Exploring the roof of Jovian atmosphere by large and small groundbased telescopes in visible and infrared light

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Planets do not have their roofs. Their atmospheres are unstable area connected to outer space. This report summarizes our recent observations of this region on Jupiter, by large-sized (8-m class) telescopes and our Tohoku University small-sized telescopes in visible and infrared. There are several targets, (1) the emission from the stratosphere seen in mid-infrared, (2) the emission from the thermophere and ionosphere seen in near-infrared, and (3) the emission from the magnetosphere filled with Io materials seen in visible light. Those have provided the support acytivity combined with the Juno orbiter and JAXA Hisaki UV/EUV telescope, linked to the virtical couplings by diffusions, atmospheric waves, and magnetic field.
For (1), variation of hydrocarbons in the stratosphere is seen. High-energy particles that produce H2 emission in the polar cap can penetrate into the stratosphere. Up to this region, CH4 rises from the lower layer, and high-energy particles create more complex hydrocarbon molecules. These CxHy molecules have a lot of absorption and emission in the mid IR. This range has been covered by Subaru COMICS mid-infrared imaging spectrometer, which was closed at the end of July 2020.
For (2), Jupiter's intense magnetic field captures electrons and ions with orders of magnitude and energy higher than Earth. These enter into the thermosphere (altitude: ~200-1000s km), hit and heat the dilute atmosphere, producing strong aurora emissions. On the dayside seen from the earth, this emission is buried in the cloud reflection light. However, in UV and near IR light, the reflection light is suppressed by the CH4 absorption in the stratosphere (altitude: <~200 km), and thermospheric emission can be seen. In near IR, H3+ emission is evident. This range has been covered by Subaru IRCS near-infrared imaging spectrometer and mid-large sized telescopes. Metalic ions can also contribute to the conductivity in this region, and it could be the next target for this wavelength range.
For (3), with UV/EUV range observed by Hisaki, Tohoku University's 40-cm (T40) and 60-cm (T60) telescopes at Mt. Haleakala (Hawaii) have provided the support information in the visible range. It can provide the Na nutral cloud which is from the Io volcanic acgtivities. It is not trapped by magnetic field, and distributed in very wide places. It is suitable to be monitored by small-sized telescopes and we have used this data as the index of Io volcanic activities. Sulfic ion lines are confined in the Io torus region and can provide the energetic information with Hisaki.
In 2021 and later, we have plan to modify our Haleakala telescopes. (a) To closure of T-40 and to shift this function to T-60, and (b) To start the near-infrared observation by T-60. The construction activity of the 1.8-m PLANETS telescope (a collaborated project of Tohoku University with Nagoya and Kyoto Universities in Japan, University of Hawaii, Germany, and Brasil) will also be reported.

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