Characterizing Proxima b (and others) with SPHERE+ESPRESSO

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Atmospheric characterization of Proxima b by coupling the SPHERE high-contrast imager to the ESPRESSO spectrograph

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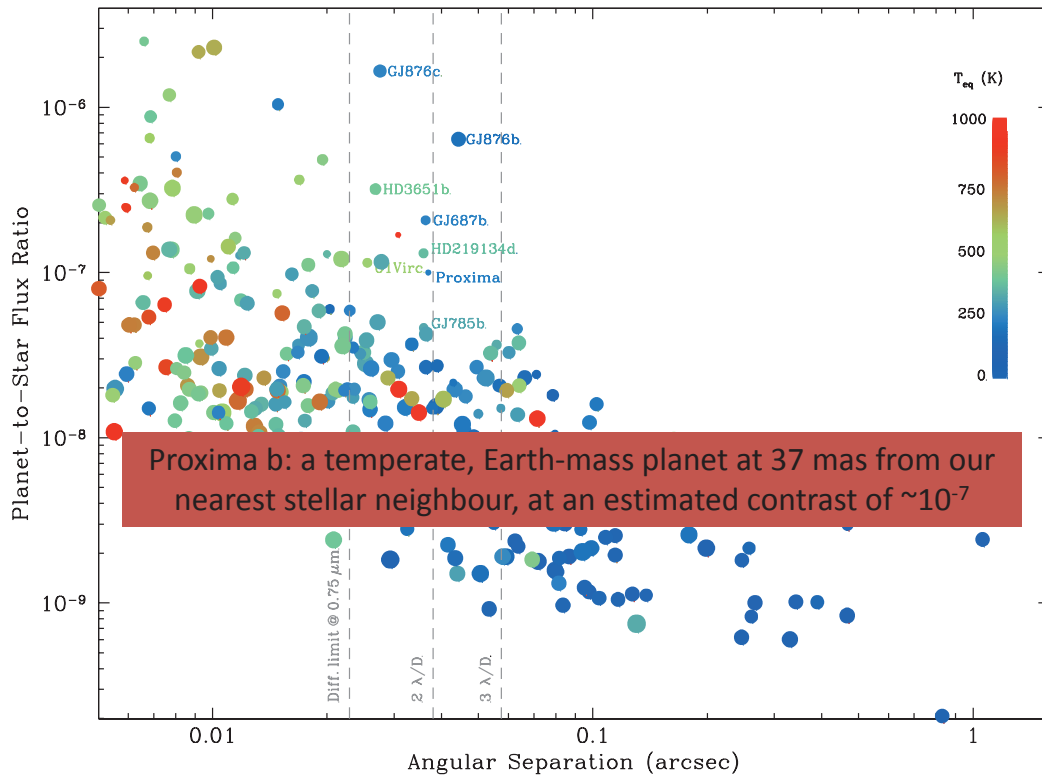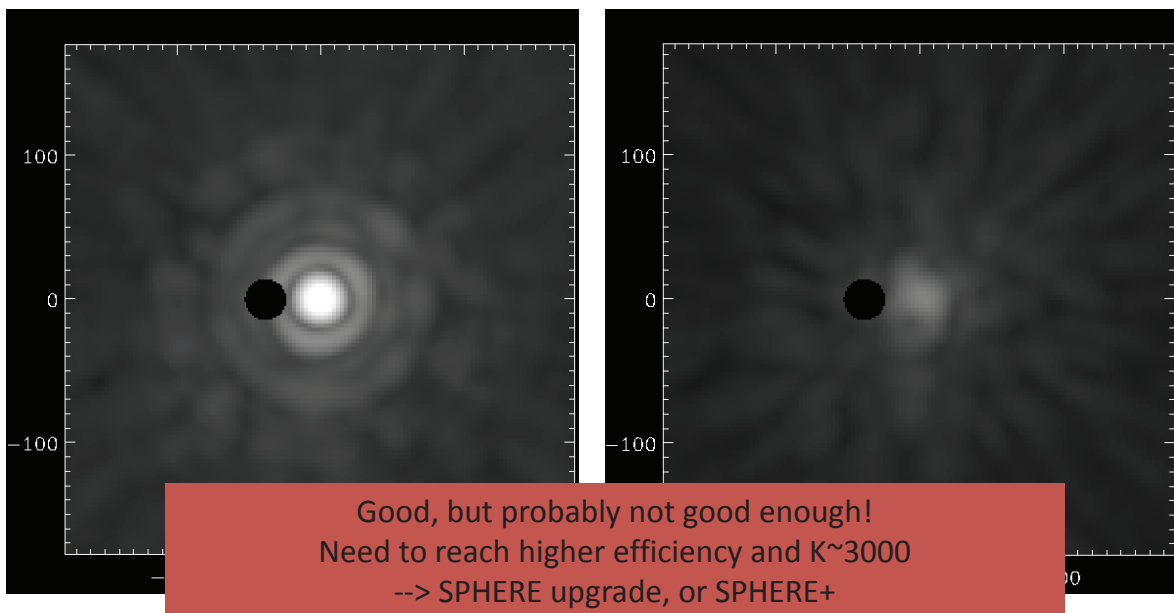
ABSTRACT

Context. The temperate Earth-mass planet Proxima b is the closest exoplanet to Earth and represents what may be our best ever opportunity to search for life outside the Solar System.
Aims. We aim at directly detecting Proxima b and characterizing its atmosphere by spatially resolving the planet and obtaining

Known exoplanets in reflected light

Proxima b: a temperate, Earth-mass planet at 37 mas from our nearest stellar neighbour, at an estimated contrast of ~10^{-7}

Realistic SPHERE simulations in the visible assuming an optimized beamsplitter and coronagraph

Good, but probably not good enough!
Need to reach higher efficiency and K~3000
--> SPHERE upgrade, or SPHERE+

Fiber coupling efficiency for the planet: ~38% / Stellar light rejection factor: ~500, with a fiber of 14 mas (optimum)
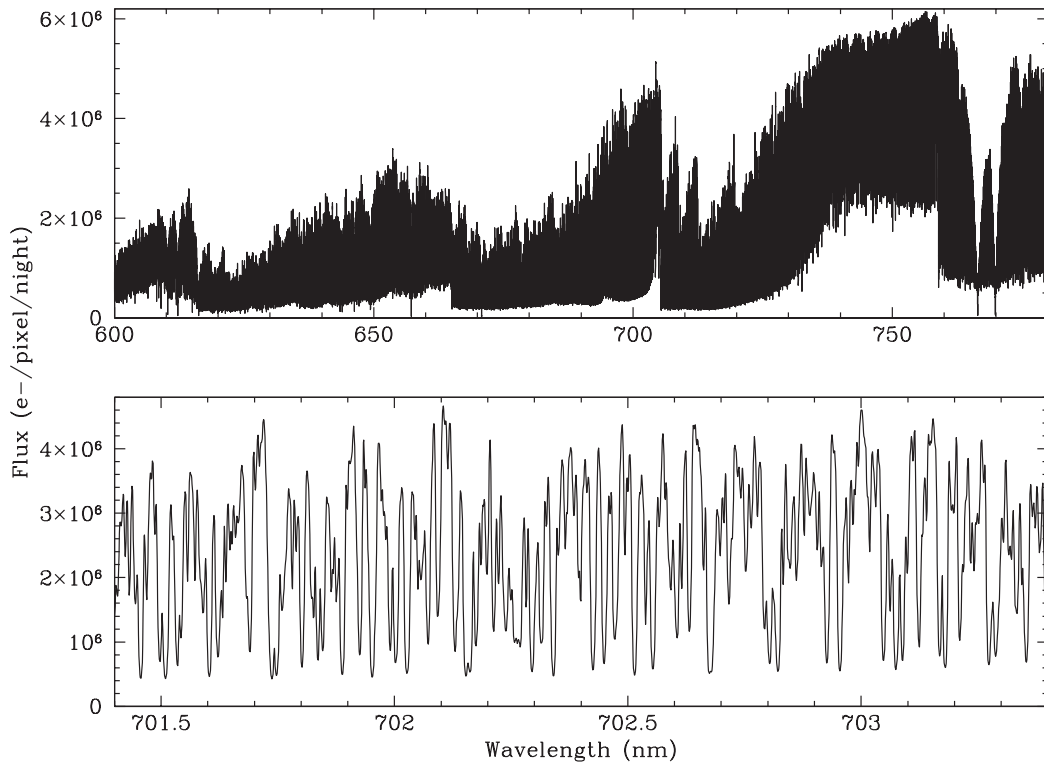
Transmission budget

Item	Throughput
Atmosphere	0.97
Telescope	0.65
SPHERE CPI	0.50
Coronagraph	0.70
Fiber Coupling	0.60
Fiber Link	0.80
Spectrograph	0.40
Total	0.042

Transmission II
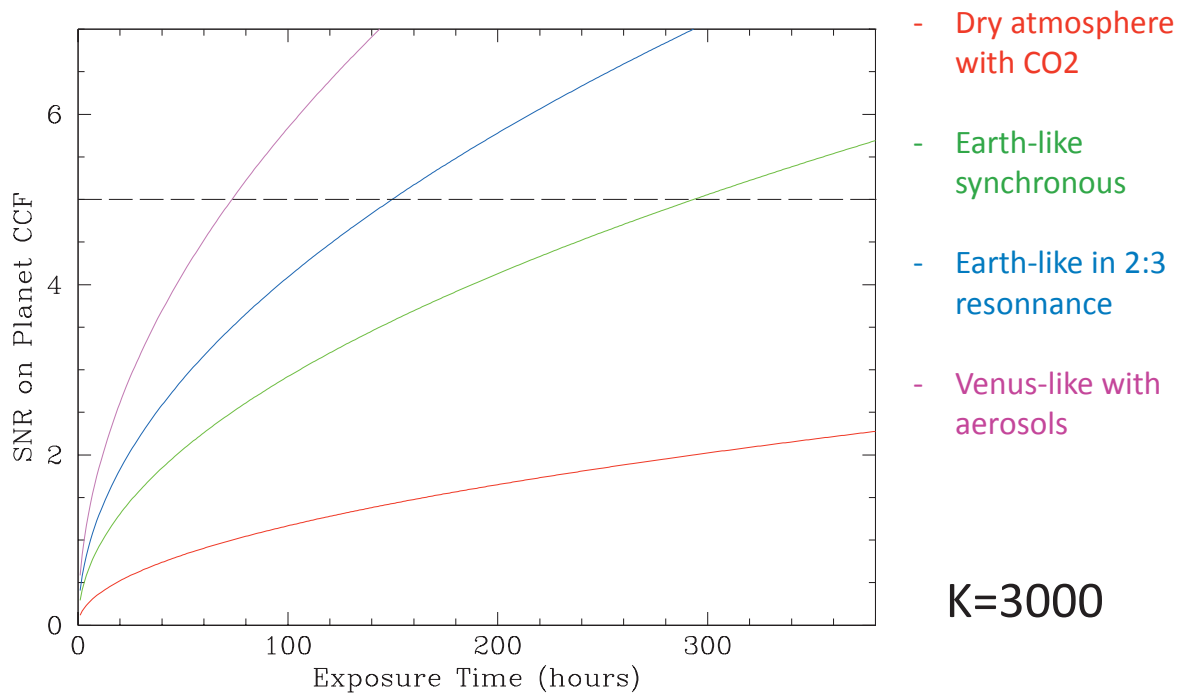
Assuming a star – planet contrast of 10^{-7}, the the average flux from Proxima b is 0.3e-/pix per 8-hour operation

Seems over-the-top, but today, with HARPS we already observe CCF's where the Moon contamination at sub e- level is clrearly seen with R.O. noise of 12 e-

Detecting the planet reflected spectrum with ESPRESSO (R=220,000) and cross-correlation techniques


Detecting the planet reflected spectrum with ESPRESSO (R=220,000) and cross-correlation techniques

- Dry atmosphere with CO2
- Earth-like synchronous
- Earth-like in 2:3 resonnance
- Venus-like with aerosols
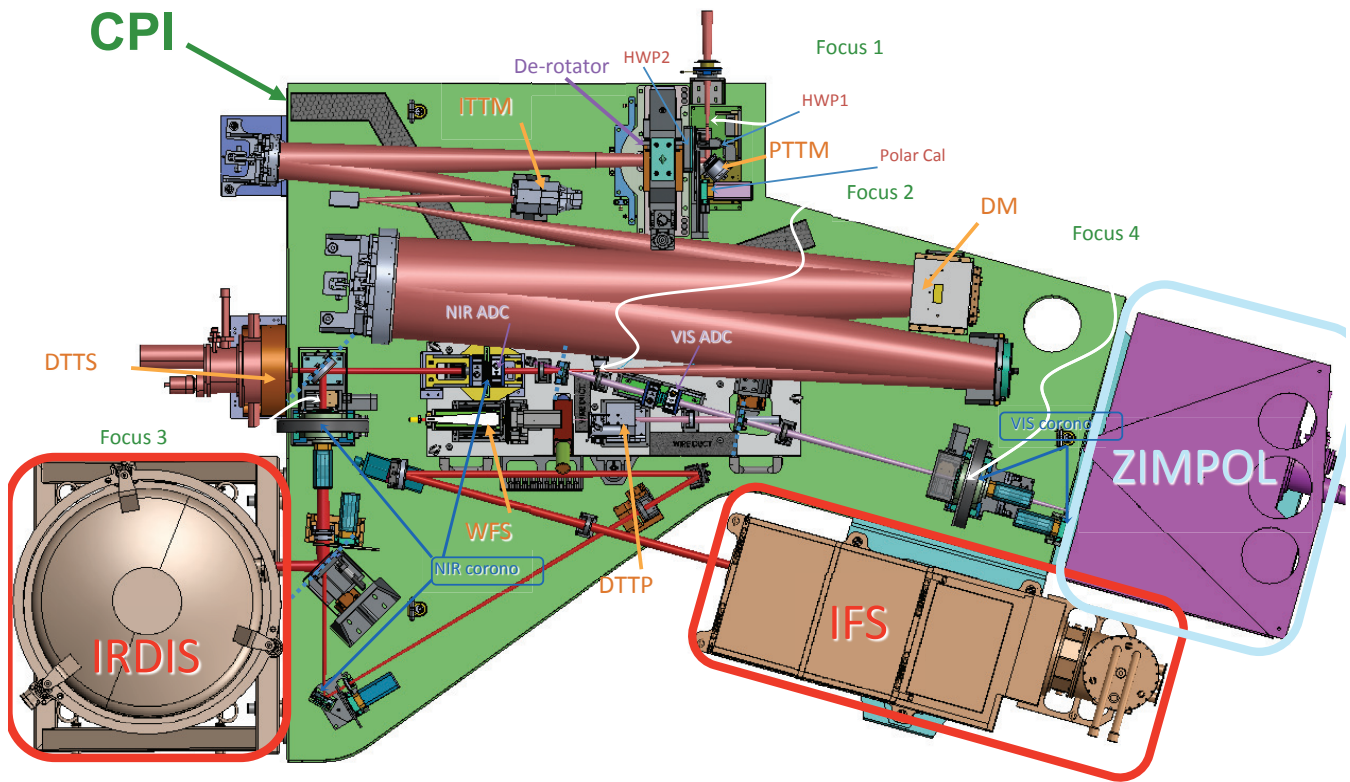
K=3000

Observing Proxima b

- Giving the angular separation, orbital period, position on the sky and observation time required, Proxima b is observable efficiently in about 34 nights per year.
- Therefore it is observable in one year
- Observing will fully determine the orbit
- Will give insight in fundamental properties, but albedo, radius, phase function are entangled

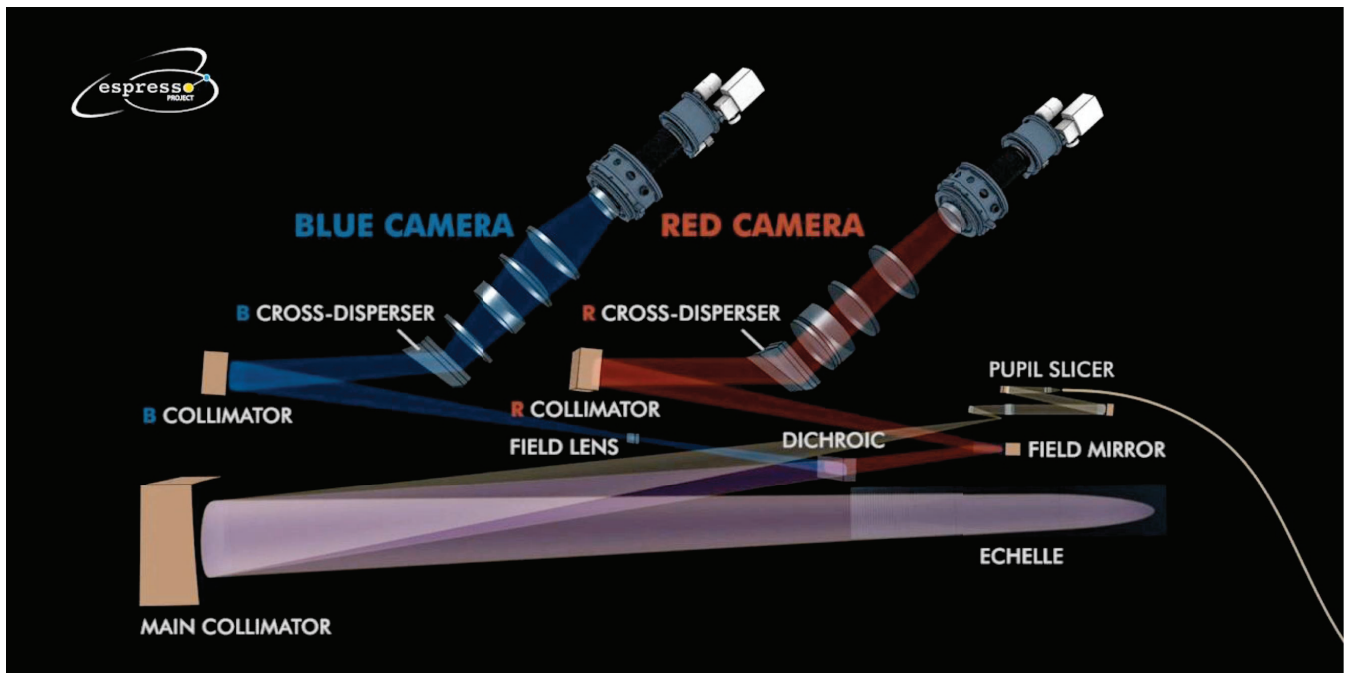Search for O_2 absorption in the albedo spectrum
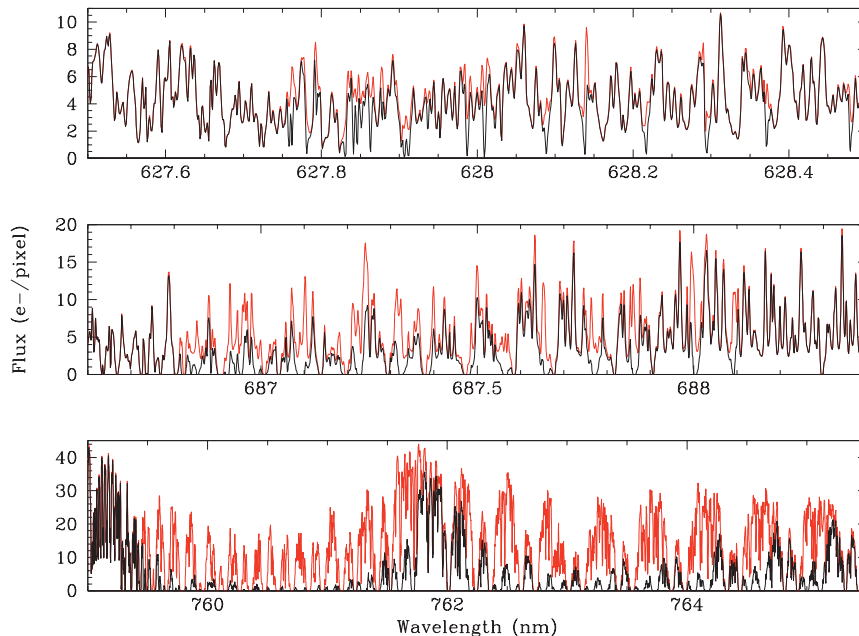
Given SPHERE+ and an Earth-like atmosphere, a 3.6-sigma detection is possible in about 60 nights with the VLT. K=5000

CPI

Focus 1

De-rotator   HWP2

ITTM

HWP1

PTTM

Polar Cal

Focus 2

DM

Focus 4

NIR ADC

VIS ADC

DTTS

Focus 3

VIS corono

ZIMPOL

WFS

NIR corono

DTTP

IFS

IRDIS

ESPRESSO

220'000 resolution @0.5 arcsec FOV

BLUE CAMERA   RED CAMERA

B CROSS-DISPERSER   R CROSS-DISPERSER

PUPIL SLICER

B COLLIMATOR   R COLLIMATOR

FIELD LENS   DICHROIC   FIELD MIRROR

ECHELLE

MAIN COLLIMATOR

Requirement	Standard 1-UT	4-UT	Very-High Res 1-UT
Wavelength Range	380-686 nm	380-686 nm	380-686 nm
Resolving Power	120.000	30.000	220.000
Aperture on Sky	1.0 arcsec	4x1.0 arcsec	0.5 arcsec
Sampling (average)	3.3 pixels	4.0 pixels (binned x2)	2.1 pixels
Spatial Sampling	6.9 pixels	4.0 pixels (binned x2)	3.5 pixels
Simultaneous reference	Yes (no sky)	Yes (no sky)	Yes (no sky)
Sky subtraction	Yes (no sim. ref.)	Yes (no sim. ref.)	Yes (no sim. ref.)
Total Efficiency	>10% at peak	>10% at peak	> 7% at peak
Instrumental RV precision (requirement)	<10 cm/sec	<=5 m/sec	<=5 m/sec