P R O G R A M A

astro ESUL

Astronomia no Extremo SUL

ENSINO

PESQUISA

EXTENSÃO

http://astroesul.wixsite.com/astronomia | https://www.facebook.com/astroESUL/ | astroesul@gmail.com

AstroBioGeoChemistry: Organic Molecules in Active Galaxies

Dinalva A. Sales[1]

astroESUL[2]

[1]Universidade Federal do Rio Grande; [2]Várias instituições

Where I came from ...

Rio Grande city

Federal University of Rio Grande
FURG

astroESUL

É um programa criado com o objetivo de desmistificar a astronomia, estimulando a sociedade para a busca de conhecimentos nesta área e facilitando o acesso ao tema por meio de projetos de ensino, pesquisa e extensão, idealizado e liderado pela Profa. Dra. Dinalva Aires de Sales do Instituto de Matemática, Estatística e Física - IMEF, da Universidade Federal do Rio Grande - FURG, no extremo Sul do Brasil.

ENSINO

PESQUISA

EXTENSÃO

FURG | IMEF INSTITUTO DE MATEMÁTICA, ESTATÍSTICA E FÍSICA | astro ESUL Astronomia no Extremo SUL

ENSINO

Astronomia como Ferramenta Lúdica para o Ensino de Física

Este projeto objetiva contribuir para a melhoria do processo de ensino-aprendizagem nas disciplinas de física geral da FURG, utilizando os fenômenos astronômicos como ferramenta lúdica para induzir o pensamento investigativo dos alunos, explicitando conceitos, elucidando dúvidas, disponibilizando estratégias de resolução de exercícios através dos materiais produzidos pelo grupo do projeto.

Pré-Física

O componente curricular de Física Geral, da área de conhecimento Ciências da Natureza, Matemática e suas Tecnologias, está presente de forma necessária e imprescindível na matriz curricular dos cursos de física ofertados pelo Instituto de Matemática, Estatística e Física (IMEF) da Universidade Federal do Rio Grande (FURG). O professor deste componente curricular precisa estar preparado para enfrentar as dificuldades de entendimento dos conteúdos relacionados aos programas das disciplinas, bem como das suas aplicações tecnológicas, frequentemente presentes no próprio cotidiano dos discentes e que passa despercebido. Portanto, este projeto tem como principal objetivo atender "in-loco" os alunos das disciplinas de Física Geral no processo de resolução de problemas, assim, oportunizará e potencializará o processo do ensino-aprendizagem para preencher as lacunas

Revista Brasileira de Ensino de Física, vol. 42, e20190054 (2020)
www.scielo.br/rbef
DOI: http://dx.doi.org/10.1590/1806-9126-RBEF-2019-0054
Pesquisa em Ensino de Física
Licença Creative Commons

Astronomia como ferramenta lúdica para o ensino de física: teoria cinética dos gases através de aglomerados de estrelas

Astronomy as a playful tool for physics teaching: kinetic theory of gases through star clusters

Walas Silva-Oliveira*[1], Dinalva A Sales[1], Matheus J Lazo[1]

[1]Universidade Federal do Rio Grande, Instituto de Matemática, Estatística e Física, Rio Grande, RS, Brasil

Espaço de Aprendizagem Cooperativa de Mat., Est. e FÍSICA

SALAMat

SALAFís+Est

Projeto de Ensino

[PRÉ] FÍSICA

Profa. Dra. Dinalva A. Sales

FURG IMEF INSTITUTO DE MATEMÁTICA, ESTATÍSTICA E FÍSICA | astroESUL Astronomia no Extremo SUL

EXTENSÃO

Estendendo o astroESUL

O principal objetivo deste projeto é promover observações do céu em Rio Grande/RS, assim como ministrar palestras e oficinas voltadas à comunidade universitária, escolar e público em geral da seguinte forma: promovendo oficinas sobre fases lunar, eclipse e estações do ano; realizando palestras sobre mapeamento do céu noturno; promovendo exposições de astrofotografia, com as fotos produzidas pelas observações; apresentando planisférios e tecnologias como softwares e simuladores voltados para a astronomia; e, promovendo a relação dialógica entre a universidade e sociedade.

PESQUISA

1) Galáxias com Emissão de Megamaser de OH como Traçadoras do Núcleo Ativo de Galáxia

O objetivo principal deste estudo é relacionar o estado de fusão das galáxias megamaser de OH à fase de evolução e crescimento do núcleo ativo de galáxias, formação estelar, bem como, a concentração e estrutura do gás ionizado da região central das galáxias, com dados dos telescópios Hubble, Gemini, VLA-A, IRTF, WHT e Herschel.

2) Moléculas Orgânicas em Galáxias

O projeto de pesquisa objetiva compreender a evolução química das moléculas orgânicas de hidrocarbonetos aromáticos policíclicos (PAHs) observadas nas galáxias contribuindo para melhorar nosso conhecimento sobre a origem e presença da vida na Terra e no Universo.

3) Laboratório de Ciência de Imagens

O laboratório de ciência de imagens tem como principal objetivo utilizar metodologias matemáticas robustas, como transformadas de Fourier e Wavelets, para tratar dados de imagens seja elas de origem geofísica, obtidas pelos satélites na plataforma espacial da NASA, e/ou de origem astrofísica como dados obtidos pelos telescópios espaciais e em Terra. Este laboratório está em consonância com a nova era de profissões do século XXI, cuja missão é conseguir trabalhar com "Big Data" e extrair informações úteis para o avanço da ciência e também para a transferência de tecnologia. Este projeto está em sinergia e contribui diretamente com a missão da FURG que é o estudo do ecossistemas costeiros e oceânicos.

What are the fundamental questions?

Over the next decade we can expect to make great strides in addressing the three grand challenges of molecular astrophysics:

(1) How can we use molecules to study the Universe?
(2) What is the role of molecules in the evolution of the Universe?
(3) What is the organic inventory of space and how does that relate to the prebiotic origin of life?

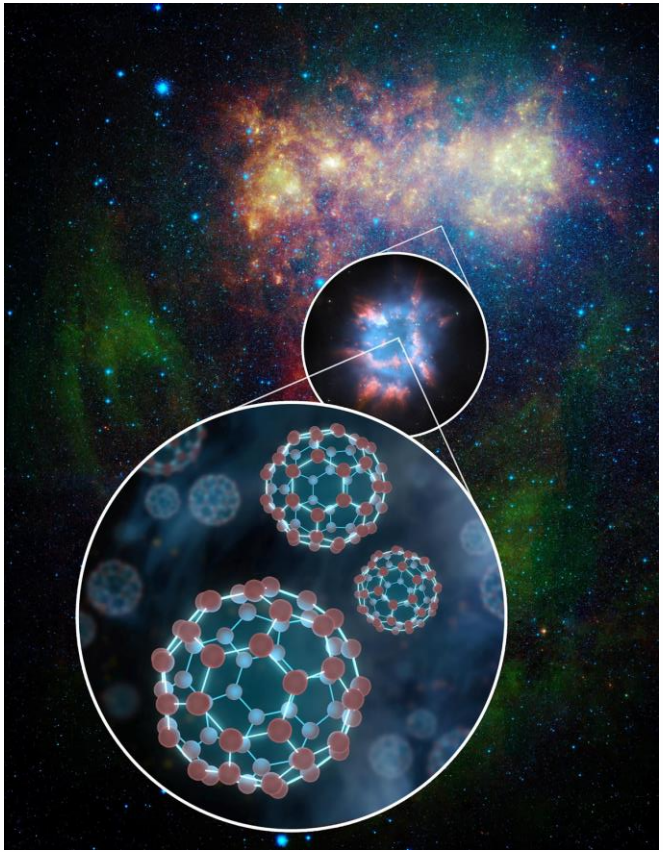
Summary

1º - AstroBiology → Motivation and high spatial resolution
2º - AstroChemistry → How can we observe and study molecules in the Universe?
3º - AstroGeo → How can we use it to solve issue in the Earth?

AstroChemistry

The study of molecular processes in space.

- Types of chemical reactions in space
- Which reactions occur under which conditions
- Chemical composition of astrophysical objects
- to infer the physical properties
- Links to Astrobiology



A multi-field approach

Observations

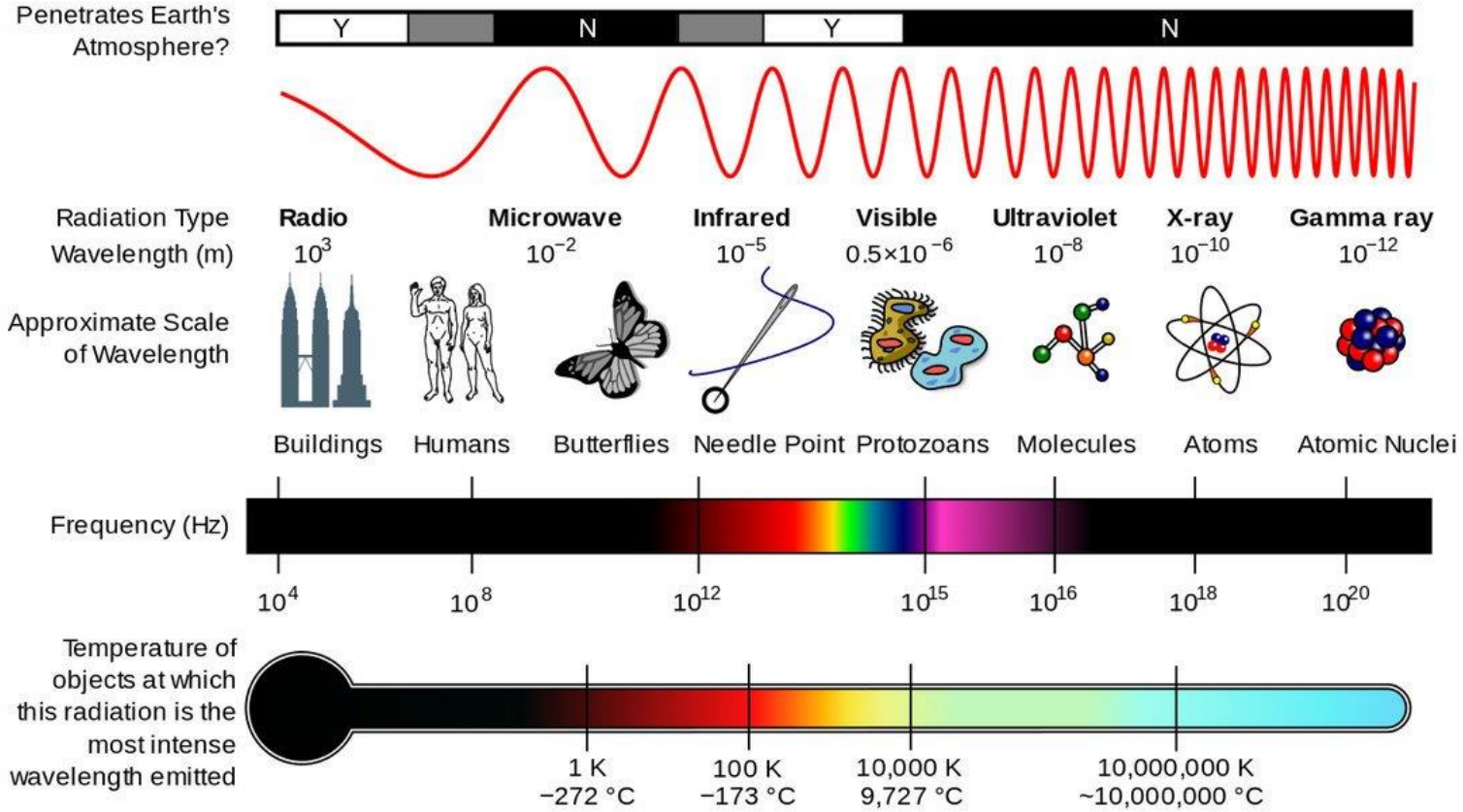
- infrared
- radio
- visual / UV
- X-rays

Models

- early universe
- interstellar clouds
- star-forming regions
- planetary atmospheres

Laboratory / computation

- spectroscopy
- collision rates
- reaction rates
- grain surface processes


Penetrates Earth's Atmosphere?
Y
N
Y
N
Radiation Type
Wavelength (m)
Radio
10^{3}
Microwave
10^{-2}
Infrared
10^{-5}
Visible
0.5×10^{-6}
Ultraviolet
10^{-8}
X-ray
10^{-10}
Gamma ray
10^{-12}
Approximate Scale of Wavelength
Buildings
Humans
Butterflies
Needle Point
Protozoans
Molecules
Atoms
Atomic Nuclei
Frequency (Hz)
10^{4}
10^{8}
10^{12}
10^{15}
10^{16}
10^{18}
10^{20}
Temperature of objects at which this radiation is the most intense wavelength emitted
1 K
−272 °C
100 K
−173 °C
10,000 K
9,727 °C
10,000,000 K
~10,000,000 °C

1° Astrobiology - Line forests

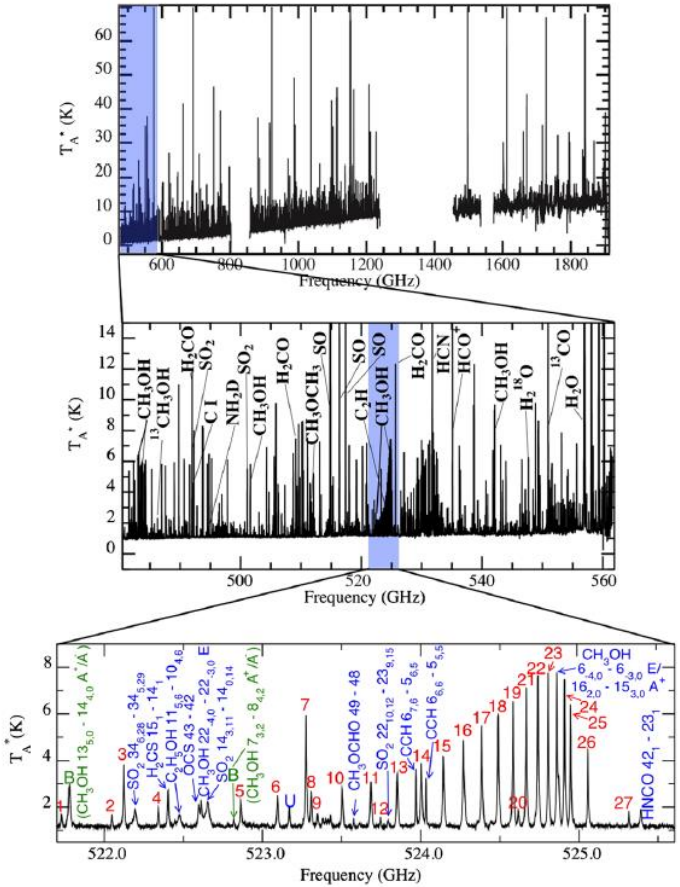


Fig: HIFI spectral survey of the Orion KL region. Top panel: The complete spectral scan (490 GHz to 1.9 THz) reveals the rich line forest. There are some 105 lines in this spectrum. Middle panel: A zoom in on the 490–530 GHz spectral range with some of the stronger lines identified. Bottom panel: The 522:5–525:5 GHz range shows velocity-resolved lines. The numbered lines are CH3OH lines used in the analysis of the temperature structure of the region (Tielens 2013).

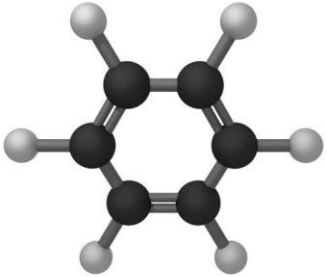
COMs - Complex Organic Molecules

- molecules with 6 or more atoms including C (Herbst & van Dishoeck 2009)

- CH_3OH, CH_3CN, CH_3CHO, CH_3OCH_3,

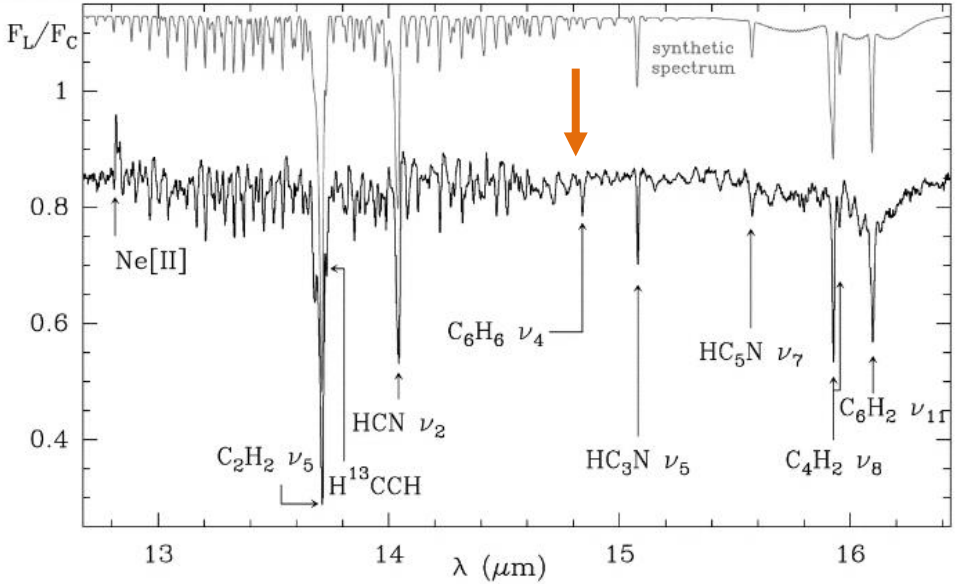
- Prebiotic molecules
  - NH_2CHO (formamide)

  - Benzene



BENZENE C_6H_6

Cernicharo et al 2001 (ISO)



Search for interstellar emission of N-heterocycles

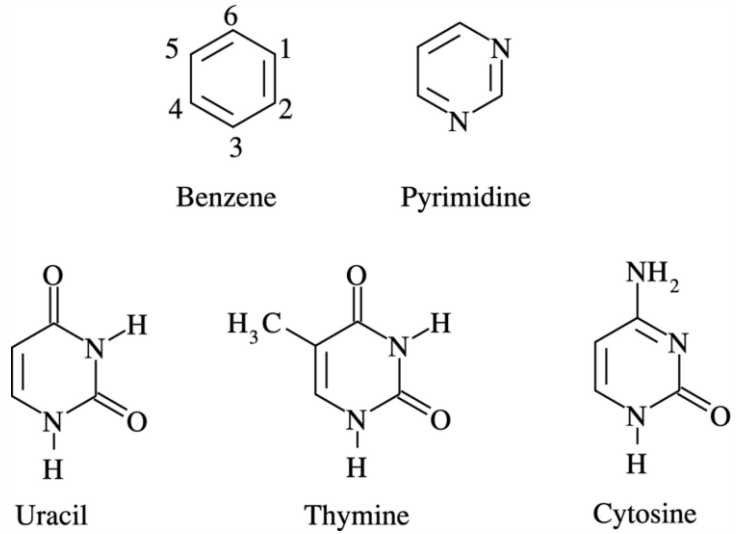


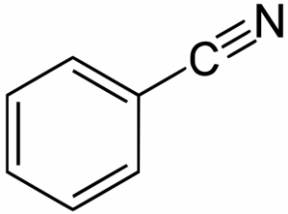
Fig.: Molecular structure of benzene, pyrimidine and pyrimidinic nucleobases uracil, thymine and cytosine (Mendoza et al. 2013).

- Motivation → prebiotic chemistry
- Formation of nucleobases
- Presence in meteorites (e.g. Murchison) (Allamandola et al. 1999, Martins et al. 2005, 2008)
- Large dipole moments → detection at radio wavelengths (Charnley et al. 2005)

N-heterocycles (tentatives of) detection in ISM

- Vinyl cyanide, pyrimidine and pyridine in 1973 (Martha Simon & Michal Simon, 1973)
- Pyridine, pyrimidine, quinoline, isoquinoline (Charnley et al. 2005, Kuan et al. 2006)
- Benzonitrile!

  (Mcguire et al. 2019)



Still a challenge:

- Low abundances
- Photodissociation

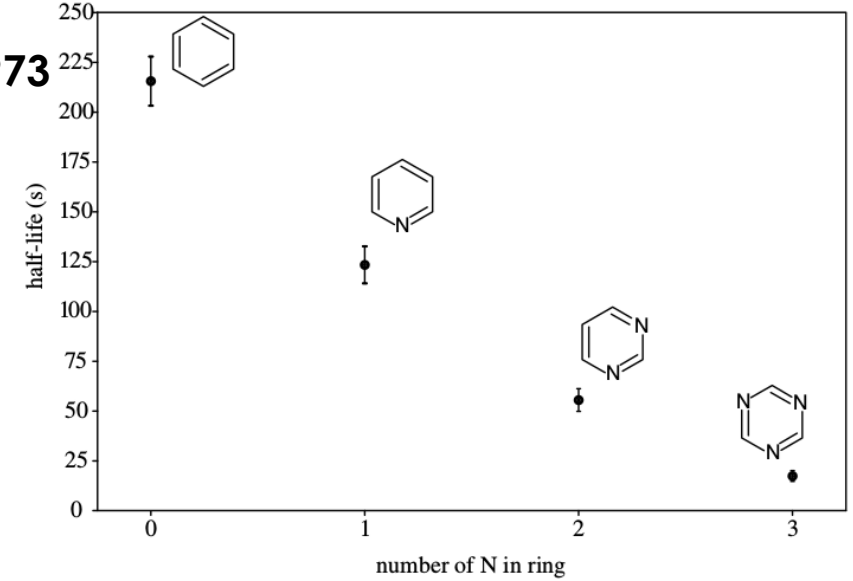
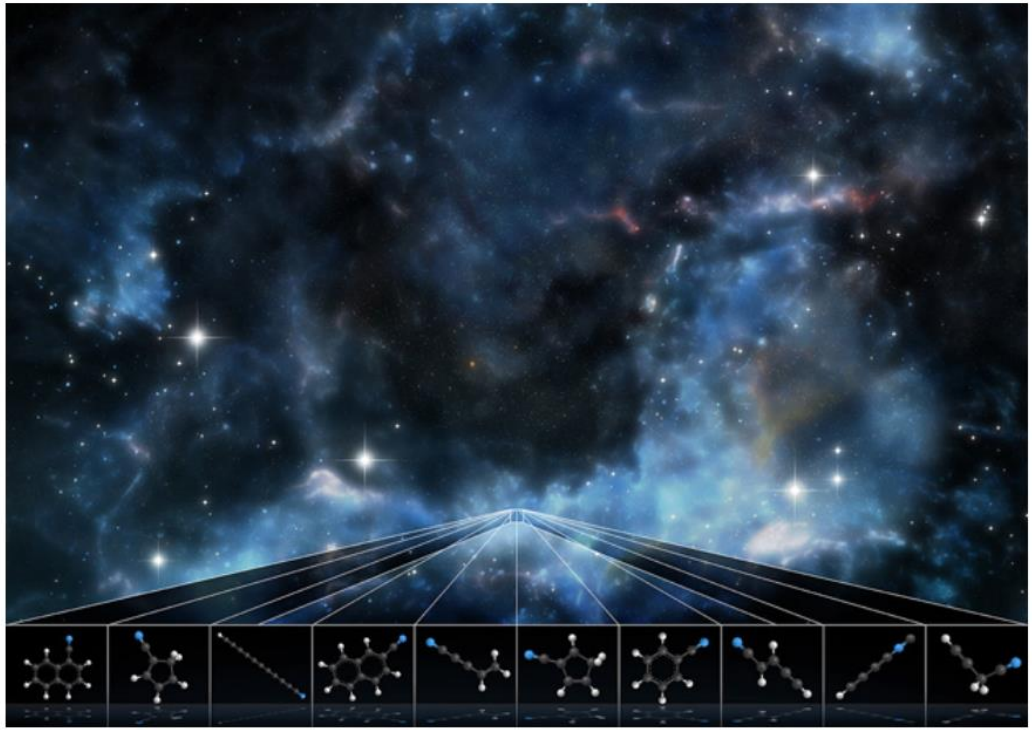


Fig.: The half-lives of the three N-heterocycles plotted against the number of nitrogen atoms in the ring. (Z. Peeters et al. 2005).

Green Bank Discovers Many Complex Molecules Never Before Seen In Space

Source: Green Bank Posted March 18, 2021 10:46 PM 0 Comments



Series of 9 papers!!

GOTHAM
Green Bank Telescope Observations of TMC-1: Hunting Aromatic Molecules

http://astrobiology.com/2021/03/geen-bank-discovers-man-complex-molecules-never-before-seen-in-space.html

TMC - 1

- very early evolutionary phase (precollapse)
- source of unsaturated carbon-chain molecules
- evidence of five-membered and bicyclic CN-functionalized rings

→ unexplored area of organic chemistry in space

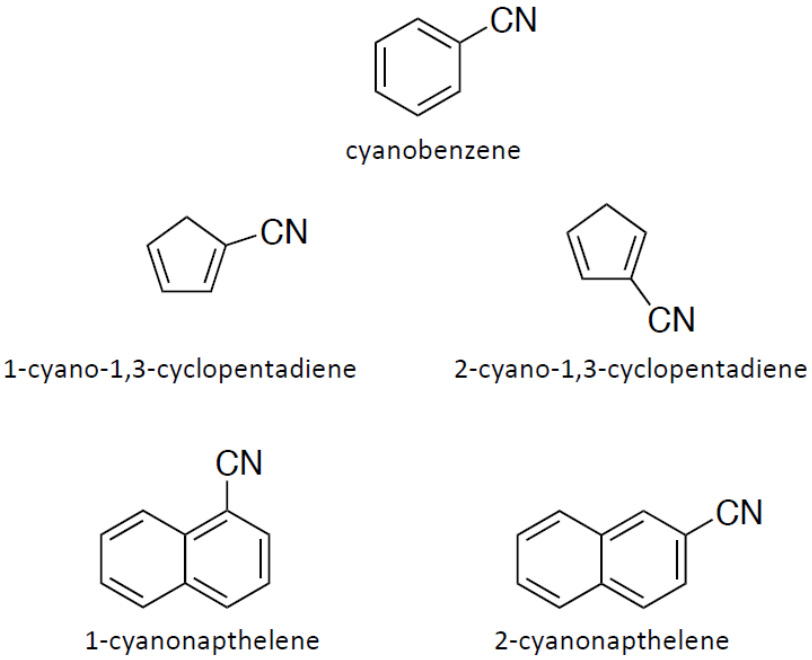


Figure 1: Structures and common chemical names of the five aromatic or cyclic molecules that have recently been discovered in the dark molecular cloud TMC-1 on the basis of precise laboratory rest frequencies using the 100 m Green Bank Telescope.

Search for N-heterocycles precursors

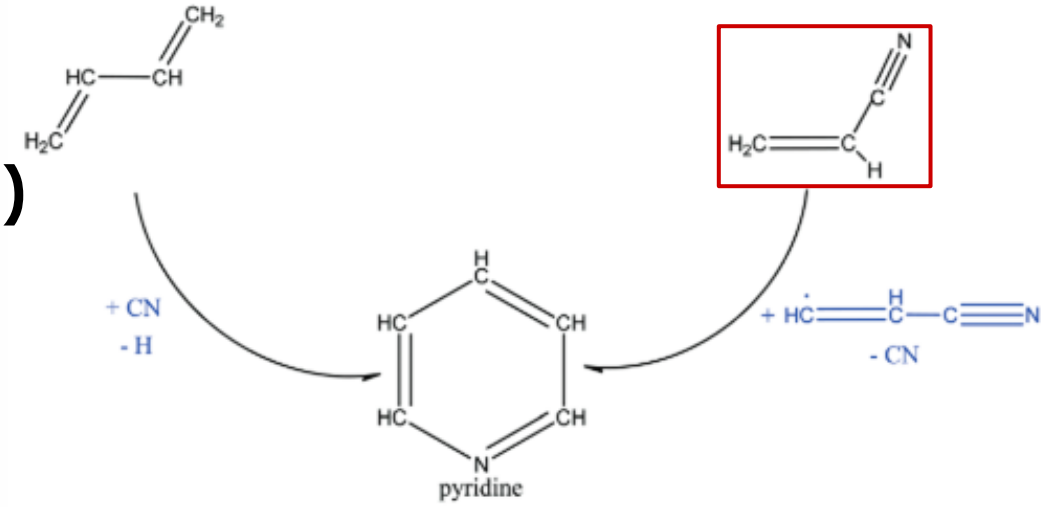
- **HNCO, HC3N, C3H and HC_3NH^+**

(Majumdar et al. 2015)

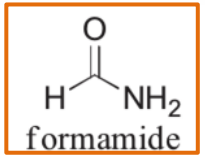
- **Formamide**

- **Vinyl cyanide (C2H3CN)**

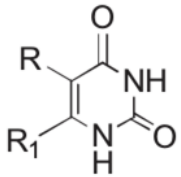
(Parker & Kaiser, 2017)



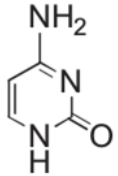
Formamide



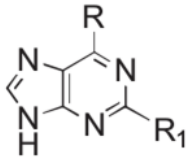
protons (170 MeV)
meteorite, 243 K



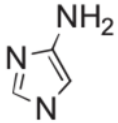
R=R$_1$=H; uracil (1)
R=Me; R$_1$=H; thymine (3)
R=H; R$_1$=COOH; orotic acid (10)



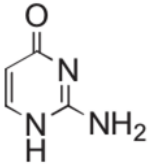
cytosine (2)



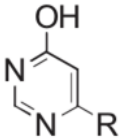
R=NH$_2$; R$_1$=H adenine (4)
R=OH; R$_1$=NH$_2$ guanine (5)
R=R$_1$=H purine (6)
R=OH; R$_1$=H hypoxanthine (8)
R=R$_1$=NH$_2$ 2,6-diaminopurine (9)



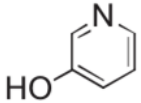
4-AMI (16)



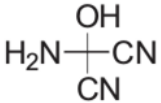
isocytosine (7)



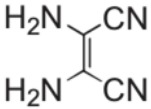
R=OH 4,6-DHP (11)
R=H 4(3H)pyrimidone (12)



3(OH)pyridine (13)



AHMN (14)



DAMN (15)

Products of high-energy proton irradiation of formamide in the presence of meteorites. Nucleobases, nucleobase analogs, and intermediates of the condensation (Saladino et al; 2015).

Formation of HNCO

- Gas phase reactions do not reproduce the observations

- GRAIN REACTIONS

  Interstellar ice analogues processed by proton or UV radiation

(Fedoseev et al. 2015)

$$\boxed{NH + CO \rightarrow HNCO}$$

$$NH_2 + CO \rightarrow HNCO + H$$

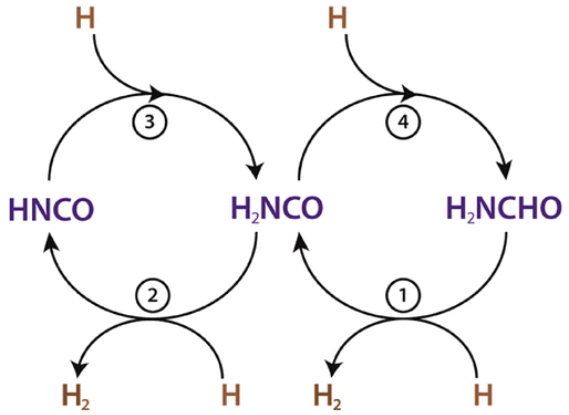
$$N + CO \rightarrow NCO$$

$$H + NCO \rightarrow HNCO$$

HNCO and NH2CHO

- [HNCO]/[NH2CHO] ~ 3.0
  (e.g. Mendoza et al. 2014)

- They may share a common solid state formation scheme
  (Haupa et al. 2019)



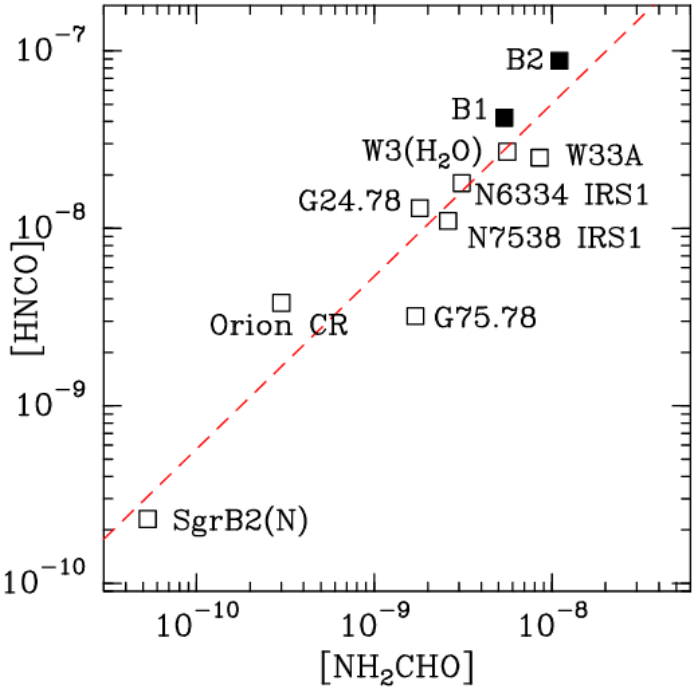
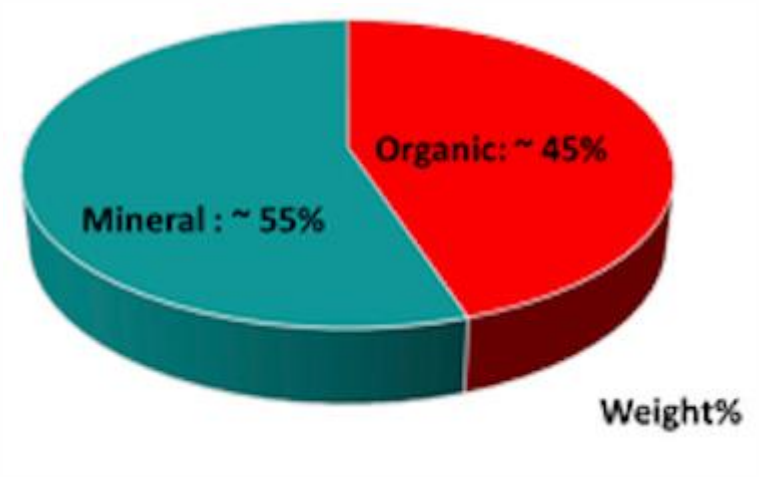


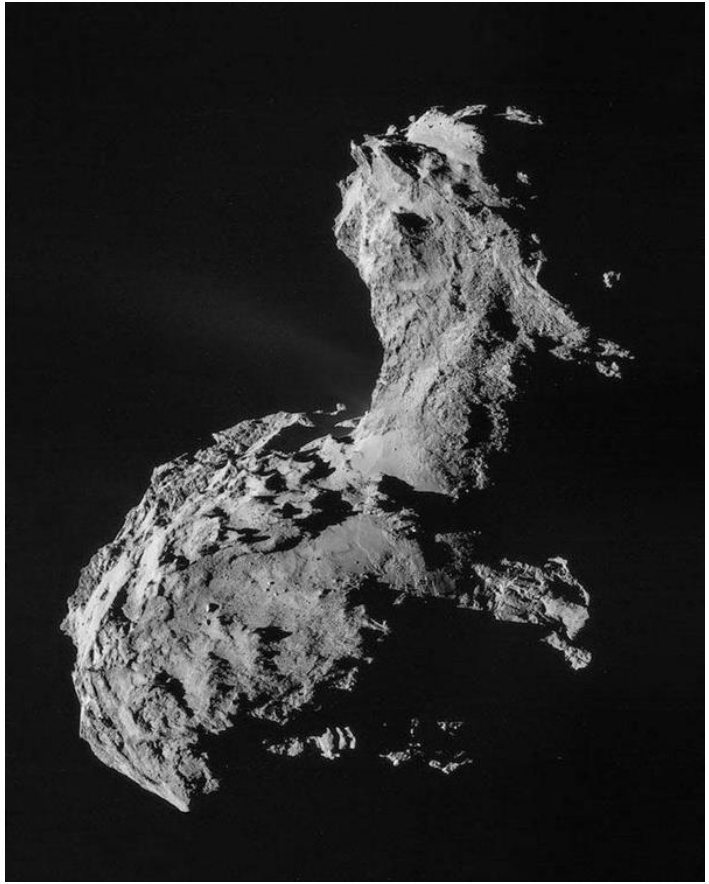
Figure 7. Comparison of molecular abundances for NH_2CHO and HNCO in a sample of Galactic sources. Filled symbols indicate our values measured towards the protostellar shocks B1 and B2. The data were taken from by Jackson, Armstrong & Barrett (1984), Sutton et al. (1995), Bisschop et al. (2007), Martín et al. (2008), and Halfen et al. (2011). The best power-law fit $[HNCO] = 3.0 \times [NH_2CHO]^{0.97}$ is drawn in dashed.

Comets, asteroids and meteorites

67P/Churyumov-Gerasimenko

- **Rosetta/Philae mission**
- **glycine**





FURG IMEF INSTITUTO DE MATEMÁTICA, ESTATÍSTICA E FÍSICA | astro ESUL Astronomia no Extremo SUL

2021 Census of Interstellar, Circumstellar, Extragalactic, Protoplanetary Disk, and Exoplanetary Molecules

Brett A. McGuire[1,2,3]

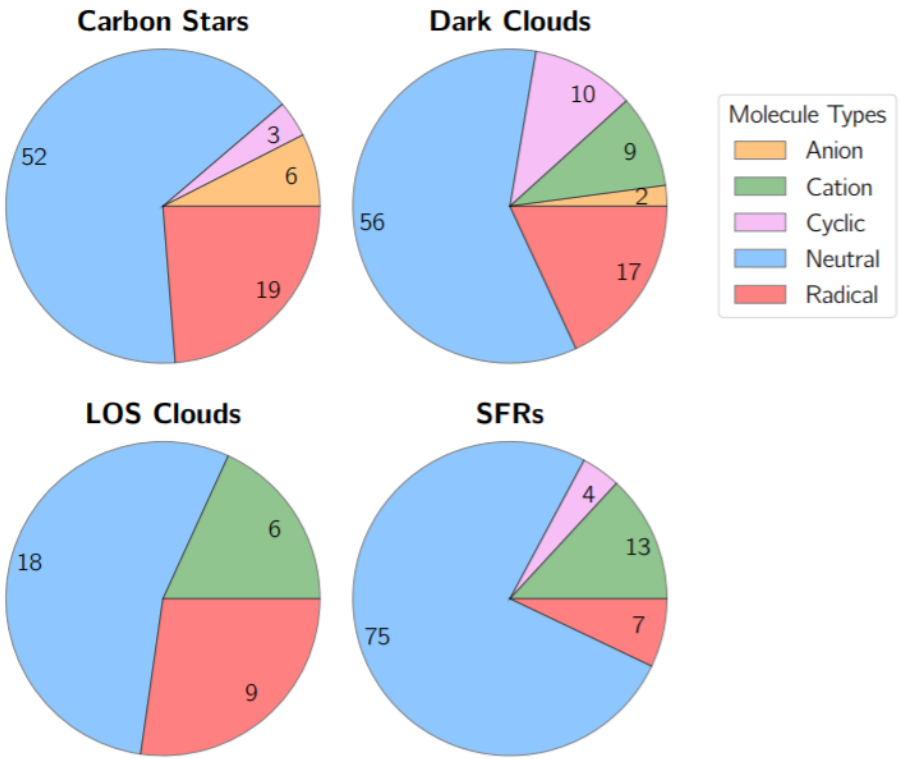
[1] *Department of Chemistry, Massachusetts Institute of Technology, Cambridge, MA 02139, USA*
[2] *National Radio Astronomy Observatory, Charlottesville, VA 22903, USA*
[3] *Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA*

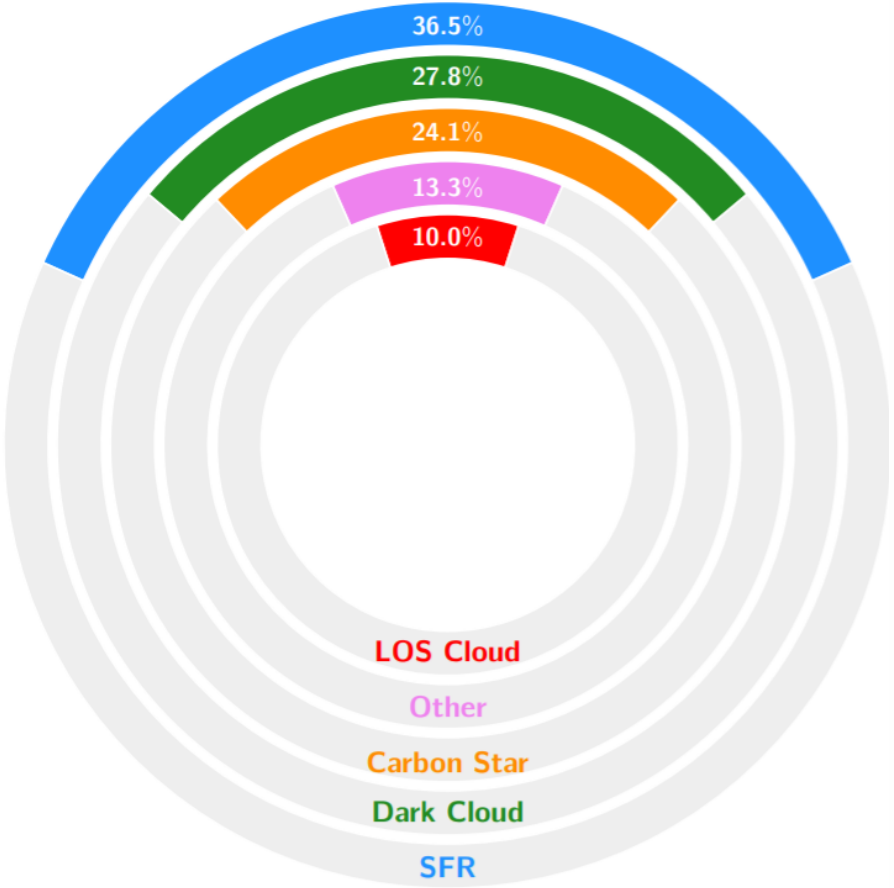
ABSTRACT

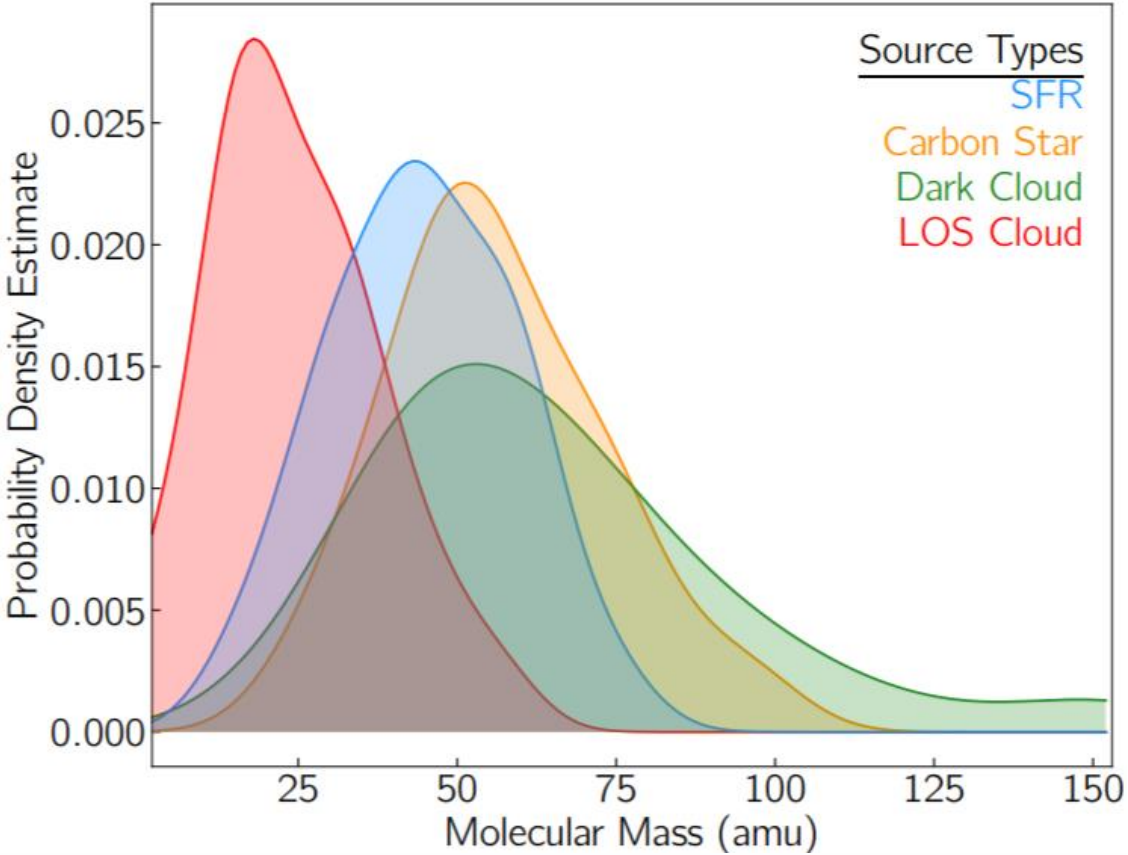
To date, 241 individual molecular species, comprised of 19 different elements, have been detected in the interstellar and circumstellar medium by astronomical observations. These molecules range in size from two atoms to seventy, and have been detected across the electromagnetic spectrum from cm-wavelengths to the ultraviolet. This census presents a summary of the first detection of each molecular species, including the observational facility, wavelength range, transitions, and enabling laboratory spectroscopic work, as well as listing tentative and disputed detections. Tables of molecules detected in interstellar ices, external galaxies, protoplanetary disks, and exoplanetary atmospheres are provided. A number of visual representations of this aggregate data are presented and briefly discussed in context.

Keywords: Astrochemistry, ISM: molecules

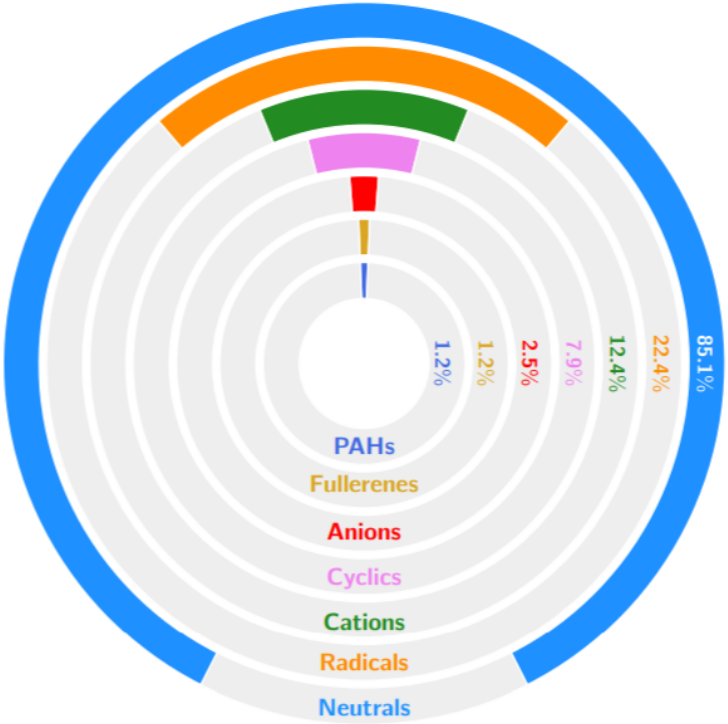
Census of molecules (McGuire+2021)







Census of molecules (McGuire+2021)



FURG IMEF INSTITUTO DE MATEMÁTICA, ESTATÍSTICA E FÍSICA astro ESUL Astronomia no Extremo SUL

Census of molecules (McGuire+2021)
241 species and 19 elements

1 **174** **H** 1.00794 Hydrogen																	2 **1** **He** 4.002602 Helium
3 **Li** 6.941 Lithium	4 **Be** 9.012182 Beryllium											5 **B** 10.811 Boron	6 **189** **C** 12.0107 Carbon	7 **93** **N** 14.0067 Nitrogen	8 **76** **O** 15.9994 Oxygen	9 **3** **F** 18.9984032 Fluorine	10 **Ne** 20.1797 Neon
11 **2** **Na** 22.98977 Sodium	12 **6** **Mg** 24.305 Magnesium											13 **5** **Al** 26.981538 Aluminum	14 **13** **Si** 28.0855 Silicon	15 **6** **P** 30.973761 Phosphorus	16 **30** **S** 32.065 Sulfur	17 **7** **Cl** 35.453 Chlorine	18 **1** **Ar** 39.948 Argon
19 **2** **K** 39.0983 Potassium	20 **1** **Ca** 40.078 Calcium	21 **Sc** 44.95591 Scandium	22 **2** **Ti** 47.867 Titanium	23 **1** **V** 50.9415 Vanadium	24 **Cr** 51.9961 Chromium	25 **Mn** 54.938049 Manganese	26 **1** **Fe** 55.845 Iron	27 **Co** 58.9332 Cobalt	28 **Ni** 58.6934 Nickel	29 **Cu** 63.546 Copper	30 **Zn** 65.409 Zinc	31 **Ga** 69.723 Gallium	32 **Ge** 72.64 Germanium	33 **As** 74.9216 Arsenic	34 **Se** 78.96 Selenium	35 **Br** 79.904 Bromine	36 **Kr** 83.798 Krypton
37 **Rb** 85.4678 Rubidium	38 **Sr** 87.62 Strontium	39 **Y** 88.90585 Yttrium	40 **Zr** 91.224 Zirconium	41 **Nb** 92.90638 Niobium	42 **Mo** 95.94 Molybdenum	43 **Tc** 98 Technetium	44 **Ru** 101.07 Ruthenium	45 **Rh** 102.9055 Rhodium	46 **Pd** 106.42 Palladium	47 **Ag** 107.8682 Silver	48 **Cd** 112.411 Cadmium	49 **In** 114.818 Indium	50 **Sn** 118.71 Tin	51 **Sb** 121.76 Antimony	52 **Te** 127.6 Tellurium	53 **I** 126.90447 Iodine	54 **Xe** 131.293 Xenon
55 **Cs** 132.90545 Cesium	56 **Ba** 137.327 Barium		72 **Hf** 178.49 Hafnium	73 **Ta** 180.9479 Tantalum	74 **W** 183.84 Tungsten	75 **Re** 186.207 Rhenium	76 **Os** 190.23 Osmium	77 **Ir** 192.217 Iridium	78 **Pt** 195.078 Platinum	79 **Au** 196.96655 Gold	80 **Hg** 200.59 Mercury	81 **Tl** 204.3833 Thallium	82 **Pb** 207.2 Lead	83 **Bi** 208.98038 Bismuth	84 **Po** 209 Polonium	85 **At** 210 Astatine	86 **Rn** 222 Radon
87 **Fr** 223 Francium	88 **Ra** 226 Radium		104 **Rf** 261 Rutherfordium	105 **Db** 262 Dubnium	106 **Sg** 266 Seaborgium	107 **Bh** 264 Bohrium	108 **Hs** 277 Hassium	109 **Mt** 268 Meitnerium	110 **Ds** 281 Darmstadtium	111 **Rg** 272 Roentgenium	112 **Cn** 285 Copernicium	113 **Nh** 286 Nihonium	114 **Fl** 289 Flerovium	115 **Mc** 289 Moscovium	116 **Lv** 293 Livermorium	117 **Ts** 294 Tennessine	118 **Og** 294 Oganesson

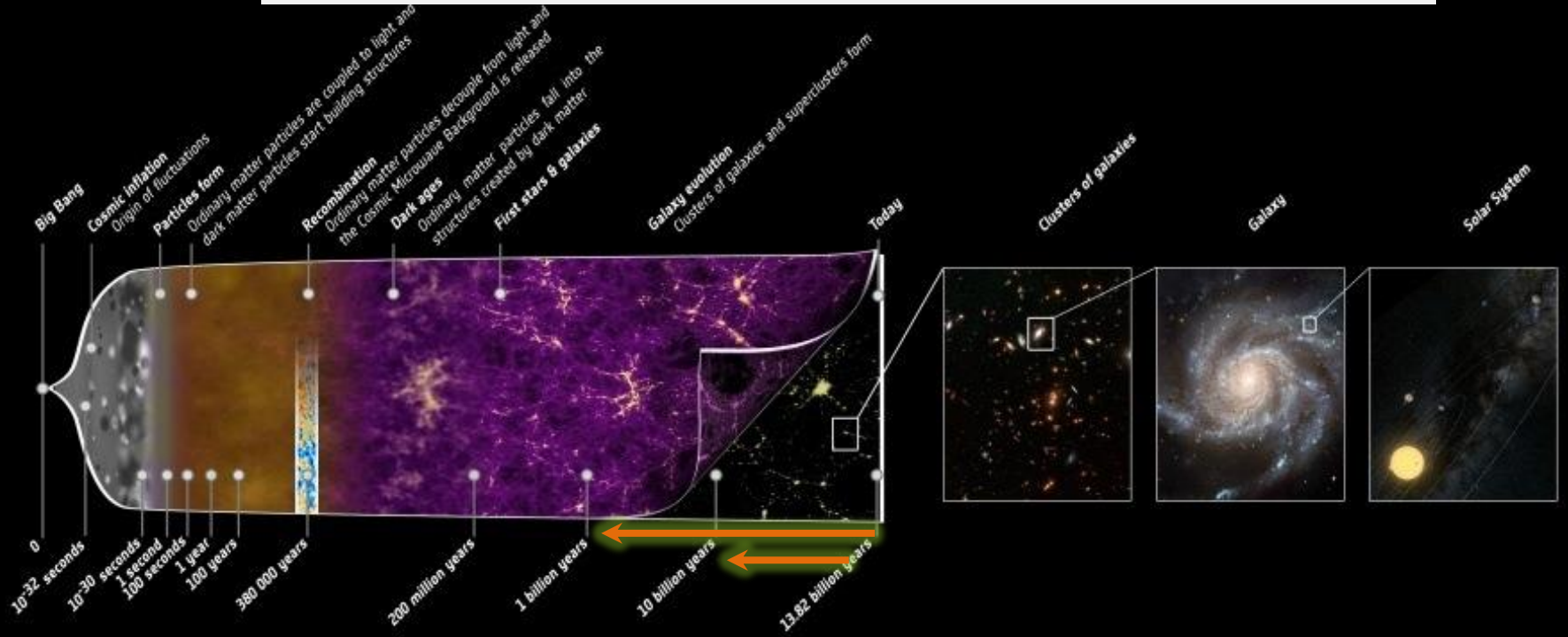
2º - AstroChemistry

Galaxies …

It is a huge system of gas (~10%), dust (1%), billions/trillion of stars and dark matter all held together by gravity.

It can be considered as "fundamental blocks" of the Universe.

(1) How can we use molecules to study the Universe?

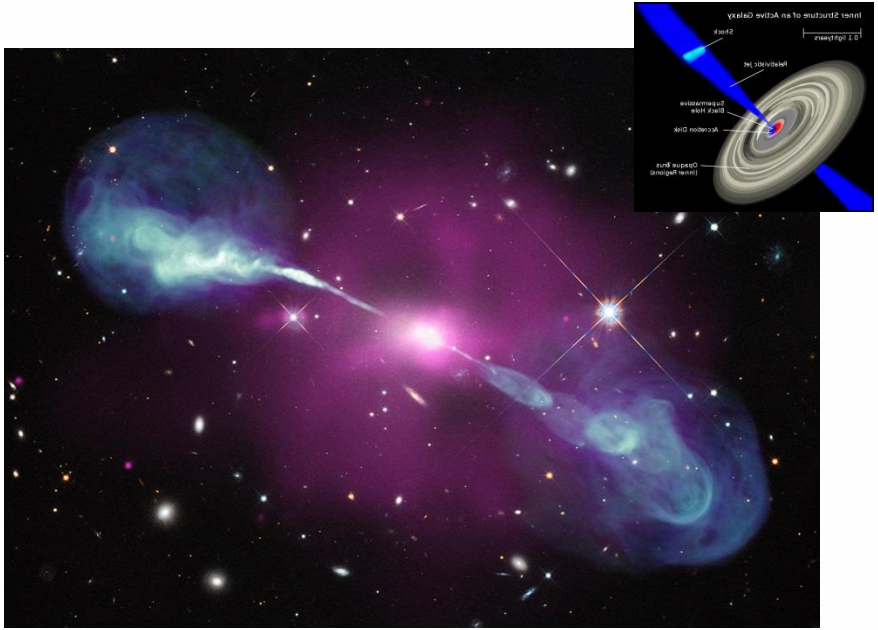


Active Galaxies

Star Formation Rate

Milk Way ~ 3 $M_\odot$/ano

Starburst > 100 $M_\odot$/ano

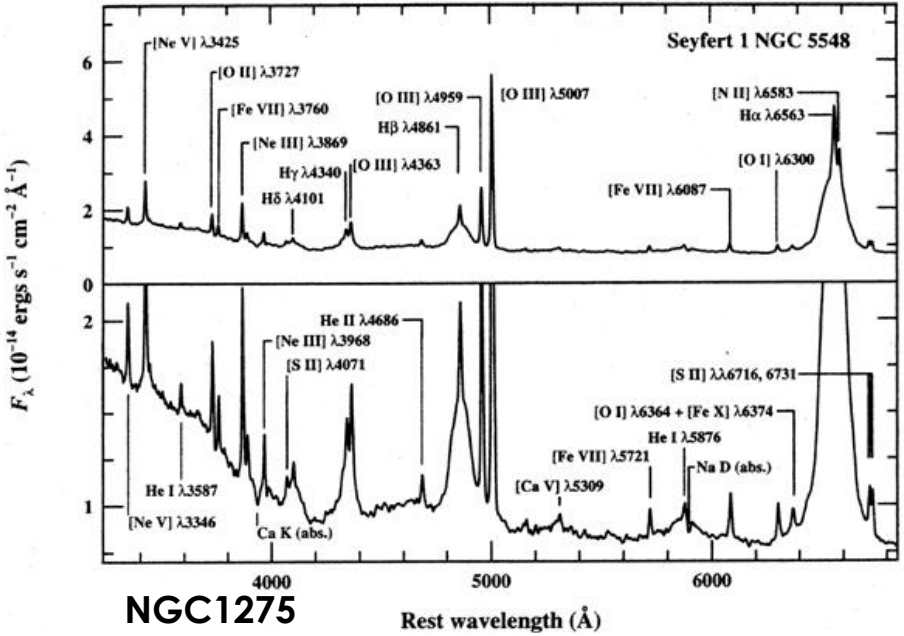


Active Galactic Nuclei – SMBH $10^{4\text{-}7}(M_\odot)$

Starburst

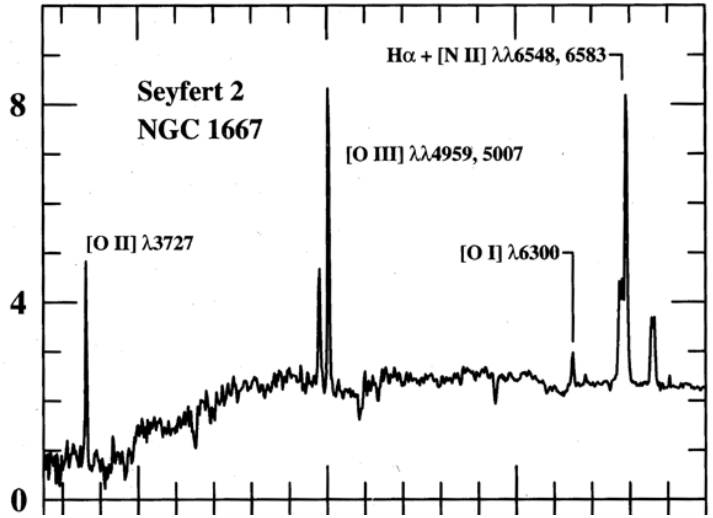
Carl Seyfert (1943, ApJ, 97, 28) are characterized by extremely bright nuclei (~$10^{11}L_{\odot}$).

Seyfert 1 – BLR (FWHM ~ 5000km/s) + NLR (FWHM ~ 500km/s)



NGC1275

Seyfert 2 – NLR (FWHM ~ 500km/s)

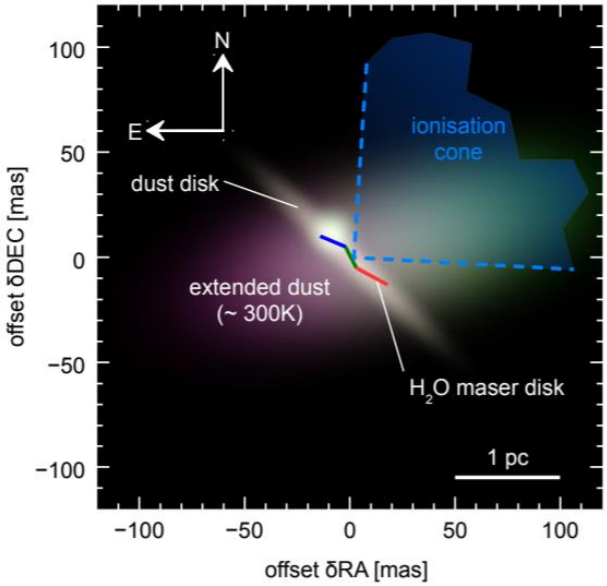


NGC1667

Image taken from https://ned.ipac.caltech.edu/level5/Glossary/Essay_seyfert.html

AGN Unified Model

Antonucci & Millher (1985, ApJ, 297, 621)



Tristram et al. 2014

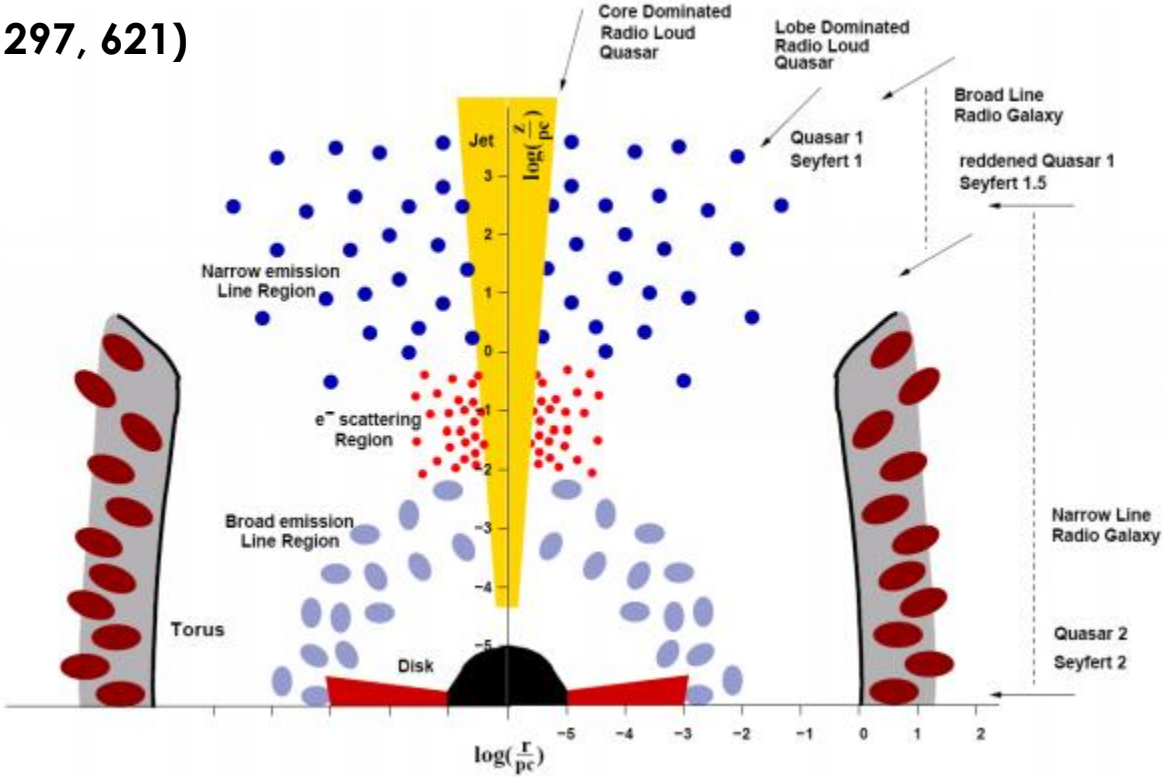


Figure taken from Zier &Biermann (2002, A&A, 396, 91)

Polycyclic Aromatic Hydrocarbons (PAHs)

First observation was performed by Gillett et al. (1973)

First physical and chemical properties (Puget & Leger (1989); Allamandola (1989))

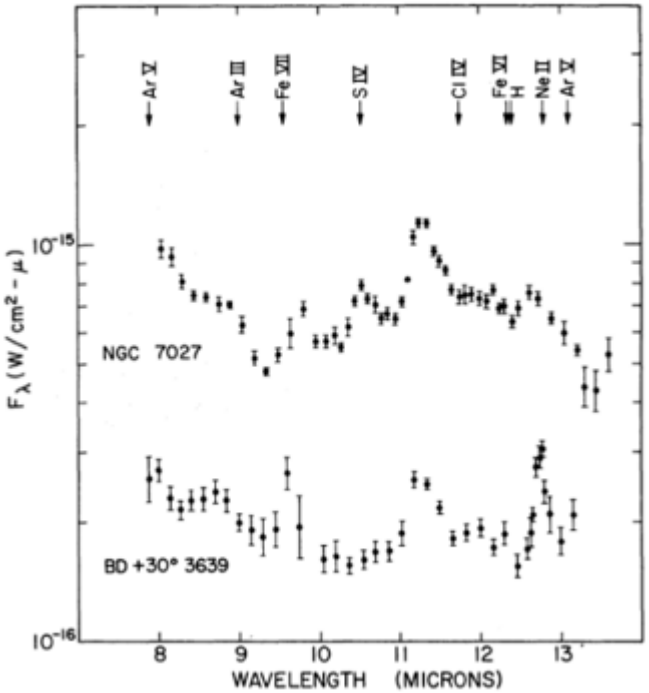


Figure taken from Gillett et al. (1973)

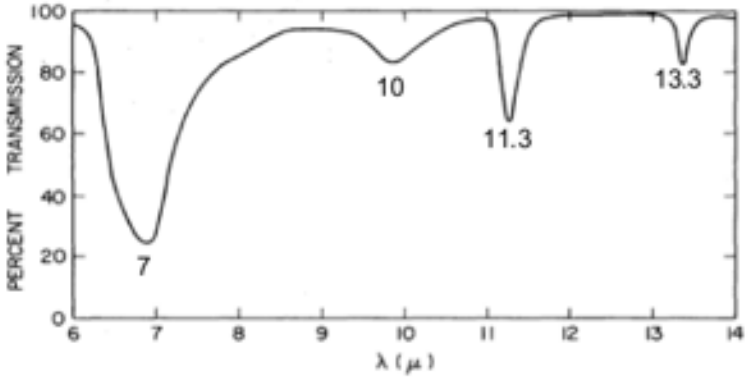
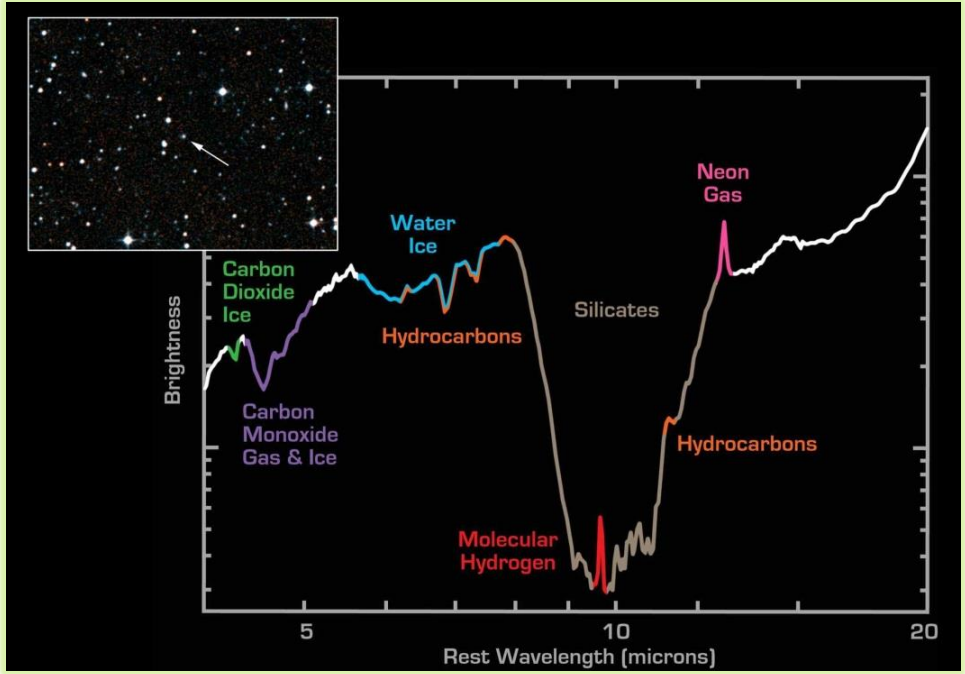
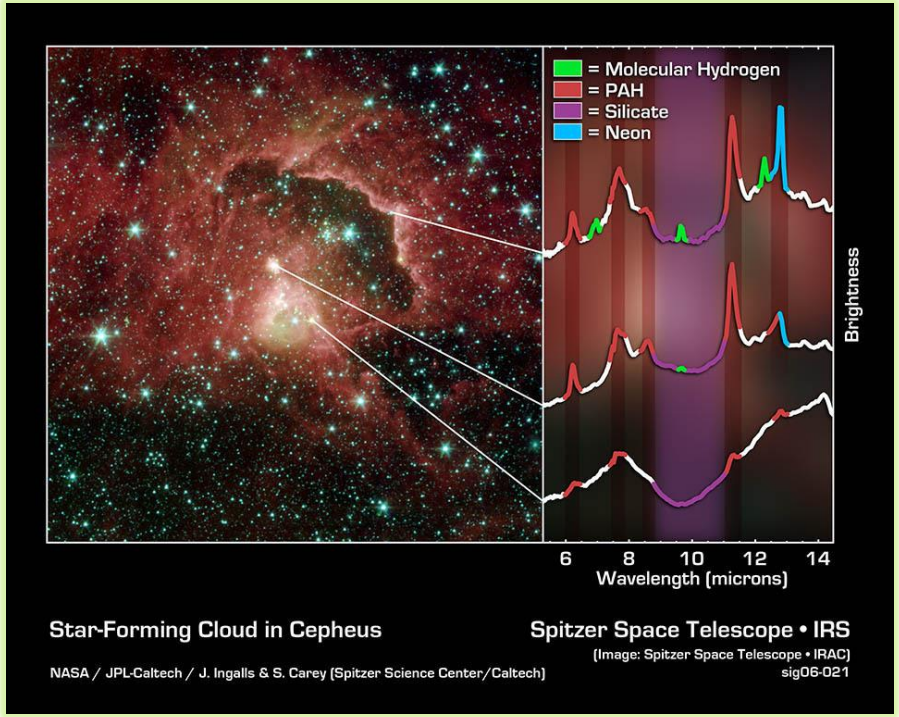


Figure taken from Hunt at al. (1950)

Signature of the molecules in the MIR

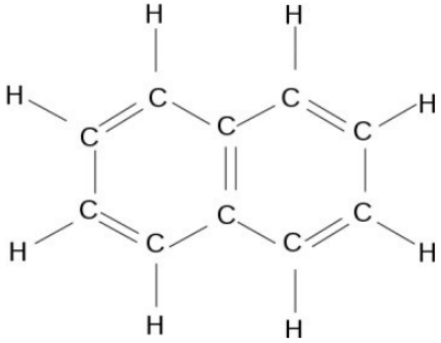




(1) How can we use molecules to study the Universe?

PAHs and Astrobiology

- **P**olycyclic **A**romatic **H**ydrocarbon (PAH)
- 20% or more of the carbon in the ISM (Joblin et al., 1992)
- 50% of the mid-IR luminosity (Li et al., 2004)
  (3.3, 6.2, 7.7, 8.6, 11.3 and 12.7 μm)
- Star formation tracers
  (Tielens et al. 2008)



Naphthalene $C_{10}H_8$

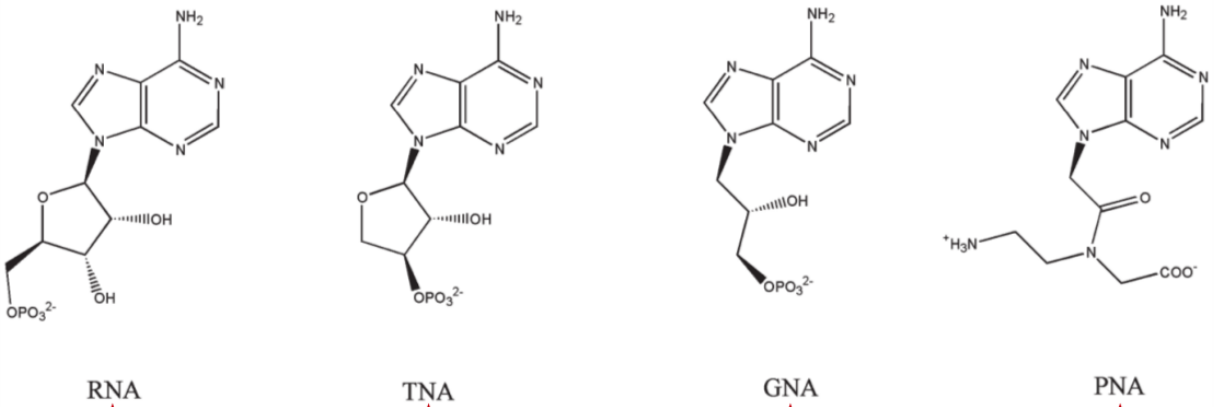
Sales et al. 2010, 2013 – Ruschel-Dutra et al. 2013

(2) What is the role of molecules in the evolution of the Universe?

PAHs and Astrobiology

- Prebiotic role
- PANH

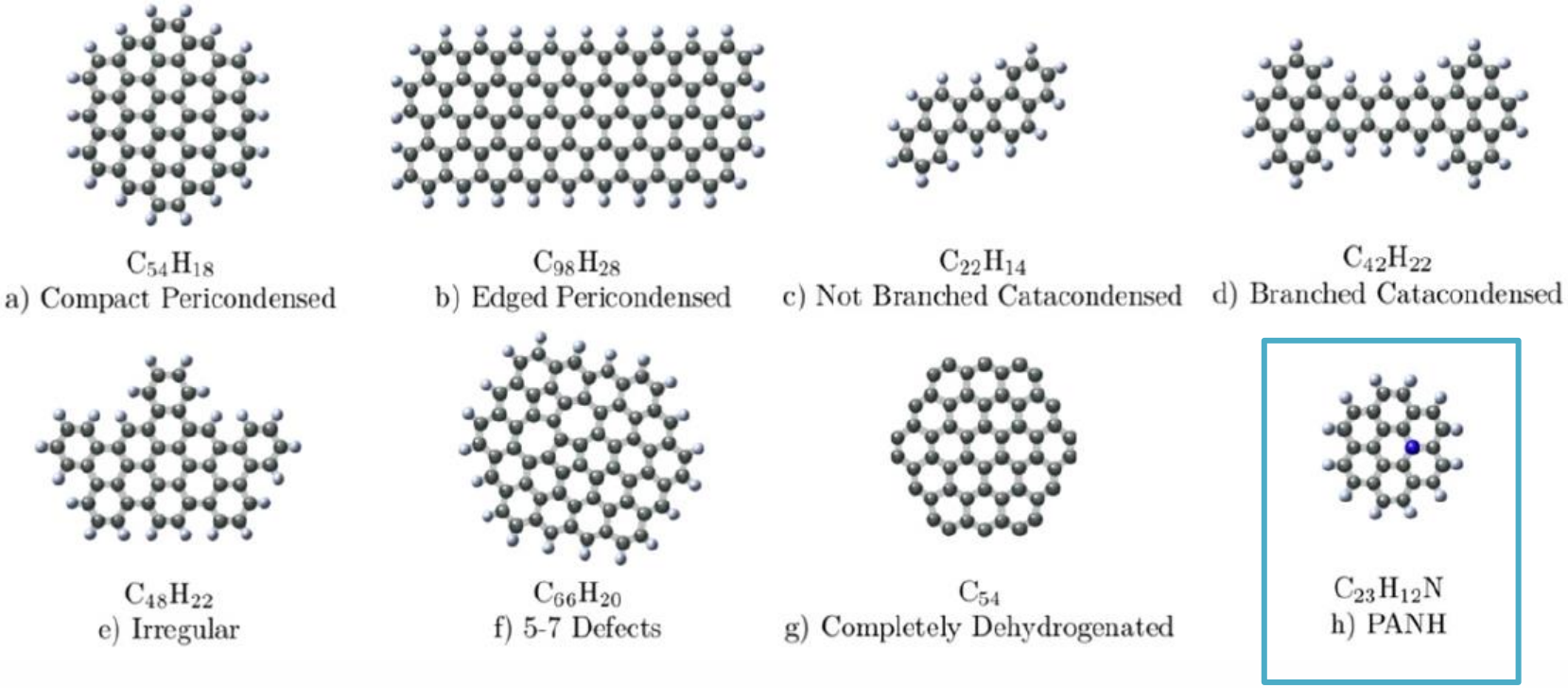
The Aromatic World
(Ehrenfreund et al. 2006)



See Canelo, Friaça, Sales et al. 2008, MNRAS, 475, 3746
Canelo, Sales, Friaça et al. 2021, accepted

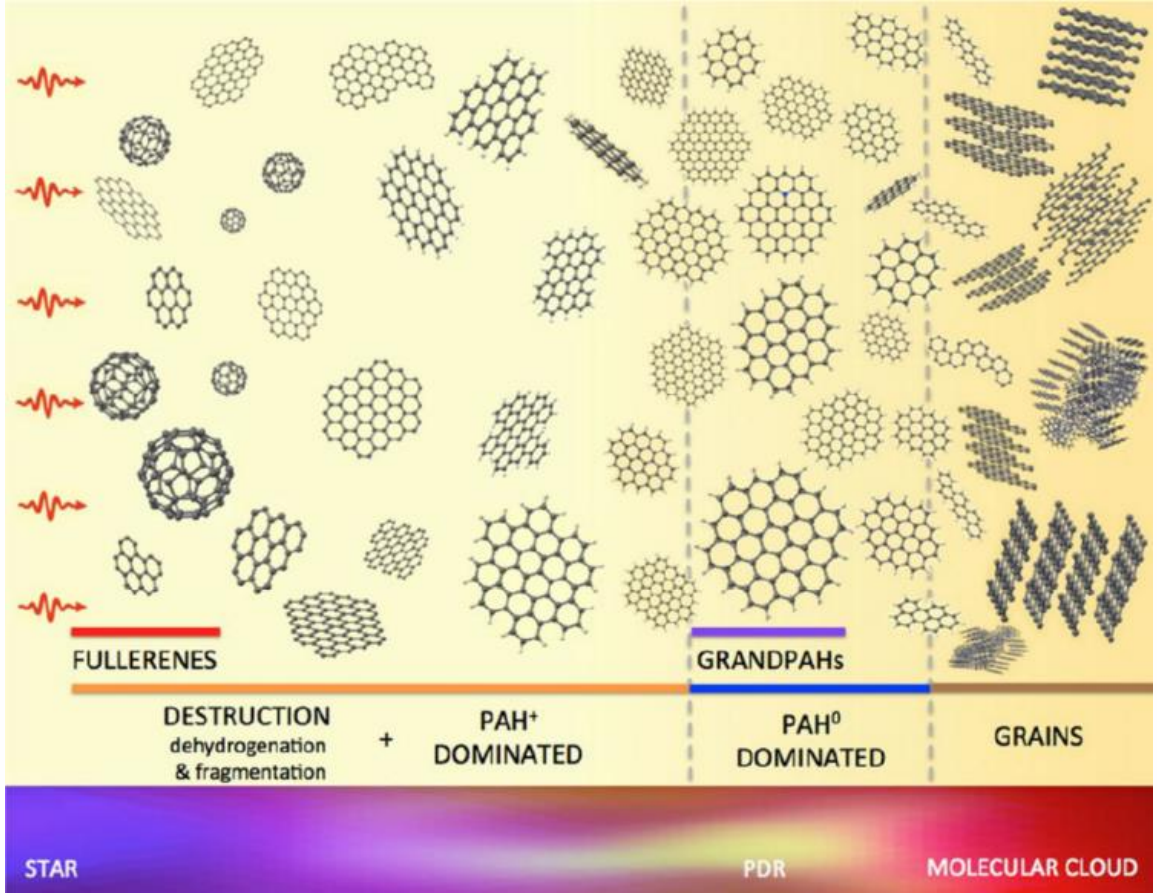
Slide adapted from Carla M. Canelo

Structures of PAHs

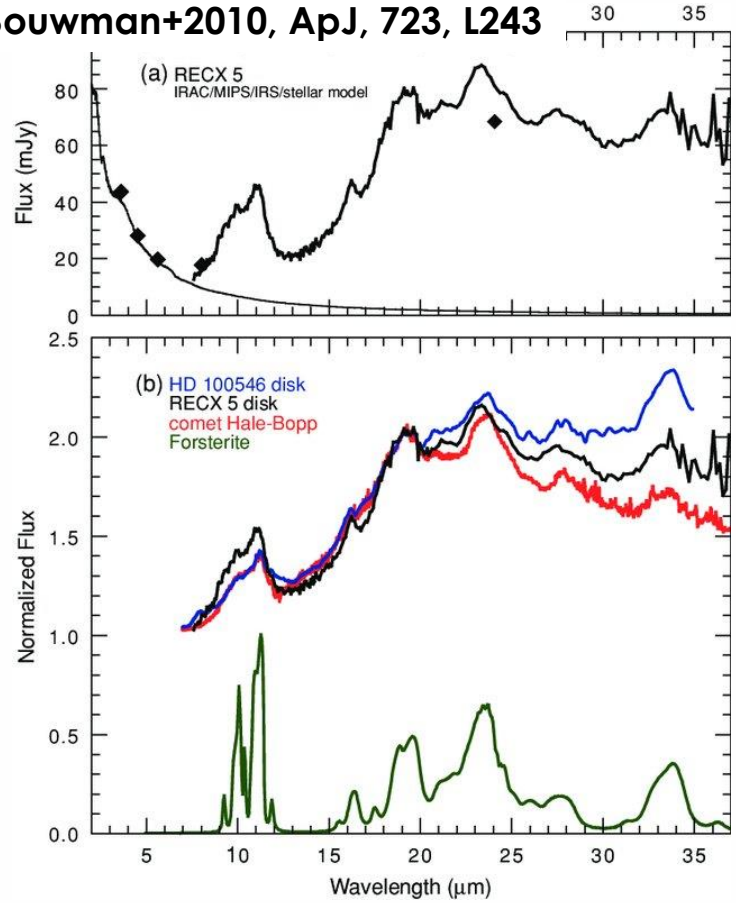


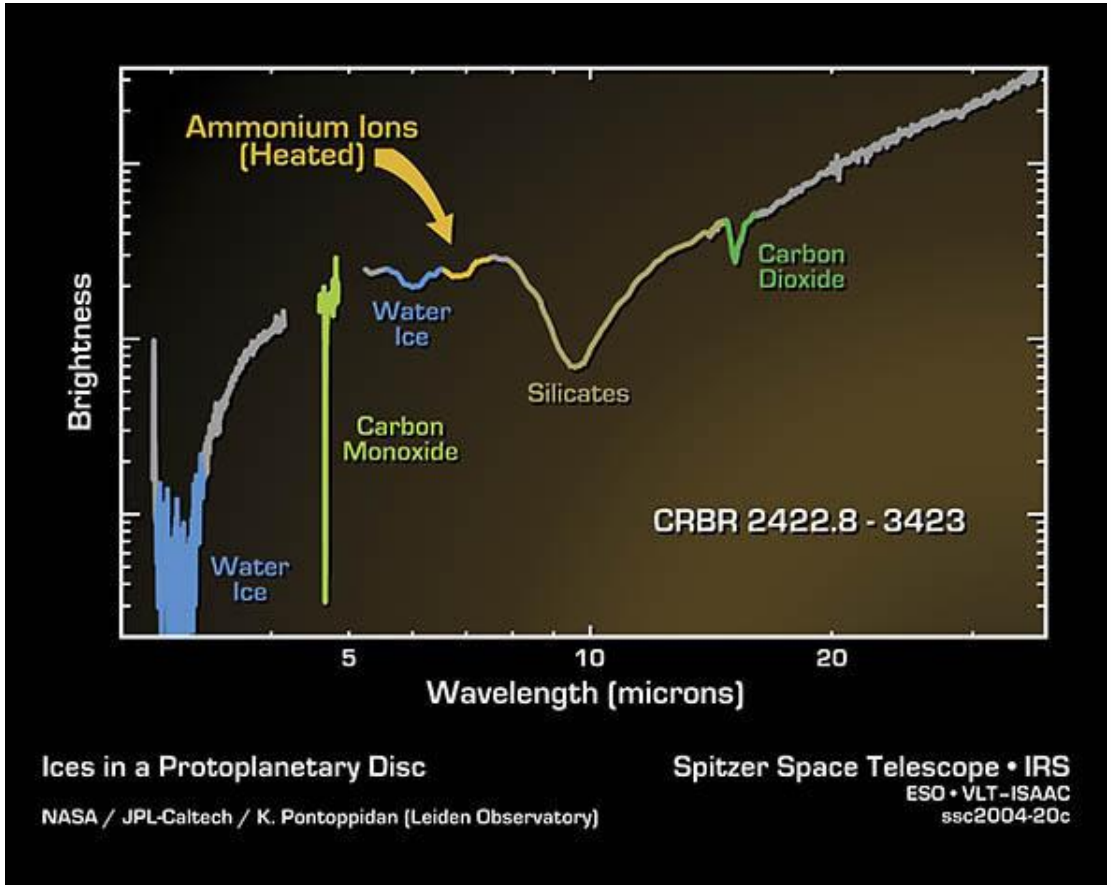
Different kinds of PAH structures (Andrews et al., 2015)

Proposed evolution of PAHs and carbonaceous molecules (Andrews et al., 2015)

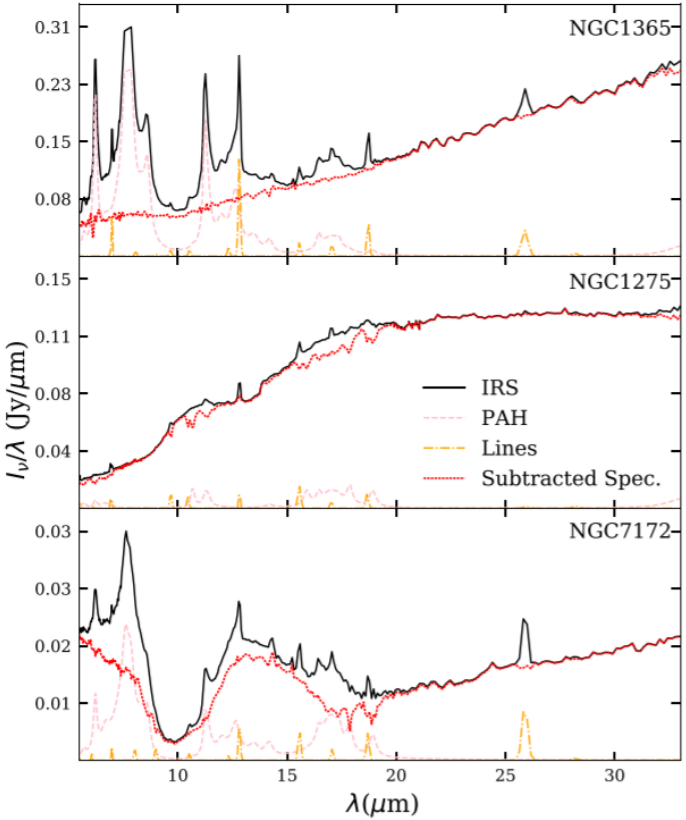


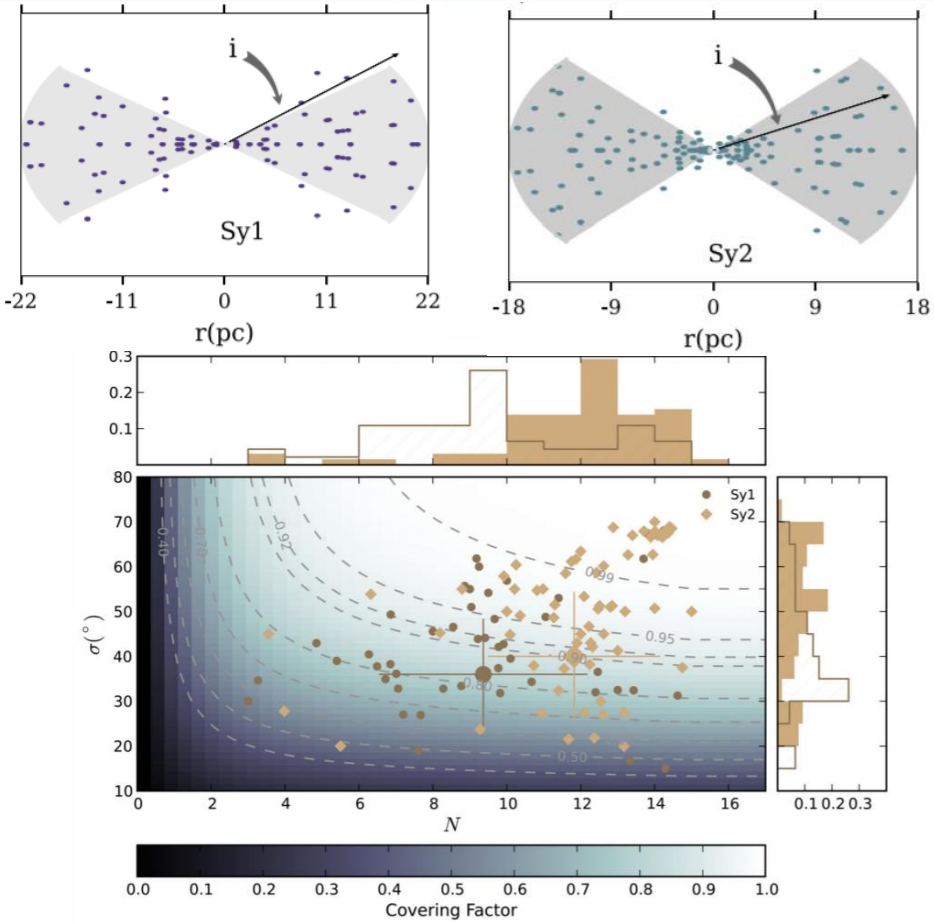
Bouwman+2010, ApJ, 723, L243



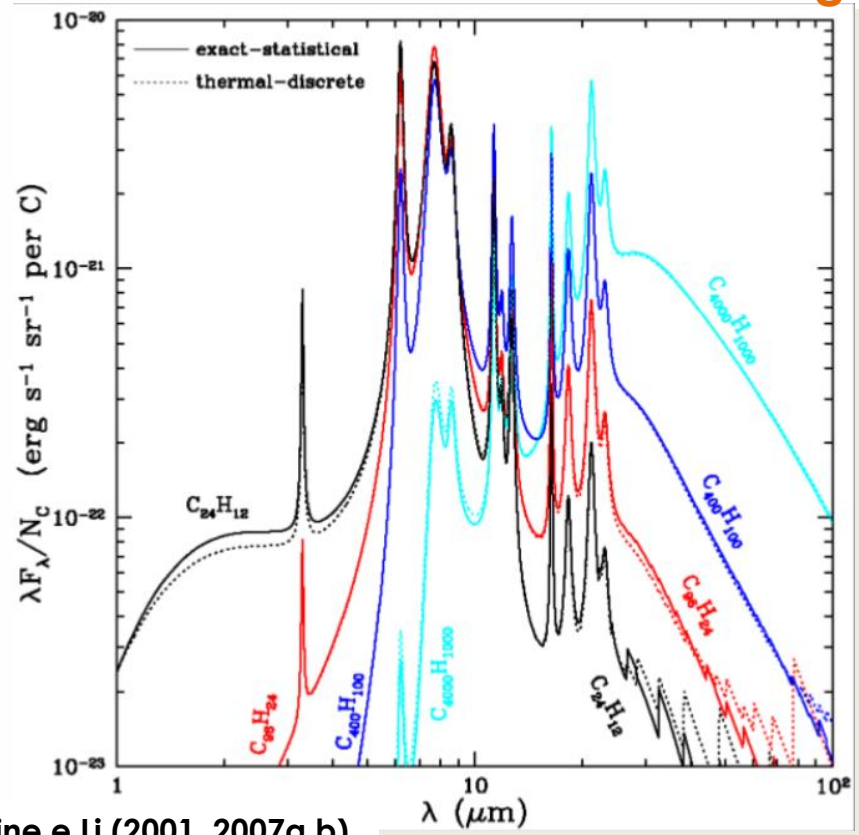


Audibert, Riffel, Sales +2017, MNRAS, 464, 2139

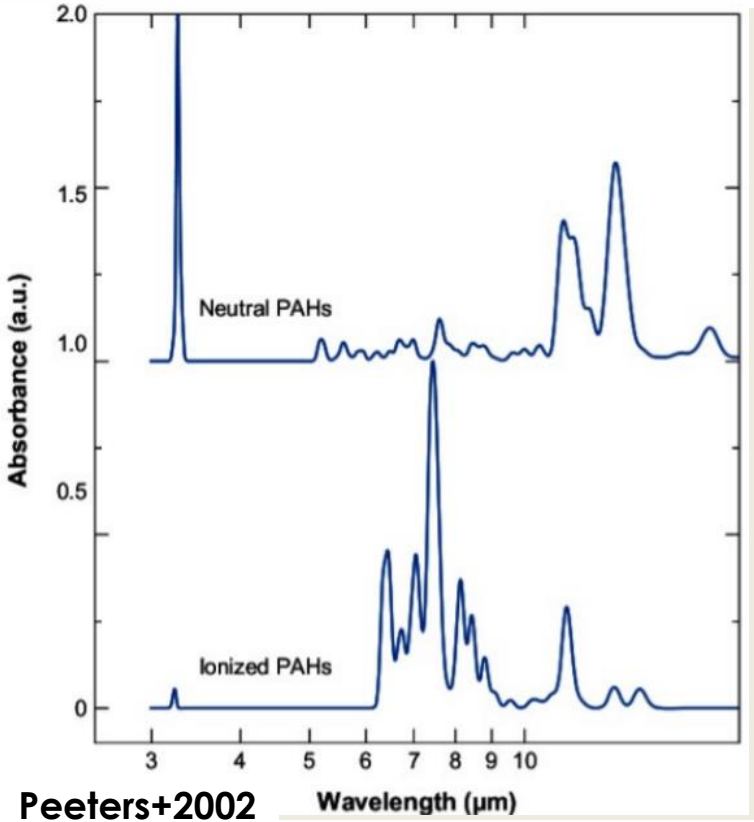




Size and Charge of the PAHs

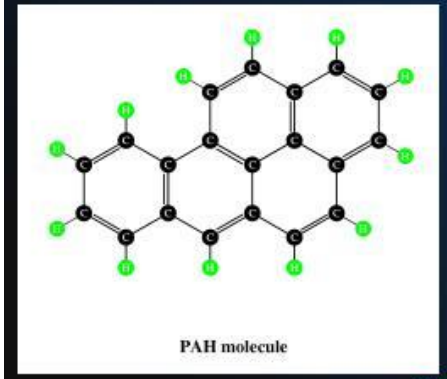


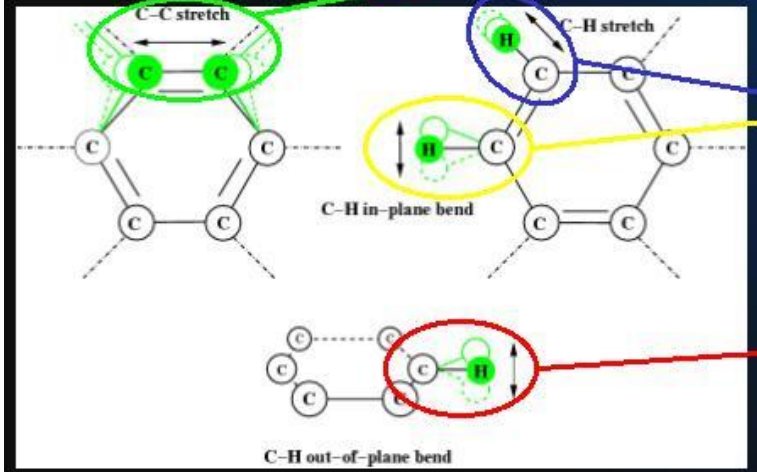
Draine e Li (2001, 2007a,b)

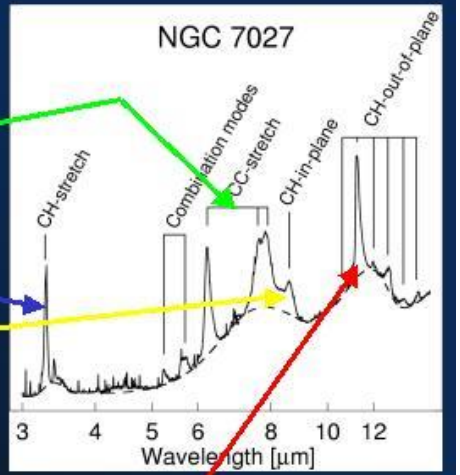


Peeters+2002

PAH Normal Modes



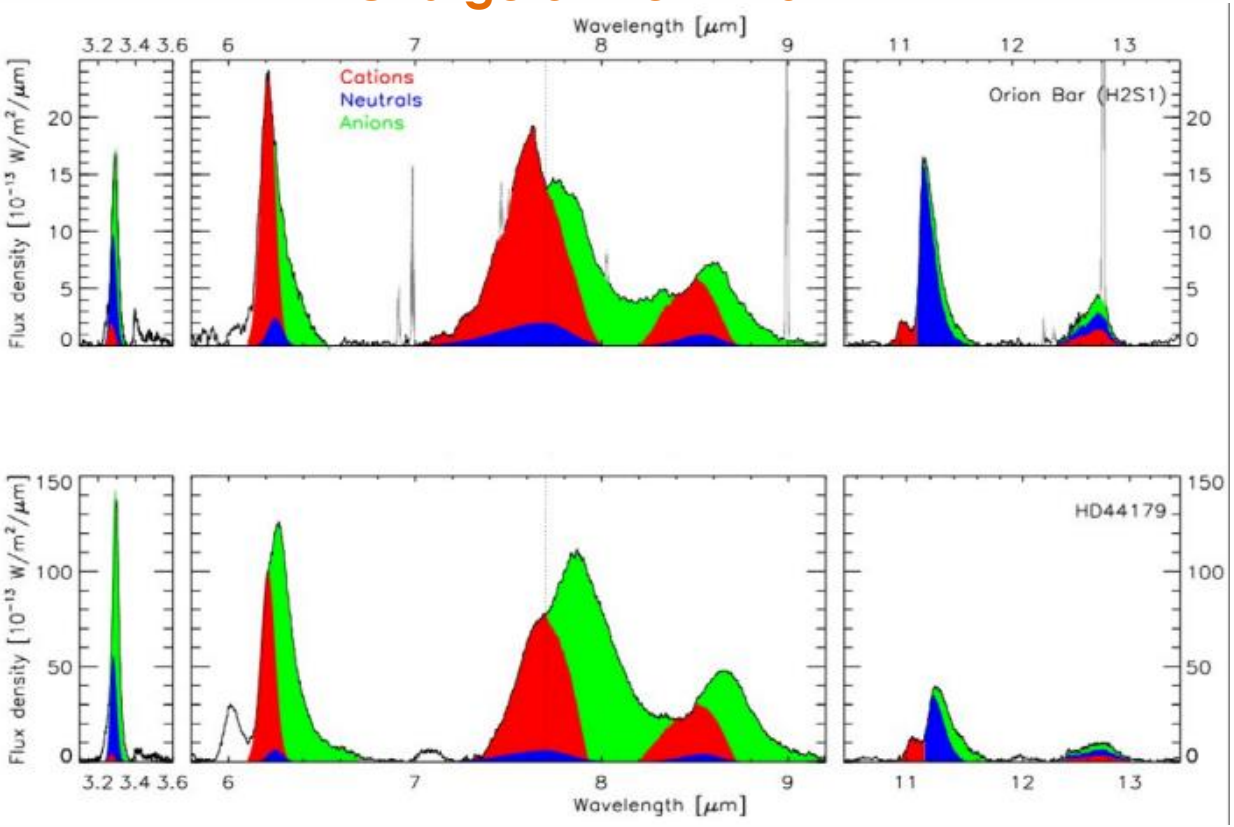




Peeters

Hony

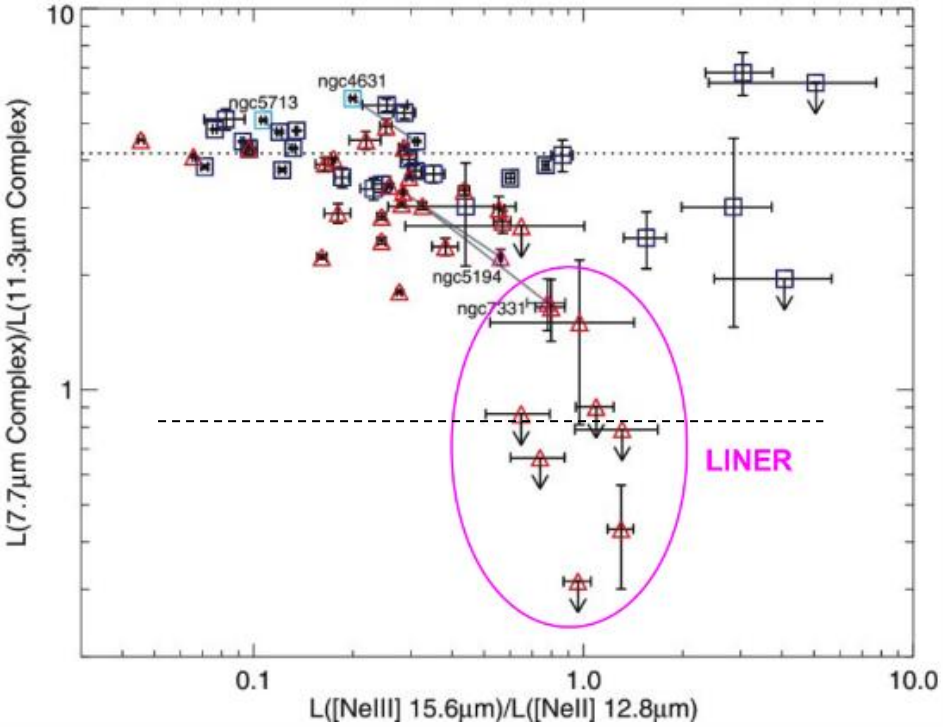
Charge of the PAHs



Bauschlicher, Peeters & Allamandola (2009)

Motivation

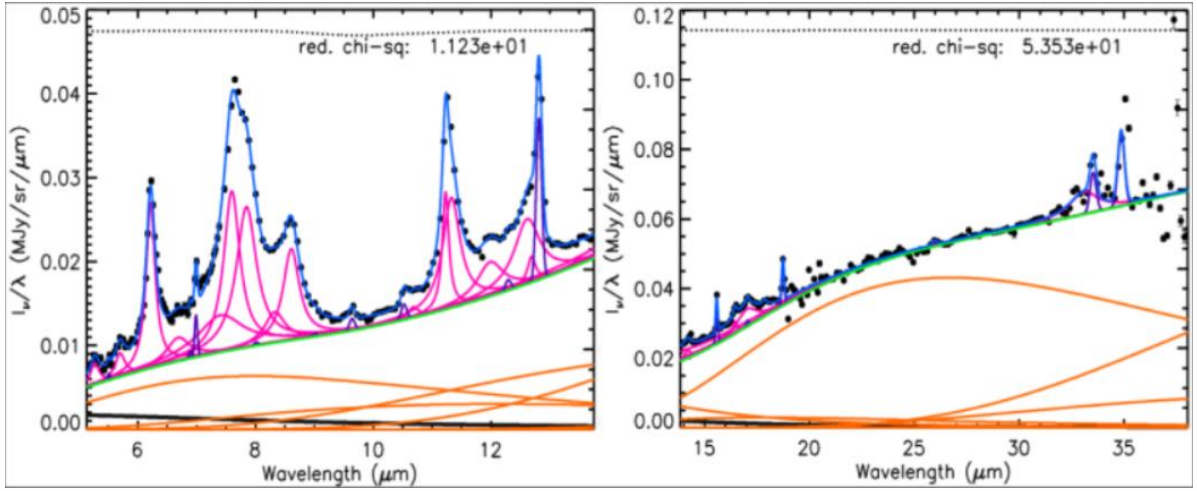
It has been claim that PAHs is destroyed in AGN host galaxies



Smith+2007

The sample and data reduction observed by Spitzer telescope

- 186 galaxies (AGNs+SB+HII) observed by Spitzer IRS;
- 5 – 14μm wavelength range;
- Emission line fit using PAHFIT code (Smith+2007);
- Stellar continuum with T=5000K;
- Termal continuum with T= 35 – 300K;
- Ionic lines and molecular hydrogen (H2);
- PAH bands.

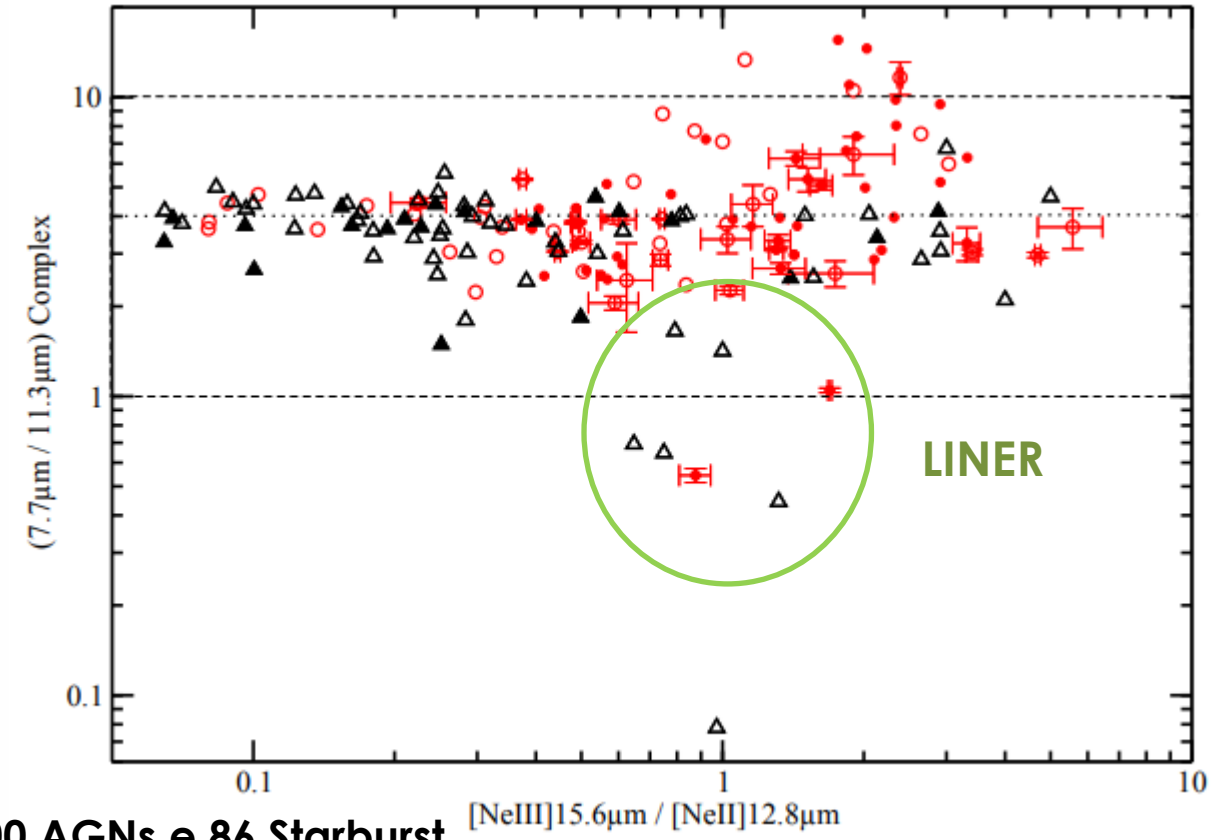


Telescópio Espacial Spitzer

Infrared Spectrograph (IRS)

O que já aprendemos de PAHs em Galáxias?

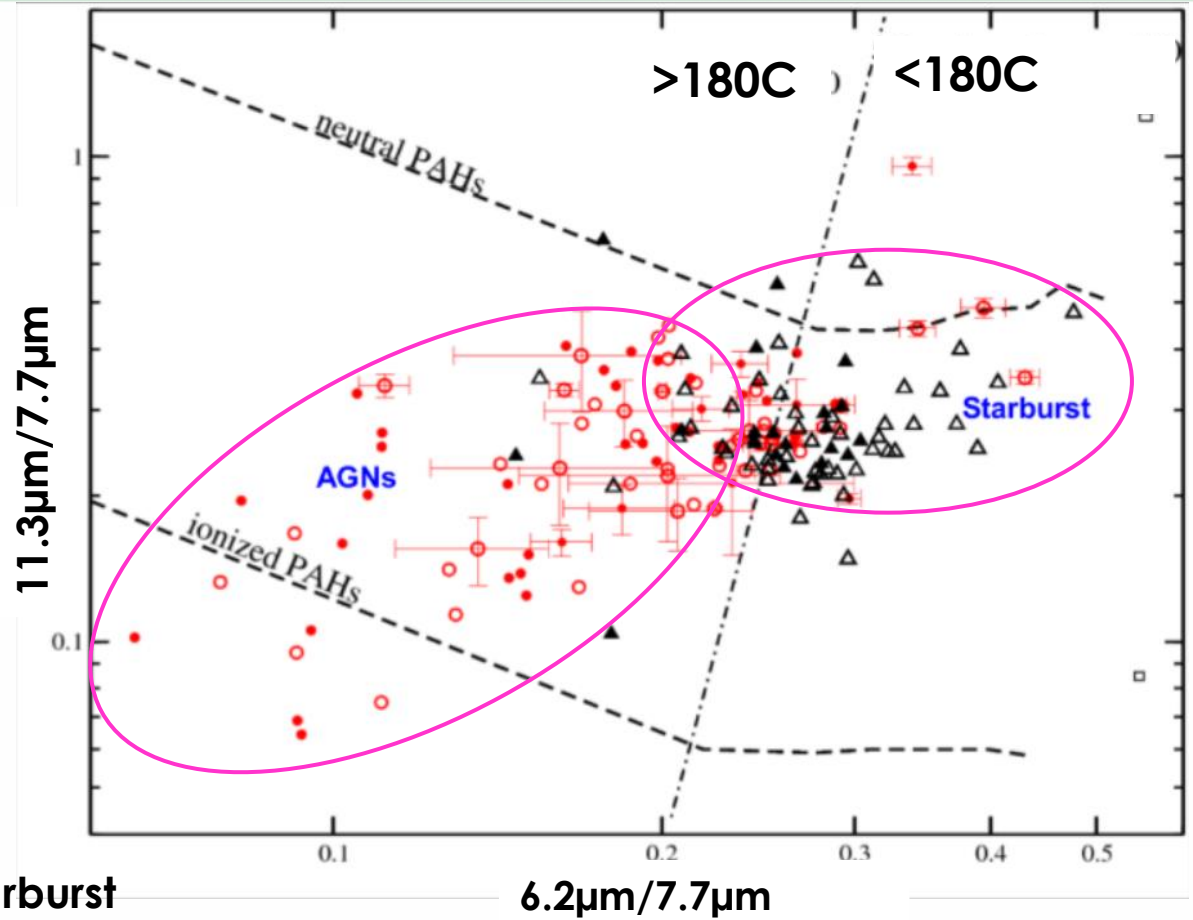
Será que PAHs são destruídos em Galáxias Ativas?



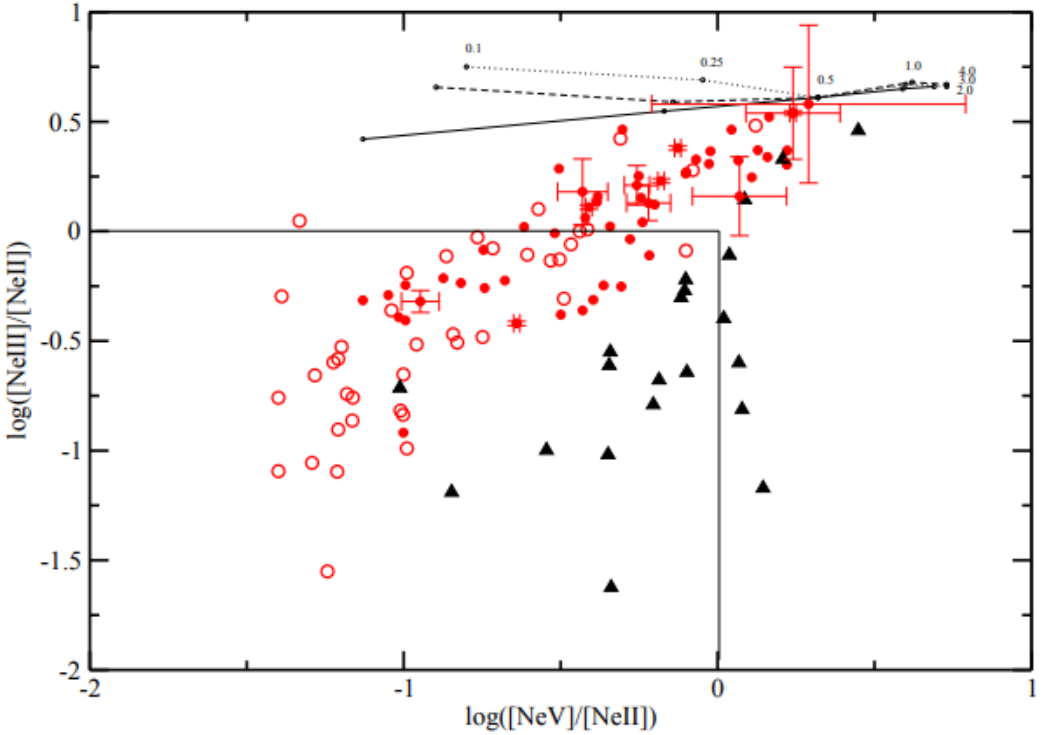
Sales+2010 – 100 AGNs e 86 Starburst

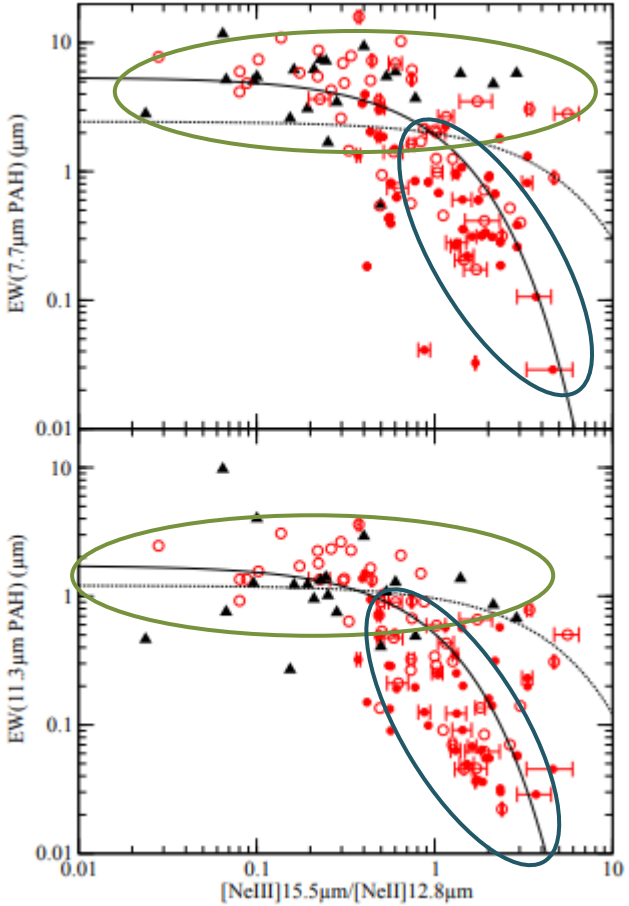
O que já aprendemos de PAHs em Galáxias?

Será que PAHs são destruídos em Galáxias Ativas?



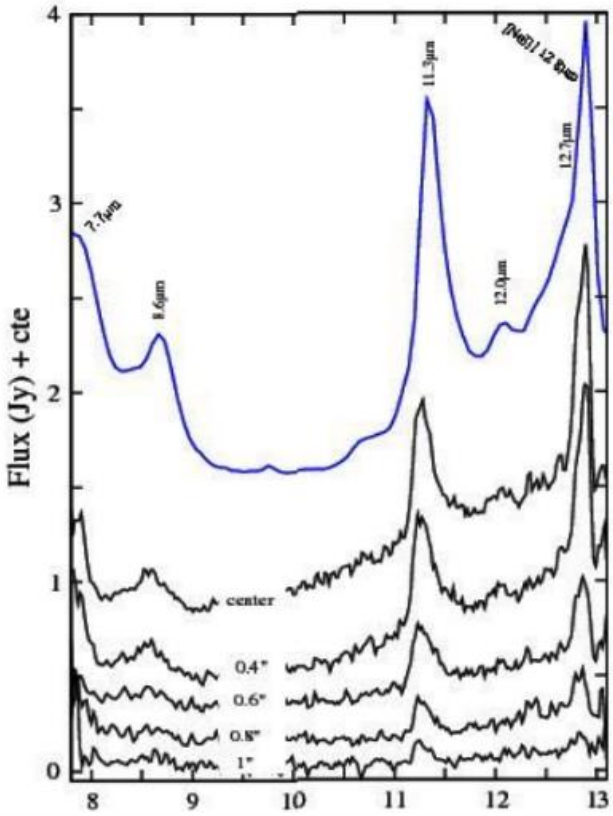
Sales+2010 – 100 AGNs e 86 Starburst





Sales+2010 – 100 AGNs e 86 Starburst

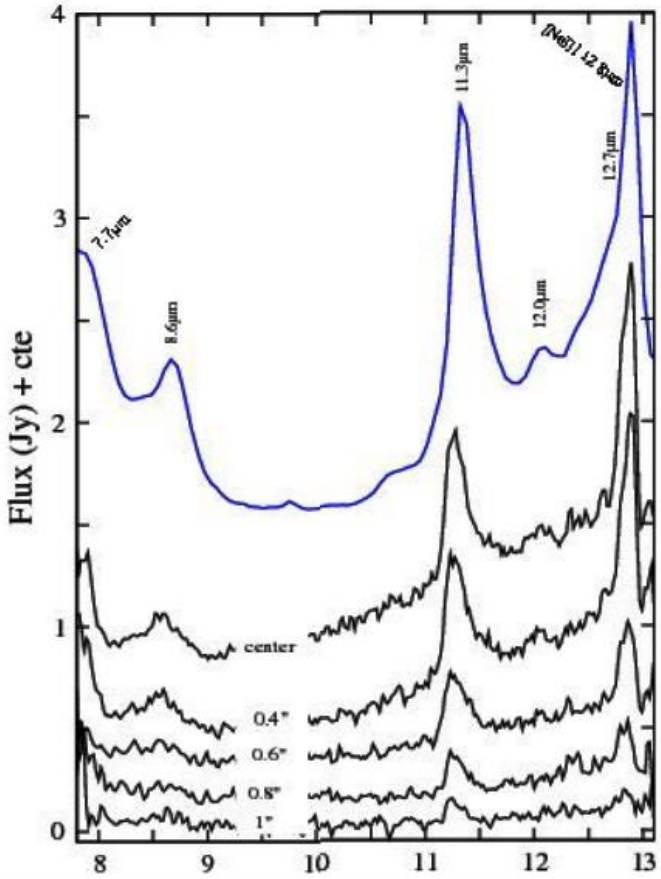
NGC1808

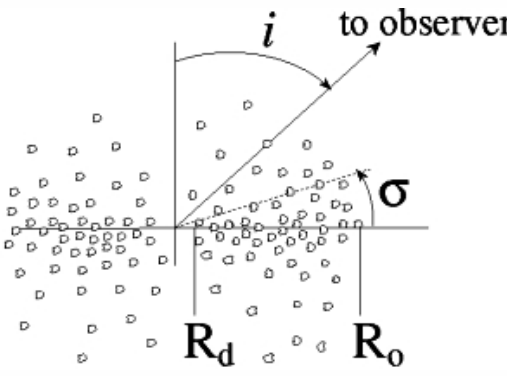


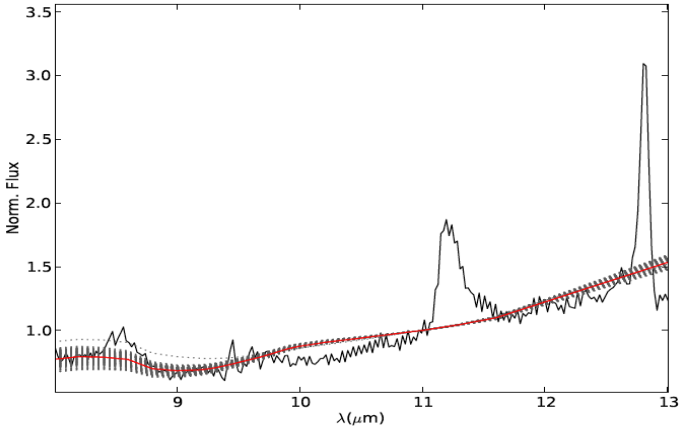
O que já aprendemos de PAHs em Galáxias?

Será que PAHs são destruídos em Galáxias Ativas?

Sales+2012 | Gemini (8m) | ~2 x 10^{14}km
Alonso-Herrero+2014 | ~3 x 10^{14}km





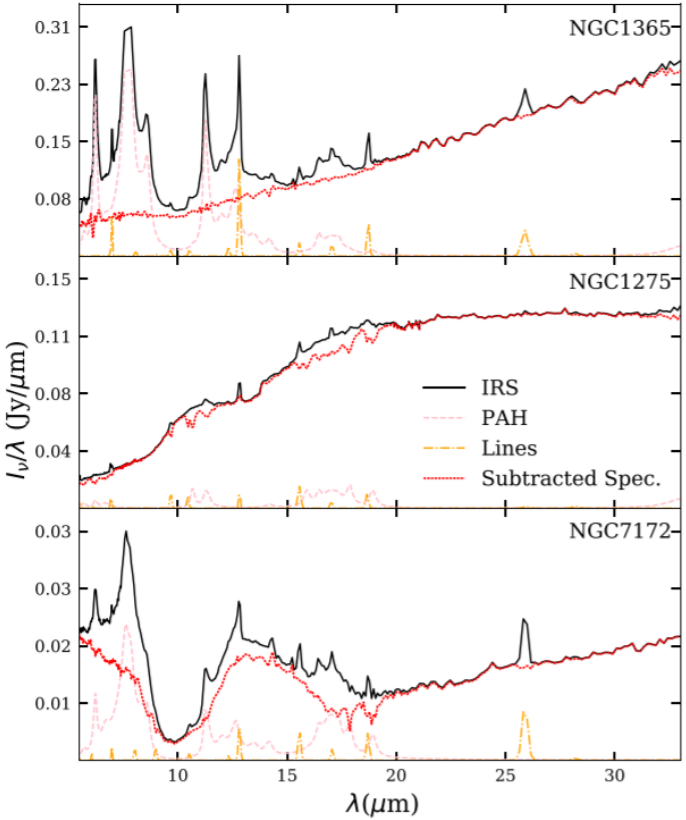


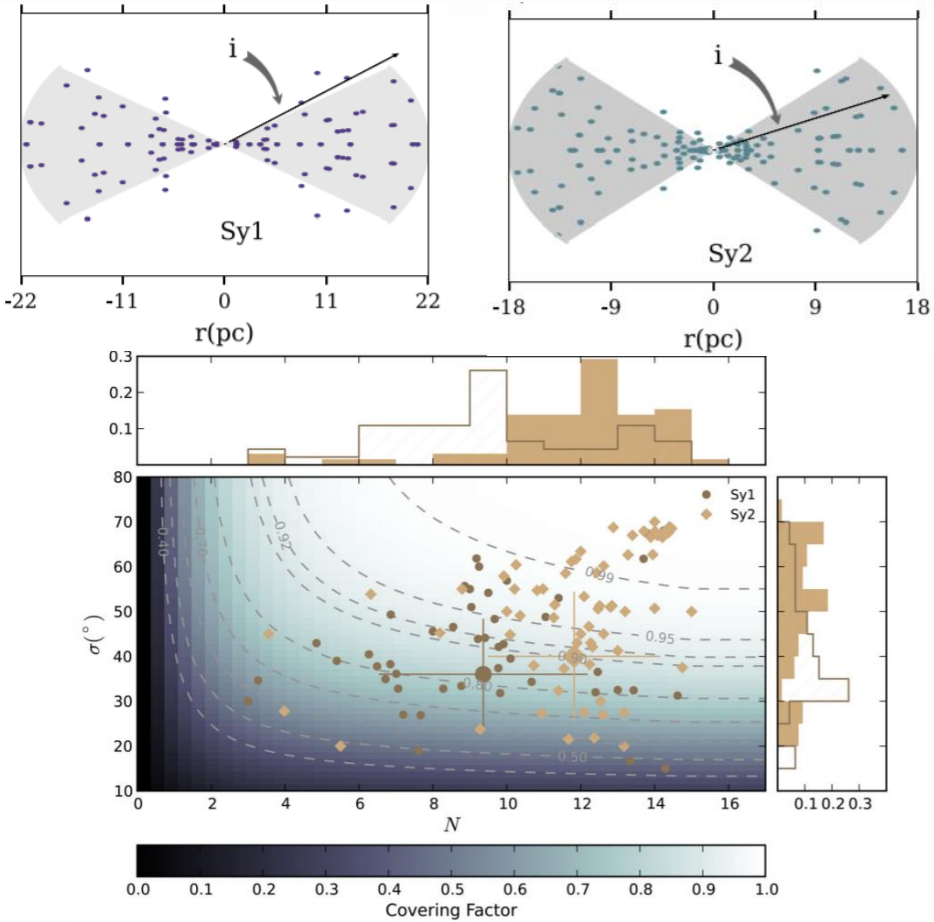
N_0 – clumps along a radial equatorial ray
τ_V – visual optical depth of individual clumps
$Y = R_0/R_d$ – radial torus thickness
r^{-q} - radial distribution power law exponent
σ – torus angular distribution
i - observe view angle

Voit 1992a, Voit 1992b – $N_H \sim 10^{23} cm^{-2}$

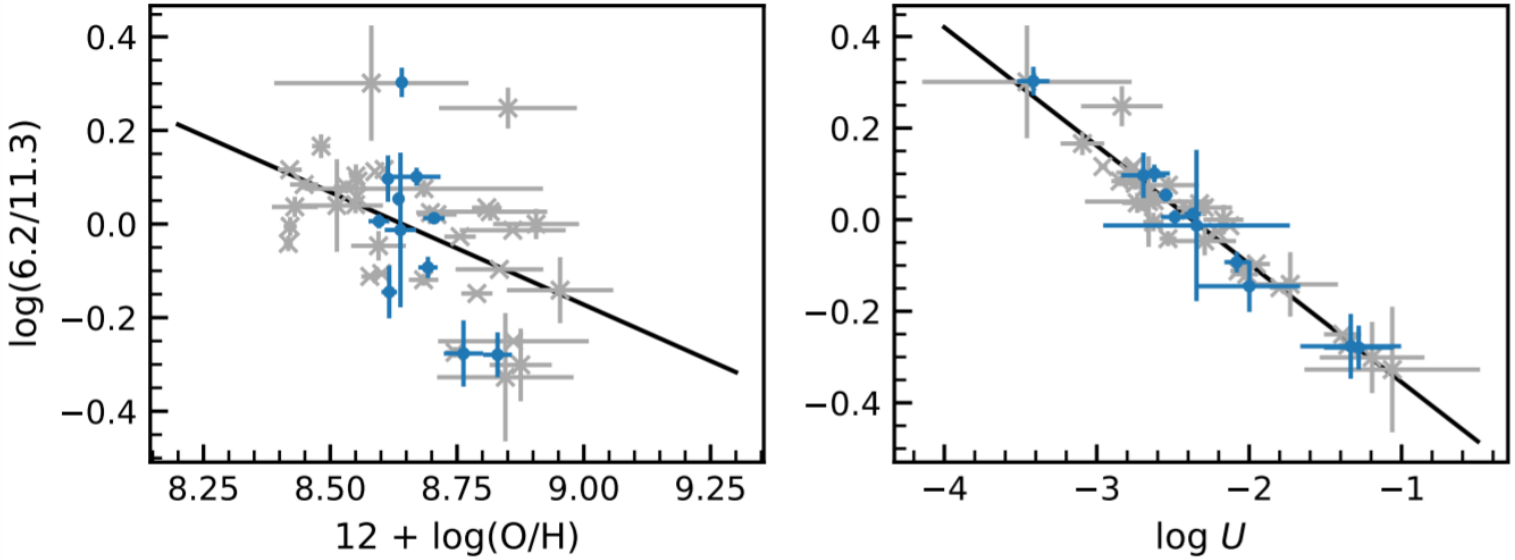
$N_H \sim 1.5 \times 10^{24} cm^{-2}$
$i = 90$, $r^{-1.5}$, $R_0/R_d = 10$, $R_0 = 5pc$

Audibert, Riffel, Sales +2017, MNRAS, 464, 2139





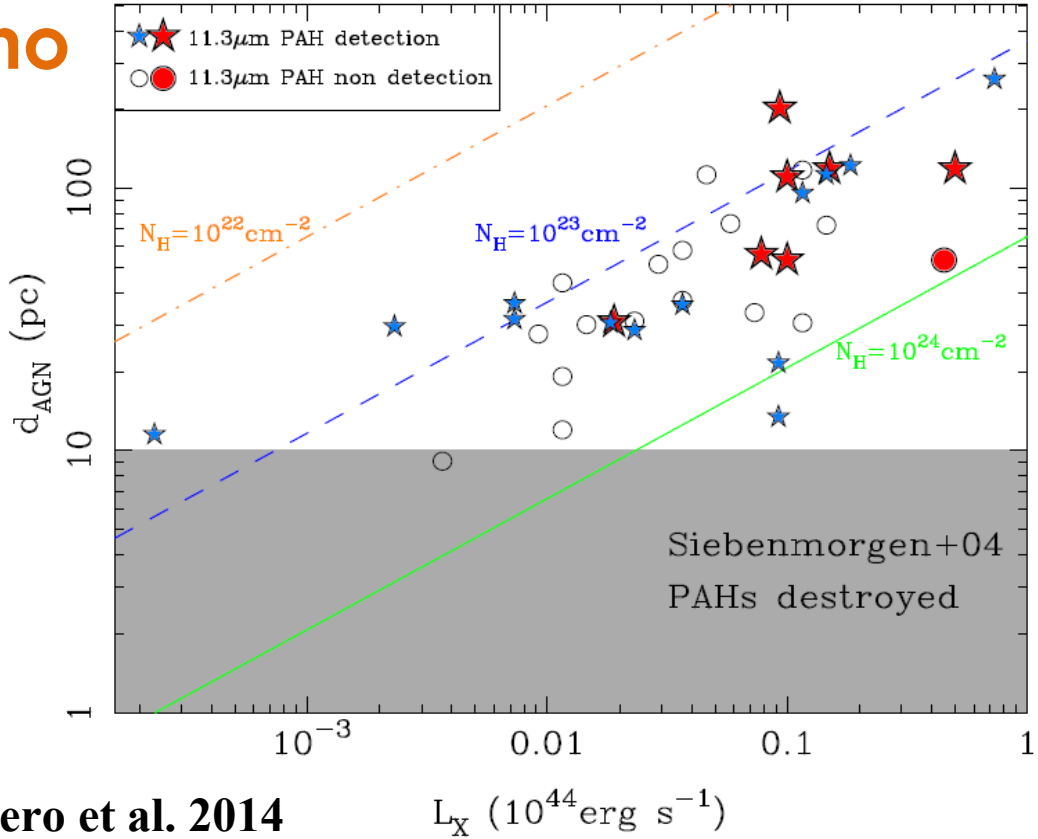
Emissão 11.3μm PAH no centro de AGN



Silva, Krabbe, Canelo, Monteiro, Sales et al. 2021, MNRAS aceito

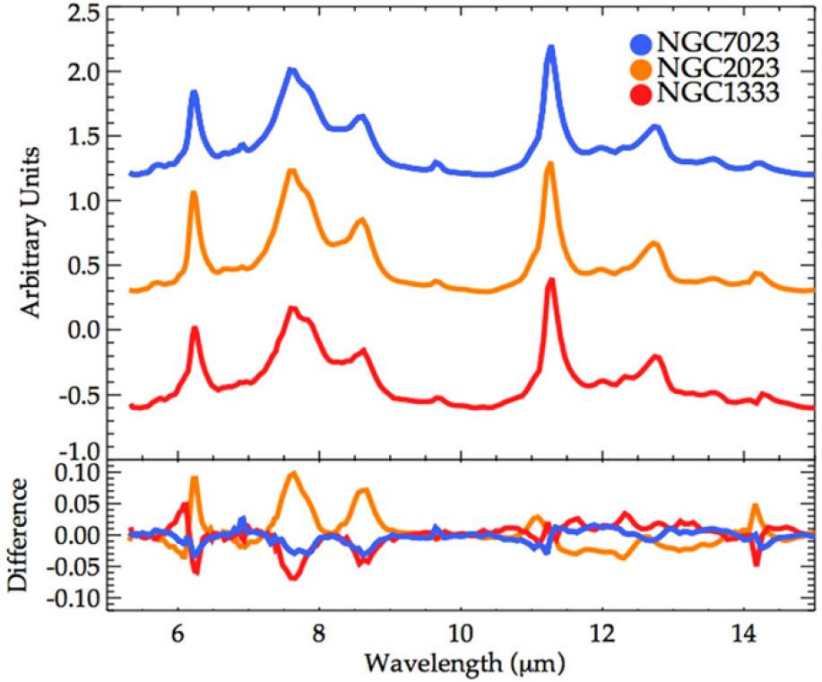
What actually I want to say …
AGN
Torus
Stars
PAHs

Emissão 11.3μm PAH no centro de AGN

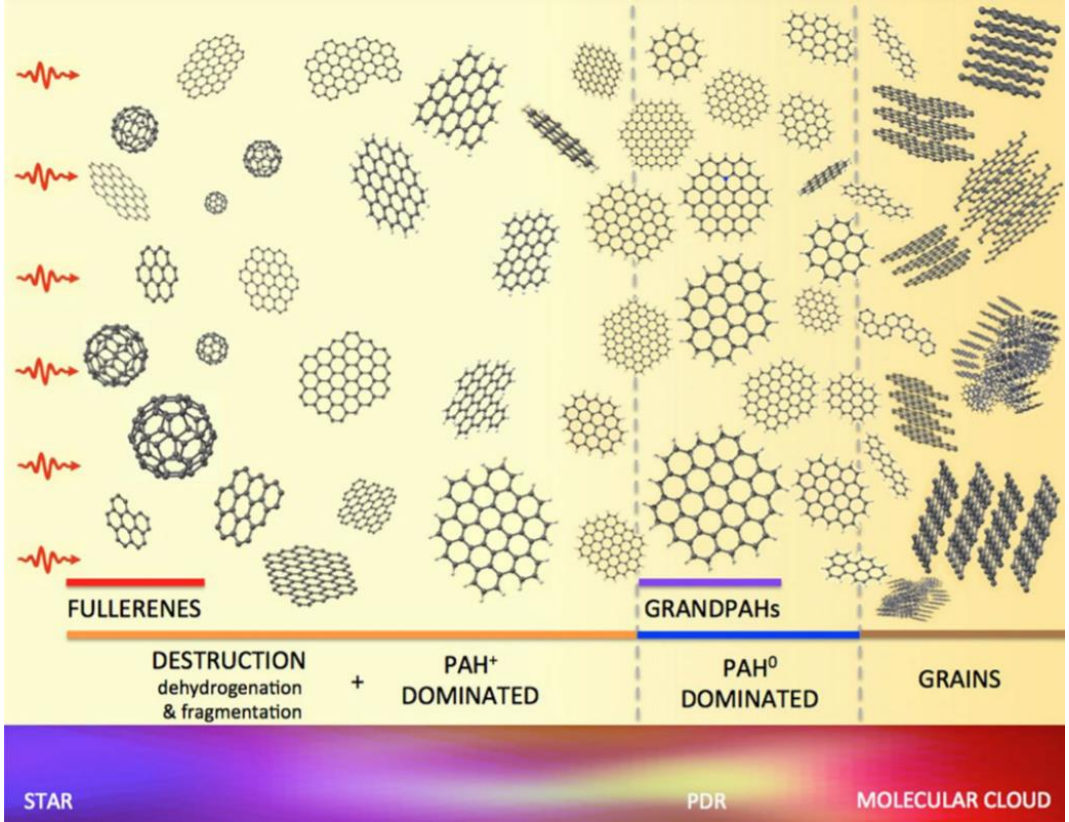


Alonso-Herrero et al. 2014

GrandPAHs – Tielens 2018



Andrews et al. 2015

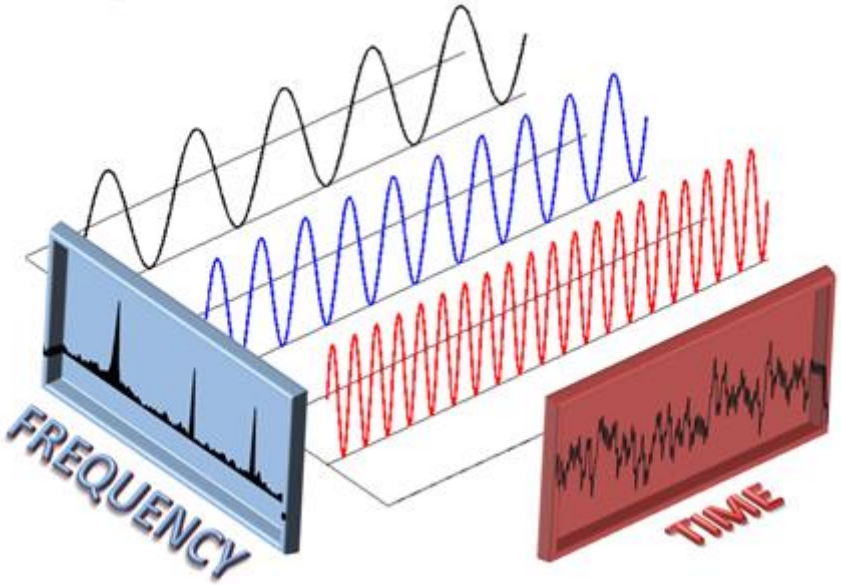


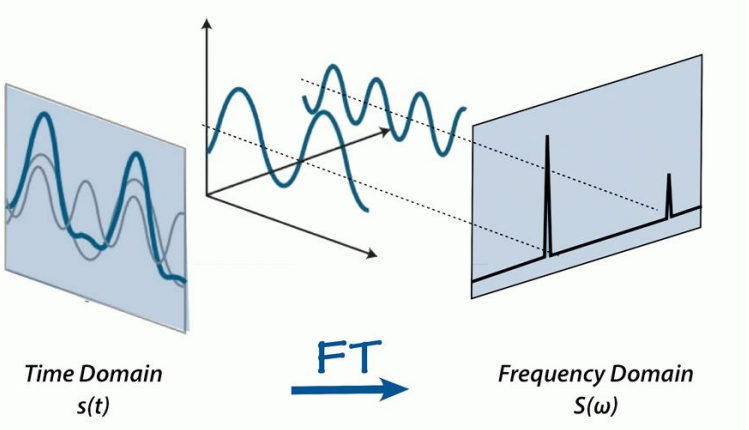
Qual é o maior desafio na decomposição de um sinal???

Pensando em Big Data
Telescópio Espacial James Webb
Grandes telescópios (d=40m, LSST,GMT)

Decomposição de um sinal

Usando Fast Fourier Transform (FFT) | Transformada de Fourier Rápida





Transformada Discreta de Fourier

Receita da frequência = Somar Contribuições para esta frequência, de cada pico no tempo

$$X_k = \sum_{n=0}^{N-1} x_n \cdot e^{-i2\pi kn/N}$$

$$x_n = \frac{1}{N} \sum_{k=0}^{N-1} X_k \cdot e^{i2\pi kn/N}$$

Ponto no tempo = Somar Contribuições para este ponto no tempo, de cada frequência

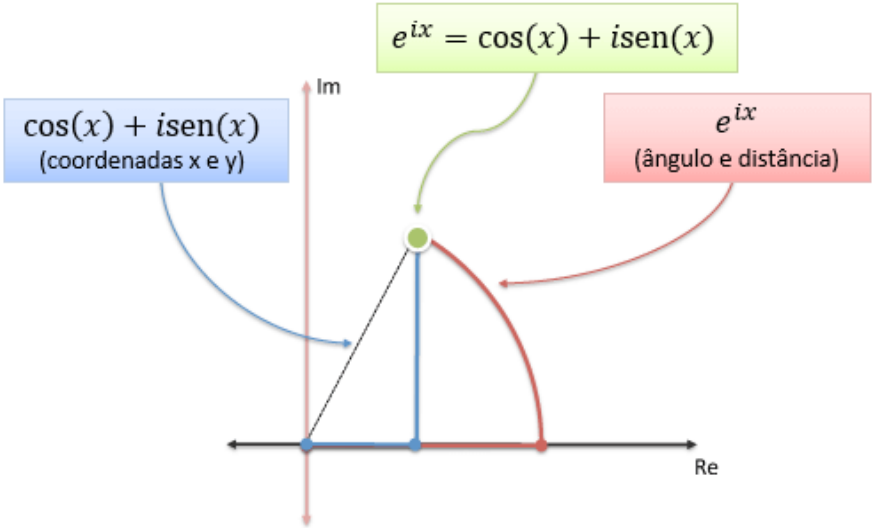
N → número de amostras de tempo que temos.
n → amostra atual que estamos considerando
xn→ valor do sinal de n
k→ frequência
Xk → quantidade da frequência k no sinal (amplitude e fase, um número complexo).

Transformada Discreta de Fourier

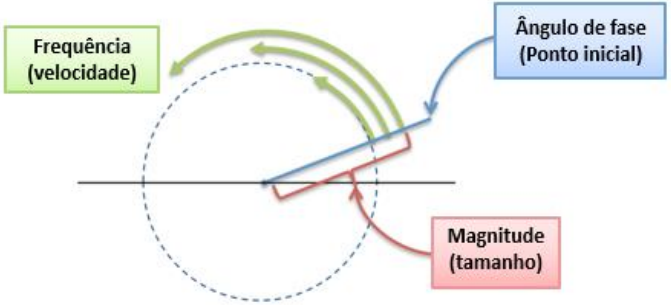
$$X_k = \sum_{n=0}^{N-1} x_n \cdot e^{-i2\pi kn/N}$$

$$x_n = \frac{1}{N} \sum_{n=0}^{N-1} X_k \cdot e^{i2\pi kn/N}$$

Dois Caminhos, Mesmo Resultado



Descrever um Caminho Circular



Transformada Discreta de Fourier

$$X_k = \frac{1}{N}\sum_{n=0}^{N-1} x_n e^{-i2\pi k\frac{n}{N}}$$

Para encontrar a energia em certa frequência, gire o seu sinal ao redor de um círculo naquela frequência, e tome a média de um monte de pontos ao longo do caminho.

Vetor com auto-valores

$$X_k = \sum_{n=0}^{N-1} x_n \cdot e^{-i2\pi kn/N}$$

Vetor com auto-vetores

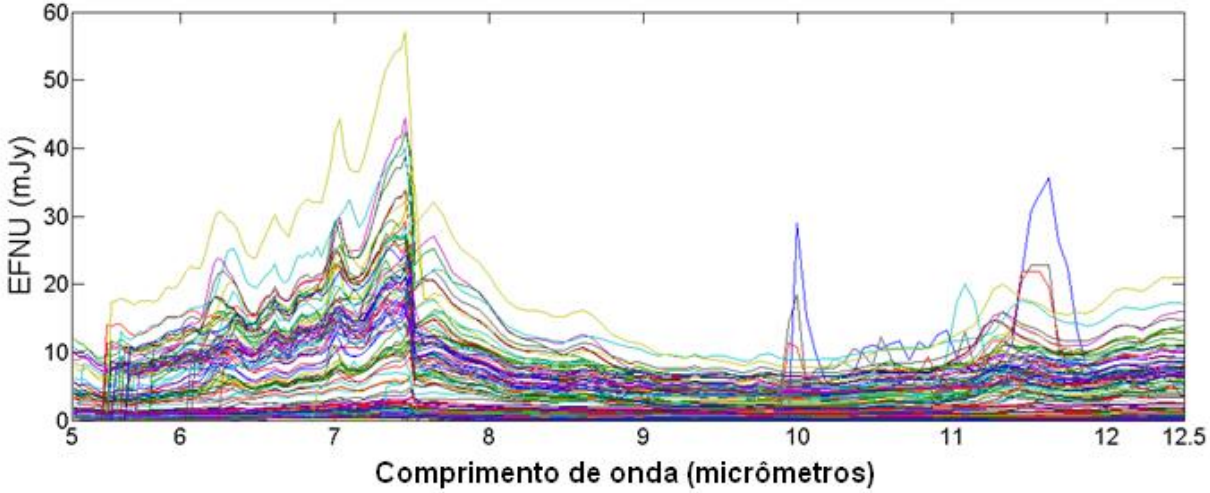
$$x_n = \frac{1}{N} \sum_{n=0}^{N-1} X_k \cdot e^{i2\pi kn/N}$$

Desafio!!!

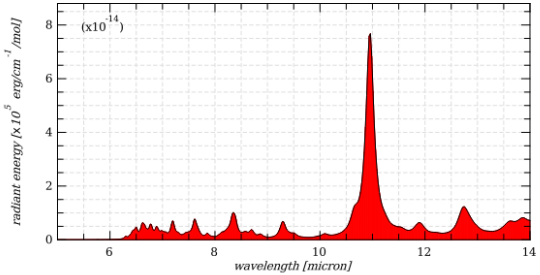
A multiplicação de 2 pontos se comporta como N^2

$10^2 = 100$

Análise química das moléculas de PAHs em Galáxias Starburst (~230 objetos)



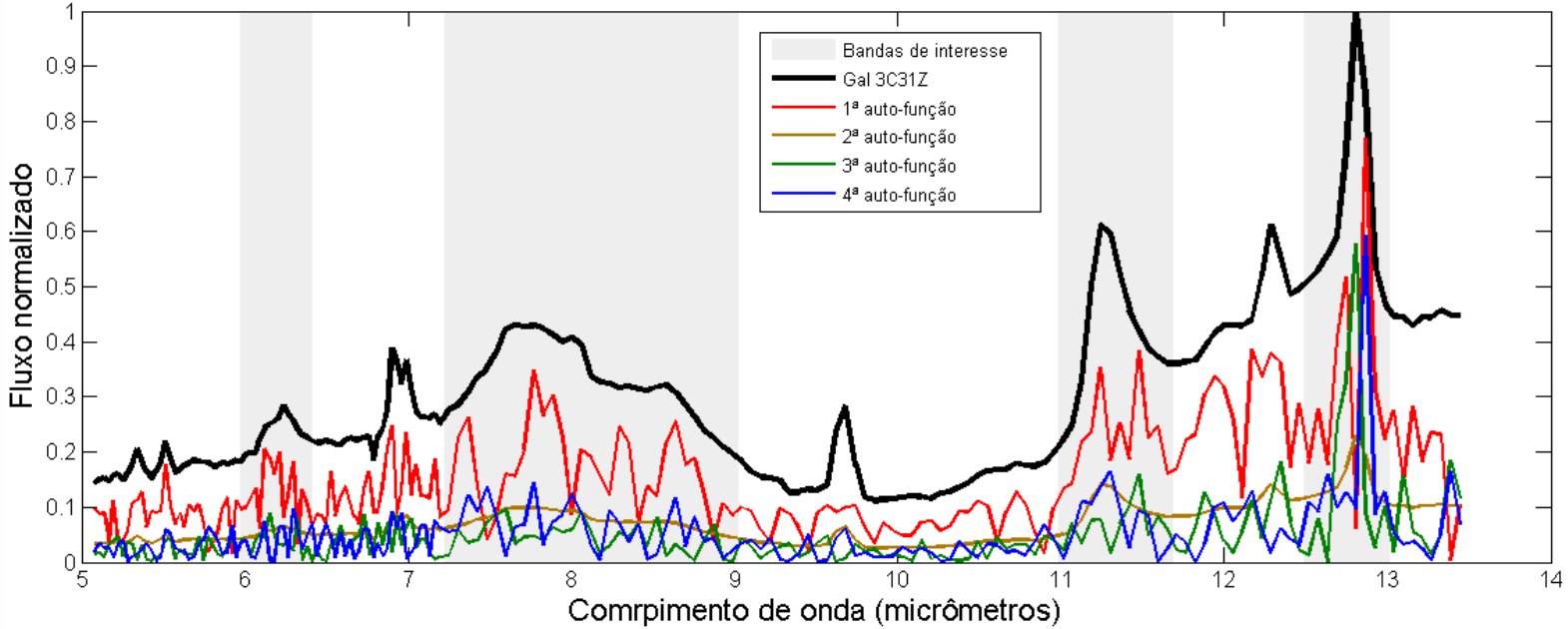
Moléculas teóricas
700 espécies



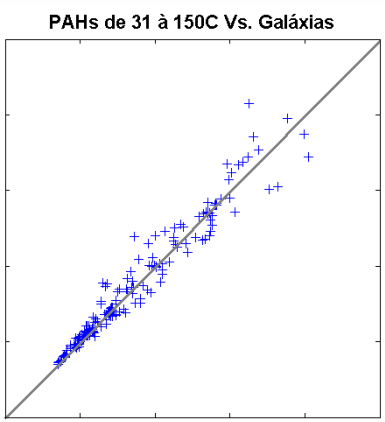
$C_{384}H_{48}$

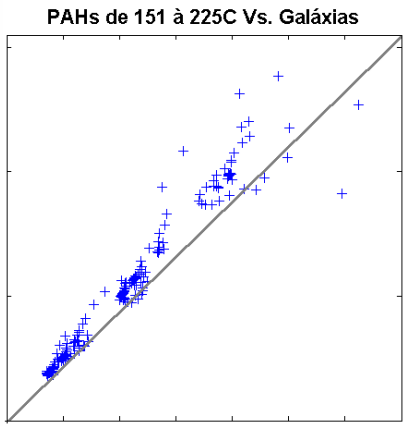
Espinoza, Sales, Canelo e Matoso (2021 in prep.)

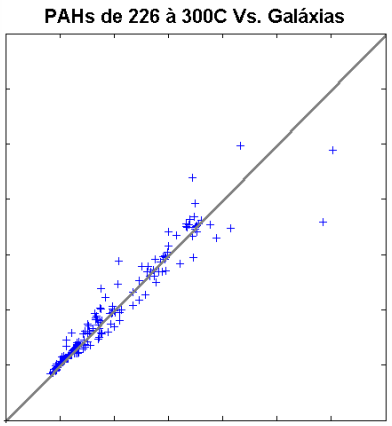
Análise química das moléculas de PAHs em Galáxias Starburst (~230 objetos)

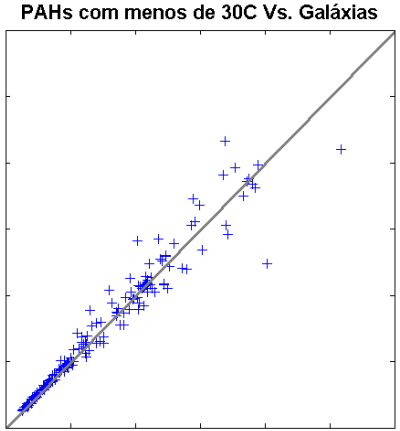


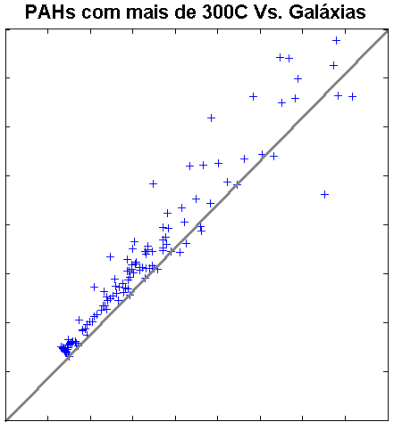
Espinoza, Sales, Canelo e Matoso (2021 in prep.)





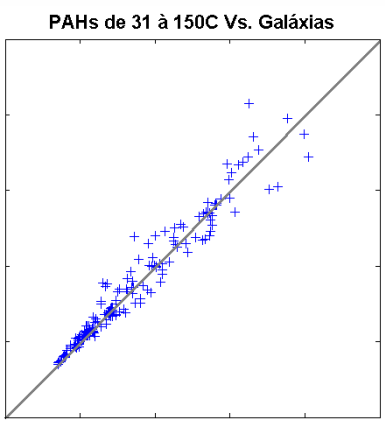


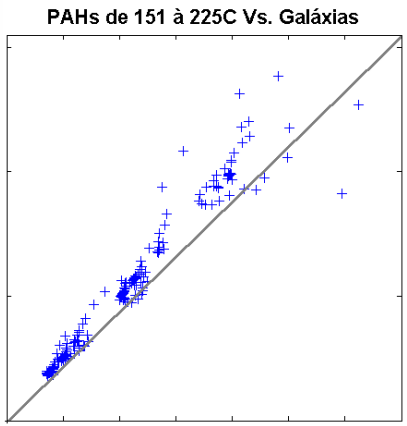


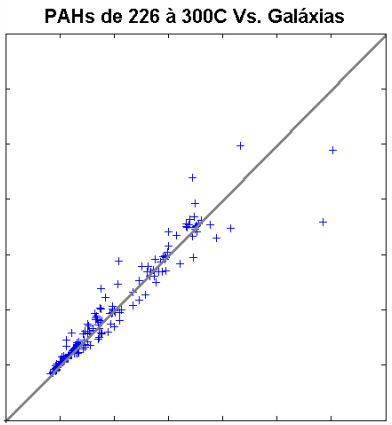


Composição das moléculas de PAHs em Galáxias Starburst (~230 objetos)

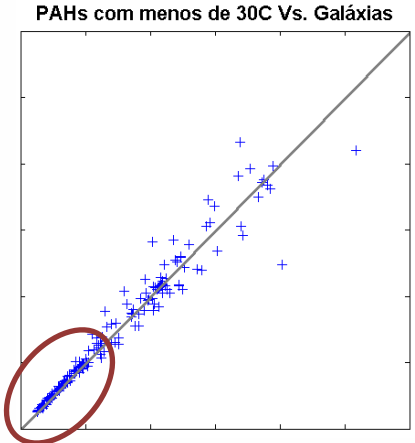
Espinoza, Sales, Canelo e Matoso (2021 in prep.)

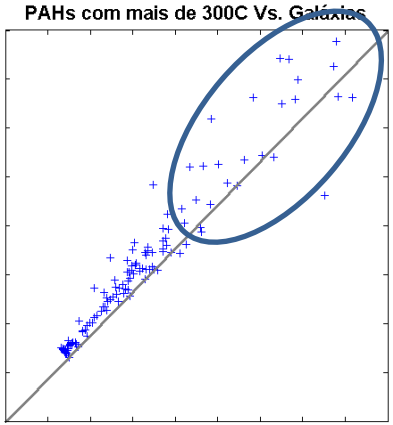






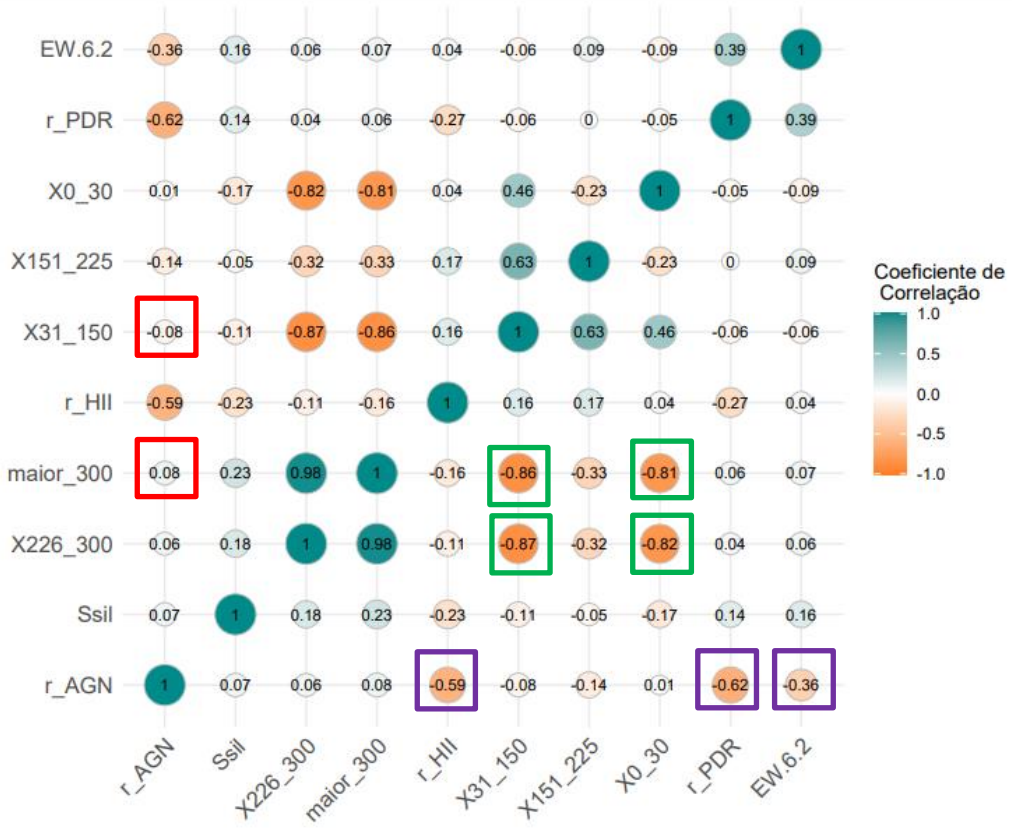
Composição das moléculas de PAHs em Galáxias Starburst (~230 objetos)





- Muitas moléculas pequenas (<30C), mas com pouca contribuição (auto-valor)
- Poucas moléculas grandes (>300C), mas com intensa contribuição (auto-valor)

Espinoza, Sales, Canelo e Matoso (2021 in prep.)



Composição das moléculas de PAHs em Galáxias Starburst (~230 objetos)

- Muitas moléculas pequenas (<30C), mas com pouca contribuição (auto-valor)
- Poucas moléculas grandes (>300C), mas com intensa contribuição (auto-valor)

Espinoza, Sales, Canelo e Matoso (2021 in prep.)

•PAH profile variations - Peeters' classes
(Peeters et al. 2002, 2005)
•
F7.6/F7.8 > 1 → class A
•
*Class A 6.2 μm → PANHs
(Hudgins et al. 2005)
•
Another reservoir of N
(e.g. Canelo 2016)

15264-96559

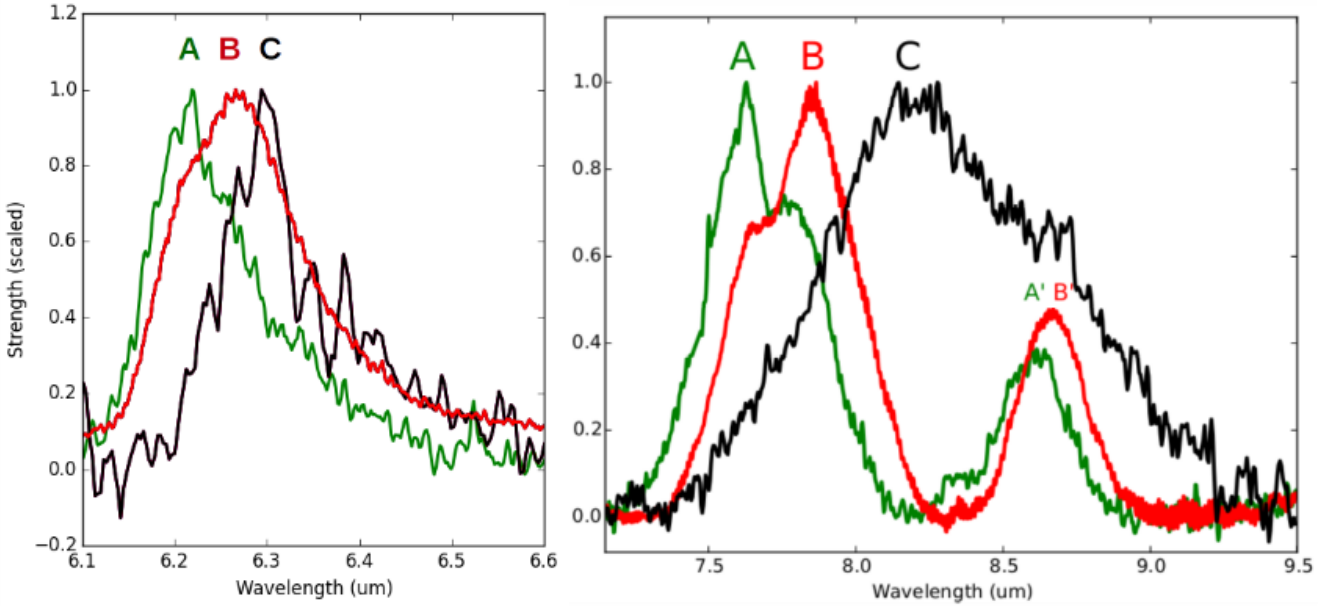
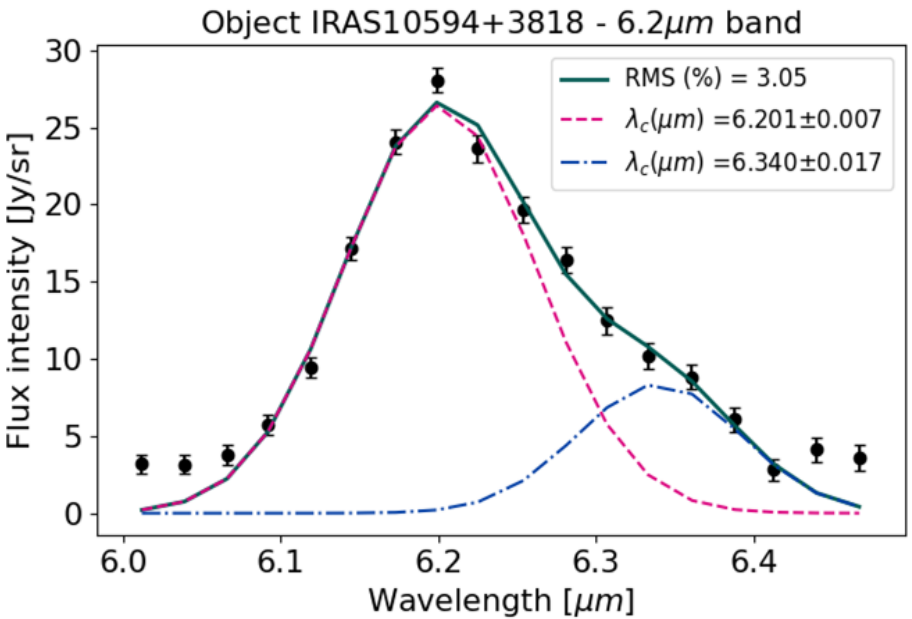
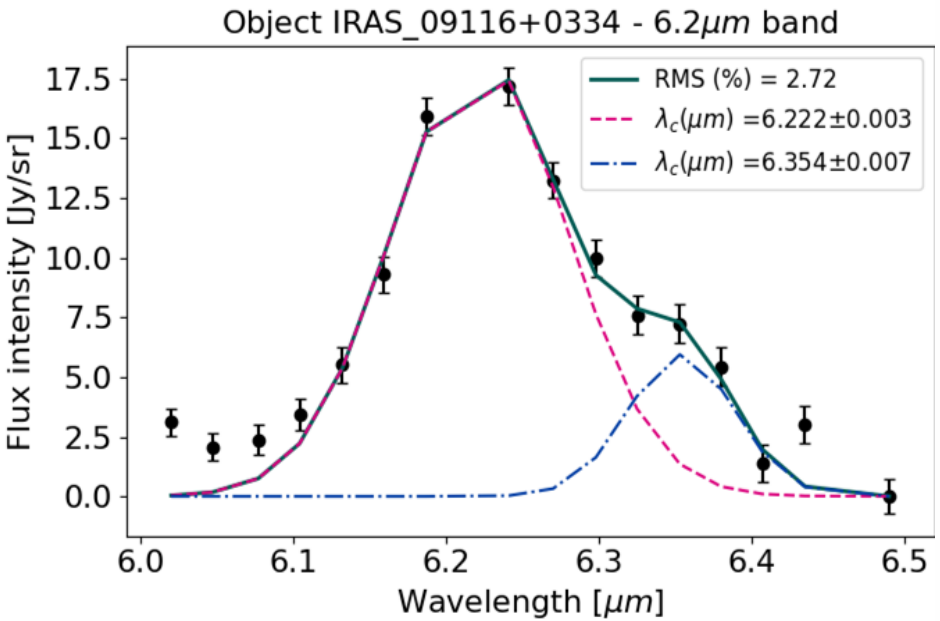


Fig.: Overview of possible variations in the profile of the PAH bands 6.2, 7.7 and 8.6 μm, divided into three classes - A, B and C (Peeters et al., 2002; van Diedenhoven et al., 2004).

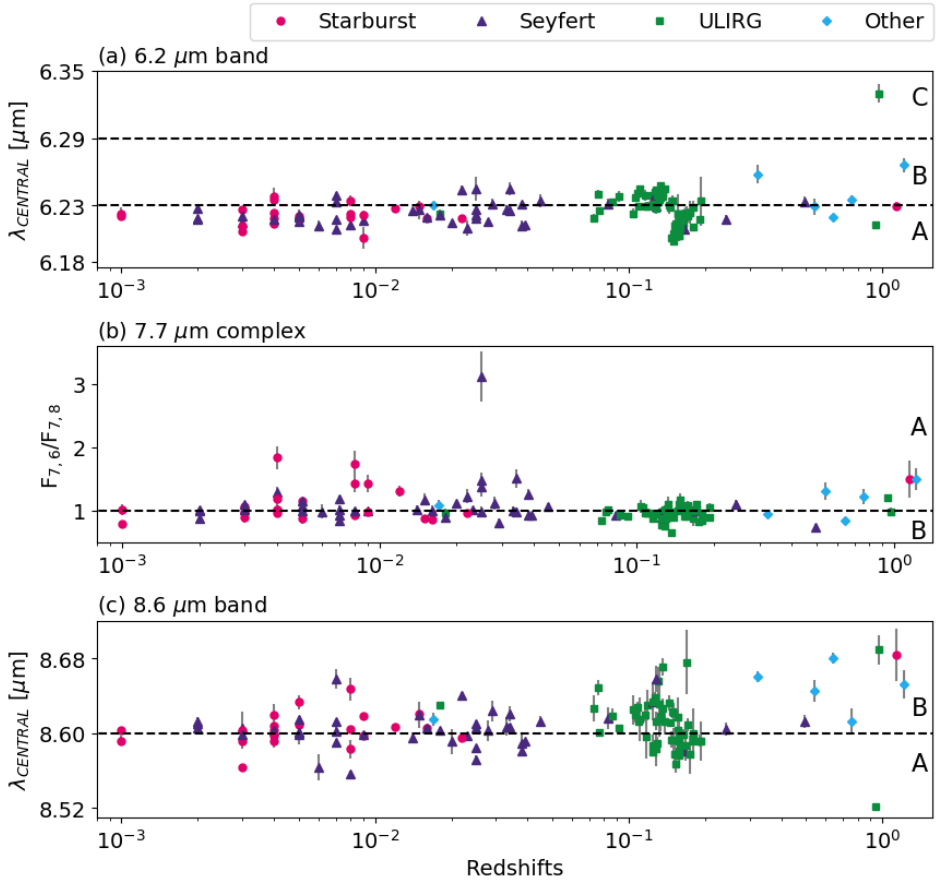
6.2 μm PAH band





- **Or another feature?**

Fig.: Profiles of the 6.2μm band for two sources using two Gaussians (Canelo et al. 2018).



- more class B sources in higher redshifts

- possible PAH evolutionary timescale

(e.g. aromatic evolution in stellar lifecycle, Shannon & Boersma, 2019)

Fig.: Distribution of the PAH bands into Peeters' classes according to the galaxies redshift (Canelo et al. 2018, 2021).

A inovação a partir do [enter]

https://inoventerfurg.wixsite.com/inoventer

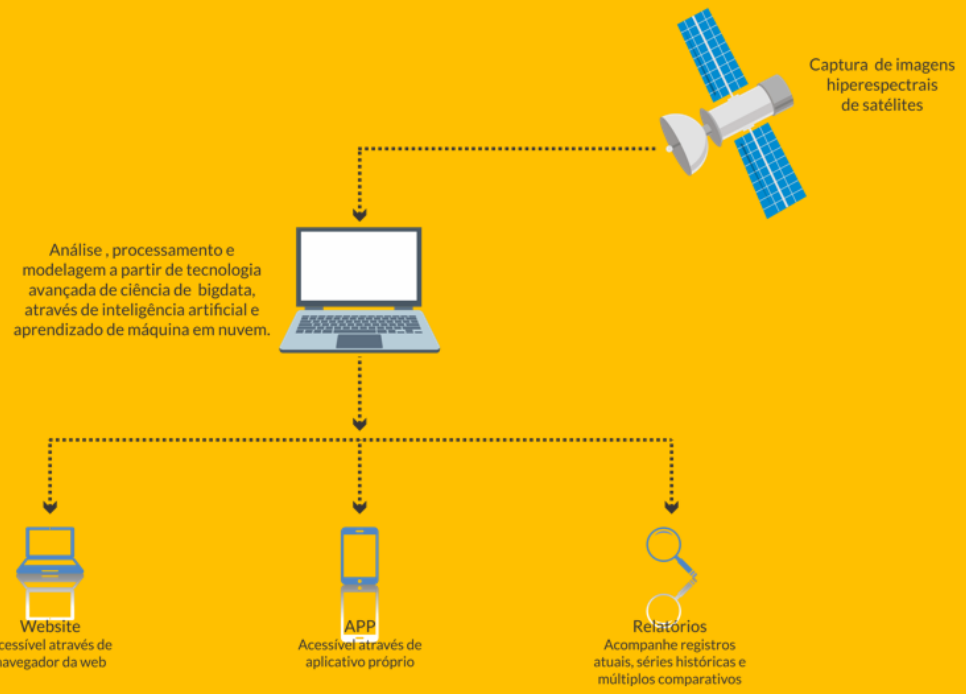
Fanpage @inoventer

Instagram @inoventer.oficial

INOV[ENTER]

A tecnologia dos satélites a serviço a sociedade

Plataforma de Monitoramento Online



Capaz de fornecer informações sobre compostos moleculares através de imagens, gráficos, séries históricas (olhando para o passado e projetando o futuro) e relatórios combinados, como por exemplo:

- *cidade, região, localização específica;*
- *composto desejado;*
- *períodos passados e atuais;*
- *limites permitidos e excedentes, conforme a legislação.*

INOV[ENTER]

Time

Astrofísica
Profa. Dra. Dinalva Aires de Sales

Químico Analítico
Prof. Dr. Ednei Gilberto Primel

Físico-químico
Prof. Dr. Felipe Kessler

Administradora
Daniele Rodrigues Garcia

FURG IMEF INSTITUTO DE MATEMÁTICA, ESTATÍSTICA E FÍSICA | astro ESUL Astronomia no Extremo SUL

Reconhecimento

SBF
SOCIEDADE BRASILEIRA DE FÍSICA

Ganhadora 2020

PRÊMIO Carolina NEMES

FÍSICAS EM INÍCIO DE CARREIRA

Profa. Dra. Dinalva A. Sales
FURG/IMEF

FURG IMEF INSTITUTO DE MATEMÁTICA, ESTATÍSTICA E FÍSICA | astroESUL Astronomia no Extremo SUL

Parceiros(as) do astroESUL

PESQUISADORES:

Dr. Alan Alves Brito - UFRGS | Porto Alegre/RS | Brasil
Dr. Alberto Rodríguez Ardila - LNA | Itajubá/MG | Brasil
Dr. Amâncio Friaça - USP | São Paulo/SP | Brasil
Dr. Andrew Robinson - RIT | Rochester/NY | USA
Dr. Chris O'Dea - University of Manitoba | Winnipeg | CA
Dr. Daniel Silveira - FURG | Rio Grande/RS | Brasil
MSc. Eliane Cappelletto - FURG | Rio Grande/RS | Brasil
Dr. Felipe Kessler - FURG | Rio Grande/RS | Brasil
Dra. Hekatelyne Carpes - UFSM | Santa Maria/RS | Brasil
Dr. Jack Gallimore - Bucknell University | Lewisburg/PA | USA
Dr. Jacques Lepine - USP | São Paulo/SP | Brasil
Dr. Juliano Vicenti - FURG | Rio Grande/RS | Brasil
Dr. Luis Colina Robledo - CAB | Madrid | ES
Dra. Miriani Pastoriza - UFRGS | Porto Alegre/RS | Brasil
Dra. Preeti Kharb - IIAP | Bangalore | Índia
Dra. Rafaele Araújo - FURG | Rio Grande/RS | Brasil
Dr. Rogemar Riffel - UFSM | Santa Maria/RS | Brasil
Dra. Stefi Baum - University of Manitoba | Winnipeg | CA
Dra. Thaisa Storchi Bergmann - UFRGS | Porto Alegre/RS | Brasil
Dr. Valmir Heckler - FURG | Rio Grande/RS | Brasil

ALUNOS DE GRADUAÇÃO:

Ana Beatriz Minari - FURG | Rio Grande/RS | Brasil
Bruna Apolinario Dias | Rio Grande/RS | Brasil
Caroline Vanessa Bauman Bertti | Rio Grande/RS | Brasil
Cristian Debortolli | Rio Grande/RS | Brasil
Gabriela Garcia | Rio Grande/RS | Brasil
Henrique Domingues Hirsch | Rio Grande/RS | Brasil
Jonathan Alves dos Santos | Rio Grande/RS | Brasil
Juliana Flores da Silva | Rio Grande/RS | Brasil
Lucas Gregolon - FURG | Rio Grande/RS | Brasil
Priscila Coelho - FURG | Rio Grande/RS | Brasil
Victor Orsi Fadel | Rio Grande/RS | Brasil
Vitor das Neves Avelaneda | Rio Grande/RS | Brasil
Wesley Alberto de Farias | Rio Grande/RS | Brasil

ALUNOS DE MESTRADO:

Dr. Jean Marcel Espinoza - FURG | Rio Grande/RS | Brasil
Wallas Silva - FURG | Rio Grande/RS | Brasil
Lara Gatto - FURG | Rio Grande/RS | Brasil
Brenda Matoso - FURG | Rio Grande/RS | Brasil

ALUNOS DE DOUTORADO:

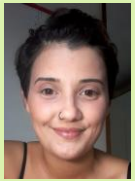
MSc. Carla Canelo - USP | São Paulo/SP | Brasil
Msc. Willian Rubira - FURG | Rio Grande/RS | Brasil

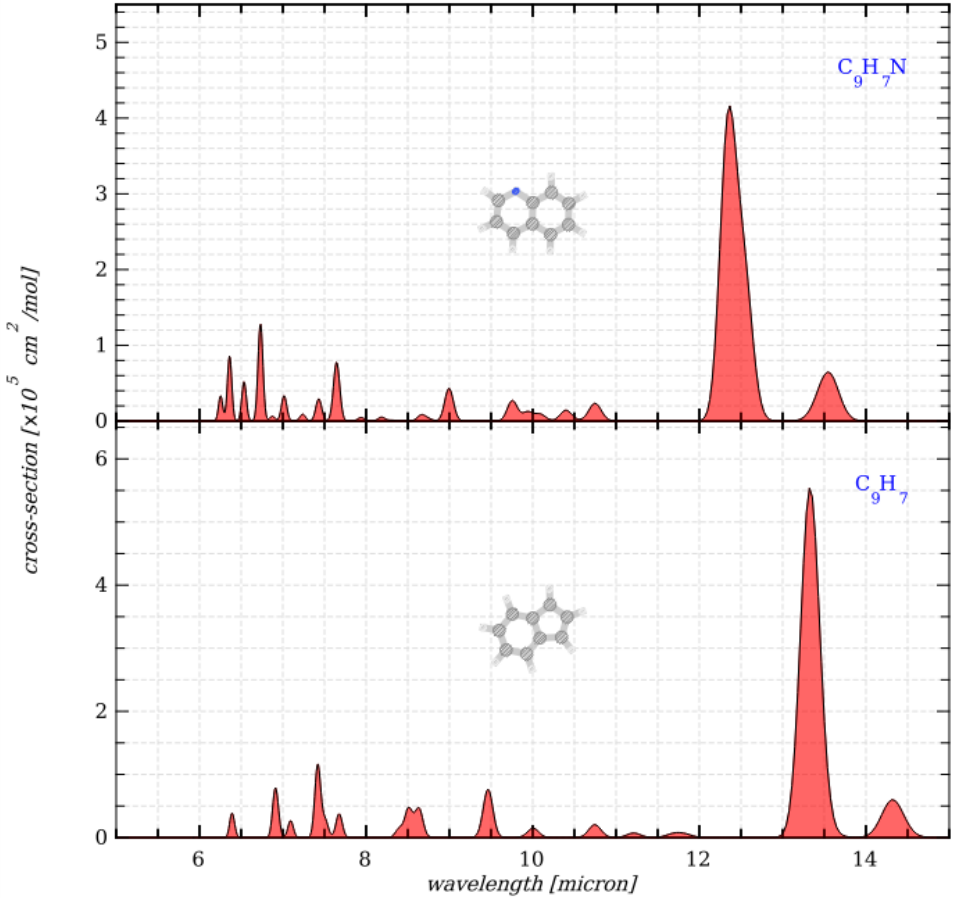
CONSULTORA ORGANIZACIONAL DO PROGRAMA:

Adm. Daniele Garcia - FURG | Rio Grande/RS | Brasil

FURG IMEF INSTITUTO DE MATEMÁTICA, ESTATÍSTICA E FÍSICA

astro ESUL Astronomia no Extremo SUL




C_9H_7N
C_9H_7
cross-section [x10^5 cm^2/mol]
wavelength [micron]
0
1
2
3
4
5
6
8
10
12
14

Qual é o maior desafio na decomposição de um sinal???

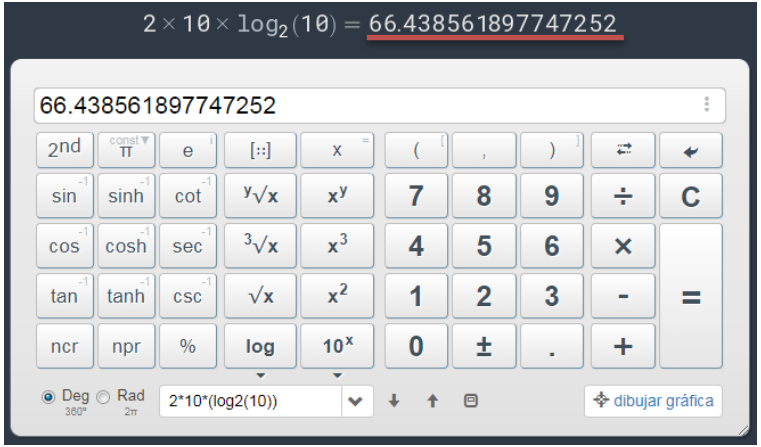
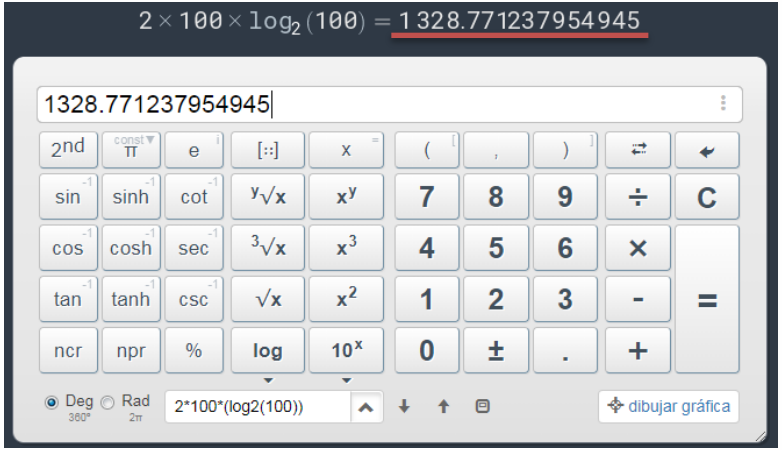
Pensando em Big Data
Telescópio Espacial James Webb
Grandes telescópios (d=40m, LSST,GMT)

Decomposição de um sinal

Usando Fast Fourier Transform (FFT) | Transformada de Fourier Rápida

A interpolação de 2 pontos se comporta como N^2 Cooley & Tukey (1965) soluciona como $2N \log_2(N)$

$10^2 = 100$



$100^2 = 10.000$