Science Week 2014 Dec 1 – 4

RESEARCH AREA(S): F

1. European Southern Observatory, Germany
2. National Astronomical Observatories, Chinese Academy of Sciences, China
3. Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Italy
4. Istituto Nazionale di Astrofisica, Osservatorio Astrofisico di Catania, Italy
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Characterising the Earth's atmosphere in the ultraviolet band

- towards future exo-Earth observations

Background

Astronomers have now catalogued nearly two thousands confirmed exoplanets including some rocky bodies with a mass comparable with that of Earth. One major goal of the next generation of large telescopes such as the E-ELT is to characterise the atmospheres of rocky exoplanets, leading to the identification of potential Earth-like objects.

Observing our Earth as an exo-Earth can serve as an invaluable benchmark and so provide crucial information for future exo-Earth characterisations. For example, Pallé et al. (2009) and Yan et al. (2014) observed lunar eclipses to obtain the transmission spectrum of the Earth's atmosphere. However, both the atmosphere and surface of our Earth have been evolving since their formation over 4.5 billion years ago. It is of great interest to study directly how an exo-Earth may appear at different stages of this history. As the Earth has been geologically active with periods of significant global volcanic activity since its formation, observing volcanoes will provide us with valuable information for the future characterisation of exo-Earths similar to the ancient Earth.

Observations

We organised an expedition to the Mt. Etna volcano in Italy to perform spectroscopic observations of the volcanic outgassing. We were very lucky to witness an eruption during our stay there (see Fig. 1). There was a a continuous gaseous plume originated from the volcanic outgassing. We observed the plume with a UV spectroscopy to obtain the transmission spectrum of the volcanic gas (Fig. 2).

Figure 1. A photograph of the Mt. Etna during eruption on June 15, 2015.

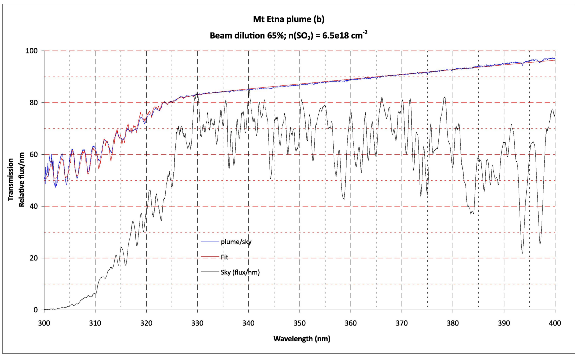

Figure 2. The observed transmission spectrum of the gas plume (blue line). The red line is a spectral model containing the SO_2 absorption band below 330 nm. The black line is the spectrum of the clear sky which is used as the reference to obtain this transmission spectrum.

Observation details:
A newly purchased fibre-fed UV spectrograph (Ocean Optics USB4000, 290 - 510 nm) was used for this observation. The fibre was pointed directly towards the gas plume to get the spectrum. We also took a spectrum of the clear sky as reference (the black line in Fig. 2). Then the transmission spectrum shown in Fig. 2 was determined by using the ratio of the plume spectrum to the clear sky spectrum.

Spectral model:
The transmission spectral model contains the volcanic gases (SO_2, NO_2, BrO) and also a power-law fit for the continuum. According to the spectrum fit, the SO_2 is the dominating feature in the UV wavelength and the NO_2 or BrO is barely observed. The column density of SO_2 along the observing line of sight is measured to be 6.5×10^{18} cm^{-2} after taking account of beam dilution.

Emission spectrum of lava

During the eruption of the volcano, the lava was ejected as can be seen in the photo (Fig. 3). We observed the emission spectrum of the hot lava using a small telescope pointed at the vent.

Figure 3. A photograph of the hot lava taken during the night of June 14, 2015.

The observation was performed with a near-infrared spectrograph (800 - 2500nm). Both spectrometers were calibrated for wavelength and flux per unit wavelength (see Fosbury 2013 for more details). Fig. 4 shows the final calibrated lava spectrum. By fitting the continuum of the spectrum with a black-body function after taking account of water vapour absorption, we measure the lava temperatures as 1260 K which is consistent with other basaltic lava studies (e.g. Ciro Del Negro et al. 2013)

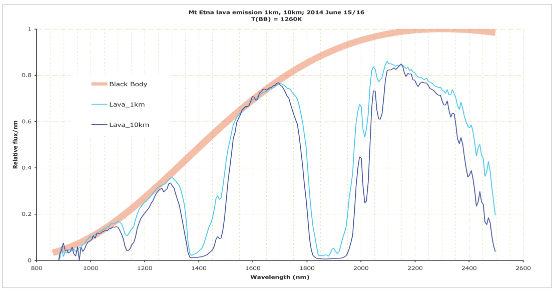

Figure 4. The emission spectra of the hot lava. There are two spectra which were taken at distances of 1 km and 10 km, respectively. The absorption features in the spectrum are H_2O, O_2 and CO_2. The H_2O and CO_2 are partly from the volcanic outgassing. The temperature of the lava is around 1260 K according to the black-body fit (the red line).

Outlook

By observing a volcano on the Earth with portable spectrometers, we can obtain the spectral features of the volcanic gas and the lava. This type of study is important for designing the future measurements of the atmosphere and surface of exo-Earths with major volcanic activity.

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References: E. Pallé et al. 2009, Nature; C. Oppenheimer 2010, ELEMENTS; R. Fosbury, 2013, Journal of the Fluorescent Mineral Society; Ciro Del Negro et al. 2013, Nature; F. Yan et al. 2014, International Journal of Astrobiology