PlanetS
National Centre of Competence in Research

Project 3

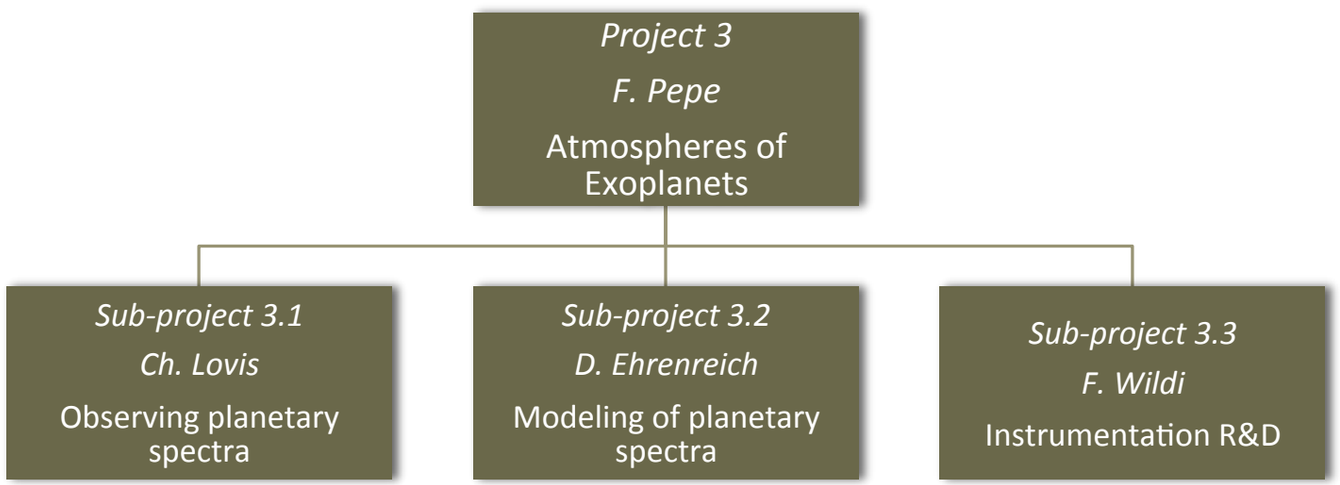
Atmospheres of Exoplanets

Project 3

Atmospheres of Exoplanets

Moving from detection to characterisation

+ Experience in Doppler-velocimetry, thus spectroscopy



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Project 3

Atmospheres of Exoplanets

3.1 – Observing atmospheres

People involved in **3.1**

- Christophe Lovis
  Project 3.1 coordinator, UGE

- Aurélien Wyttenbach
  SNF PhD student (Pepe's SNF grant), UGE

- Adrien Coffinet
  PhD student (internal grant), UGE

- Danuta Sosnowska
  Project 3.2 + 7 PhD computer scientist, UGE

- Alex Segovia, Ehrenreich, F. Wildi, F. Pepe
  Links and exchange within Project 3 and UGE Projects: **ESPRESSO/Spirou/…**

The National Centres of Competence in Research (NCCR) are a research instrument of the Swiss National Science Foundation

3.1 Internal collaborations

- PlanetS Project 3 – Atmospheres of exoplanets
  - **Christophe Lovis**
  - David Ehrenreich
  - François Wildi
  - **Francesco Pepe**

☛ **Spectroscopic data**

Collect high-resolution data, understand and improve existing and future data

3+7 collaboration will enable ‘the global picture’

- PlanetS Project 7 – Architecture of systems
  - Stéphane Udry
  - Damien Ségransan

☛ **Properties of planetary systems**

Swiss National Science Foundation

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3.1 Internal collaborations

- PlanetS Project 3 – Atmospheres of exoplanets
  - **Christophe Lovis**
  - **David Ehrenreich**
  - François Wildi
  - Francesco Pepe

☛ **Spectroscopic data**

Develop new data analysis algorithms and tools

3+DACE will enable integration, exploitation dissemination of high-quality data

- PlanetS Platform – DACE
  - **Stéphane Udry**
  - **Damien Ségransan**

☛ **Properties of planetary systems**

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3.1 Exploring the limits of existing facilities

- Use of HARPS/HARPS-N to probe transmission/ reflection spectra of exoplanets orbiting bright stars
- HEARTS proposal for HARPS (PI: D. Ehrenreich)
- Study of ESPRESSO capabilities
- Near-IR instruments: CRIRES, GIANO, ...

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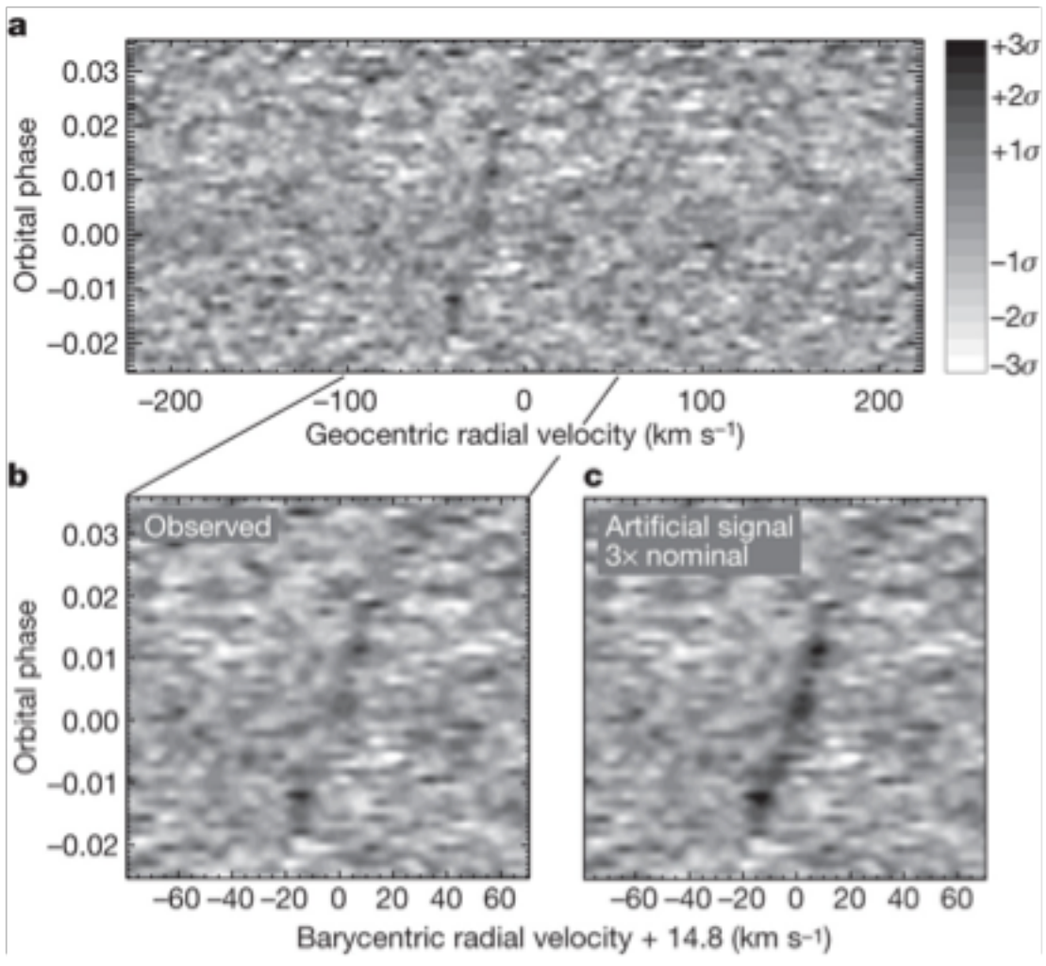
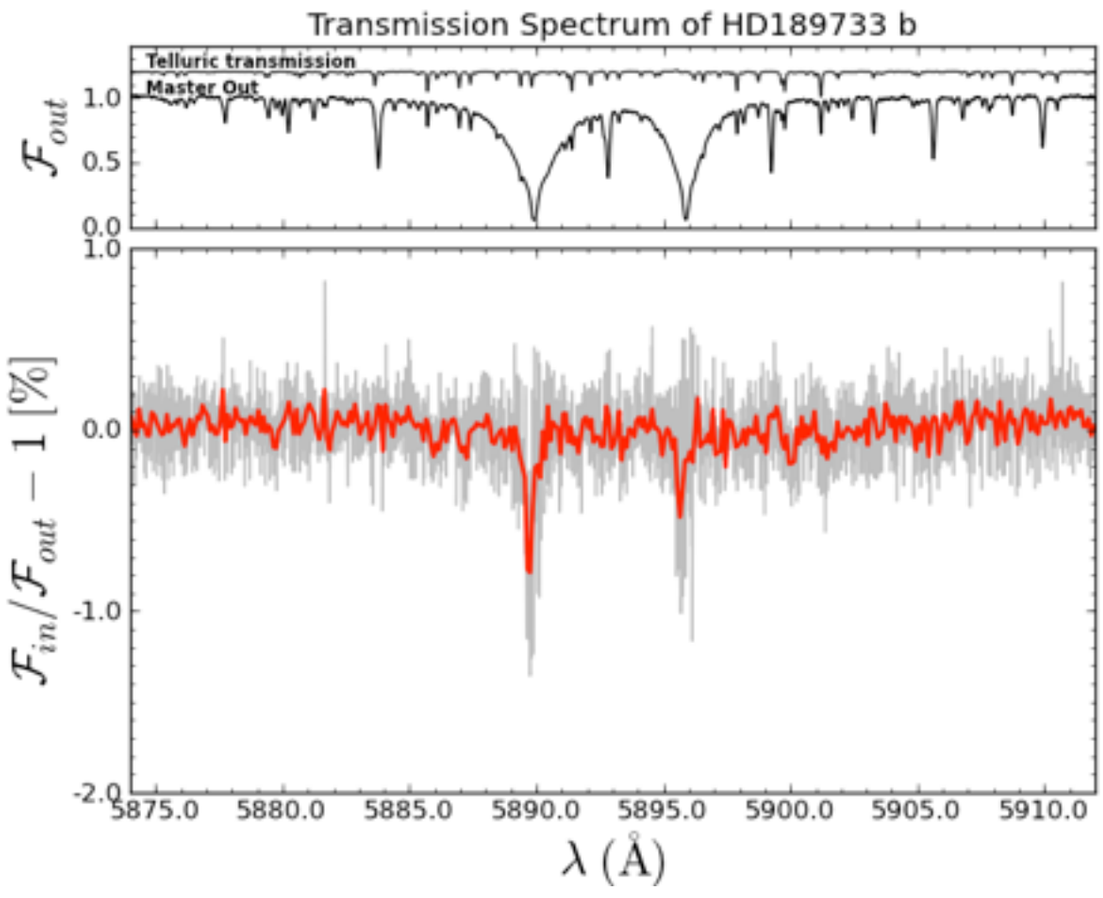
3.1 Exploring the limits of existing facilities

Carbon monoxide - CRIRES



Snellen et al. 2010

Sodium - HARPS



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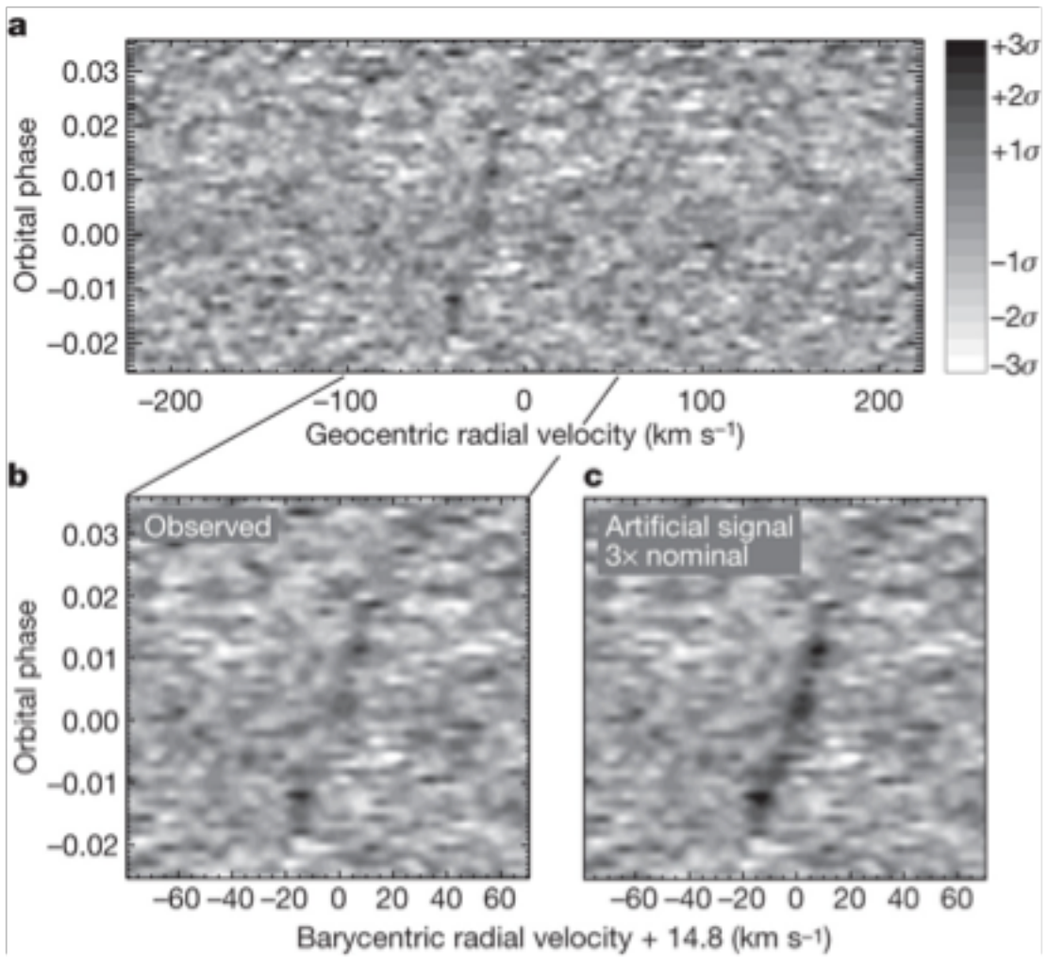
Carbon monoxide - CRIRES



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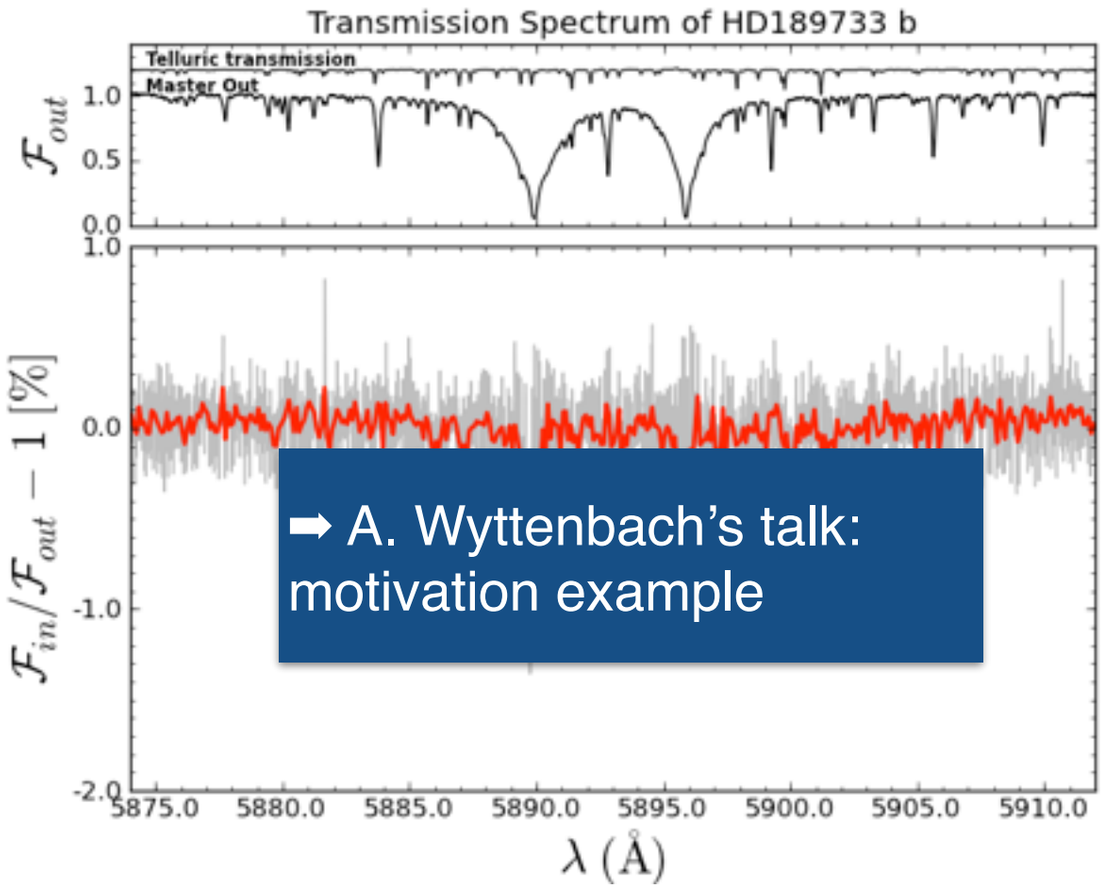

➡ A. Wyttenbach's talk: motivation example

3.1 Develop near-infrared spectroscopy

- Direct participation in ongoing projects: SPiROU, NIRPS (hardware/software developments)
- Develop science requirements for E-ELT HiRES
- Explore limiting factors in the near-IR: telluric absorption, detector performances, etc

3.1 Creating spectroscopic analysis tools

- Visualization tools for high-resolution spectra (stacking/differencing, line identifications, ...)
- Visualization tools for databases of atomic and molecular transitions at high resolution
- New algorithms to filter out telluric lines
- Integration into DACE

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Project 3

Atmospheres of Exoplanets

3.2 – Modeling of planetary spectra

People involved in 3.2

- David Ehrenreich
  Project 3.2 coordinator, UGE

- Vincent Bourrier
  Project 3.2 postdoc, UGE (since 15/10/14)

- Baptiste Lavie
  Project 3.2+5 PhD student, UBE + UGE

- Ch. Lovis, F. Wildi, F. Pepe
  Links and exchange within Project 3 and UGE projects

3.2 internal collaborations

- PlanetS Project 3 – Atmospheres of exoplanets
  - Christophe Lovis
  - **David Ehrenreich**
  - François Wildi
  - Francesco Pepe

☛ **Collecting new data (space + ground)**

Predict & detect atmospheric signatures, provide science drivers for new instruments

3+5 collaboration will enable transfer of expertise

- PlanetS Project 5 – Physics of exoplanets
  - **Kevin Heng**
  - **Baptiste Lavie**

☛ **Retrieving atmospheric properties**

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3.2 internal collaborations

- PlanetS Project 3 – Atmospheres of exoplanets
  - Christophe Lovis
  - **David Ehrenreich**
  - François Wildi
  - Francesco Pepe

☛ **Collecting new data**

Example of collaborative effort:
Hot Exoplanet Atmospheres Resolved with Transit Spectroscopy (♥)

Proposed ESO LP (P95–P98)
for atmospheric characterisation
of hot jupiters with HARPS

- PlanetS Project 5 – Physics of exoplanets
  - **Kevin Heng**
  - **Baptiste Lavie**

☛ **Retrieving atmospheric properties**

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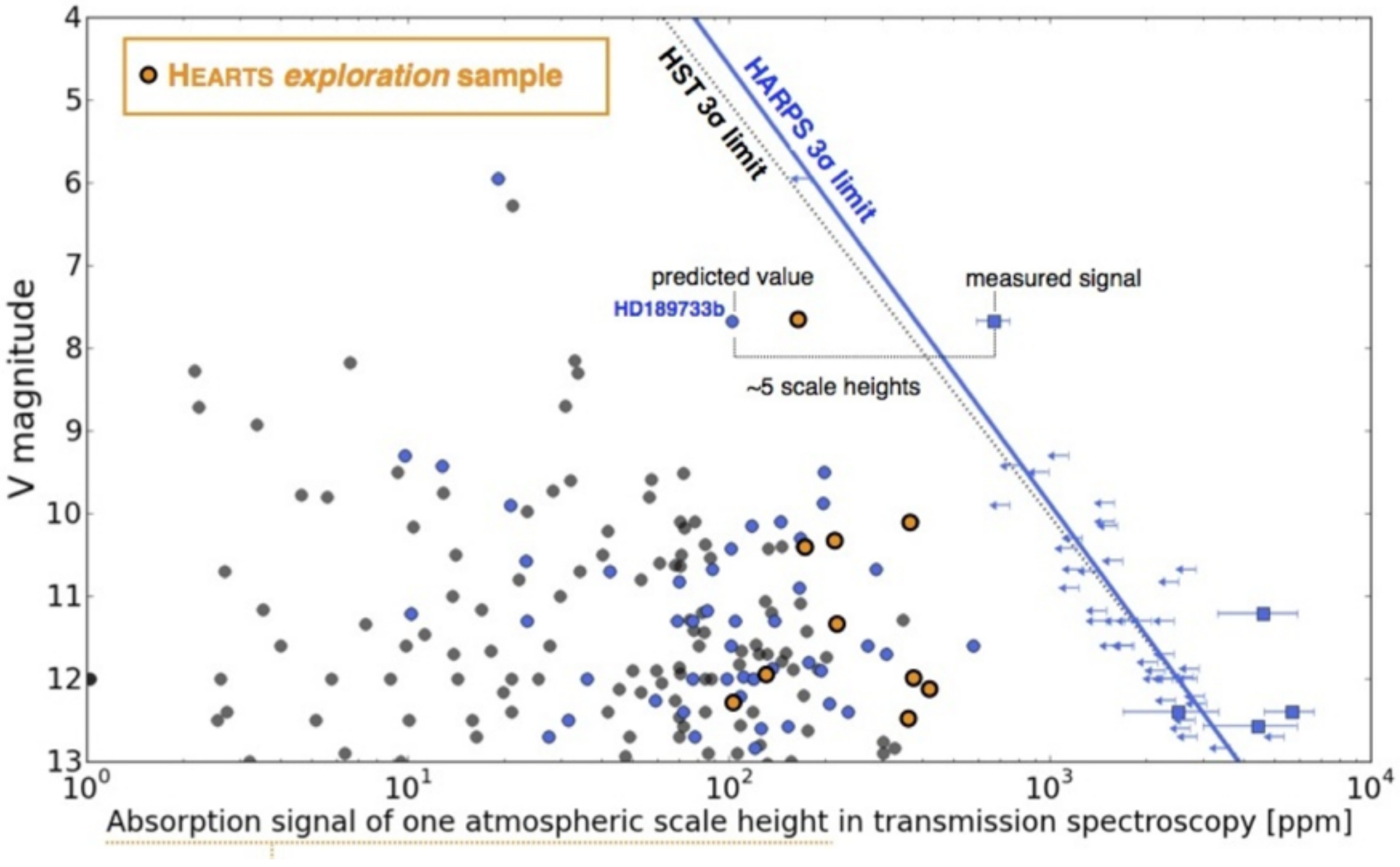
♥ 19 targets
79 HARPS nights over 2 years

➡ A. Wyttenbach's talk: motivation example
➡ D. Ehrenreich's talk: theoretical expectations



Working tools

- Currently available tools

  ➡ ***η***: a simple predictive forward model for transmission spectroscopy in the lower atmospheres of exoplanets

  ➡ **EVE**: forward model (particle simulation) for transmission spectroscopy of the escaping exospheric clouds and impact of stellar radiation and wind

- Tools to be developed in **project 3.2**

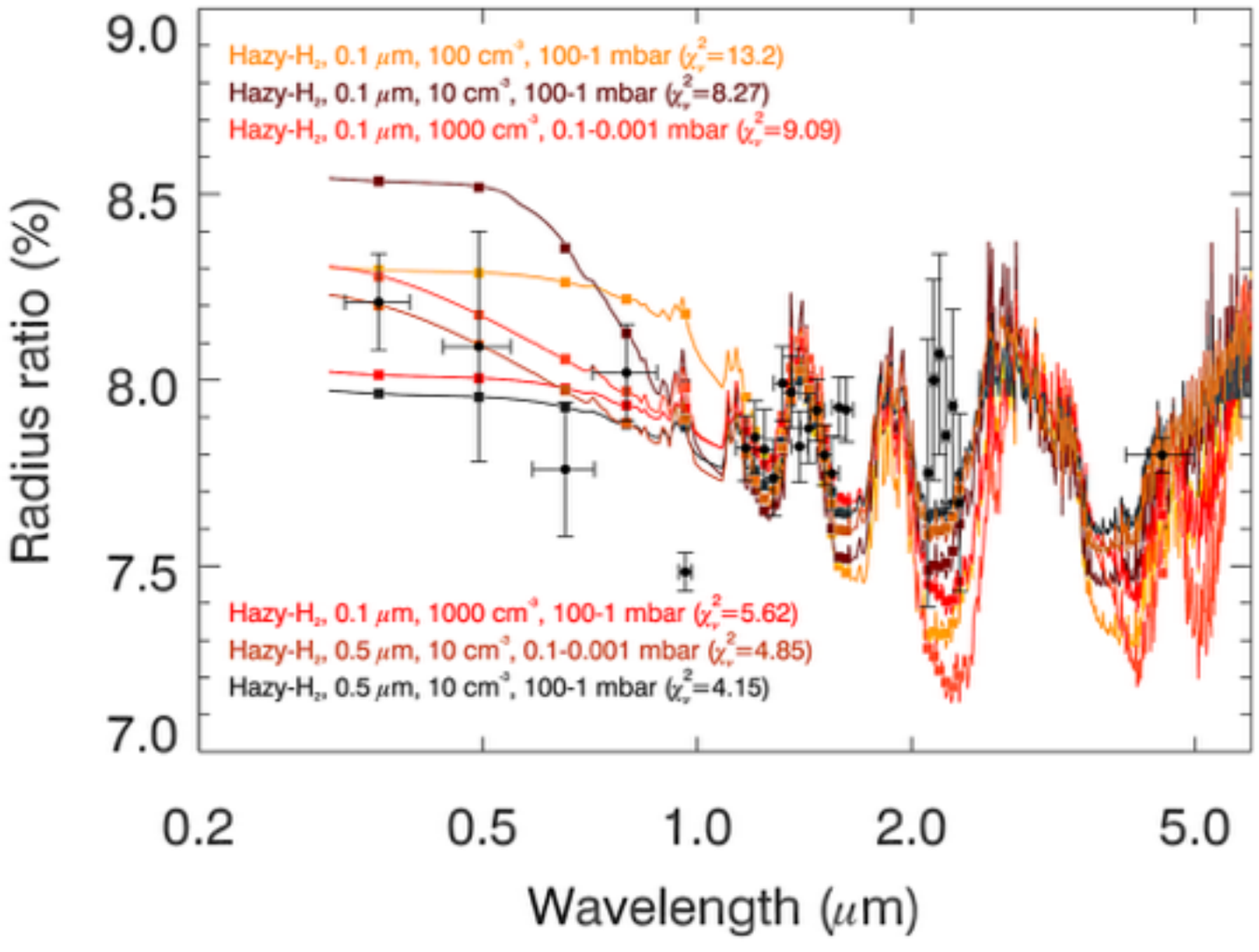
  ➡ A model extension linking the lower and upper parts of the atmospheres/exospheres ➡ V. Bourrier's talk

  ➡ An inverse model to retrieve atmospheric parameters + uncertainties in a Bayesian frame ➡ B. Lavie's PhD thesis & Project 5

Working tools (1)

η (Extrasolar Transit Atmospheres)

Predictive forward model for transmission spectroscopy in the lower atmospheres of exoplanets



HST data of GJ 3470b

Computes opacities
atoms+molecules@high resolution
Rayleigh+Mie scattering

Ehrenreich+2006 • Vidal-Madjar+2010 • Ehrenreich+2012 • Arnold+2014 • Ehrenreich+2014

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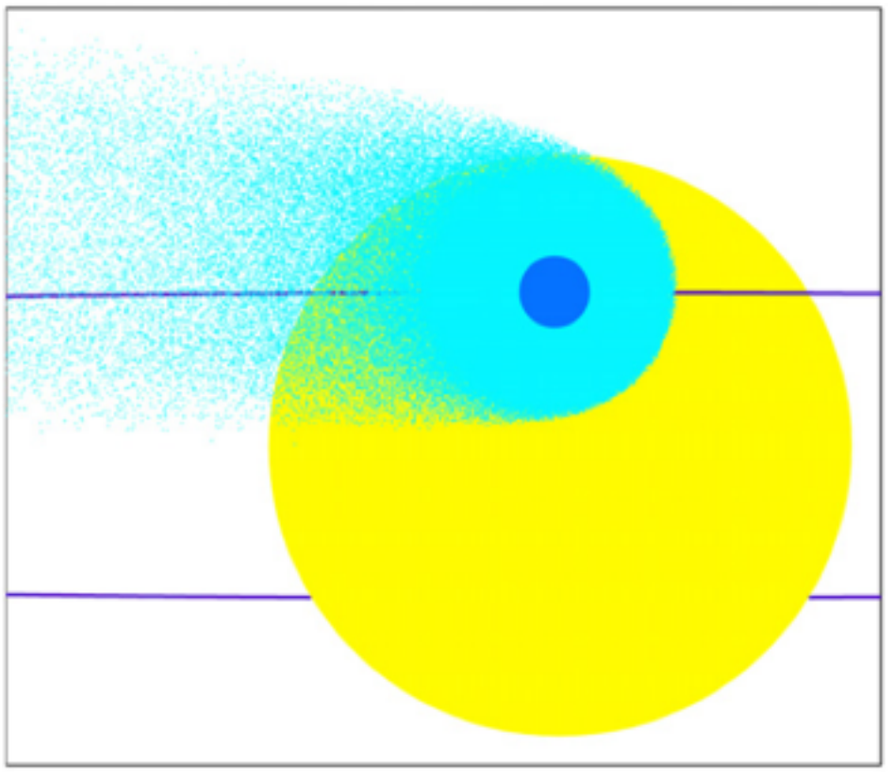
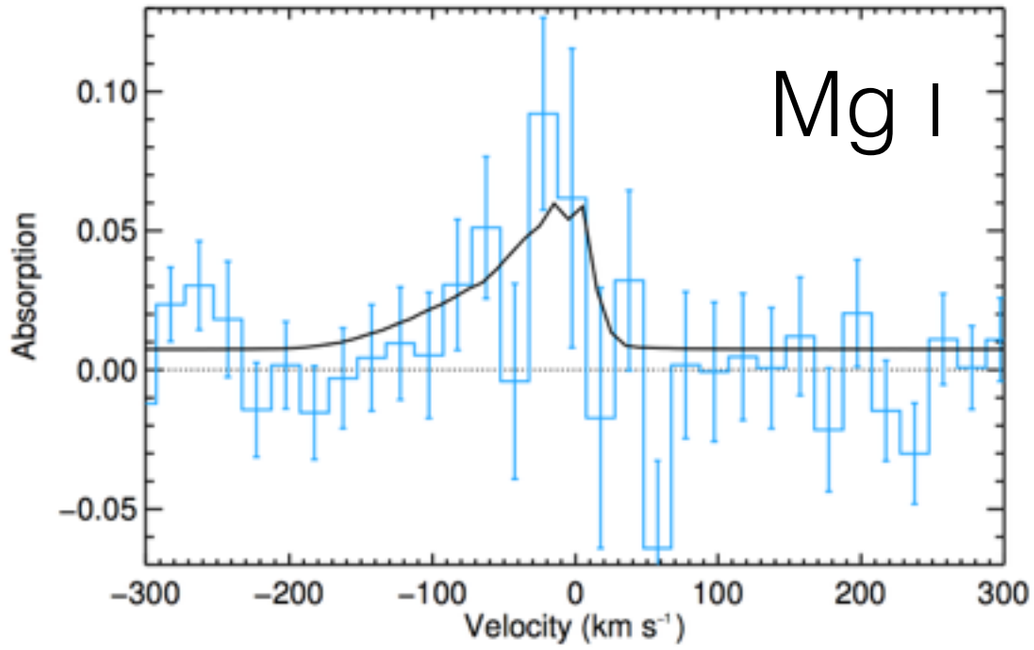
Working tools (2)

EVE *(Evaporating Exoplanets)*

Predictive forward model for transmission spectroscopy in the lower atmospheres of exoplanets





➡ V. Bourrier's talk

Lecavelier+2012 • Ehrenreich+2012 • Bourrier+Lecavelier2013 • Bourrier+2013 • Bourrier+2014

FNSNF Swiss National Science Foundation

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Project 3

Atmospheres of Exoplanets

3.3 – Instrumentation R&D

People involved in **3.3**

- François Wildi
  Project 3.3 coordinator, UGE

- Federica Cersullo
  SNF PhD student (Pepe's SNF grant), UGE

- Uriel Conod
  Project 3.3 PhD student (since 1/9/2014), UGE

- NN
  Project 3.3 postdoc/engineer, UGE (to be hired)

- B. Chazelas, Ch. Lovis, D. Ehrenreich, F. Pepe
  Links and exchange within Project 3 and UGE

3.3 Internal collaborations

- PlanetS Project 3 – Atmospheres of exoplanets
  - Christophe Lovis
  - David Ehrenreich
  - **François Wildi**
  - **Francesco Pepe**

☛ **New instrumentation**

Participation to AO-IR spectroscopy projects

3+1 collaboration will enable exchange of knowledge and extension of tools

- PlanetS Project 1 – Disks and planets
  - **Michael Meyer**

☛ **Disks and planet formation, AO, Imaging**

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3.3 Internal collaborations

- PlanetS Project 3 – Atmospheres of exoplanets
  - Christophe Lovis
  - David Ehrenreich
  - **François Wildi**
  - **Francesco Pepe**

☛ **New instrumentation**

R&D of new components and development of new concepts

3+TP collaboration will enable new R&D and change with industry and technical universities

- PlanetS Platform – Technology Platform
  - **Francesco Pepe**
  - **Nicolas Thomas**

☛ **Technology and knowledge exchange**

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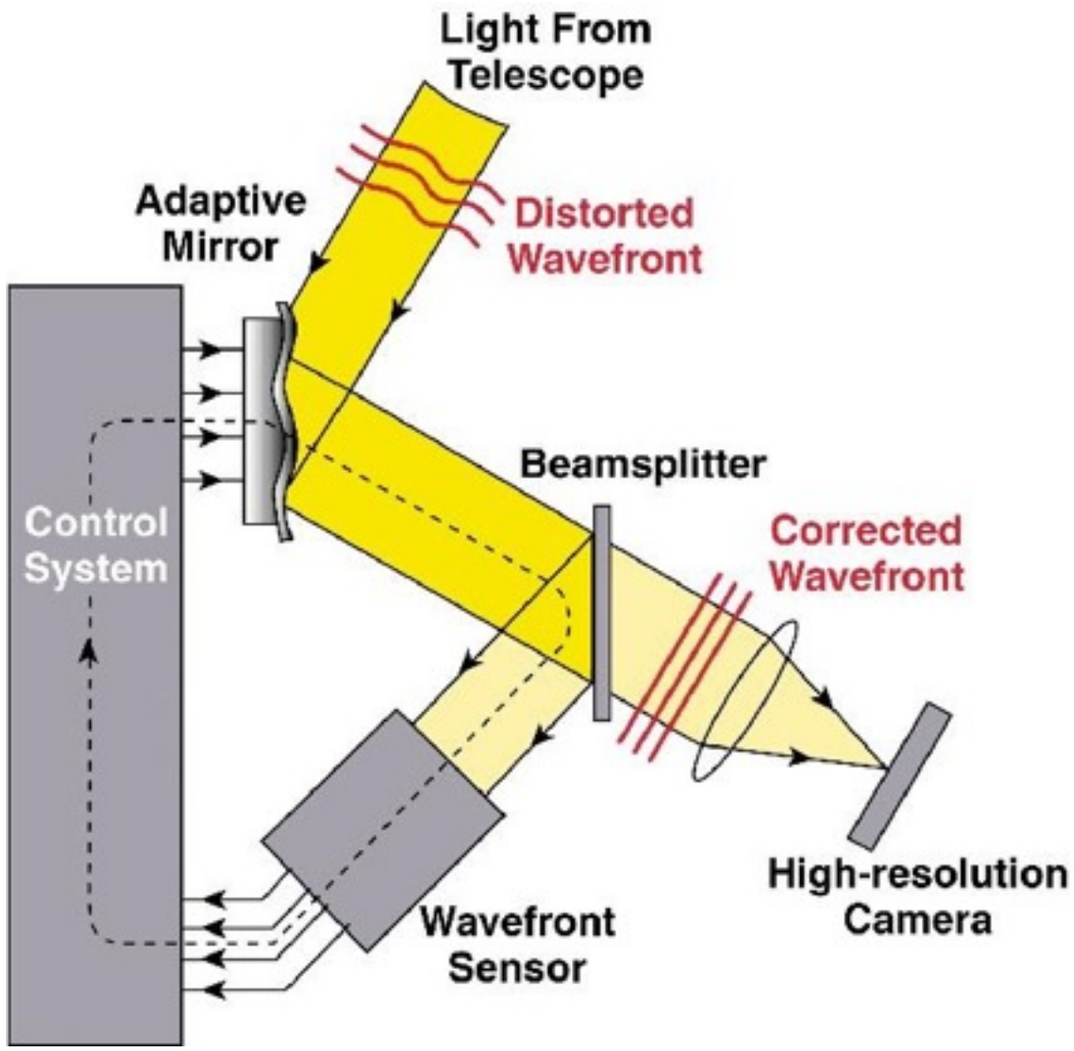
3.3 Key technologies for future high-resolution high-precision spectrographs

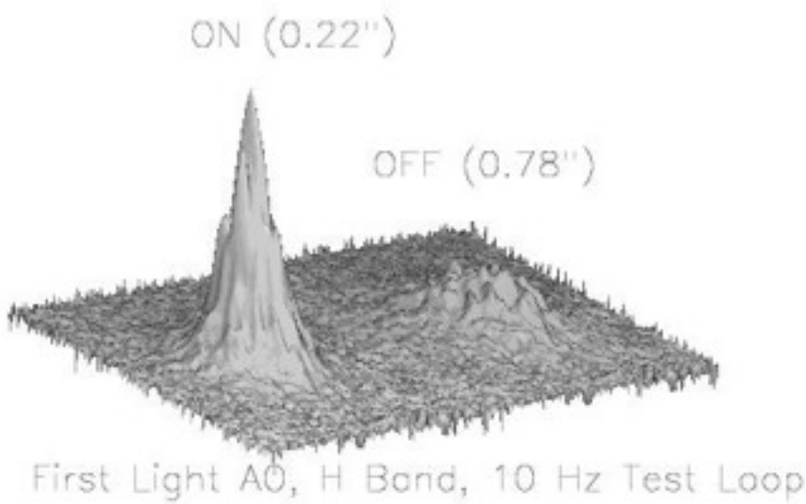
- Improving signal-to-noise ratio in high resolution spectra
- Increase the size of the telescope
- Increase the energy coupled from the (existing) telescope to the instrument
- Stabilize the way the energy is coupled into the spectrograph to avoid second order effects.
- Increasing the size of the telescope increases the etendue of the beam and will increase the size of all optics/opt-mecanics in the spectrograph and the cost (not to mention technical diffculties)

$$\$ \approx E \approx (A\Omega)^3$$

3.3 Example: AO-assisted fibre-fed spectrographs

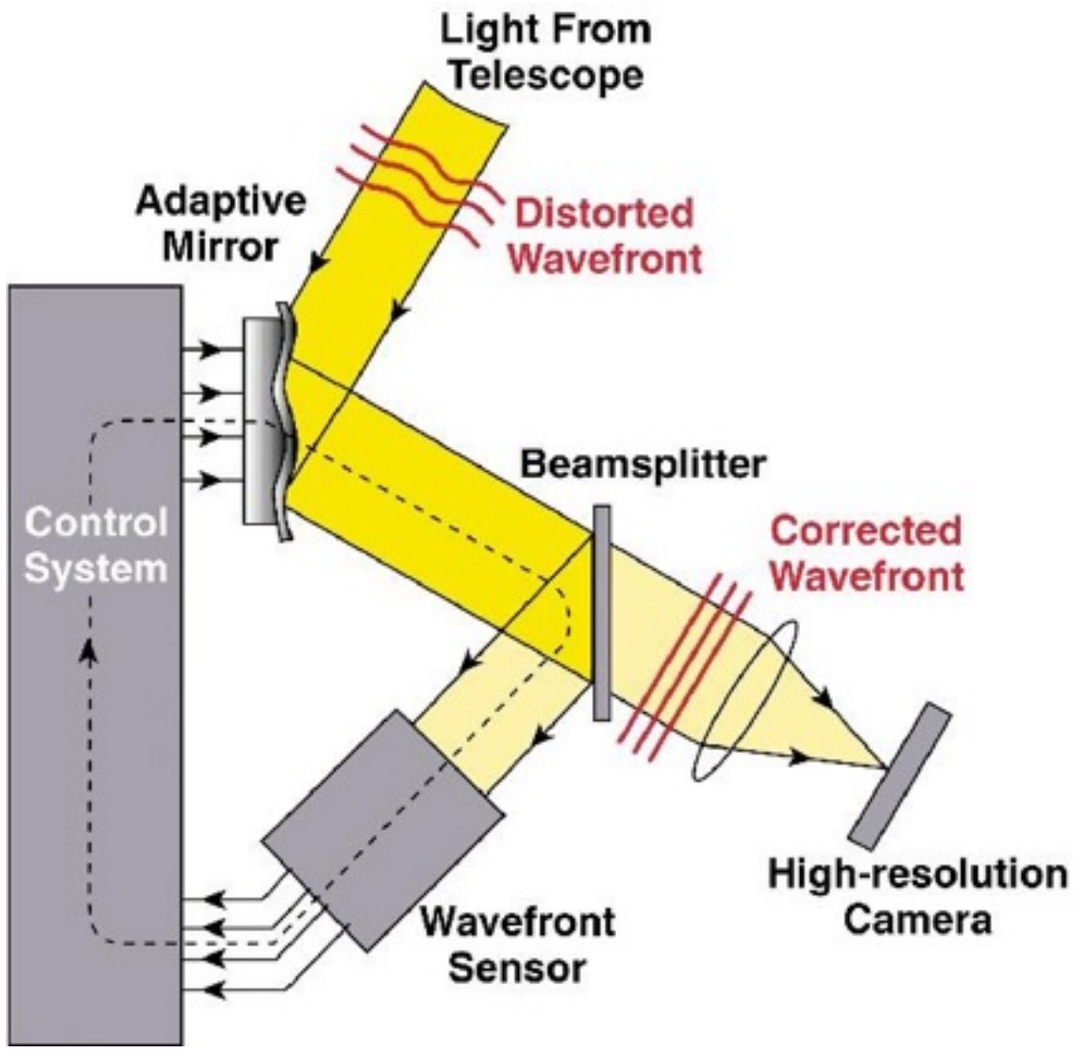
AO principles and effects

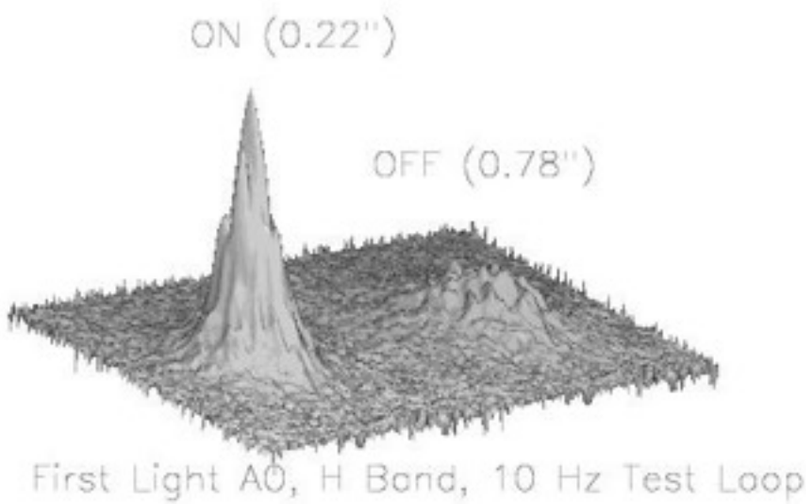




3.3 Example: AO-assisted fibre-fed spectrographs

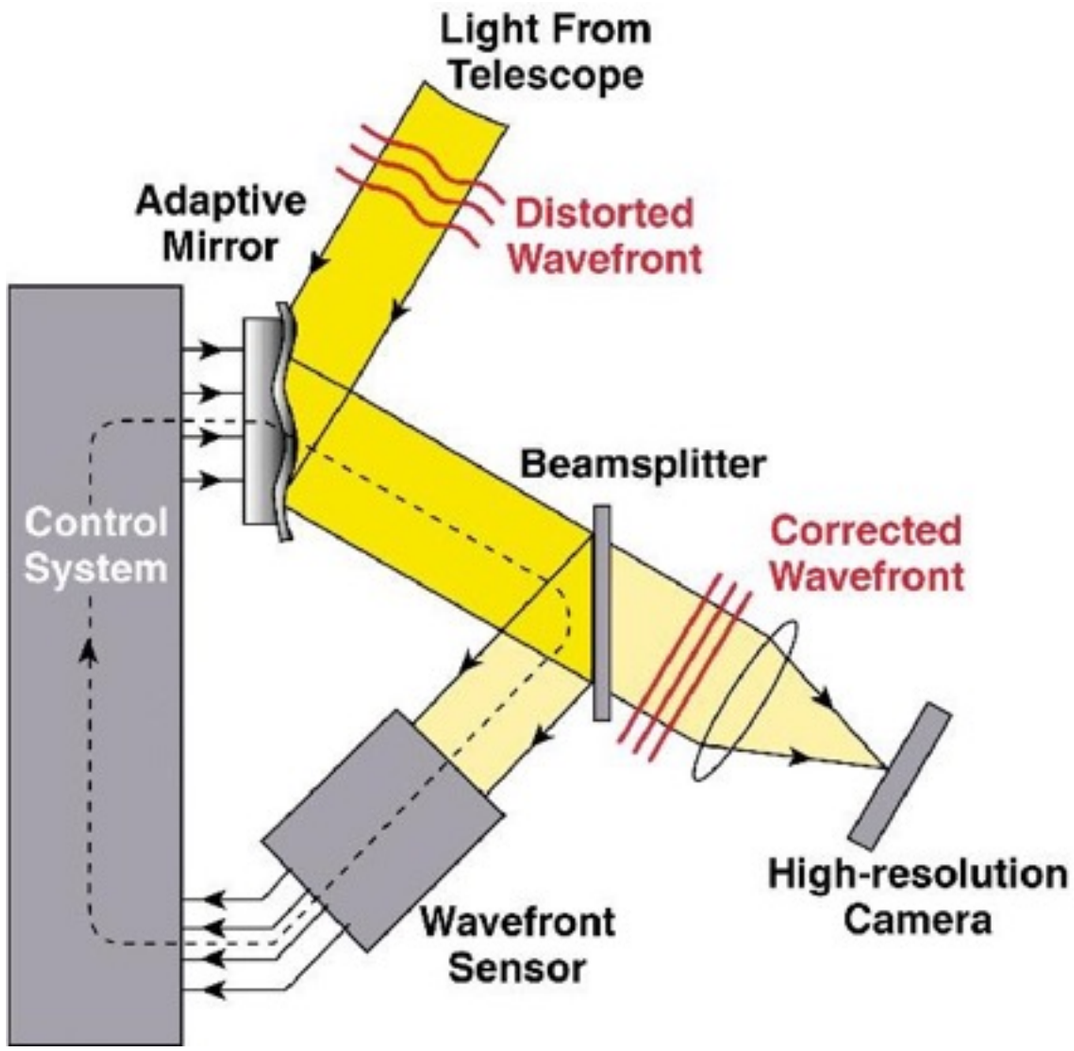
AO principles and effects

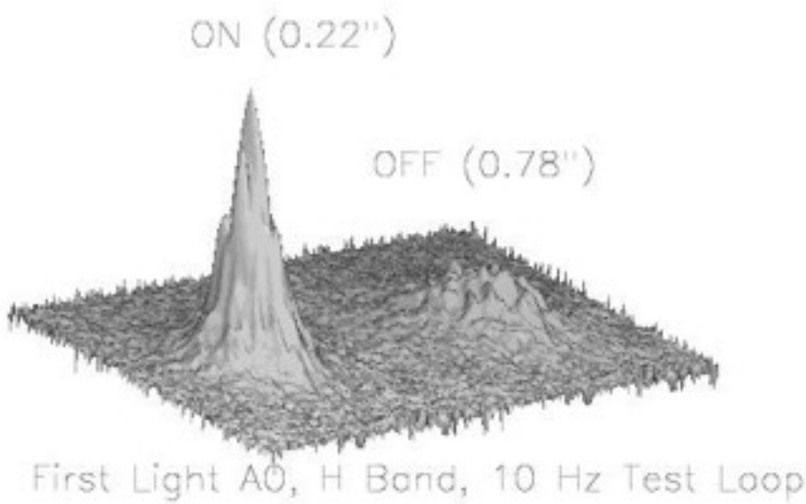




3.3 Example: AO-assisted fibre-fed spectrographs

AO principles and effects





3.3 Example: AO-assisted fibre-fed spectrographs

Solution: Adaptive optics assisted fiber feed

- We will work towards defining and testing an adaptive optics system optimized for fiber-fed spectrographs
- 1st order estimates are VERY promising!