Using ALMA Spectra to Investigate a Potential Transient Exosphere of Ceres M. Parks[1,2], C. Nixon[2], M. Cordiner[3,2], S. Charnley[2], A. Thelen[3,2], V. Allen[4,2], M. Palmer[3,2], Y.-L. Chuang[5], Y.-J. Kuan[5], [1]University of Maryland Baltimore County, [2]NASA Goddard Space Flight Center, [3]Catholic University of America, [4]Universities Space Research Association, [5]National Taiwan Normal University

Introduction: Over the past three decades, observational data has pointed to a possible transient atmosphere around Ceres. The International Ultraviolet Explorer detected possible OH signatures in the early 1990s, but follow-up investigations in the mid 2000's by the Very Large Telescope yielded no confirmation [1]. Subsequent submillimeter observations by the Herschel Space Observatory gave no results in 2011, but in late 2012 and 2013 showed strong signals of OH. Models simulating thermal collisions indicate that any H2O is on the borderline between being bound gravitationally and not bound, but heavier elements would last longer [2]. This research uses spectra from the Atacama Large Millimeter/submillimeter Array (ALMA) to investigate the possibility of a transient exosphere and detect its composition. This builds on preliminary work carried out by a collaborating team, Chuang et al. (in prep). We have searched for absorption lines of species including HCN, HCCCN, CCCN, CS, and KCL, as we felt that searching for water in the frequency windows available to ALMA would be hampered by terrestrial atmospheric absorption features.

Methods: We utilized the ALMA Archive Query tool available at http://almascience.nrao.edu/aq/ to identify publicly available observation data sets which used Ceres as a flux calibrator. We then filtered out data sets which had less than 4MHz frequency resolution, and downloaded an even spread of data sets from between 2013 and 2017, with preference given to observations of Ceres with longer integration times and larger arrays, when available.

Once data had been collected, we manually recalibrated the raw data using the CASA calibration scripts and, when available, the CASA pipeline. We then imaged Ceres for each observation and analyzed its spectrum, searching for any anticipated absorption or emission lines related to the molecules HCN, HCCCN, CCCN, CS, and KCL. These molecules were chosen both due to their plausibility in the Cerean environment and because they are within spectral windows which ALMA often searches, increasing the number of available data sets for us to search through.

Results: We analyzed approximately 5% of the 180 data sets which met our criteria. The data sets analyzed reflected a selection of the sets with the longest integration times and largest arrays. Of the 9 spectra analyzed, within 8 we found no possible detections of any sought molecules.

One set analyzed had a possible, if very faint, signal of HCNv2=1 at the 354 GHz line, that merited further study. However, a follow up 0th Moment Map (Fig.1) did not show a conclusive detection. Furthermore, analysis of a data set from two days later yielded no support of any HCN signal within the 354 GHz window.

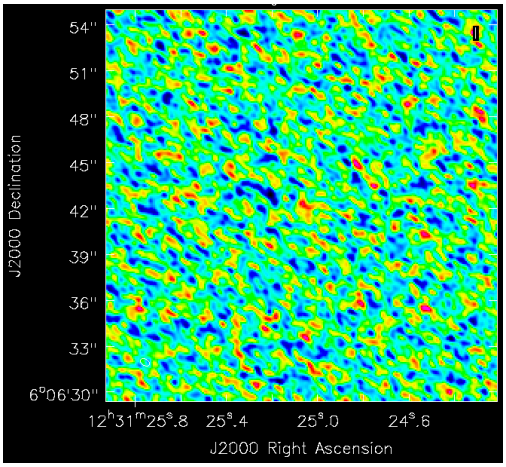

Fig. 1: 0th Moment Map of possible HCNv2=1 Transition

Discussion: It is worth noting the transient nature of the exosphere for which we were searching. Villarreal et al. (2017) suggests solar high energy particles as a mechanism for creating an exosphere due to sputtering H2O ice at or near the surface of Ceres [5]. If this is the case, any exosphere would be correlated with recent solar activity.

This highlights a flaw in our use of archival, flux calibration observations. As each calibration observation is tied to the primary science objective of its parent project, the best available data will be those that are most closely timed to follow up on solar energetic particle events. However, those data sets will not necessarily be taken with the sensitivity needed to detect a Cerean exosphere. Even in our set of 9 observations, half were data sets from the less sensitive Atacama Compact Array (ACA). Dedicated, full-array observations taken immediately after solar energetic particle events would be much better suited to the investigation.

Conclusion: We searched the ALMA archive for calibration data which might capture a transient exosphere around Ceres, and allow us to characterize its

chemical composition. We found no conclusive evidence to support a detection of a Cerean exosphere. Given the limitations of our methodology, we conclude that Archival Mining is an ineffective method of detecting a transient phenomenon, due to the lack of control over timely observations. Future investigations of the transient exosphere of Ceres should be carried out using dedicated observations, timed after solar energetic particle events. Such observations would help confirm whether or not the solar energetic particle events are indeed the formation mechanism, providing evidence one way or the other.

References:

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