EPSC Abstracts
Vol. 10, EPSC2015-861, 2015
European Planetary Science Congress 2015

The balloon-borne exoplanet spectroscopy experiment (BETSE)

E. Pascale (1), N. Butler (2), M. Line (3), P. Mauskopf (2), C. B. Netterfield (4), J. Patience (2), P. Scowen(2), B. Swinyard (5), I. Waldmann (5)
(1) Cardiff University, School of Physics and Astronomy, Cardiff, United Kingdom (enzo.pascale@astro.cf.ac.uk), (2) School of Earth and Space Exploration and Department of Physics, Arizona State University, Tempe, AZ 85287, (3) California Institute of Technology, Pasadena, CA 91125, (4) Department of Physics, University of Toronto, 60 St. George Street, Toronto, ON, Canada M5S 1A7, (5) Department of Physics & Astronomy, University College London, Gower Street, WC1E 6BT, UK

Abstract

The balloon-borne exoplanet spectroscopy experiment (BETSE) is a proposed balloon spectrometer operating in the 1-5 μm band with spectral resolution of R = 100. Using a 50 cm diameter telescope, BETSE is desgnied to have sufficient sensitivity and control of systematics to measure the atmospheric spectra of representative sample of known hot Jupiters, few warm Neptunes, and some of the exoplanets TESS will soon begin to discover. This would for the first time allow us to place strict observational constraints on the nature of exo-atmospheres and on models of planetary formation. In a LDB flight from Antarctica, BETSE would be able to characterize the atmospheres of 20 planets. If a ULDB flight is available, the combination of a longer flight and night time operations would enable BETSE to ground-breakingly characterize the atmospheres of more than 40 planets. Prior to an LDB or ULDB flight, BETSE would be tested in a 24 hr flight from Fort Sumner, NM, in order to test all subsystems, also observing more than 4 planets with SNR greater than 5.

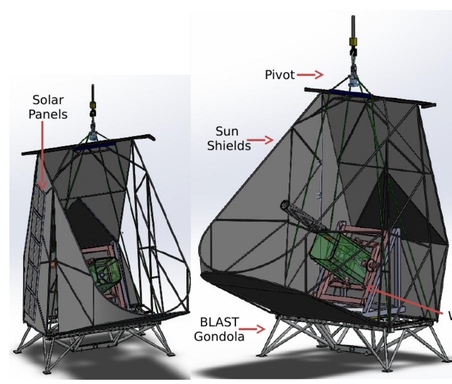

Figure 1: A CAD rendering of the BETSE instrument concept. The main telescope and spectrometerare mounted on the WASP (in red) platform which is held by an A-frame on the BLAST gondola outer frame (Pascale et al. 2008). The gondola outer-frame is connected to the flight chain by a pivot and suspension cables. Sun shields are required for day time operations. The telescope will also be provided with a baffle to further reduce stray light. Solar panels will be mounted on the right, left and back side of the gondola. The CAD shows only one side with solar panels for clarity.

1. Introduction

The Balloon-borne Exoplanet Transit Spectrocopy Experiment (BETSE) is a proposed balloon mission capable to conduct a spectroscopic survey of a statistically representative sample of the atmospheres of transiting extrasolar planets in the 1 to 5μm region of the elecromagnetic spectrum.

More than 1,000 extrasolar systems have been discovered, hosting nearly 2,000 exoplanets with a huge range of masses, sizes and orbits: from rocky Earth-like planets to large giant planets. However, we still know very little about the true nature of these alien worlds beyond their basic physical parameters (orbit, mass, radius) and, for a few, some sparse multiband photometry or near-infrared spectroscopy obtained using the *Hubble Space Telescope (HST)*, *Spitzer* and other ground based instrumentation. What we know is very limited. It appears that there is no clear relation between the nature of the host star and the observed orbital, mass and radius parameters of the orbiting exoplanets. What is the chemical composition of the atmospheres of discovered exoplanets? How is the chemical composition of exoplanet atmospheres linked to the formation environment? What is the role

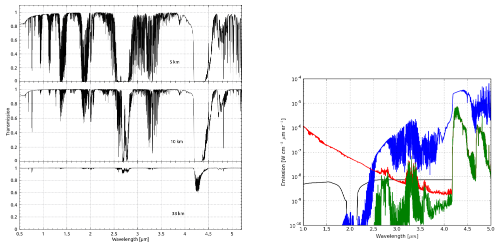

Figure 2: Left panel. Earth's atmospheric transmission for a site located on the Atacama Desert (5 km altitude), at aircraft altitude(10 km) and for the environment available from a stratospheric balloon-borne experiment (38 km). The 1 to 5μm band in its entirety cannot be accessed by ground-based or air-borne instrumentation. Only at balloon altitudes the Earth stratosphere is sufficiently transparent to allow spectroscopy over the whole band. Right panel. The Earth atmosphere emission is simulated at balloon altitude (night flight in green and day flight in red) and for a ground telescope located at Atacama (blue line). Skyglow is also represented by the black line (Leinert 1998).

of the parent star in driving the physics and chemistry of the planet's birth and evolution? BETSE (see Figure 1) will be the first instrument with sufficient sensitivity and control of instrument systematics to address these questions in a systematic way by conducting a volume-limited survey of hot Jupiters and warm Neptunes orbiting nearby stars.

2 Experimental Approach

The near to mid-IR part of the spectrum contains several key molecular signatures. Tinetti et al. (2013) list relevant molecules, and discuss the necessity to measure not one, but several molecular features and their continua to break the degeneracies which would otherwise jeopardise the retrieval process.

Large portions of the near and mid-IR spectral band that is not available to ground-based or air-borne instrumentation (Figure 2). Even at aircraft altitude, several key bands are still saturated. Bands which can be considered sufficiently transparent to be accessible by ground instrumentation are actually affected by atmospheric variations which can easily blind the exoplanet signal or increase the experimental uncertainties severely compromising the detection. As shown in the left panel of Figure 2, the greatly reduced air pressure (about 4 mbar) at balloon altitudes, together

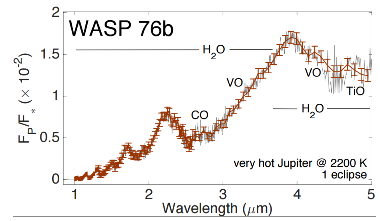

Figure 3: EChOSim simulations of hot Jupiter HD 189733b (left) detection with BETSE. The host star has a k-band magnitude of 8.5. A single secondary eclipse is assumed. The right panel shows simulations of hot Jupiter WASP 76 b observed during a single occultation. The hst star has a k-band magnitude 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 $\lambda/\Delta\lambda = 100$ grid).

with the stability of the stratosphere, allows exoplanet transit spectroscopy over the whole BETSE band, and enables observations even in daytime. This is important, as a survey experiment will have to be operated in day-time for a LDB campaign, and during both day and night in a ULDB campaign.

A $\sim$ 0.5 m-class telescope, fit with a moderate-resolution spectrometer from 1 to $\sim 5\mu$m is adequate to undertake the first spectroscopic survey of the atmospheres of a significant sample of transiting hot Jupiter and warm Neptune exoplanets. This would result in ground breaking science, particularly since there are currently no alternative facilities to perform spectroscopy of exoplanets over the whole required band. BETSE will be equipped with a moderate resolution spectrometer, and a photometric channel in the visible for stellar monitoring and for the fine pointing system. In Figure 3 we present simulations obtained with EChOSim (Pascale et al., 2014, Waldmann et al., 2014), the end-to-end simulator originally developed for the EChO space mission (Tinetti et al.m 2012) and adapted to include the balloon-specific systematics.

While these simulations also show how effective BETSE is in measuring the spectra of hot Jupiters such as WASP-76b with suficiently high SNR in a single transit, the ability to observe multiple transits and eclipses of the same exoplanets in LDB and ULDB flights allows to stack several observations to increase the SNR on a much larger number of systems. Comparing different transits/occultations of the same exoplanet also allows detailed quantification of experimental uncertainties and systematics.