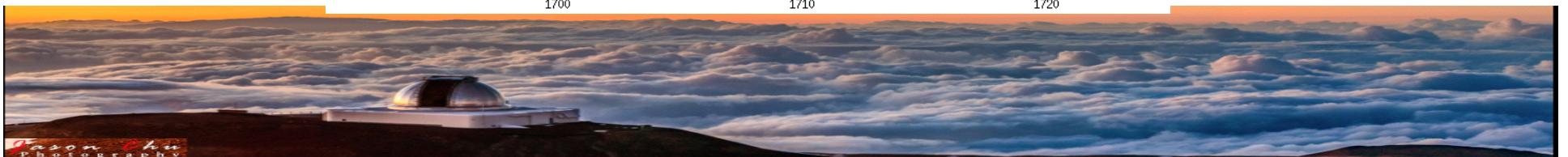
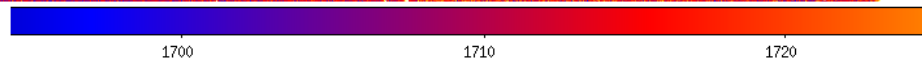
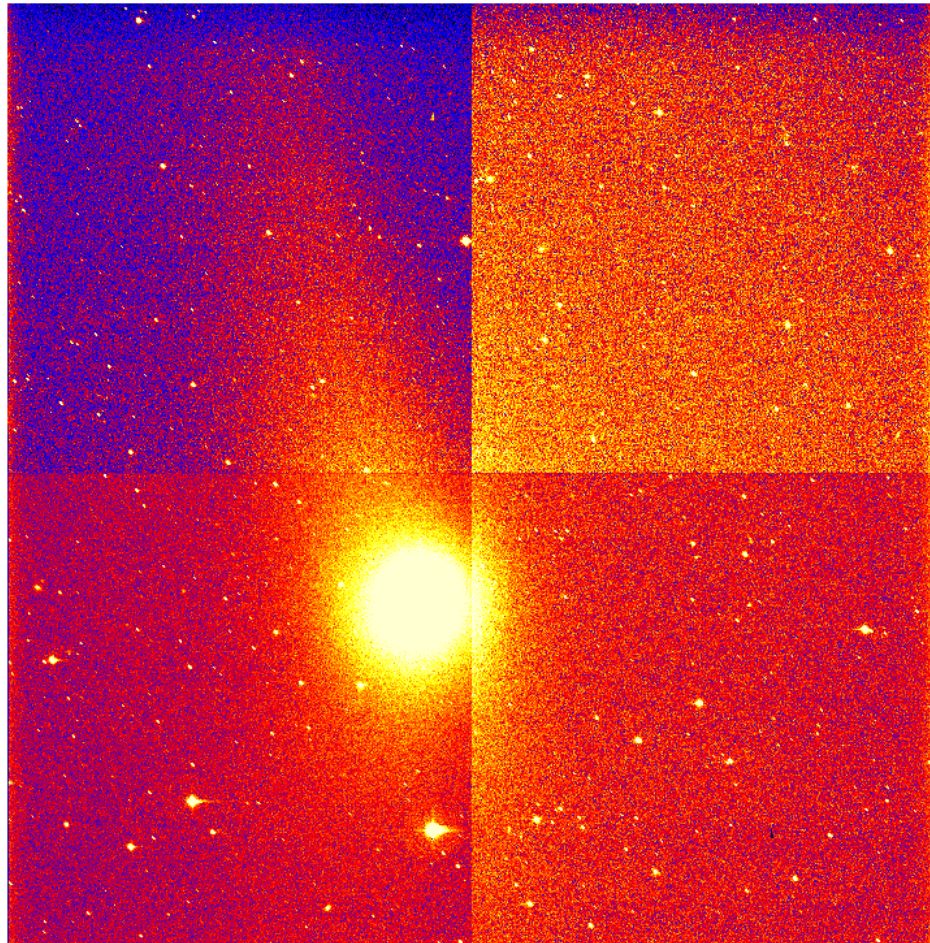


Small Bodies - The IRTF Advantage - Dust in Comet Comae

Chick Woodward (U. Minnesota) for the “Comet Dust Team”

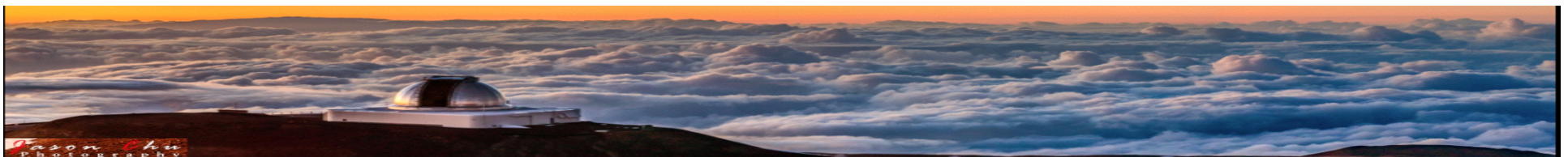


Small Bodies - The IRTF Advantage - Dust in Comet Comae

Refractory organic matter in comets (including 'carbon') provide key data and insights into the properties, formation and evolution of dust from the interstellar medium (ISM) and from our protoplanetary disk.

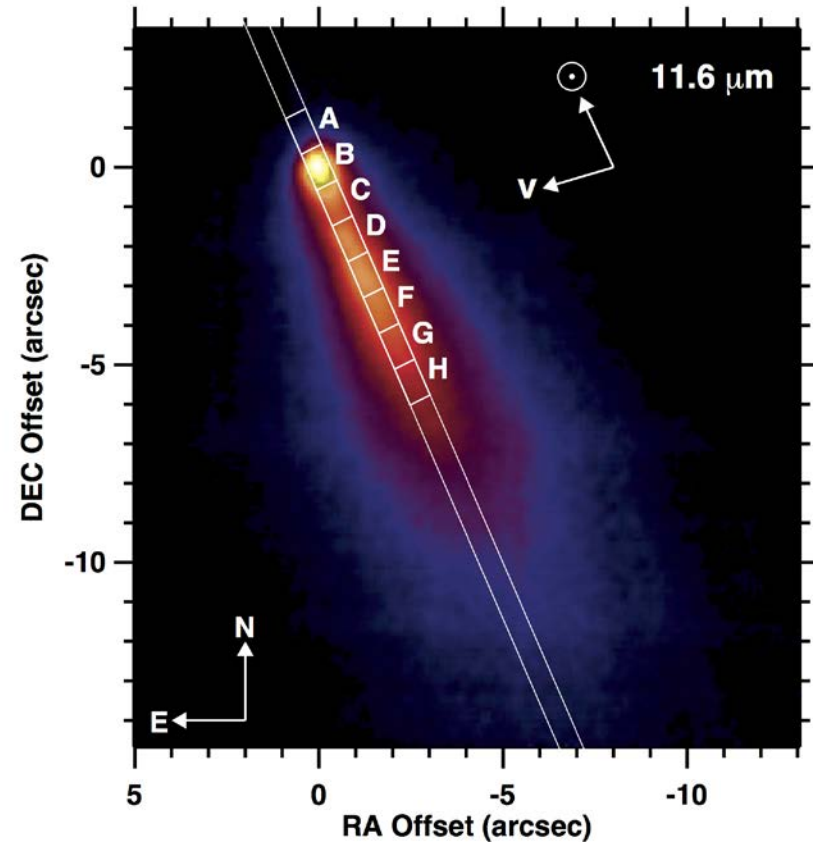
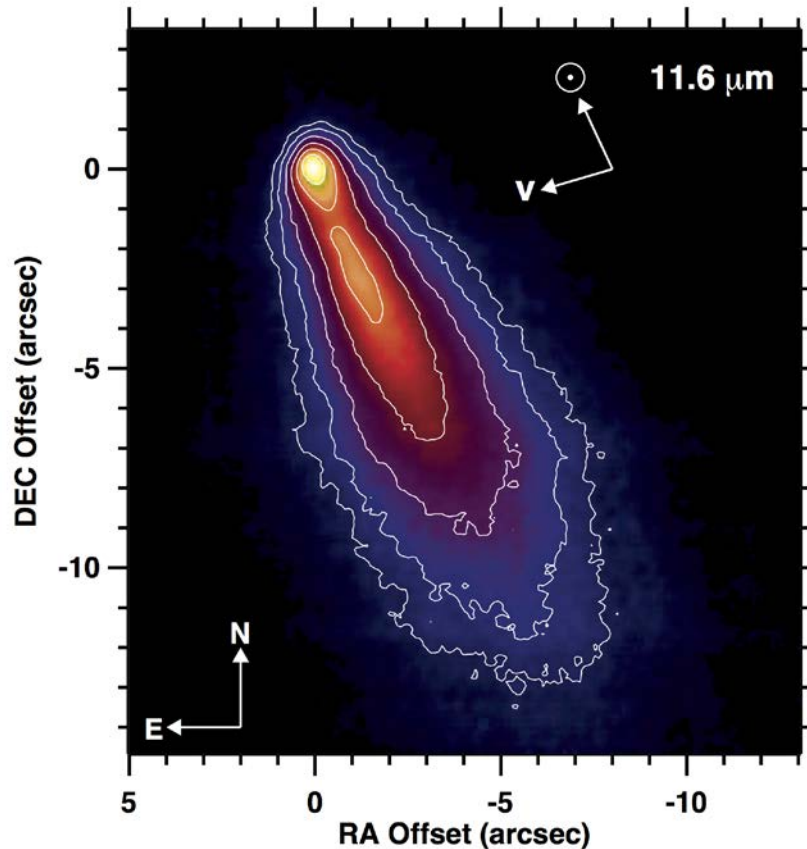


Adopted from astrobiology.gsfc.nasa.gov/mandell/

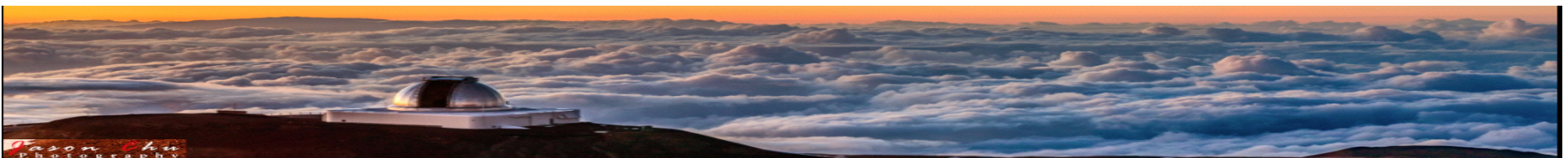


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Mid-Infrared spectral region contains solid state resonances of materials and emission features from organics species enabling compositional diagnostics



Adopted from Harker et al. 2011

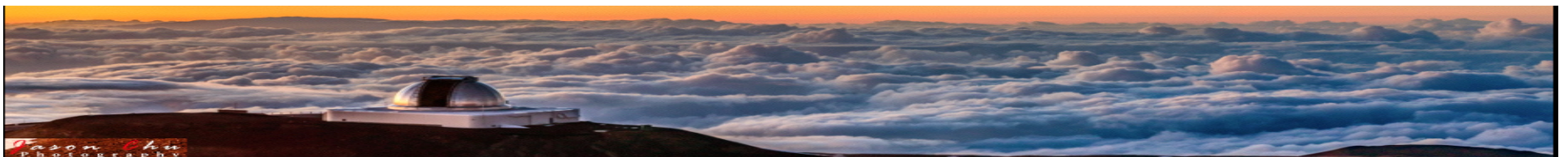
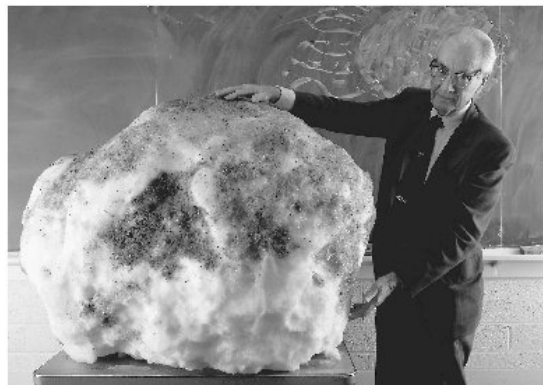


Small Bodies - The IRTF Advantage - Dust in Comet Comae

Old Paradigm: Comet dust (simple scenario) is a combination of amorphous carbon and Mg–Fe amorphous silicates, which are inherited from the ISM, and Mg-rich silicate crystals, which are early solar nebula condensates.

Dust considered to be fine-grained, i.e., dominated by sub-micron to micron-sized components of discrete single-mineral grains or grains aggregated into micron-sized and larger porous particles.

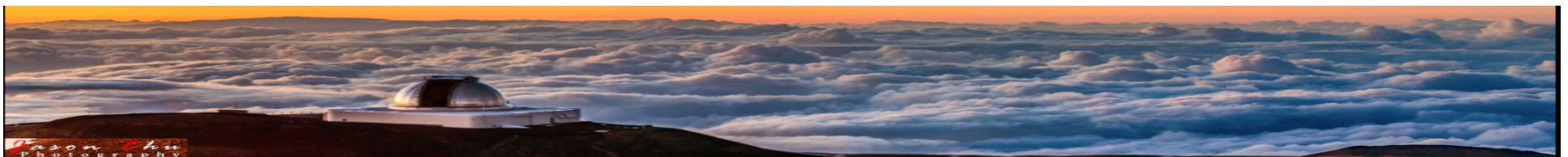
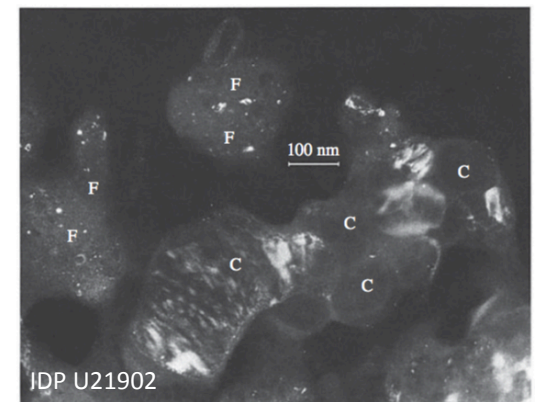
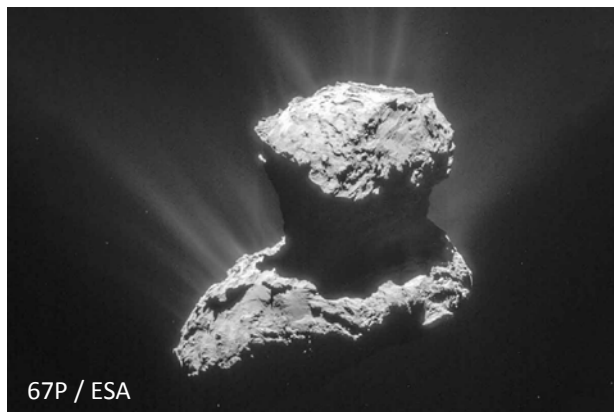
Dust: Comet inheritance + comet condensates



Small Bodies - The IRTF Advantage - Dust in Comet Comae

New Paradigm: Driven by Stardust 81P/Wild2 (type II chondrule fragments) vs. giant CP IDPS vs. Rosetta 67P (ROSINA/COSIMA) insight into similarities and differences in comet dust reservoirs and formation ages, variance is oxygen fugacity, aggregate particle assemblages, and crystals as condensates.

Dust: Comet – chondritic connections + Comet – organic connections



Small Bodies - The IRTF Advantage - Dust in Comet Comae

Emerging Questions:

What does the derived proper crystalline mass fractions imply about comet formation, ages, and radial transport?

Where are the spectral signatures of FeO and (chondritic) Fe-bearing materials?

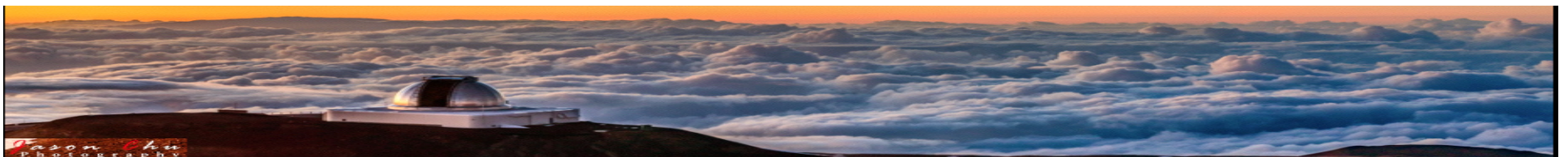
What does abundance of amorphous carbon reveal about the outer solar system?

Are silicates and carbon mixed as aggregates?

The role and trigger to episodic outbursts?

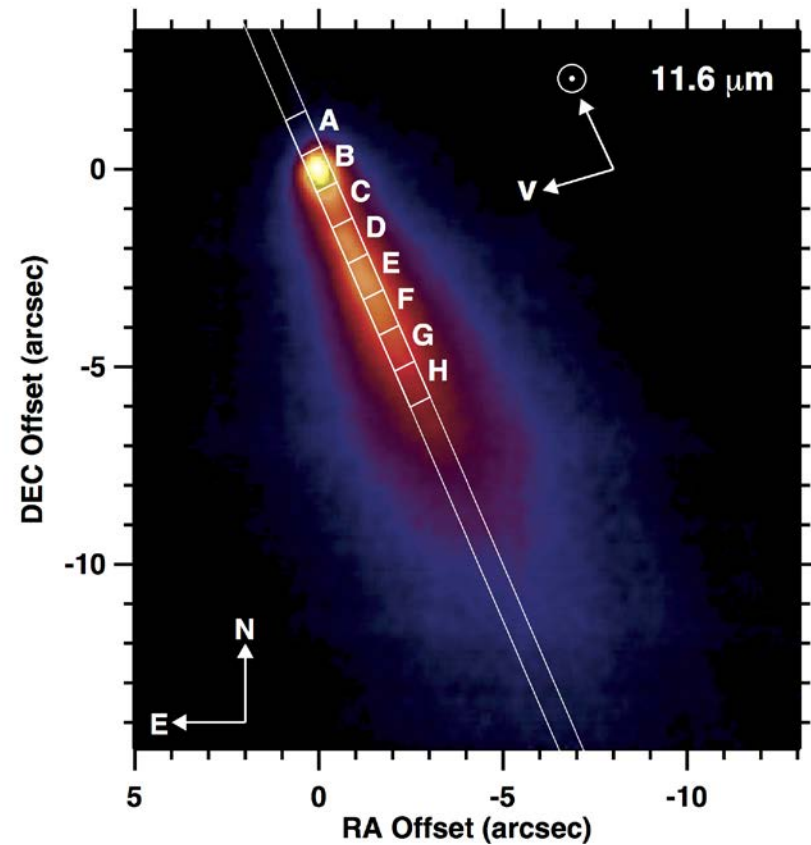
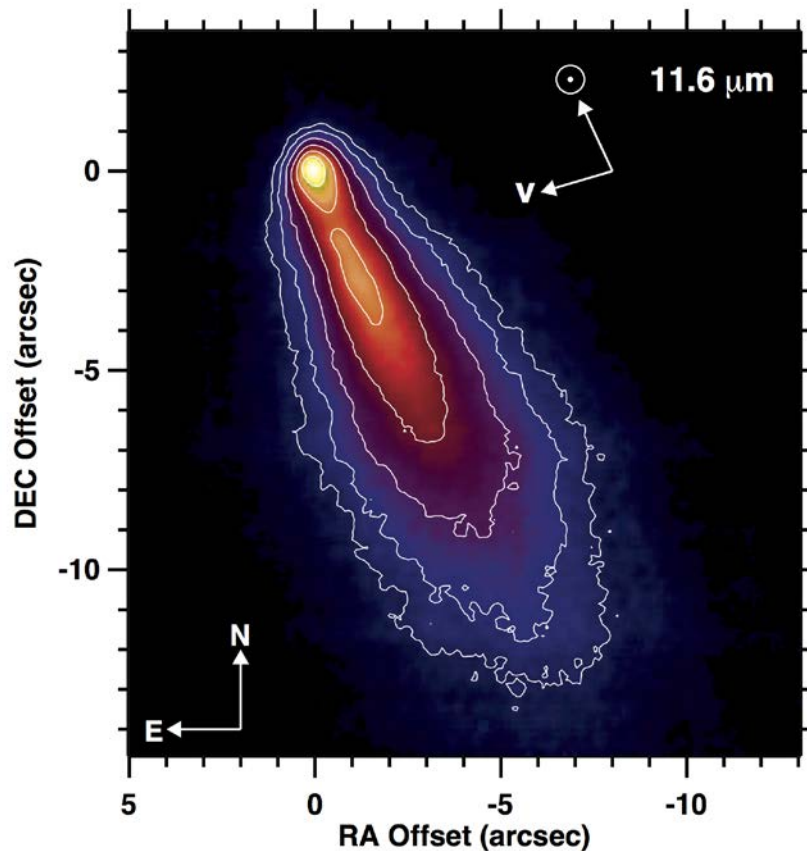
How does the heliocentric behavior of coma characteristics change?

Are astrobiological materials present in comet comae?

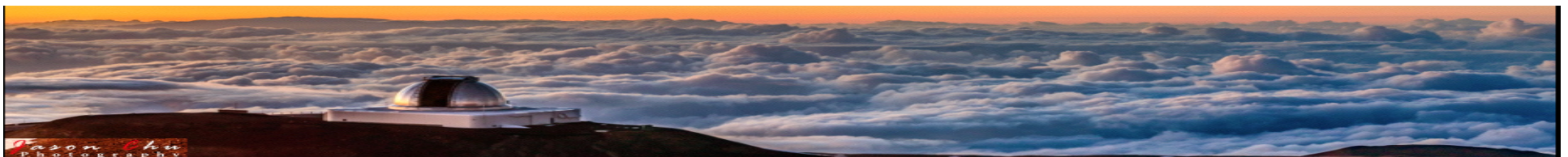


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Mid-Infrared contains solid state resonances of materials and emission features from organics species

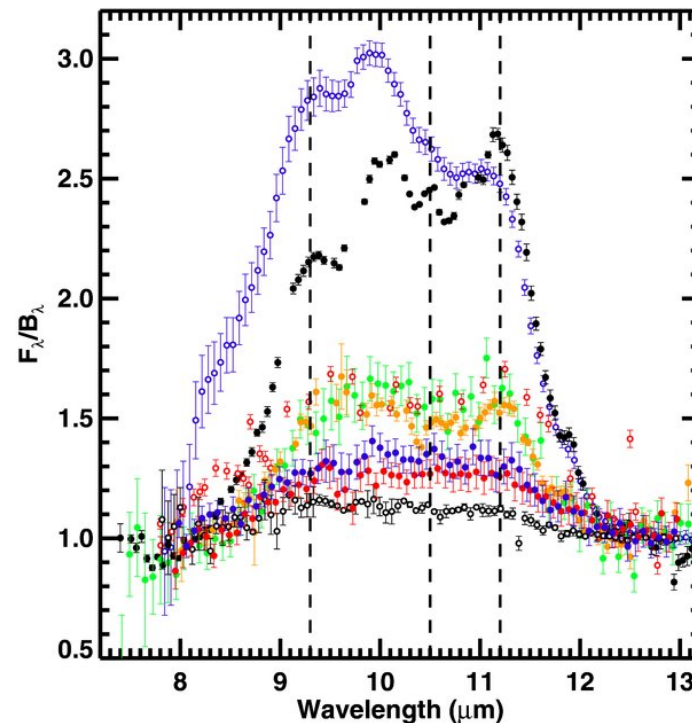


Adopted from Harker et al. 2011

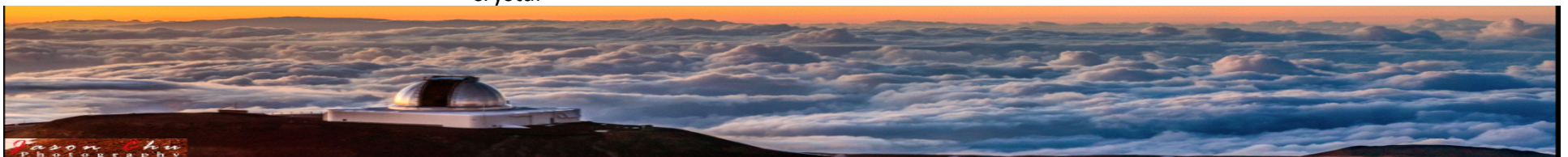


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Mid- to far-infrared spectra of comet SEDs are best-fitted by thermal models by a few materials that include amorphous silicates, amorphous carbon and Mg-rich crystals with crystal mass fractions ranging from 20 to 75%.



*The silicate crystal mass fraction is defined as $f_{\text{crystal}} = m_{\text{crystal}} / (m_{\text{crystal}} + m_{\text{amorphous silicate}})$, where m_{crystal} is from forsterite or forsterite plus enstatite



Small Bodies - The IRTF Advantage - Dust in Comet Comae

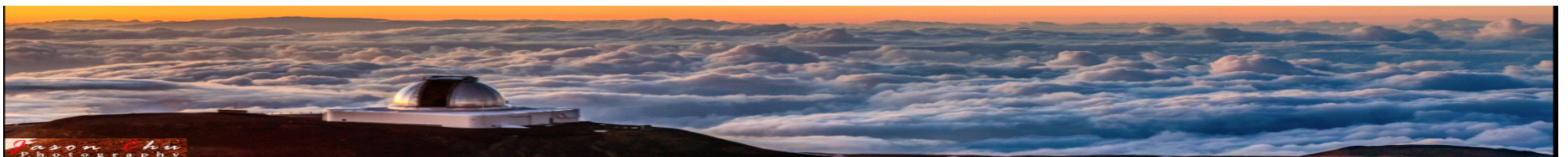
Crystalline Mass Fraction

Comet crystal mass fractions deduced from thermal models of IR spectra are similar to laboratory examinations of Ultra-Compact Antarctic Micrometeorites (UCAMMs) where $f_{\text{crystal}} \sim 25\%$.

Measured f_{crystal} values challenge for radial disk transport models

Ternary diagrams geochemically difficult to interpret.

No clear distinction in crystal mass fractions between Oort cloud versus Jupiter Family comets yet (agrees with predictions of the 'Nice model' for comets arising from the trans-Neptune region and the two dynamical families arising from different orbital excitation mechanisms).



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Carbon

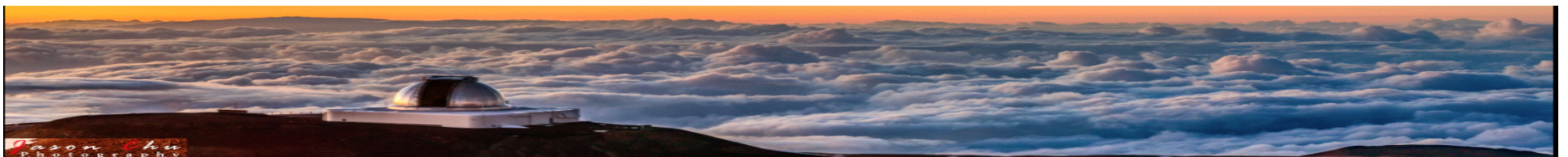
Amorphous carbon is used to fit the ubiquitously present warm featureless pseudo-continuum emission in the near- and mid-infrared spectra of comets, i.e. featureless thermal emission.

In some comets, models of infrared spectra imply dust compositions are very carbon-rich: 80% amorphous carbon and 20% silicates.

The high abundance of carbon distinguishes cometary dust from asteroidal dust where carbonaceous chondrites may have up to 5% carbon.

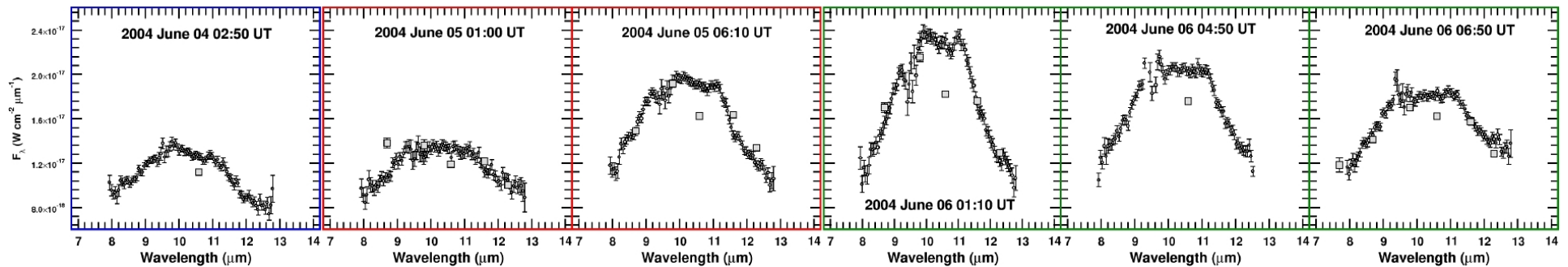
50%–80% of the mass of Ultra Carbonaceous Antarctic Micrometeorites (UCAMMs) is carbonaceous matter and UCAMMs probably are from comets

Related to materials that darken surfaces in outer solar system?



Small Bodies - The IRTF Advantage - Dust in Comet Comae

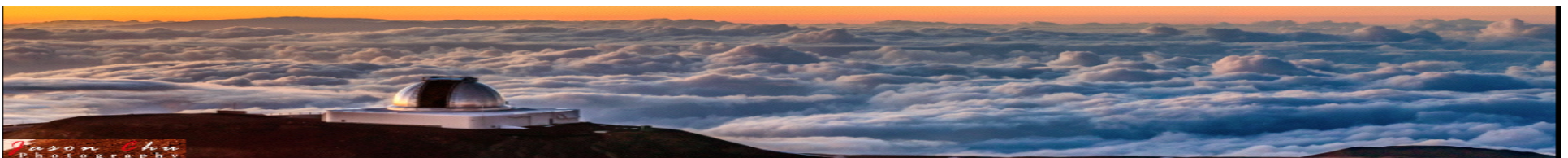
Carbon



MIRSI observation of comet 2001/Q4 (NEAT) 2004 June 04-06.

The dust properties changed over the timescale of a few hours.
The silicate-to-carbon ratio varied with activity (jet crossings).

Amorphous carbon increased when activity increased, this also seen in the outburst of 67P/CG (cf., Bockelée-Morvan et al. 2017)



Small Bodies - The IRTF Advantage - Dust in Comet Comae

Challenges to Global Interpretations Uniquely Addressable with the IRTF

Hampered by small number statistics

Heliocentric variations unknown

Jets/Hyperactivity/Rotation

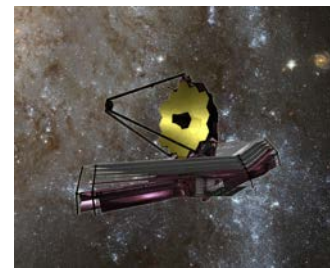
Dust/Gas/Ice Correlation

Spatial Variations of Materials in the Coma

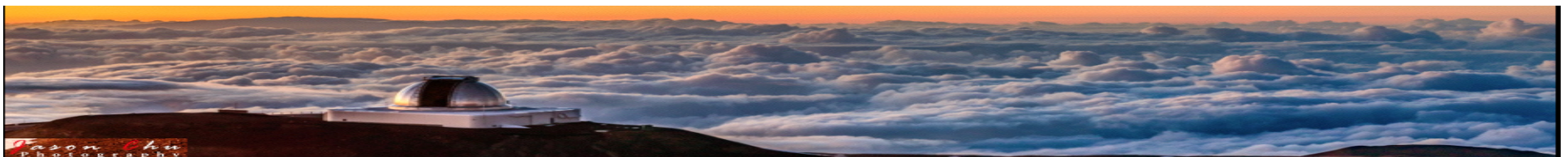


Adopted from MPIA

complements



Adopted from NASA



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Future IRTF Capabilities Enhancing Comet Science

Programmatic: [1] Daytime observing for comet apparitions; [2] Quick instrument changes to enable contemporaneous dust, ices, and gas studies of a given comet; [3] Continued access to on-site and/or remote telescope observing enables entrepreneurial / serendipitous opportunities; [4] Synoptic and long duration campaigns.

Instrumentation: [1] Full access to **both 10 and 20 micron windows** : MIRSI – 5-20 μm camera (85''x64'' FOV), 12 filters and 8-20 μm GRISMS ($R=100-200$), [2] Simultaneous access to optical wavelengths: MOC – increase filter slots and/or wheel with **Hale-Bopp suite, R' and I'** ; [3] Enhanced support for niche visitor instrumentation: BASS

Telescope: [1] Improved image quality, [2] Access to chopping secondary with fast settle and nod rates, [3] Fast track rates and appropriate guiding capabilities

