Water
Astrochemistry
ISM Physics
Fundamental Astronomy

- ISM constituents
- ISM dust formation
- Ionization rate through astrochemistry
- THE way to study objects in astronomy
**Dark H$_2$**

- C$^+$, HF
- accounts for ~30% of the molecular mass of the milky way
- context:
  - Molecular hydrogen halo’s without CO around CO-traced molecular cloud
  - formation/destruction of molecular clouds

*Pineda et al. 2013*
0.4-0.7 solar masses of dust made in ~20 years!
Short-lived Ions as probes

- detection of OH$^+$, H2O$^+$ - completely new and provides a unique measurement of the ionization rate of the diffuse ISM --- CH$^+$ not new but now spectrally resolved

- key points:
  - ions are short lived with a lifetime of 30 yrs × [1 cm$^{-3}$/n(H$_2$)]
  - needs high production rate -- if you know n(H$_2$) you can estimate the formation rate, i.e. ionization rate or trace energy
  - direct link between extragalactic and galactic science -- this is from the diffuse ISM which fills a telescope beam
THE way to understand...

J. Bouwman
+ DIGIT
• near complete census (to sensitivity limit) of chemistry from simple hydrides to complex organics
• excellent relative calibration -- reliable fluxes to model tens to thousands of lines for a given species
• abundances, densities, temperatures, linewidths -- physics and chemistry of dense ISM
• legacy product
New Physical Insights

- molecular excitation - formation pumping
- SF energy output - CO ladder
$\text{H}_3\text{O}^+$ - Formation Pumping
Water and Dynamics

Kristensen et al. 2012, 542, 8

- Dominates emission: key part of the water story in the interstellar medium

- Tracer of dynamics more broadly -- infall from prestellar to low mass to high mass (Caselli - Mottram - Herpin)

Nisini et al. 2010
A&A, 518, L120, Codella+ 2010
1. Water is made in prestellar phase under cold conditions as ice, D enrichments implanted.

2. Collapse seeds disk with water ice. Initial suggestions are this is mostly unaltered.

3. Water vapor is readily detected on disk surface in inner and rarely in outer disk. Seen as ice in outer disk - midplane remains hidden.

Herschel has made a large part of the water trail clear.

Still need to characterize the young forming disk - the missing stage and see the midplane.