FY24 R&TD Innovative Spontaneous Concepts (ISC)

DSN Observations of Ammonia in the Exceptional Comet C/2023 A3

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Strategic Focus Area: Innovative Spontaneous Concepts

Objectives: Using the DSS-43 70-m antenna in Canberra, we will observe ammonia inversion lines in the exceptional Oort cloud comet C/2023 A3 to test the hypothesis that refractory compounds, such as ammonium salts are the source of cometary ammonia. Near its perihelion, in late September – early October 2024, the comet will be at a heliocentric distance of ~0.4 au, resulting in high amounts of ammonia production from thermal degradation of ammonium salts, if present. This tasks FY'24 objectives are to plan the observations and put in place the required analysis and modeling tools.

Background:
Comets are among the most primitive objects of the Solar System. The chemical composition of their ices is representative of the molecular composition of the outer regions of the Solar Nebula (the Solar protoplanetary disk) where they formed, 4.6 Gyr ago. It thus provides insights into the conditions of formation and evolution of the early Solar System. Ammonia (NH_3) and hydrogen cyanide (HCN) are dominant reservoirs of volatile nitrogen in comets. Understanding the NH_3 abundance is critical for addressing the nitrogen depletion in comets. The observed increase in the NH_3 abundance with the heliocentric distance points to origin from refractory compounds, such as ammonium salts, which were detected by *Rosetta* in comet 67P.

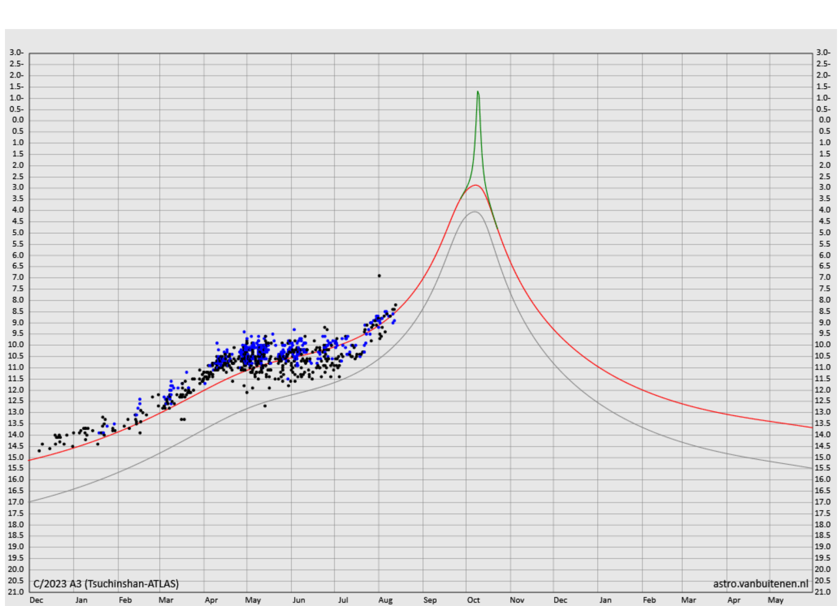

Figure 1. The observed light-curve of comet C/2023 A3.

Approach: Despite its high abundance, ammonia is difficult to observe from the ground, as its strongest lines are affected by telluric absorption. The 572 GHz far-infrared rotational transition was detected by *Herschel* in comet 10P/Tempel 2 but is no longer accessible with the present NASA facilities. The new DSS-43 K-band receiver gives access to the 23 GHz ammonia inversion lines.
Figure 1 shows the latest comet C/2023 A3 light curve. Following a plateau in May – June, the comet brightness started increasing again in mid-July, as the comet approaches perihelion.
We model the intensity of the ammonia inversion lines in comet C/2023 A3, using the PSG tool (https://psg.gsfc.nasa.gov). The key model parameters are the water production rate, $Q = 2 \times 10^{30}\ s^{-1}$ near perihelion, the coma temperature T = 60 K around 1 au, and an NH_3 mixing ratio of 0.5% with respect to water. In addition to NH_3, HC_3N and methanol are included in the model, as they have lines in the DSS-43 frequency range. Figure 2 shows the simulated comet spectrum. The horizontal dashed line corresponds a 5σ detection threshold in a 10 h integration, based on past observations using the same instrument.

Results: The PSG model suggests that three lowest energy ammonia inversion lines, (1,1) to (3,3) should be detectable above 5σ level. The intensity of these lines is sensitive to the coma temperature and Figure 3 shows model spectra for coma temperatures of 40, 60, and 80 K. The detection of multiple lines would allow direct determination of the coma temperature. The hyperfine splitting, if detected, would further provide a measure of the line optical depth.
Our analysis confirms detectability of the ammonia inversion lines in comet C/20023 A3 near perihelion for the expected water production rate. The model suggests that methanol may also be detectable.

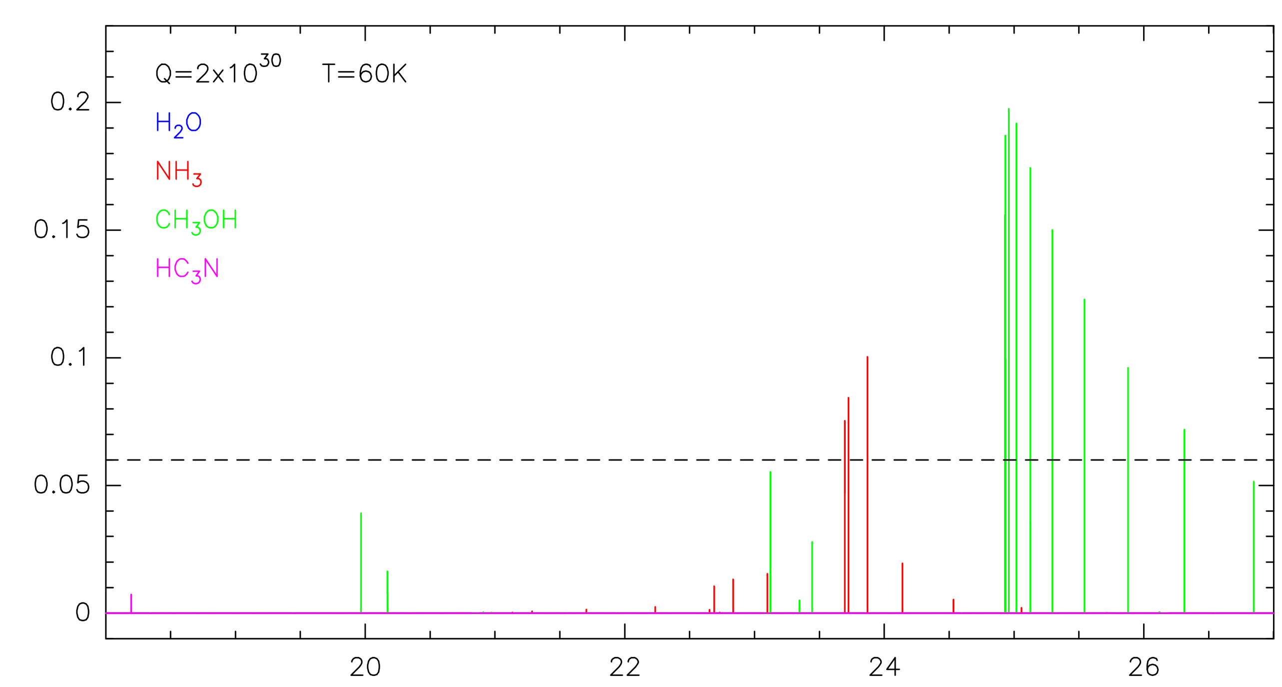

Figure 2. Model spectrum of comet C/2023 A3 in the DSS-43 frequency range. The horizontal dashed line shows expected 5σ sensitivity of DSS-43 in a 10 h integration. The horizontal scale is frequency in GHz and the vertical scale main beam brightness temperature in K.

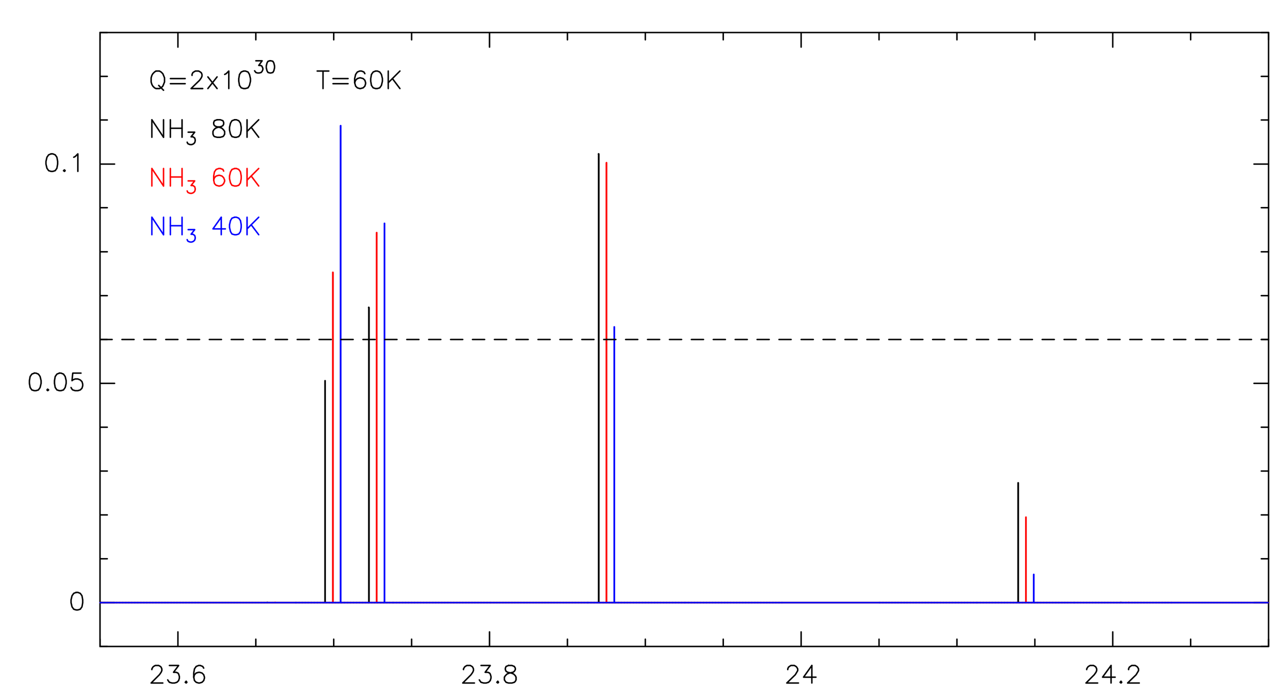

Figure 3. Model spectra of the ammonia lines in comet C/2023 A3 for coma temperatures of 40, 60, and 80 K, corresponding to a range of heliocentric distances (blue, red and black lines, respectively). The three spectra are shifted in frequency to avoid overlap.

Significance/Benefits to JPL and NASA: This task enhances scientific return on the JPL investment in the DSN. In the absence of current far-infrared space facilities, a detection of the ammonia inversion lines would open a new avenue for testing the hypothesis that refractory compounds, such as ammonium salts are the source of cometary ammonia. Successful DSS-43 observations would enable follow-up ROSES proposals to the NASA Solar System Observations (SSO) program, as well as Solar System Workings (SSW) proposals to develop a detailed non-LTE excitation model for cometary ammonia, building upon the JPL model of the water line emission in comets.

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