Atmospheres of PLATO planets

David Ehrenreich
Outline

- State-of-the-art
- New approach for atmospheric characterisation of PLATO planets
Transmission spectroscopy works best with bright, nearby stars
Transmission spectroscopy

The planet (partially) eclipses the star

Transmission spectroscopy through the limb
State-of-the-art

Exosphere: mass loss, & star-planet interaction
Ehrenreich+2012

- 55 Cancri (G8v@12 pc)
- HD 189733 (K0v@19 pc)
- GJ 436 (M2.5v@10 pc)
- PLATO ➡ >10,000 nearby M dwarfs
- HD 209458 (G0v@50 pc)
UV transit spectroscopy

HST/STIS (Bourrier+ 2013)

HD 189733

12.3±3.7%
FAP 3.6%

Out of transit
In transit

HD 209458

Out of transit
In transit

Bourrier & Lecavelier des Etangs 2013

Escape rate = $10^9$ g s$^{-1}$
Ionizing flux = 3 solar units

⇒ Other signatures in C II and Mg I
(Vidal-Madjar+ 2013, Bourrier+ 2014)
State-of-the-art

Upper atmosphere: scattering, alkali, & clouds

Exosphere: mass loss, & star-planet interaction
Visible+NIR transit spectroscopy

HST/STIS+WFC3 transmission spectrum of Wasp-31b (Sing+2014)
State-of-the-art

Exosphere: mass loss, & star-planet interaction

Upper atmosphere: molecules, albedos, & clouds

Lower atmosphere: molecules, albedos, & clouds

Exosphere: mass loss, & star-planet interaction
Emission spectroscopy
Emission $\times$ transmission spectroscopy

HST/WFC3 emitted spectrum of Wasp-43b (Kreidberg+2014)

HST/WFC3 transmission spectrum of Wasp-43b (Kreidberg+2014)
Emission × transmission spectroscopy

HST/WFC3 emitted spectrum of Wasp-43b (Stevenson+2014)

Typical JWST studies
NIR transmission spectroscopy at high resolution

VLT (8m)/CRIRES transmission spectrum of HD 209458b (Snellen+2010)
Imaging × spectroscopy

VLT/NACO Lagrange+ 2009, 2010

VLT/CRIRES slit

VLT/CRIRES Snellen+ 2014
State-of-the-art: summary

• Promising results for giant planets

• Target-starved field for low-mass objects
  ➡ more bright stars
State-of-the-art: summary

- Promising results for giant planets
- Target-starved field for low-mass objects ➔ more bright stars
- “Deep-field” characterisation on few targets
  - Small planets: Flat lines at low- to mid-spectral resolution
  - Giant planets: each new feature detected ➔ new class of objects!
    - Fantastic diversity!
    - Tale-tell sign that more targets are needed!
PLATO is a game changer
PLATO is a game changer

- Brings atmospheric characterisation in a survey era
- Statistical approach and constraints possible!
A “Champaign mission”

Bottleneck of targets for atmospheric characterisation

PLATO
PLATO is a game changer

• Brings atmospheric characterisation in a survey era

• Statistical approach and constraints possible!

• **Save the bubbles:**
  New approach for characterisation follow-up, in addition to validation/mass follow-up
  (both can be coupled)
Atmospheric characterisation of PLATO planets
New approach required!

• Which targets?
• Which instruments?
• What purposes?
Atmospheric characterisation of PLATO planets
3-stage approach

• **Reconnaissance** (~1,000 targets)
  - Survey: observes as much targets as possible
  - Dedicated, “small” instruments
    - Partly done by PLATO + RV follow-up (density) + PLATO **colours**
    - Further filtering out could be needed: “CHEOPS+” w/ chromatic capacities
Atmospheric characterisation of PLATO planets
3-stage approach

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- **Focused observations** (~100 targets)
  - Determines several atmospheric properties
  - Dedicated instruments or LPs
Atmospheric characterisation of PLATO planets
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  - LPs on most powerful instruments
Atmospheric characterisation of PLATO planets

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caveat: beware of sequential approach
E-ELT HR detection of $O_2$

in the atmosphere of a planet@nearby late M dwarf

Snellen +2013

See also Rodler & Lopez-Morales 2014
Take away:

- PLATO will change the approach to atmospheric characterisation
- Reconnaissance: S mission? Ground?
- Turning RV device ➔ characterisation machines
  - Deep characterisation
    HR spectrograph@ELT (arXiv:1412.1048)
  - Focused observations:
    HR spectrograph@4–8m telescopes
- Pathfinder programmes possible now will explore and enable this vision

Thank you!
Atmospheric Science in the Context of CHEOPS, TESS, K2 and PLATO 2.0

Where: German Space Agency (DLR) [Adlershof] Berlin
When: March 2\textsuperscript{nd}-4\textsuperscript{th} 2015
Organizer: John Lee Grenfell (DLR Berlin)
Coordinator: WG Atmospheres 116-500

Themes: Atmospheric Albedo, Escape, Climate, (Photo)chemistry, Spectra - from Hot Jupiters down to Super-Earths

Science: PLATO Yellow Book Section 2.19 “Planetary Atmospheres”
Submissions: Oral and Posters welcome
Note: Limited to 80 places

REGISTRATION WEBSITE COMING SOON
(planned for same website as Taormina meeting)

SOC: John Lee Grenfell, Helmut Lammer, Kevin Heng, Nicolas Iro, Heike Rauer
LOC: John Lee Grenfell, Mareike Godolt, Barbara Stracke, Ruth Titz, Claudia Drever