Evolution of water vapor on comet 67P/CG – in the view of Rosetta MIRO

2016 UCAT Summer Student Program

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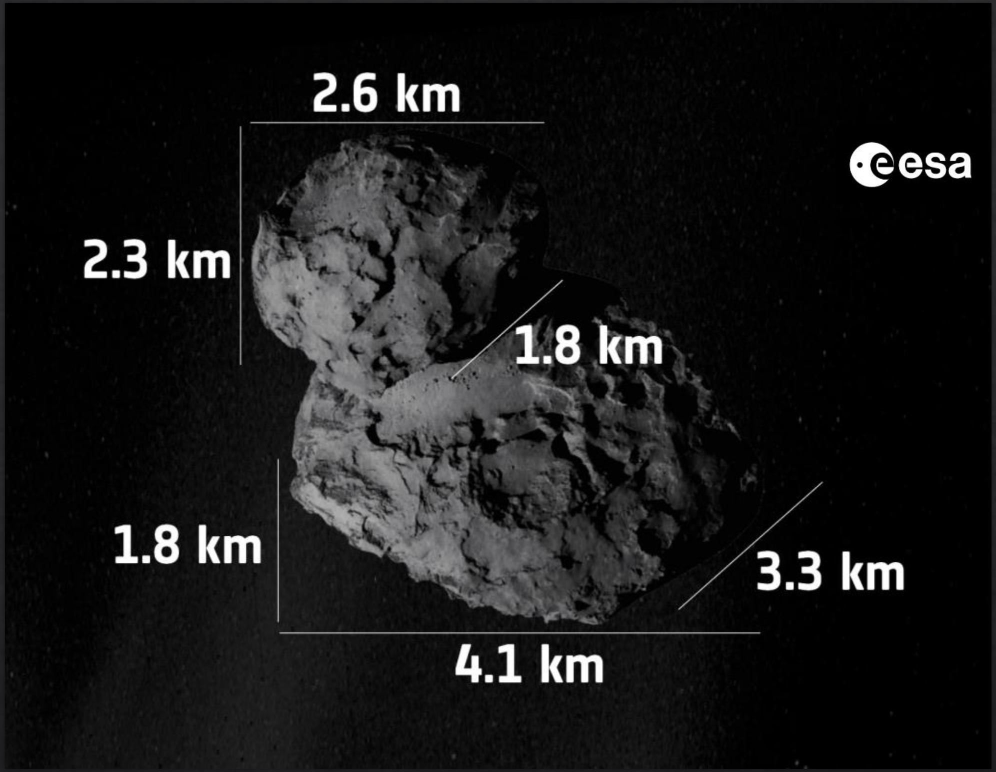
Motivation

- Water outgassing activity on comet 67P
- Comet structures, compositions and origins
- The environment of primitive solar system

Comet 67P/Churyumov-Gerasimenko

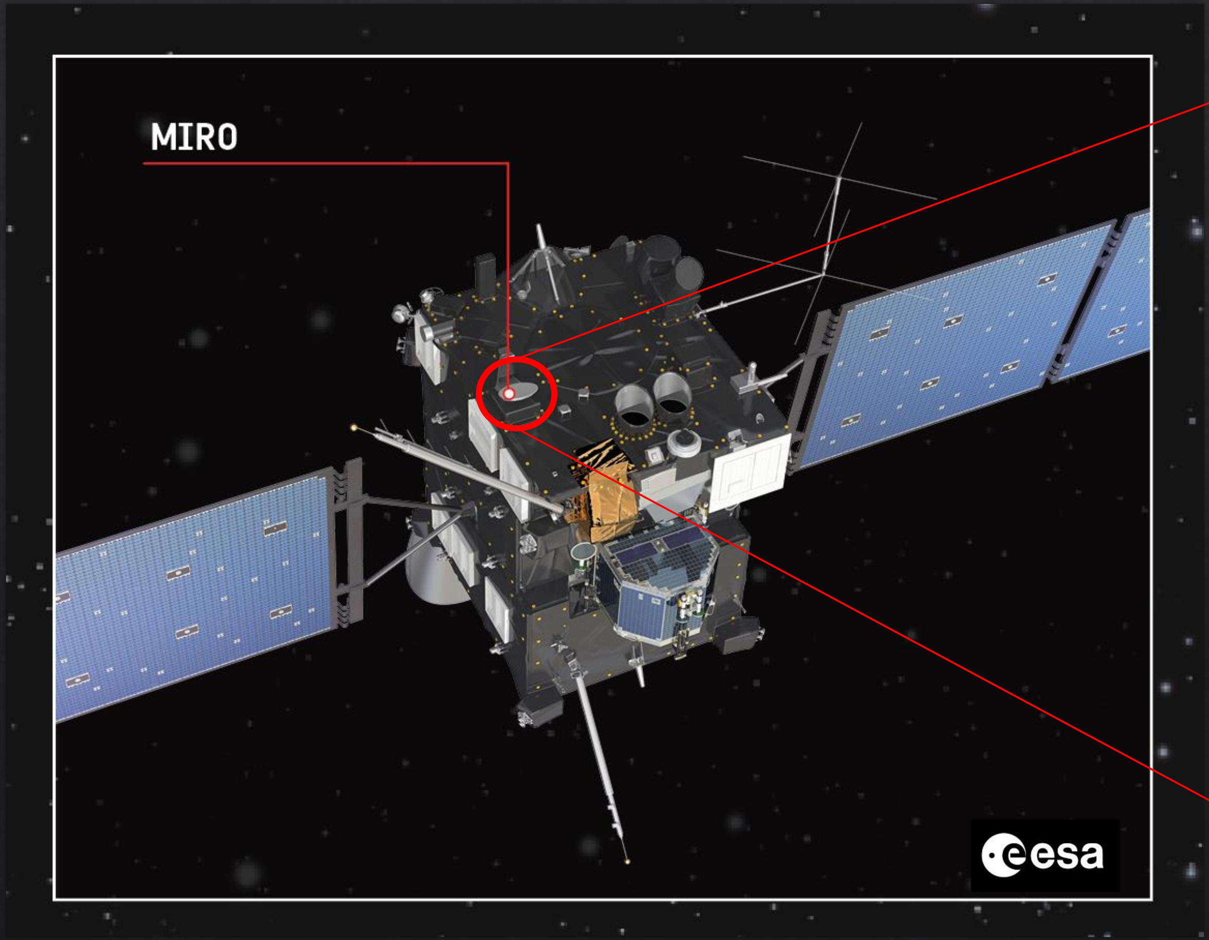
- Orbit period : 6.5 years
- Rotation period : 12.4 hours
- Mass : 1.0 x 10^{13} kg
- Density : 470 kg/m^3
- August, 2014 – Rosetta arrived at the comet.
- 13 August, 2015 – Comet reached its perihelion at 1.24 AU from the Sun.



Credits for individual results:
Shape model and rotation properties: OSIRIS
Mass: RSI
Density: RSI/OSIRIS
Comet images: NavCam

Microwave Instrument for the Rosetta Orbiter (MIRO)

- Millimeter wave mixer receiver and a submillimeter heterodyne receiver



MIRO's Science goals

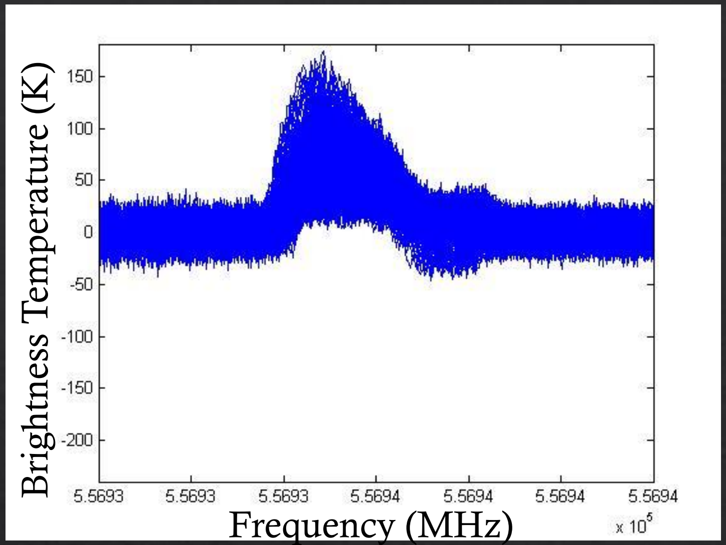
- Measure H_2O, CO, NH_3, CH_3OH in the coma – gas abundance, outgassing rate, isotopic ratio.
- Measure the near surface temperature of the comet nucleus.

(S.Gulkis 2012)

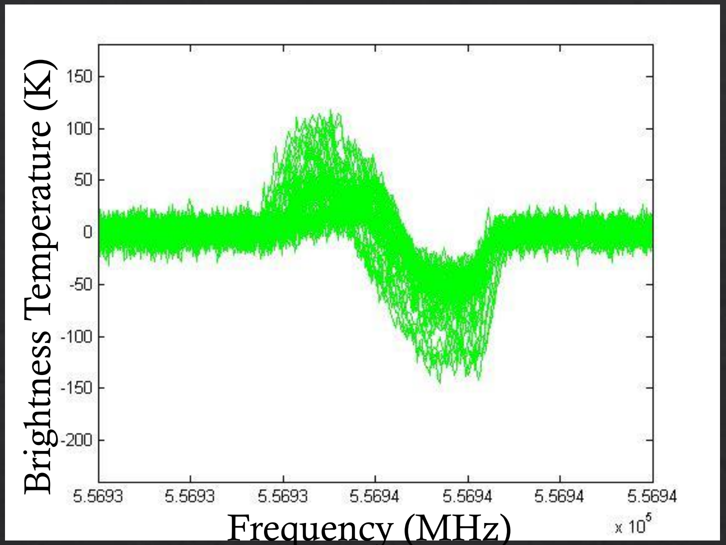
Observations

- Observation time : 10h35 – 14h22 UT on 7 September 2014
- Heliocentric distance : 3.4 AU
- Frequency :
  - H_2O (110-101) line at 556.936 GHz

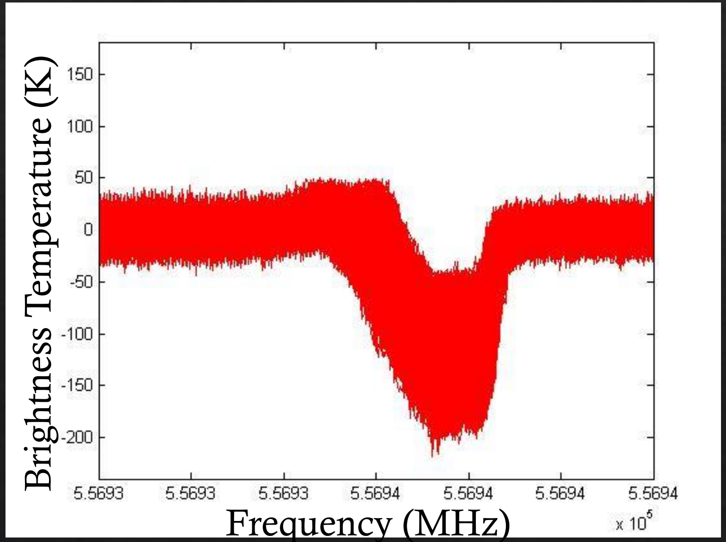
Spectrum types



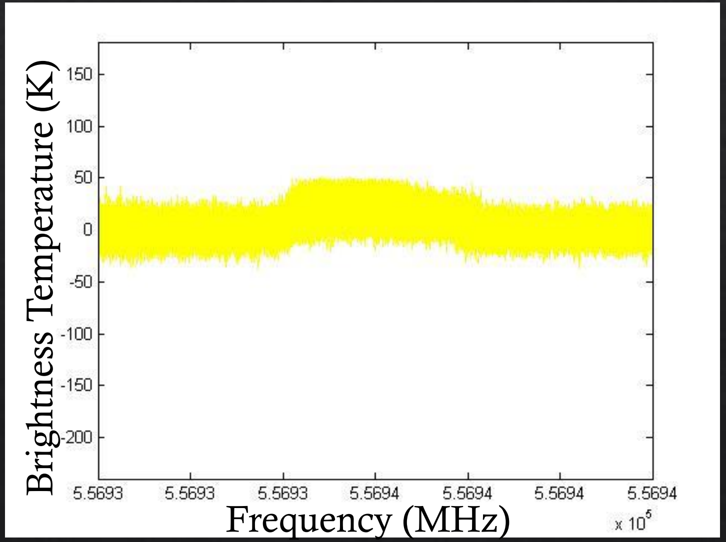
Emission lines (2882 spectra)



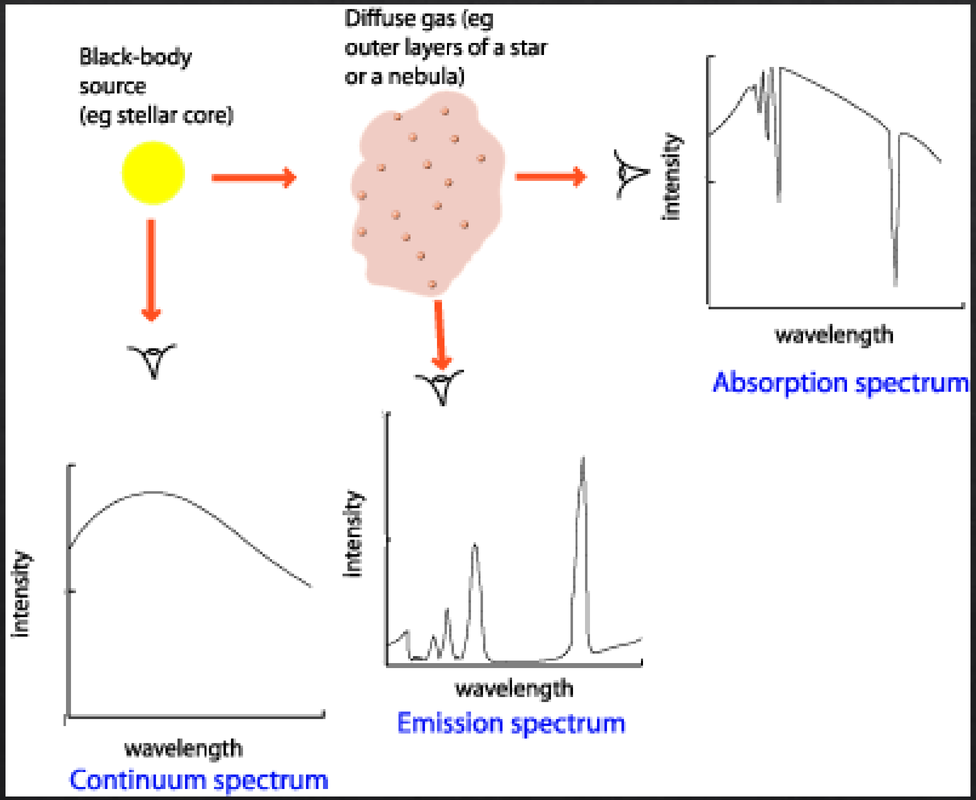
Both emission and absorption lines (63 spectra)



Absorption lines (6257 spectra)

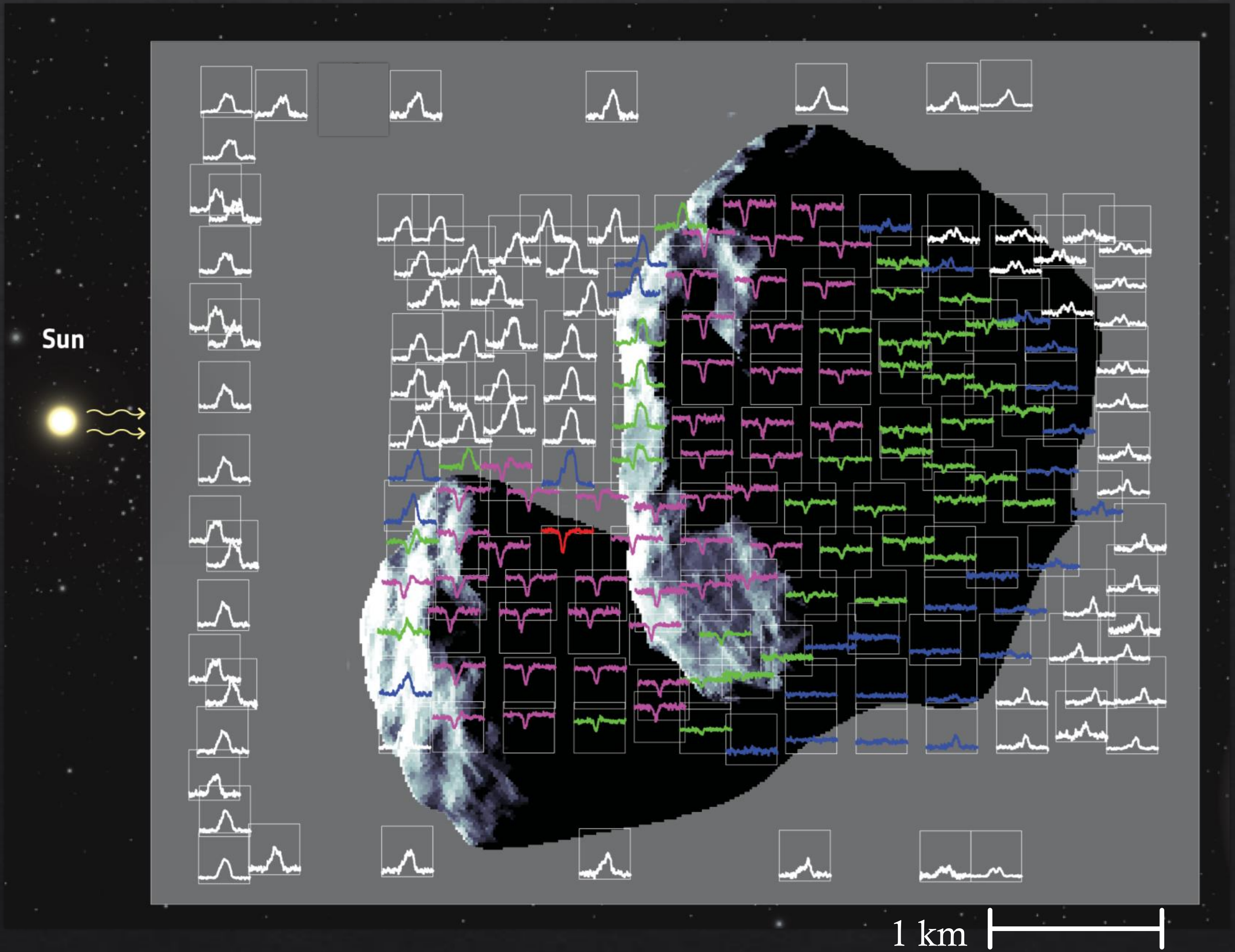


Almost-flat lines (787 spectra)



(James B. Kaler, in "Stars and their Spectra," Cambridge University Press, 1989.)

Map of water vapor around comet 67P



- H_2O line at 556.936 GHz
- 10h35 – 14h22 UT on 7 September 2014

Color scales : temperature of background emission from the nucleus

(white: < 3K, blue: 3-50K, green: 50-100K, pink: 100-150K, red: > 150K)

(N. Biver et al. 2015)

Data stacking and fitting

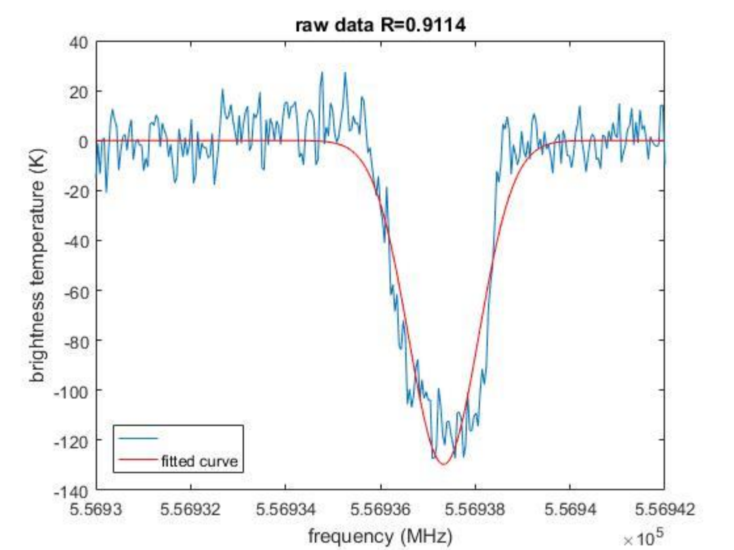


Fig.1. Raw data R= 0.9114
(30s , 44kHz spectral resolution)

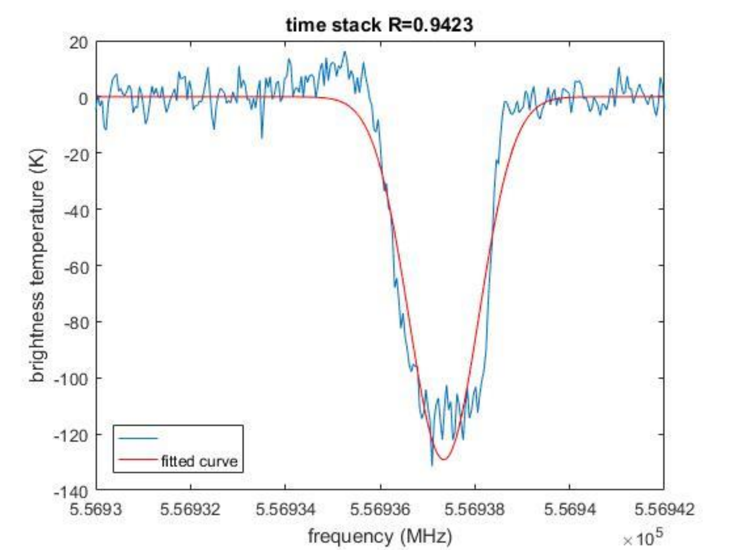


Fig.2. R= 0.9423
(120s integrations, 44kHz spectral resolution)

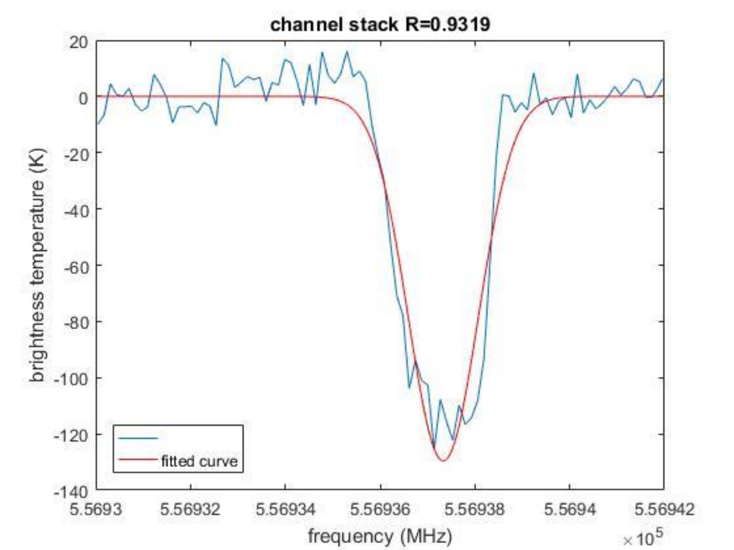


Fig.3. R= 0.9319
(30s integrations, 132kHz spectral resolution)

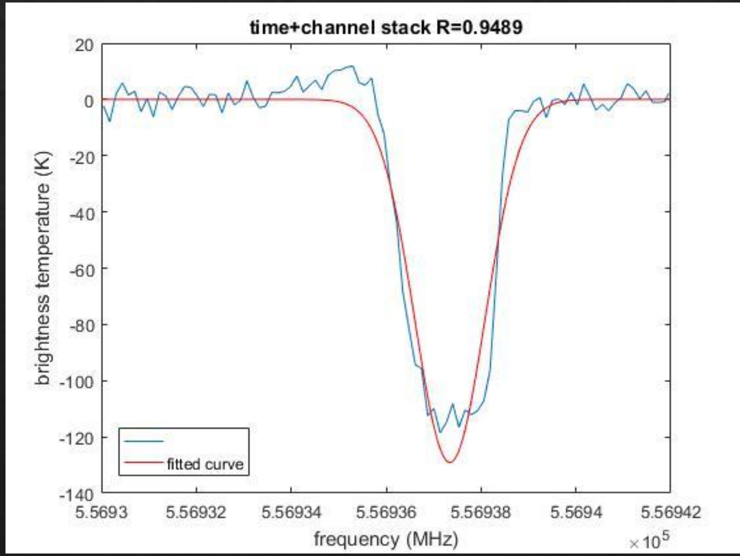


Fig.4. R= 0.9489
(120s integrations, 132kHz spectral resolution)

- Fit line profiles with Gaussian function
- R : Determine goodness of fitting, R close to 1 represents good fitting
- Stacking enhances signal to noise ratio and R value

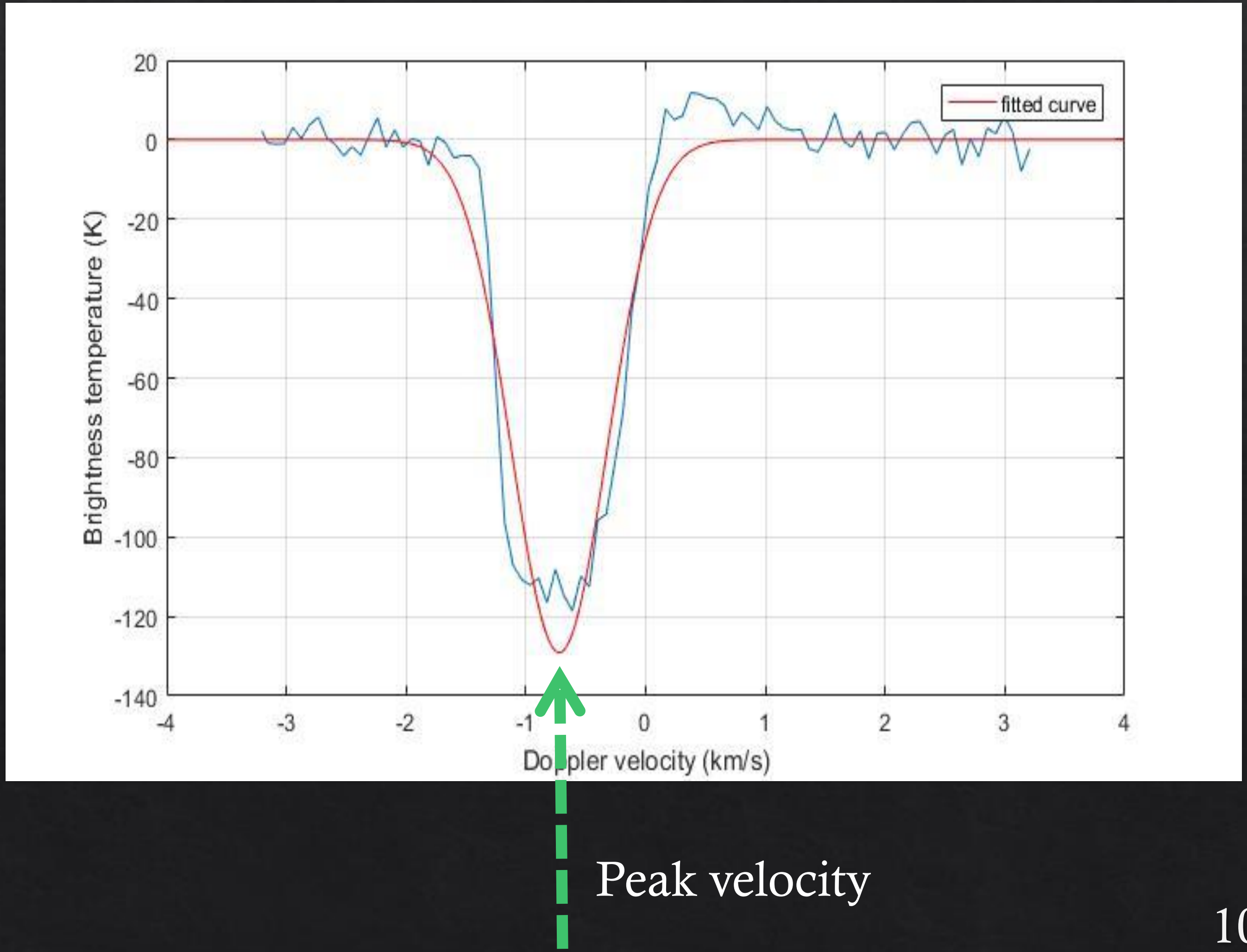
Data stacking and fitting

- Line profiles should be identified as having either emission or absorption component, and be separated apart before undergo the stacking process to avoid losing spatial resolution.

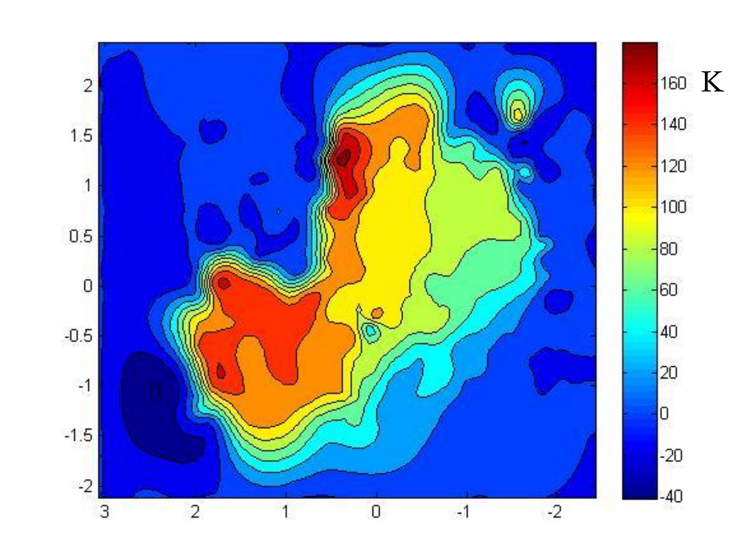
- Stacking line profiles can enhance S/N ratio and fitting accuracy, however over stacking will lead to poor spatial or channel resolution and an unfavorable mapping result.

Retrieved information

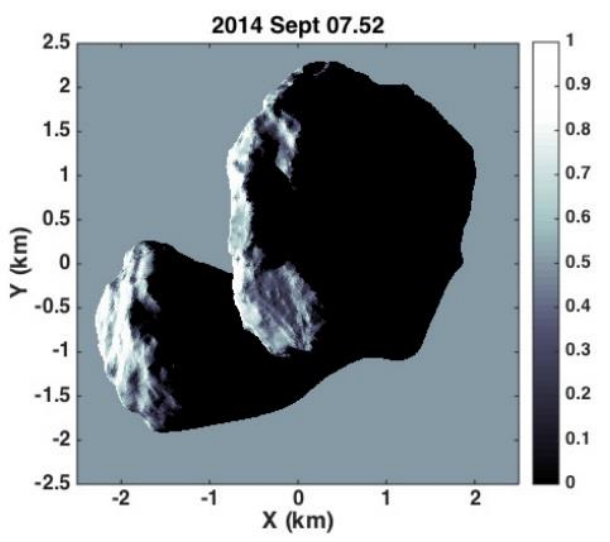
- Peak velocity : Line-of-sight mean gas velocity
  - Positive : redshift
  - Negative : blueshift
- Line area : gas column density and production rate



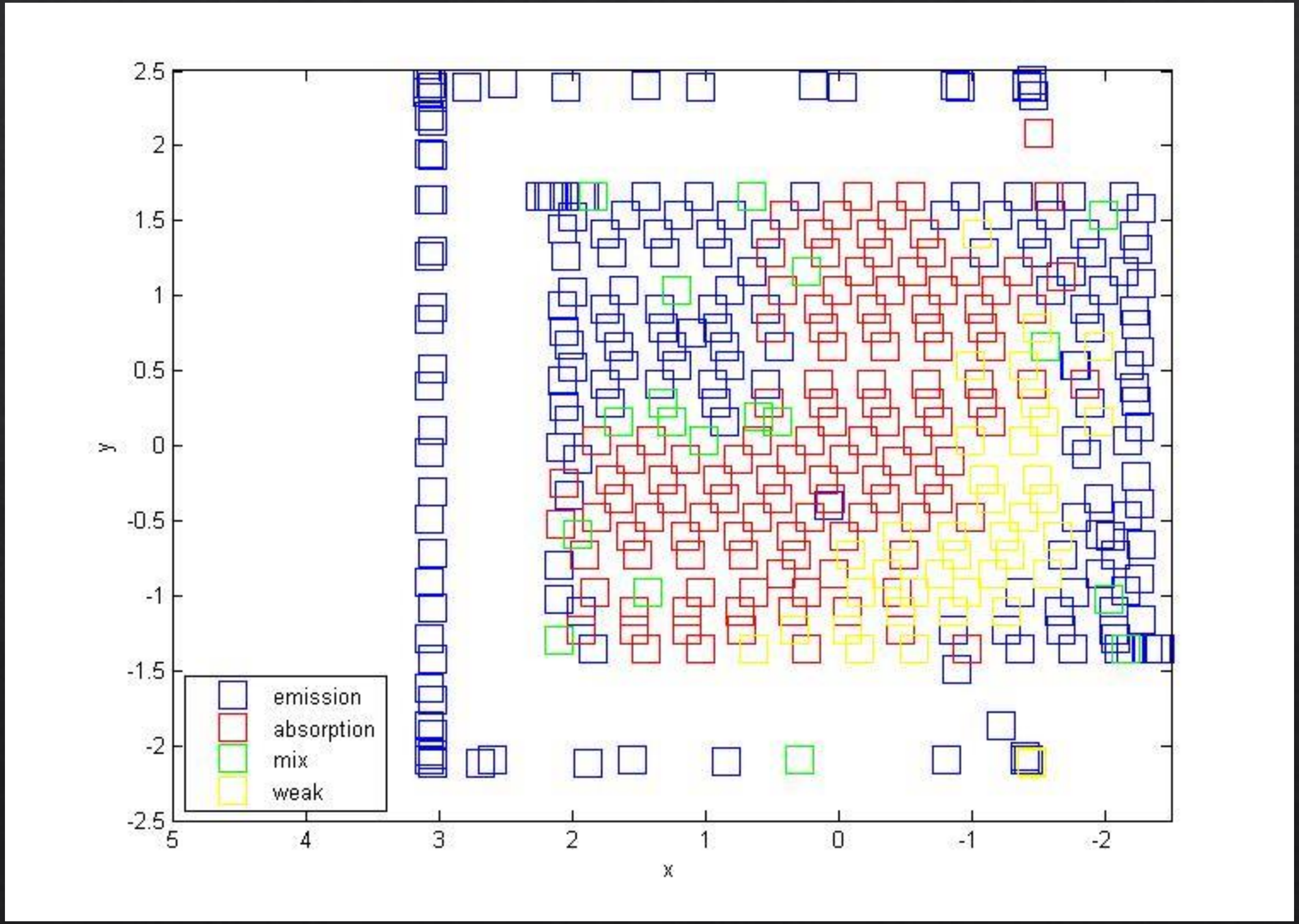
Map of water vapor around comet 67P



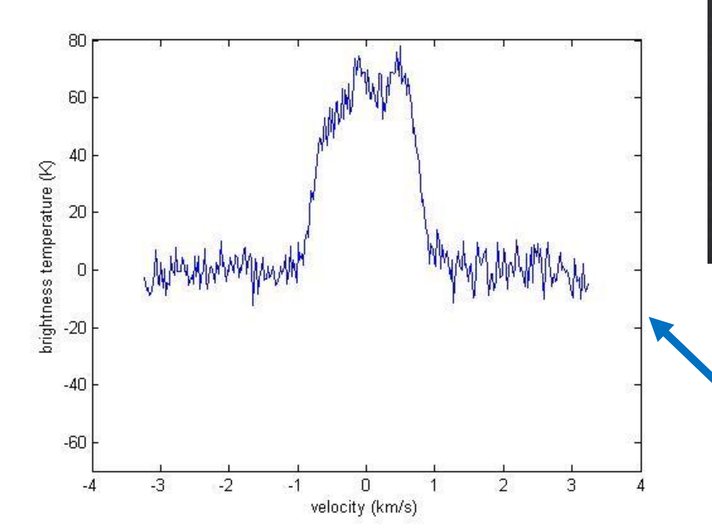
Submillimeter continuum of the nucleus



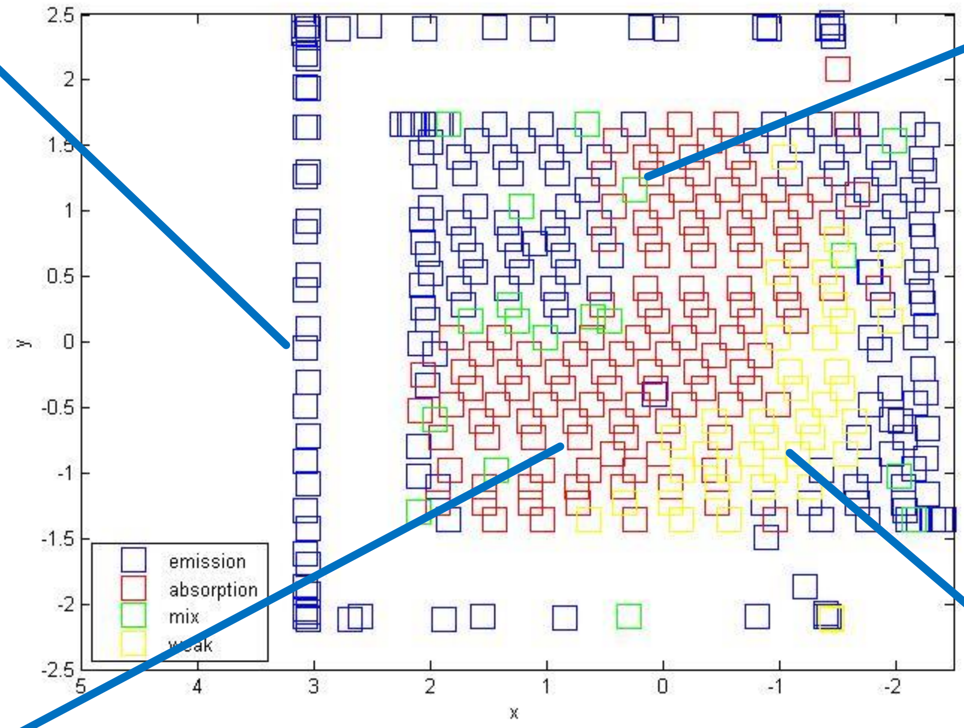
Shape 5 model of 67P at the central time
of the observation 12h30UT (N. Biver et al. 2015)

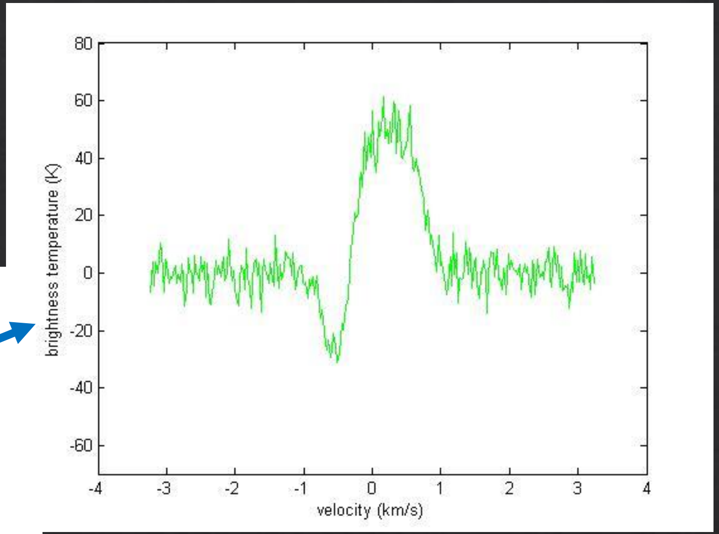


Map of water vapor around comet 67P

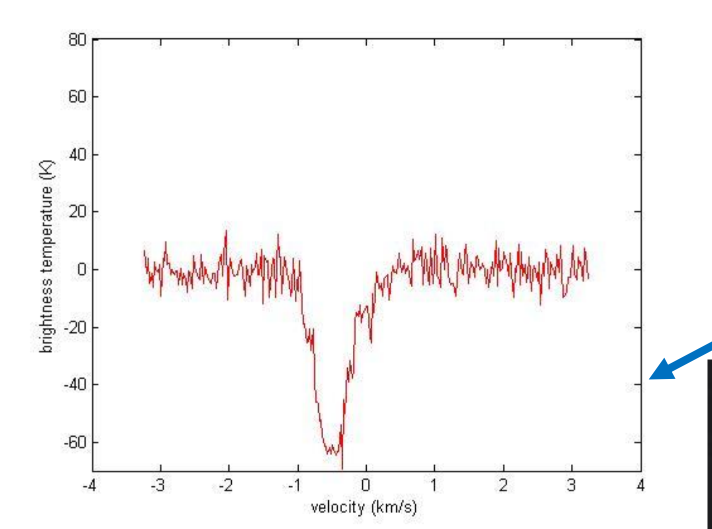


Emission line

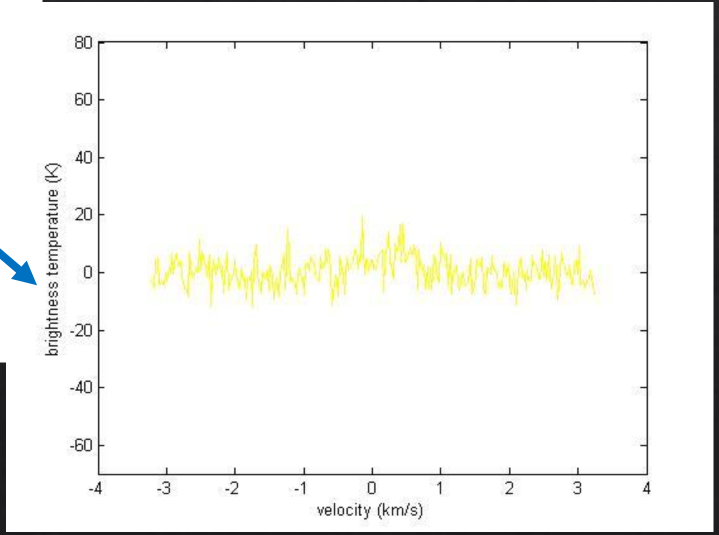




Both emission and absorption line

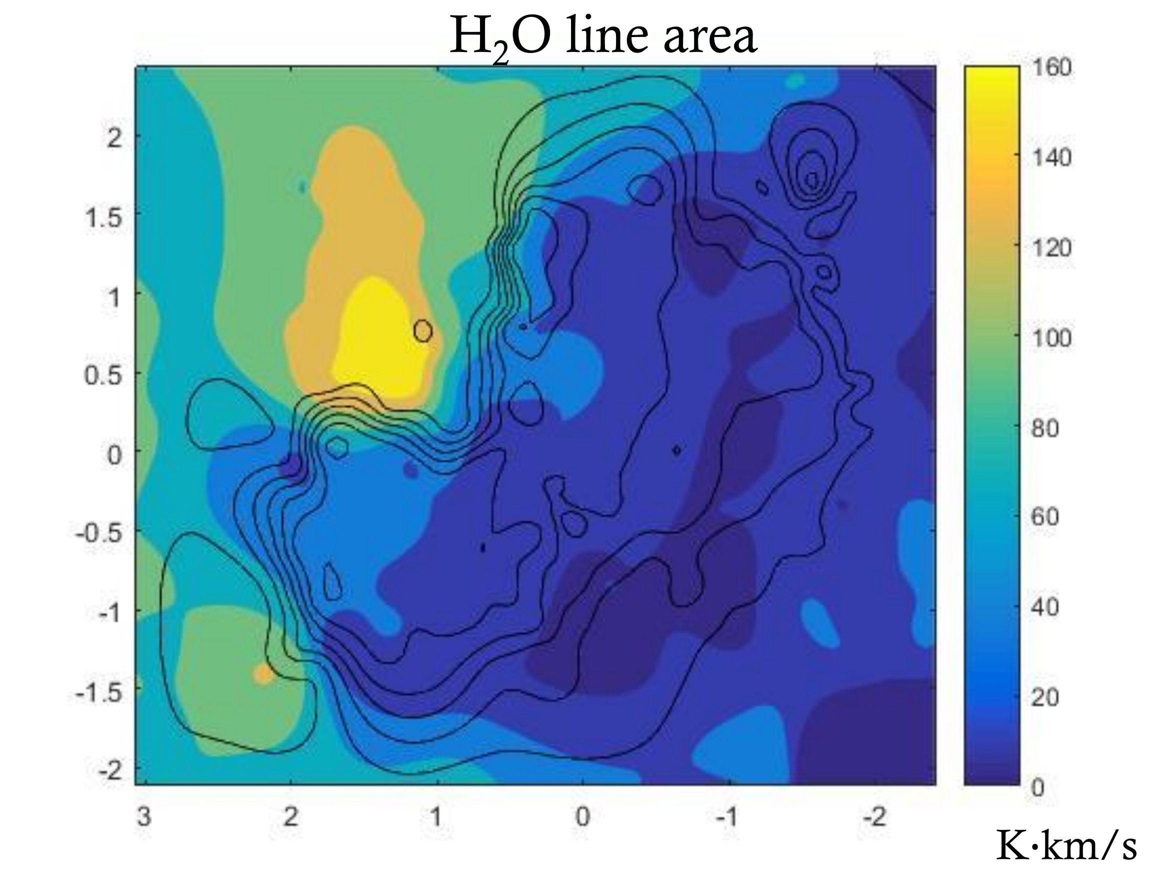


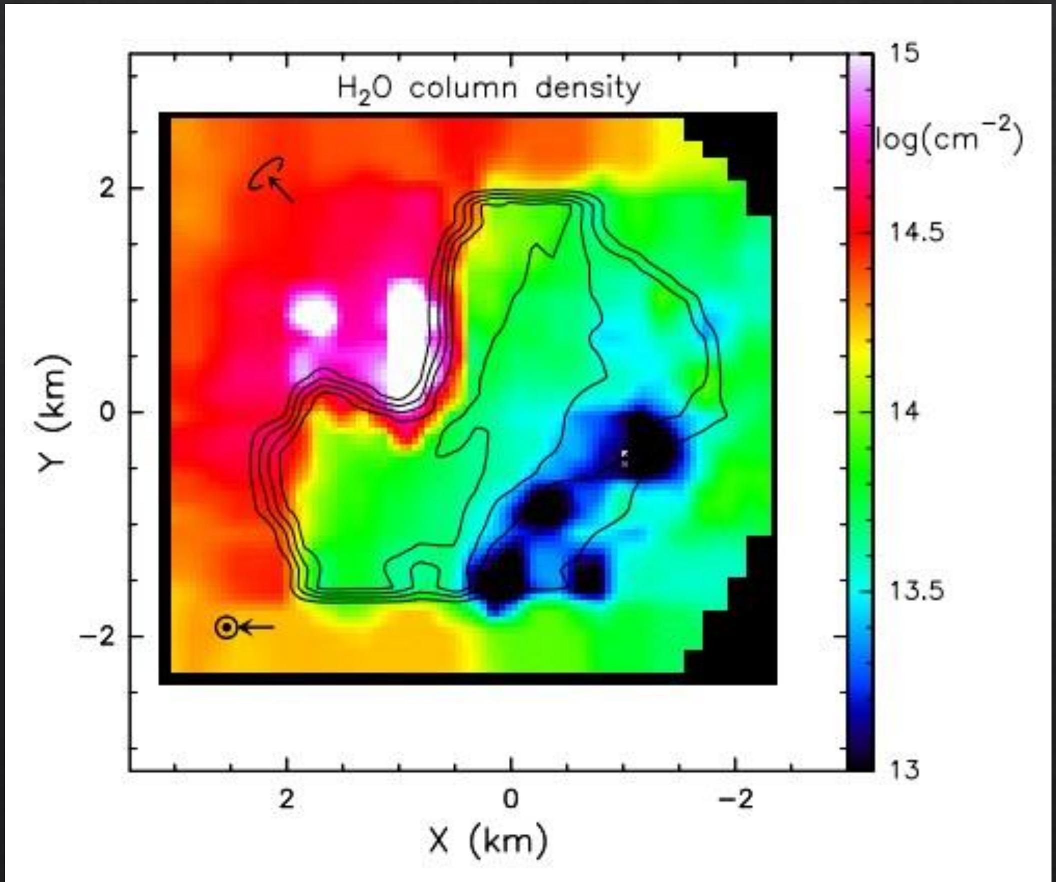
Absorption line



Almost-flat line

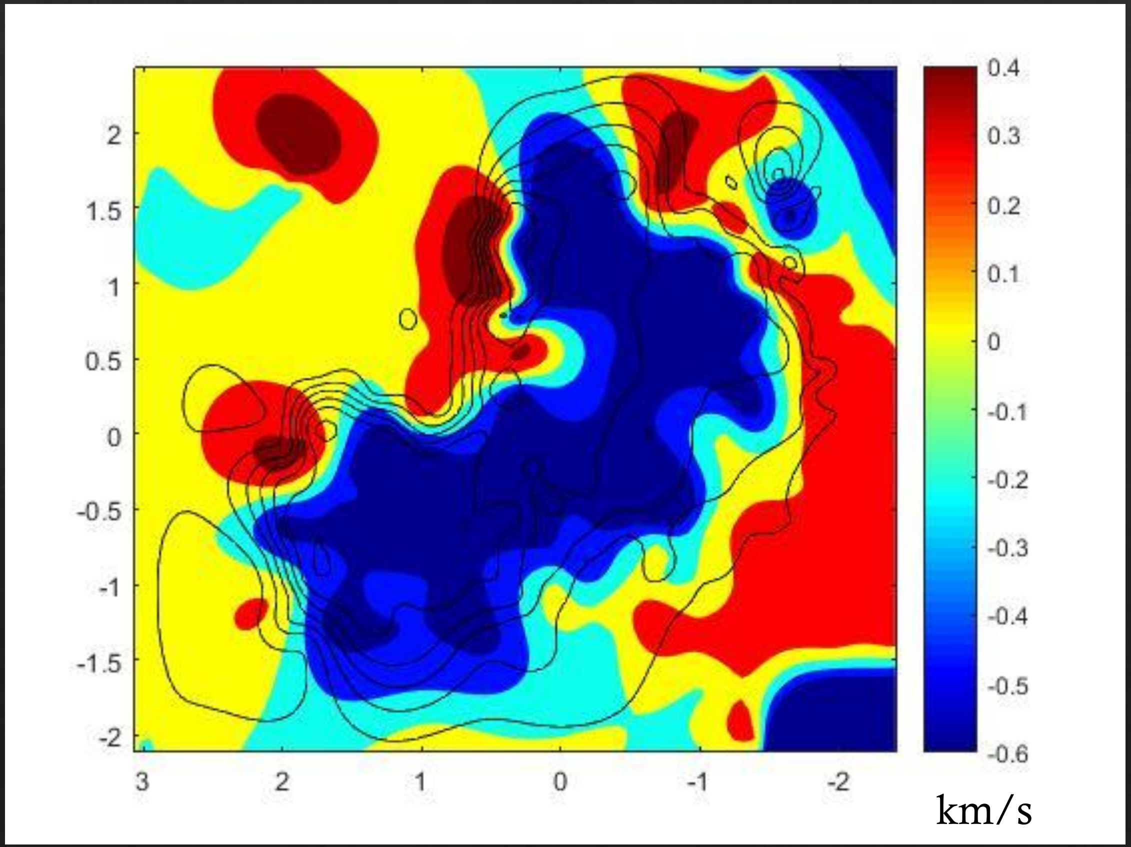
Line area of H_2O line

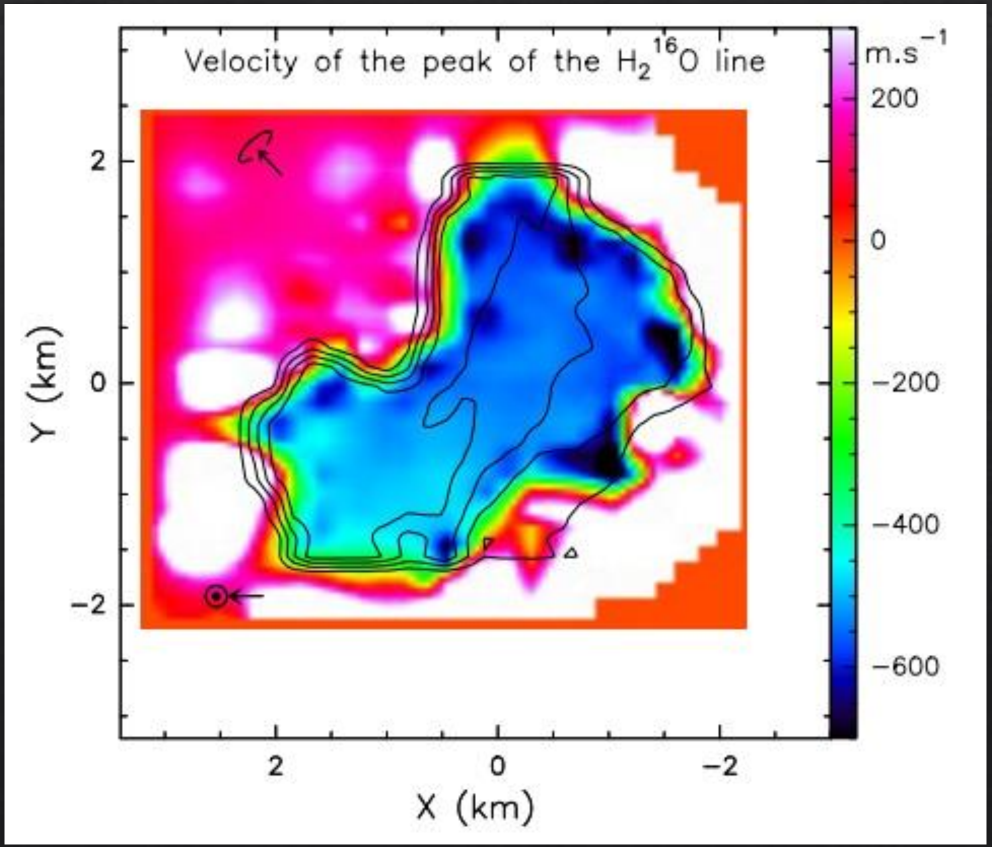




(N. Biver et al. 2015)

Peak velocity of H_2O line





(N. Biver et al. 2015)

Discussion and Conclusion (1)

- The line area of H_2O lines are highly correlated to H_2O gas column density.
- As discussed in Biver et al. (2015), the values of line area on the dayside are higher than nightside. Significant high value is seen in the neck to subsolar region in coma. The concentration of water gas in this region implies that the outgassing activity is not only depends on illumination but also topography.
- When the H_2O density is high, especially on dayside or close to perihelion, the line is optically thick and the line area becomes nonlinearly depend on column density. An alternatively way is to scale the density of H_2O using the $H_2{}^{18}O$ line assuming a certain abundance ratio of them.

Discussion and Conclusion (2)

- Values of the peak velocity of H_2O can be retrieved from Gaussian-fitting.

- Negative velocities (blueshifted) seen in front of the nucleus indicates flow toward the observer. Off the nucleus, most of the velocities are positive (redshifted), which means that the gas moving away from us dominate the spectrum.

Summary

- Gas outgassing activity on comets can be observed and explained by radiative transfer of H_2O molecules.
- Different types of line profiles result from different observation line of sight.
- Line area of H_2O line is correlated with column density when the gas is optically thin.
- Outgassing activity on comets depends partially on illumination, and partially on topography.

Future work

- To analyze more H_2O line profiles in different observation periods as the comet moves through perihelion and beyond.
- To construct a radiative transfer model which can fit and derive gas column density and gas production rate better.

Thank you for your listening!