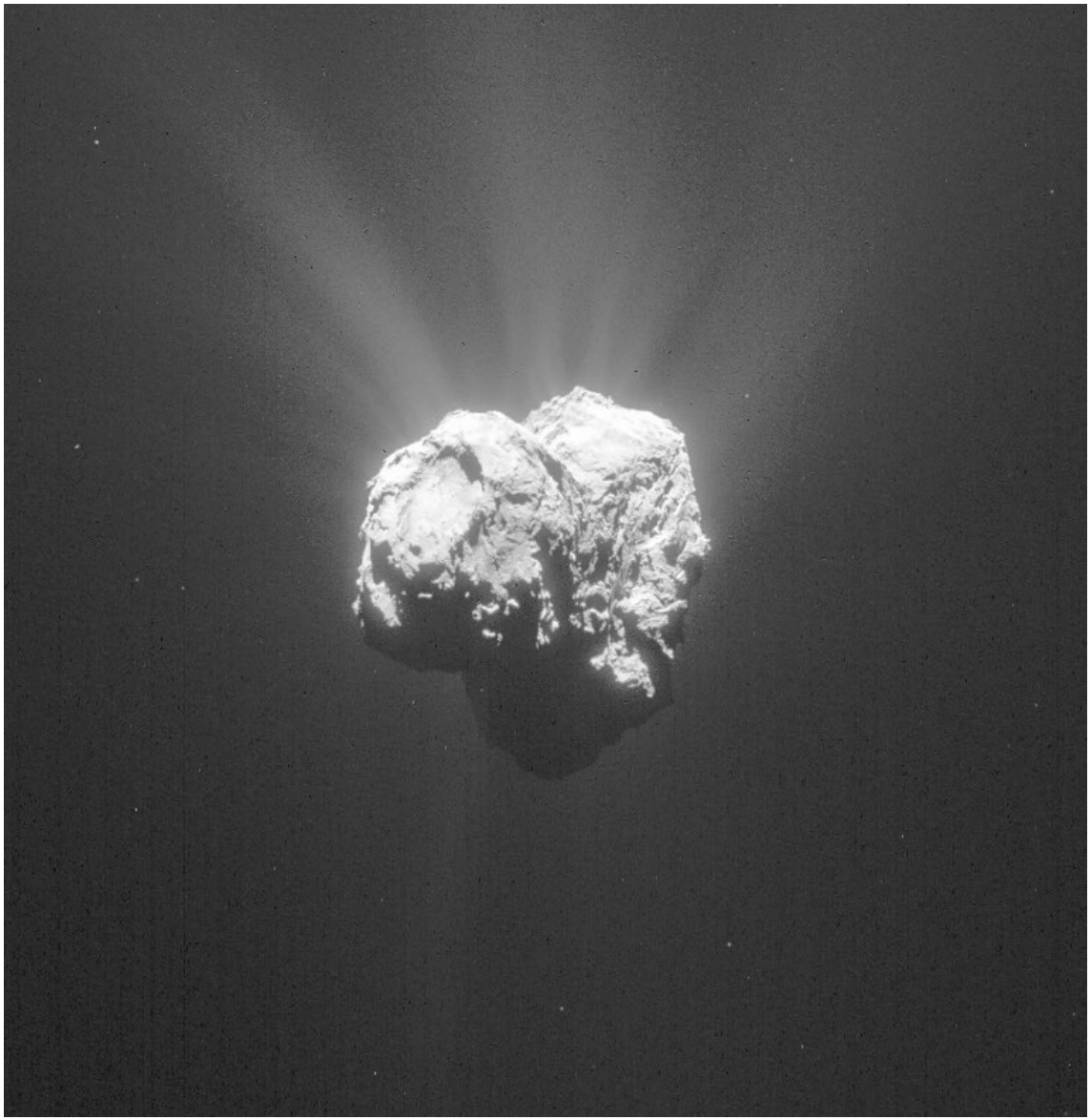
Atomic and molecular spectroscopy of comets

Alan Fitzsimmons
Astrophysics Research Centre
Queen's University Belfast

Comet Structure - Nucleus and inner coma

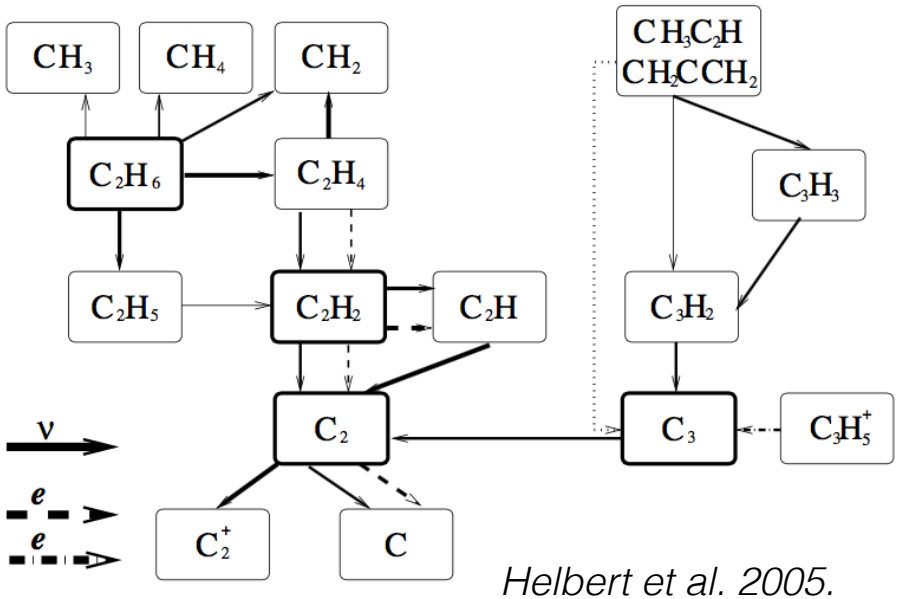


67P from Rosetta - 15/03/2015

Near nuclear surface sublimation and collisional chemistry

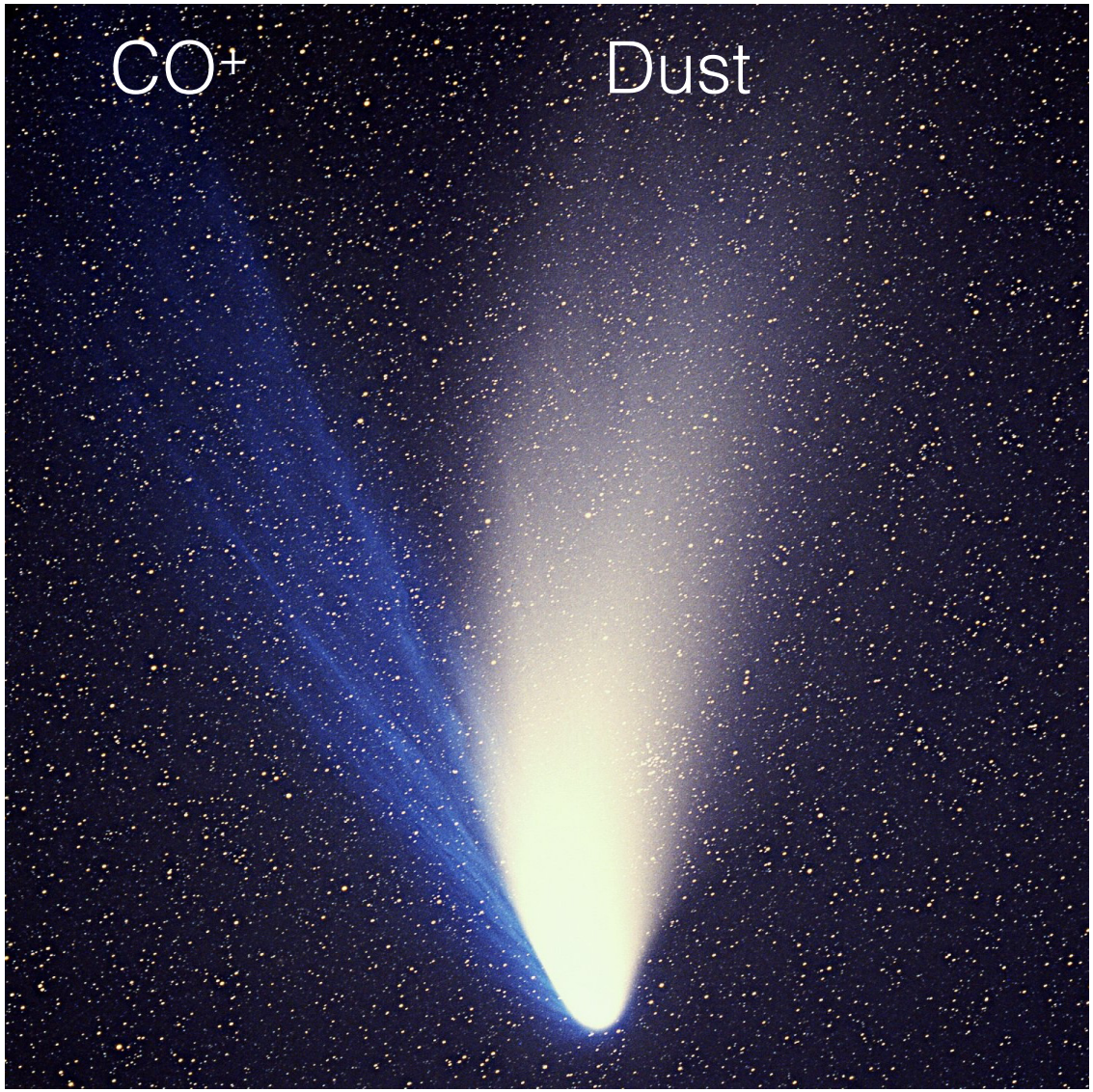
T~200-300K
v~500-1000 m/s
n~10^8 cm^{-3}

Collision Radius ~10^1-10^3 km



Helbert et al. 2005. Astron Astrophys 442, p1107

Comet Structure - Coma and Tails



Beyond ~10^3 km, simple photodissociation and photoionisation dominates chemical/atomic structure of the coma.

$$H_2O + \gamma \rightarrow OH + H$$

$$(OH + \gamma \rightarrow O + H)$$

$$H_2O + \gamma \rightarrow O[^1D] + H_2$$

$$H_2O + \gamma \rightarrow H_2O^+ + e^-$$

Primary Excitation Processes

1. Collisional Excitation

Occurs due to H_2O and/or CO in inner coma.

2. Radiative Vibrational Excitation

Fundamental vibrational bands in *IR* excited by direct solar radiation.

3. Resonance Fluoresence

Established by solar pumping and spontaneous decay, seen in the *optical*.

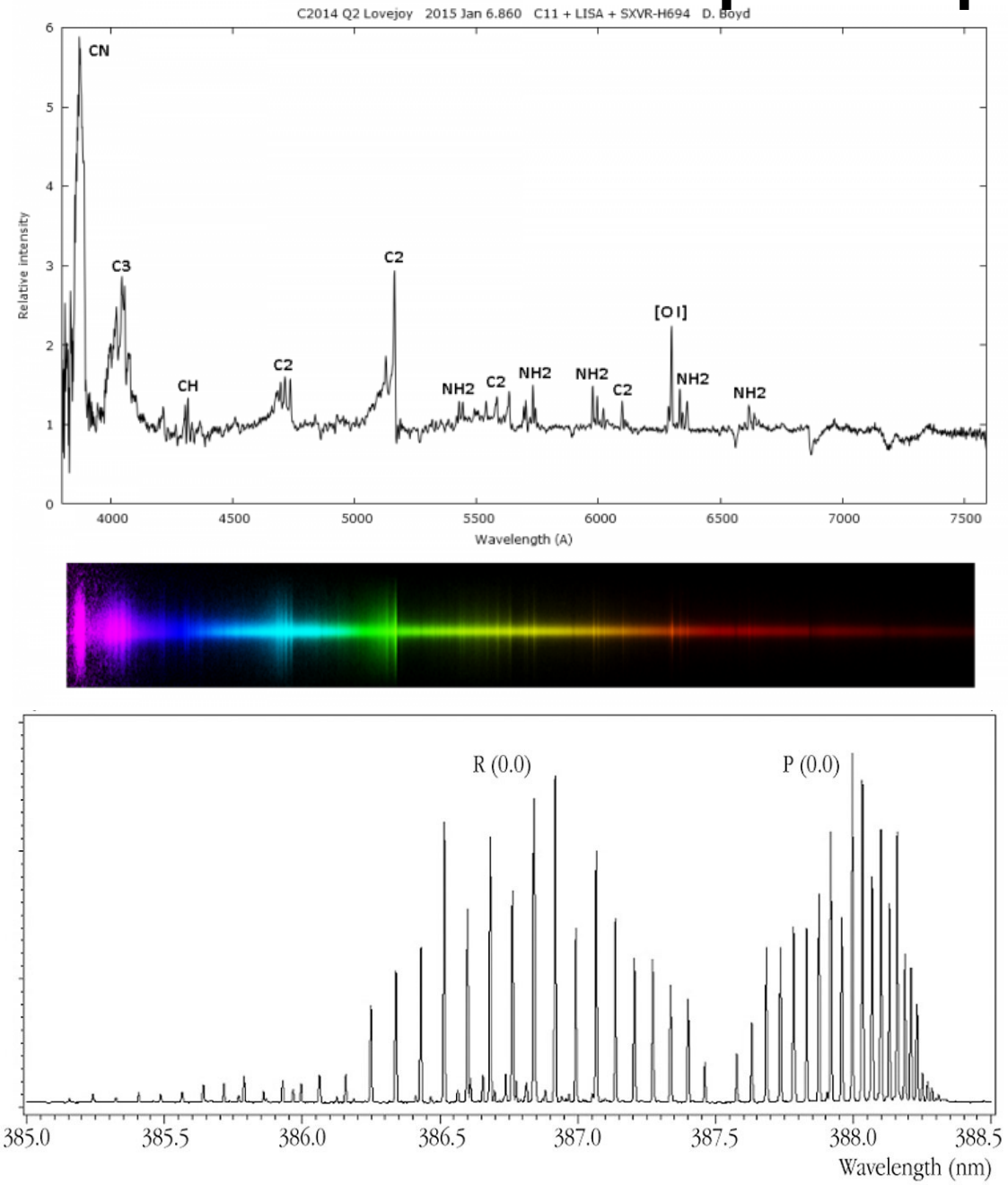
4. Radiative Electronic Excitation

Excitation of electronic transitions in *UV* by solar radiation.

5. Charge Exchange

Observed in *X-rays* between solar wind ions and radicals in outer coma.

Optical Spectra



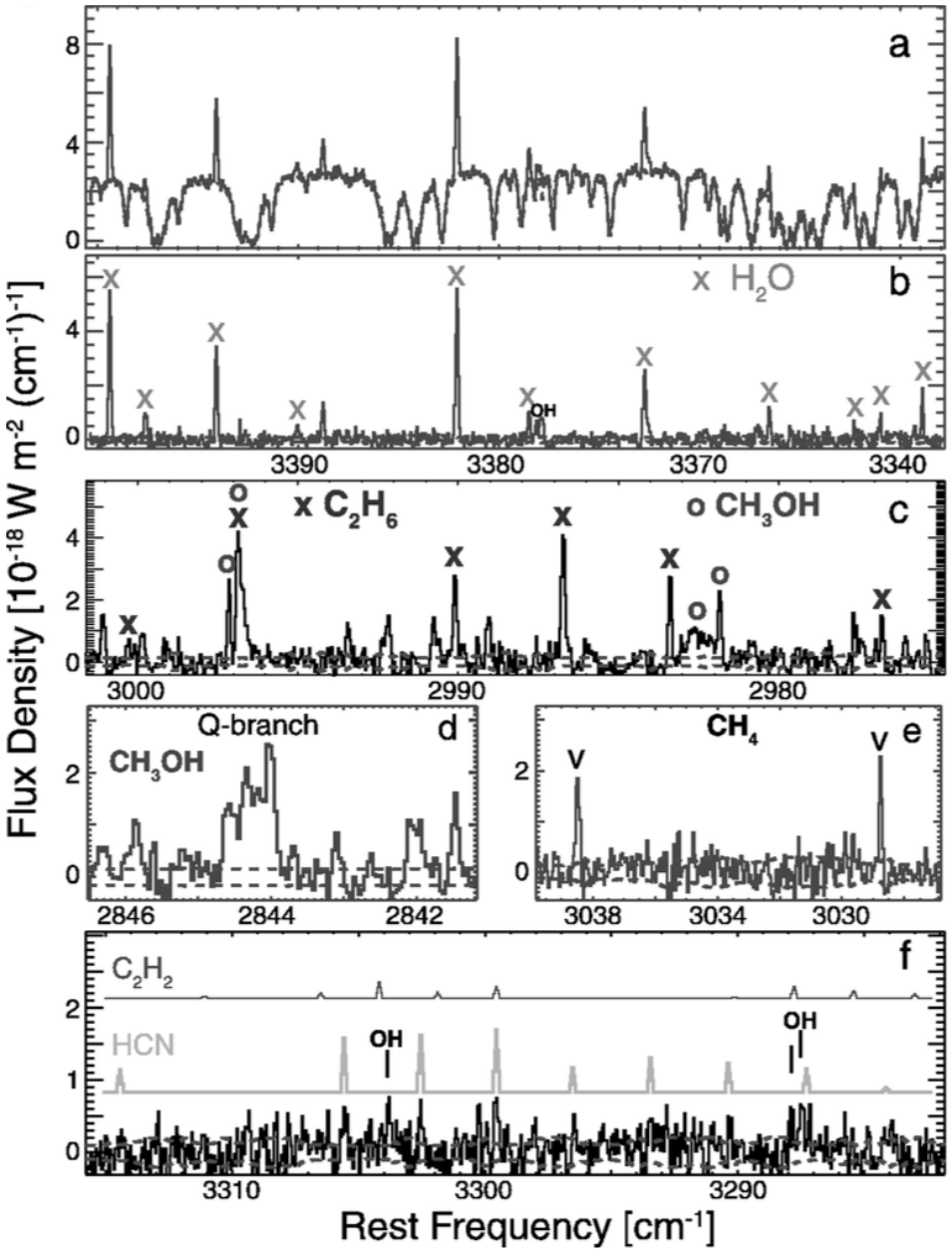
Dominated by electronic -vibrational transitions in photodissociation products

Almost all emission from resonance fluorescence with solar photons.

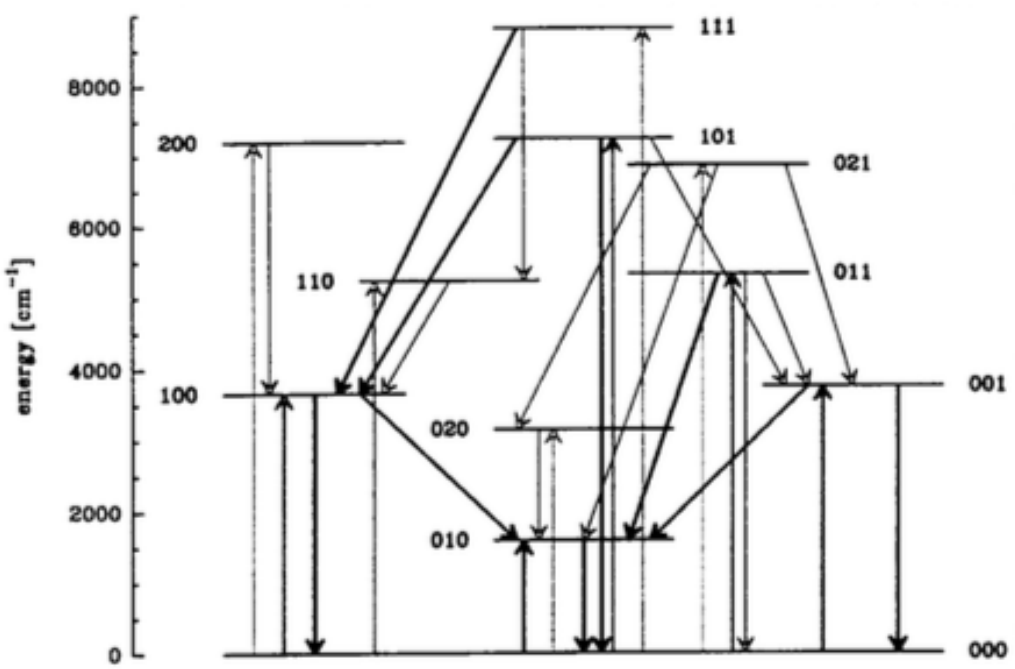
Matching to fluorescence excitation model gives column densities

Ro-vibrational structure at high resolution allows detailed comparison with excitation model, plus C,N isotope measurement.

IR Spectra

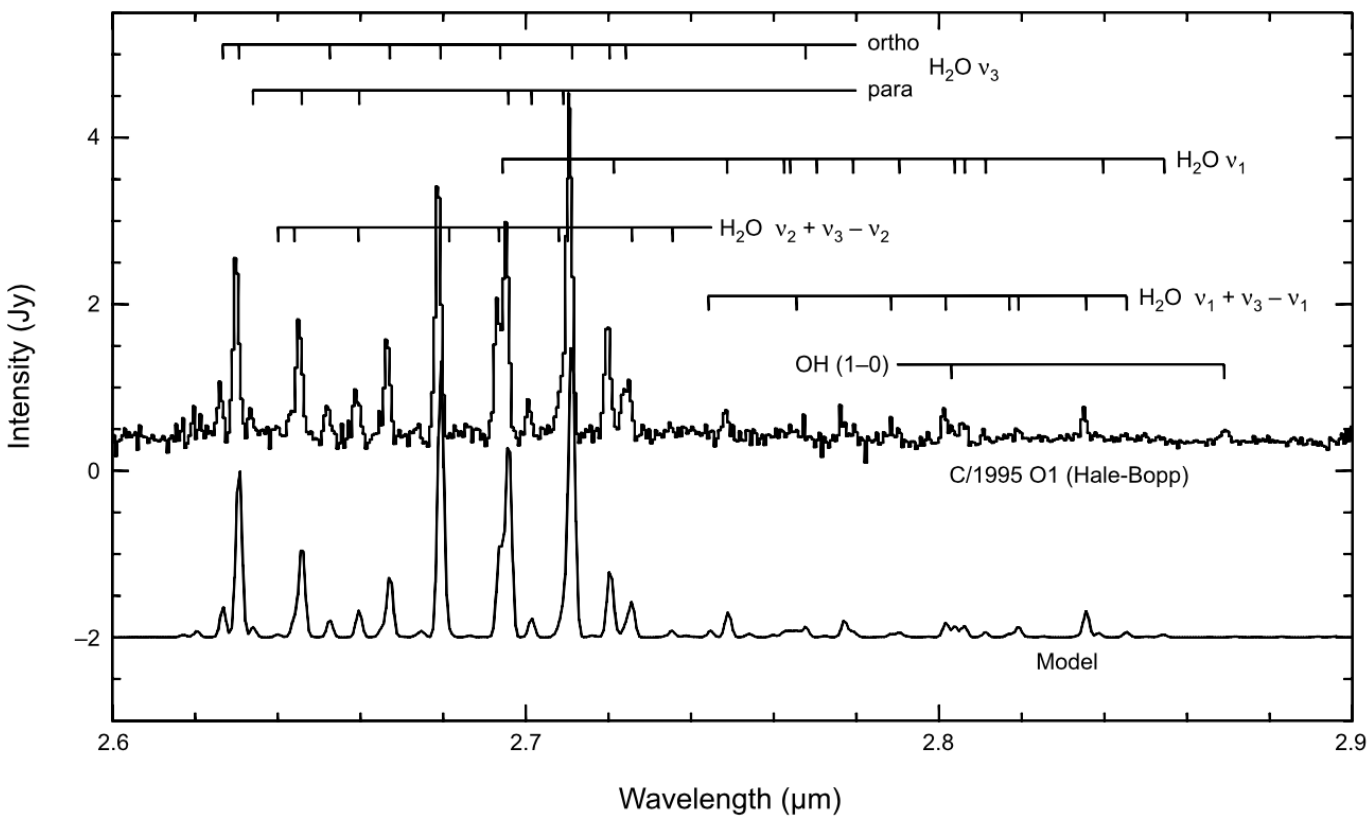


Fluorescence of hot vibrational bands of parent comet species.



Bonev et al. 2008, ApJ Lett. 680, L61.

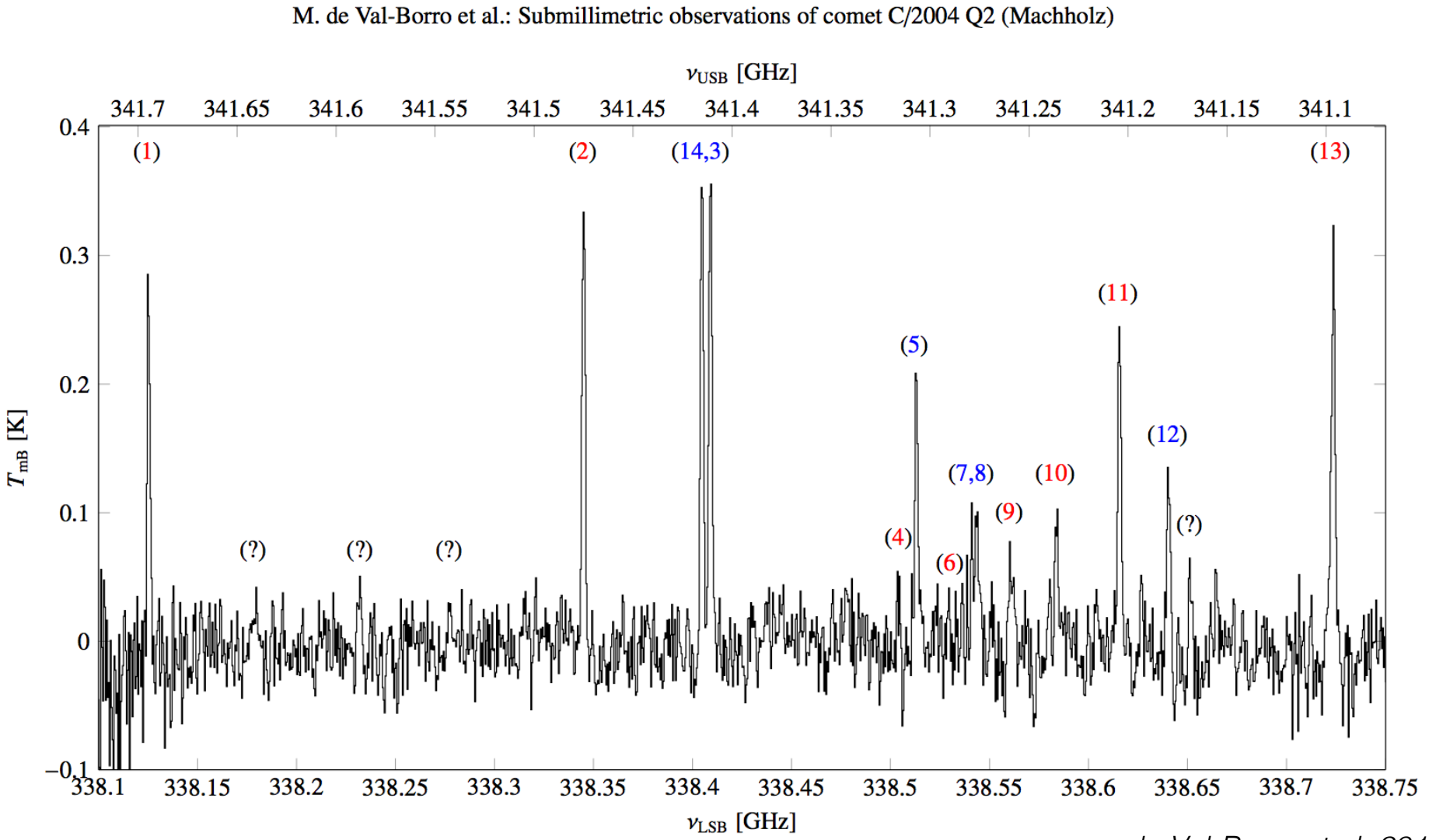
IR Spectra



Observations of bright comets allow Ortho/Para ratio measurements, leading to formation temperature estimates.

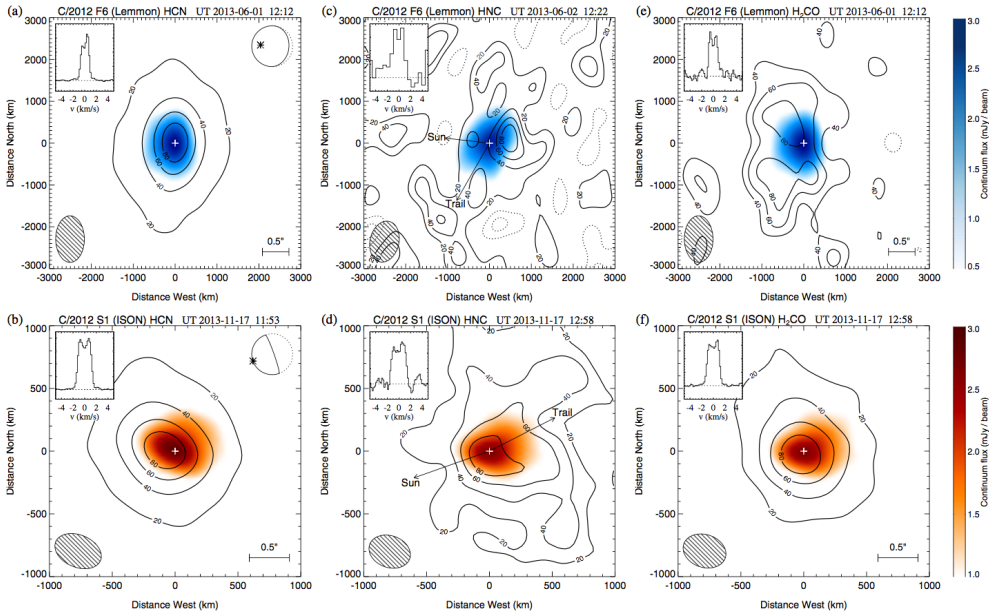
Bocklee-Morvan et al. 2006, Comets II p.396

Sub-mm Spectra



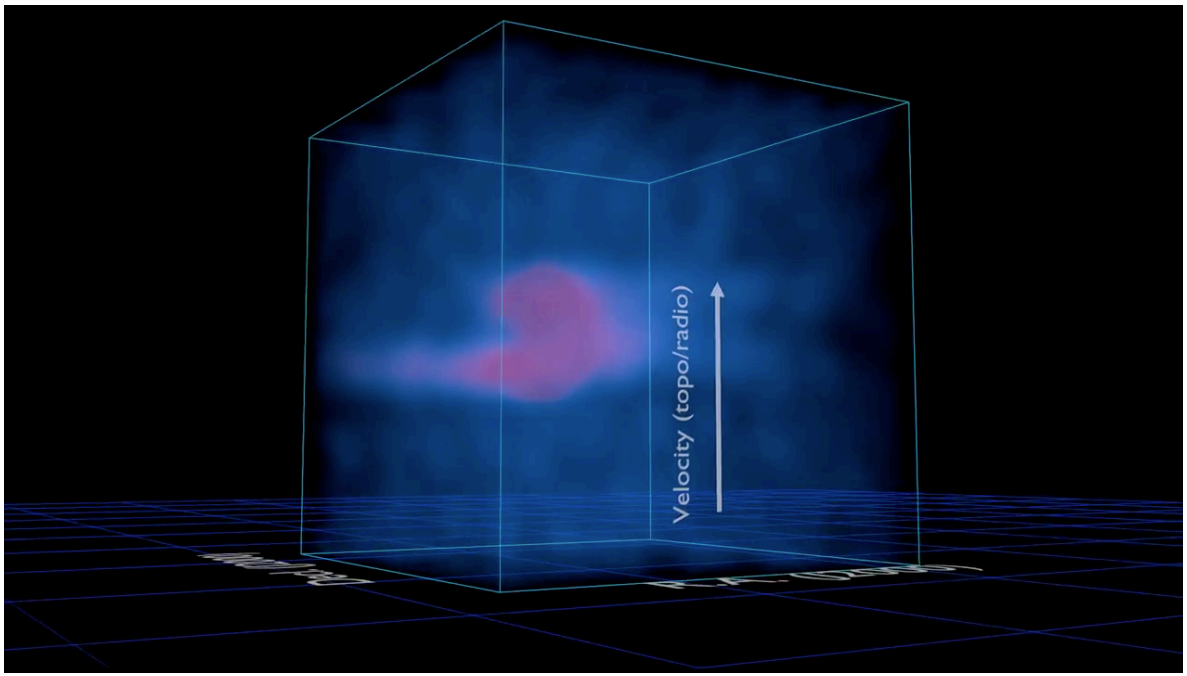
de Val-Borro et al. 2012.
Aston Astrophys 545, p2.

Sub-mm Spectra

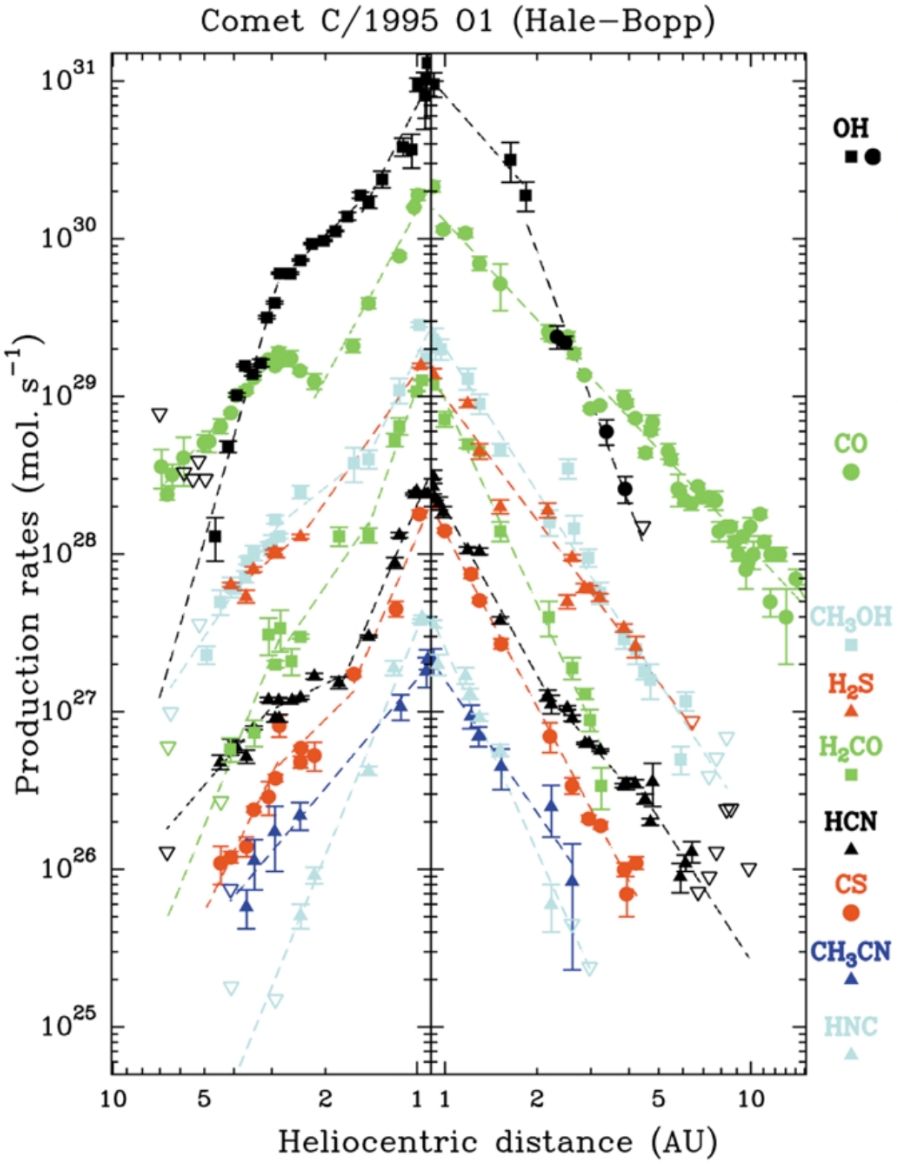


Alma now providing first high quality spatial maps of inner coma molecular distribution.

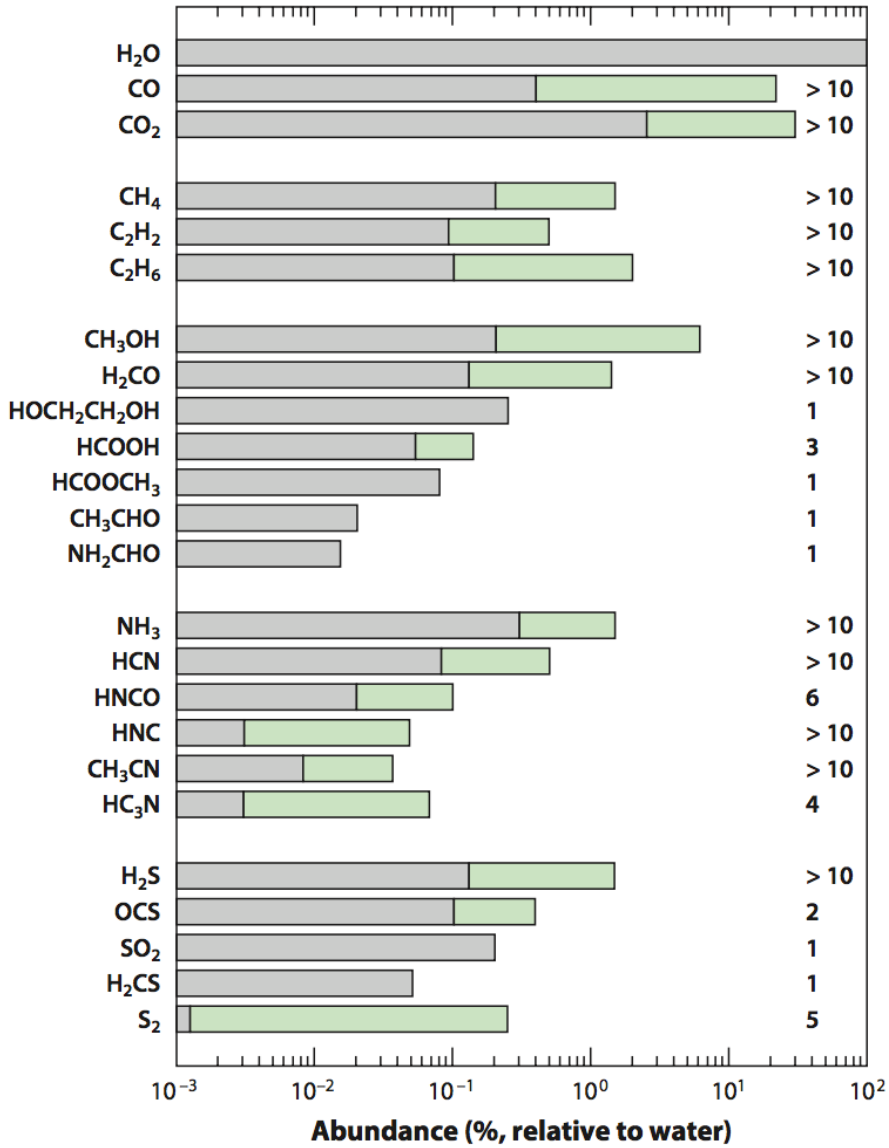
Cordiner et al. 2014
ApJ Lett. 792, L2



Comet Molecular Abundances

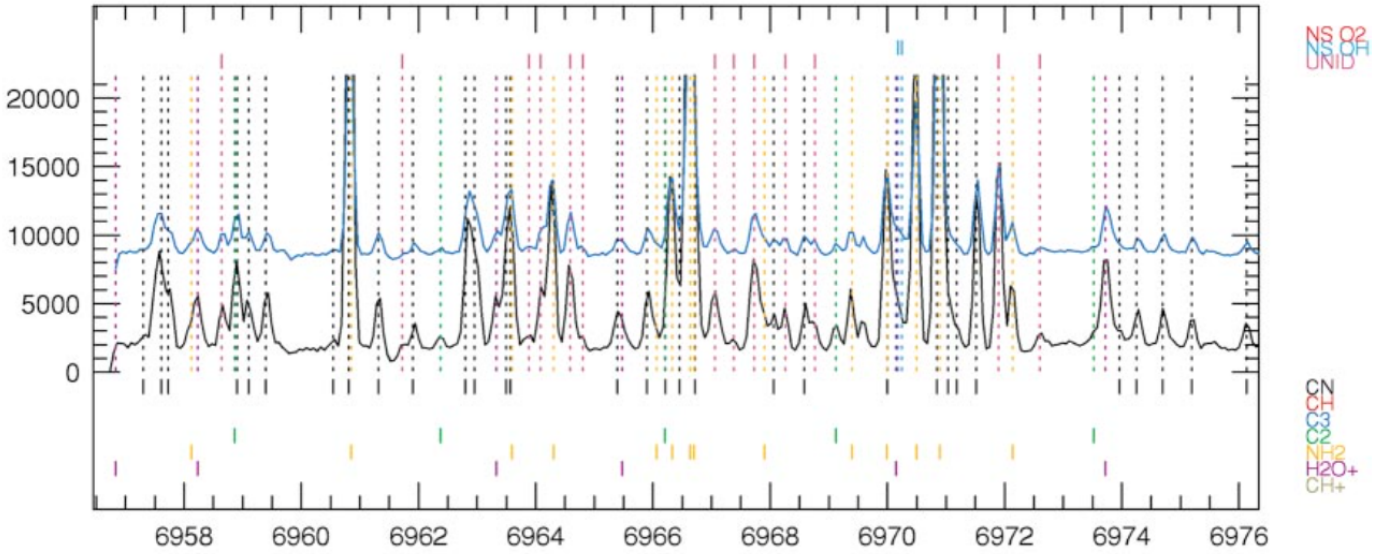


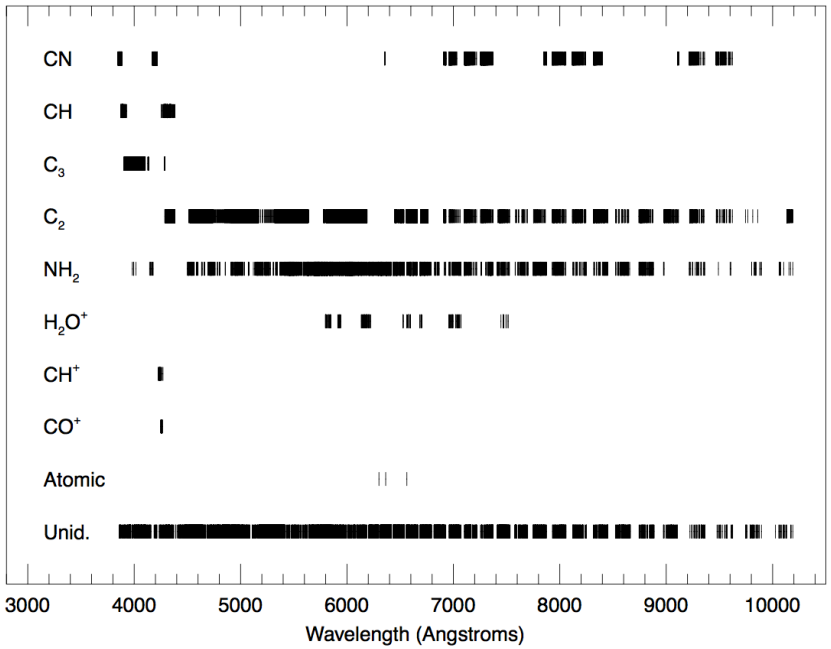
Biver et al. 2002.
Earth Moon & Planets 90, p5.



Momma & Charney 2011.
Ann Rev. A & A 49, p471.

Optical Spectra - unknown lines





~10%-20% of lines in high-resolution UV-optical spectra unidentified.

Most probably due to uncatalogued NH2 transitions? But…

28 lines of CS2 identified by comparison with laboratory studies (Jackson et al. 2004. ApJ 607, L139).

Summary

- Comet spectroscopy requirements very similar to ISM.
- Column densities and relative abundances require molecular data for UV–Radio transitions.
- Requirement for both theoretical and laboratory measurements for further identification/calculation of photon scattering coefficients.
- Next bright comet at negative declination will swamp field with ALMA and NIR detections and data.