The Balloon-borne Exoplanet Spectroscopy Experiment: BETSE

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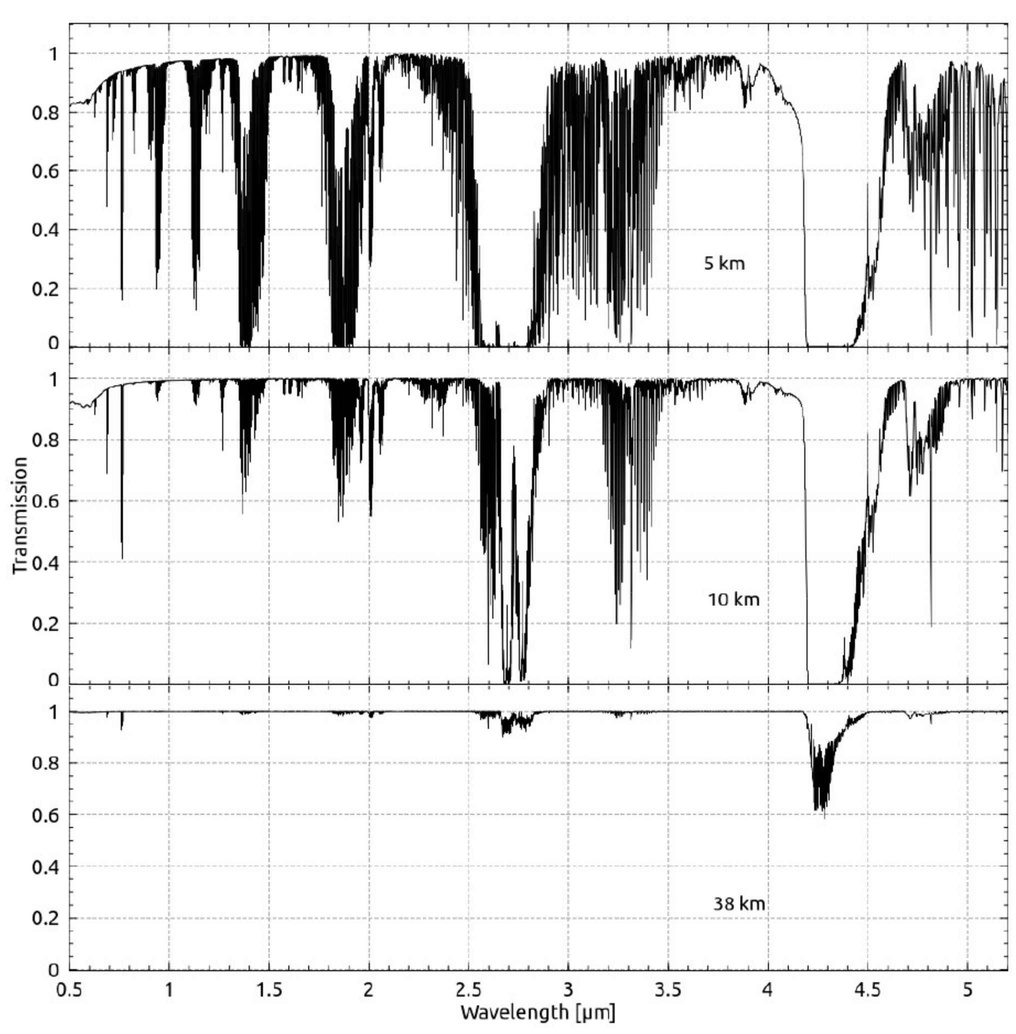
Almost 2,000 exoplanets have been discovered during the past 20 years. Apart from mass, density and orbital period, little is known about these worlds. Spectroscopy in the near-IR and mid-IR holds the key to answering important questions about the existence and composition of their atmospheres. Transiting spectroscopy has emerged as an effective technique to detect and model exoplanet atmospheric compositions. Observations are notoriously challenging from the ground, because observational conditions are not stable and are limited to narrow atmospheric windows, and from space, currently using facilities not optimized for this type of observations.

Balloon-Borne telescopes operating in the upper stratosphere have access to observational conditions which are similar to the ones available to space instrumentation. Observations through the stable residual (0.5%) Earth atmosphere are not limited to a few windows, and allow multi-transit observations of tens of exoplanets, thanks to flight time ranging from 30days (LDB) to ~100days (ULDB). This class of experiments represents a unique opportunity to improve our (limited) knowledge of extrasolar systems when no dedicated exoplanet characterization missions are scheduled in the next ~10 years, and additional targets will soon be available from TESS and other space/ground surveys.

BlastPol ready for launch in Antarctica. An exoplanet balloon mission will look similar.

The Balloon Environment

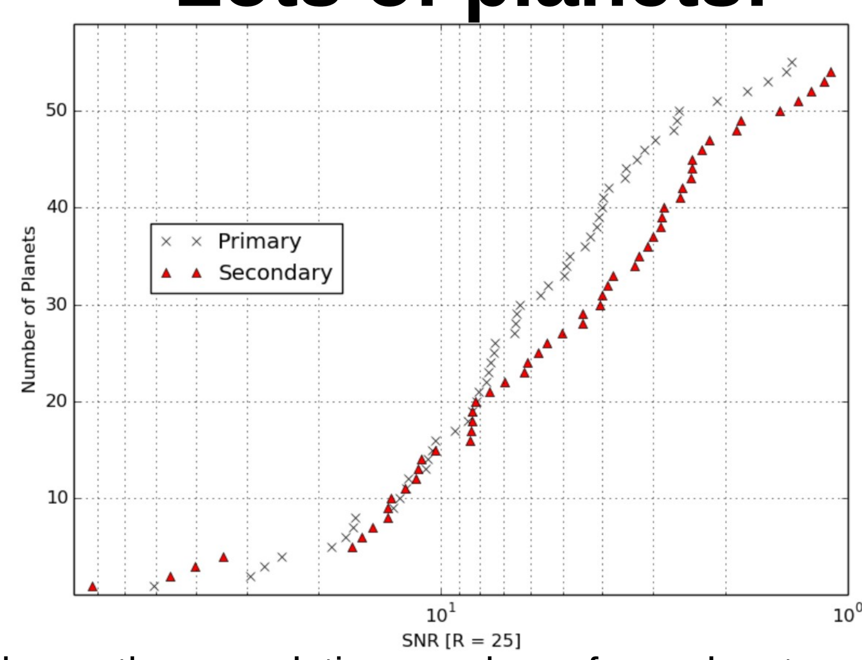


Earths atmospheric transmission is estimated (left plot) for a site located in the Atacama Desert (5 km altitude), for the Sofia aircraft (10 km) and for the environment available from a stratospheric balloon-borne experiment (38 km). **The 1 to 5μm MWIR band is only available at stratospheric altitudes accessible by balloon instrumentation,** or from space.

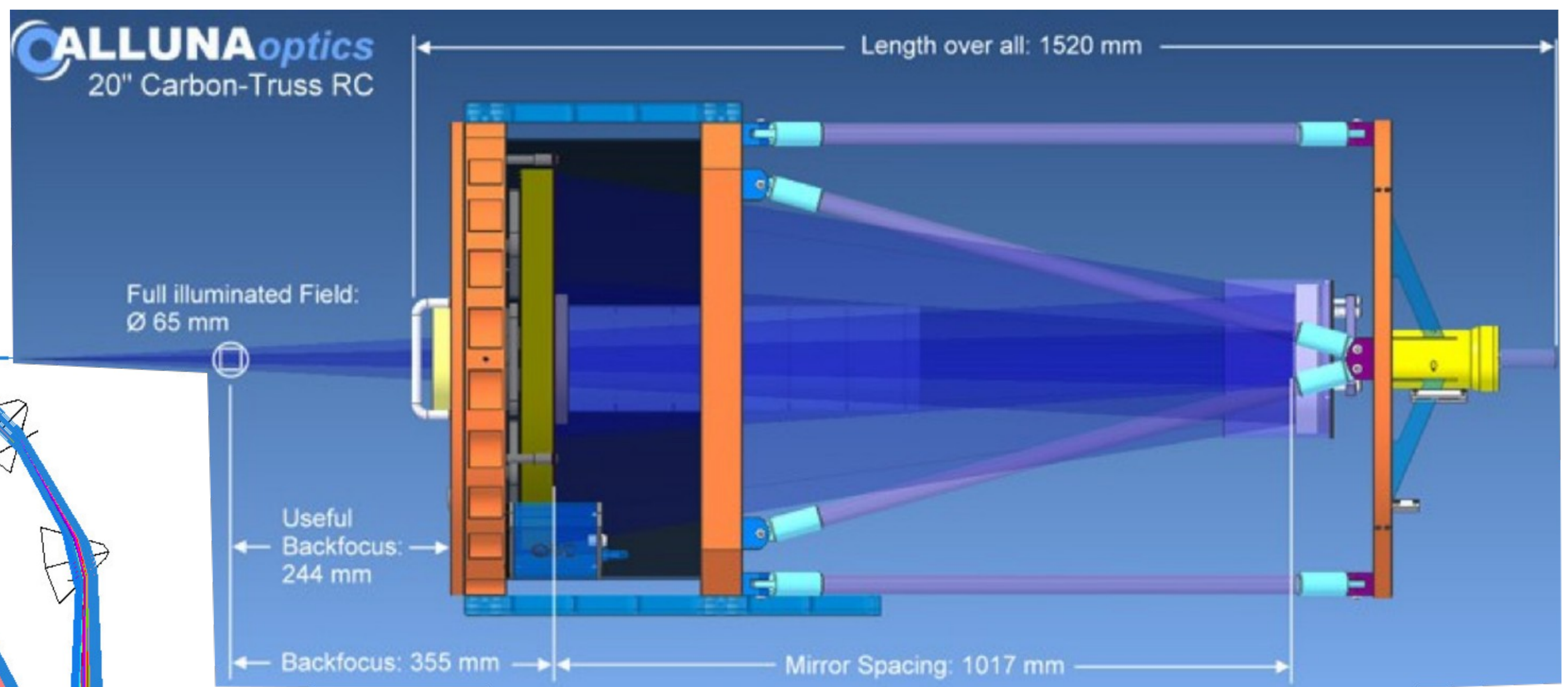
With a 4mbar average ambient pressure, the Earth atmosphere emission is greatly reduced compared to ground observations. **The stratosphere is very stable**, which means that any residual background is constant and can be efficiently removed in data analysis.

State of the art attitude control systems have reached sub-arcsecond stability, allowing for integration times of hours required to capture the transit light curve and reach photon-noise limited performances.

Lots of planets!



Plot shows the cumulative number of exoplanets with spectra contained above the SNR in the x-axis (R = 25) in a 100day long ULDB flight from New Zealand. A total of 48 planets are observable in a single flight with SNR > 3. A 30day long LDB flight from Antarctica can detect 24 planets with SNR > 3. Multiple flights with the same payload are possible from different geographical locations which would result in a larger number of observable planets. Estimates based on current catalogues of know exoplanets. List will be larger in the near future.



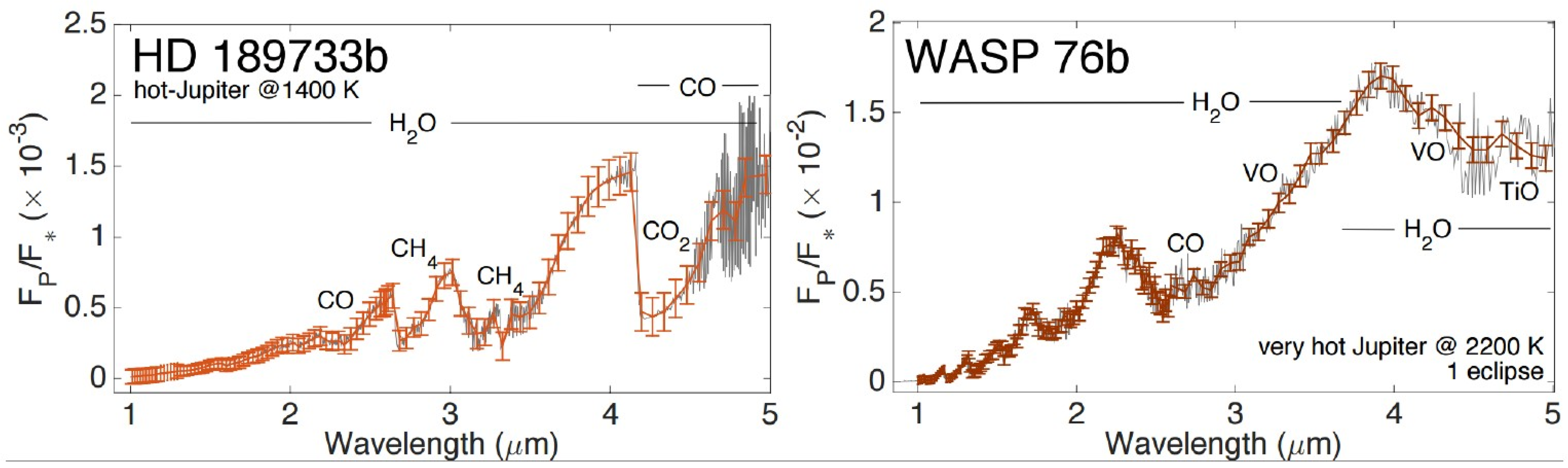
Instrument Design

BETSE technology is largely off-the-shelf. The instrument is based on a Cassegrain 50cm telescope and prism spectrometer (R~100) using Teledyne H1RG detectors. This is a low-cost, fast track experiment using the NASA Goddard WASP pointed platform.

BETSE can observe both during the night and during the day to increase observing time.

Pointing stability of 100masc is achieved by the fine WASP pointing system and the hexapod-controlled focal plane array (NASA development at ASU).

Performance



ExoSim simulations of hot Jupiter HD 189733b (left) detection with BETSE. The host star has a K-band magnitude of 8.5. A single secondary eclipse is assumed. The right panel shows simulations of hot Jupiter WASP 76 b observed during a single occultation. The host star has a K-band magnitude of 5.9. For this class of planets BETSE achieve a detection at a SNR > 7 in a single eclipse observed in day-time (assumed spectrum binned to a constant λ/Δλ = 100 grid).