The Detection of Prebiotic Molecules in the ULIRG Arp 220

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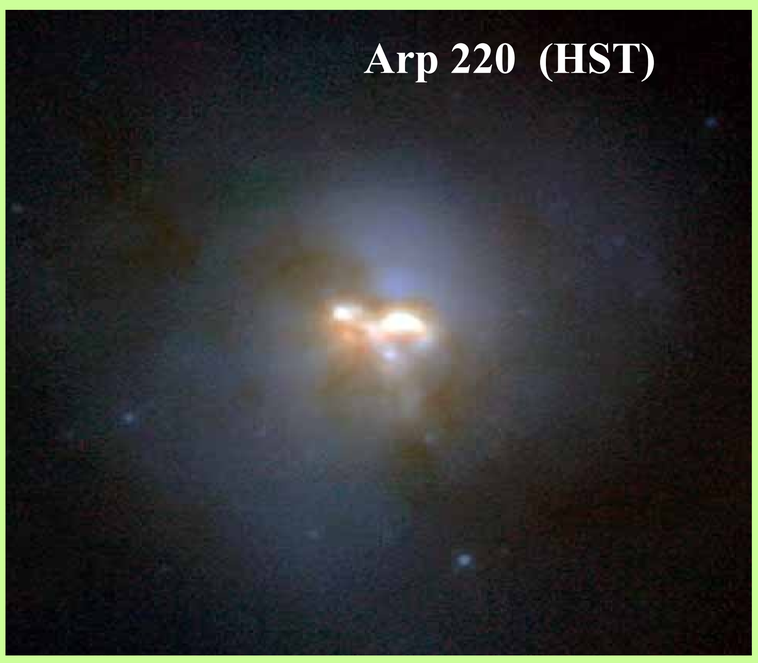
ABSTRACT

Organic molecules in space are thought to form mostly on the surface of dust grains. Heating events, such as the formation of a protostar, release the icy grain mantles into the gas phase. Once released, these molecules may form amino acids by the combination of organic species known as "pre-biotic" molecules. Methanimine (CH_2NH) is one such pre-biotic molecule. This can either combine with HCN to form aminoacetonitrile (H_2CNNH_2) and then glycine, the simplest amino acid, via hydrolysis (Strecker Synthesis), or combine with Formic Acid (HCOOH) directly to form glycine (NH_2CH_2COOH). Methanimine has been detected towards Sgr B2, and tentatively in the nearby galaxy, NGC 253, but has never been seen beyond the neighborhood of our Galaxy (i.e. beyond ~5 Mpc).

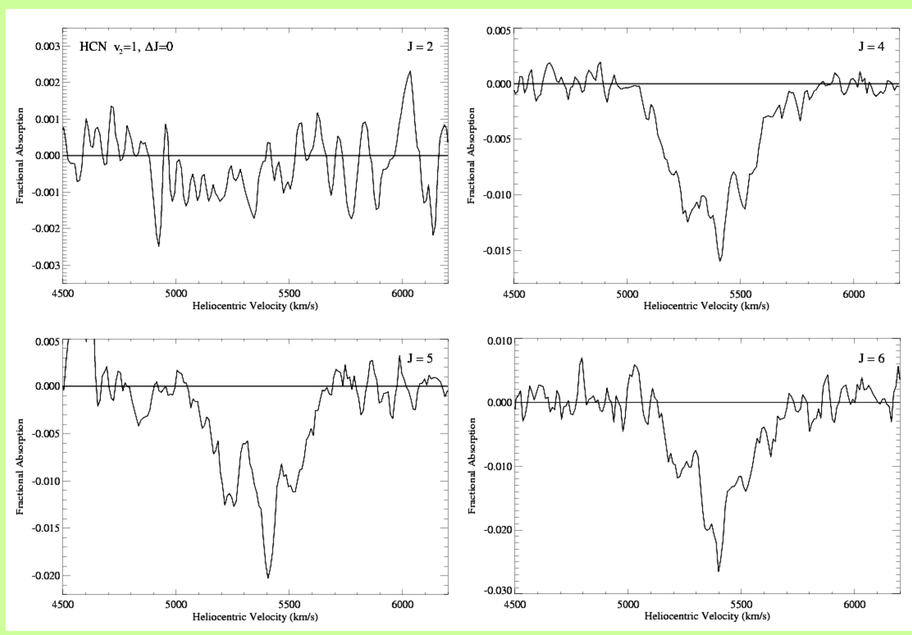
We are conducting a cm-wave molecular line census in Arp 220, the nearest Ultraluminous Infrared Galaxy (ULIRG) and the prototype OH-megamaser source, using the Arecibo 305-m telescope. Among our results to date is the first detection of the prebiotic molecule methanimine in a distant galaxy. Methanimine is seen in emission, and is likely to be a weak maser. Also detected are three "direct l-type transitions with $\Delta J = 0$" of Hydrogen Cyanide (HCN) from the J= 4, 5 and 6 levels. These HCN lines, previously undetected in any source, appear in absorption against the continuum radiation of this galaxy. The HCN J=2 line should lie near 1370 MHz, but is not detected. This is likely to be due to foreground free-free absorption within Arp 220.

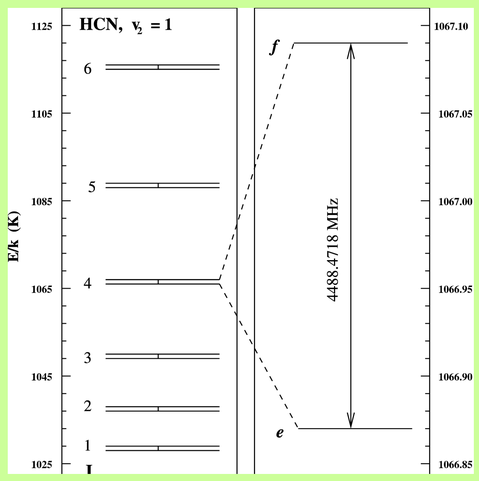


Observations

- Using the Arecibo 305-m telescope, a complete spectral scan of Arp 220 between 1.1 &10 GHz with 24 kHz resolution is in progress.
- The WAPP spectrometer is used in its recently-commissioned “dual-board” mode with simultaneous 8 × 100-MHz coverage in both polarizations.
- A modified Double Position Switching technique was used: a 5-min ON/OFF scan on Arp 220 being followed by a 1-min ON/OFF on a calibrator, J1531+2402.

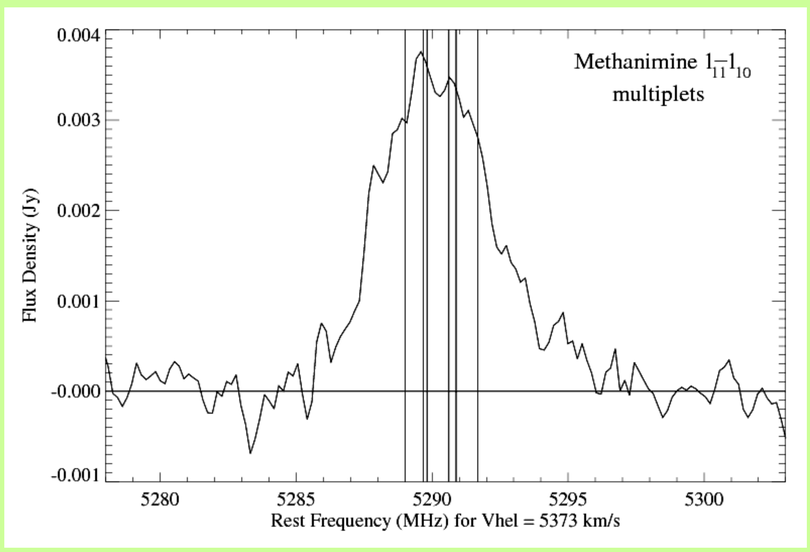
HCN Absorption





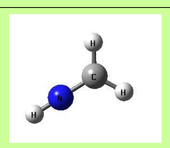
The spectra show the first astronomical detection of the v_2=1 direct l-type absorption lines of HCN with vibrational levels J = 4, 5 and 6. The relative line integrals suggest an excitation temperature of ~120-150 K. The non-detection of the J=2 vibrational level is likely to be due to free-free absorption in the foreground ionized ISM.

Methanimine Emission



The emission spectrum of the blended 1_{10}–1_{11} methanimine (CH_2NH) multiplet, whose 6 transitions are marked by vertical lines. Using an angular size upper limit of $0''.27 \times 0''.21$ (from a published H_2CO map), we derive a lower limit on the brightness temperature of ~2800 K. Since this is more than the decomposition temperature of methanimine (1300 K), this detection is likely to represent weak maser emission.

Reactions



Methanimine is a pre-biotic molecule which can form the simplest amino acid, glycine (NH_2CH_2COOH), either by (1) first combining with HCN to form aminoacetonitrile (NH_2CH_2CN), with subsequent hydrolysis:

$$HN{=}CH_2 + H{-}C{\equiv}N \rightarrow H_2N{-}CH_2{-}C{\equiv}N$$

$$H_2N{-}CH_2{-}C{\equiv}N + H_2O \rightarrow H_2N{-}CH_2{-}C(=O){-}NH_2$$

$$H_2N{-}CH_2{-}C(=O){-}NH_2 + H_2O \rightarrow NH_2CH_2COOH + NH_3$$

or (2) directly combining with HCOOH:

$$HN{=}CH_2 + HCOOH \rightarrow NH_2CH_2COOH$$