Jupiter Ammonia Absorption Imaging: Highlights 2020-21

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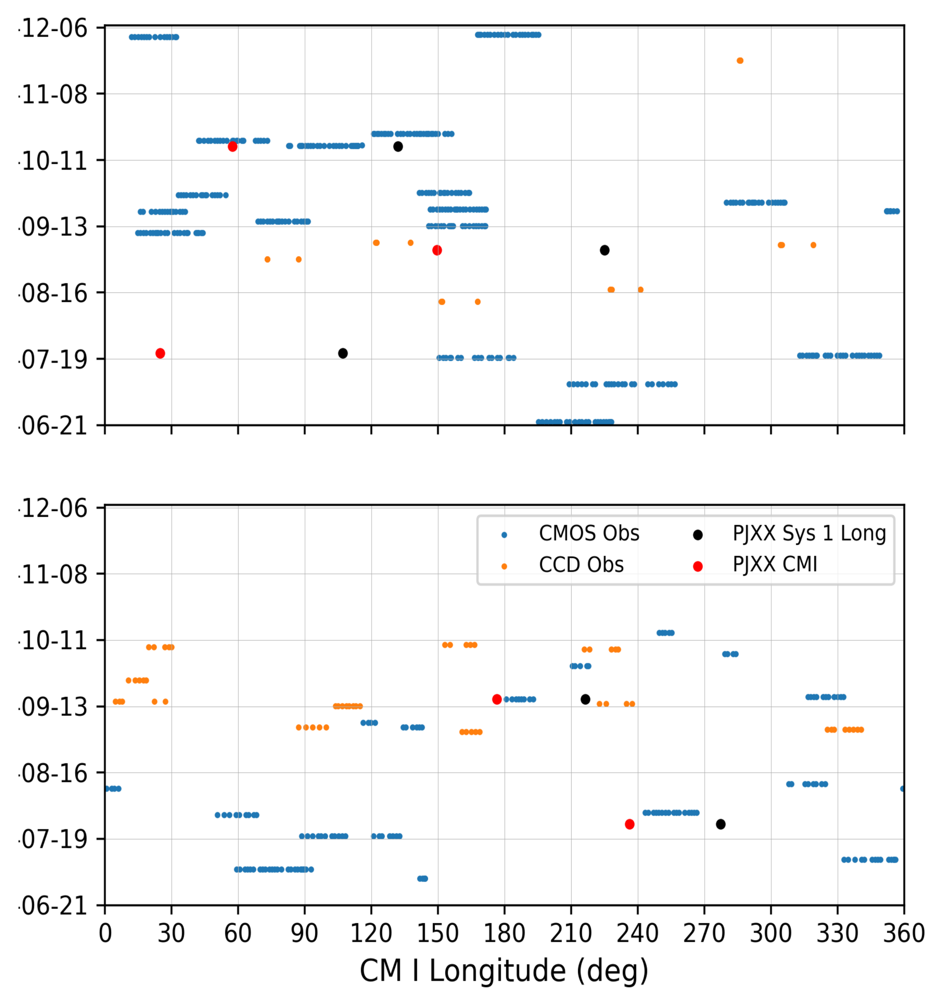
Introduction & Background

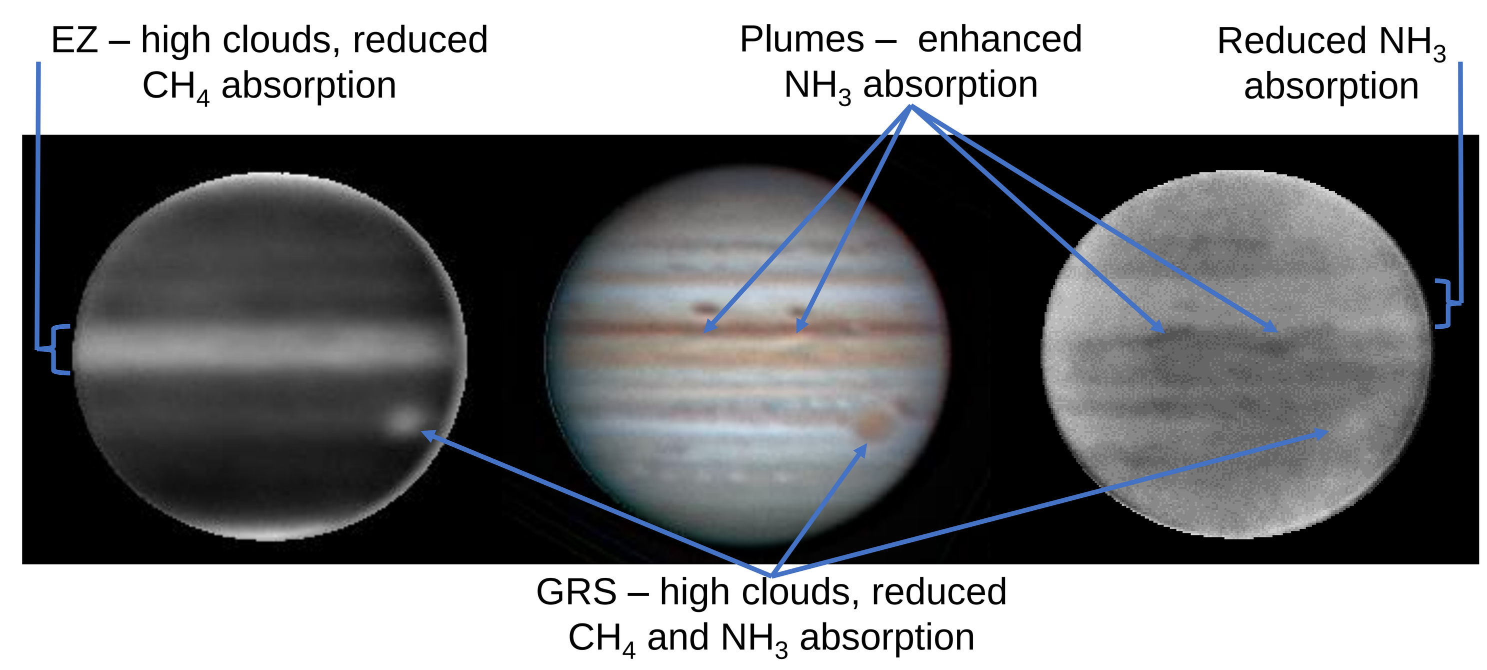
As a potential pro-am complement to professional Jovian ammonia observations, continuum-divided 645 nm ammonia absorption observations were made using a small (0.28 m) telescope. Continuum filters used were at 632 nm and 656 nm. This paper presents highlights of observations during 2020 and 2021. If this low-cost technique can be promulgated among amateurs, then routine atmospheric monitoring of Jupiter would reach a new level of sophistication.

Thirty-nine usable observing sessions were carried out during 2020-2021 from the author's observatory in Denver, Colorado. During July and September 2020 observations overlap with the longitudes observed by Juno on PJ28 and PJ29. The best adjacent observations in 2021 occurred in October (PJ37). Also, near Juno perijove (PJ36), the System 1 longitude range of 140-180 degrees was observed multiple times. This allows for observing the evolution of features in the Equatorial Zone (EZ).



Observing sessions in 2020 (bottom) and 2021 (top). Individual images contributing to ammonia absorption observations are shown (CMOS: blue; CCD: orange). Juno perijove longitudes (Sys. 1) and Earth-facing central meridians (Sys. 1) at perijove are indicated in black and red, respectively.

New microwave and mid-infrared (MIR) observations, along with models, reveal much about Jupiter's ammonia cycle at depth. For example, the Juno microwave radiometer (MWR) instrument permits the retrieval of the average ammonia abundance to a depth of 100 bar [1]. Additional recent work has used MIR observations to probe to depths of several bars [2-3]. Similarly, there have been efforts at global retrievals using hyperspectral imaging in the optical and near-infrared (NIR) [4-5]. Complementing these efforts have been notable improvements in the understanding of the ammonia optical and NIR absorption bands [6]. Slit spectrometry data extend an already long record [7]. Finally, recent work has shown the efficacy of imaging Jovian upper tropospheric features in the 645 nm ammonia absorption band [8], which the current paper expands upon.



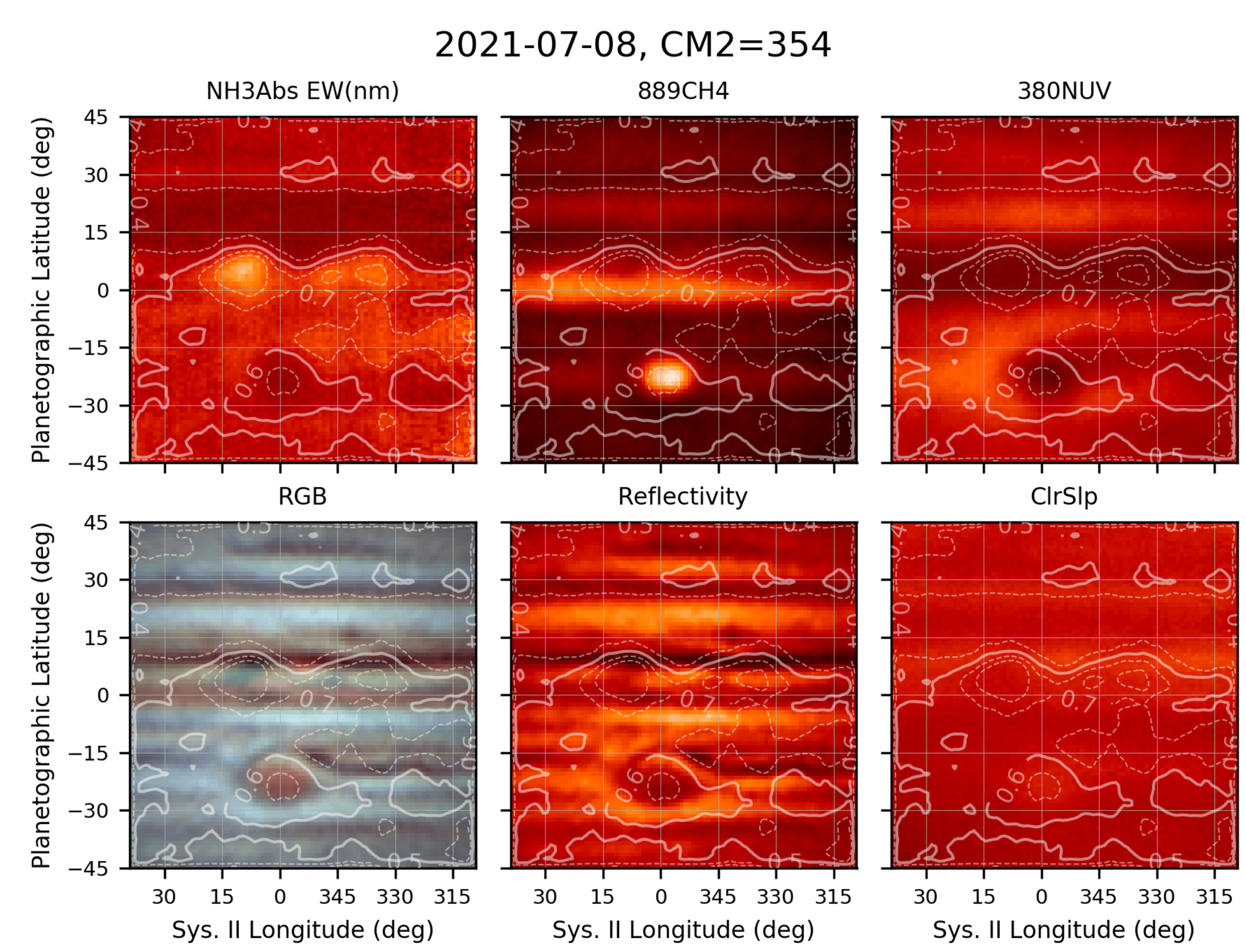
Example of features seen in methane (889 nm), visible, and ammonia absorption (647 nm divided by a synthetic continuum image). Images from 2021-09-15, CM2 ~ 43

Mapped Highlights

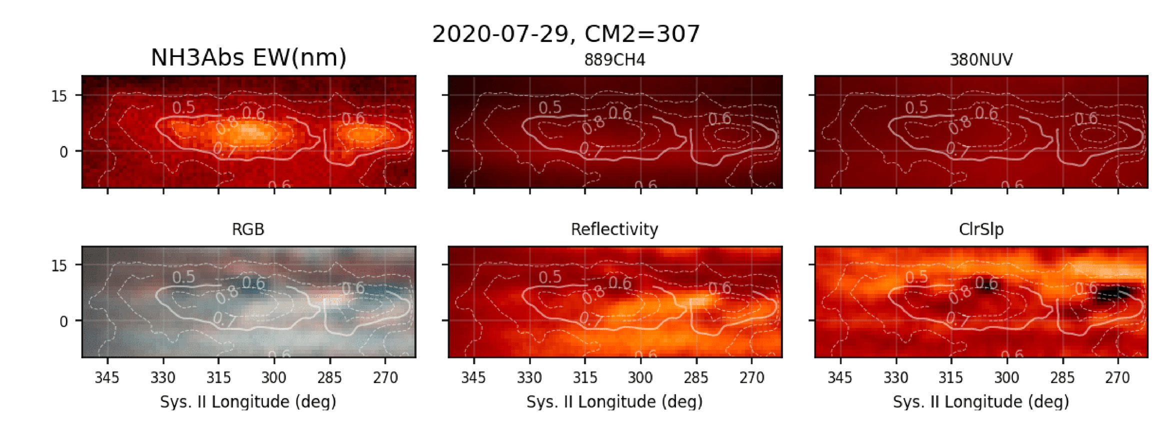
Numerous features of interest are seen in mapped observations of ammonia and context images. The NEB and GRS show reduced ammonia absorption while the EZ – especially the NEZ – shows enhanced absorption. Note the correlation and lack of correlation with obvious visible features. There is a reduction correlated with the GRS, but the reduced absorption region from about 15-25N includes both bright and dark features.

At the boundary of the EZ and NEB there are ammonia absorption enhancements near plumes and dark features. Dark features look deep into the atmosphere and the bright plumes represent high clouds. Thus, the ammonia absorption can't tell the story of actual abundance without better knowledge of the scattering path length.

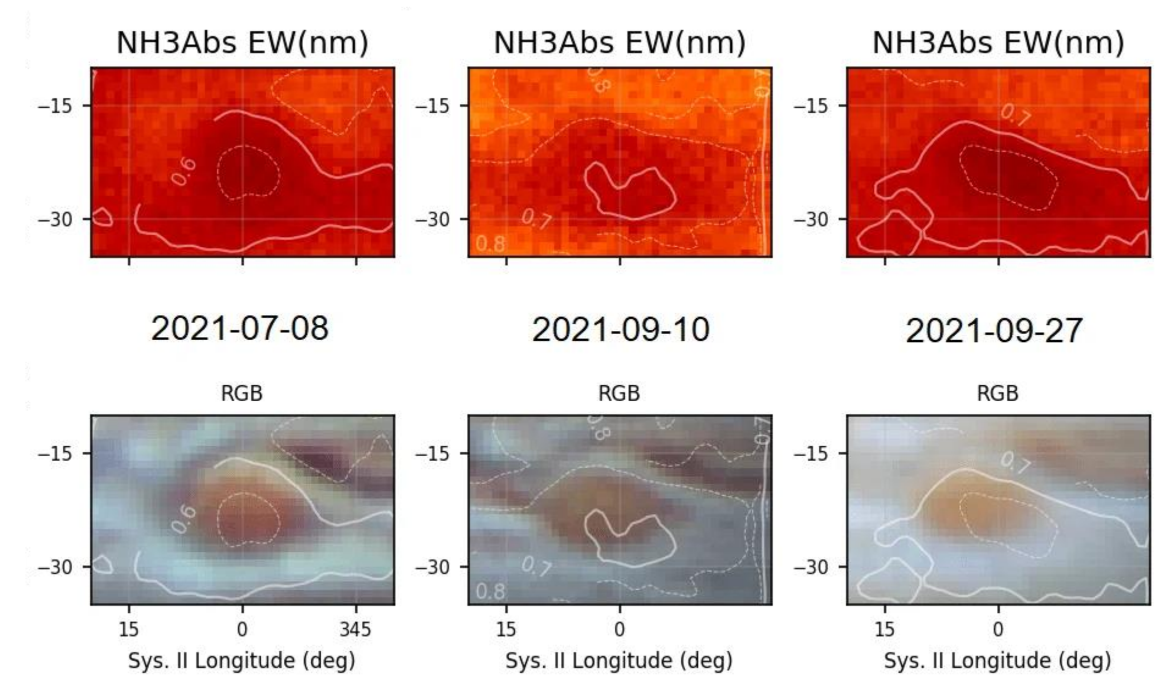
Ammonia absorption in and around the GRS from July through September 2021 shows depletion over the GRS and to the southeast. This depletion is mostly due to the high altitude of the scattering layer and has been noted [7].



Ammonia absorption and context maps. Brightness scaling is adjusted for visual effect. Contour levels are estimated ammonia absorption equivalent width in nm. "ClrSlp" is relative color slope with redder areas shown as brighter.



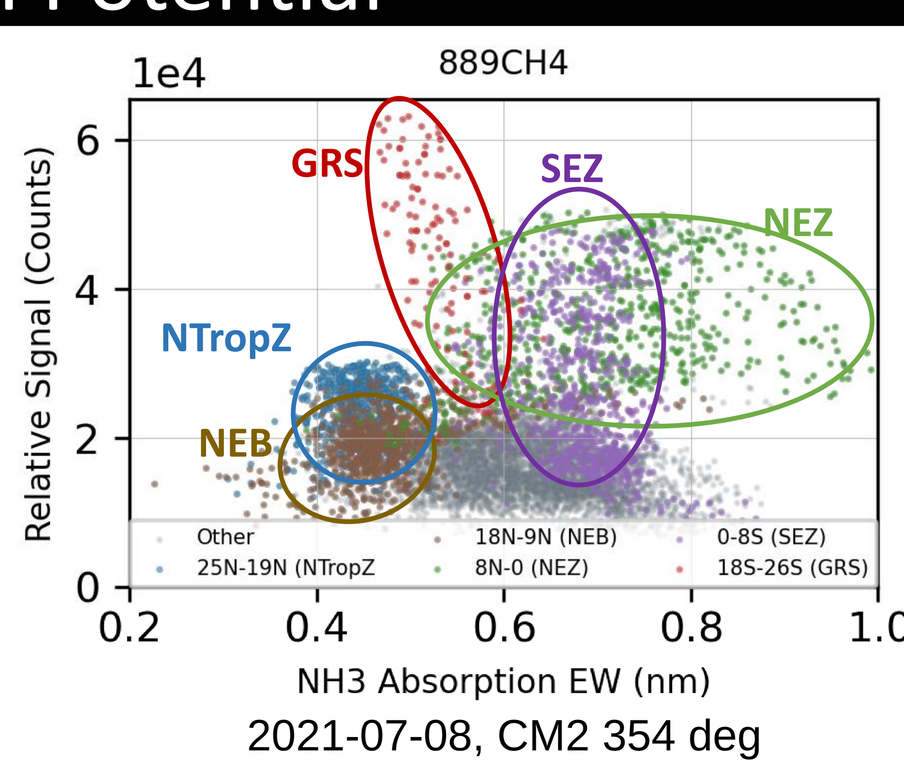
Enhanced absorption near plumes and dark features in the NEZ.



Reduced ammonia absorption over the Great Red Spot at three epochs in 2021.

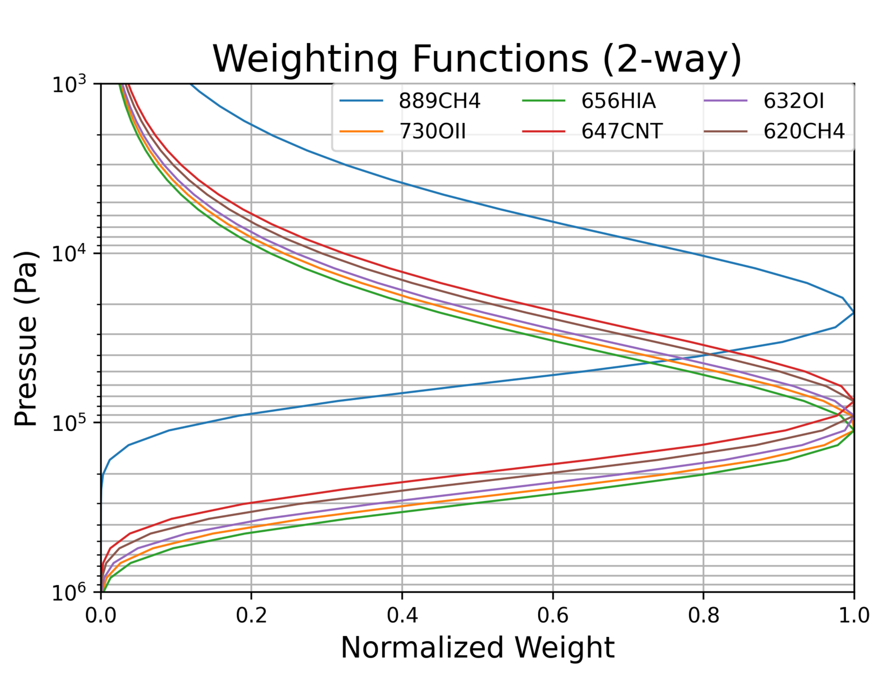
Retrieval Potential

A scatter plot of 889 nm brightness versus ammonia equivalent width shows the distributions of different features. High brightness in the methane band indicates higher cloud tops, which leads to a shorter absorption path. Thus, the GRS has a high 'reflecting layer' and the ammonia equivalent width (EW) is low, consistent with a short absorption path. The EZ (green and purple) exhibits high brightness in methane, but also a wide range of ammonia EWs suggesting a range of features related to ammonia abundance or cloud height. The NEB (brown) shows uniformly low methane brightness, indicating deeper cloud tops, but also shows low ammonia absorption. This suggests an actual depletion in ammonia abundance.



Scatter plot 889 nm methane relative signal versus ammonia equivalent width.

Weighting functions for some of the filters used in this work show the differences in pressure height being sampled in a cloud-free Jovian atmosphere. Notably, the 889 nm band is sampling much higher in the atmosphere than the red filters for continuum (632, 656 nm), ammonia (647 nm), and methane (620, 730 nm). The 620 and 730 nm methane bands have been introduced during the 2022 apparition and already show distinct differences from the 889 nm methane band. Scatter plots will be made in order to explore the relationship of ammonia absorption to the 620 nm methane band absorption. These should yield more meaningful results since scattering paths and Rayleigh effects will very similar.



Weighting functions for a cloud-free Jovian atmosphere with methane and ammonia absorption and Rayleigh scattering.

Conclusion & Future Work

Using simple equipment and concepts, ammonia absorption in Jupiter's atmosphere can be imaged and analyzed. Ammonia is important, because it plays a role much like water in Earth's atmosphere, forming clouds, evaporating, and condensing. Over two years of observations, the technique has been refined and interesting findings recorded. The findings include confirmations of long-known features like reduced ammonia absorption above the high clouds of the Great Red Spot as well as in Jupiter's North Equatorial Belt. More dynamic features are also seen. Steps are being taken to quantify the results so they may be useful in atmospheric retrievals of parameters like ammonia humidity. Professional researchers using data from the Jupiter-orbiting Juno spacecraft and major Earth and orbital observatories look at ammonia deep into Jupiter's atmosphere. The technique presented here, if widely adopted by amateurs, would provide routine surveillance of the upper boundary conditions for ammonia, complementing deeper observations.

The scatter plot analysis suggests that a simple Reflecting Layer Model might provide meaningful first-order retrievals of atmospheric properties [9]. The goal during 2022 will be to retrieve reflectivity, cloud-top pressure, and ammonia abundance by extending this model. In addition, observations will be shared on amateur collaboration websites.

References

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