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High-Spectral Resolution Potassium Observations of the Lunar Exosphere

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Abstract

We present the first potassium D1 (7698.9646 Å) line profile measurements of the lunar exosphere from Rosborough et al. [6]. Throughout 2014, we observed potassium emissions off the sunlit limb of the Moon using a Fabry-Perot Spectrometer. We determined an effective temperature of 1920 ± 630 K for waxing gibbous phase and 980 ± 200 K for waning gibbous phase. Monte carlo models suggest that the measured line widths follow a combination of photon-stimulated desorption and impact vaporization sources that replenish the thin atmosphere. The relative intensity decreases by about half during the gibbous phases. Intensity is brightest at the limb near the Aristarchus crater in the lunar northwest, which is a potassium-rich surface region. There is a more rapid decrease of intensity and increase of line width during the waxing phase than waning phase, which implies a dawn-dusk asymmetry.

1. Introduction

The Moon's atmosphere is replenished by several sources; solar wind, photo-stimulated desorption (PSD), thermal desorption, and micrometeoroid impact vaporization (MIV) [3]. Lunar exospheric potassium is a key tracer and provides insights to source and sinks mechanisms of the Moon's atmosphere. However, previous studies on lunar exospheric potassium are sparse with notable results by Potter and Morgan [5], who made the discovery, Colaprete et al. [2] with the Lunar Atmosphere Dust and Environment Explorer (LADEE) mission, and Yokota et al. [7] with the Kaguya lunar orbiter. [2] and [7] reported a dawn-dusk asymmetry as well as column density dependence with location to Potassium and Rare-Earth Elements (KREEP) regions on the surface, which are consistent with our results. Here we present the data and models of effective temperature (velocity derived from line width) and relative intensity of lunar K D1 in the atmosphere with respect to phase angle.

2. Method

We collected high-spectral resolution (R$\sim$180,000, $\Delta v = 1.7$ km s^{-1}) images in January, February, April, May and December of 2014 at the National Solar Observatory (NSO) McMath-Pierce (MMP) telescope in Kitt Peak, Arizona. A 3 arcmin field of view (FOV) (336 km at mean lunar distance of 384,400 km) was placed tangent to the limb in a cardinal direction for a reference crater to capture the atmosphere. We recorded the data in an annular summing mode, with a spectral bin spacing of 0.3097 km s^{-1}, encompassing 0.1 nm spectral range in a single exposure onto a CCD [1]. We obtained the instrument profile from a Th-Ar (7647.380 Å) hollow cathode lamp for determining a deconvolved lunar potassium line width. The resultant spectra were fit with three line profiles; the solar K D1 absorption feature (7698.9646Å) and two s-resolved hyperfine lunar K D1 emission features (7698.9681Å, 7698.9586Å in 5:3 intensity ratio).

3. Results

For waxing gibbous phase, the average effective temperature is 1920 ± 630 K. The waning gibbous phase average is about half of the waxing temperature at 980 ± 200 K. The model temperature of PSD is estimated as $\sim$ 1200 K as an upper limit in Figures 1 and 2. The models in Figure 1 suggest an offset towards lunar dawn and a combination of MIV and PSD sources.

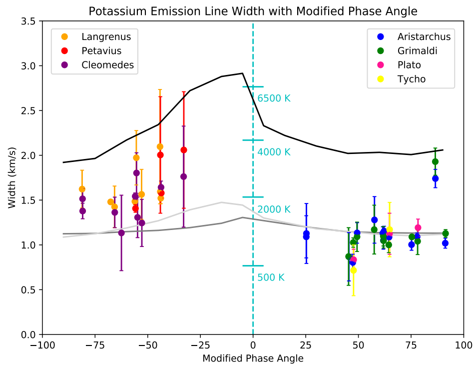

Figure 1: The black line simulates the line width of a MIV source. The gray and light gray lines simulate PSD process sources, with the light gray line given a 20° peak shift from noon towards dawn [6].

The relative intensity is noticeably affected by location to the KREEP regions. Aristarchus (in the West) is in and Plato (in the North) is very close to a KREEP region on the surface. Meanwhile, Grimaldi (in the East) and Tycho (in the South) are consistently less bright than Aristarchus and Plato, respectively. The intensity curve and y-intercepts of the linear lines suggest that the source rate decreases faster during the waxing phase with local time than the waning phase.

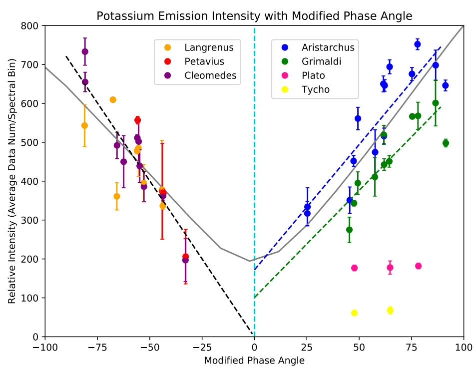

Figure 2: As with Figure 1, the gray line is a PSD model centered at the subsolar point. The black dashed line is a linear fit to the waxing phase. Likewise, the blue and green dashed lines are linear regressions to the Aristarchus and Grimaldi data, respectively [6].

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