Origins of Phosphorus Nitride in Star-forming Regions

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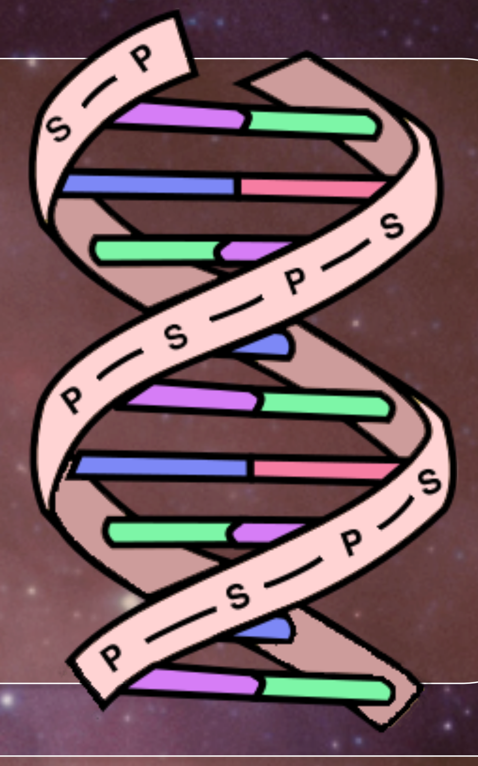
Abstract: Phosphorus is one of the key elements of life as we know it on earth, as it plays a central role in the structure of essential biotic molecules, such as nucleic acids (DNA & RNA) and the adenosine triphosphate (ATP) [1]. Despite its importance, the chemistry of Phosphorus in the interstellar medium (ISM) is still poorly known. The molecule of PN is one of the two P-bearing molecules detected in star-forming regions (PN & PO) (e.g. [2], [3], [4]), but it is still not clear under which conditions it is formed. In order to understand it, we present multi-line observations of PN towards 9 massive dense cores, in different evolutionary stages.



Observations & Methods:

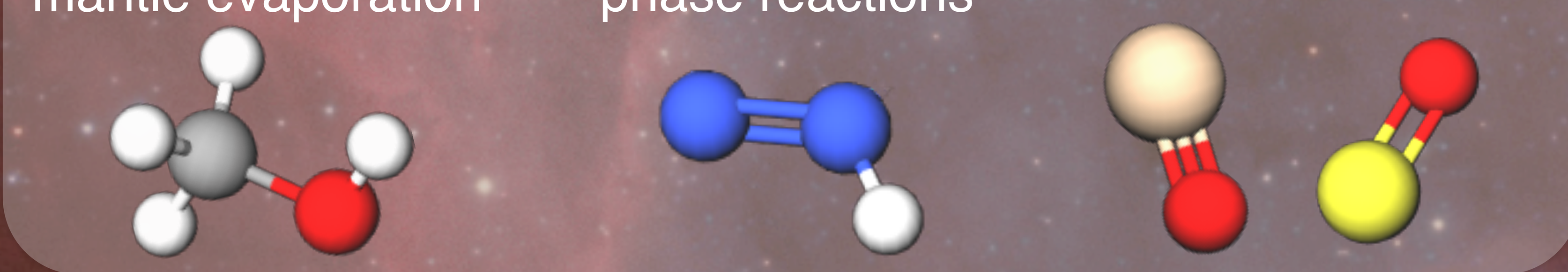
- Rotational lines PN(2-1), PN(3-2) and PN(6-5) observed with IRAM-30m Telescope.
- Rotation Diagram method to determine the total column density, N_{tot}, and excitation temperature, T_{ex}.
  ↳ assumptions: optically thin lines populated by the same T_{ex}.

PN formation models:

1. via high-temperature gas-phase reactions [5]
2. via cold ion-neutral gas-phase reactions [4]
3. via sputtering of dust grains [2], [6], [7]

To test these three scenarios we have chosen:

1. CH_3OH tracer of dust mantle evaporation
2. N_2H^+ tracer of pure gas phase reactions
3. SiO & SO shock tracers



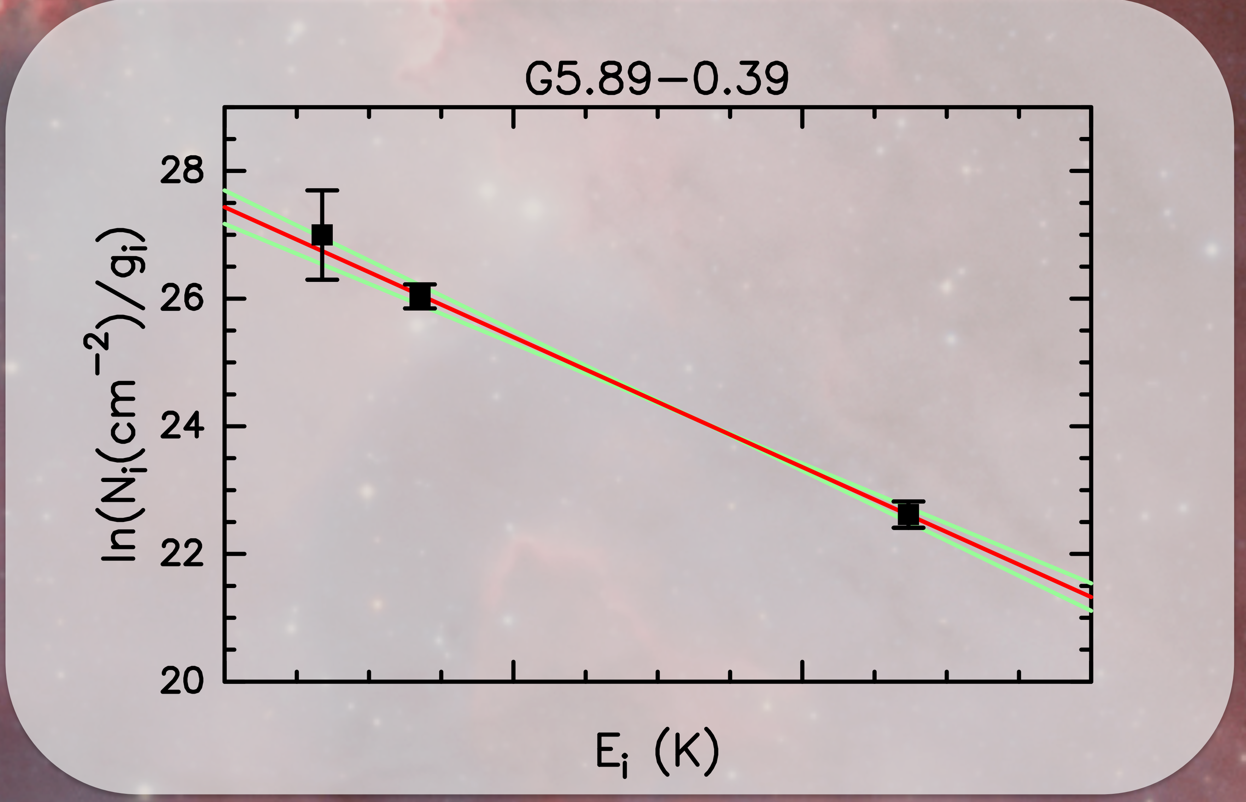
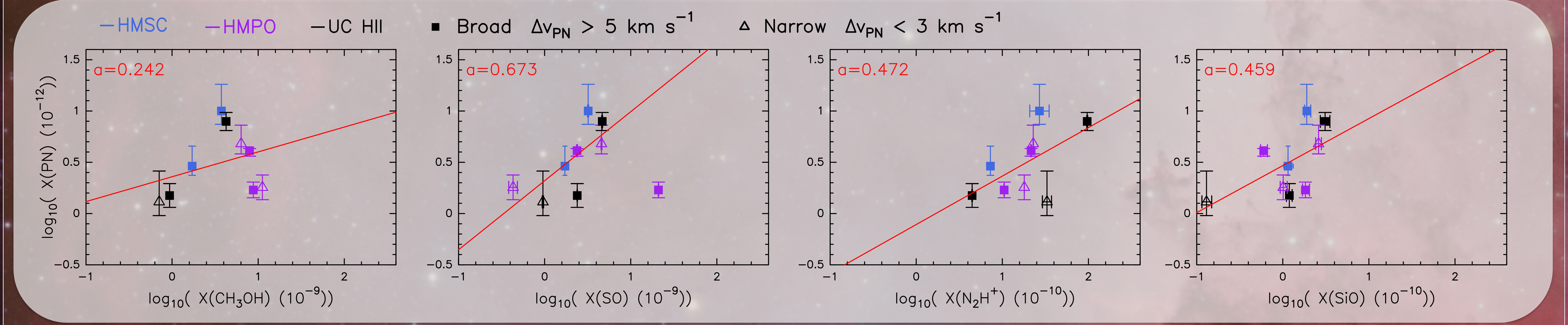


Figure 1: Rotation Diagram of PN for G5.89-0.39

Abundance of PN against those of (from left to right): CH_3OH, SO, N_2H^+, SiO.

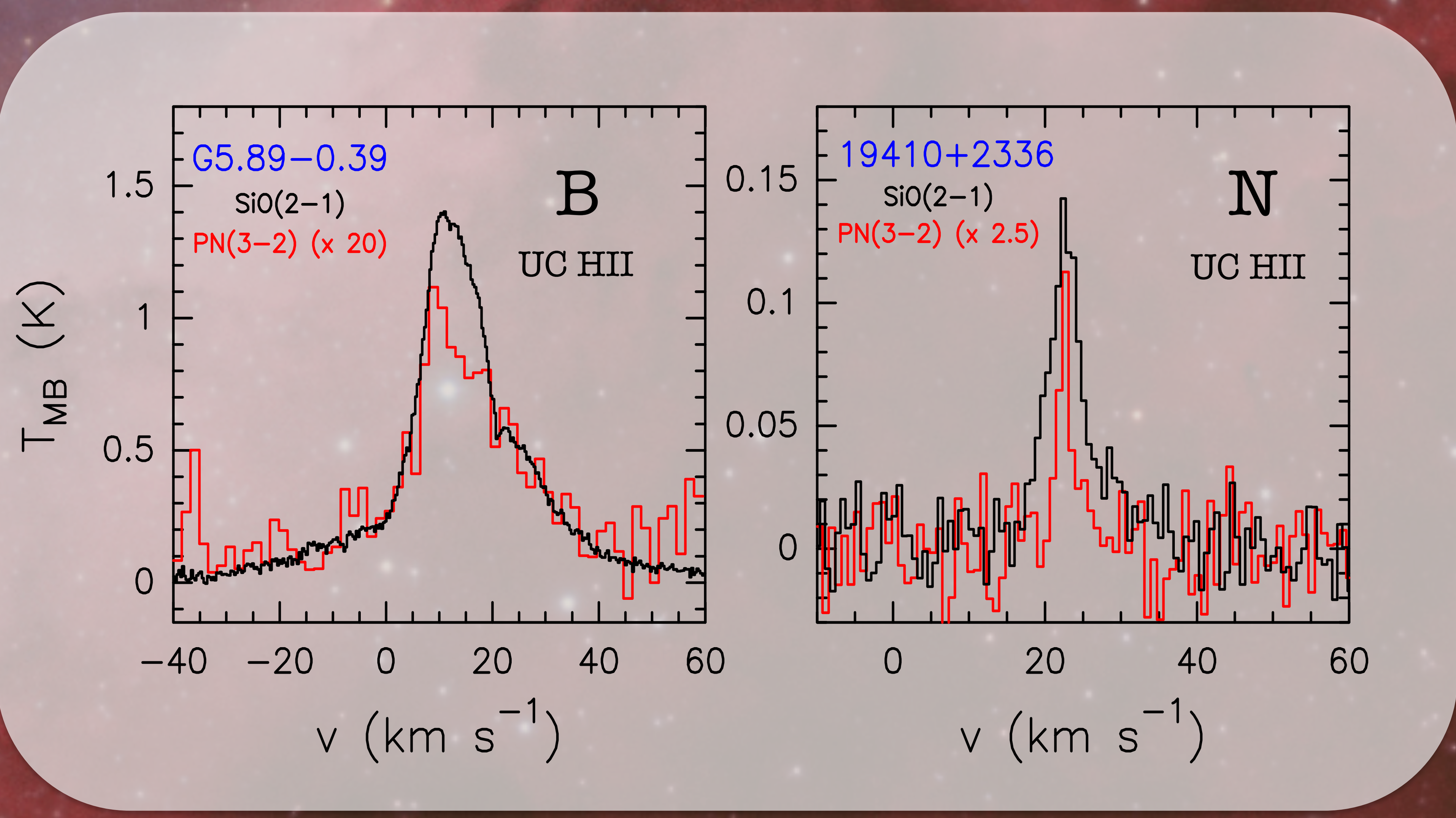


We find :
- no correlation with CH_3OH;
- faint but significant correlation with SO, N_2H^+ and SiO;
- no trend with evolution.

Profile of PN and SiO in the sources G5.89-0.39 and 19410+2336. These two sources represent two scenarios:

- Broad (B) sources (6): PN line profiles follow nicely those of the shock tracer SiO, with $\Delta v_{PN(3-2)} > 5$ km s^{-1}.
- Narrow (N) sources (3): the linewidths of PN are notably lower than those of SiO, with $\Delta v_{PN(3-2)} < 3$ km s^{-1}.

These analyses indicate that a source of PN is certainly shocked gas. However, the narrower PN profiles in which shocks are detected in SiO, indicate that the origin of PN cannot uniquely be in shocked gas, but also in more quiescent material via alternative gas-phase route.



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References:
[1] Pasek et al., AsBio 5, 515 (2005)
[2] Turner et al., ApJ 321, L75-L79 (1987)
[3] Fontani et al., ApJ 822, L30 (2016)
[4] Rivilla et al., ApJ 826, 161 (2016)
[5] Charnley et al., MNRAS 270, 570-574 (1994)
[6] Lefloch et al., MNRAS, 462, 3937L (2016)
[7] Rivilla et al., MNRAS 475, L30-L34 (2018)