Observations of the 18cm OH lines of 23 comets

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Background

003-1040559 1250 003-77156.8 1760 0009-14563.7 73273

Motivation

- Primitive solar system bodies
- Early solar system/solar system formation
- Earth's evolution and water origin

Orbits

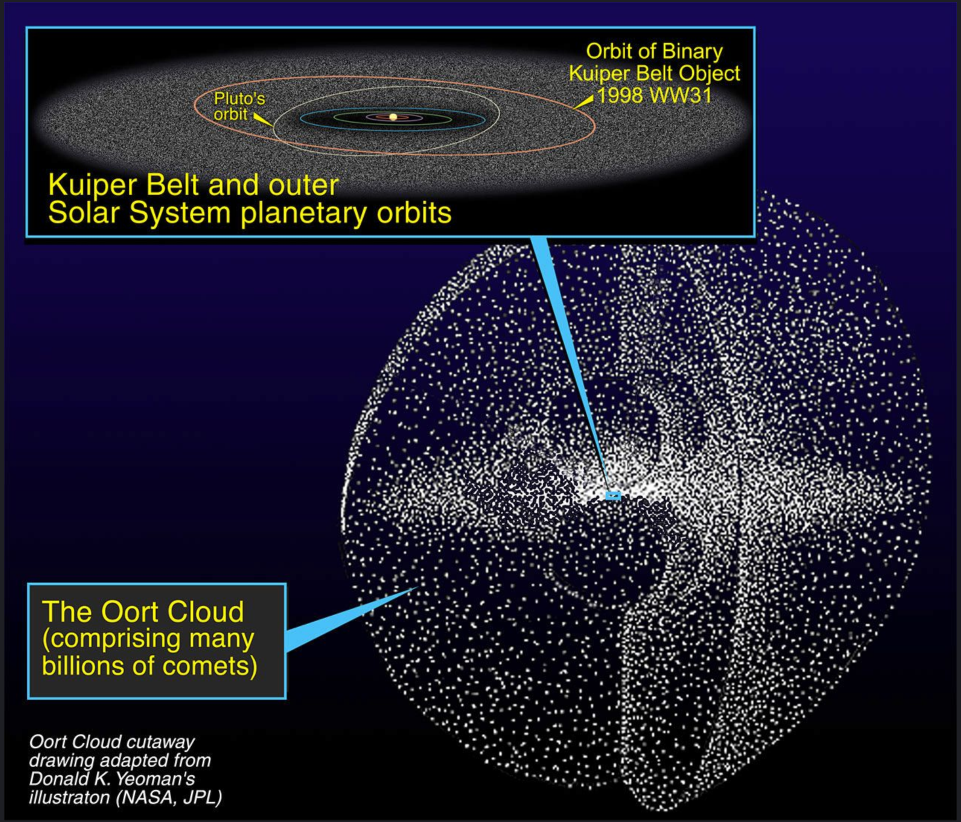

Figure 1: Oort Cloud and Kuiper Belt diagram
Credit: NASA/ESA and A. Feild (Space Telescope Science Institute)

Sample Orbit

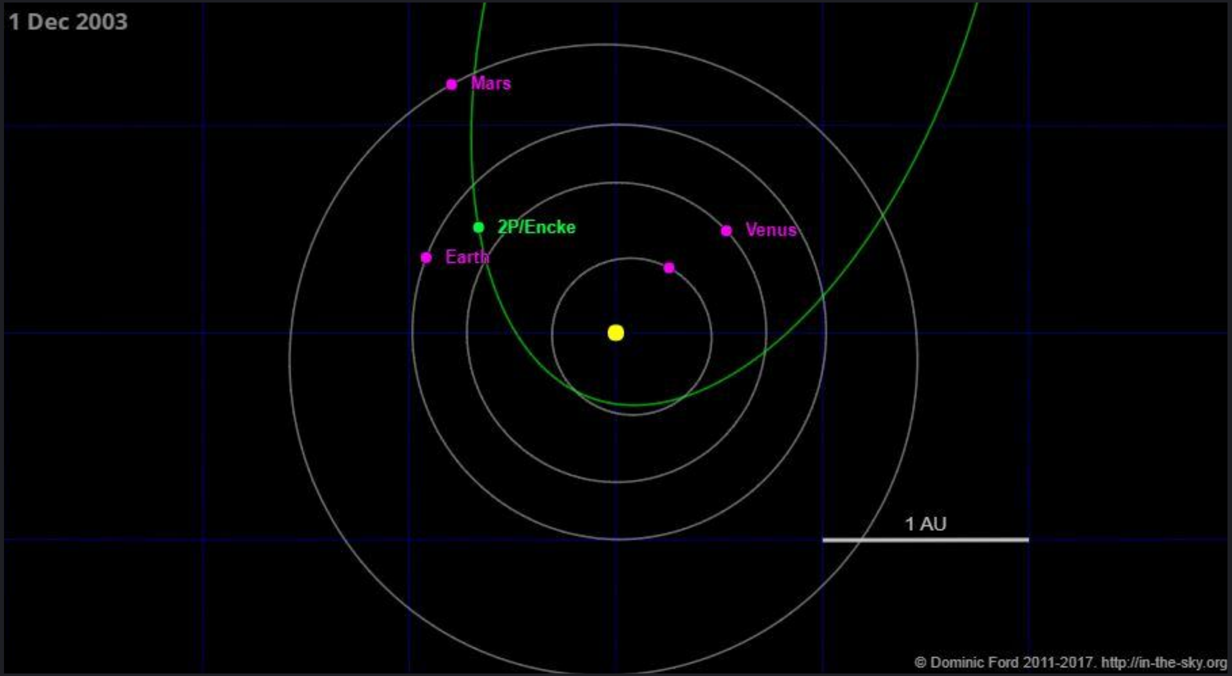

Figure 2: Orbit of comet 2P/Encke
Credit: Dominic Ford, in-the-sky.org

Comet Anatomy

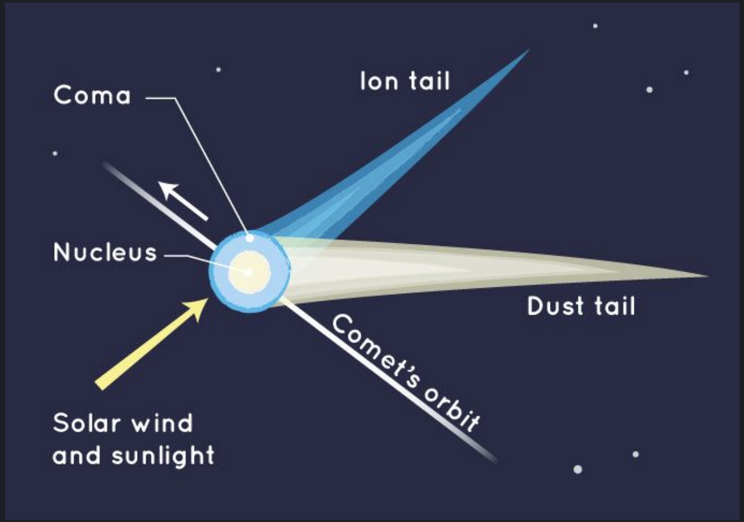

Figure 3: Diagram of comet anatomy
Credit: NASA/JPL-Caltech

Photodissociation

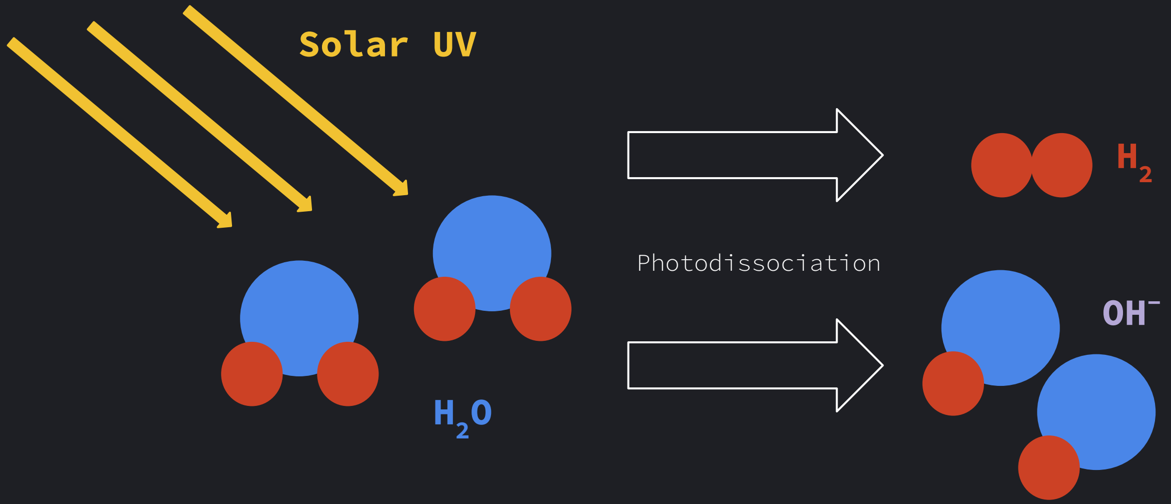

Figure 4: Photodissociation of water molecules into hydrogen and hydroxide ions

Methods

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Aim

- To map and model gas production rates and outflow velocities of OH^- molecules in comets nearing perihelion

Observations

- Data spanning 16 years (2001-2017)
- Over 30 comets; we look at 23
- Arecibo Observatory and Green Bank Telescope, ground-based radio observations, 18 cm Λ-doublet

Monte Carlo Simulation

- Produce synthetic coma, divide into sections, look at doppler shift to map
- Generate **10^6 H_2O molecules**, sublimated
- Randomly assign parent production time, parent destruction time, daughter destruction time, and azimuthal (**φ**) and polar (**θ**) angles of motion for each molecule
- Grid of different sublimation/initial velocity $\mathbf{v_0}$ and quenching radii $\mathbf{r_q}$

Calculations

- Parent lifetime Δt_1, sine and cosine projections
- Final parent position:

$$x_{12} = v_0 \, \Delta t_1 \, \sin(\theta_1) \, \cos(\phi_1)$$

$$y_{12} = v_0 \, \Delta t_1 \, \sin(\theta_1) \, \sin(\phi_1)$$

$$z_{12} = v_0 \, \Delta t_1 \, \cos(\theta_1)$$

- Velocity due to photodissociation $v_p = 1.05$ **km/s**
- Final daughter x-velocity, sublimation + photodissociation

$$v_3 = v_0 \, \sin(\theta_1) \, \cos(\phi_1) + v_p \, \sin(\theta_2) \, \cos(\phi_2)$$

Results

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Spectral Mapping

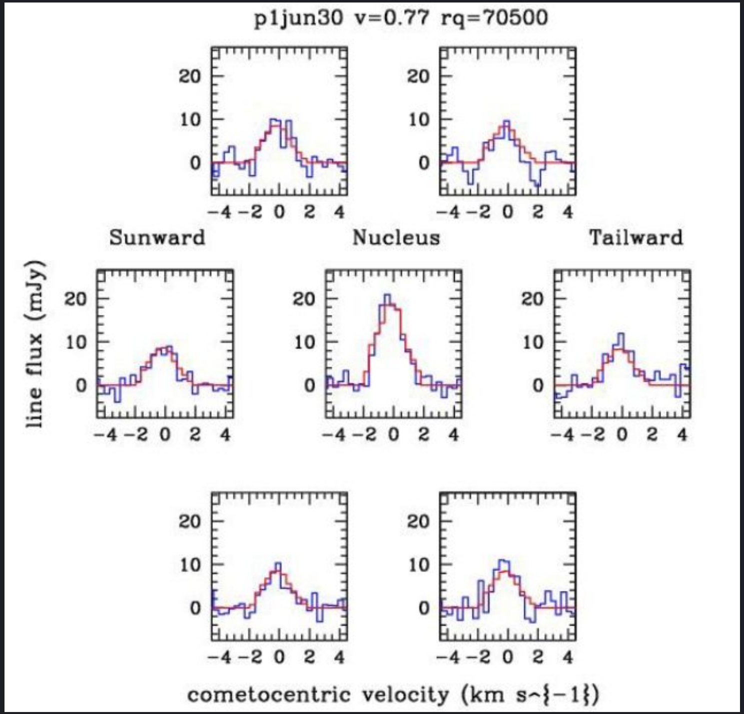
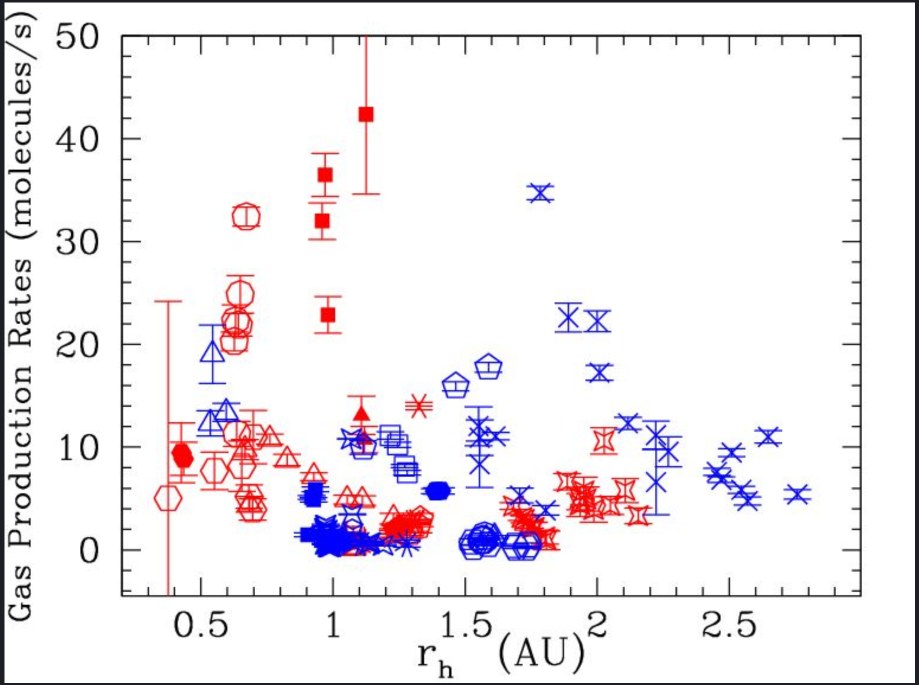


Figure: Spectrum for C/2009 P1 Garradd at 2.757 AU from the Sun on June 30, 2011

Gas Production vs Heliocentric Distance



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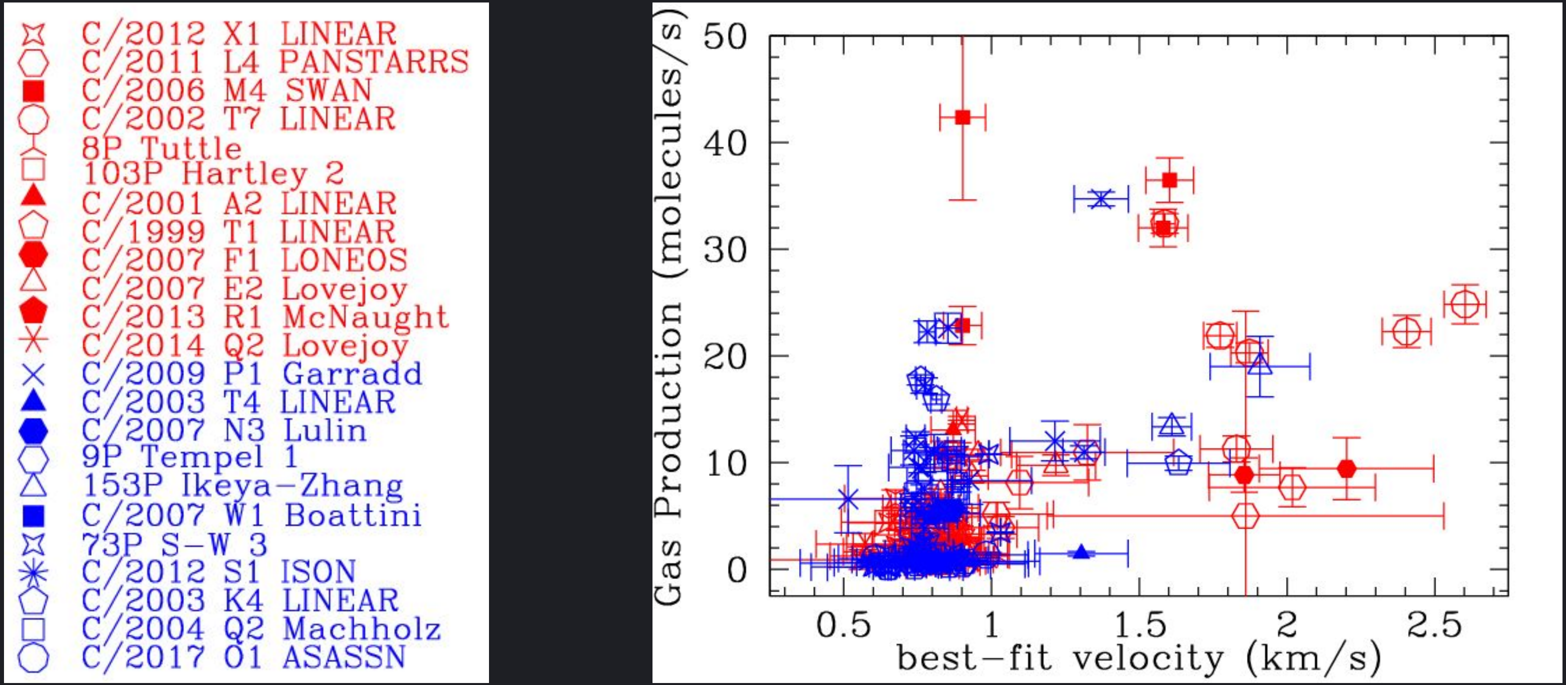
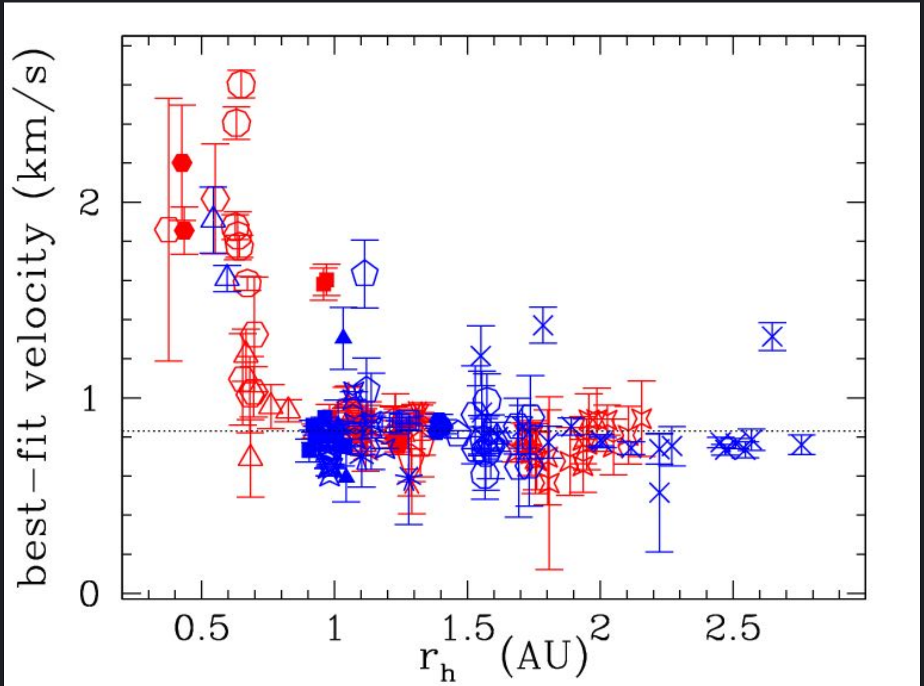
Gas Production vs Gas Velocity



OH Velocity vs Heliocentric Distance



Conclusions and Future Work

- Correlations between gas outflow velocity and heliocentric distance
- Fewer correlations between gas production and distance or gas production and velocity
- Possible reasons for poor fit for some comets: high velocities, spectral inversion factor
- Examine different OH initial velocities

Sources

- A. J. Lovell, E. S. Howell, and F. P. Schloerb (unpublished). Observations and Modeling of 18 cm OH Lines in Twenty-Seven Comets. 2016.
- A. J. Lovell, E. S. Howell, F. P. Schloerb, B. M. Lewis, and A. A. Hine. Arecibo observations of the 18cm OH lines of six comets. *Asteroids, Comets, and Meteors: ACM 2002* 500:681-684. 2002.
- A. J. Lovell, A. Bonsall, H. Sizemore, and F, Ghigo. Ground-based Observations of Small Solar System Bodies: Probing Our Local Debris Disk. *Bulletin of the AAS*, 51.3. 2019.
- A. L. Cochran, A. Levasseur-Regourd, M. Cordiner, E. Hadamcik, J. Lasue, A. Gicquel, D. G. Schliecher, S. B. Charnley, M. J. Mumma, L. Paganini, D. Bockelee-Morvan, N. Bover, and Y. Kuan. The composition of comets. *Space Science Reviews*, 197.1:9-46, July 2015.
- B. Presler-Marshall, Bachelor's thesis, Agnes Scott College, 2019.
- B. Presler-Marshall, Master's thesis, University of Central Florida, 2021.
- L. E. Tacconi-Garman, F. P. Schloerb, and H. J. Claussen. High spectral resolution observations and kinematic modeling of the 1667 MHz hyperfine transition of OH in Comets Halley (1982i), Giacobini-Zinner (1984e), Hartley-Good (1985l), Thiele (1985m), and Wilson (1986l). *The Astrophysical Journal*, 364:672-686. 1990.

Acknowledgments

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