# Astromineralogia

Silvia Lorenz-Martins

Observatório do Valongo/UFRJ

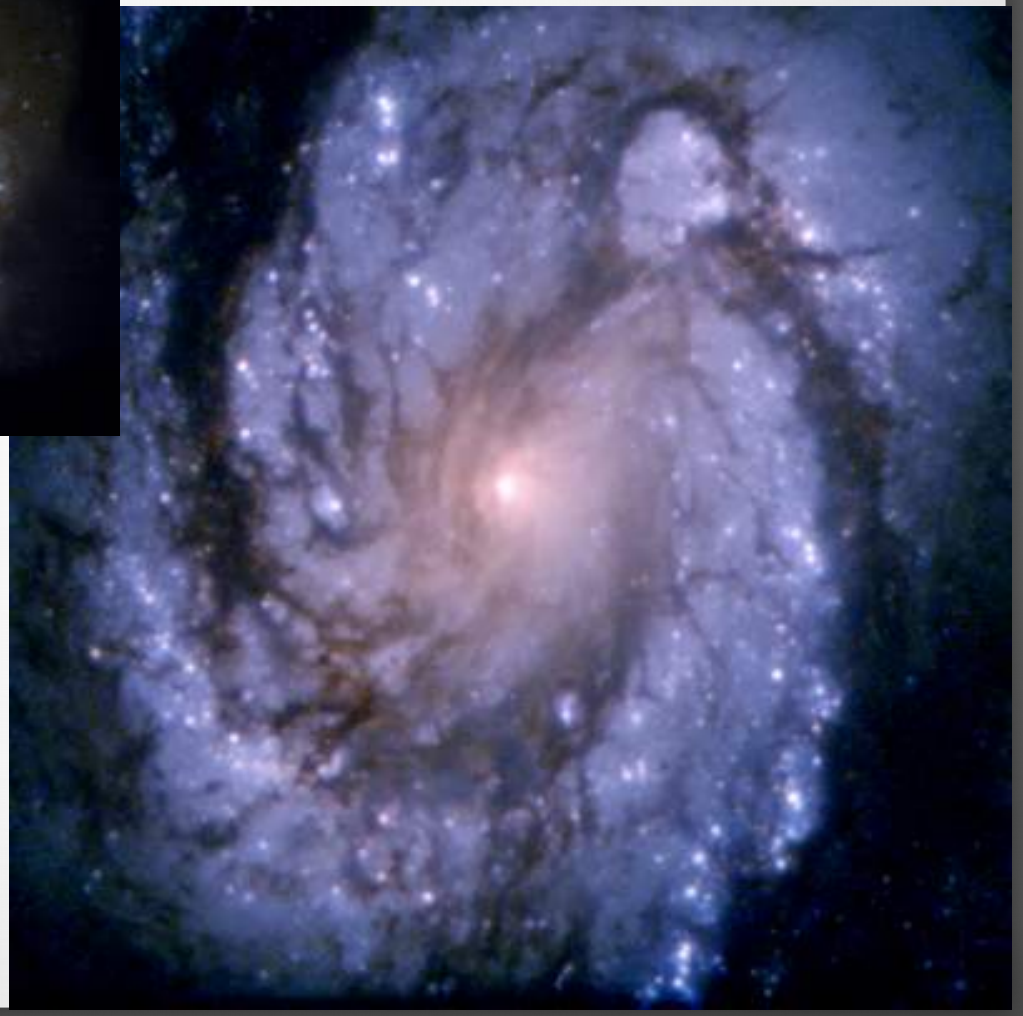
# O que é ?

- Estudo mineralógico dos sólidos (*grãos de poeira*) presentes em diferentes objetos astronomicos
  - *Identificar a composição química*
  - *Forma cristalográfica*
- Comparação com medidas de laboratório
- Utilizando modelos matemáticos

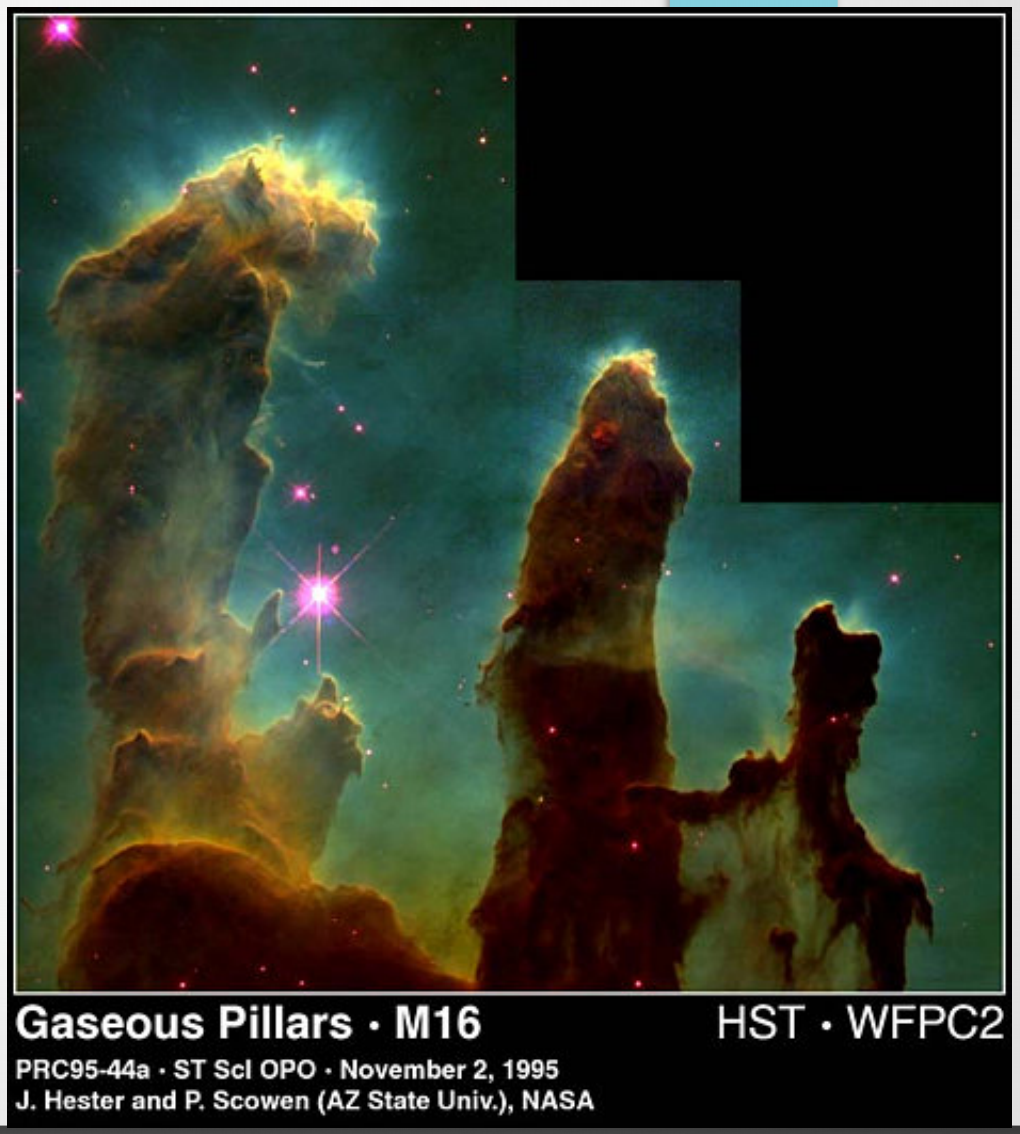
# Onde estão os grãos

- Galáxias
- Nuvens interestelares
- Discos de poeira
  - Proto-planetários
  - circunstelares
- Envoltórios circunstelares
- Sistema Solar
  - Planetas
  - Cometas, Asteroides, IDPs, etc…

# Sombrero



# Nuvens Interestelares

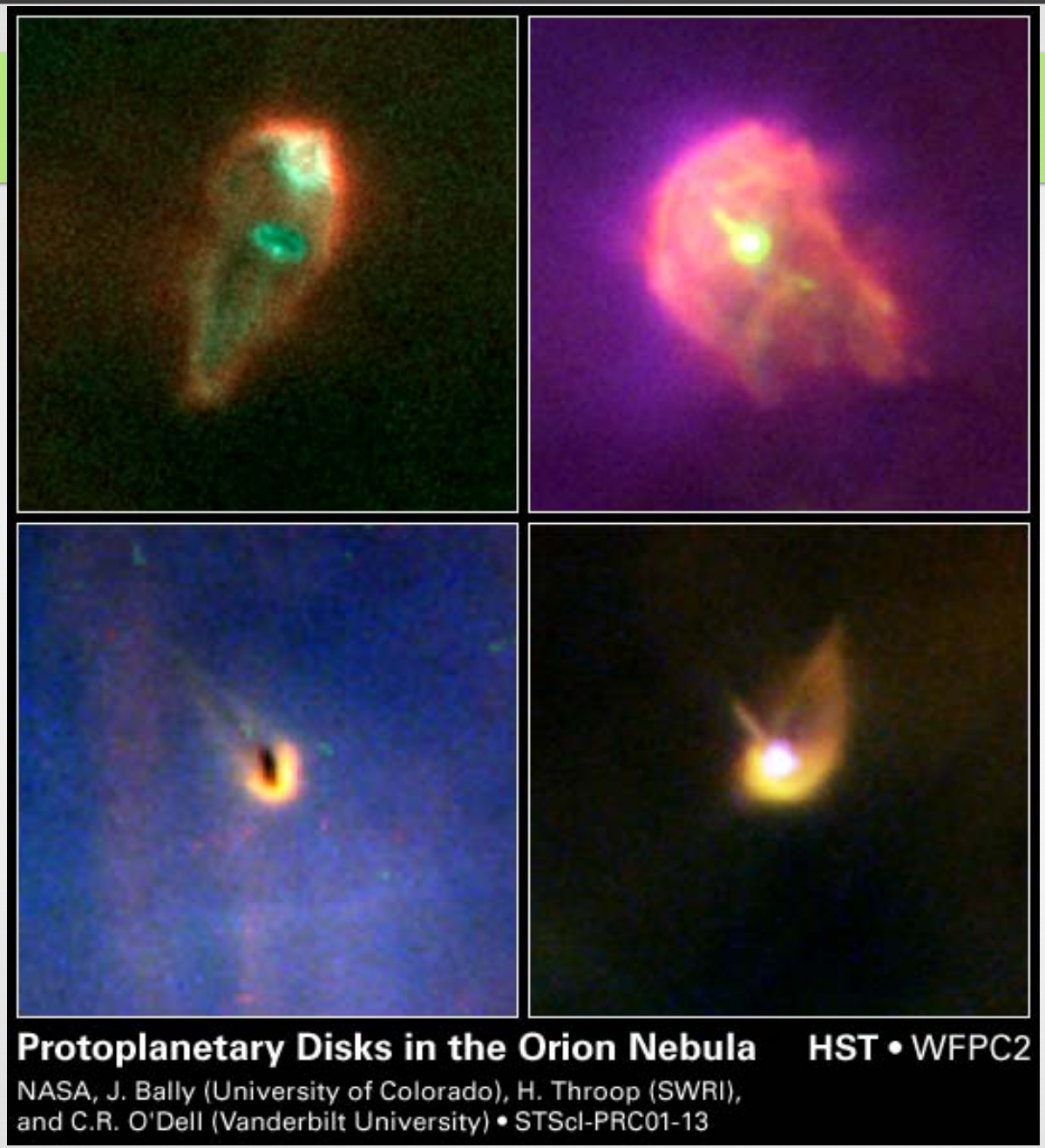



Star Shadows Remote Observatory

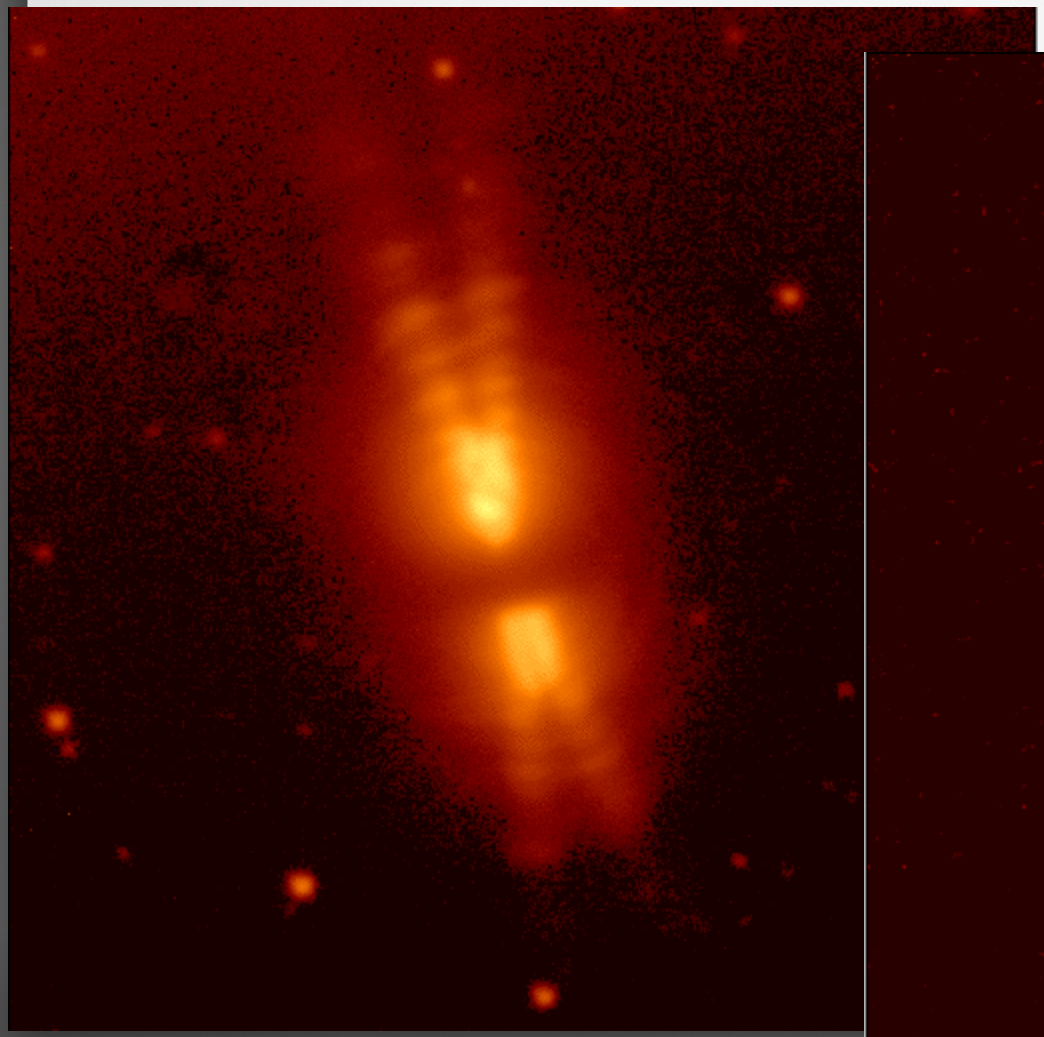
# Discos de Poeira

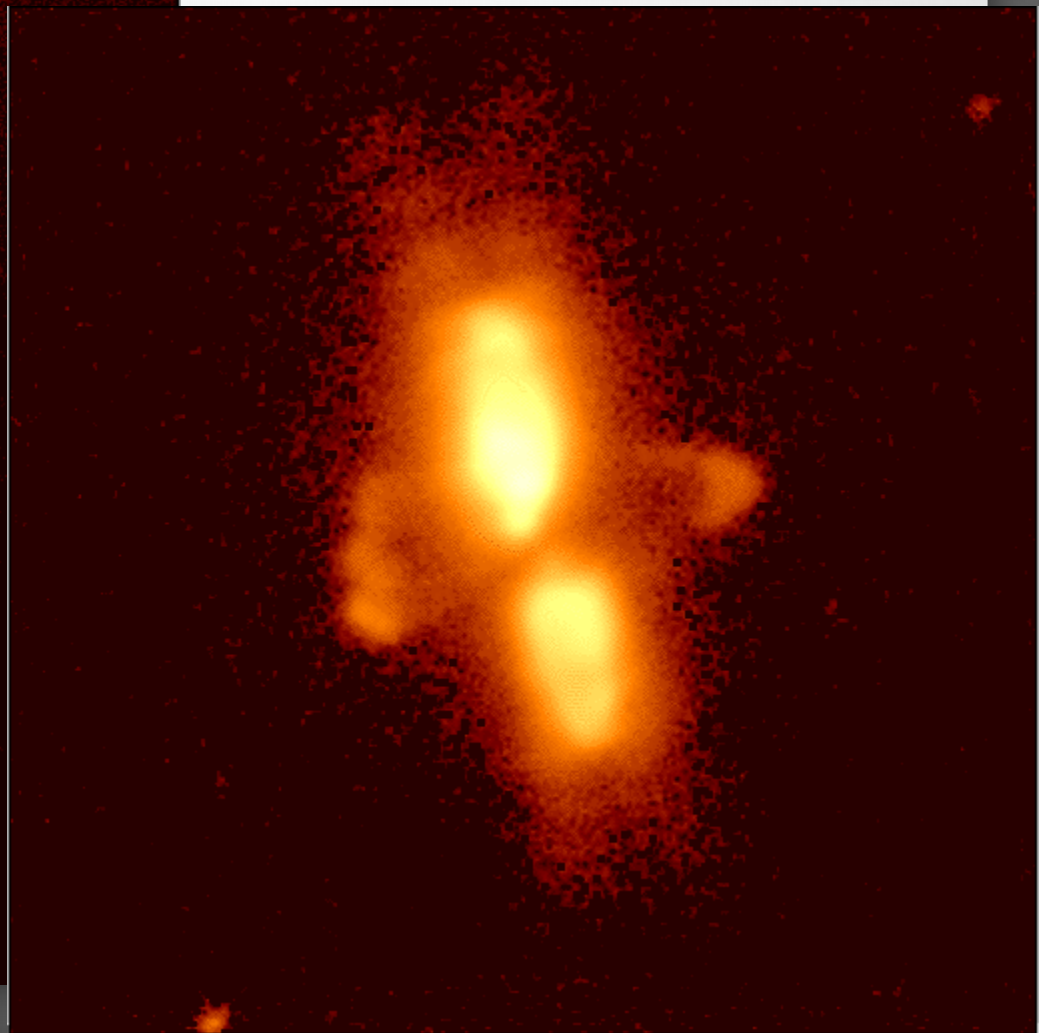
- Situações:

- Formação de uma nova estrela
- Formação de sistemas planetários
- Sistemas binários
  - Discos de acresção
- Estágios finais da evolução estelar

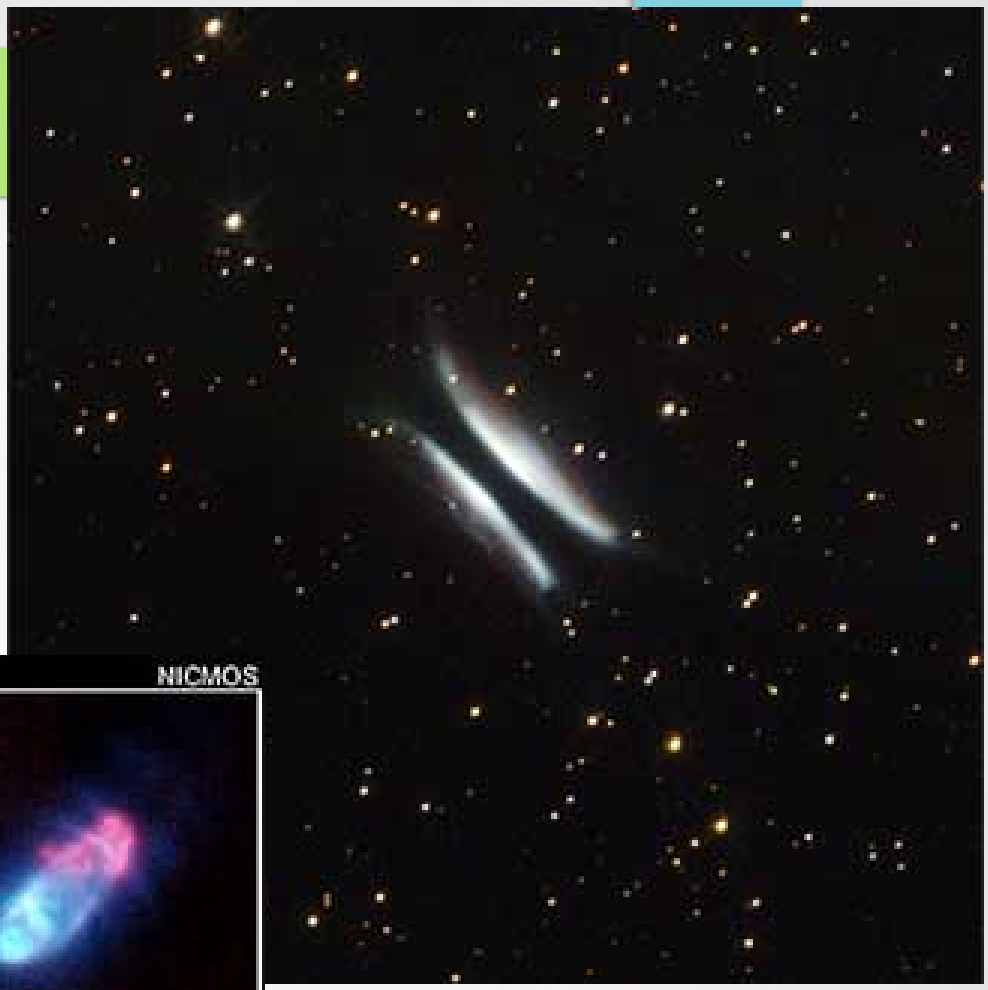

Protoplanetary Disks in the Orion Nebula
HST • WFPC2
NASA, J. Bally (University of Colorado), H. Throop (SWRI),
and C.R. O'Dell (Vanderbilt University) • STScI-PRC01-13

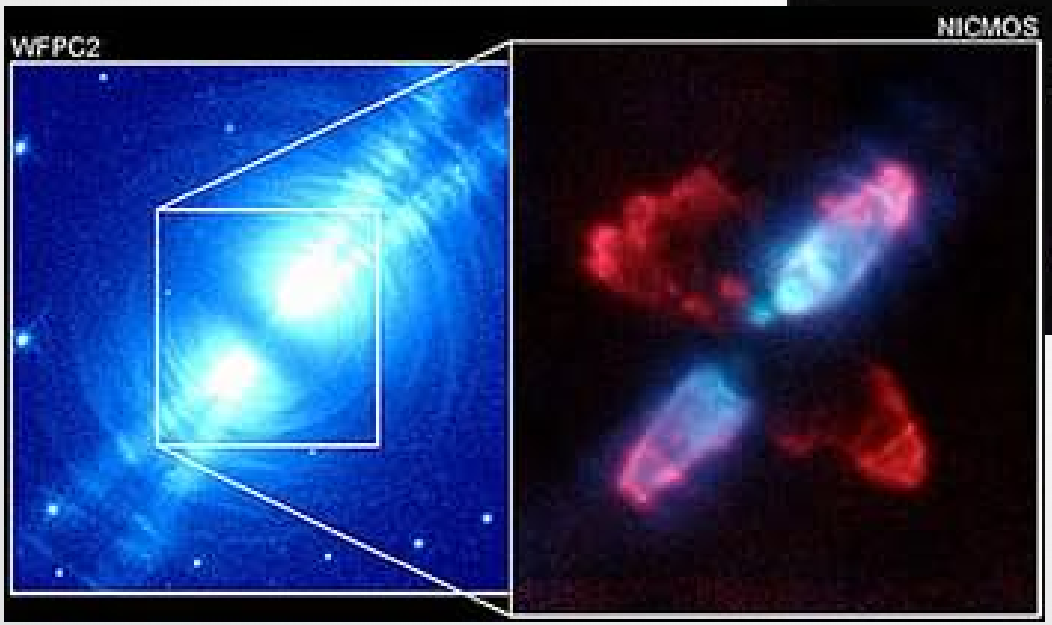
# Discos: Estágios finais da evolução





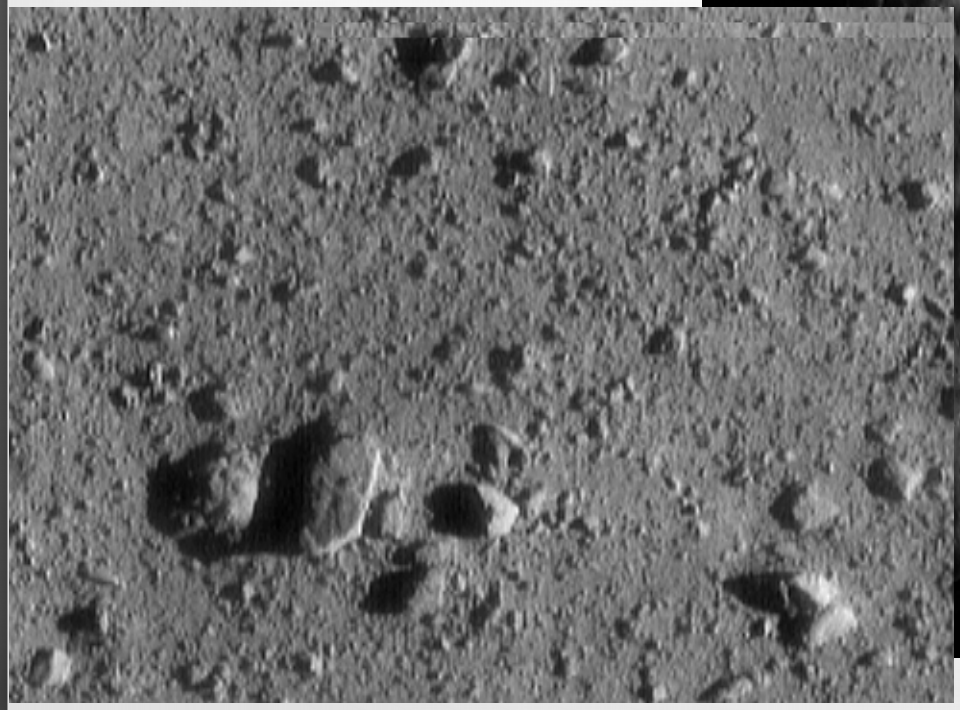
# Estágios finais

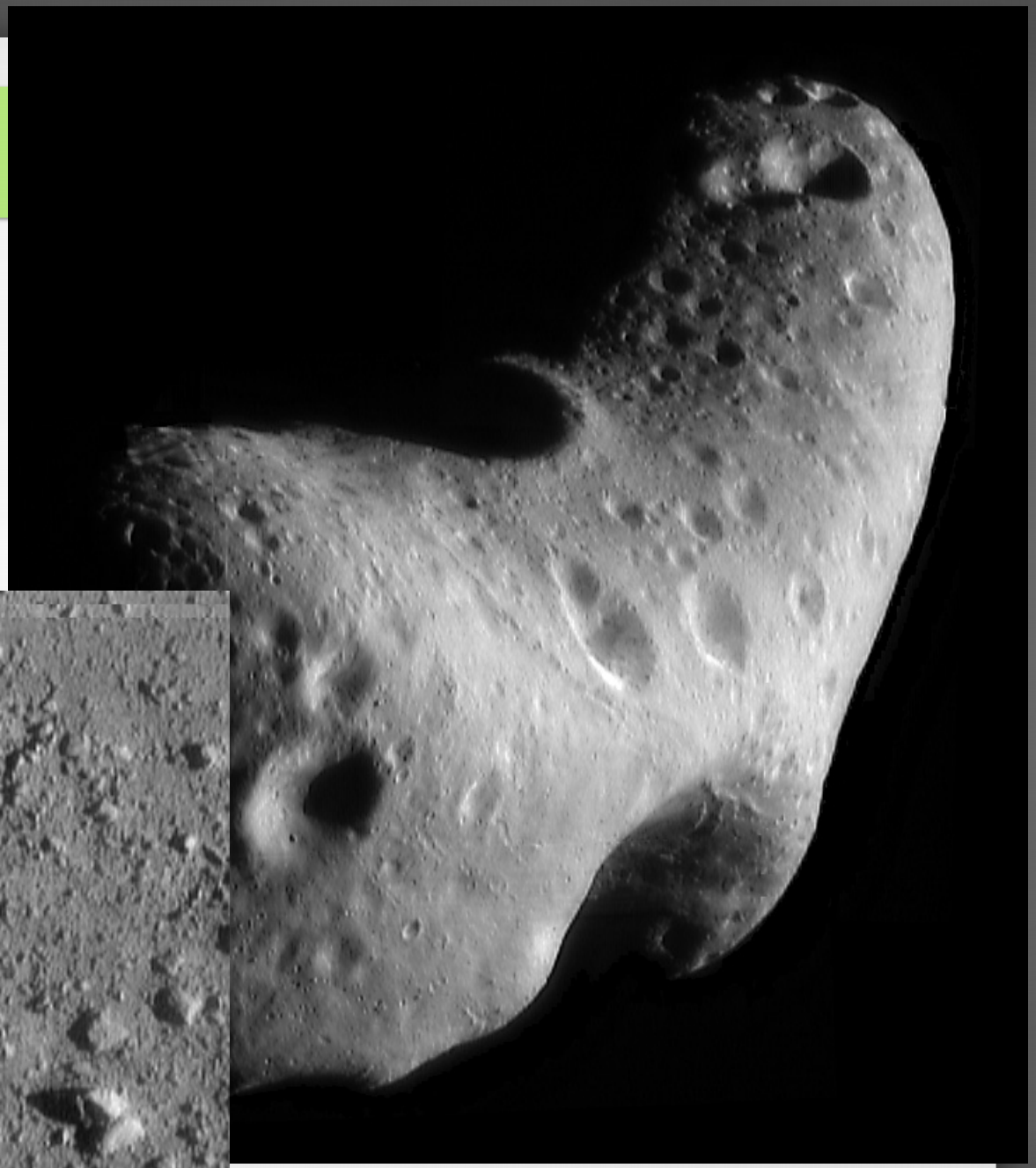




# Sistema Solar

Eros

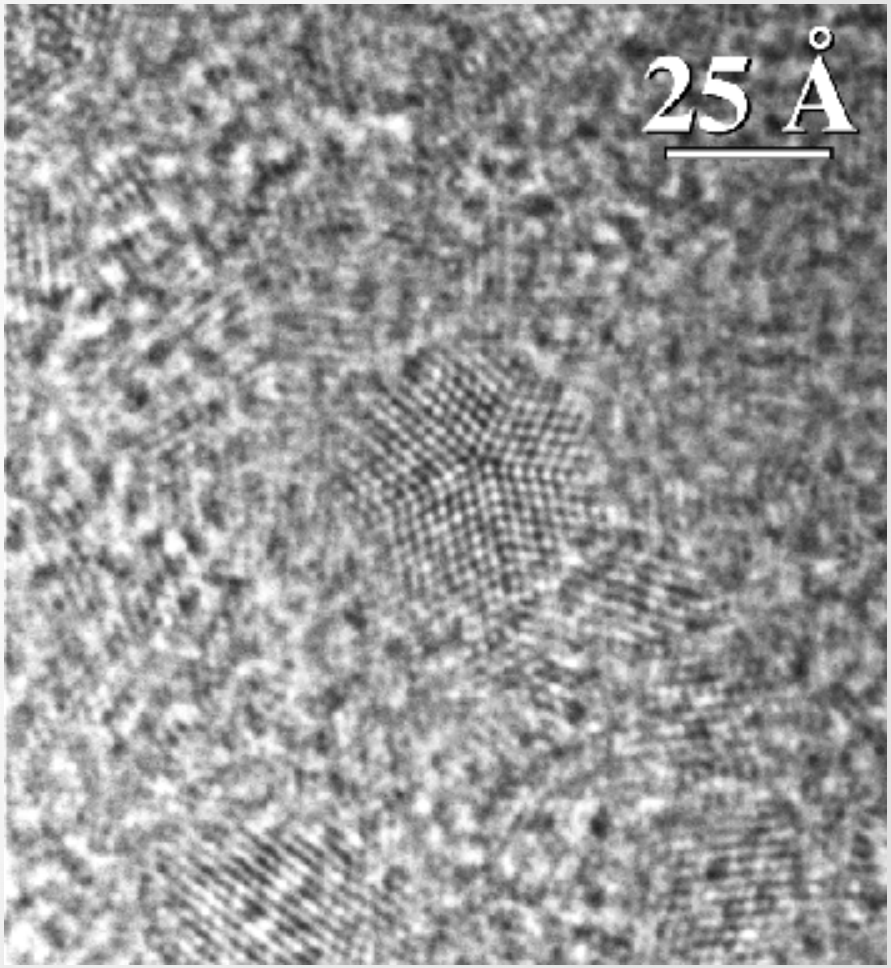




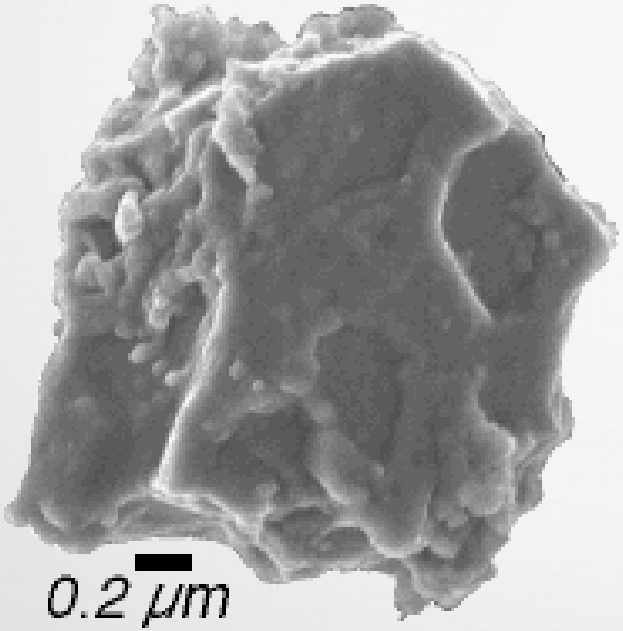
# O que são grãos de poeira ?

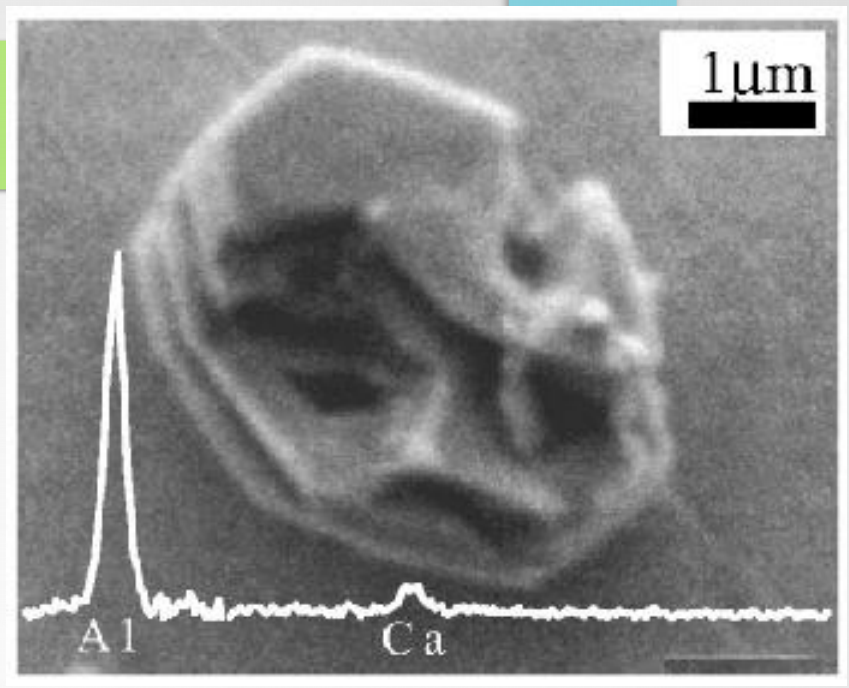
- Partículas sólidas
- Tamanhos: 25 – 10000 Å
- Diversas composições químicas

- Diamante



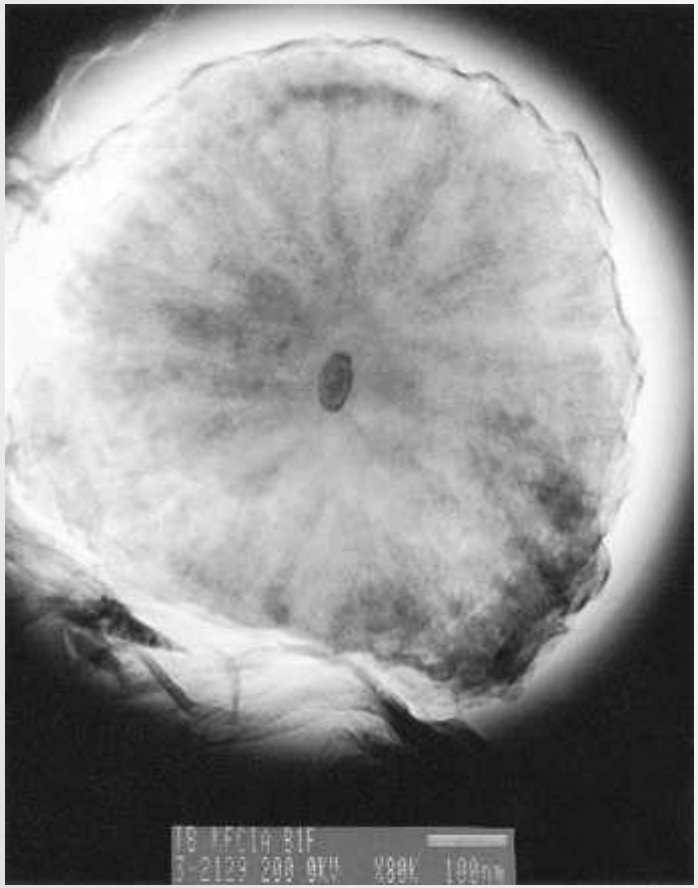
SiC

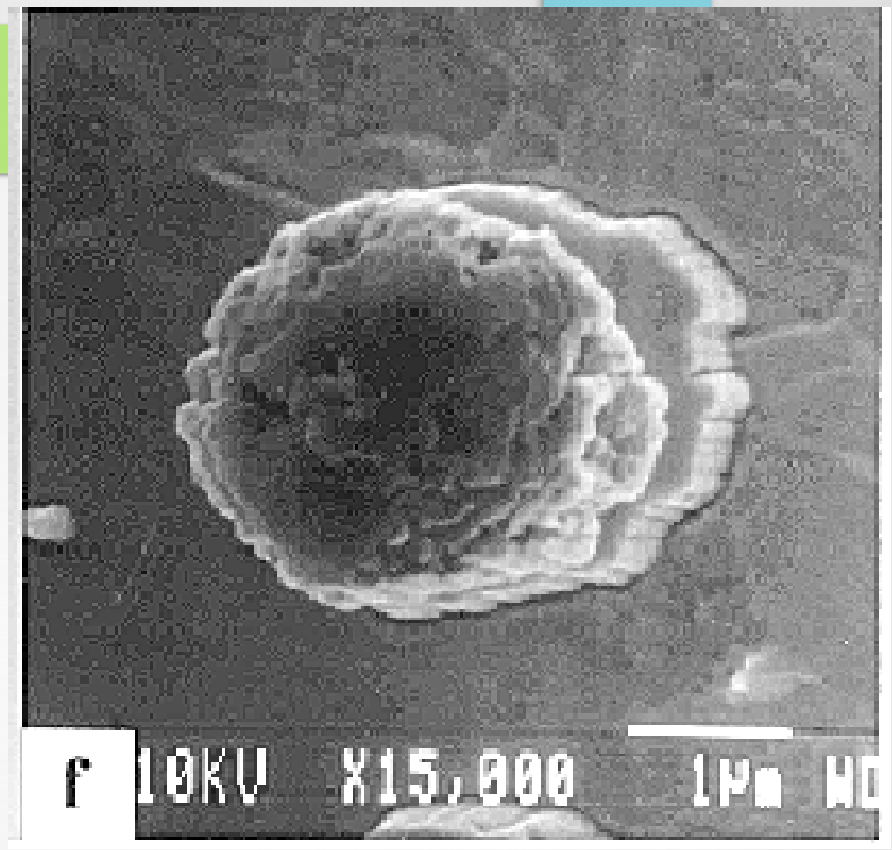


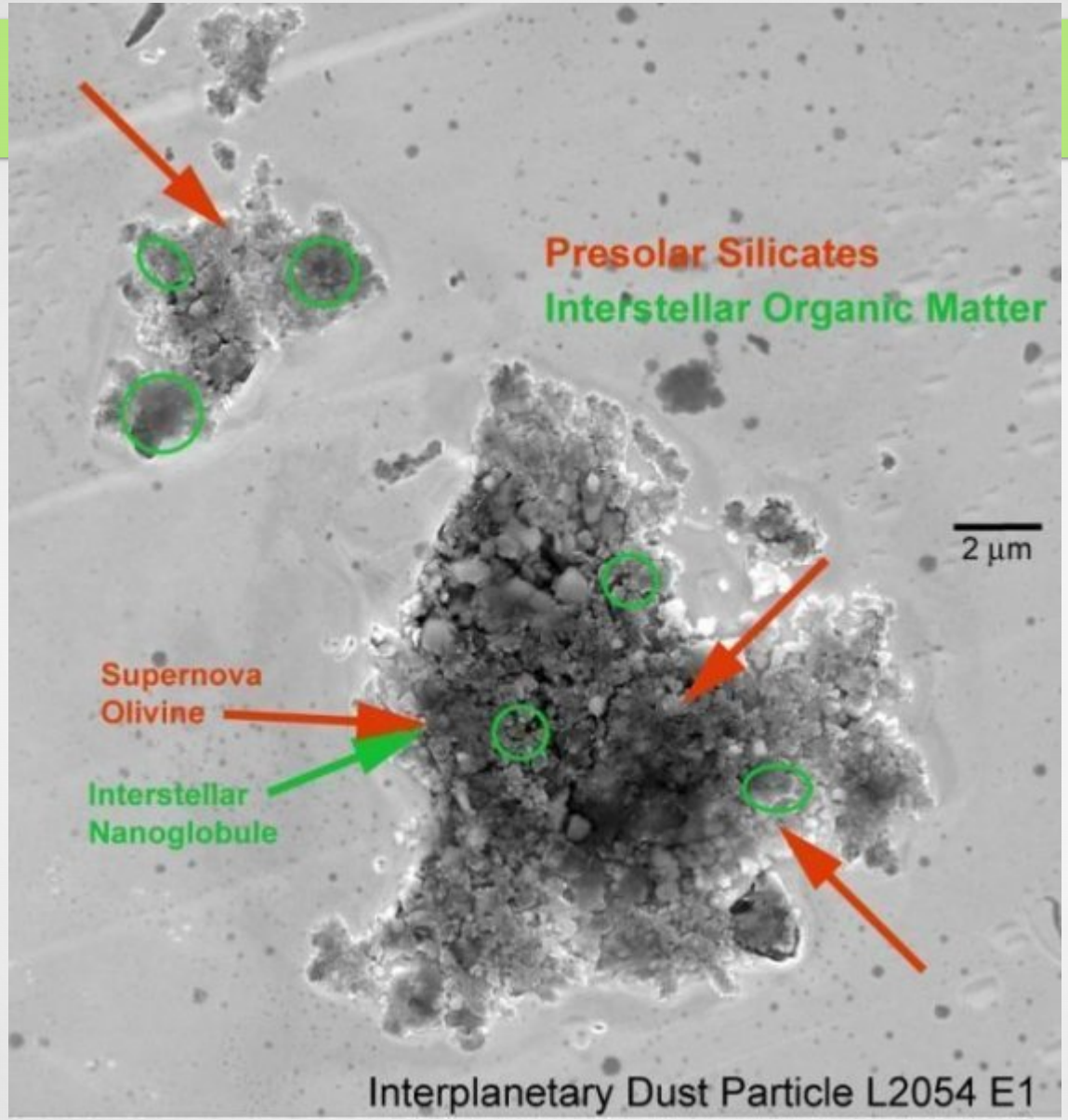




# Hibonita

# Grafite

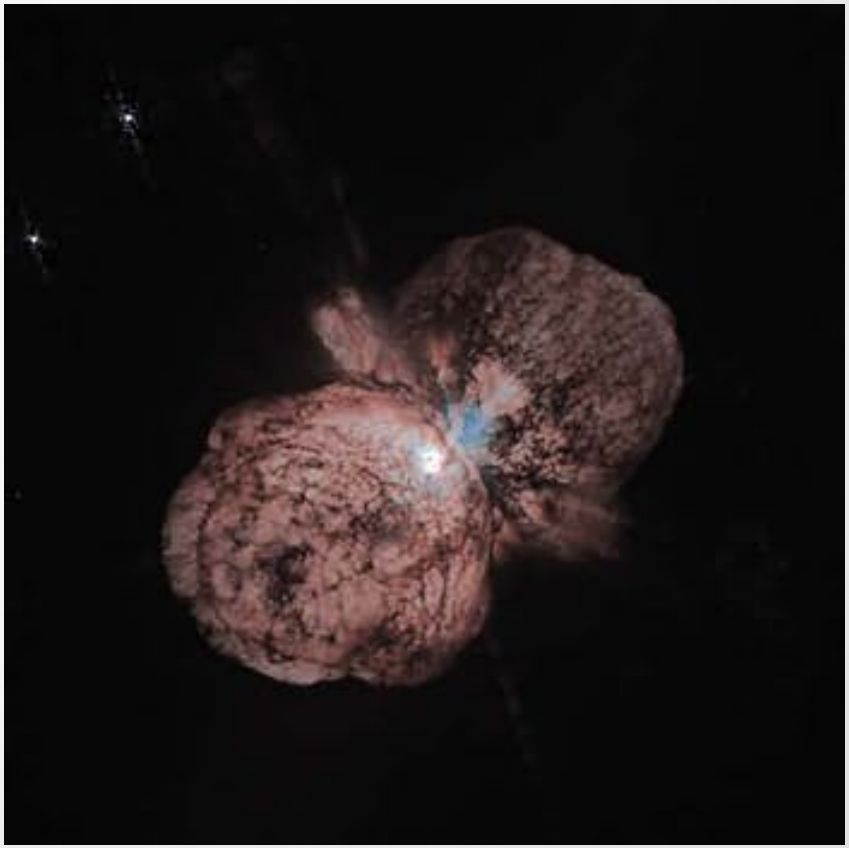





Presolar Silicates
Interstellar Organic Matter
2 µm
Supernova
Olivine
Interstellar
Nanoglobule
Interplanetary Dust Particle L2054 E1

# Formação dos grãos ⇒ Evolução

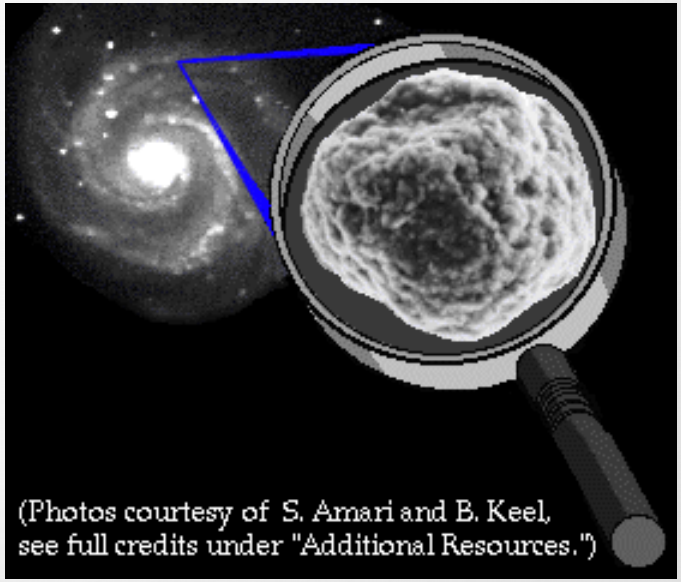
- Condensados nos Ventos de estrelas evoluídas
  - Frias
  - Quentes
  - Eta Carina



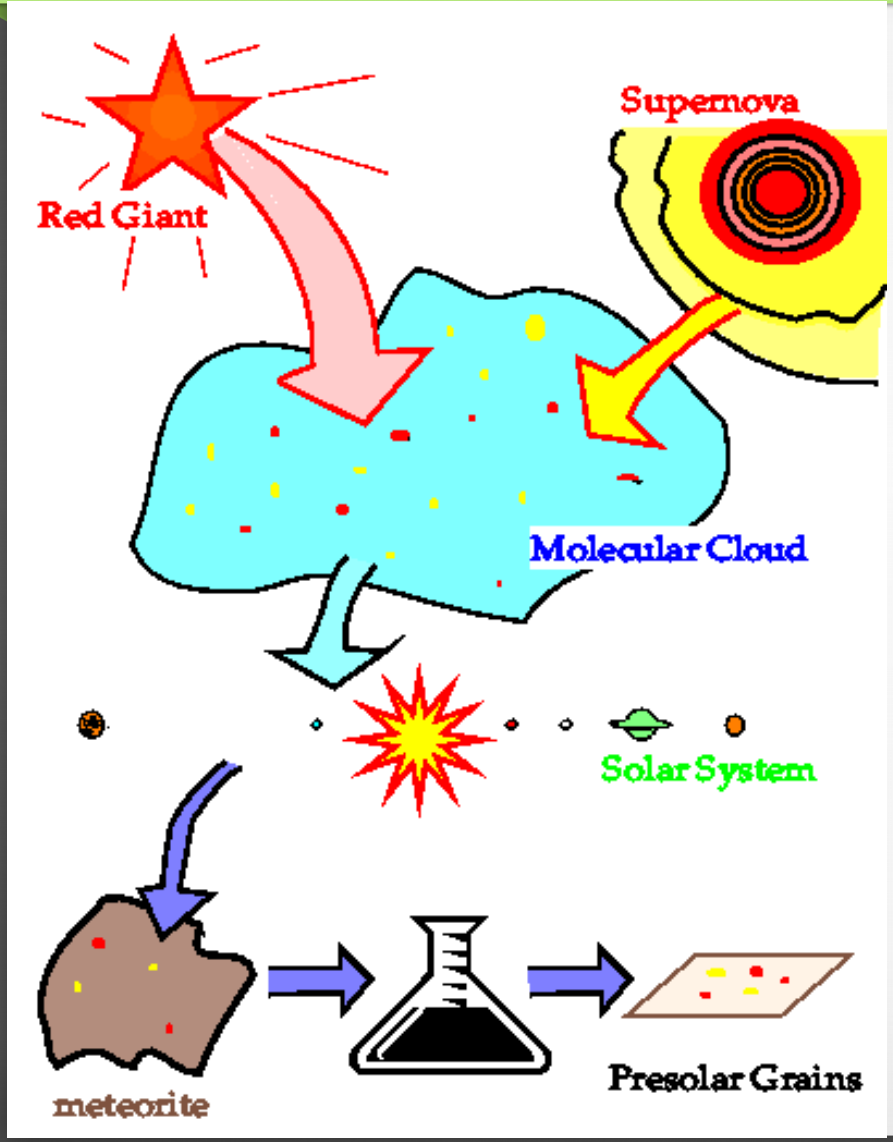
# Astromineralogia: Como estudar a poeira

- Diretos: Meteoritos, Cometa (Stardust)
  - Laboratório
- Indiretos: Observações
  - Solo
  - Telescópios Espaciais IR

$\Rightarrow$ *Modelos matemáticos*



# Método Direto: Meteoritos

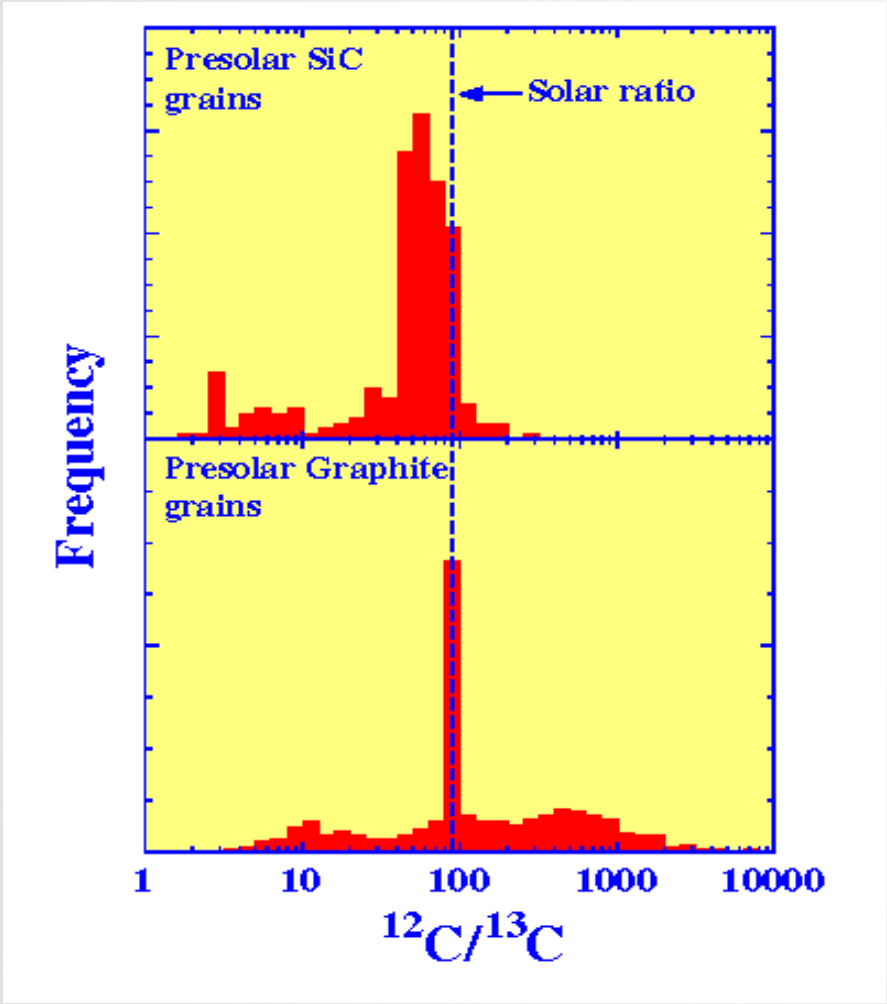



**Meteoritos mais primitivos ⇒**

Grãos pré-solares

- Condensados na fase gás
- gigantes vermelhas e SN
  - antes da formação do SS → vaporizados

# Identificação de Grãos Pré-solares




$^{12}C/^{13}C$

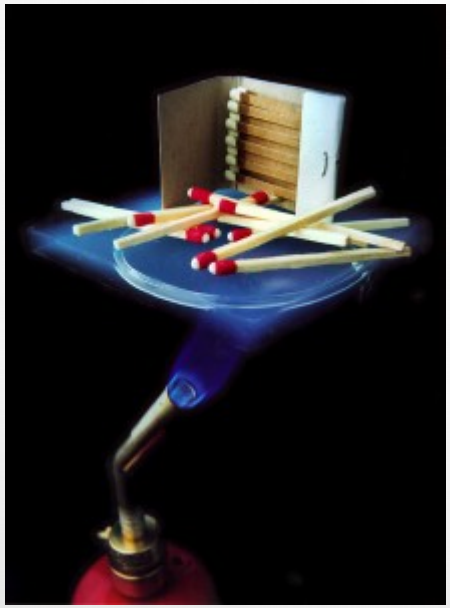
$(^{12}C/^{13}C)_{solar} = 100$

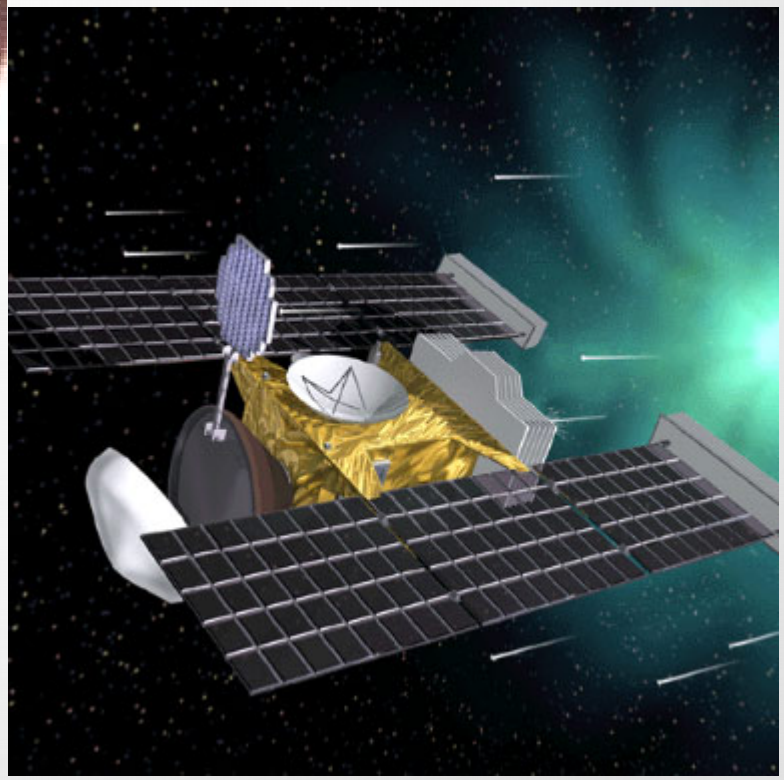
Outras fontes: grande intervalo de valores!

Conhecendo $^{12}C/^{13}C$

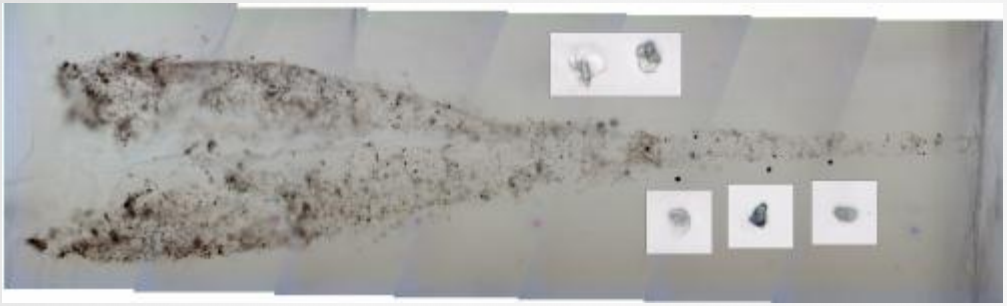
identifica-se a fonte que condensou o grão


STARDUST
NASA's COMET SAMPLE RETURN MISSION

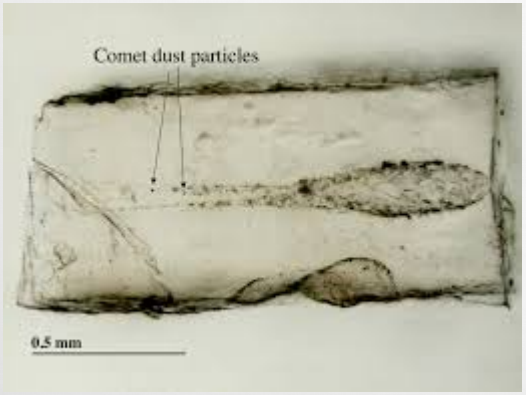


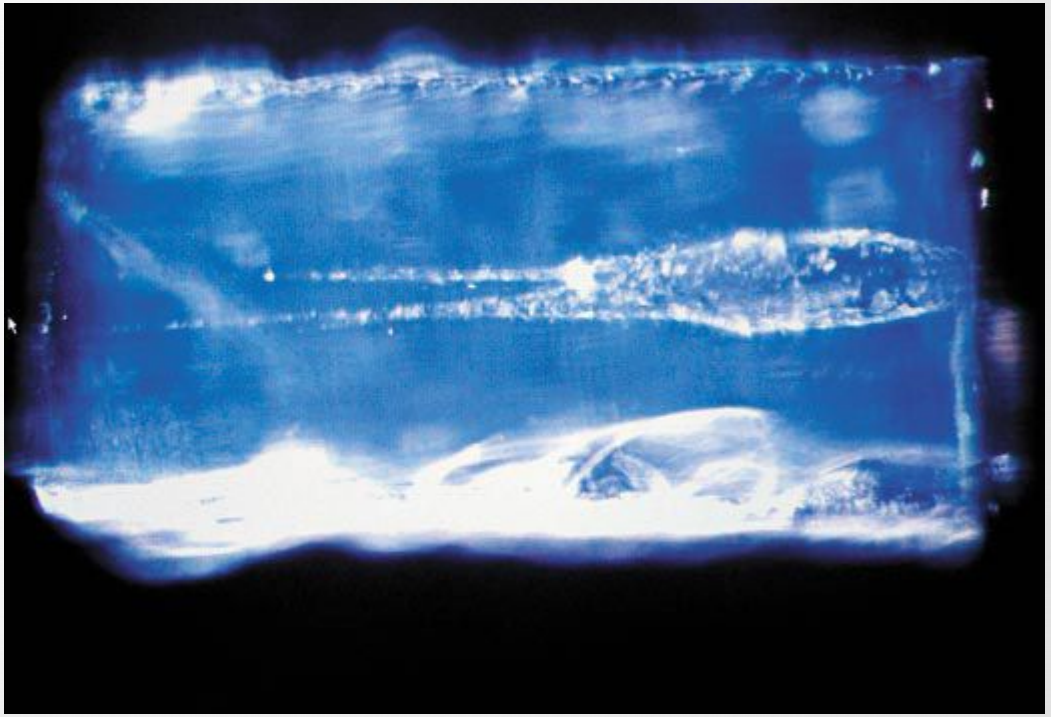


# Método Direto: Cometas

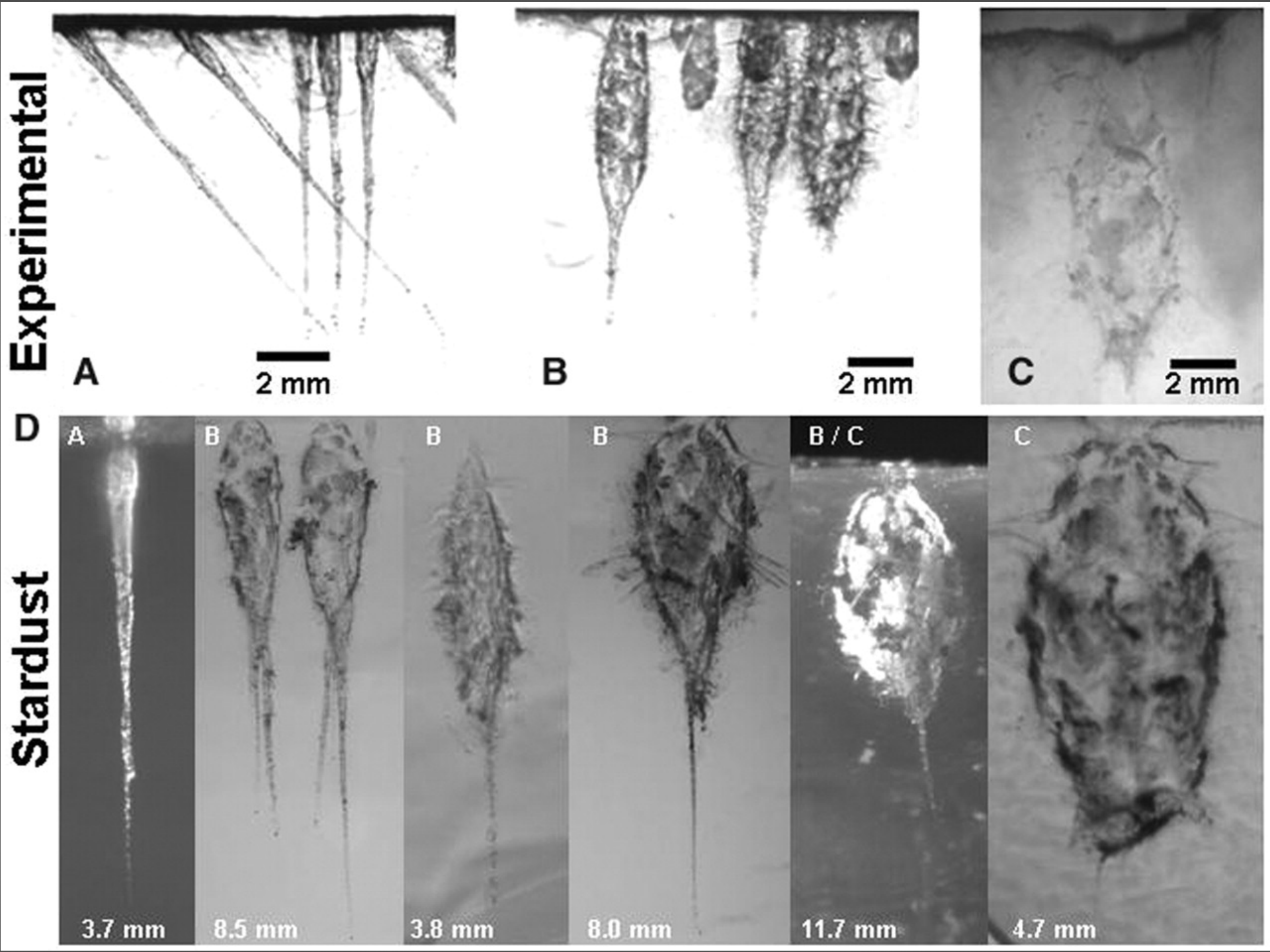


"Calcium Aluminum Inclusions" or CAI's for short.
CAI's são a mais antiga matéria formada no SS

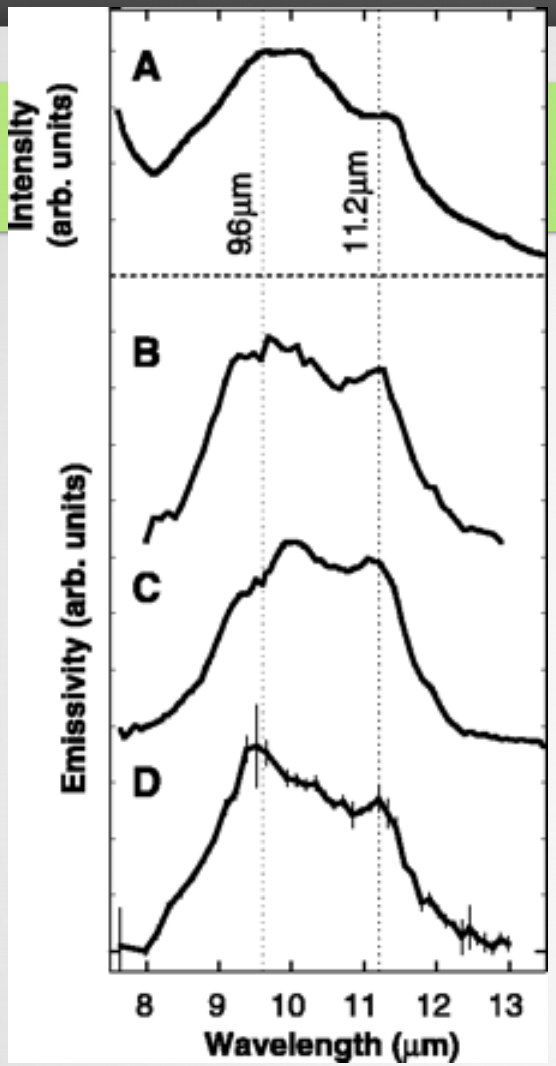


https://stardust.jpl.nasa.gov/home/index.html


Experimental
A
2 mm
B
2 mm
C
2 mm
D
Stardust
A
3.7 mm
B
8.5 mm
B
3.8 mm
B
8.0 mm
B / C
11.7 mm
C
4.7 mm

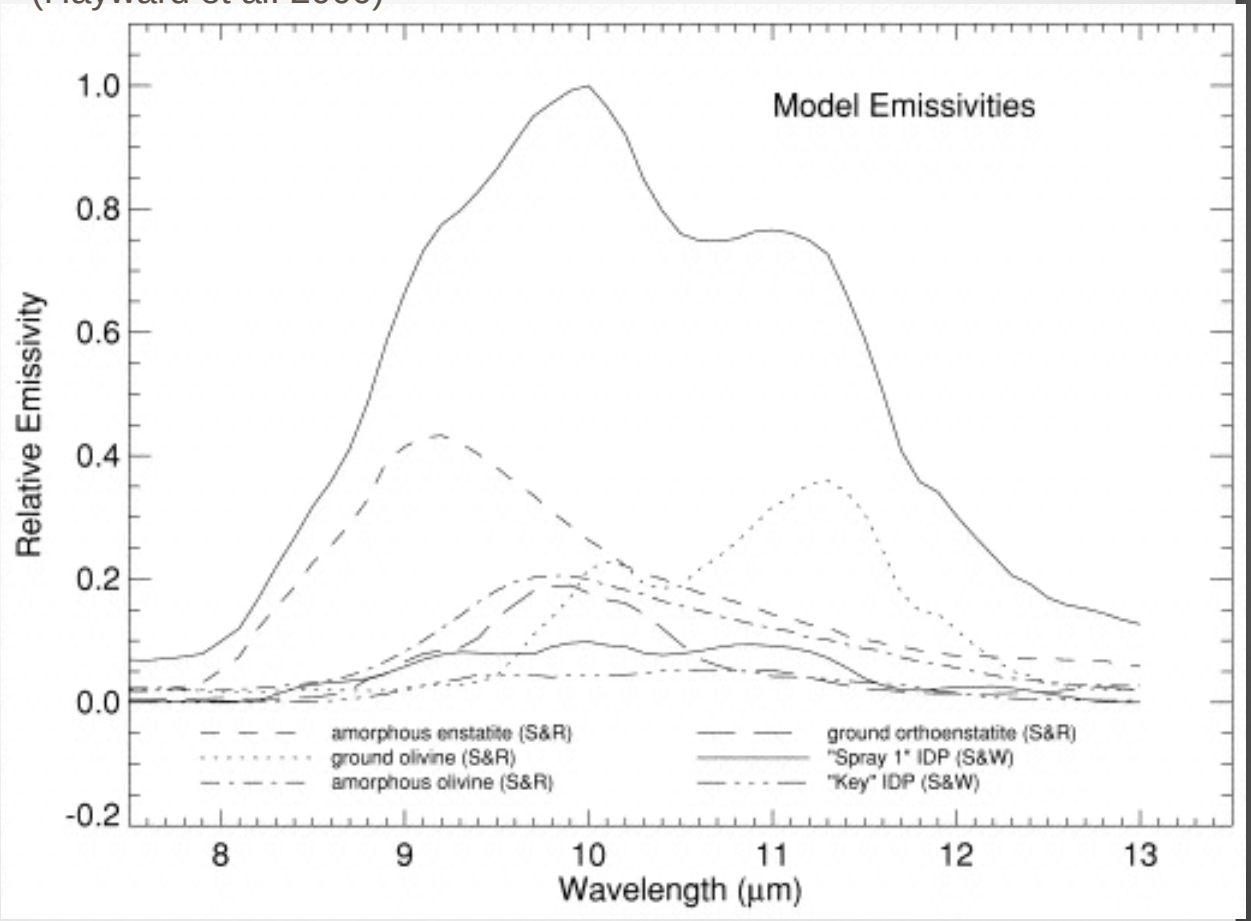
# ← Método indireto: ISO




(A) IDP
(B) Halley
(C) Halle-Bopp
(D) Herbig Ae/Be

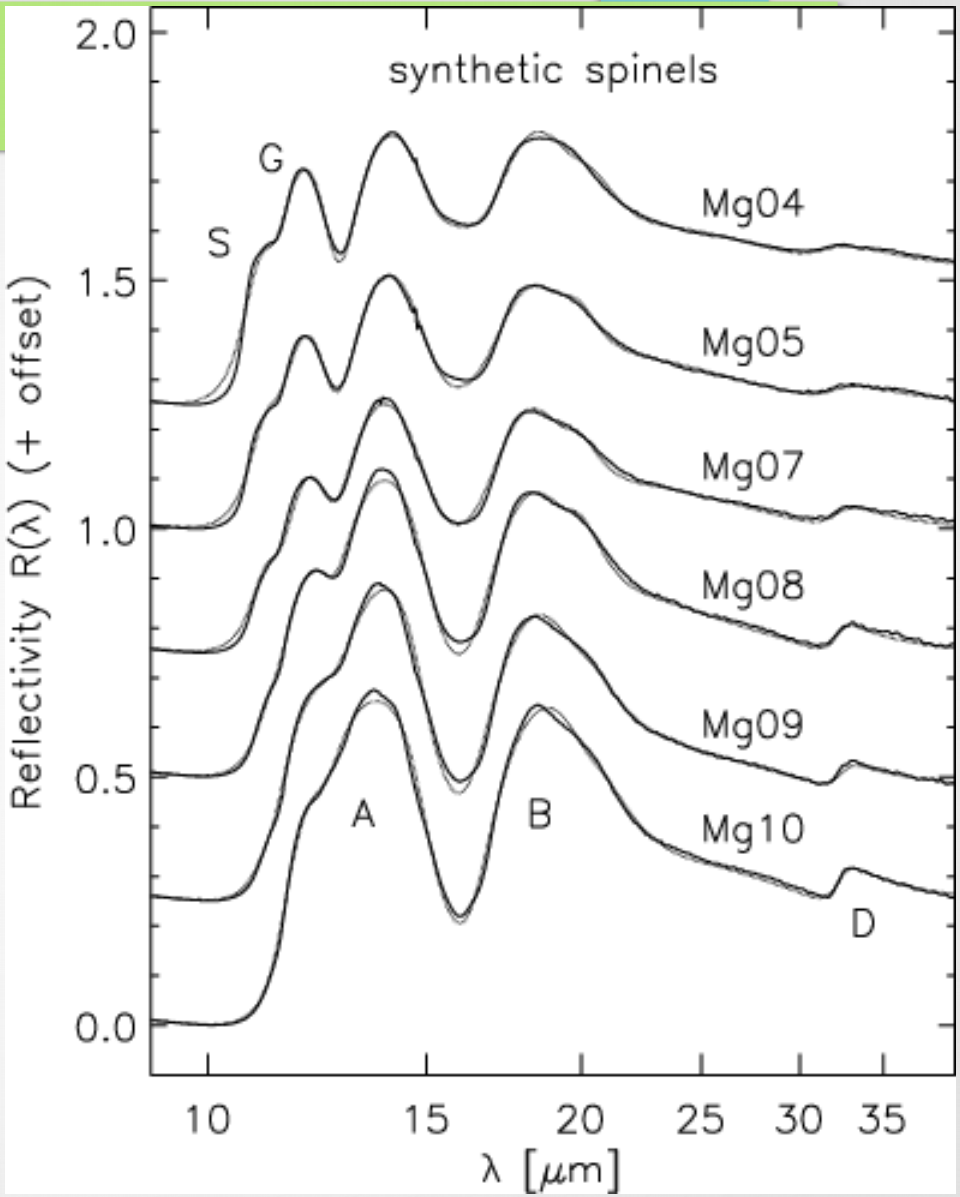
Soma das emissividades: linha cheia

(Hayward et al. 2000)



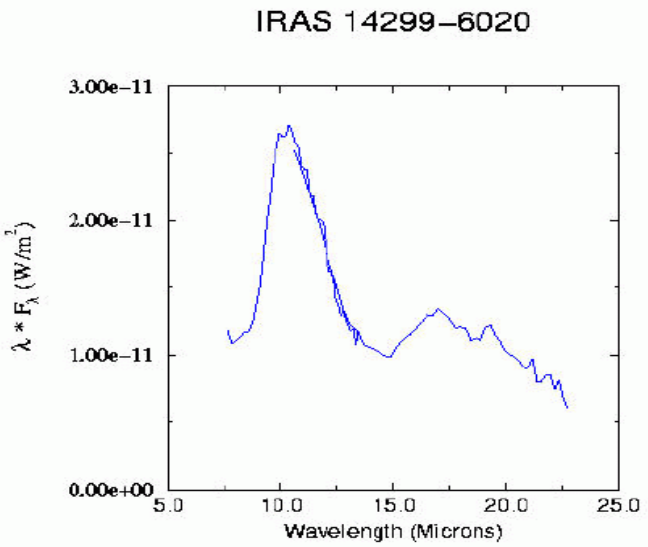
# Laboratório

Espectros obtidos em laboratório de substância sintética

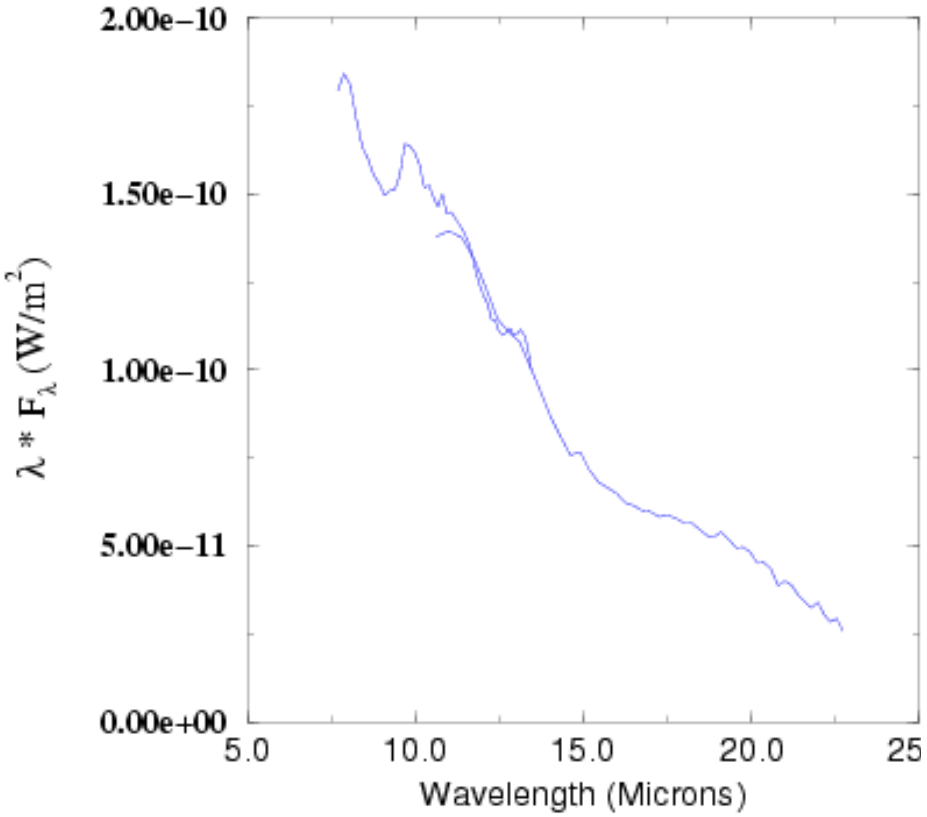


# Observações: IRAS

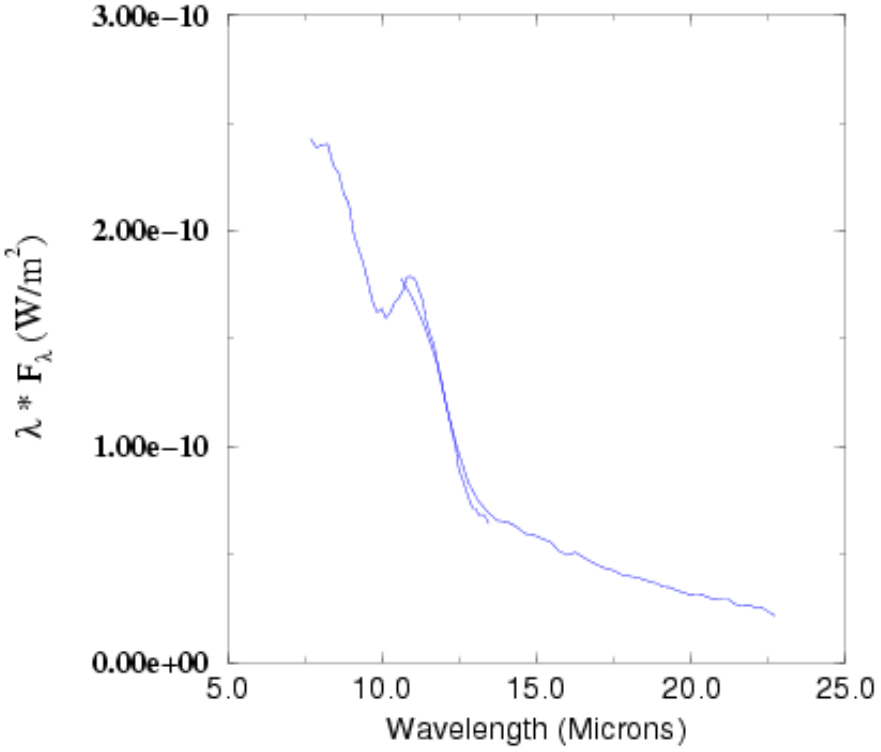
- Infrared Astronomical Satellite
- SILICATO



## IRAS 13001+0527

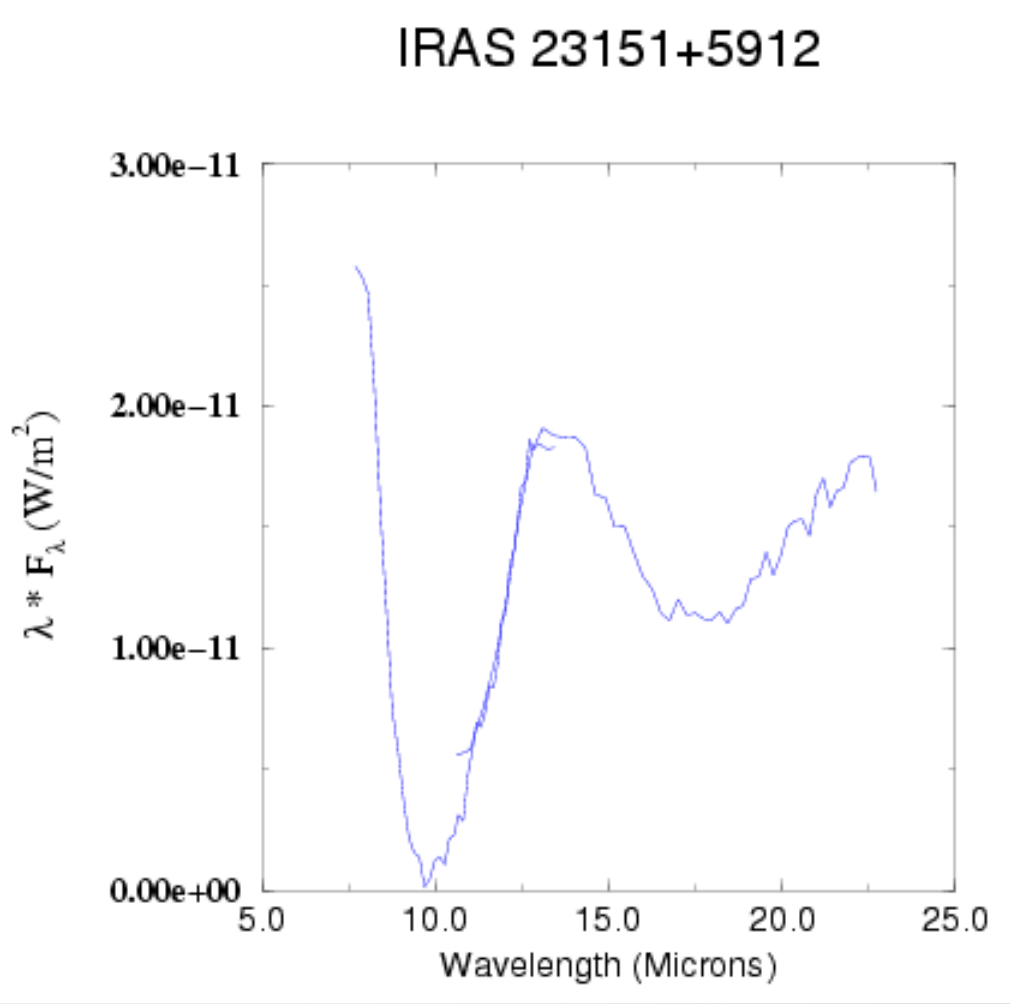



## IRAS 20396+4757



# Primeiro passo

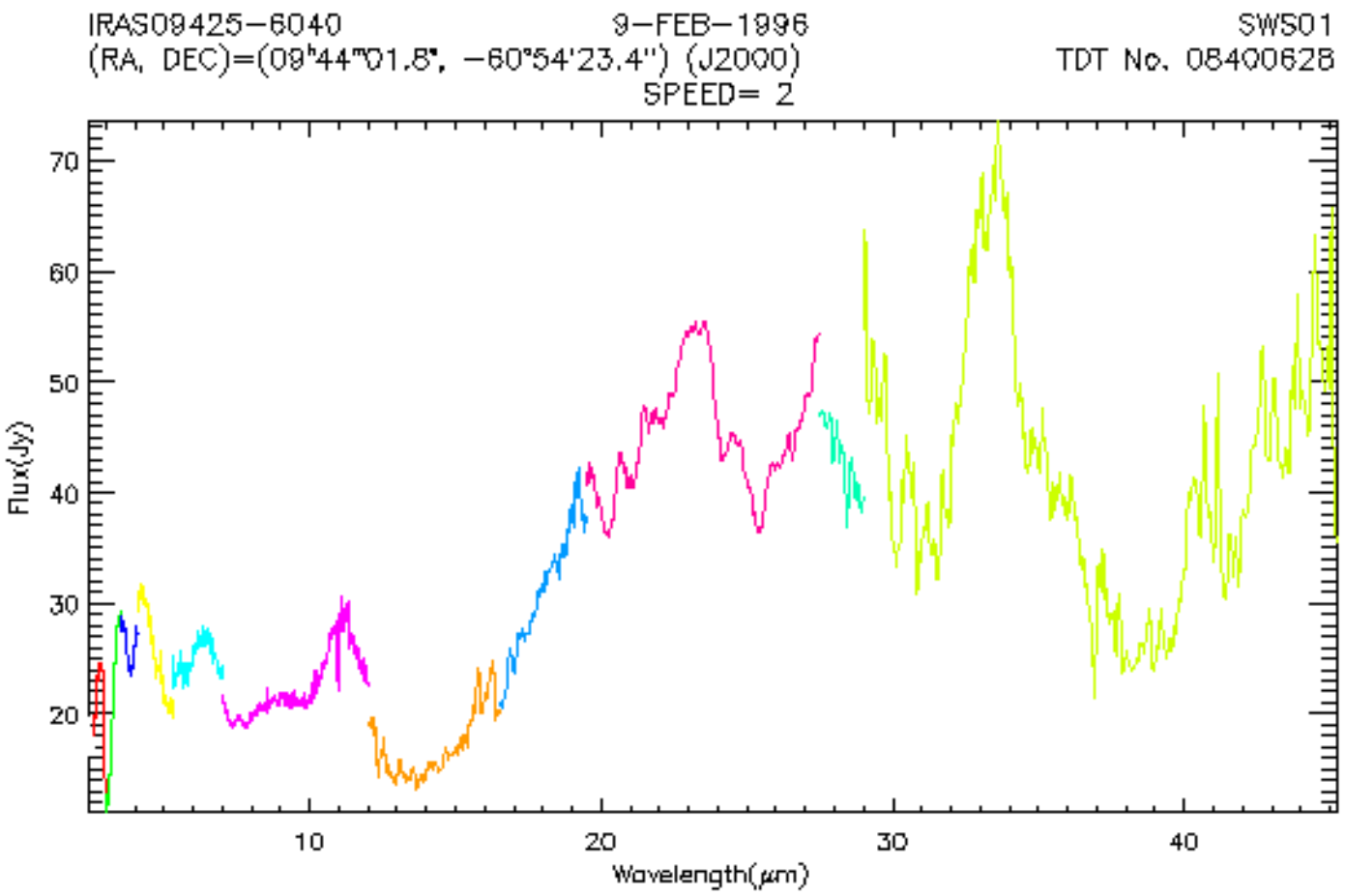
- Diferentes características espectrais – diferentes compostos químicos
- Propriedades físicas distintas



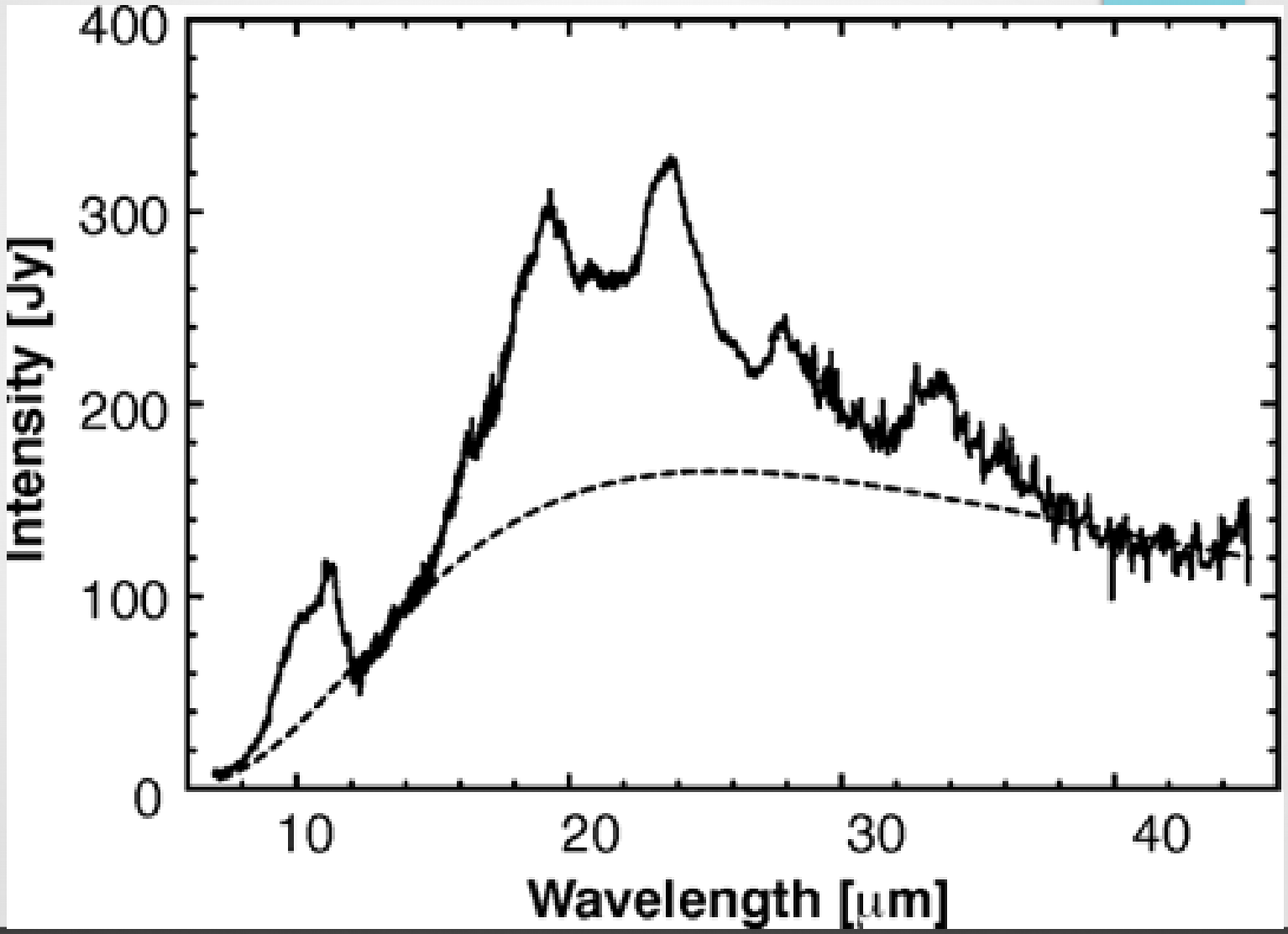
# INFRARED SPACE OBSERVATORY

esa

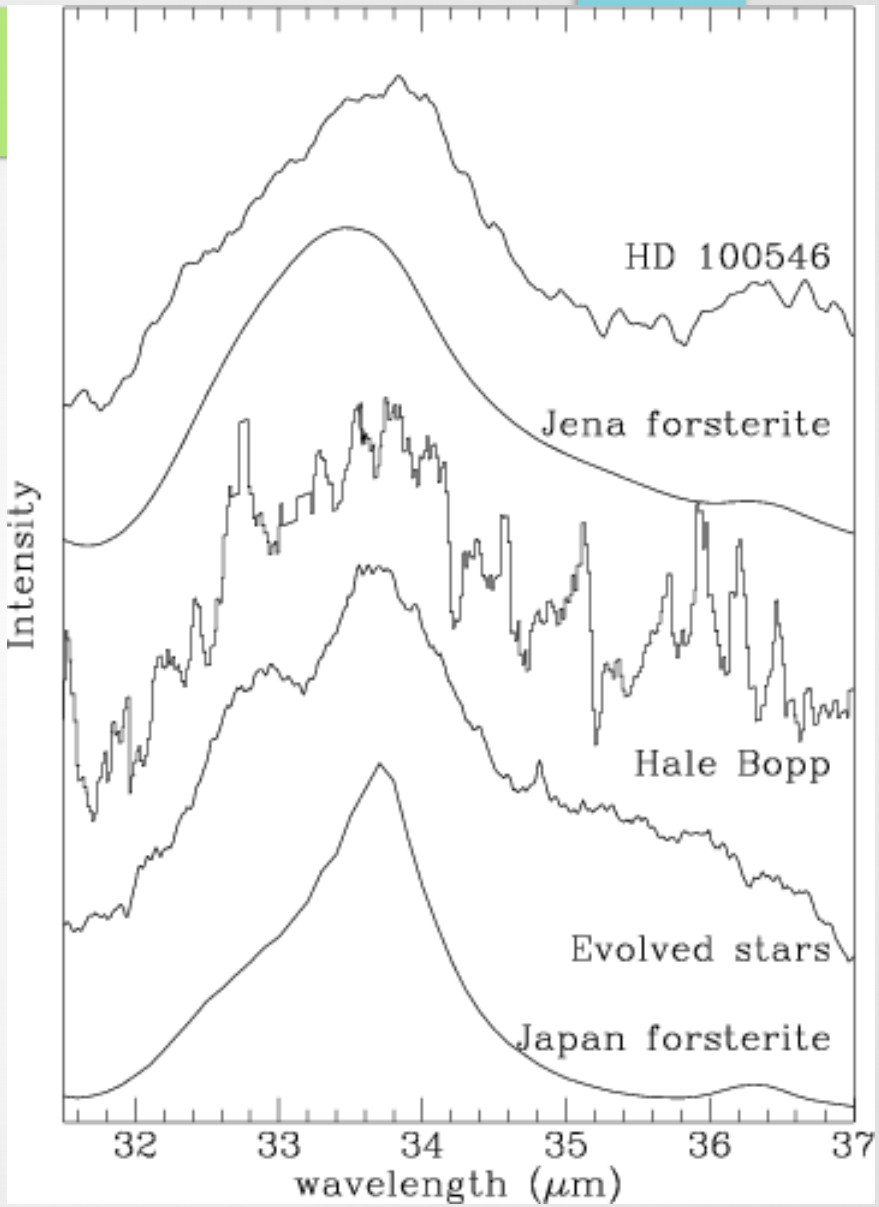
http://sci.esa.int/iso/



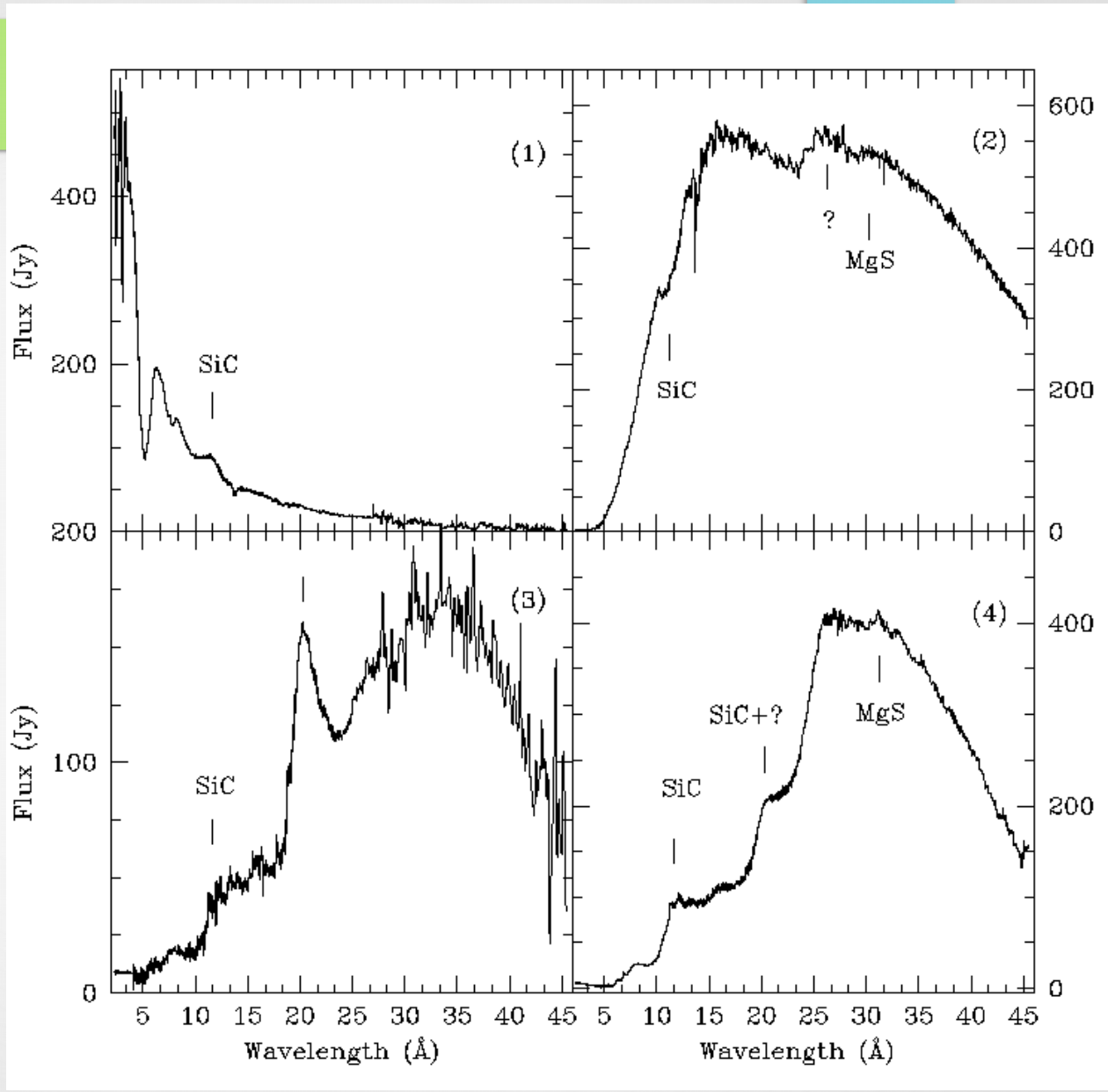
# Hale-Bopp – SWS 01 ISO



# COMPARAÇÃO

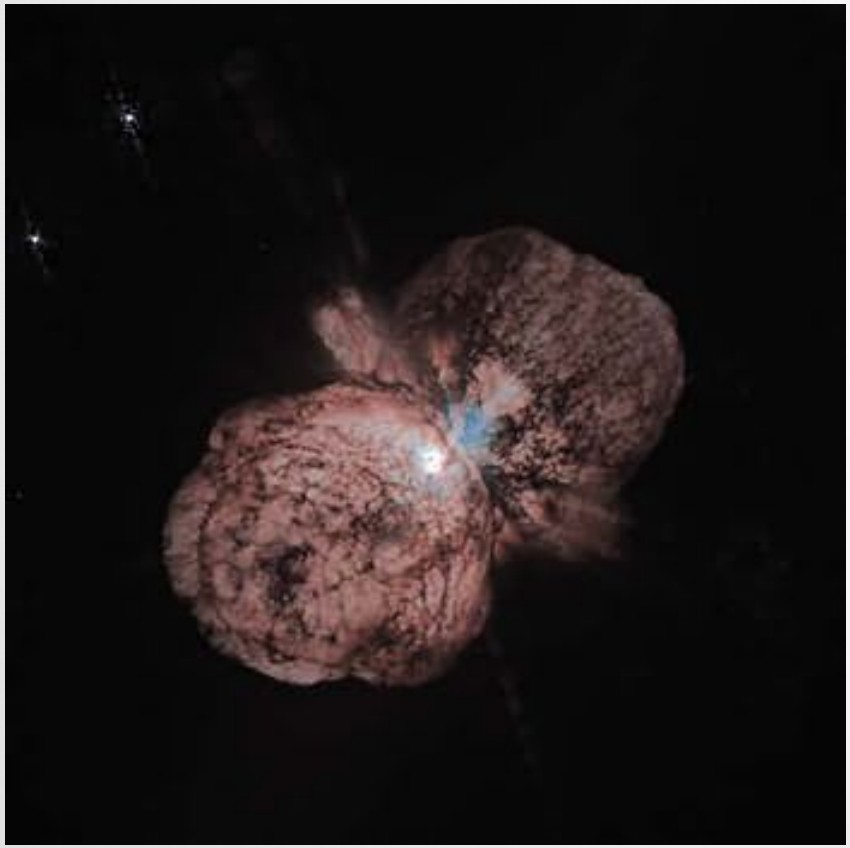

HD 100546
Jena forsterite
Hale Bopp
Evolved stars
Japan forsterite
Intensity
32
33
34
35
36
37
wavelength (μm)

# Evolução


(1)
(2)
(3)
(4)
SiC
SiC
?
MgS
SiC
SiC+?
MgS
Flux (Jy)
Flux (Jy)
Wavelength (Å)
Wavelength (Å)
200
400
100
0
600
5
10
15
20
25
30
35
40
45

# MSX - Midcourse Space Experiment

https://irsa.ipac.caltech.edu/spectra.html



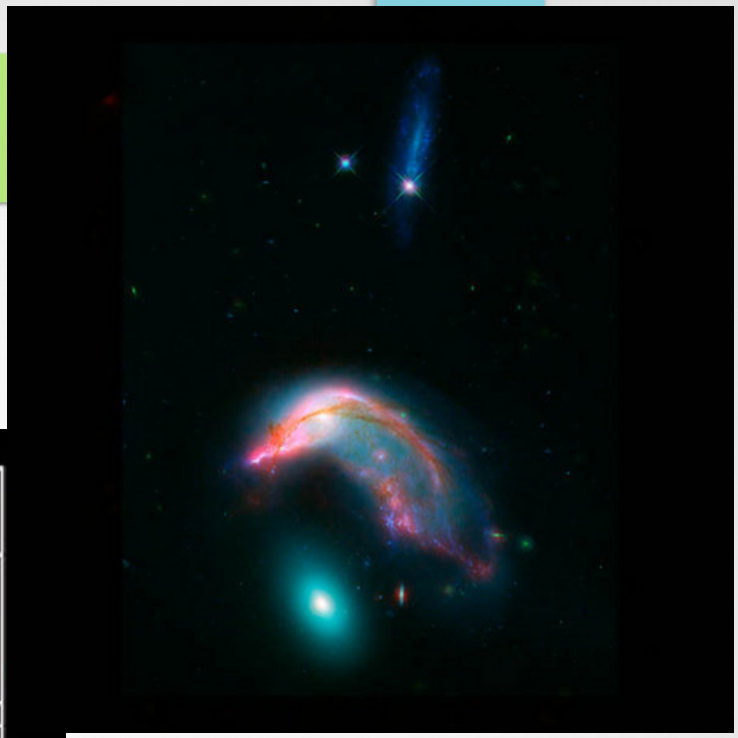
- Eta Car - poeira

# Spitzer: www.spitzer.caltech.edu

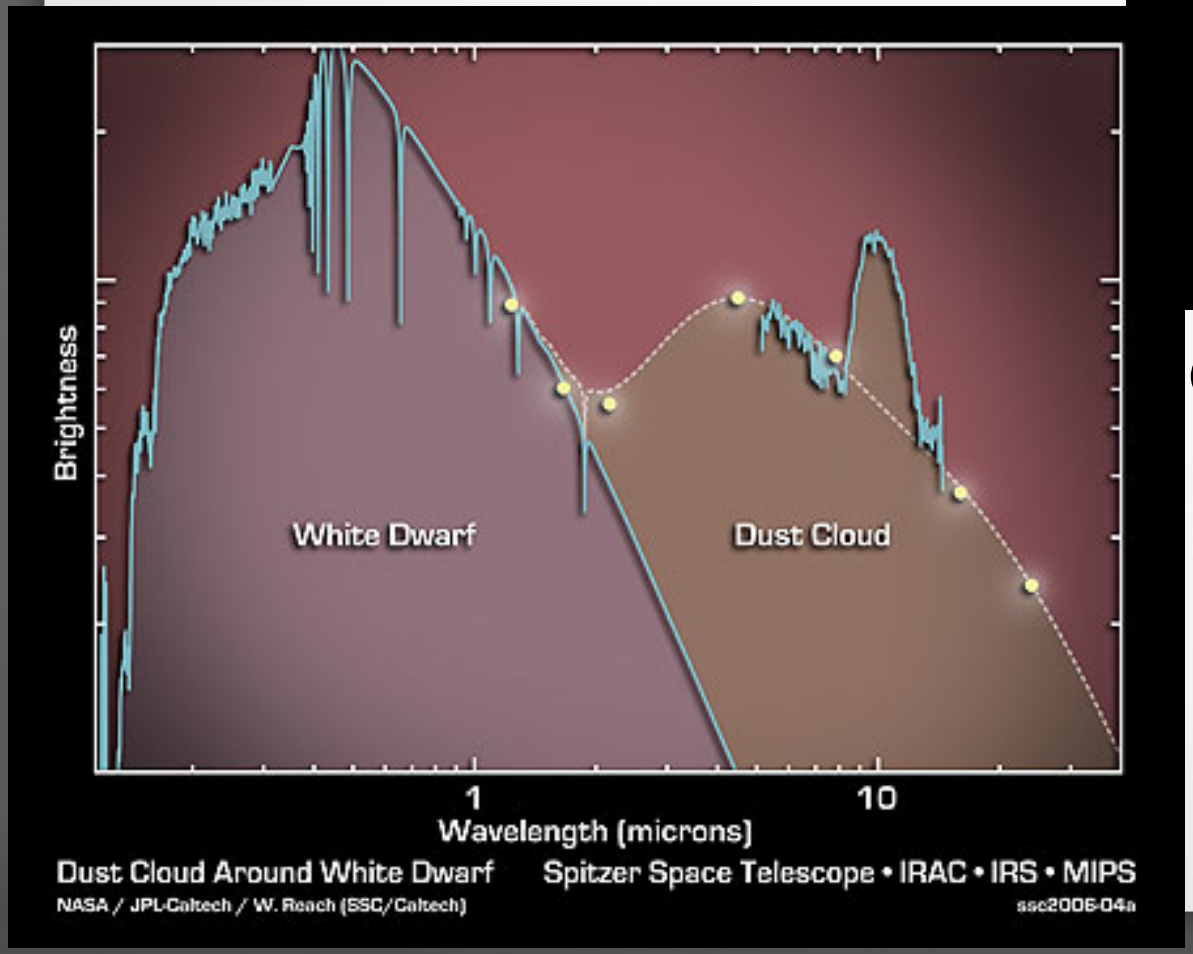
- Lançado em 25 de Agosto de 2003
- Observações IR mais profundas já feitas
  - 3 a 180 μm
- A radiação IR é bloqueada: atmosfera da Terra
- Duração : 2.5 anos

SPITZER SPACE TELESCOPE

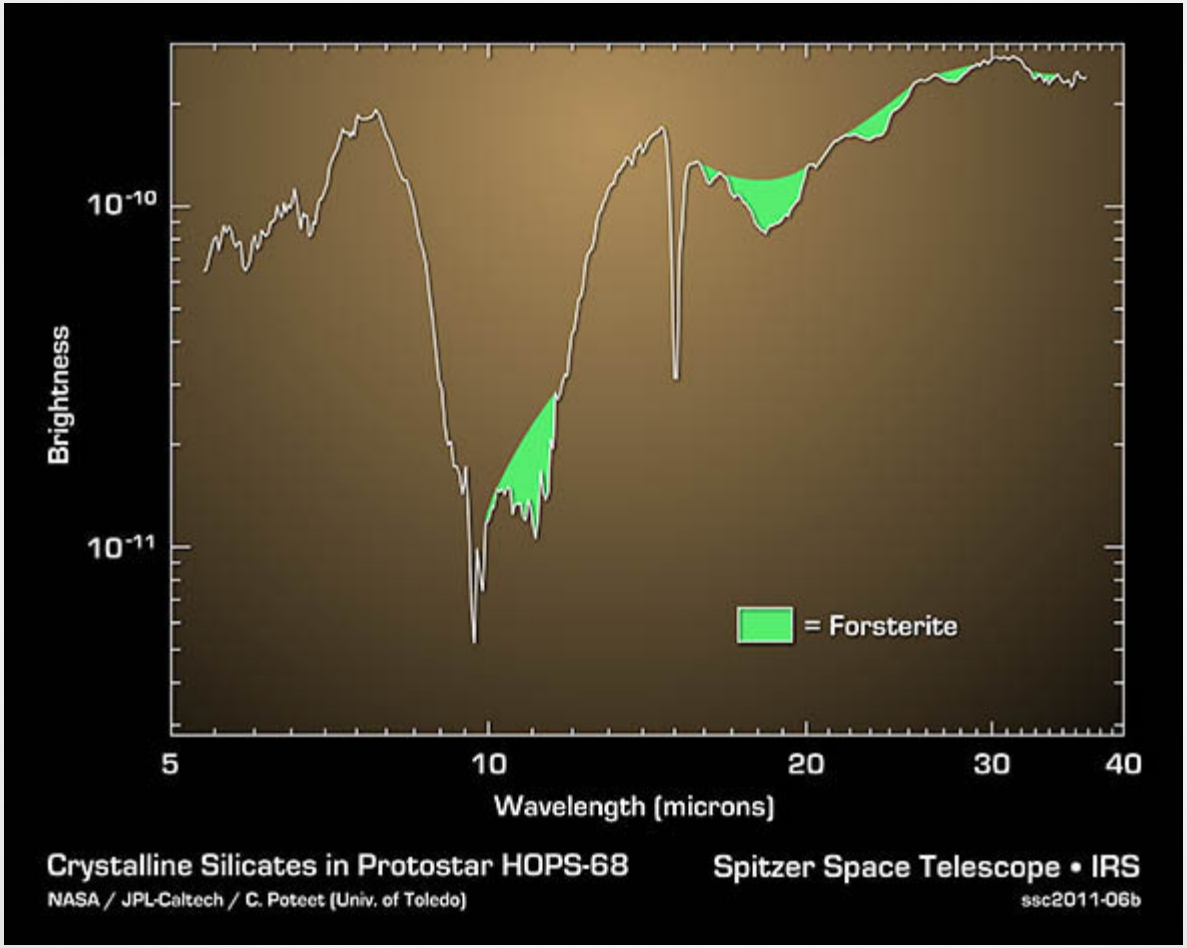
http://www.spitzer.caltech.edu/



Galáxias interagindo

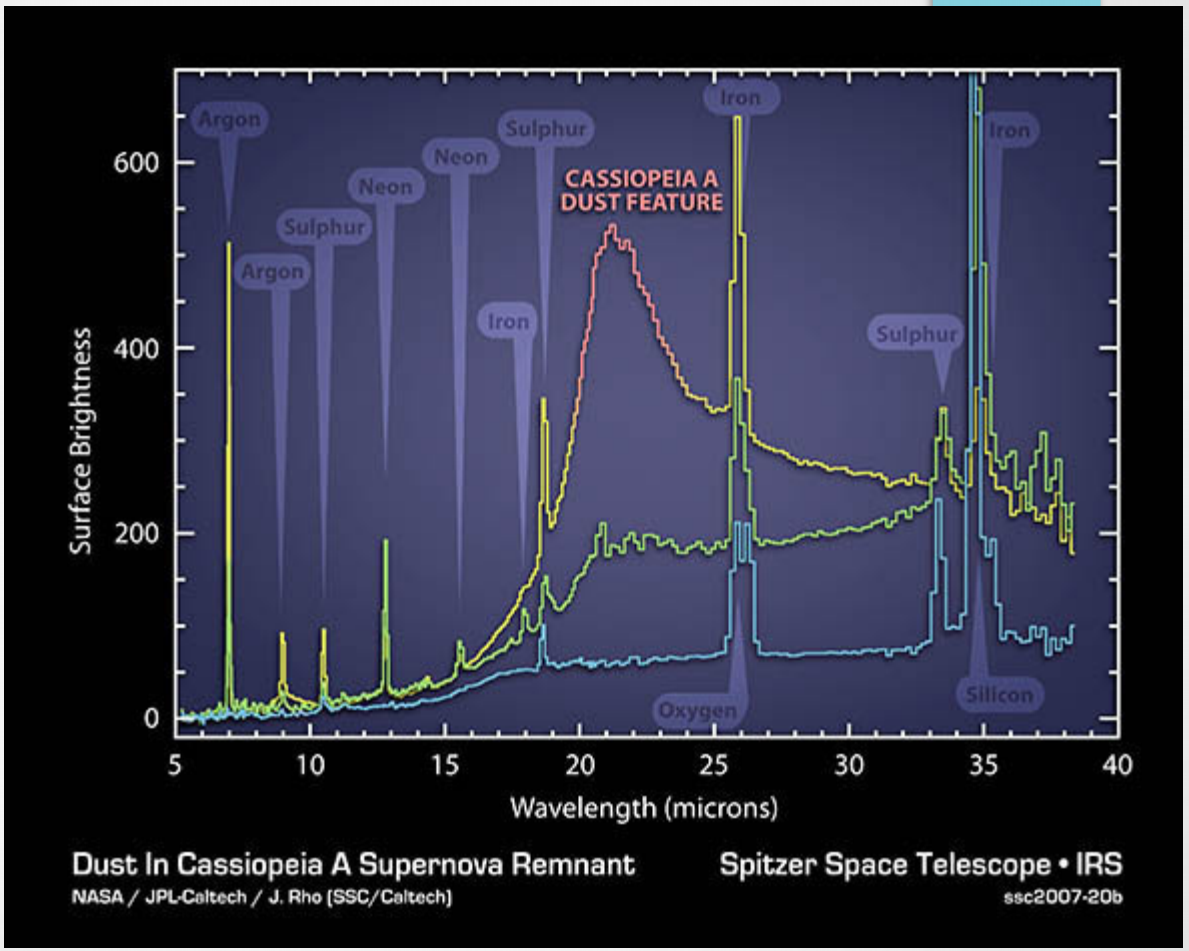


# Silicatos cristalinos



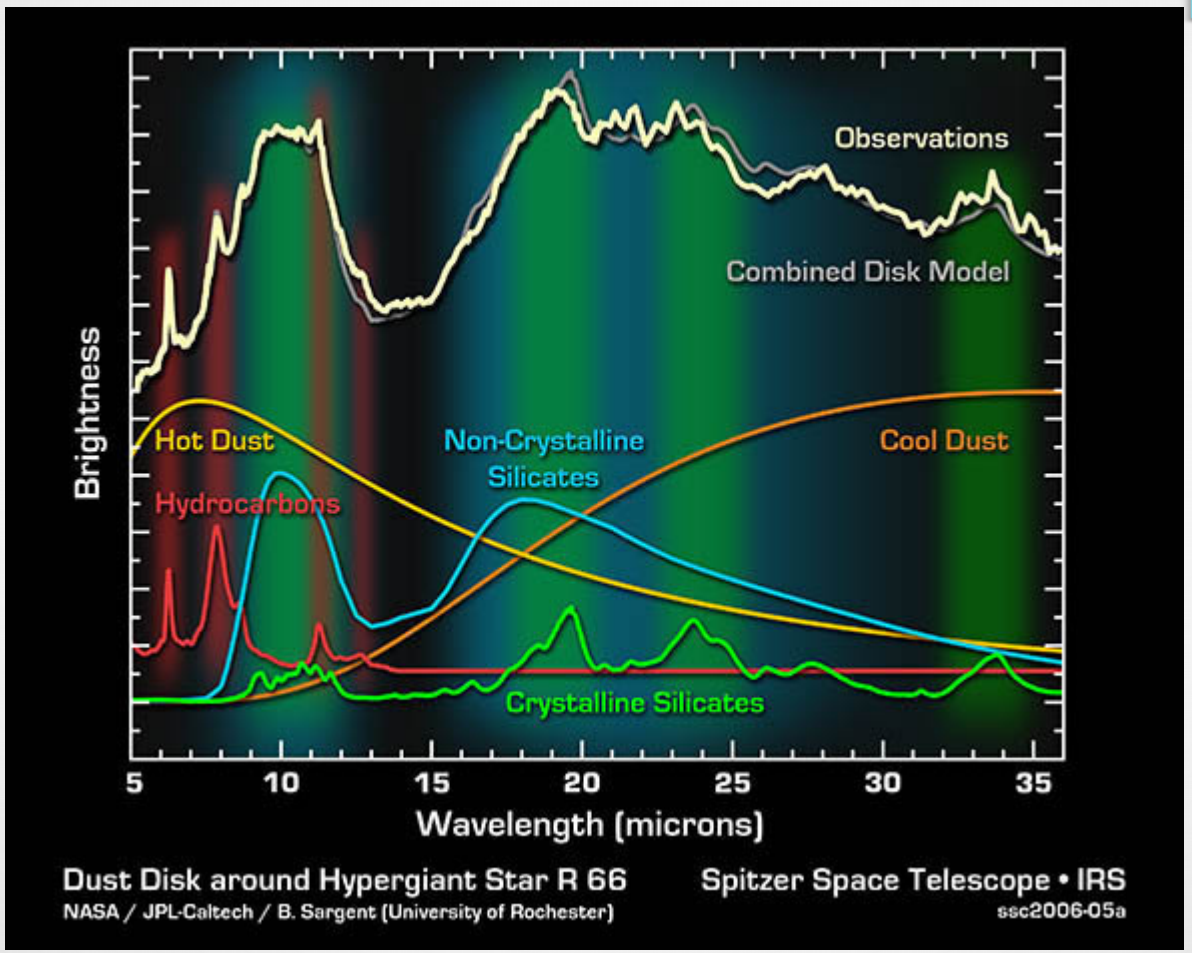
# Spitzer

silicates, silicon dioxide and iron oxide.




Each of the three lines of this plot represents a different layer of the supernova remnant, with the top yellow and red line being the outermost layer.

# Spitzer


Observations
Combined Disk Model
Brightness
Hot Dust
Hydrocarbons
Non-Crystalline Silicates
Cool Dust
Crystalline Silicates
5
10
15
20
25
30
35
Wavelength (microns)
Dust Disk around Hypergiant Star R 66
NASA / JPL-Caltech / B. Sargent (University of Rochester)
Spitzer Space Telescope • IRS
ssc2006-05a

Subaru Telescope
National Astronomical Observatory of Japan

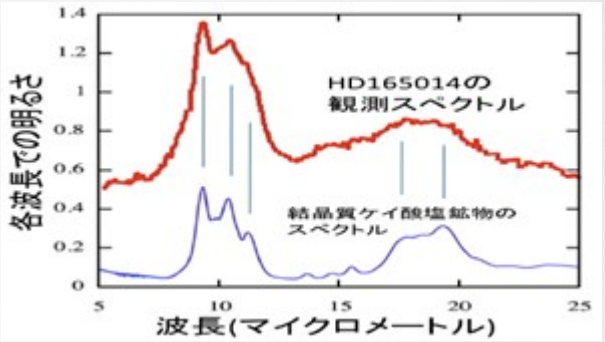
- Telescópio de 8.2 m em Mauna Kea operado pelo Japão – *Nacional Astronomical Observatory of Japan (NAOJ)*

COMICS - Cooled Mid-Infrared Camera and Spectrograph - provides imaging and spectroscopy from 7.5-25 microns.

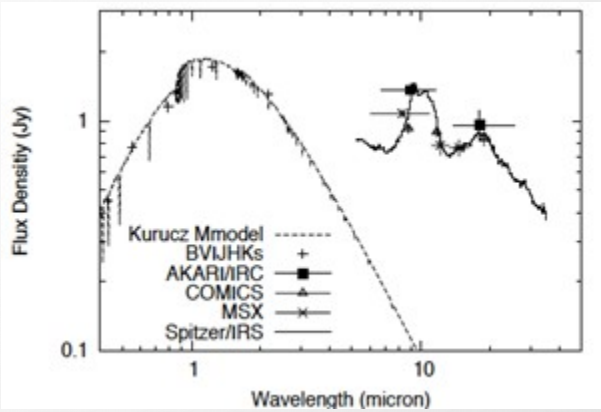
IRCS - Infrared Camera and Spectrograph - provides high-angular resolution imaging combined with AO188, low-resolution grism and high-resolution echelle spectroscopies over 0.9-5.6 microns.

https://subarutelescope.org/

Spitzer: silicato cristalino




Subaru COMICS



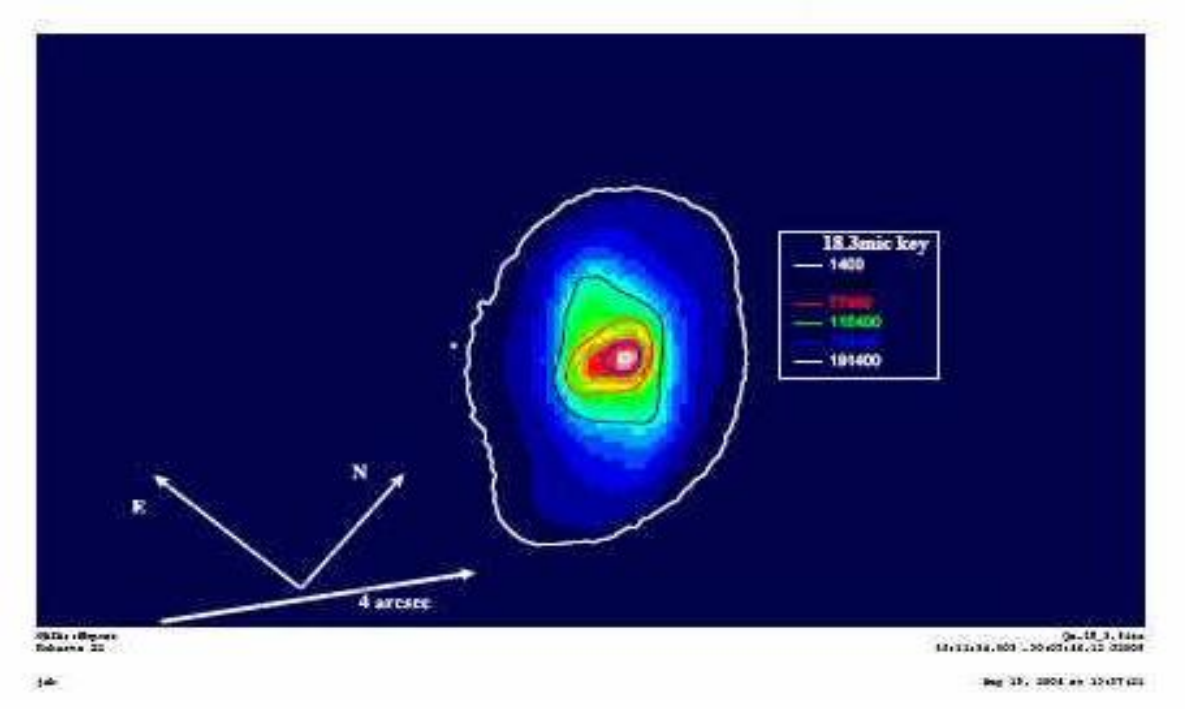

http://slideplayer.com/slide/1517695/

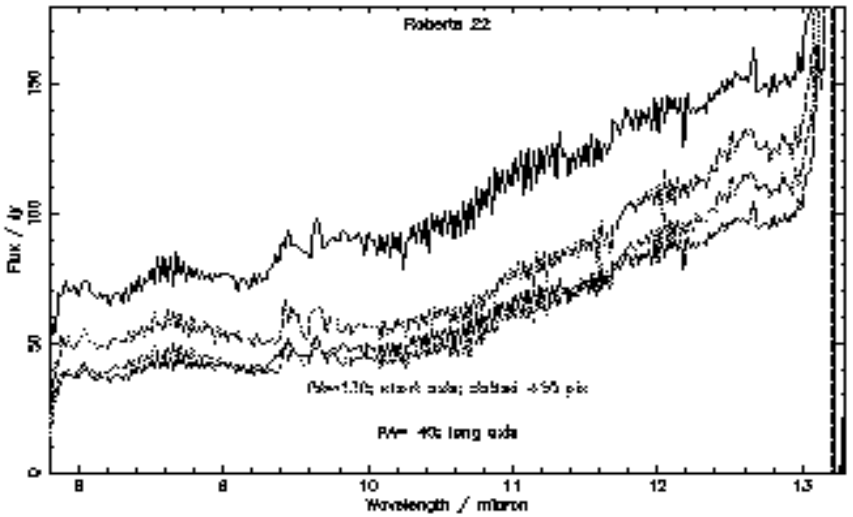
# GEMINI OBSERVATORY

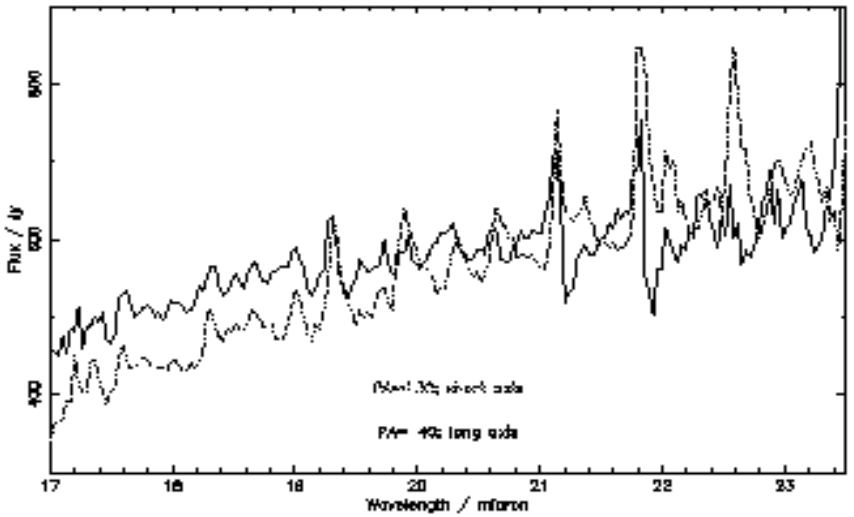
- 2 Telescópios de 8 m

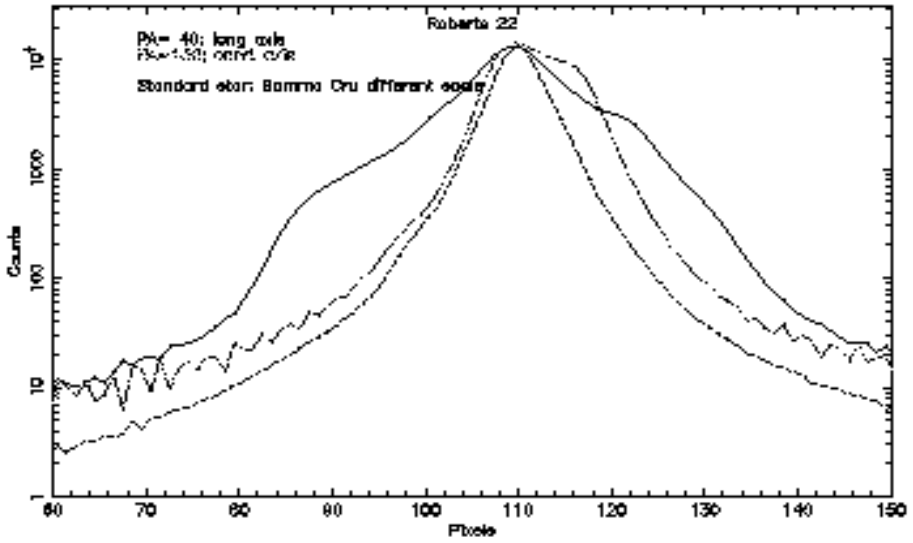
  Cerro Pachon, Chile e Mauna Kea, Havai

# Roberts 22

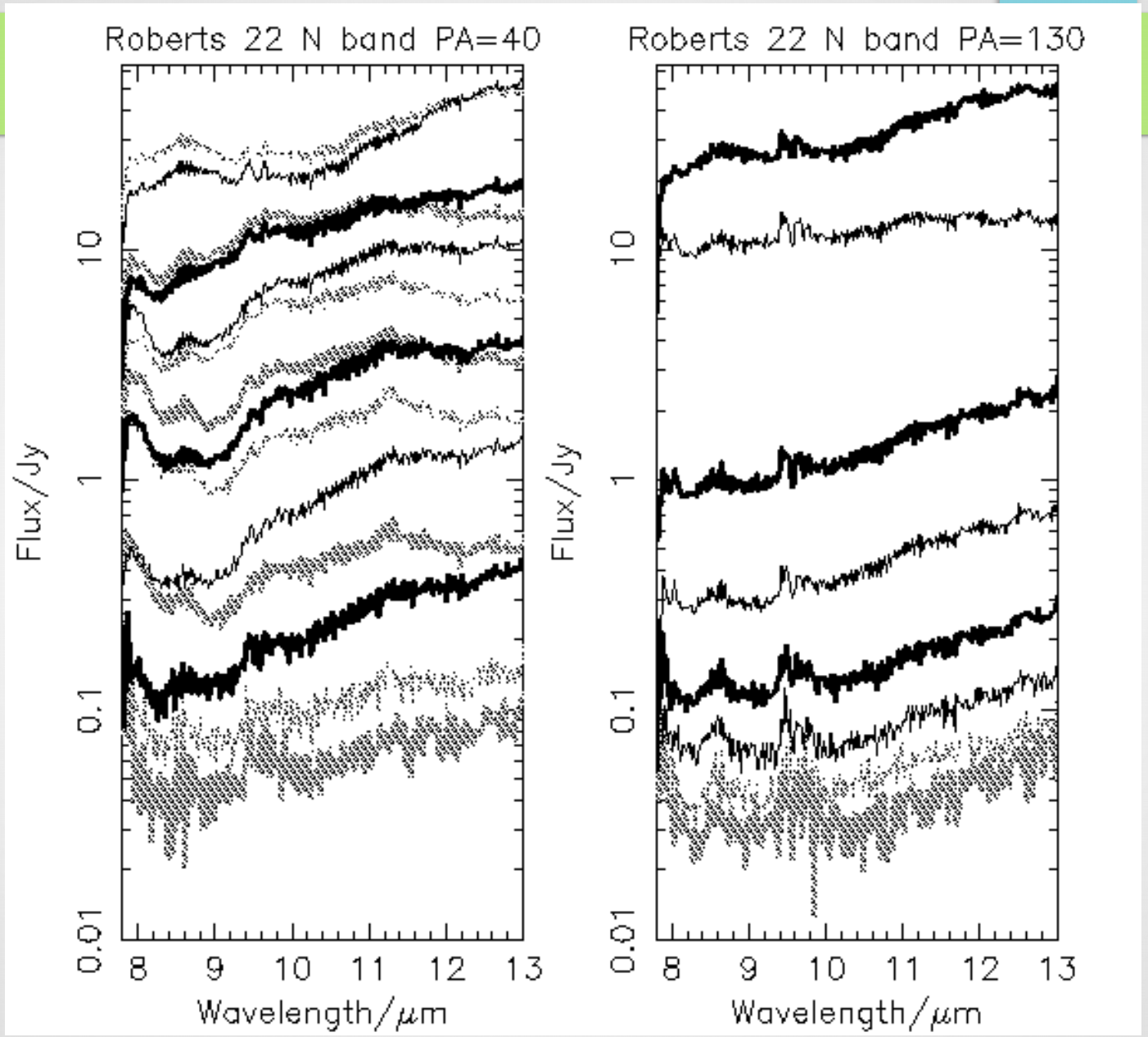



Roberts 22
Flux / Jy
Wavelength / micron
PA= 40: long axis


Flux / Jy
Wavelength / micron
PA= 40: long axis


Roberts 22
PA= 40: long axis
Standard star: Gamma Cru different scale
Counts
Pixels

# Roberts 22


Roberts 22 N band PA=40
Roberts 22 N band PA=130
Flux/Jy
Wavelength/μm
0.01
0.1
1
10
8
9
10
11
12
13