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Daytime monitoring of Mercury's sodium exosphere with Haleakala T60 adaptive optics

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We report on the development of a visible adaptive optics (AO) system for Tohoku 60cm telescope (T60) at Haleakala Observatory in Hawaii. The current goal is to join the ground-based support observation for the ESA-JAXA joint Mercury mission BepiColombo on the orbit in 2025 through 2028.

Mercury has tenuous surface-bounded exosphere containing H, He, O, Na, Ca, and K. The resonant scattering emission of the Na D-lines (589.0 nm and 589.6 nm) is bright enough to be observable from Earth. The typical time scales for variability expected from the interaction with the solar wind are on the order of a few minutes. Previous ground-based observations have shown that the north-south ratio of brightness in the Na exosphere changes on a time scale of several tens of minutes, which is consistent with the brightness response due to magnetospheric particle sputtering. There are also some global brightness patterns in Na exosphere. However, previous observations using the slit scanning technique took about an hour to get Mercury's global Na brightness distribution. Using a high-resolution spectrograph (R=50,000) equipped with an integral field unit (IFU) installed on the T60, our objective is to obtain 2-dimensional spectroscopic observation with a cadence of 5 minutes.

Mercury's maximum elongation from the Sun is only about 20 degrees. Therefore, using a regular telescope, the observation time after sunset or before sunrise is less than an hour typically. To monitor the Mercury's exospheric Na brightness through the coordinated observation with the BepiColombo mission, it is necessary to carry out continuous observations not only during short periods after sunset or before sunrise, but also during the daytime when the atmospheric seeing condition is poor (2 to 5" typically). Our visible AO system installed on T60 (T60-AO) aims to stably observe Mercury with a spatial resolution of 1 arc-seconds even during daytime with poor seeing conditions.

T60-AO consists of a 12x12 140-element MEMS deformable mirror (Boston Micromachine) and a Shack-Hartmann wavefront sensor. Field-of-view and number of pupil division for the wavefront sensor are 22" and 14.2, respectively. We updated the focal plane array of wavefront sensor in August 2024, then higher closed-loop AO control frequency 540 Hz was achieved for higher wavefront resolution 0.69"/pixel.

Then we conducted test observation of T60-AO on 9 August 2024. The result shows FWHMs of point spread function (PSF) with T60-AO were $<$1.0" under seeing conditions of 2-3" at around local time 13:00. Figure 1 shows the observed Mercury's disk image with 10 nm bandwidth centered at 590nm without(left) and with (right) T60-AO. White lines indicate circles of Mercury's disk diameter 10.5". The nighttime observation of a star with magnitude 2.2 shows the FWHM of PSF was improved from 2.0" to 0.50" with the T60-AO.