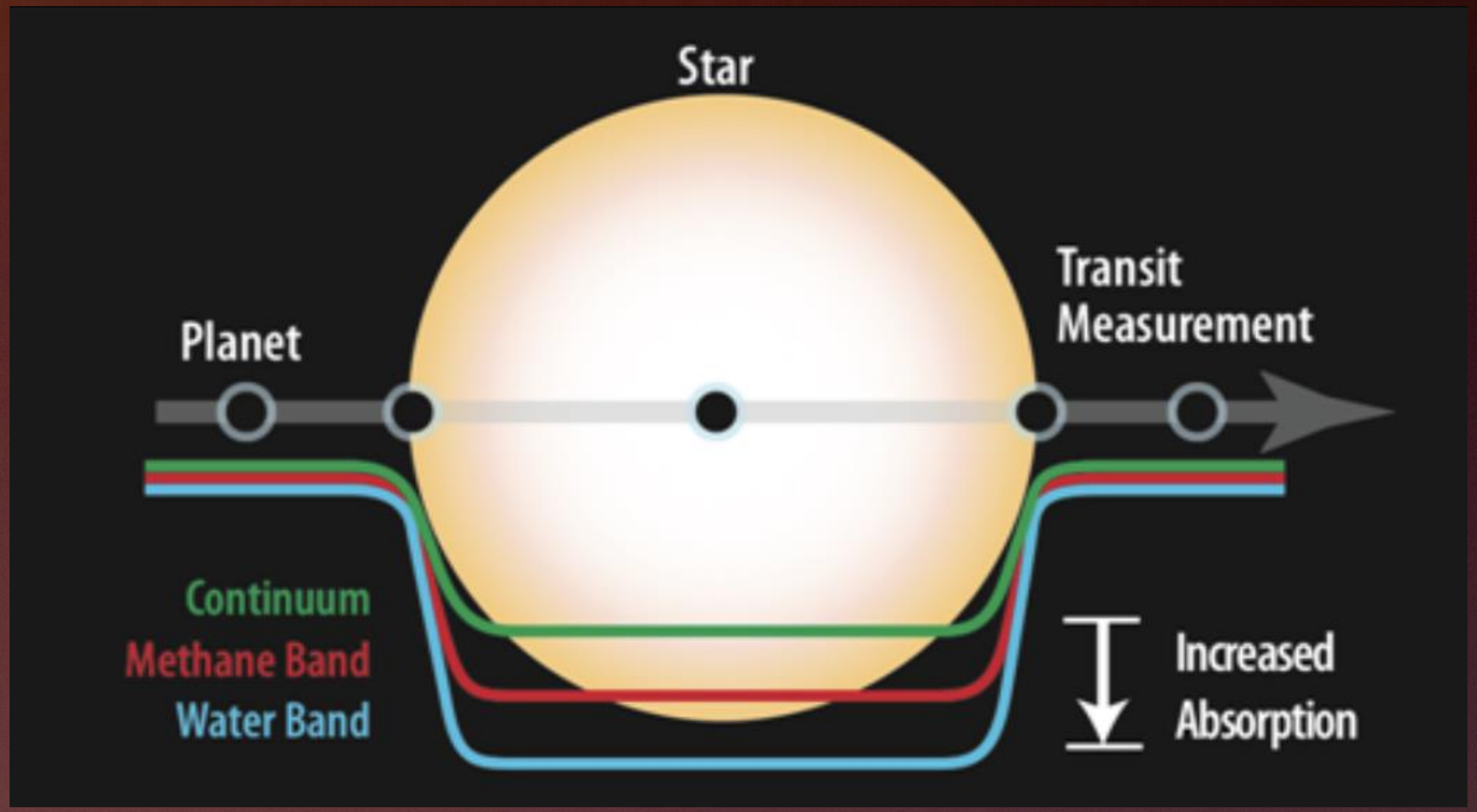
Satellite communications

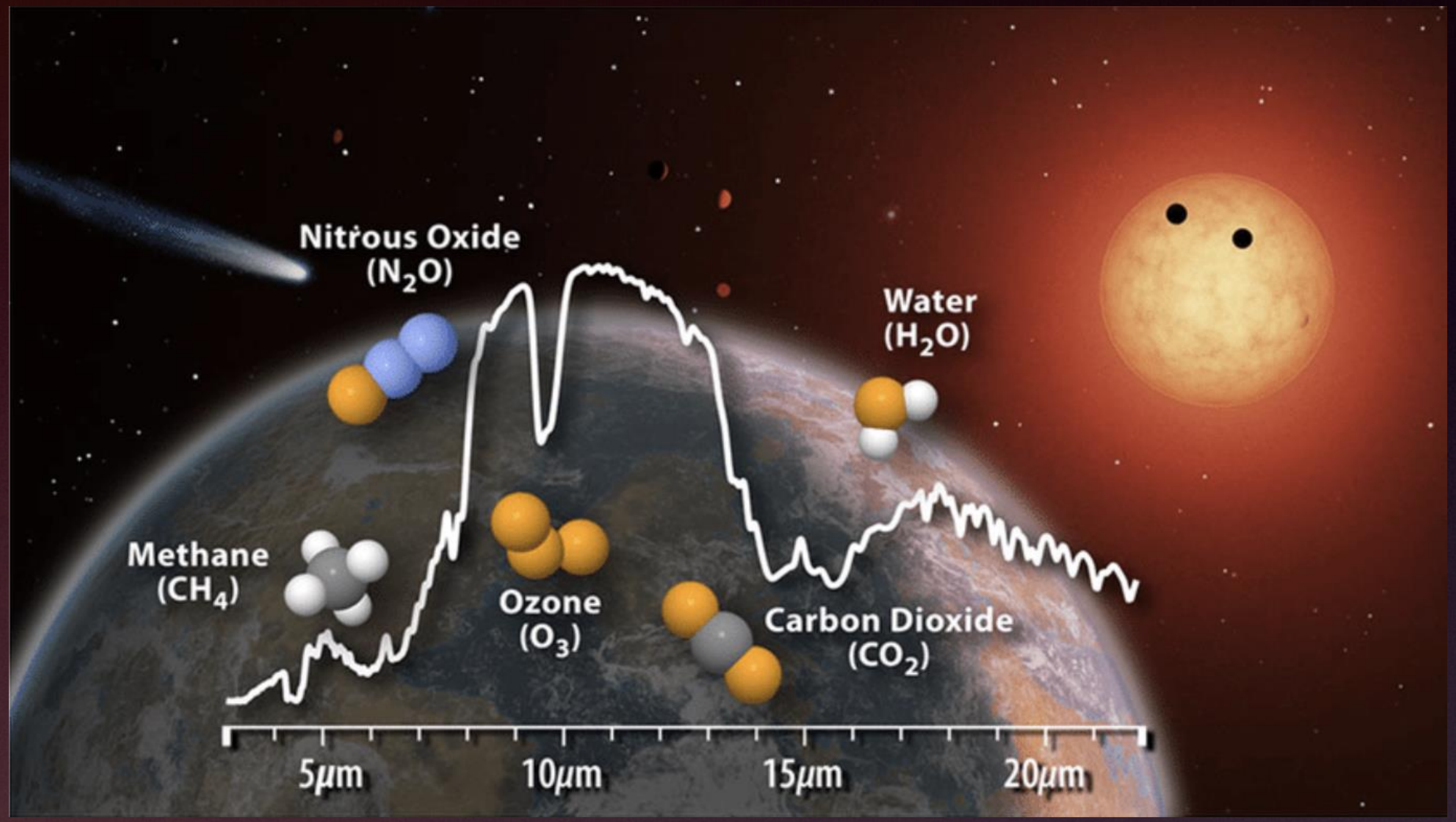
Contributions

Costs



The challenge: discovering extrasolar life





	Step 1: Discover Earth-like exoplanets	Step 2: Detect existence of atmosphere	Step 3: Detect disequilibrium biochemistry
Jupiter-sized planet around a Sun-like star	**1% transit depth**	**0.01% (100 ppm) transit depth differences**	**no biochemistry**
Earth-sized planet around a Sun-like star	**0.008% (80 ppm) transit depth**	**<1 ppm transit depth differences**	**???**
Earth-sized planet around a red dwarf star	**0.5% – 1% transit depth**	**0.005% – 0.01% transit depth differences**	**???**