Plasma analogue for astrophysical dust

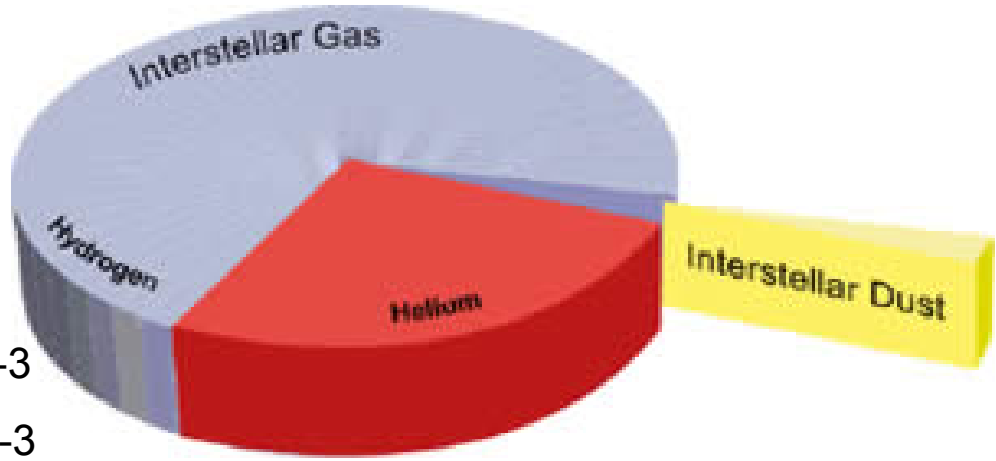
Ilija Stefanović

Experimentalphysik II, Ruhr-University Bochum, Germany

Acknoledgment

- Bochum: Applied Plasma Physics
  - E Kovačević, J Berndt, C Godde, J Winter
- Institute for Astrophysics/Observatorium, Fridrich-Schiller University, Jena, Germany
  - H Mutschke, C Jäger
- NASA Ames Research Centre, Moffet Field, California
  - Y J Pendleton

Background: Astrophysics



Gas: dust = 99 :1 (%)

Dust is omnipresent!

Dense ISM: $n \sim 10^{6\text{-}8}$ cm^{-3}
Diffuse ISM: $n \sim 1\text{-}100$ cm^{-3}

The role!!!

1. regulates star formation,
2. catalyzes molecule production and
3. reprocess UV

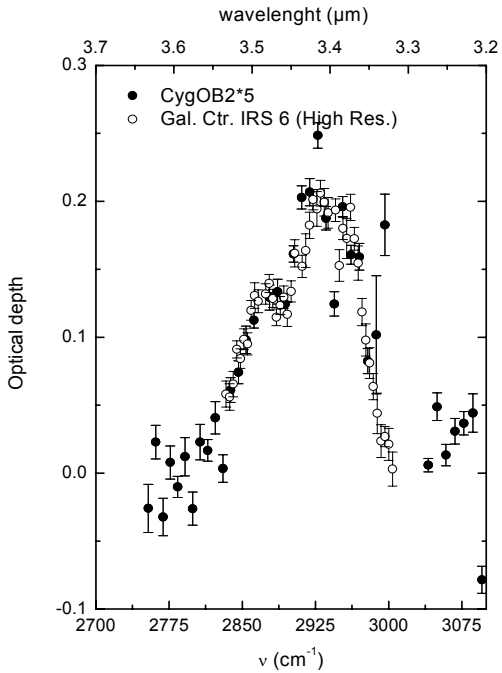
Observational data: extinction & emission

Background: Astrophysics

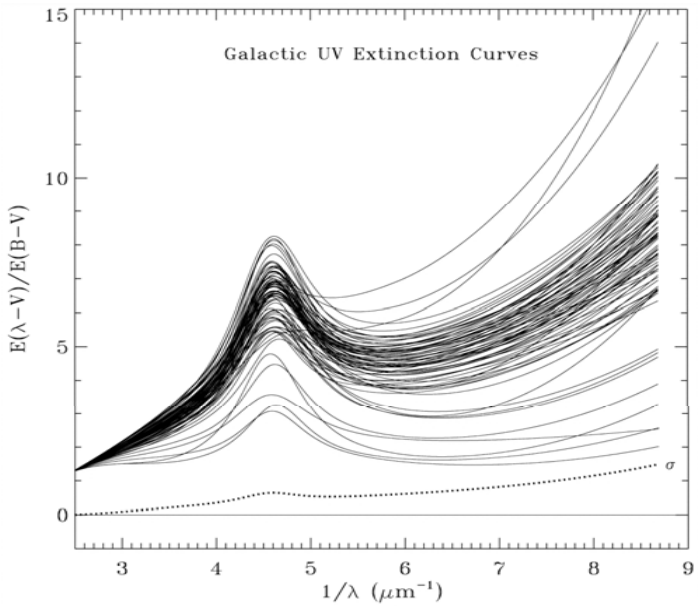
Famous example horsehead nebula

Common features

IR features



UV bump



Carbonaceous dust

- 3.4 μm IR feature: sp^3 (aliphatic) component in carbon grains

- UV bump (217.5 nm): sp^2 (graphitic, aromatic) component in carbon grains, coming from $\pi - \pi^*$ transition

Laboratory work for astrophysics/chemistry

- Astroanalogues
  - Laboratory material giving astrolike data
  - Not the „universe in small“ but scenarios!
  - Low temperature plasma jet similar to outflow regions of red giants! (circumstellar environments)
  - Carbon containing materials important!
  - Which features realy originate from carbonaceous material?

Experimental Set-up

Capacitively coupled RF

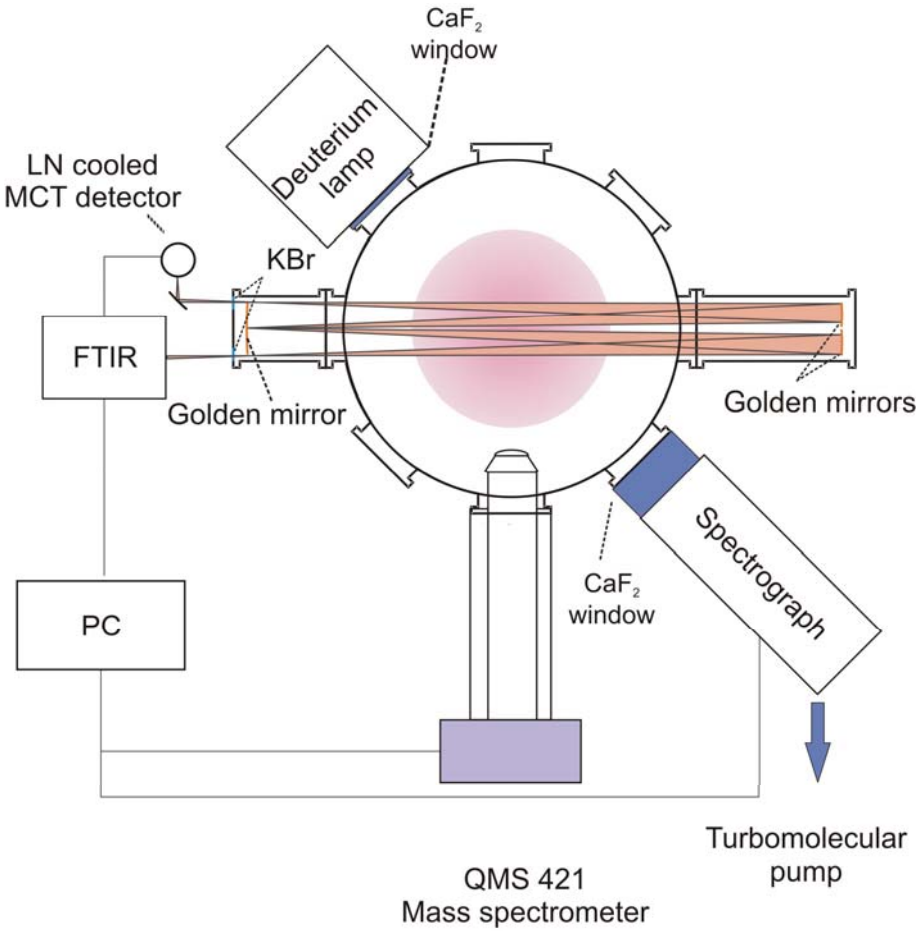
f = 13,56 MHz, d = 30 cm

p = 0,1 mbar, P = 10-20 W

Ar : C_2H_2 = 8 : 0.5 sccm

… N_2, O_2

Multipass in-situ FTIR



Experimental Set-up

Capacitively coupled RF

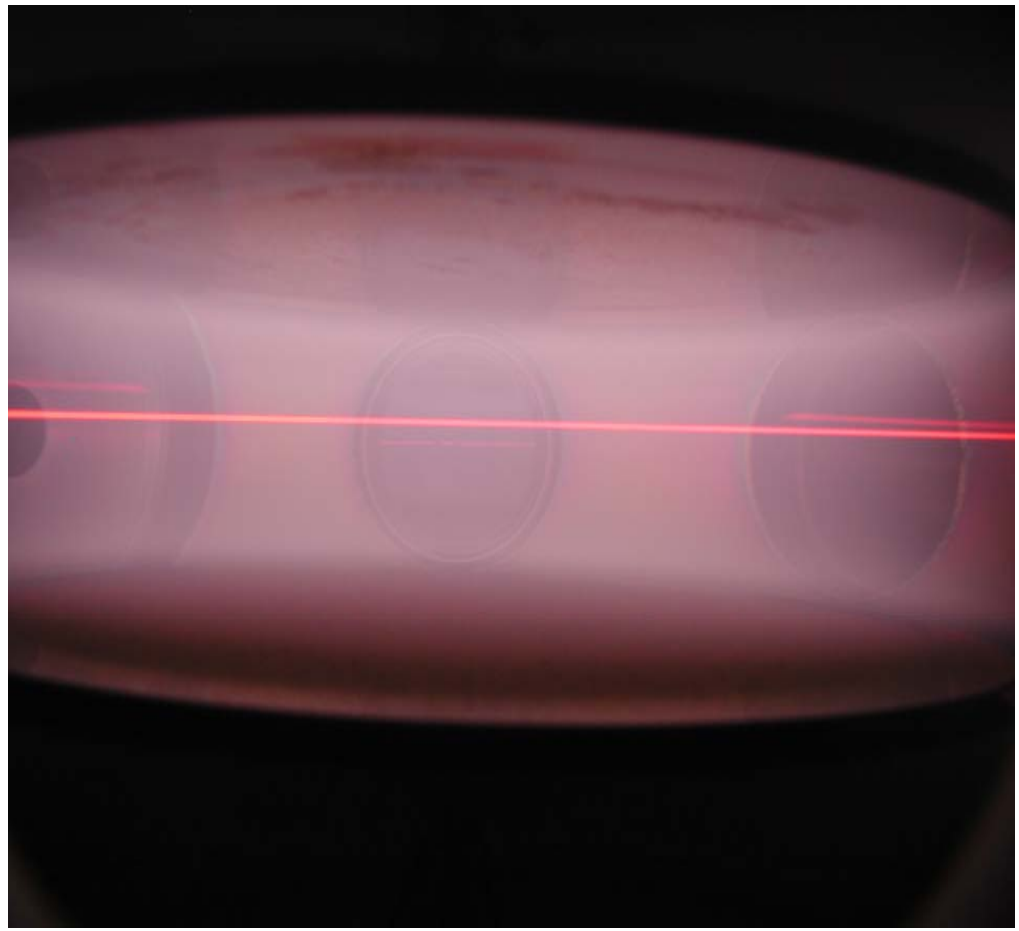
f = 13,56 MHz, d = 30 cm

p = 0,1 mbar, P = 10-20 W

Ar : C_2H_2 = 8 : 0.5 sccm

… N_2, O_2

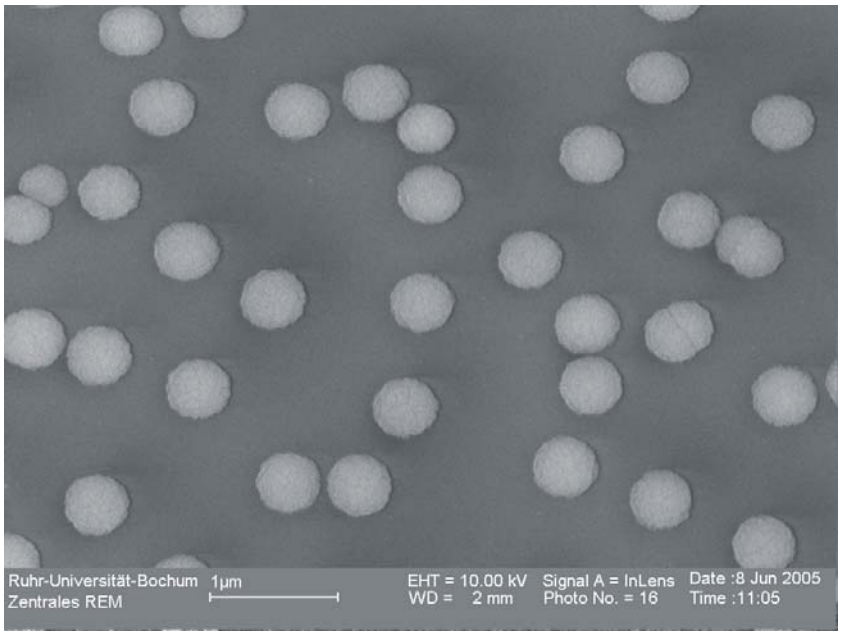
Multipass in-situ FTIR



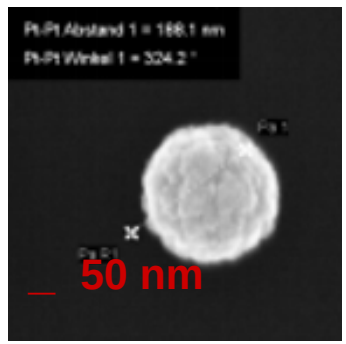
Ex-situ Identification (SEM, TEM)

Overview :

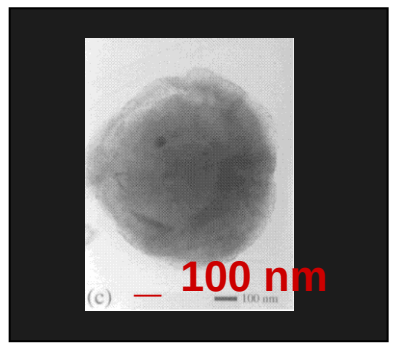
monodisperse particles



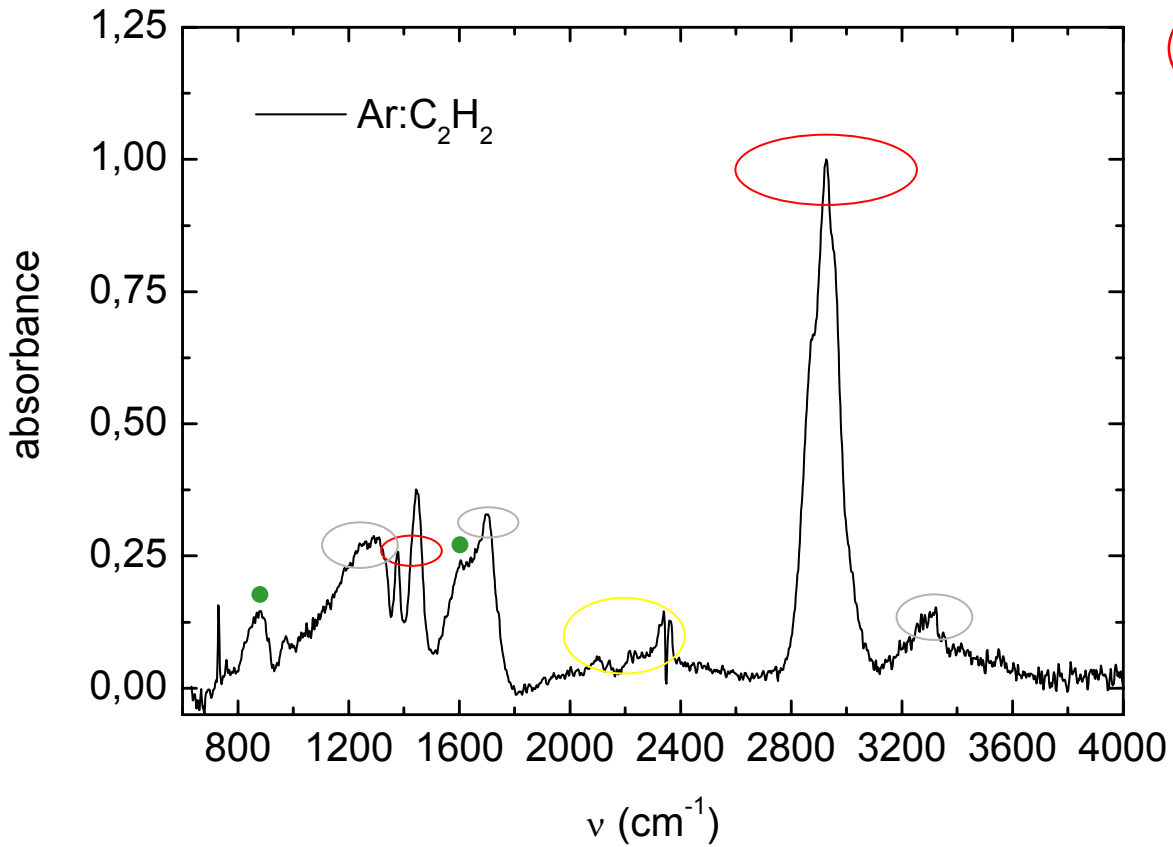
SEM



Extract from Murchison Meteorite (Bernatowicz Ap.J. 1996



C_2H_2 / Ar mixture



Aliphatics
1375, 1450, 2850-2950
H−C−C, H−C=C

C ≡ C
2100, 2300

Aromatics
888, 1604

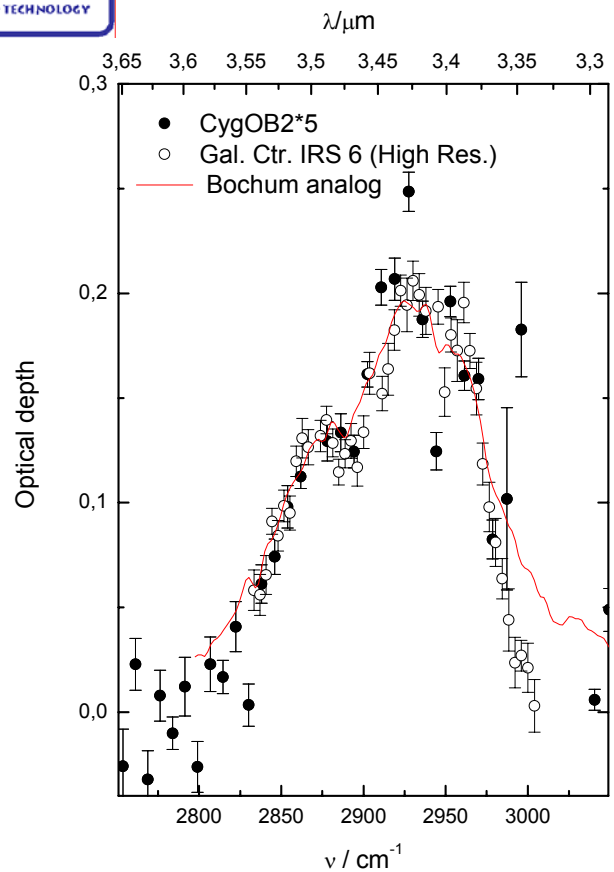
inpurities
(OH, carbonyl..)
1650-1720, 3100-3600

Criteria for a „good“ astroanalogue

Pendleton&Allamandola (*ApJS* 2002 **138** 75)

- Comparison of the profile and subpeak positions of the 2940 cm^{-1} (3.4 μm) aliphatic CH stretch
- Ratio of the optical depth (O.D) of the aliphatic stretch to the OH near 3200 cm^{-1} (3.1 μm)
- Ratio of the O.D of the aliphatic stretch to the CO near 1700 cm^{-1} (5.9 μm)
- Ratio of the O.D of the aliphatic stretch to the CH deformation modes near 1470 cm^{-1} (6.8 μm) and 1370 cm^{-1} (7.25 μm)

IR feature - data comparison



3.4μm

Observed in more than dozen galaxies

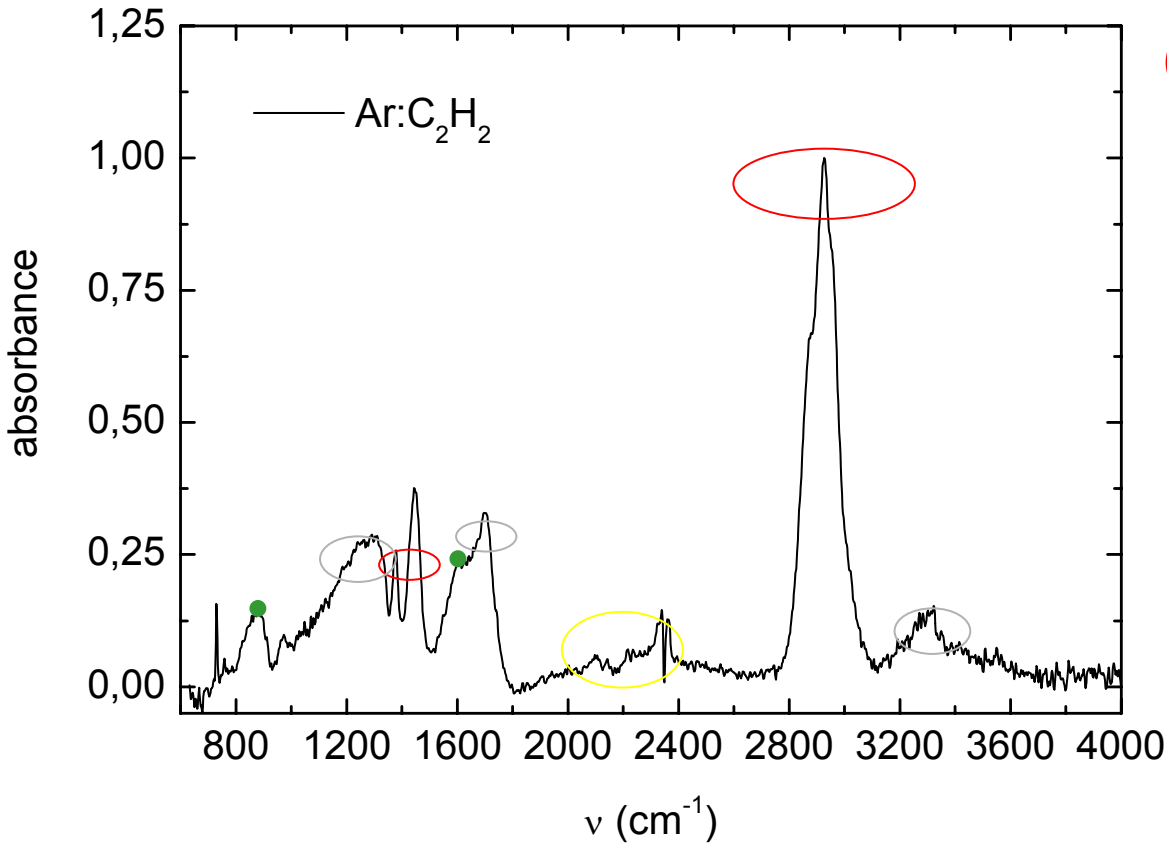
C-H stretching vibrations:

2955 cm^{-1} -CH3 antisymmetrc

2930 cm^{-1} -CH2- antisymmetric

2870 cm^{-1} -CH3 symmetric

C_2H_2 / Ar mixture

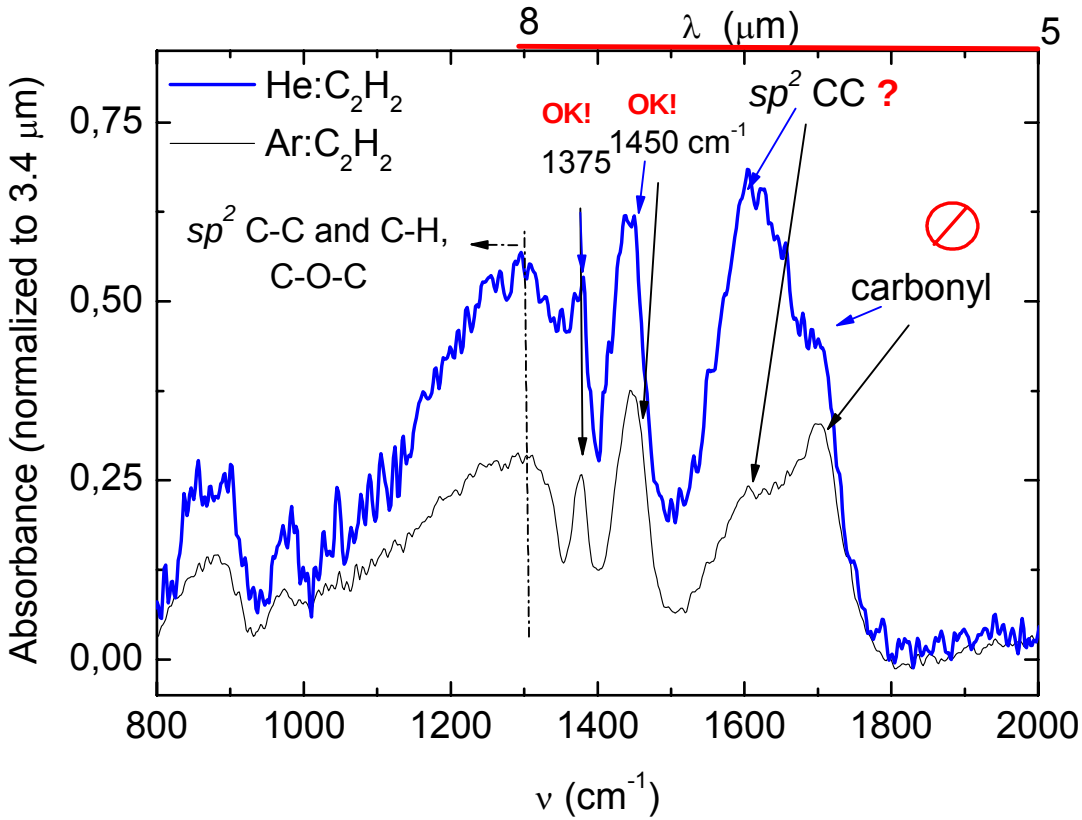


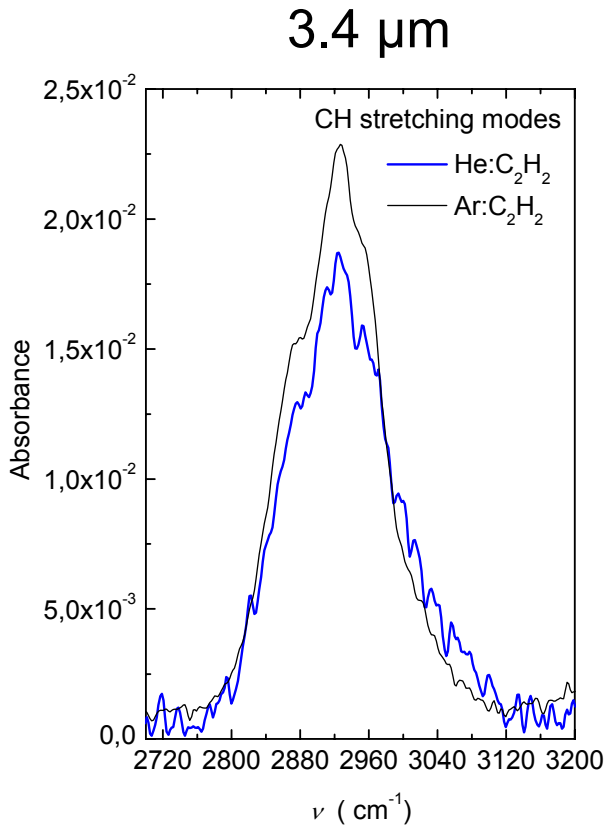
Good analogue!

Kovačević E, Stefanović I, Berndt J, Pendleton Y J, and Winter J, 2005, *ApJ* 623, 242

Spectra/particle variation

Variation of carrier gases: Ar vs. He

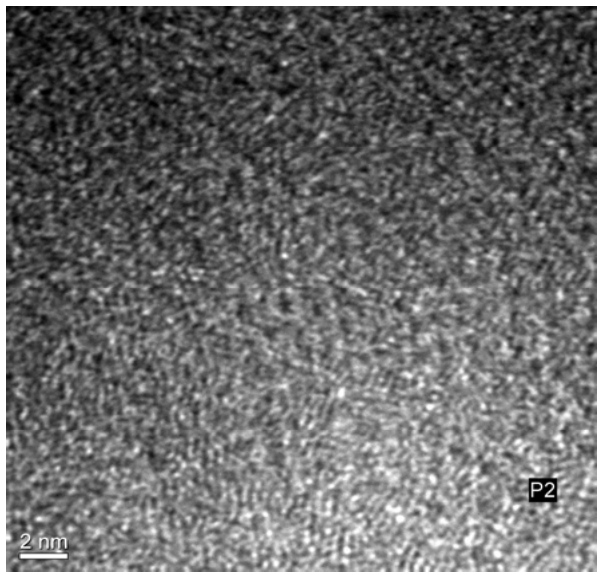




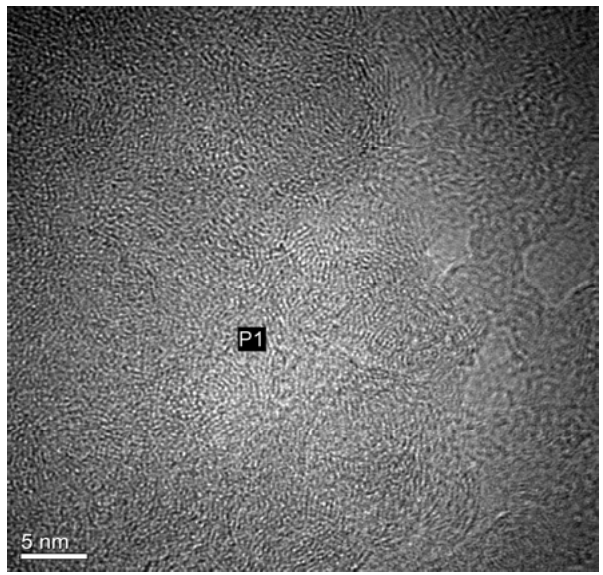
5-8 μm region- hot topic!

Spectra/particle variations

Argon



Helium

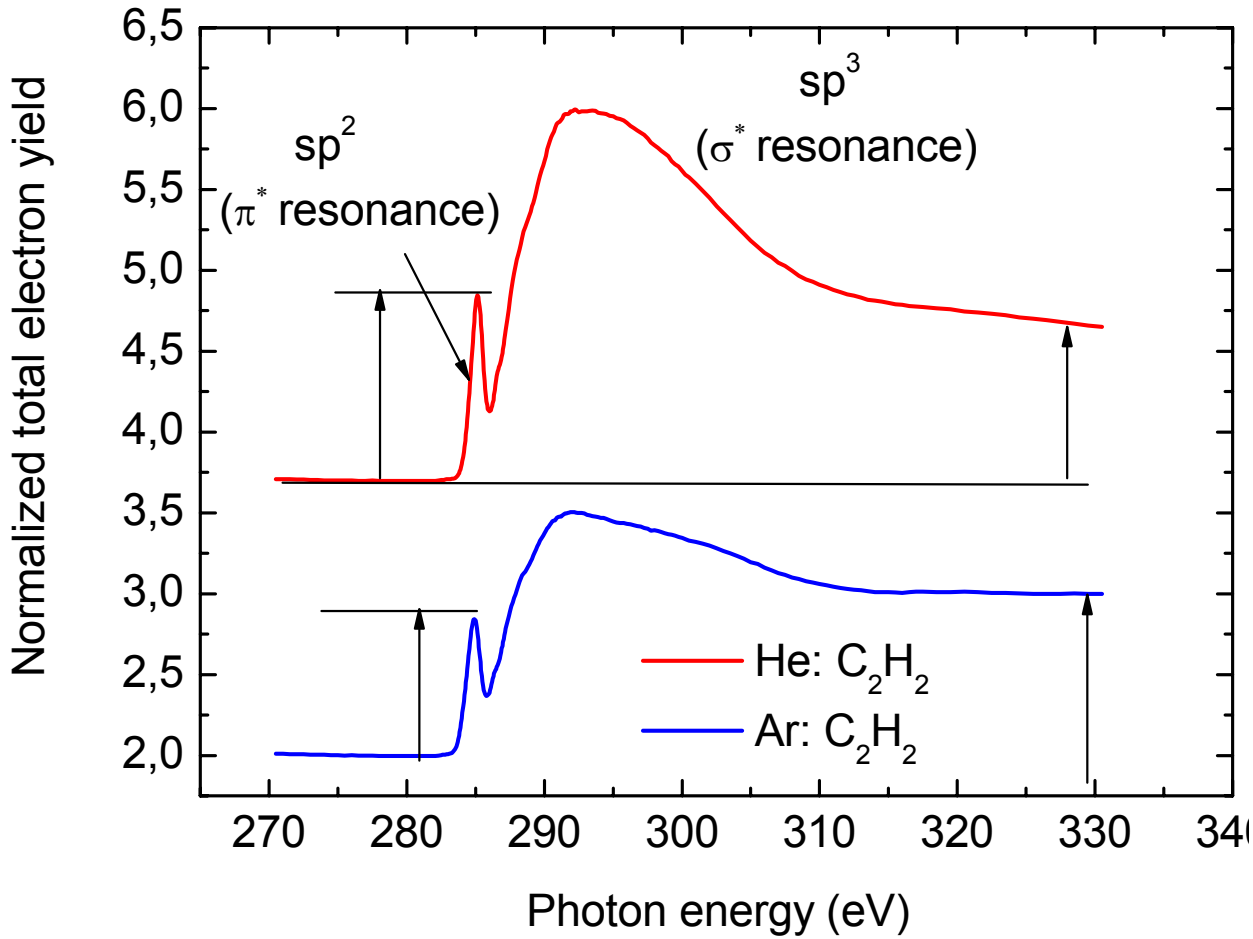


Spectra/particle variations

Variation of carrier gases: Ar vs. He

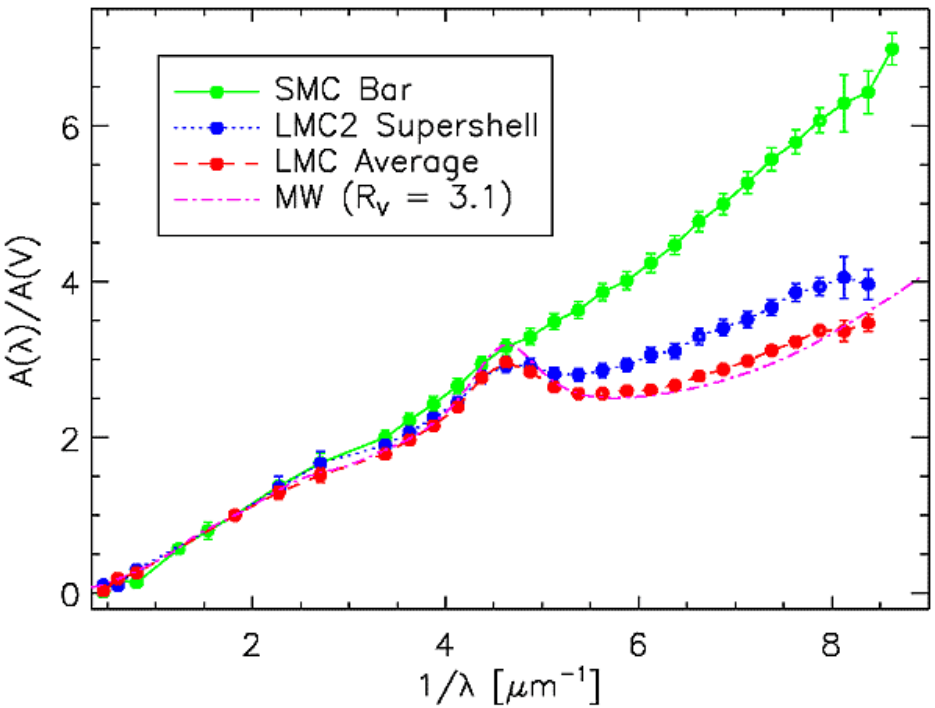
- *Ex situ* diagnostic techniques:
  - Nuclear reaction analysis (NRA):
    - Argon: ~ 50% H, ~ 50% C
    - Helium:~ 40% H, ~ 60% C (for UV bump H/C<1 supposed)
  - NEXAFS
    - sp^2 / sp^3 ratio

NEXAFS, ratio sp^2/sp^3



UV bump

Extinction curve in VIS/UV region



Extinction: scattering + absorption

1) information on the dust size

2) information on the refraction index

Bump at: 217.5 nm /~4.6 μm^{-1}

Stable position
Variation of the width

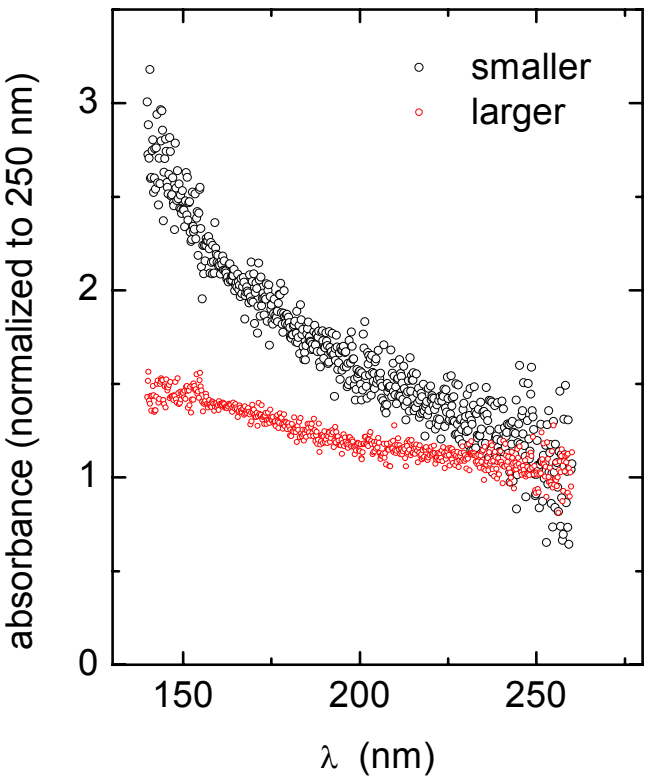
Origine:

Carbonaceous sp^2 sites

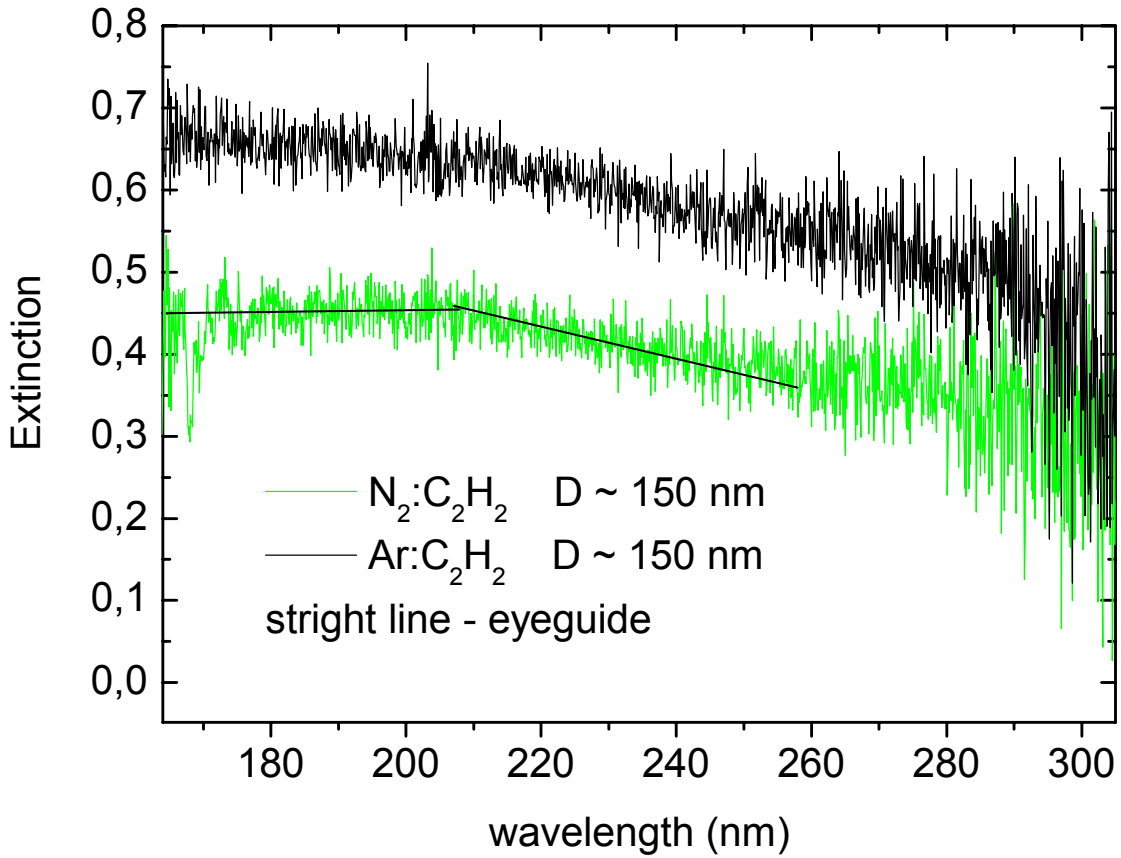
Absorption due to π-π^* transitions

UV bump

First results:



UV Extinction of the plasma analogue



Incorrporating N?

Conclusions

Plasma polymerized dust particles:

- Controlled growth of spheroid particles
- Versatile and well controlled growth process
- IR spectra fullfilling MIR criteria for ISM analog
- Particles are isolated, no agglomeration – optical measurements and simplified modeling

Outlook

- Incorrporating different heteroatoms, like nitrogen

- Trying another experimental methods to tailor the (optical) properties of nano-particles: laser ablation+plasma polymerization