WSO-UV/UVSPEX for characterization of Earth-like exoplanets

Detection - Transit, RV
↓
Characterization
=>Atmosphere
Earth and Venus

Almost the same in size
Earth R: 6371 km
Venus R: 6052 km

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<th>Feature</th>
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<th>Venus</th>
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How to distinguish?
Transit spectroscopy of exoplanetary atmosphere

Ozone in Earth-like TRAPPIST-1d
=>
60 transits by JWST (~6 years)
Barstow & Irwin, 2016
Earth and Venus

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How to distinguish?
Upper atmosphere (Exosphere)

CO\textsubscript{2} is a coolant for upper atmosphere.
Earth (Low CO\textsubscript{2}) -> 1000 K
Venus, Mars (CO\textsubscript{2} dominant) -> 200-300 K

CO\textsubscript{2} on exoplanets: detectable
CO\textsubscript{2} mixing ratio: difficult (Venus <- In-situ)
(temperature profile, height of cloud, etc.)

Temperature of upper atmosphere
<->? CO\textsubscript{2} mixing ratio
<->? Ocean and tectonics

Earth’s extended exosphere
Kameda+17
Stellar Flux at HZ of low-temperature star

- Difference between Solar and M-type stellar fluxes. (Ribas et al., 2017)

Red: Solar flux (1AU)
Black: Proxima Centauri’s flux at Proxima b (0.0485AU)

Heat source of Upper atmosphere

EUV: 10-105nm
Extended oxygen exosphere at high EUV

High EUV $\rightarrow$ expanded upper atmosphere

Temperature, K
Altitude, km

Venus
Mars
Earth

Kulikov+07
Tian+08
Oxygen Exosphere (10EUV)

- Black circle: planet  White circle: star (Proxima Centauri)
- Earth-like case: Optically thick oxygen to $\sim 8R_e$ ($1 \times 10^{14}$ cm$^{-2}$ ~ $\tau = 1$)
Oxygen Exosphere (10EUV)

- Black circle: planetary atmosphere
- Earth-like case: Proxima Centauri
- Venus-like case: Proxima Centauri

Transit depth: ~24%
(~70% at line center)

Tavrov, Kameda+2018

$\times 10^{14}$ cm$^{-2} \sim \tau = 1$
Large UV space telescope!

(HST is inside Earth’s oxygen corona)
World Space Observatory UV (WSO-UV)

Russia, Spain (UV imager) + Japan (UV spectrometer)
- Target launch: 2025 Oct
- Diameter: 1.7 m
- Spectral range: ~110-320 nm
- Orbit: GSO (6.6 Re) -> outside of Oxygen geocorona (HST ~400km)

Exoplanet
- UV irradiation
- Upper atmosphere
UV spectrograph for Exoplanets (UVSPEX)

- Slit + Concave (Toroidal) grating + Detector (MCP)
- Spectral range: 117-144 nm
- Spectral resolution: ~0.3 nm @130 nm
- Slit: 2.5” (= 200 um)
- Grating: Toroidal blazed grating, Al+MgF2 coating, φ 30 mm, 2400 gr/mm, f = 250 mm
- Detector: Image Intensifier (CsI photocathode + Funnel-type Microchannel Plate (MCP))
- Mass: < 7 kg
- Power: < 7 W

- 10-20 Earth-size exoplanets
  - Oxygen <-> Ocean
- Earth-like TRAPPIST-1e can be detected in ~13 transits
- Model for upper atmosphere
UVSPEX-S

UVSPEX-M
Earth-like planet
~4 transits (3σ)
Transit depth ~3%
Much higher flux

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~4 transits (3σ)
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Much higher flux

Kameda+, in prep
• Oxygen (+Hydrogen) Exosphere observation by VUV spectroscopy
• EUV-VUV flux is important as heat source for atmosphere
• WSO-UV is outside of oxygen geocorona
  -> Earth-like oxygen exosphere
• 2020-2030 Combination (mass, size, age, lower-upper atmosphere)
New type MCP: Specification

**R10110M07505FR**
- MgF2 window: t3.0mm
- Photocathode: CsI
- MCP: 5-stage (1st: Funnel)
- Anode: RAE
- Effective Area: 16x16mm
  (smaller than previous version)

→ Phosphor And CMOS readout
For WSO-UV