

**DETECTION OF PURE AMMONIA CLOUDS IN A JUPITER HIGH-LATITUDE REGION BASED ON AN ANALYSIS OF JUNO/JIRAM INFRARED SPECTRAL DATA.** F. Biagiotti<sup>1,2</sup>, D. Grassi<sup>2</sup>, G. Luzzi<sup>3</sup>, G. Piccioni<sup>2</sup>, G. Villanueva<sup>4</sup>, F. Oliva<sup>2</sup>, E. D’Aversa<sup>2</sup>, A. Mura<sup>2</sup>, C. Plainaki<sup>5</sup>, G. Sindoni<sup>5</sup>, A. Adriani, E. Di Mico<sup>2</sup> and the whole JIRAM Team. <sup>1</sup>Department of Physics, University of Rome “La Sapienza”, Piazzale Aldo Moro 2, 00185 Rome, Italy, <sup>2</sup>INAF – Istituto di Astrofisica e Planetologia Spaziali (INAF-IAPS), Via Fosso del Cavaliere 100, I-00133, Rome, Italy, <sup>3</sup>Università degli Studi della Basilicata, Potenza, Italy, <sup>4</sup>NASA Goddard Space Flight Center, Greenbelt, MD, USA, <sup>5</sup>Agenzia Spaziale Italiana, Rome, Italy.

**Introduction:** Ammonia is historically thought to be the main source of condensable species for Jupiter’s main cloud layer (0.6-1.1 bar level) [1]. However, measurements from Galileo first [2] and Juno later [3,4], showed that the spectral features connected to ammonia clouds are rare and not ubiquitous, and that a main cloud layer made either mainly of  $\text{NH}_4\text{SH}$  or of pure or coated tholins is an optimal solution. As of today, only two works claim to have detected pure ammonia ice clouds [5,6] and in both cases, these detections seem to be connected to transitory events. In this work, we investigate the presence of spectrally identifiable ammonia clouds (SIACs) by analyzing the infrared spectral data of the first perijove passage (JM0002 and JM0003) from the JIRAM image-spectrometer (range 2-5 microns) on board the NASA Juno mission.

**Methods:** To find the presence of SIACs we used three independent spectral parameters. The first one, following [6], is the ratio of the signal at 4 microns to that at 2.97 microns. These two wavelengths are characterized by similar transmission weighting function and therefore we should probe the same pressure level; however at 2.97 microns ammonia clouds are expected to absorb strongly. The second one is the ratio of the mean of the signal in the spectral ranges 2.98-3.01 micron and 2.94-2.98 micron. Lastly, we also performed a combined PCA-GMM (Principal Component Analysis + Gaussian Mixtures Models) clustering analysis using the scikit-learn python package.

By cross-referencing JIRAM data with JunoCam mosaics (courtesy of G. Eichstadt), we found that the first two indicators showed higher values in the proximity of a high-latitude Nautilus shaped cloud system (see Fig.1). Also the PCA-GMM analysis identified the spectra in this region as belonging to a specific cluster, different from the surroundings. We first fitted all the spectra of this region (both inside and outside the Nautilus) with a toy model. We used the pressure-temperature profile from [7], constant mixing ratio profiles for  $\text{H}_2$ , He, and  $\text{CH}_4$ , a parameterized  $\text{NH}_3$  profile (varying deep mixing ratio and relative humidity), a slab-like parameterized pure reflecting tropospheric haze (from [8]) and a Gaussian shaped parameterized tholin main cloud layer. To compute the optical properties of the tholin

cloud layer we used Mie theory and considered a log-normal distribution. A Heyney-Greeinstein approximation for the scattering phase function has been adopted, and the optical constants from [9] were used. This model is capable to reproduce reliably JIRAM data at mid-latitudes in the solar region as already shown by [3] and [4]. It is worth stressing that Titan’s like tholins must not be intended as a realistic candidate for Jupiter’s aerosol clouds but as an approximation of the real amorphous unknown material that exhibits an evident N-H-bond-like absorption.

We performed the retrievals using the NASA Planetary Spectrum Generator (PSG) [10] and the PyOE [11] python package. PSG is a powerful and hybrid radiative transfer suite used to model spectra of planets, exoplanets, and also moons, and satellites [12, 13]. As of the author’s knowledge, this is the first work regarding Jupiter for which PSG has been used.

In the retrieval, we considered only the 2.5-3.1 micron spectral range, because this interval contains most of the information content and encompasses eventual spectral features of ammonia ice clouds, thought to be present near in the 3 micron region.

We found that the described simplified model is well fitting the majority of the spectra outside the Nautilus, whereas the spectra near and inside the Nautilus require relaxing assumptions on cloud compositions.

These spectra have been re-modeled trying a different cloud composition. To do that we generated the optical properties for pure ammonia ice particles starting from the optical constants from [14] and the same methods described above. We also considered the possibility of having coated particles (tholin core and ammonia coating), for which the optical properties have been computed using the py-mie python package [15] and validated with the BART code [16].

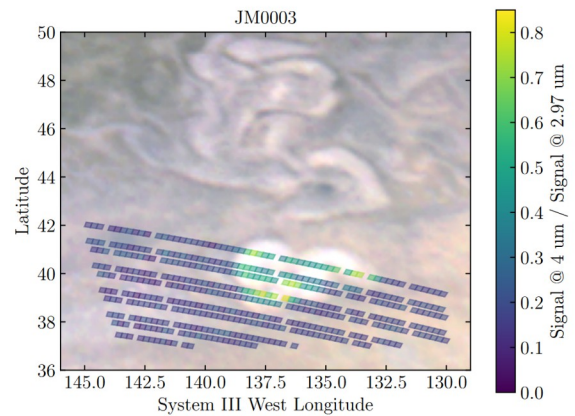
**Results:** A total of 20 spectra are best fitted by a pure ammonia ice cloud model and so have been identified as SIACs. This is the first spectral evidence of possible pure ammonia clouds obtained thanks to the analysis of Juno data. The SIACs are located at the center of the Nautilus-shaped cloud and in correspondence with the nearby swirls. In most cases, the SIACs are surrounded by

spectra best fitted by a cloud deck composed of tholins particles coated with ammonia. In conclusion, our results in correspondence with the Nautilus are suggesting: (I) higher altitude hazes and clouds, (II) higher values of ammonia relative humidity that also reach super-saturation conditions, (III) smaller effective radii for the haze particles. Such results are compatible with the presence of pure ammonia ice clouds, formed at these latitudes as a consequence of an uplifting event from the lower troposphere that brought a large fraction of fresh ammonia up to reach super-saturation conditions, triggering condensation and/or coating of mixed particles. Both these processes, combined with global circulation, may explain the Nautilus-like white cloud that is visible from JunoCam images.

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**Fig. 1** Ratio of the signal at 4 microns to the signal at 2.7 microns for a collection of P1 JIRAM spectra super-imposed to a JunoCam visible image