The Colorado Ultraviolet Transit Experiment (CUTE)

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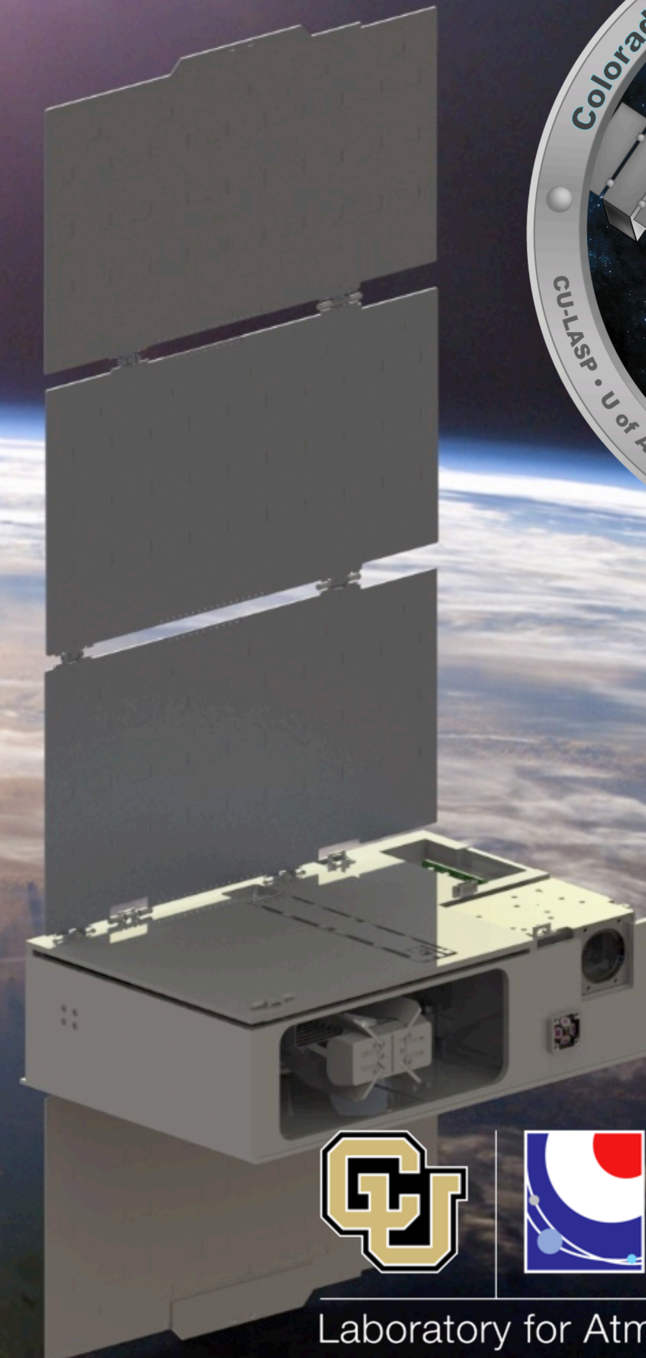

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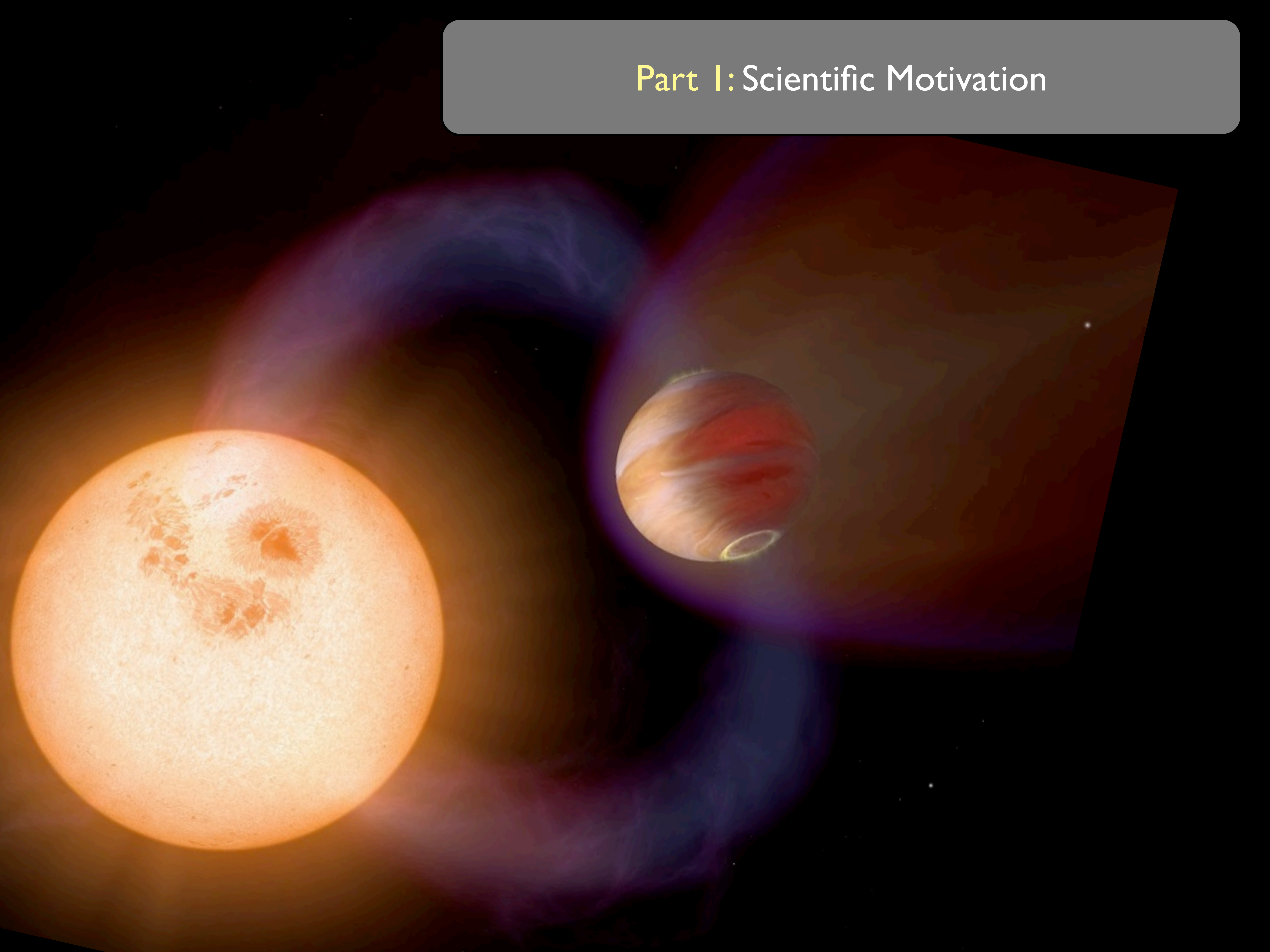
Laboratory for Atmospheric and Space Physics
University of Colorado **Boulder**

Outline

Part 1: Scientific Motivation

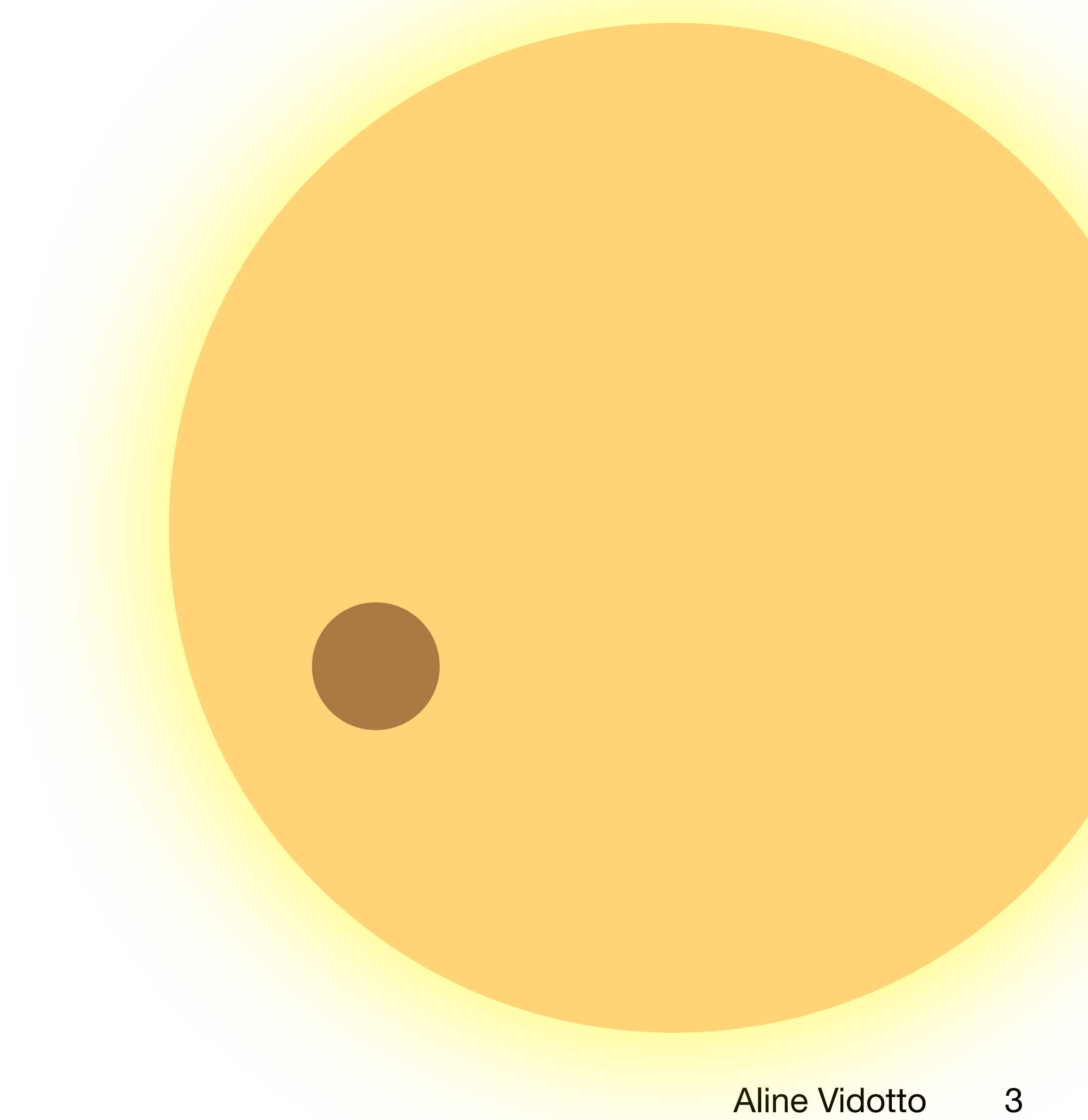
Part 2: NASA Colorado Ultraviolet Transit Experiment (CUTE)

Part 1: Scientific Motivation



Exoplanet Atmospheres

Transit depth = $(R_P/R_*)^2$



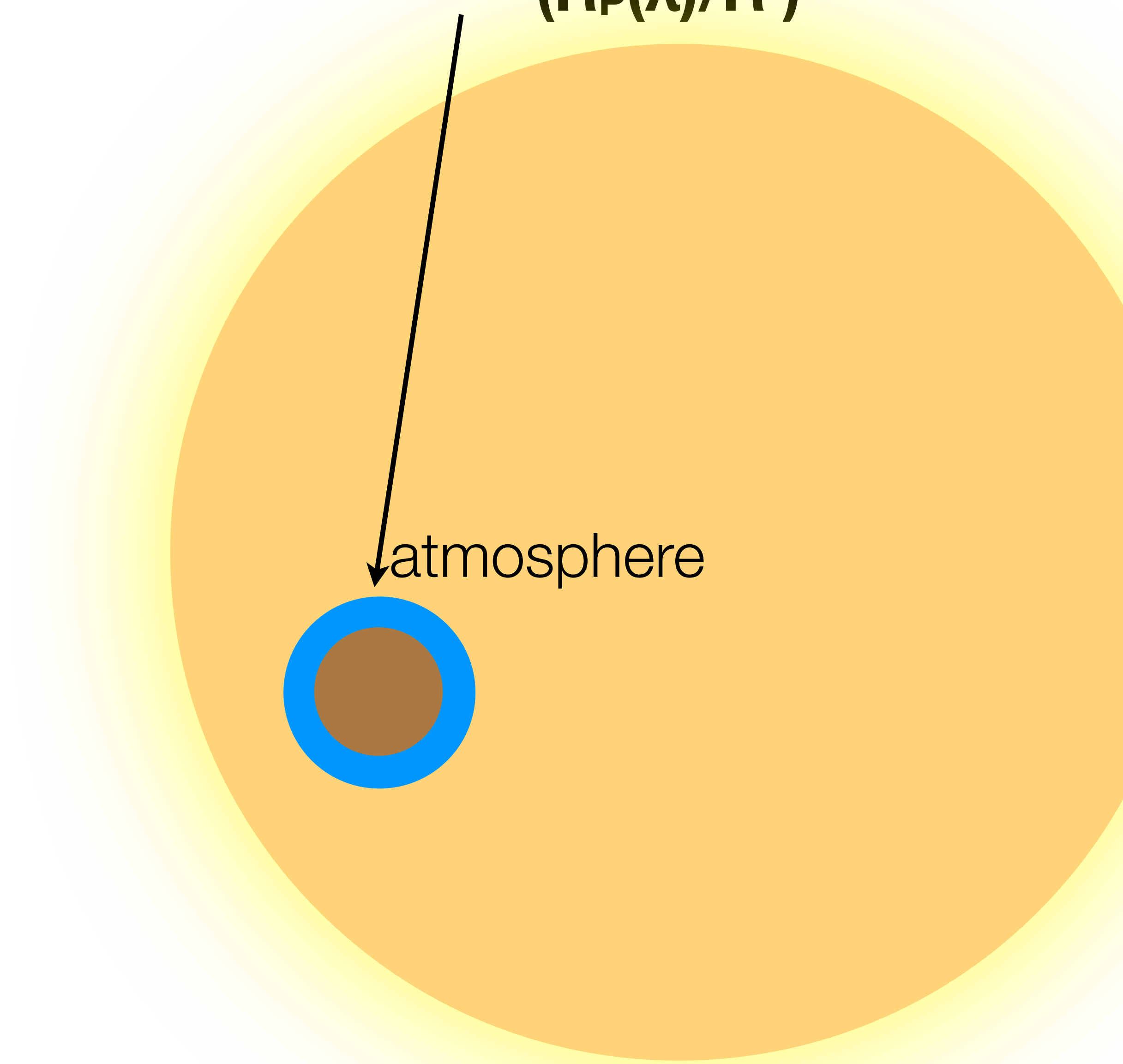
Exoplanet Atmospheres

- Narrow-band/spectroscopic transit analysis can probe absorption by specific atmospheric constituents

<u>Transit spectroscopy</u>

- in-transit *vs* out-of-transit allow us to determine atmospheric:
    - composition
    - temperature structure
    - velocity flows
    - mass-loss rates

Transit depth = $(R_P(\lambda)/R_*)^2$



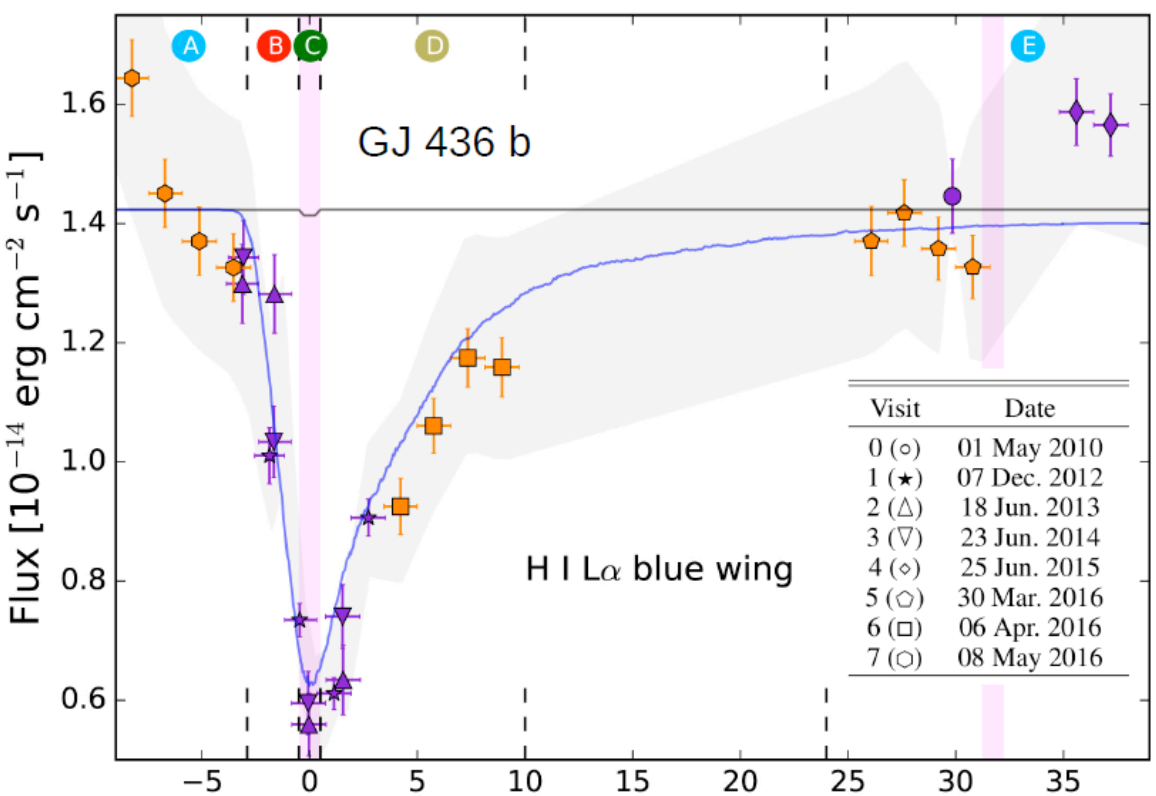
Transit spectroscopy of short-period planets

- EUV heating driving mass-loss from short-period planets
- Most spectacular example: the short-period Neptune-mass planet GJ 436b

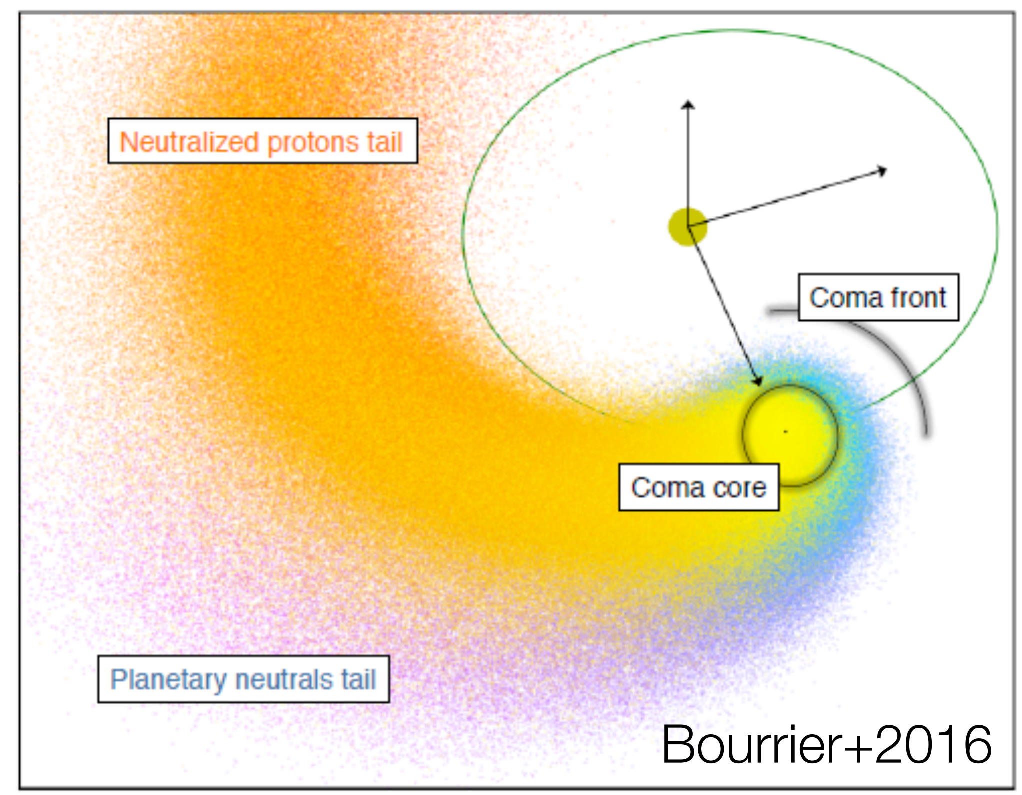
Hydrogen detected in the upper atmosphere of GJ436b

(Kulow+14; Ehrenreich+15; Bourrier+16; Lavie+17)

Transit depth ~ 50% (!)



Lavie+2017



Bourrier+2016

Extreme exoplanet atmospheres: challenges

- Sample size: ~5-6 mass-loss measurements, ~1 early-ingress, ~2 late-egress

  → **dedicated platform**

- Rarely get the same transit result twice: time-variability of the star (?), planetary mass-loss rate (?), or apples-vs-oranges observations and data reduction algorithms (?)

  → **multiple, consecutive transits, single data pipeline**

- Stellar baseline for transit measurements

  → **± 0.25 phase coverage**

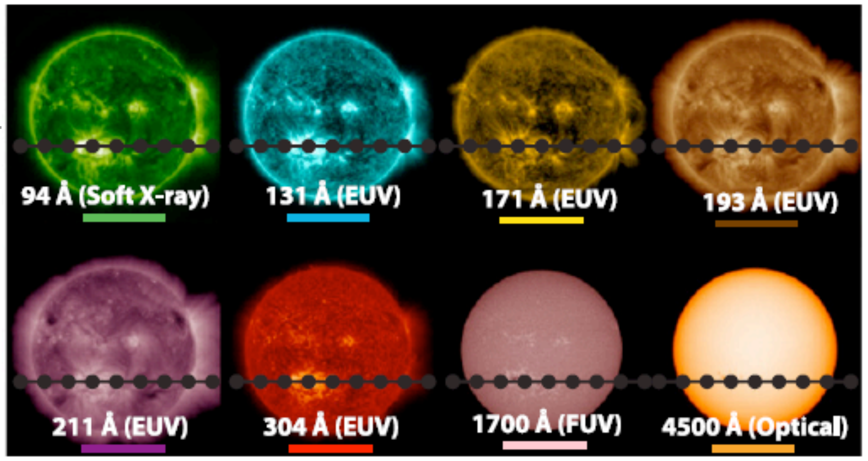
- Self-consistent modelling framework

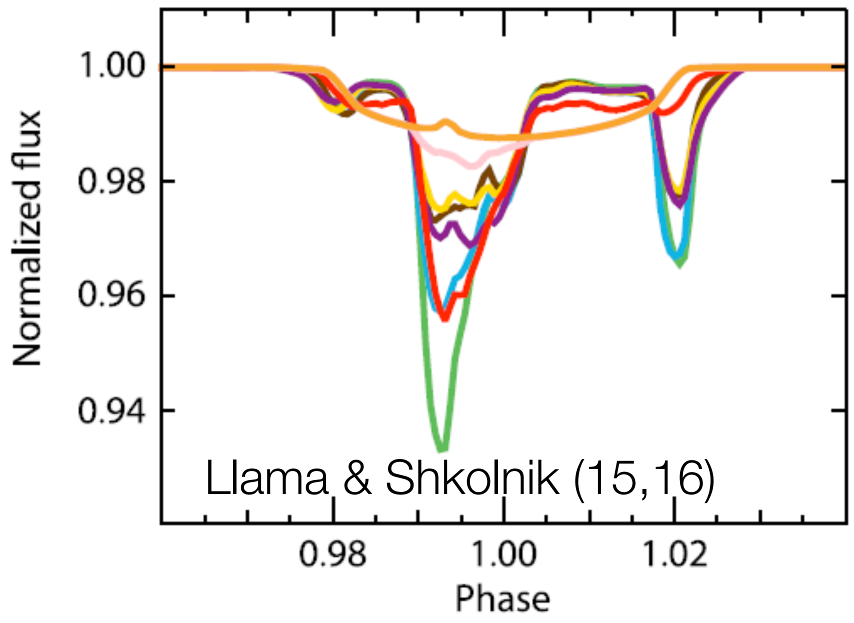
  → **state-of-the-art, physically self-consistent models**

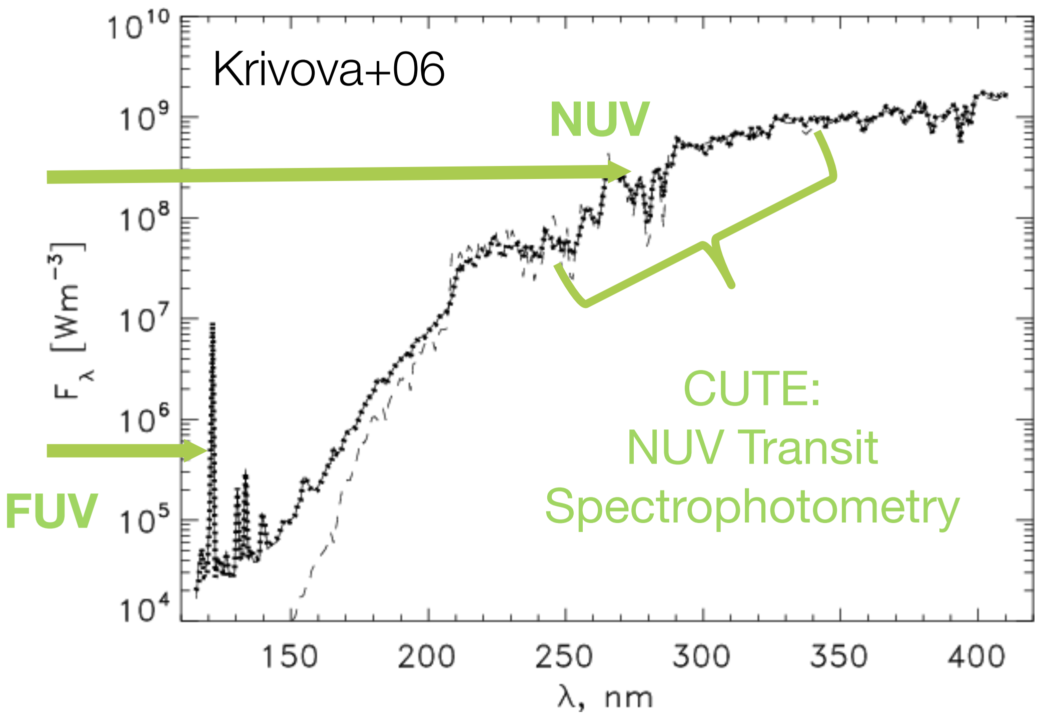
Statistics and systematics: the need for a dedicated UV transit experiment

CUTE: A new approach to atmospheric mass-loss measurements

- Almost all detections of atmospheric mass loss have been carried out in the **FUV** (Vidal-Madjar+04,13; Linsky+10; Ben-Jaffel+ 07,13; Kulow+14; Ehrenreich+15)
- Interpretations are still controversial: low-S/N, uncertain chromospheric intensity distribution (Llama & Shkolnik 15)
- Conduct observations in the **NUV**:
  - more uniform spectral region & brighter



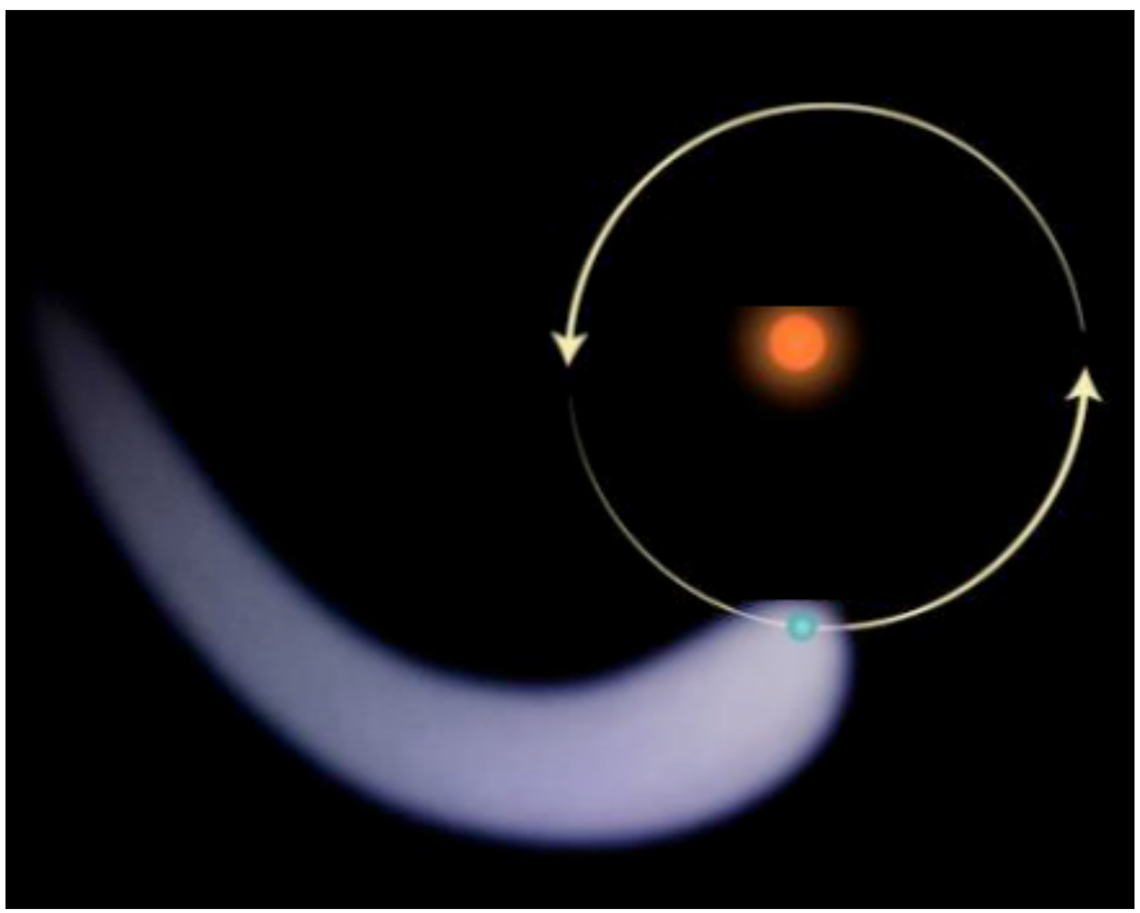




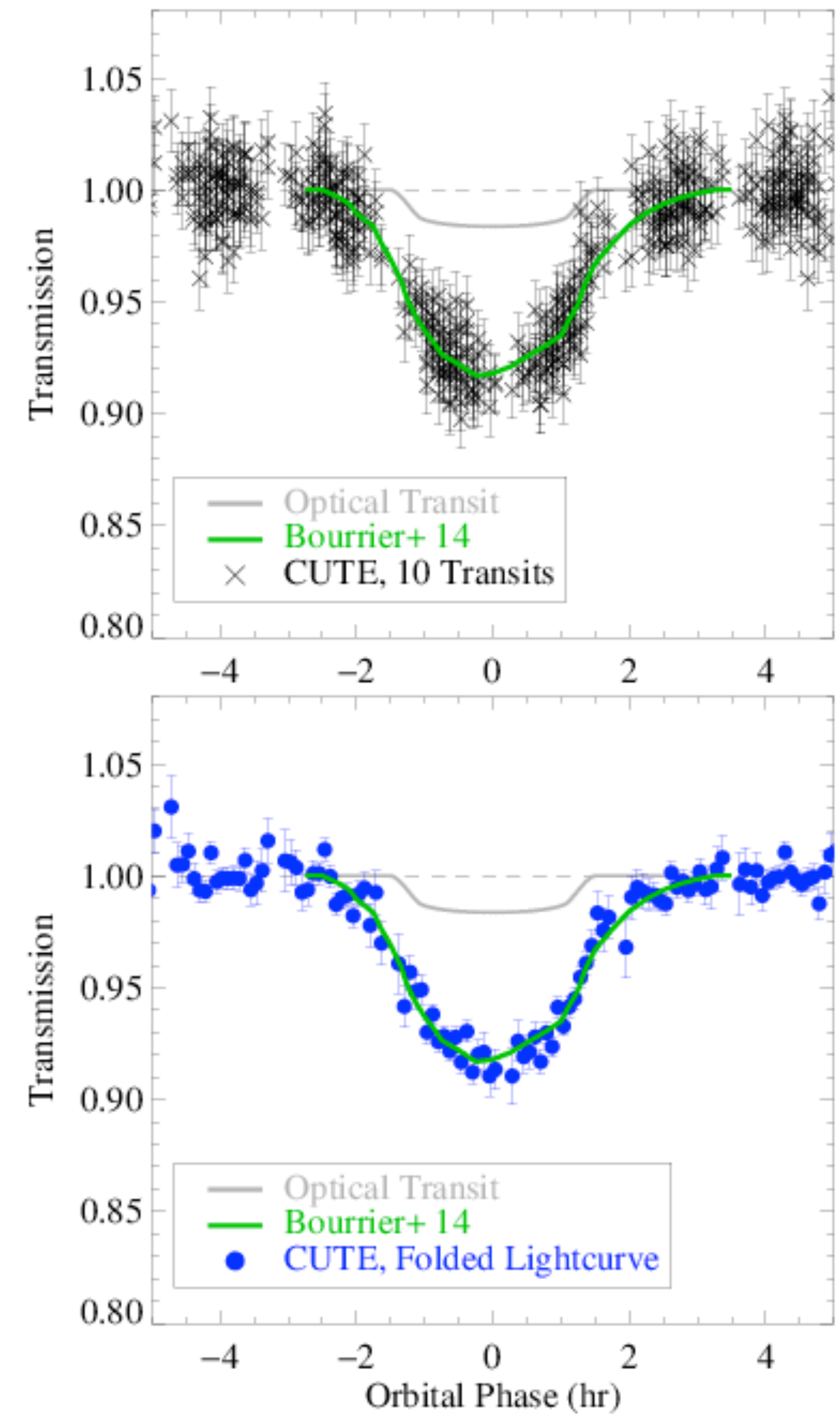
CUTE will survey of ~12-24 short-period transiting planets around nearby stars:
- Science 1: Atmospheric mass-loss
- Science 2: Exoplanet magnetic fields?

CUTE Science (1): Atmospheric mass-loss & variability

- Heavy elements will be entrained in the rapid H & He outflow, getting 'pulled' out of the planet: Mg, Fe, molecules, continuum absorption?

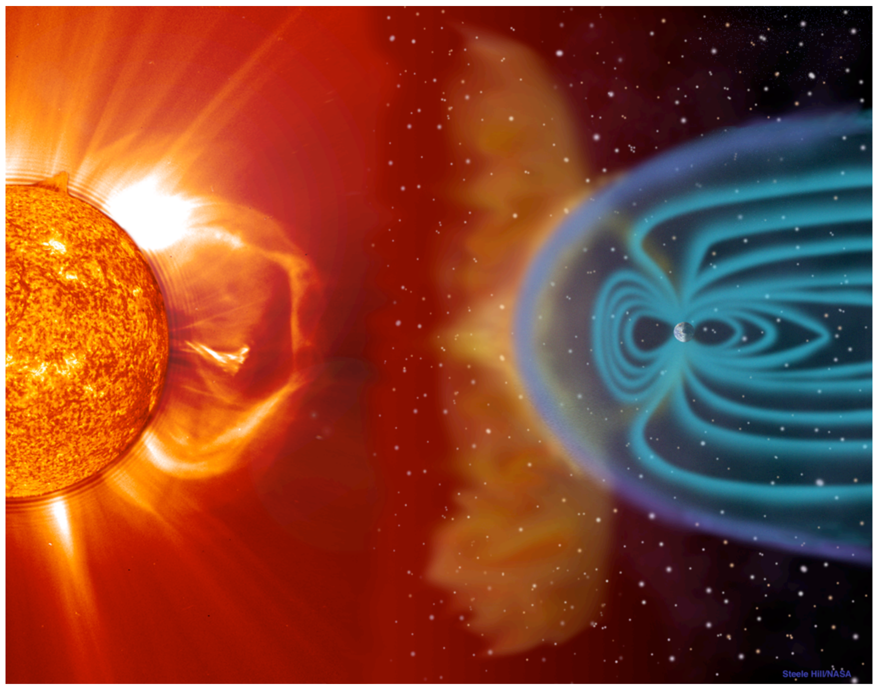


MgI - 285nm Simulation

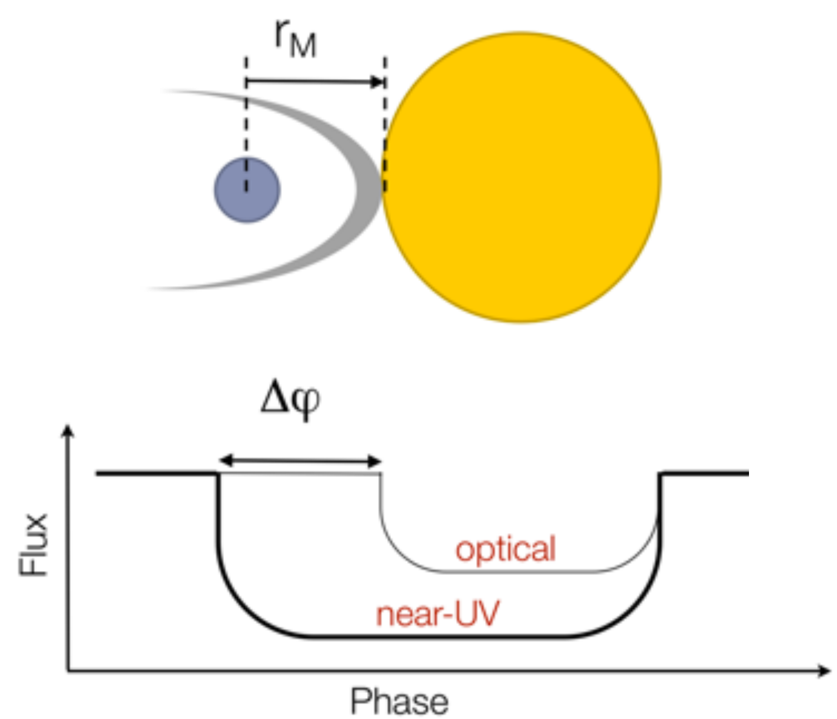


CUTE Science (2): Exoplanetary magnetic fields

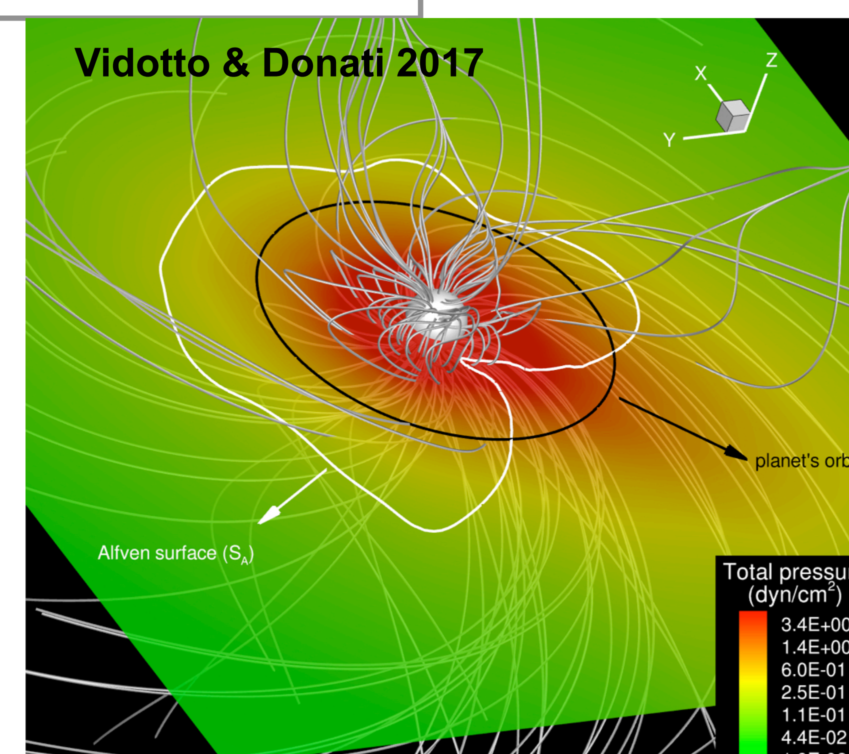
Interaction between stellar wind and planetary magnetic field creates bow shock
(Vidotto+10a,11)



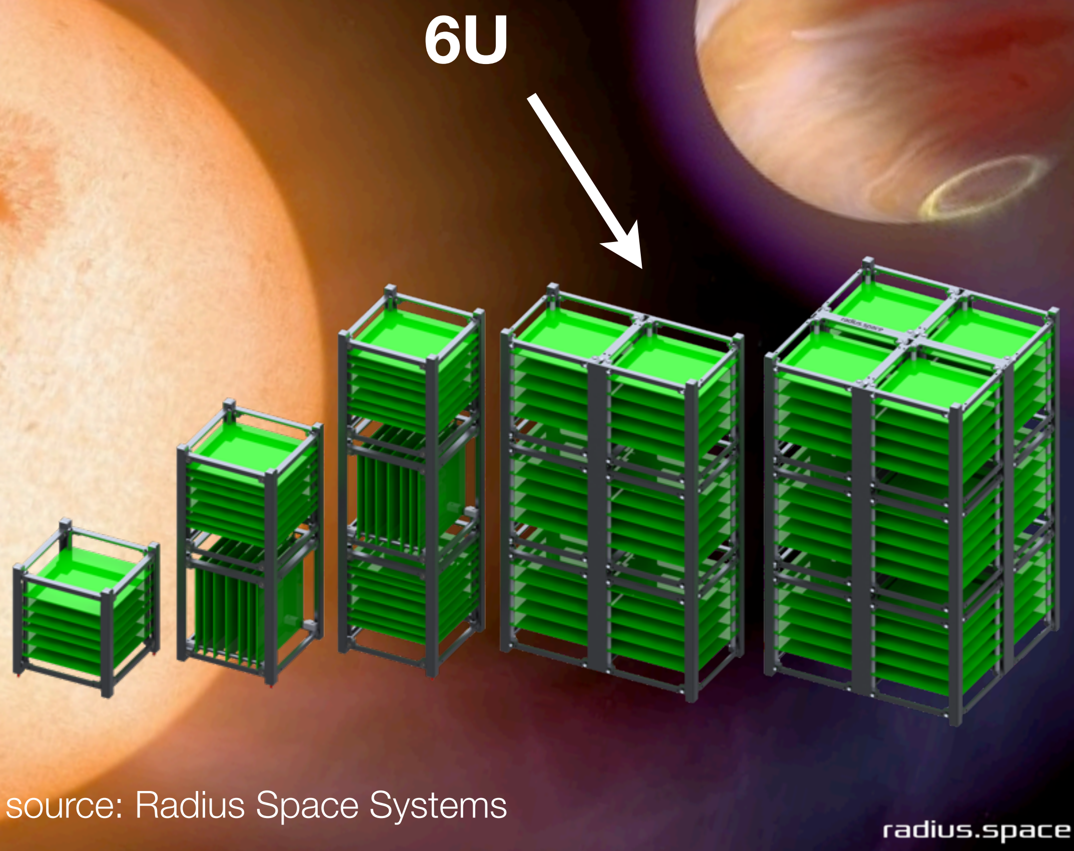
model: Vidotto+10a



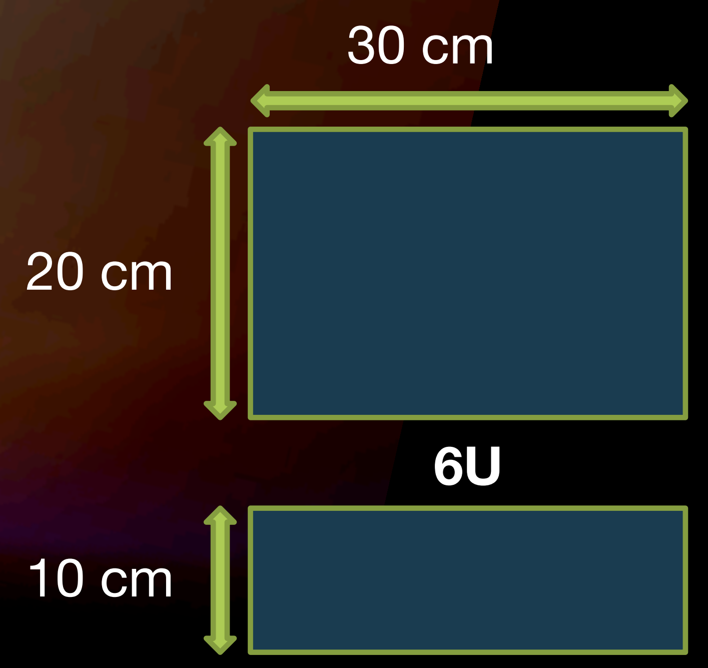
- Observations of bow shocks surrounding planetary magnetospheres → potential to discover and quantify exoplanetary magnetism
- Contemporaneous measure of stellar magnetic field (ZDI) → enable us to constrain stellar wind properties



Part 2: NASA Colorado Ultraviolet Transit Experiment (CUTE)



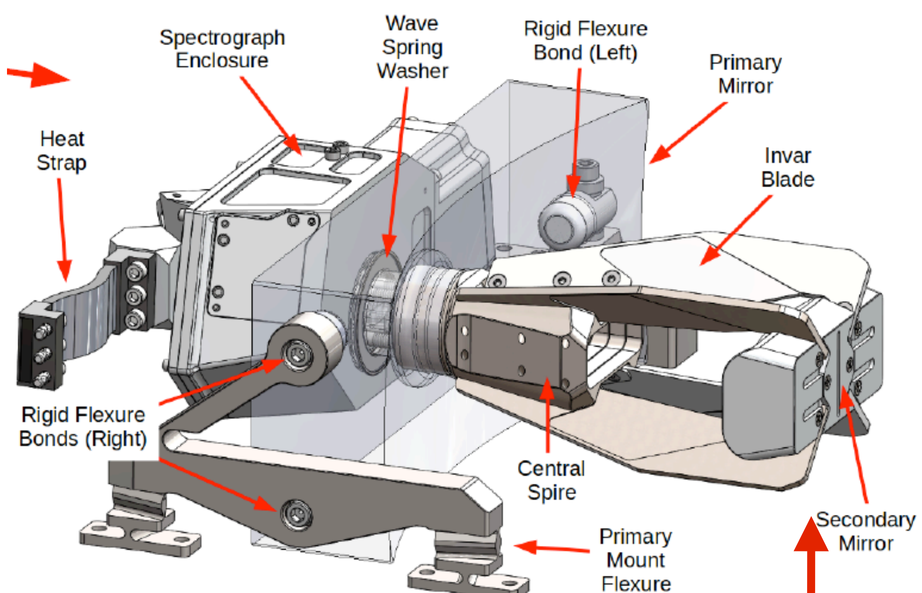
source: Radius Space Systems



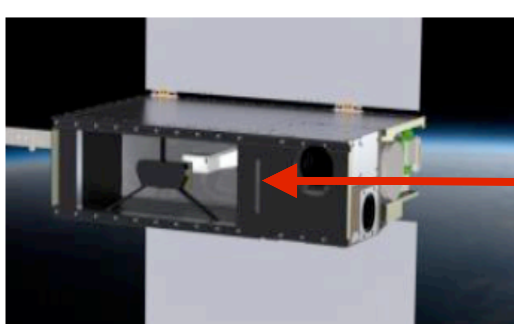
CUTE telescope

See CUTE design overview in Fleming et al. (2018)

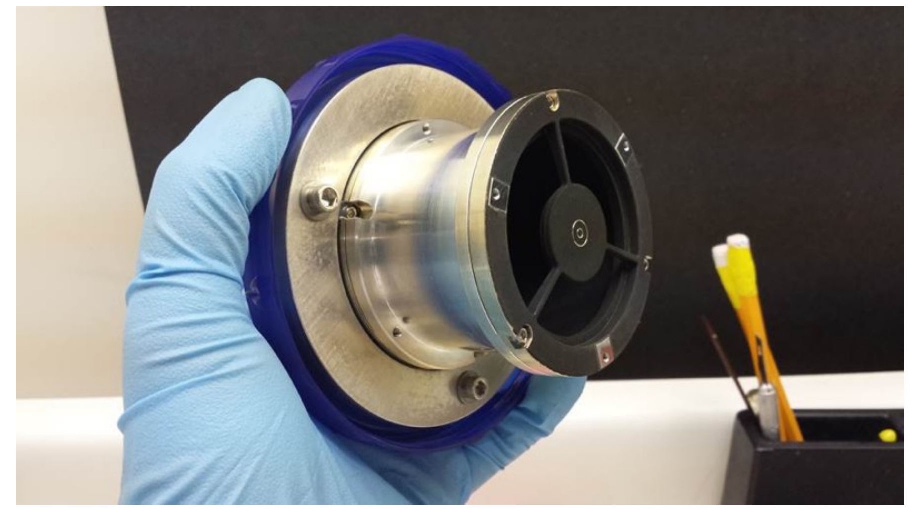
20x8cm, F/0.65 parabolic primary mirror feeding an F/2.6 classical Cassegrain telescope



Geometric clear area for a 20 x 8 cm Cassegrain:
A_T ~ 152 cm^2



For comparison:



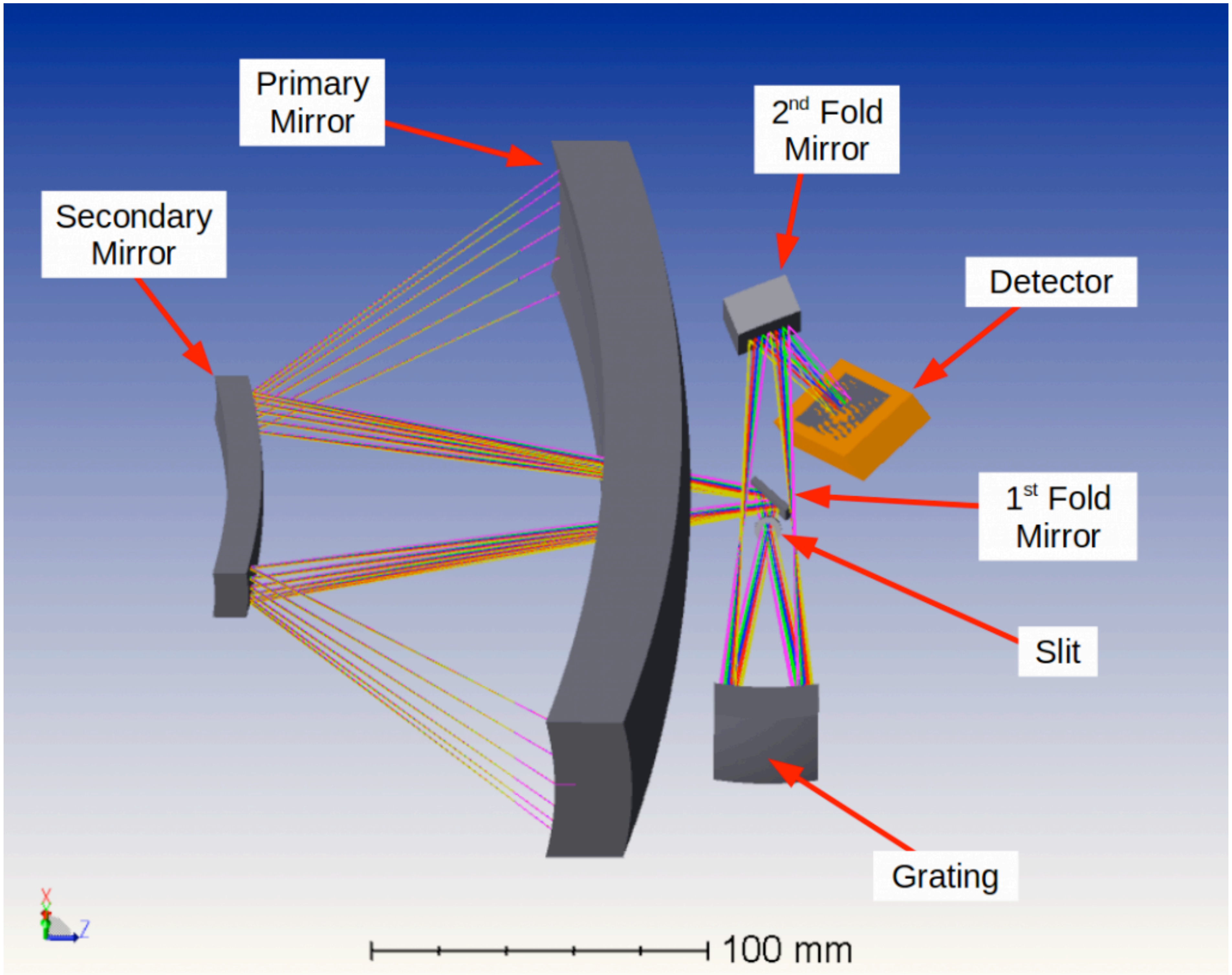
Source: Nu-Tek Precision Optics

Geometric clear area for a 9cm Cassegrain:
A_T ~ 47 cm^2

$A_{T,r}/A_{T,c}$ = **3.2x** more collecting area!

CUTE science instrument

Back-illuminated, UV-enhanced CCD detector, which has flight heritage from the Mars Science Laboratory



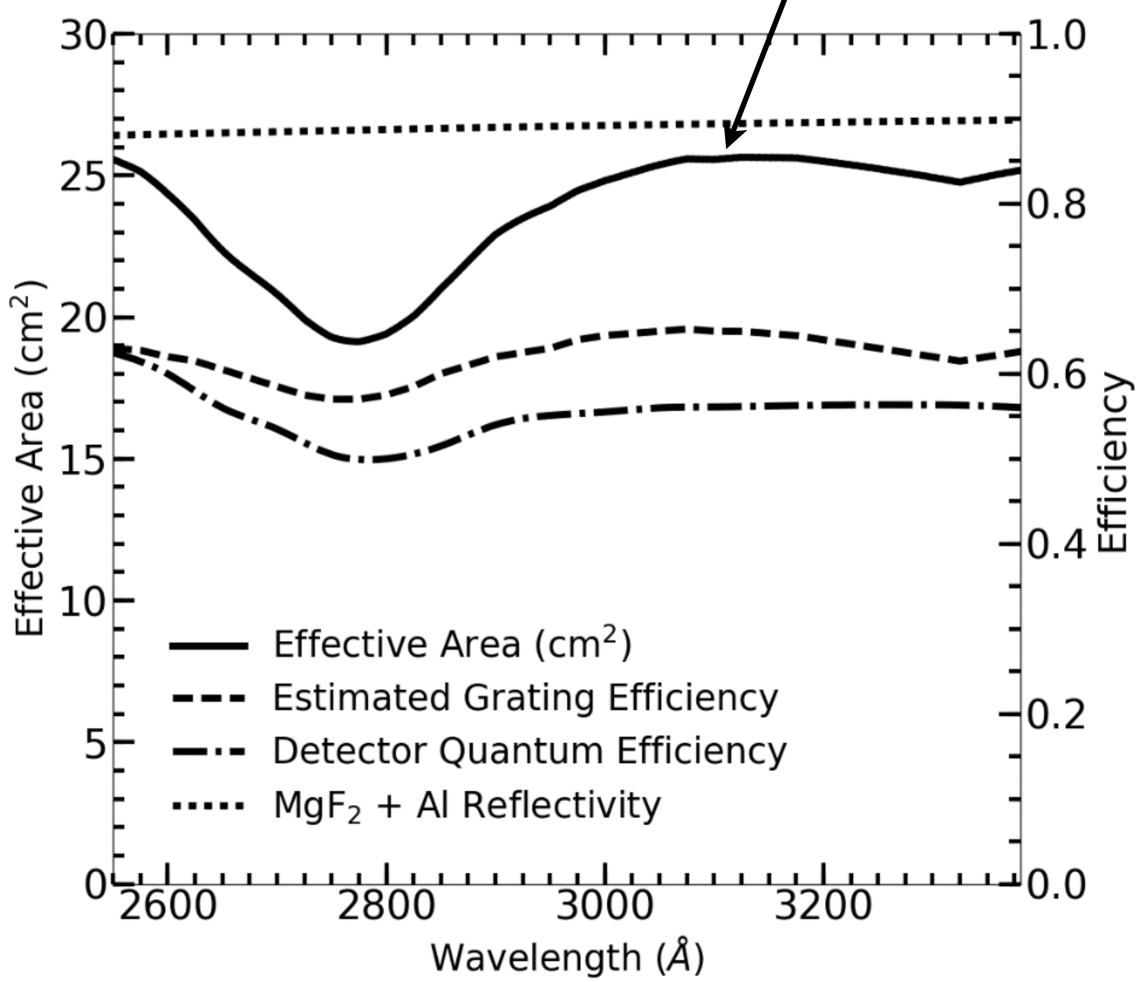
See CUTE design overview in Fleming et al. (2018)

The rectangular telescope feeds light into a compact medium-resolution spectrometer

CUTE Predicted performance

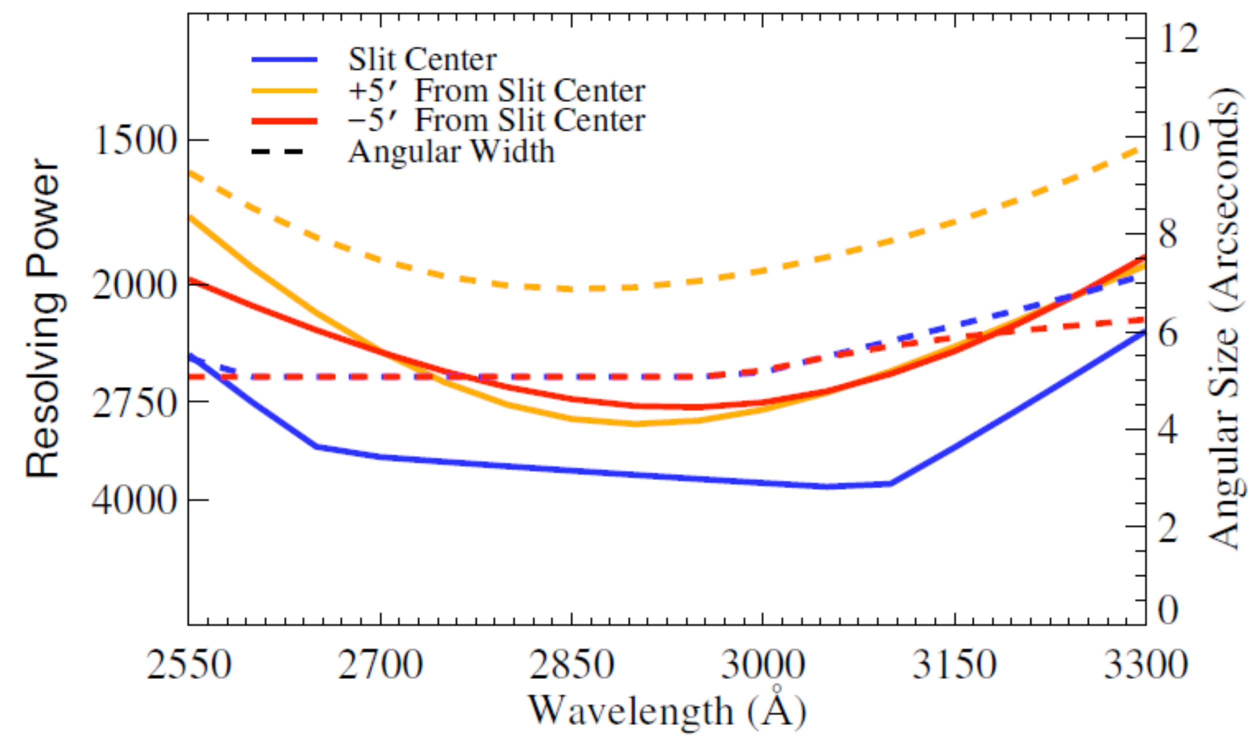
20 x 8 cm telescope:

$A_{eff} = A_T R^5 \varepsilon_{grat} QE_D =$ **20-25 cm²**



Compact spectrograph:

<R> ≈ **3,000**



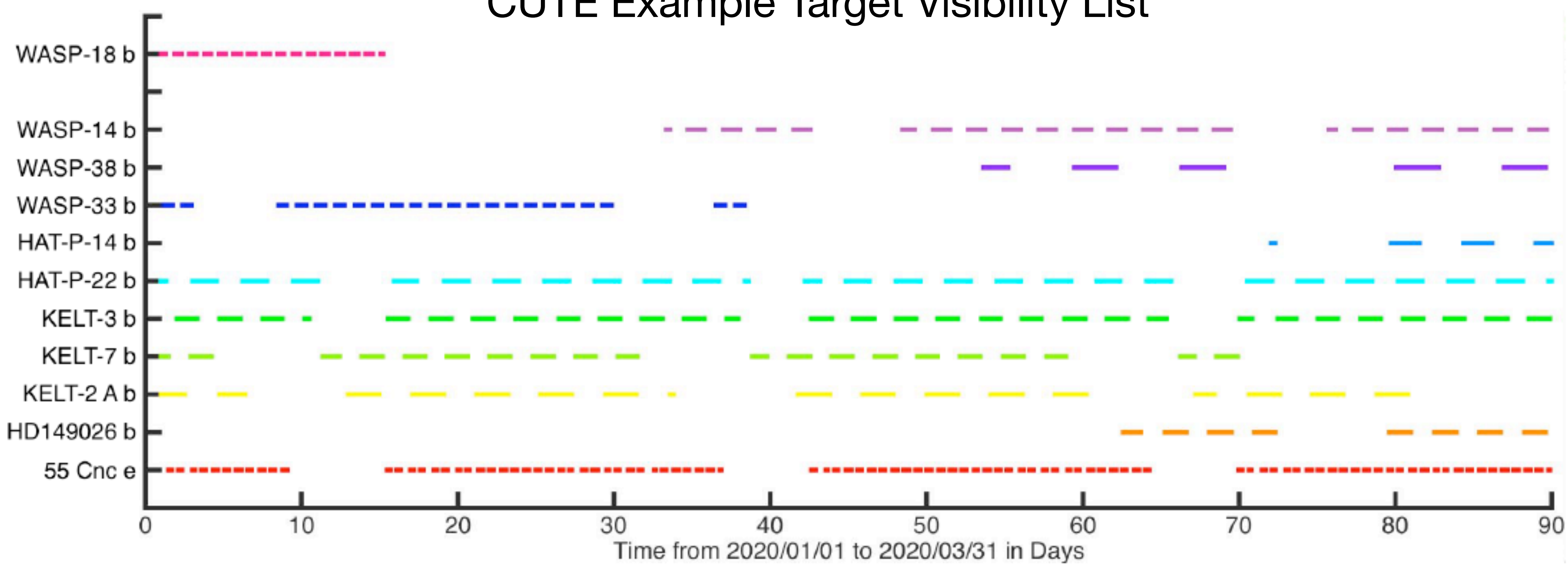
Performance relative to GALEX NUV Grism:

- $A_{eff,CUTE}/A_{eff,GALEX}$ = **~50%**
- $R_{CUTE}/R_{GALEX,NUV}$ = **40x**
- Angular Resolution: **Similar**

CUTE Predicted performance

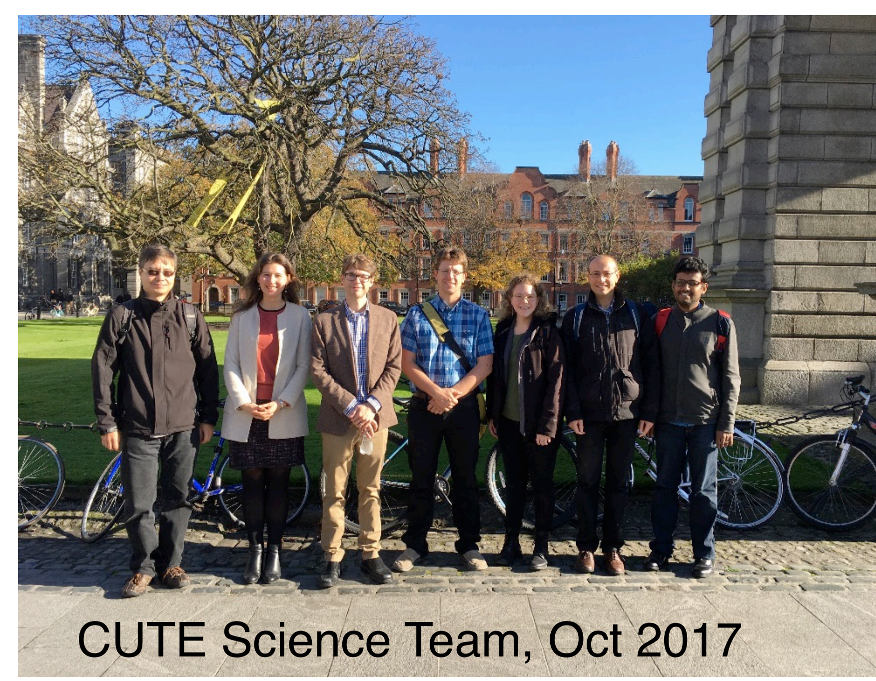
- CUTE will achieve >3σ detections of transits as low as 0.1% depth for the brightest targets, and < 1% for all baseline targets with 5+ lightcurves per target:
  - Transit sensitivity to 0.7% depth for median target over 1 transit
  - Capable of detecting geometric transit and atmospheric transit

CUTE Example Target Visibility List



CUTE Status

- Proposed Roses D.3 APRA - March 2016
- Selected February 2017
- Funded July 2017
- Science Team face-to-face meetings: Oct 2017, Nov 2018
- Long lead items arrive: ~now – Fall 2018
- Assembly, test, calibration: 2019
- Launch Q1/Q2-2020
  - 7 Month Baseline mission:
  - 12 exoplanetary systems, 6-10 transits each
  - 12 – 20 additional systems in 12 month extended mission


CUTE Science Team, Oct 2017

Interested in joining the CUTE team?

http://lasp.colorado.edu/home/cute/

- 1x Postdoc Position in Space Instrumentation (Colorado, with Kevin France)
- 1x Postdoc Position in exoplanet atmospheres (Tucson, with Tommi Koskinen)
- 2x Postdoc Positions in stellar/exoplanetary outflows (Dublin, with Aline Vidotto)