Gemini Observations of Active Centaurs Observed by JWST NIRSpec

ADAM MCKAY
APPALACHIAN STATE UNIVERSITY

Olga Harrington Pinto (University of Central Florida), Charles Schambeau (University of Central Florida), Michael Kelley (University of Maryland), Geronimo Villanueva (NASA GSFC), Lori Feaga (University of Maryland), Maria Womack (NSF), Yan Fernandez (University of Central Florida), Kacper Wierzchos (University of Arizona), Michael DiSanti (NASA GSFC), and James Bauer (University of Maryland)

JWST-Gemini Splinter Session-AAS-1/11/2023

COMETS AND PLANETARY FORMATION

Comets are primitive leftovers from the formation of the solar system, important probes of the physics and chemistry of planet formation

However, they still undergo some heating from the Sun, more primitive material?

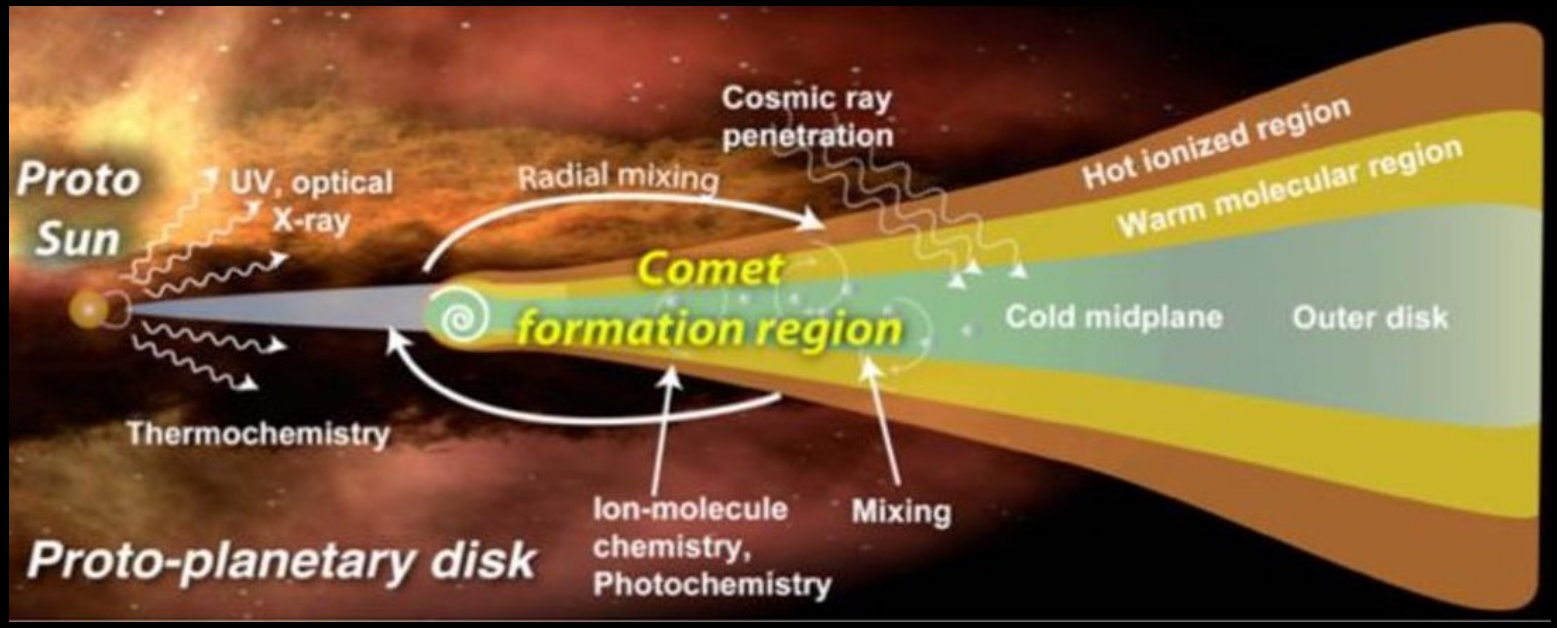


Image Credit: Geronimo Villanueva/NASA GSFC

CENTAURS: THE EARLY STAGE OF SHORT-PERIOD COMETS

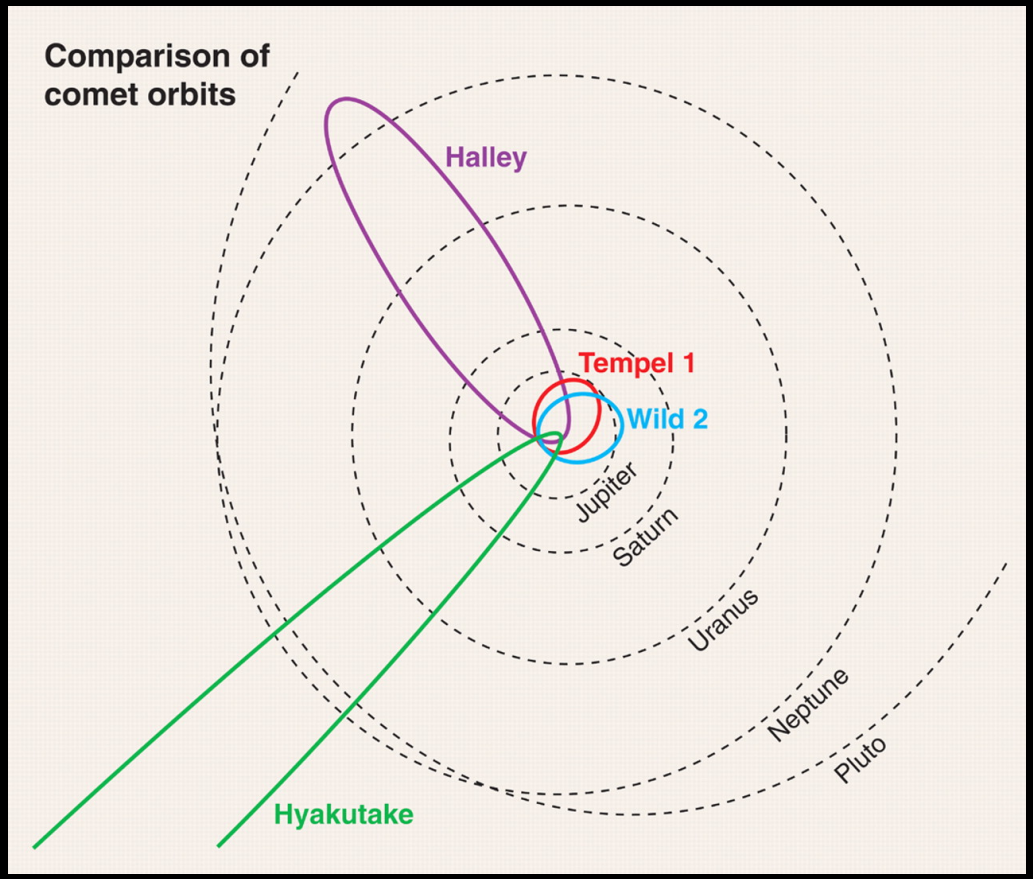
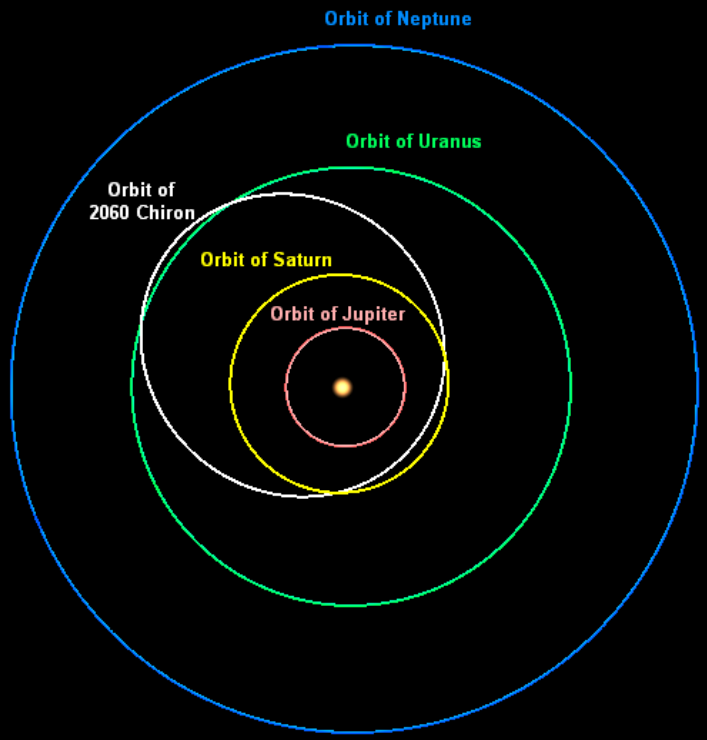


Image Credit: Tony Farnham, University of Maryland



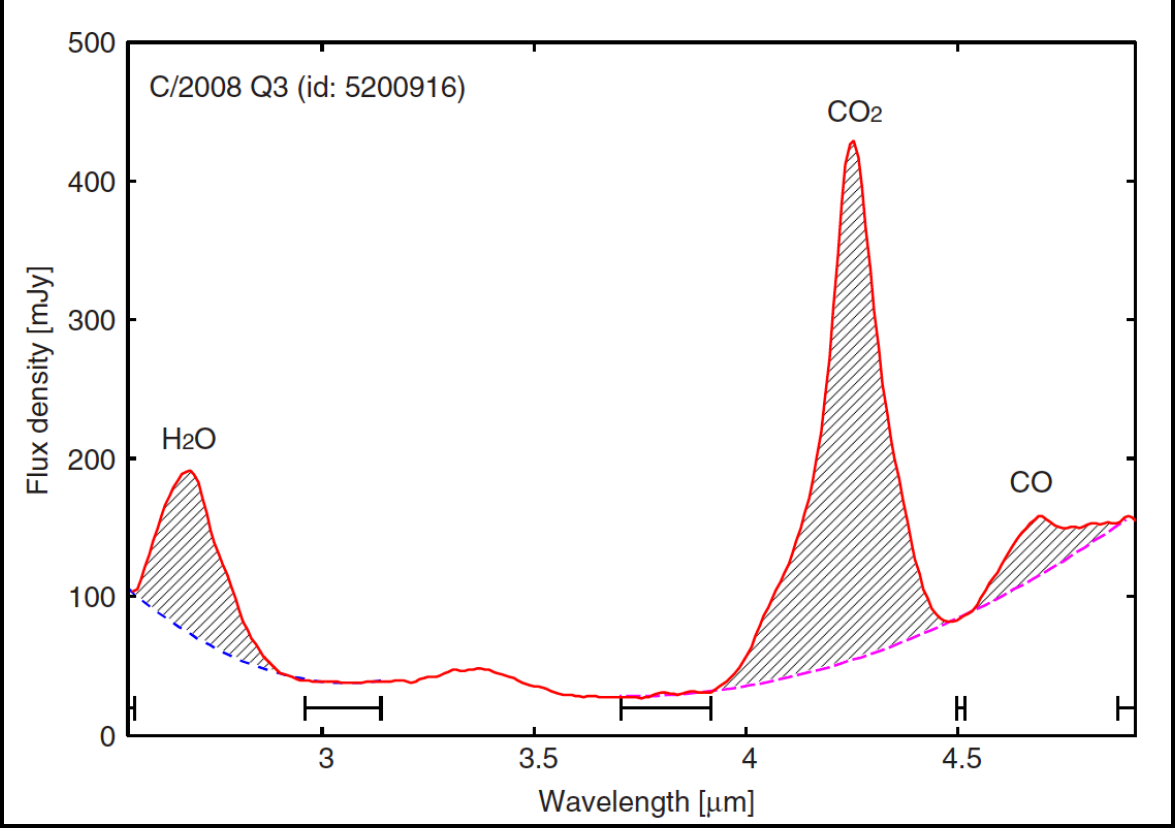
ACTIVE CENTAURS

- Some Centaurs exhibit activity like comets, but are too far from the Sun to be driven by traditional water sublimation
- Detections of molecules in Centaurs have been limited, what drives the activity?
- Lack of molecular detections means lack of knowledge about their composition. How does their composition compare to comets, in particular short period comets?

29P/Schwassmann-Wachmann 1 imaged with the Spitzer Space Telescope. Image Credit: NASA/JPL/CalTech/ Ames Research Center/University of Arizona

JWST AND CENTAURS

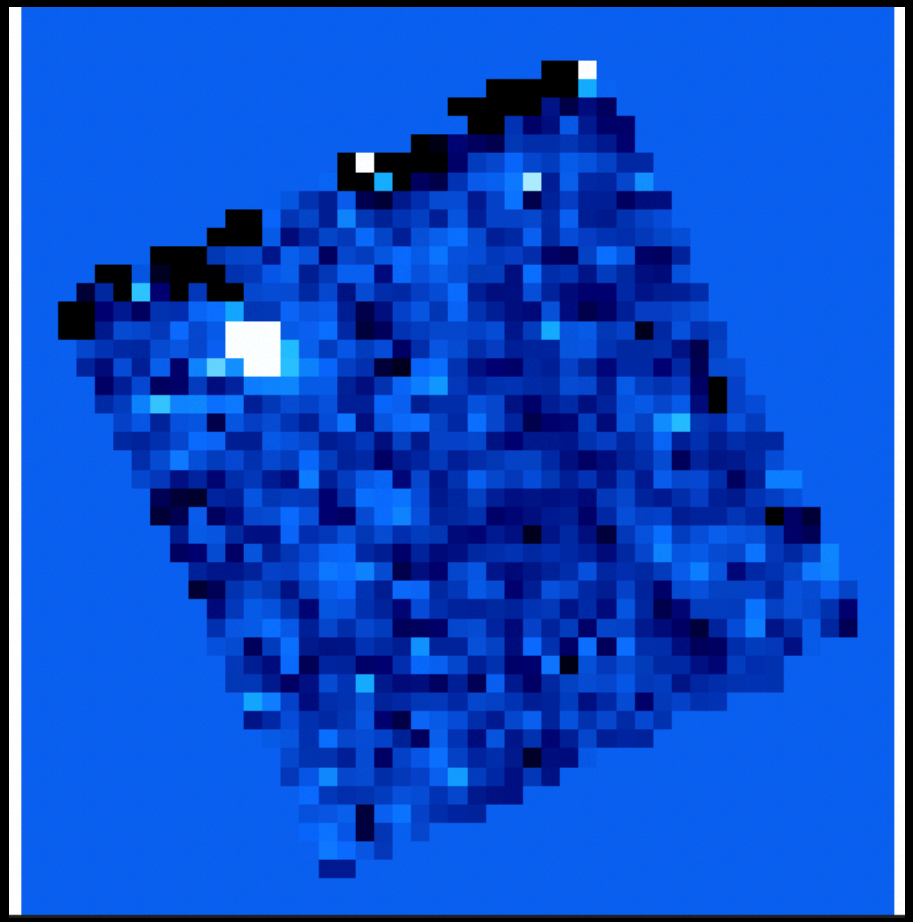
- JWST is uniquely suited to observe water, carbon dioxide, and carbon monoxide in comets and Centaurs
- Our program (JWST GO 2416, PI McKay) will observe these molecules in the comae of six active Centaurs using JWST NIRSpec to better understand their activity and how their composition compares to comets



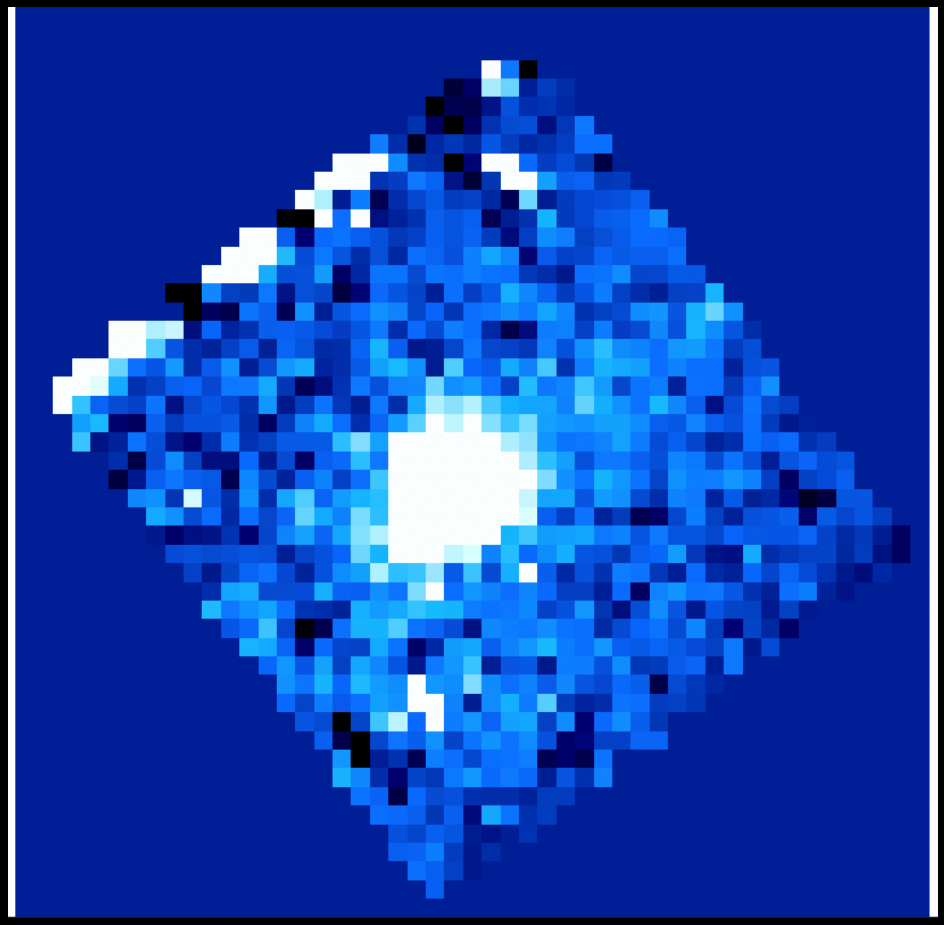
Ootsubo et al. 2012-Spectrum of comet C/2008 Q3 (Garradd) obtained with the AKARI spacecraft

JWST NIRSPEC IMAGE CUBES

39P/Oterma



C/2014 OG392



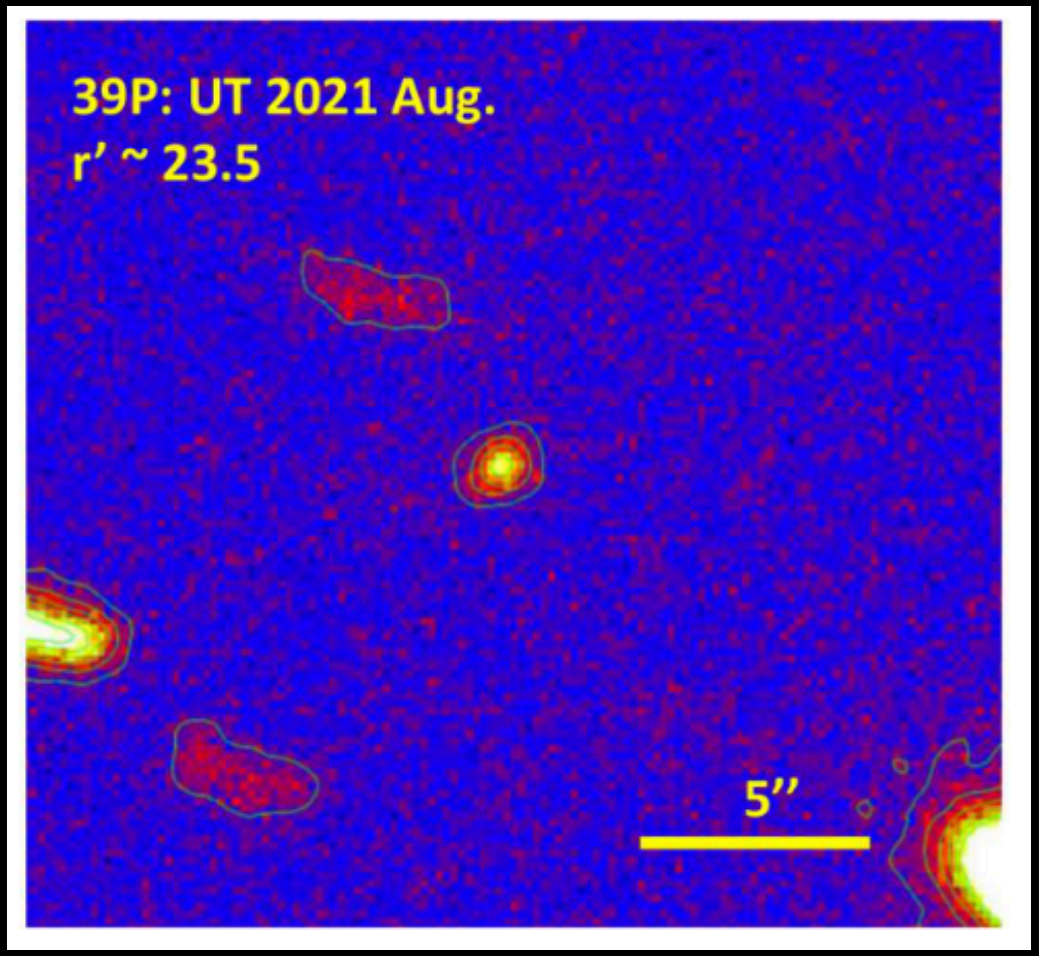
Major thanks to Olga Harrington-Pinto, Geronimo Villanueva, Michael Kelley, Charles Schambeau, and Lori Feaga for working on the data!

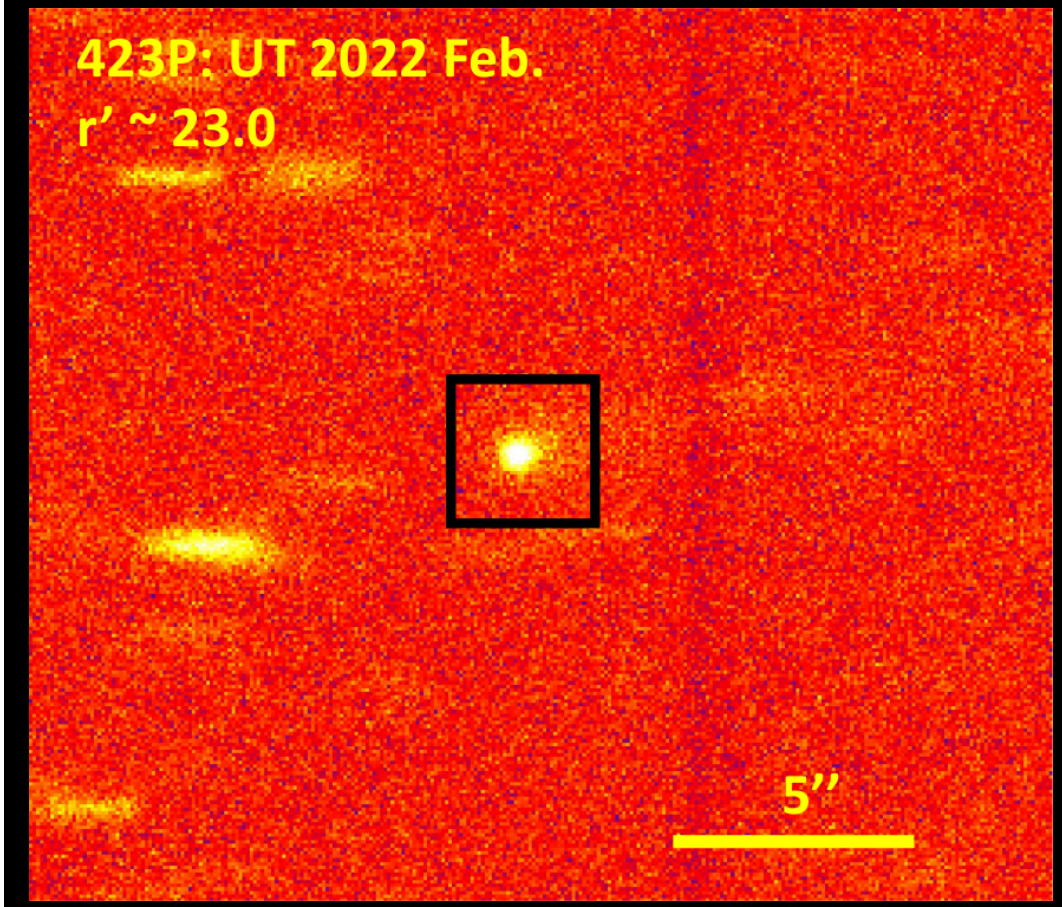
PRELIMINARY RESULTS

- First object observed was 39P/Oterma in late July
- First detection of CO_2 in a Centaur (10-sigma)
- H_2O and CO not detected (but analysis ongoing)
- Preliminary abundance ratios: $CO_2/CO > 25\%$, $CO_2/H_2O > 100\%$
- Much higher CO_2 abundance than 29P/Schwassmann-Wachmann 1, for which a sensitive upper limit on the CO_2 abundance is available (Ootsubo et al. 2012, $CO_2/CO < 1\%$)
- CO_2/H_2O ratio much higher than typically observed in comets (10-30%), but large heliocentric distance (~5.8 AU) needs to be accounted for, CO_2/CO consistent with most cometary measurements
- Four of six targets have been observed, two more (including 29P) to be executed

ORBIT RECOVERY WITH GEMINI

- Accurate ephemeris needed to ensure successful JWST observations
- Gemini observations with GMOS instrumental for refining orbits of 39P, 423P, and 450P, executed as part of LLP LP-203 (PI C. Schambeau)
- Also provide characterization of activity level

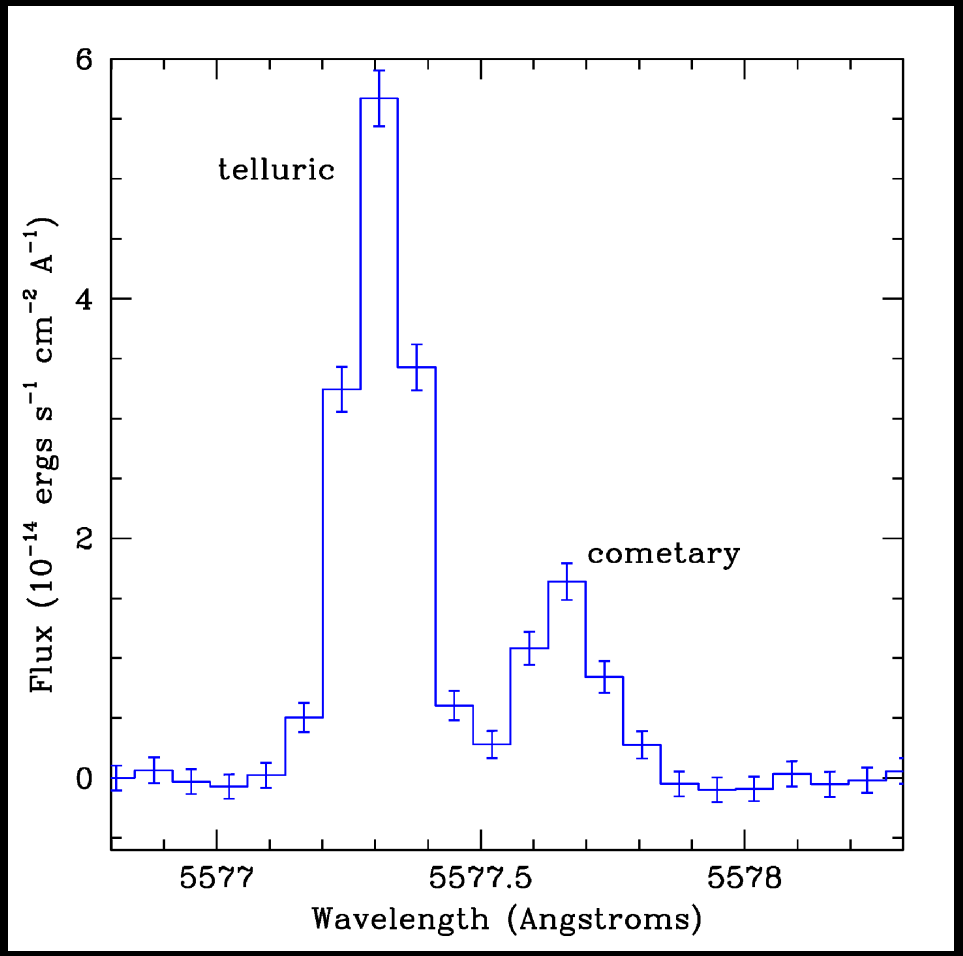




FORBIDDEN OXYGEN LINES

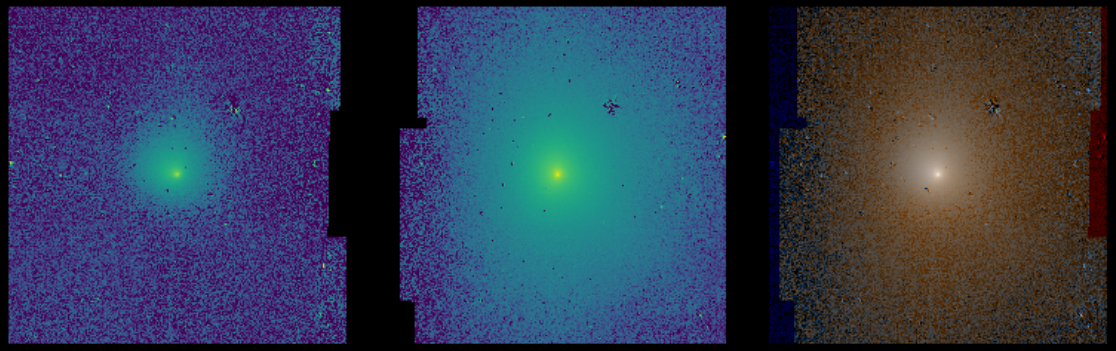
- [OI] emission results from photodissociation of H_2O and CO_2
- CO_2 abundant in comets, but difficult to observe because of Earth's atmosphere
- Flux ratio of [OI]5577/([OI]6300+ [OI]6364) (OI line ratio) lines indicative of parent molecule
- If photochemistry fully understood, can use as a proxy for CO_2/H_2O ratio

[OI]5577Å line in C/2009 P1 (Garradd)



McKay et al. 2015

CO_2-OI CONNECTION



Comet C/2013 X1 (Pan STARRS) at -2.12 au (December 26, 2015)
Spitzer Space Telescope IRAC 3.6 μm, 4.5 μm, and color combination
NASA / JPL-Caltech / Kelley et al. / Univ. Maryland

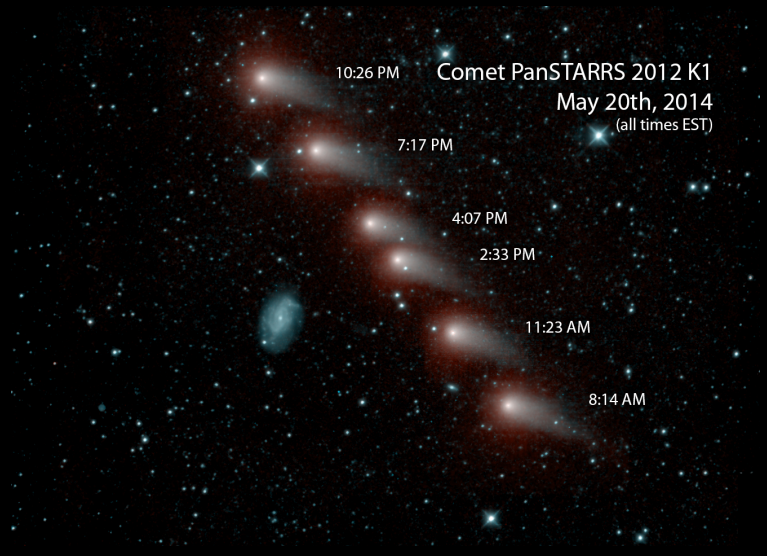
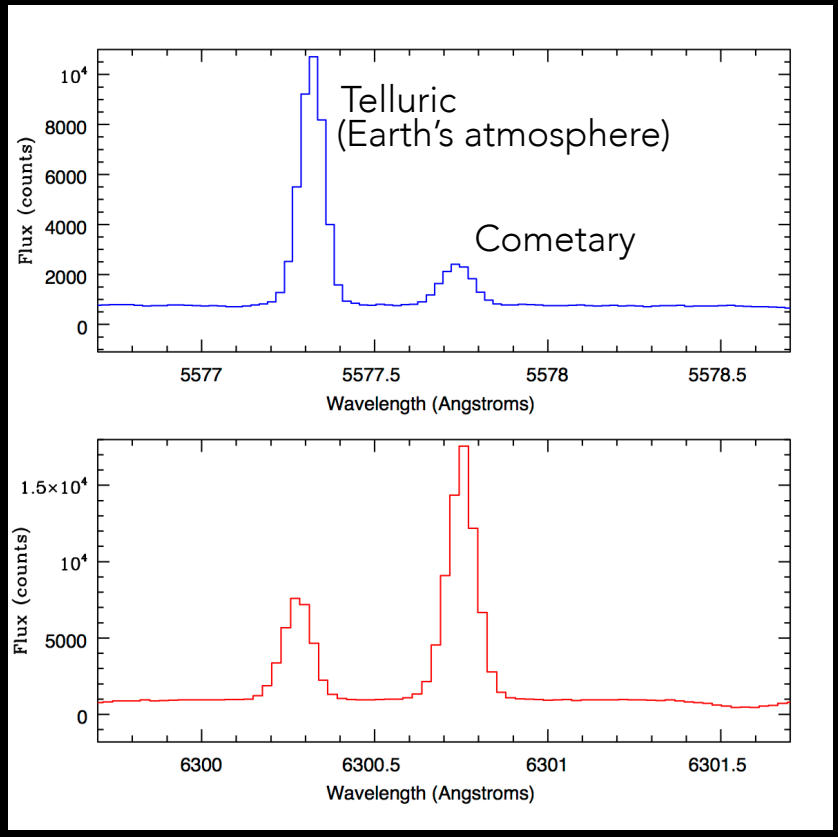


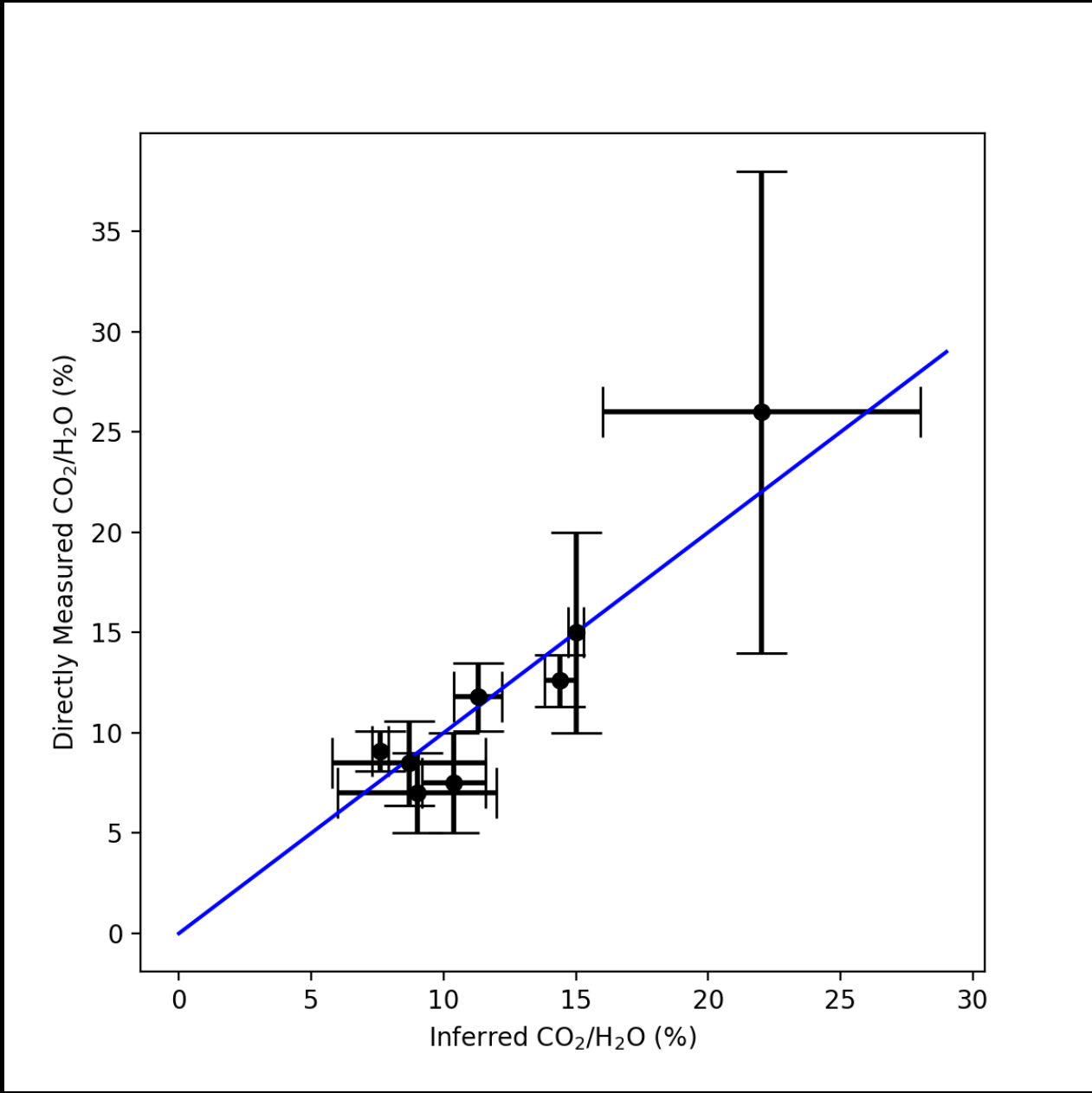
Image Credit:NEOWISE/JPL/Cal-Tech



C/2013 X1 (PanSTARRS) w/Keck HIRES

This work is funded by the NASA Solar System Workings Program

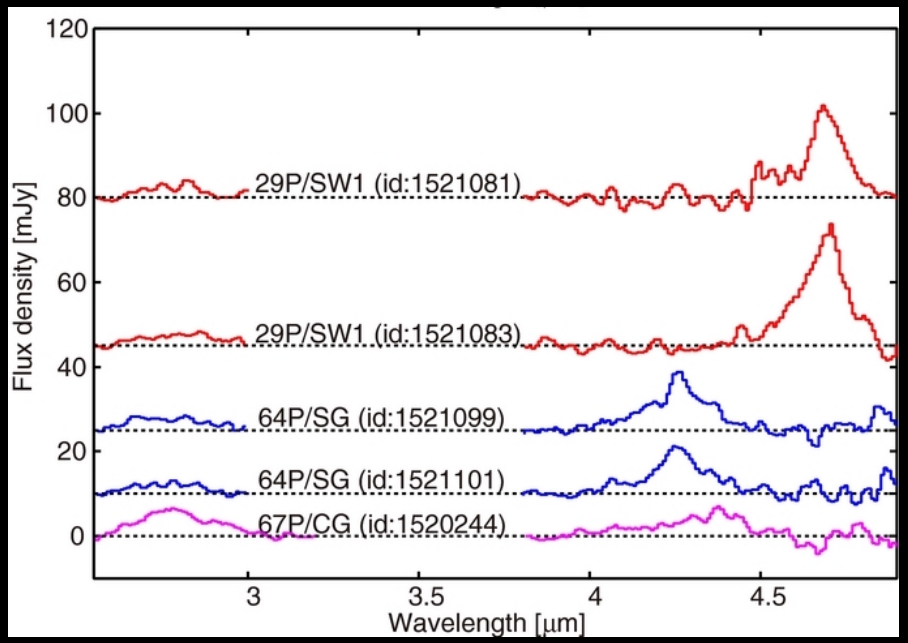
OI LINE RATIOS AS A CO_2 PROXY



Preliminary results from work funded by the NASA Solar System Workings Program

CONSTRAINING THE CO PHOTOCHEMISTRY

- Little understanding of CO photochemistry, as most comets have photochemistry dominated by CO_2 and H_2O
- 29P/Schwassmann-Wachmann 1 has CO as its dominant volatile, [OI] photochemistry should be dominated by CO
- Combine Gemini GRACES observations of [OI] with JWST observations of CO_2, CO, and H_2O in 29P/Schwassmann-Wachmann 1 to use the centaur as our "laboratory"
- JWST observations to be executed in February-March



Ootsubo et al. 2012

CONCLUSIONS AND FUTURE WORK

- Gemini astrometric observations of Centaurs help ensure successful JWST observations and provide imaging context
- Coordinating spectroscopic observations with Gemini and JWST to enhance science return from both facilities
- Four of six targets observed by JWST, analysis of observed targets ongoing, Gemini GRACES observations of 29P to be obtained

Questions?

Acknowledgments: Work presented here was funded through STScI and the NASA ROSES program.