DAY 2
Composition of Solar System Comets

Data Sources
- Comet missions
- Mass spectrometers

Sample return

Great data, but limited

We need remote sensing data
TYPES OF MOLECULES
VERY DIFFERENT AT
DIFFERENT WAVELENGTHS

PRIMARY VOLATILES
RADIO OR IR

DAUGHTER
PRODUCTS

VISIBLE
**MOST ABUNDANT PRIMARY VOLATILES**

- $\text{H}_2\text{O}$
- $\text{CO}$ ($<1$ - $40\%$)
- $\text{CO}_2$ ($1$ - $30\%$)

**SOME EXCEPTIONS, E.G. C/2016 R2**

A LOT OF $\text{N}_2 + \text{CO}$

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**ROSETTA**

**ROSINA - MANY MOLECULES IMPOSSIBLE TO SEE FROM GROUND.**

- $\text{O}_2$ up to $10\%$, AVERAGE $4\%$
- GLYCINE ...
- NOBLE GASES, ISOTOPIC RATIOS
- K. ALTWEgg's "ZOO"
Comet Taxonomies
- Compare compositions of comets

Families:
- Main Belt comets
- Jupiter Family comets (sc. disk)
- Isotropic comets
- Long period - Halley-type

Seem to be 2 classes based on prod. volatiles
Some depleted in carbon chain species
Many sub-classes possible $C_2 + C_3$

Formation vs. evolution?
TAXONOMY FROM PRIMARY VOLATILES
- NO CLEAR GROUPING
  EACH COMET
  A UNIQUE FINGERPRINT
- NO CLEAR DIFFERENCE BETWEEN DYNAMIC FAMILIES

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NO "TYPICAL" COMET

COMPLICATION: COMPOSITION OF COMET CHANGES
- DIURNALLY
- WITH HELIOCENTRIC DISTANCE
Exocomet Compositions

- Gas detections with spectroscopy

β Pic b II

Variable saturation, redshift

→ Small gaseous clouds

- UV → Al, Fe, Mg mainly ionized or strongly ionized.

First difficulties - < 1 day variability
- Strong blends
- Almost no blue shifts

27 years later > 1500 spectra
• Ca II & Fe I
• Fe I $\ll$ Fe II
• Fe II variations
• Al III variations

Highly ionized species, e.g. CIV
Shock in addition to UV.

Stargazers $< 5 R_\odot$ @ β Pic
$> 200$ km/s $^1$ redshift shape well reproduced
ISOTOPES

C & O dredged up in evolved stars

Pattern of D/H in solar system generally consistent with solid accretion spectral fingerprints of isotopologues

MODEL:

Chemistry → Opacities → Temp.

→ Synthetic Observation Parameters + Reduction

Doppler imaging

Next?
Exocomet composition within belts
- Carry complex volatiles
- Few data points

Collisional evolution ...

Observing icy exocometes when inward delivery taking place
> 20% of nearby stars have dust.

Short-lived - radiation pressure →

Must be continuously produced - collisional cascade.

Belt loses mass over time.

After protoplanetary disk formation, time-variable red-shifted gas & dust from inward-scattered exocomets. Exocomet gas - also matter of timescales. CO must be replenished - not primordial. Other species? CN? Photodissociation important.
**DISCUSSION**

- Exocomets - very complex scenarios, e.g. collisions
- Very difficult to model.
- Has equivalent of nice model scenario happened elsewhere?
  - Scattering & cascade of comets
- Are there too many comets to explain, so some comets are from other stars anyway?
  - "Exocomets may be closer than we think!"
DISCUSSION

- How weird would parent system of a local exocomet have to be to be obvious?
- Nearby stars - all similar origins?
- Look at D/H - but varies at one comet!
- Several techniques - consistent?
- Ages of comets - possible? Good chance of saying whether dynamically new.
DISCUSSION

COMETARY SCIENTISTS ARE ALWAYS LOOKING AT THE LATEST INTERESTING COMET!