TRACING LOW-MASS PROTOSTARS' PROPERTIES WITH IRAM 30M SUBMILLIMETER TELESCOPE

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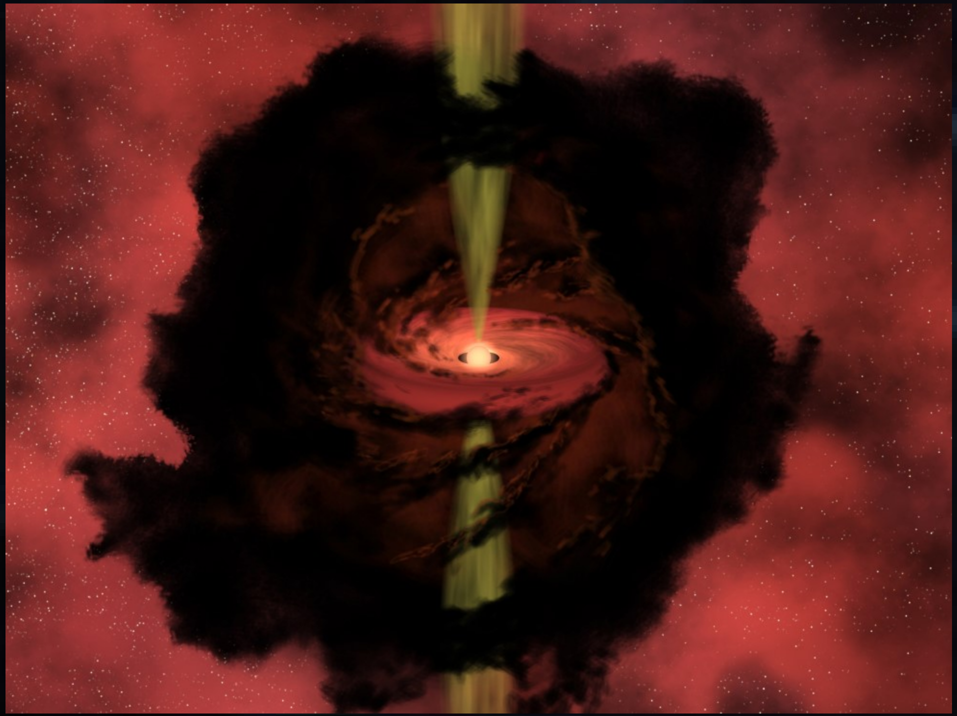
Protostars

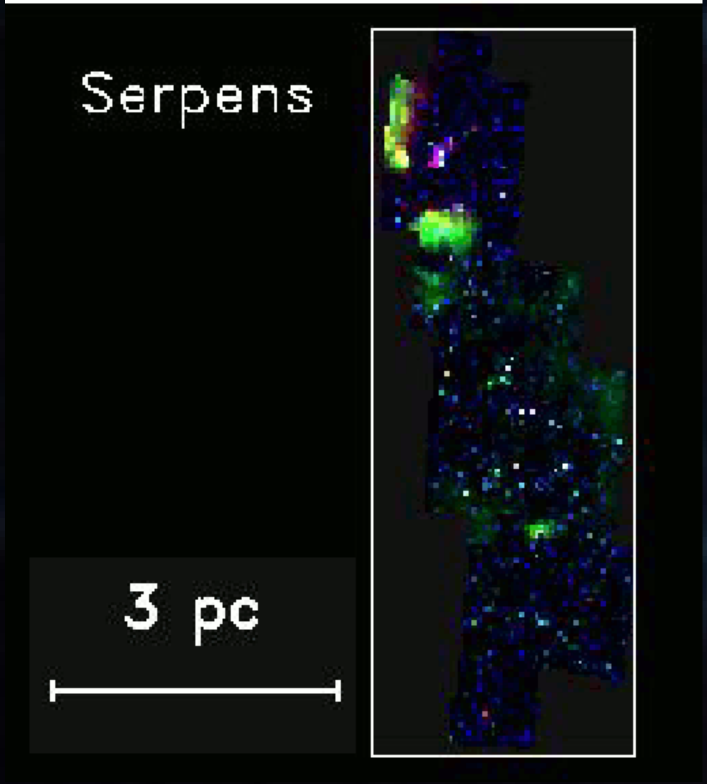


A protostar inside a Bok globule (*Artist's image*). Credit: NASA

- Deep embedded
- Bok globule
- Molecular outflows

Protostars are invisible for our eyes
They cannot be studied by direct, optical observations

STARFORMING REGION



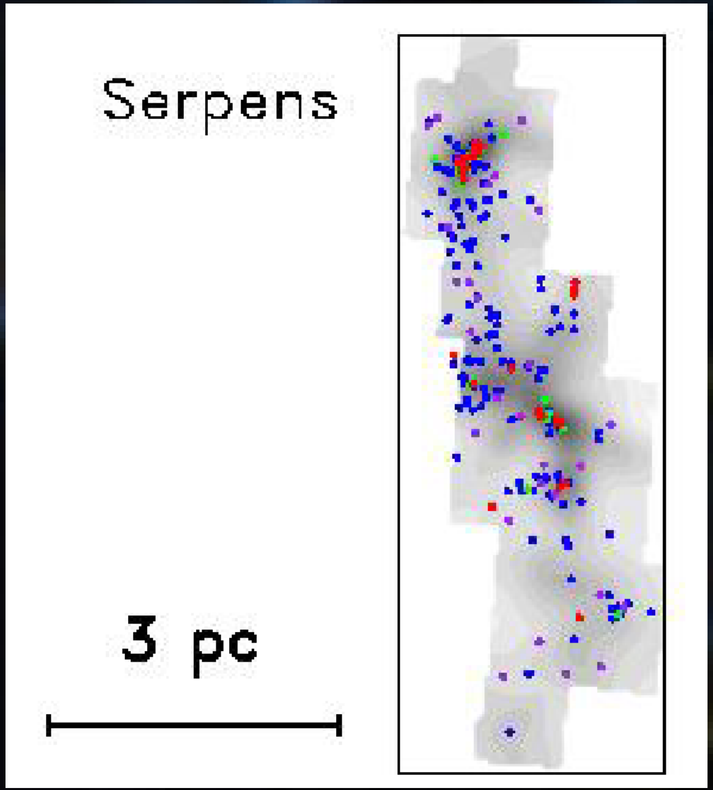
Spitzer: blue (4.5 µm), green (8.0 µm), red (24 µm)

Evans et al. 2009:

- 262 YSO
- SFR: 57 M⊙/Myr
- Mass: 2016 M⊙

Distance: 436 ± 9 pc

(Ortiz-León et al. 2018)



YSOs: red (Class I), green (Flat), blue (Class II), Purple (Class III)

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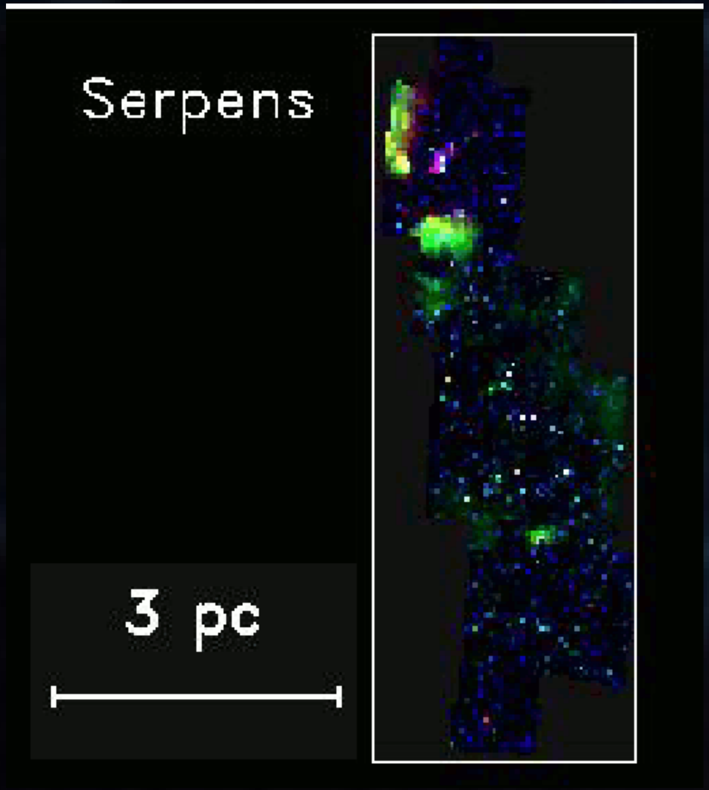

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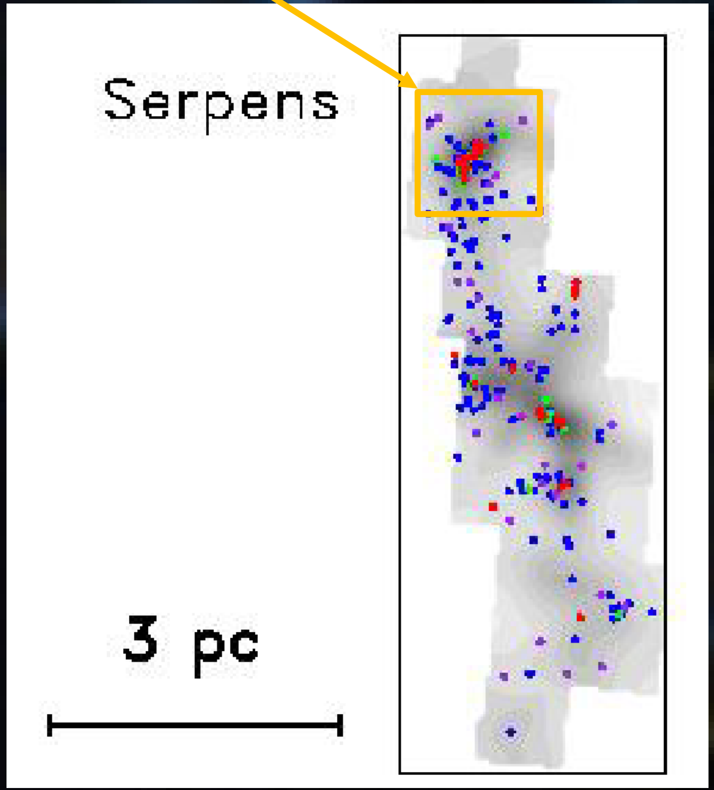

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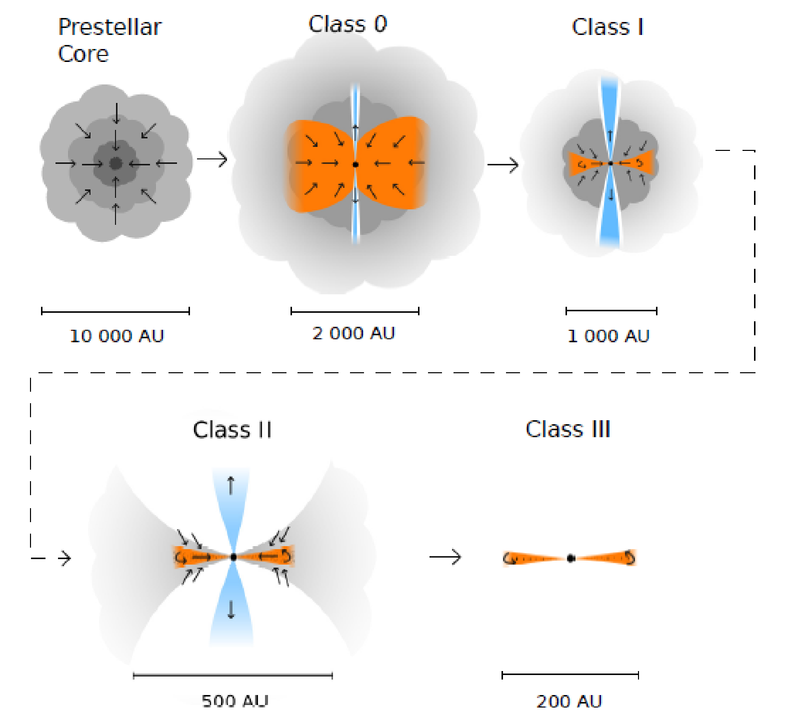
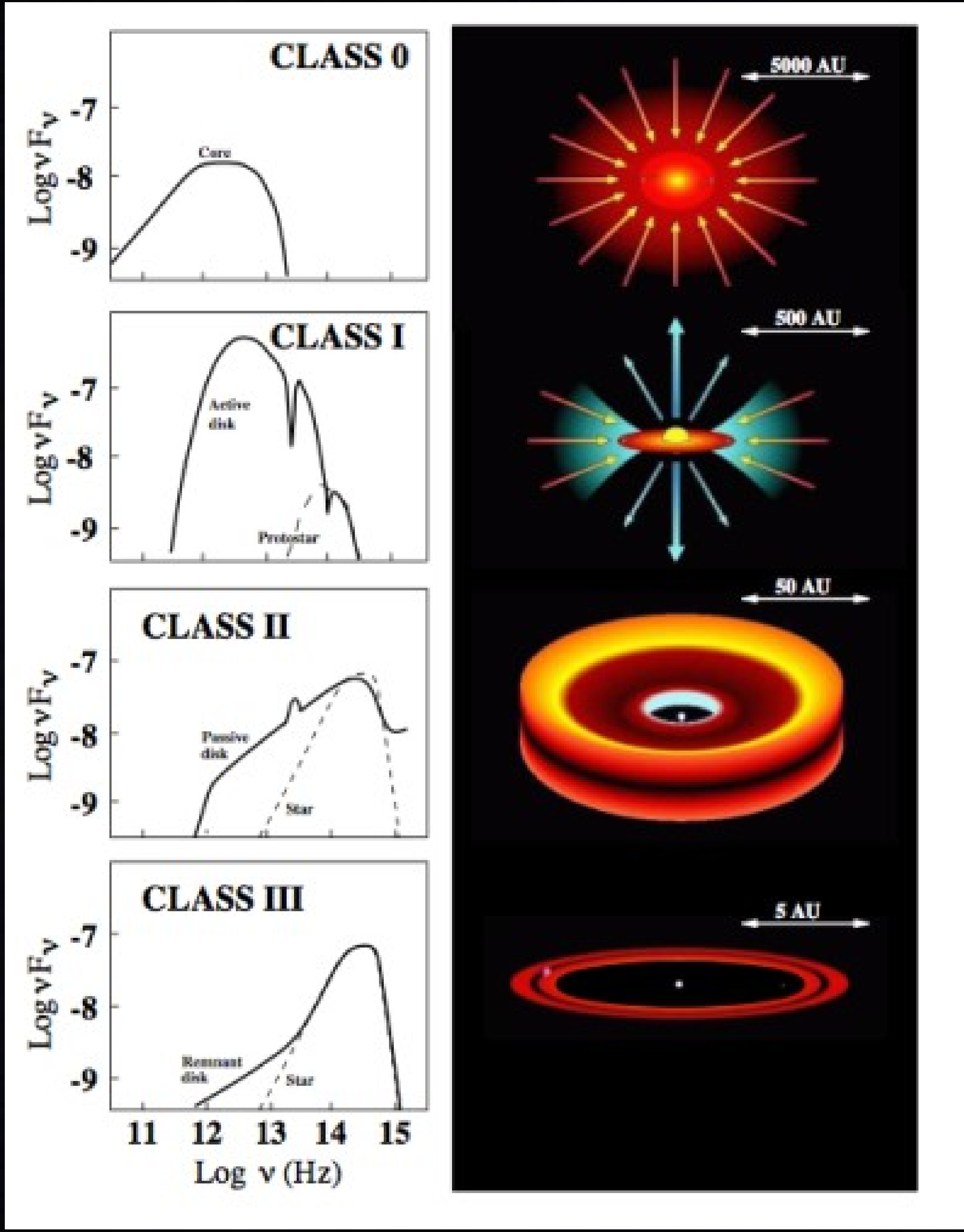
Protostars classification

$$T_{bol}: \xrightarrow{\text{Class 0}} 70\ K \xrightarrow{\text{Class I}} 650\ K \xrightarrow{\text{Class II}} 2800\ K \xrightarrow{\text{Class III}}$$



SED analysis is the best method to distinguish YSOs' evolution stage.



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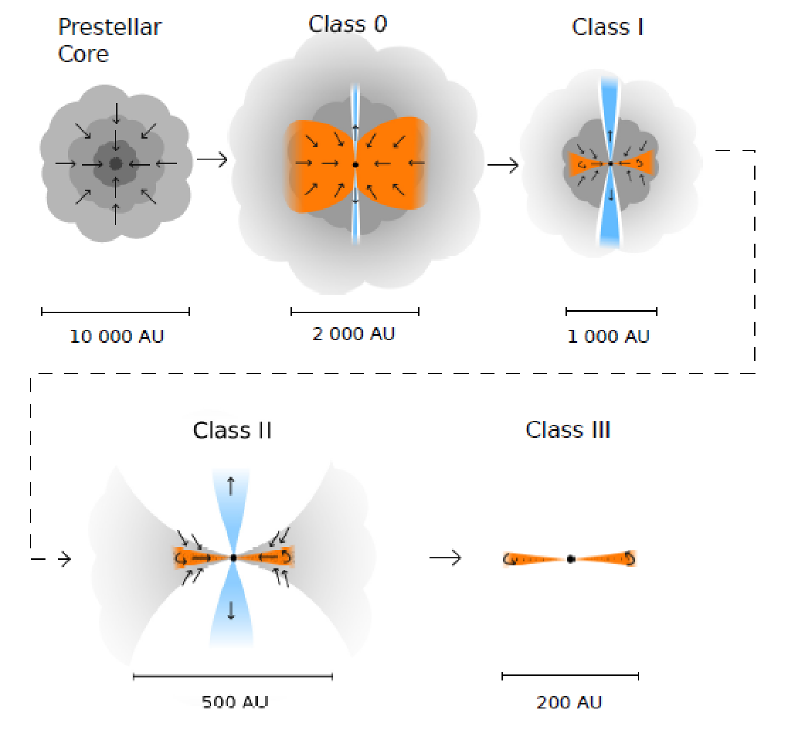
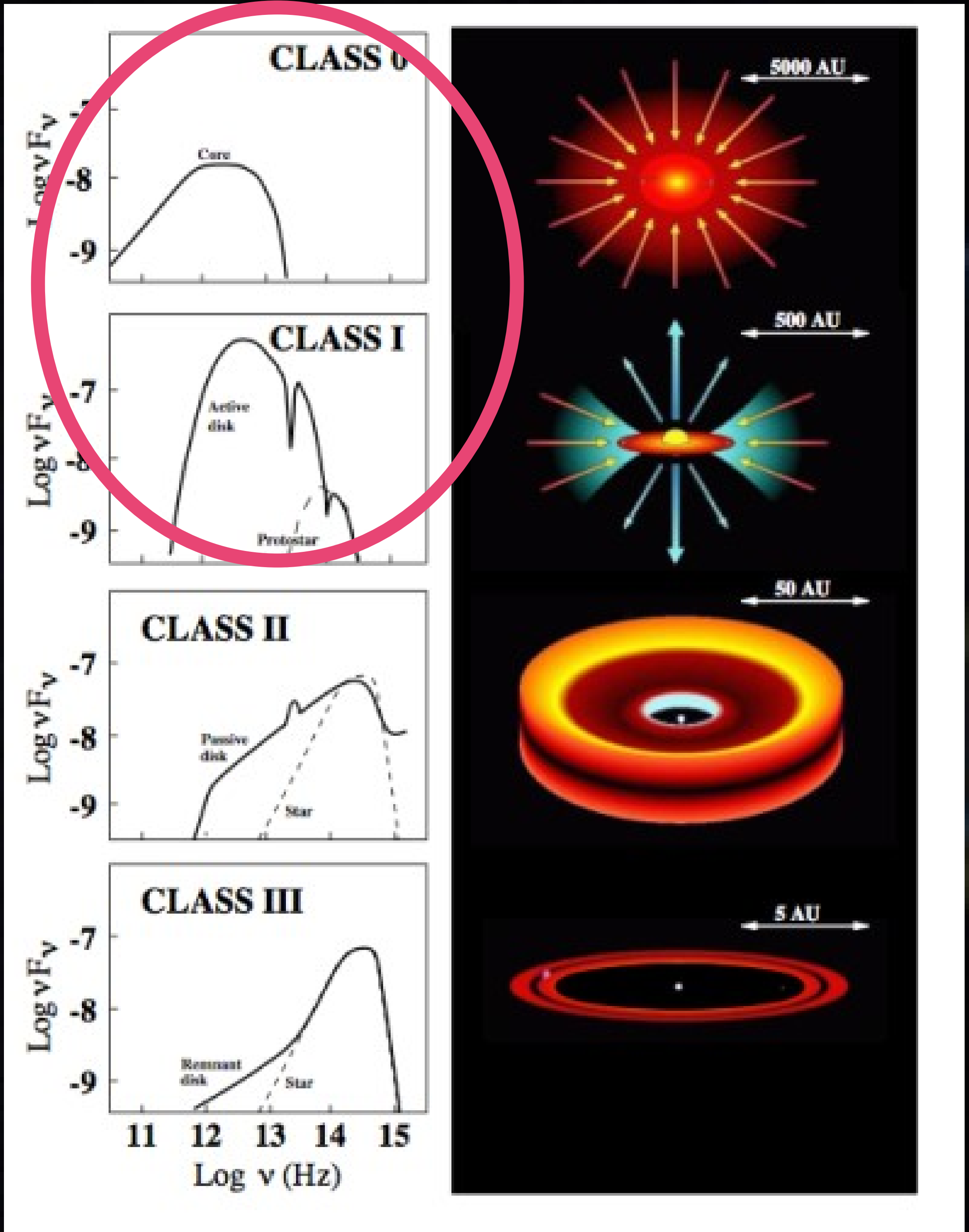




SED analysis is the best method to distinguish YSOs' evolution stage.

PHOTOMETRY - SEDS

Sbmm source	T_{bol} (K)	L_{bol} ($L_\odot$)	Class
SMM9	46.14	11.69	Early Class 0
SMM1	40.35	108.72	Early Class 0
SMM5	148.24	4.49	Early Class I
SMM10	85.09	5.13	Late Class 0
SMM4	29.54	13.6	Early Class 0
SMM6	526.44	43.39	Late Class I
SMM12	100.87	6.68	Early Class I
SMM3	42.39	27.49	Early Class 0
SMM2	41.6	5.1	Early Class 0
SMM8		0.068[a]	

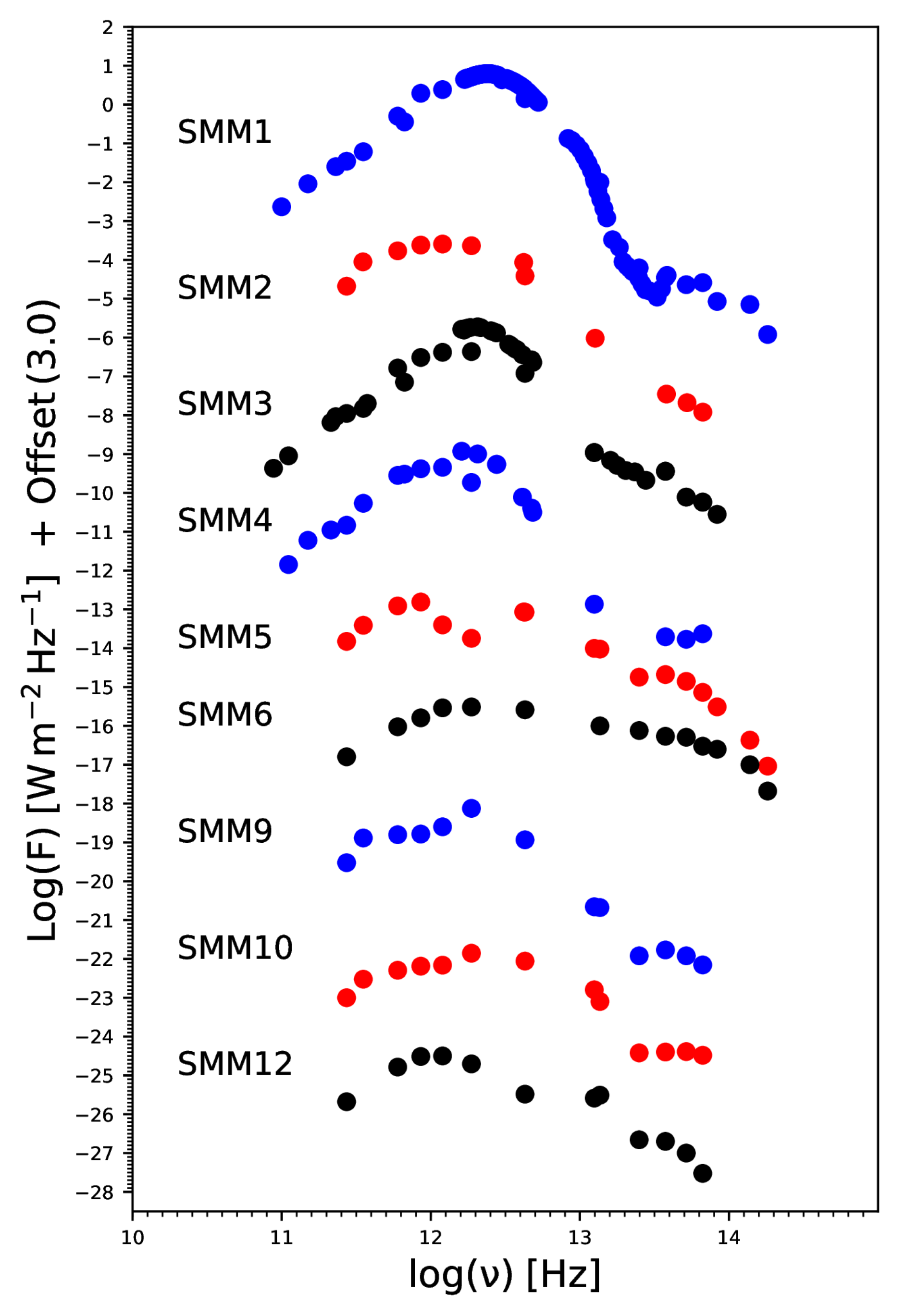
Myers & Ladd 1993

$$L_{bol} = \pi d^2 \int F_\nu d\nu$$

$$T_{bol} = 1.25\,10^{-11}\,\bar{\nu}$$

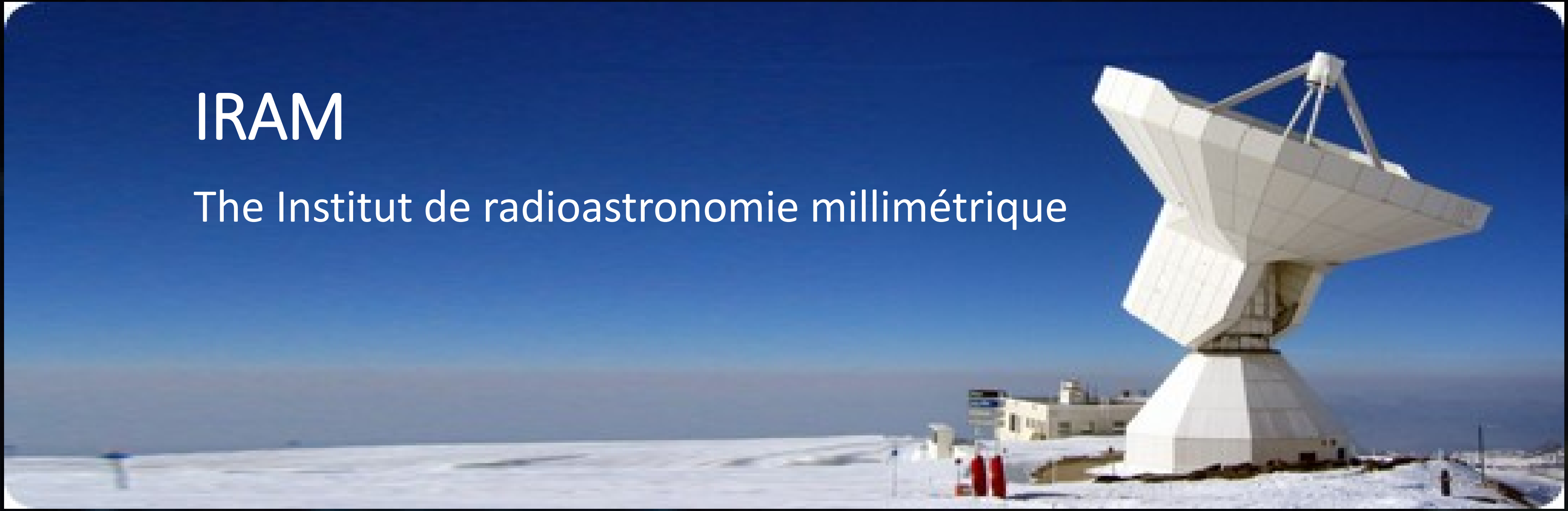
$$\bar{\nu} = \frac{\int \nu F_\nu d\nu}{\int F_\nu d\nu}$$

Protostars can be classified based on SED analysis



IRAM

The Institut de radioastronomie millimétrique



- submillimeter wavelengths: 70 – 350 GHz
- 30 m single-dish radio telescope located on Pico Veleta (2850 m)
- high altitude to reduce the absorption by water vapor
- EMIR receiver: high spectra resolution, broad bands

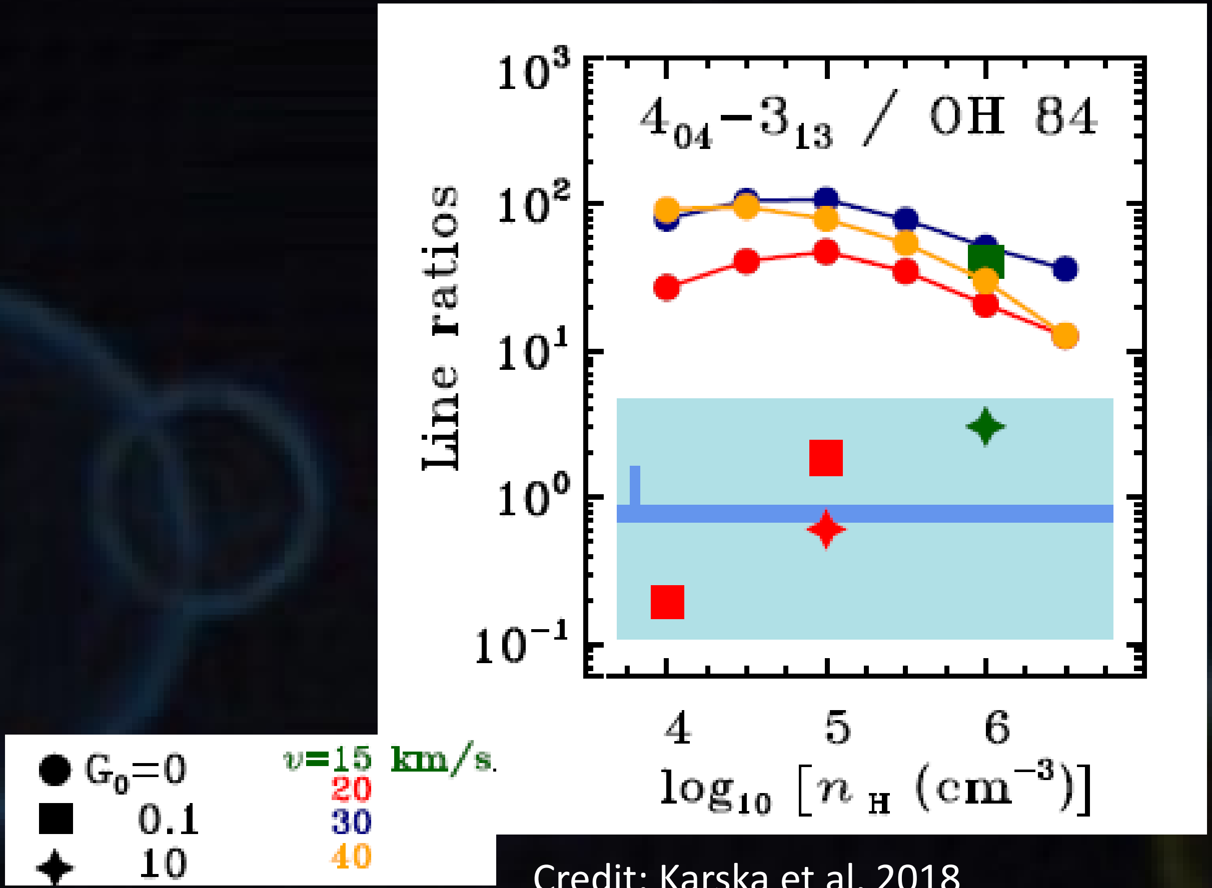
Serpens
CN 1-0
HCN 1-0
CS 3-2
$C^{34}S$ 3-2
$H^{13}CN$ 2-1
$H^{13}CN$ 1-0

Aim

Previous studies problem:

too low H_2O abundances than expected -> photodissociation

mapping CN / HCN at large scales



Credit: Karska et al. 2018

H_2O $4_{04}-3_{13}$ / OH 84µm

Pre-shock densities and velocities

Obsevations: median and standard deviation

Models: Kaufman & Neufeld 1996, Melnick & Kaufman, 2015

AIM

Quantify the strength and spatial extent of UV fields in the surroundings of low-mass protostars

CN/HCN

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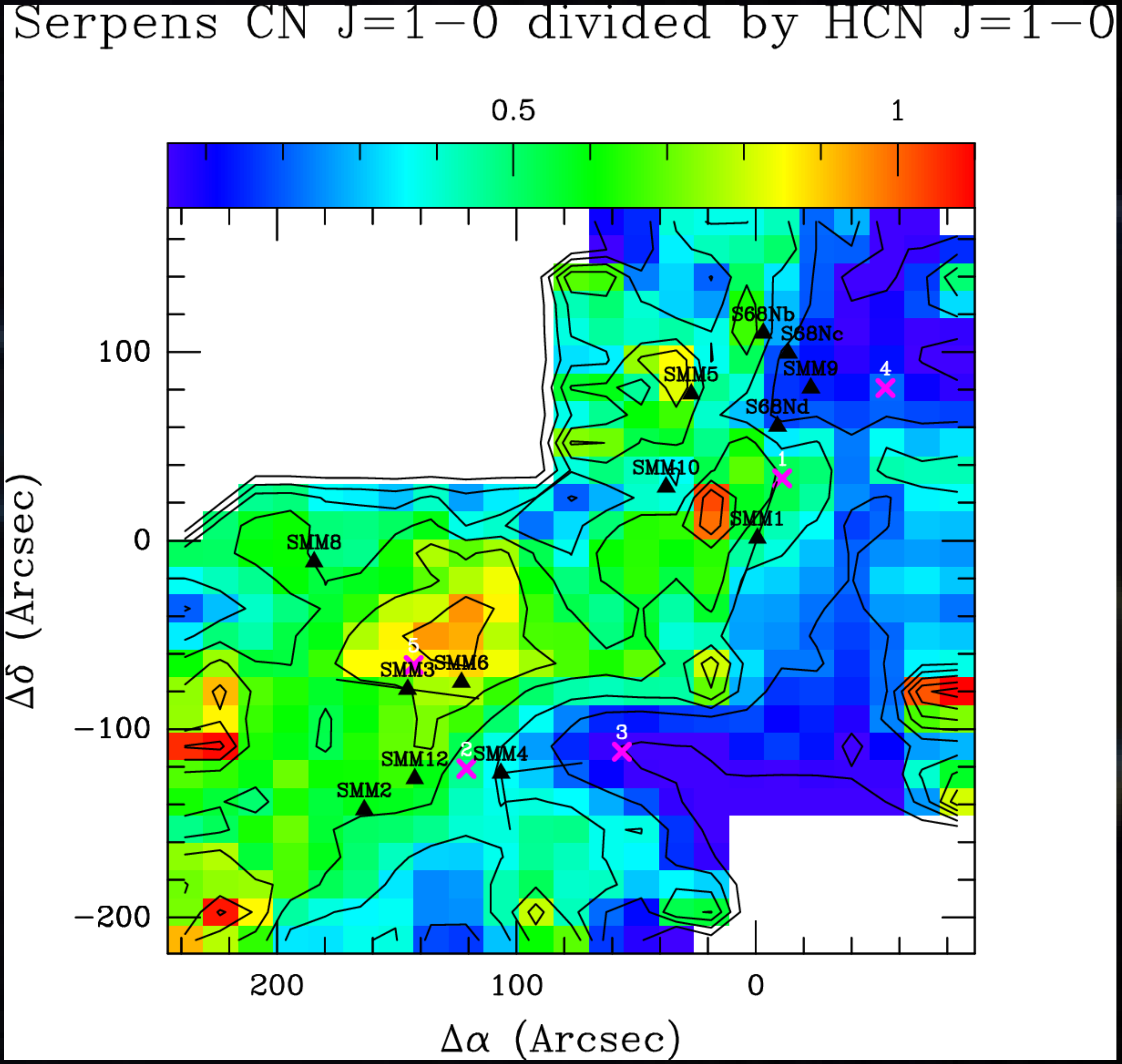
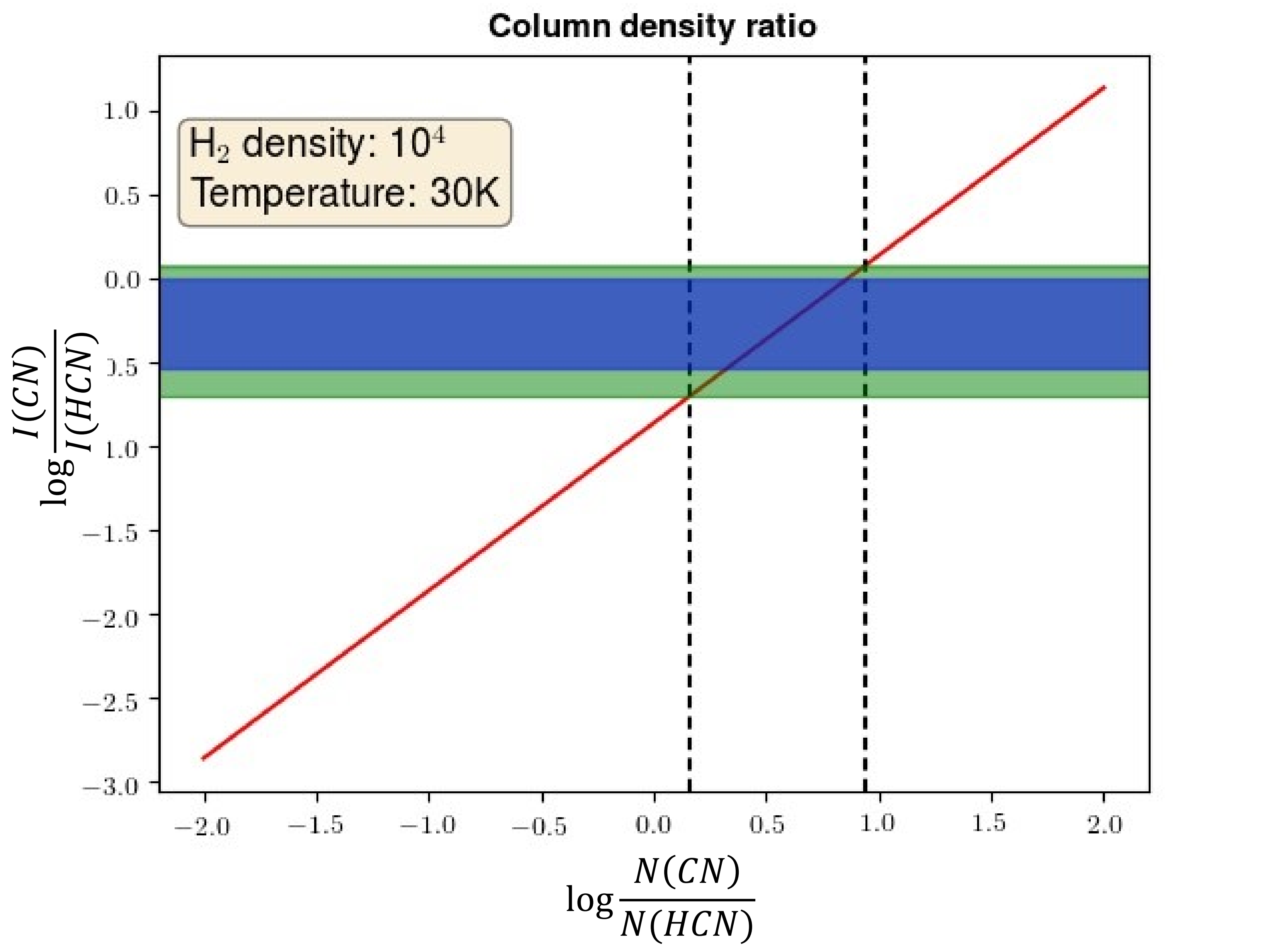


CN/HCN ratio traces the UV field

Radex models

$n(H_2)$ [cm^{-3}]	T_{kin} [K]	$\log_{10}$(N[CN]/N[HCN])
10^3	30	0.03-0.88
10^3	75	0.06-0.84
10^3	200	0.00-0.78
10^4	30	0.16-0.94
10^4	75	0.08-0.86
10^4	200	0.04-0.82
10^5	30	0.20-0.98
10^5	75	0.18-0.86
10^5	200	0.22-1.00

Column density ratio covers the range of 1-10 irrespectively of the gas parameters



NAHOON MODEL

KIDA | KINETIC DATABASE FOR ASTROCHEMISTRY

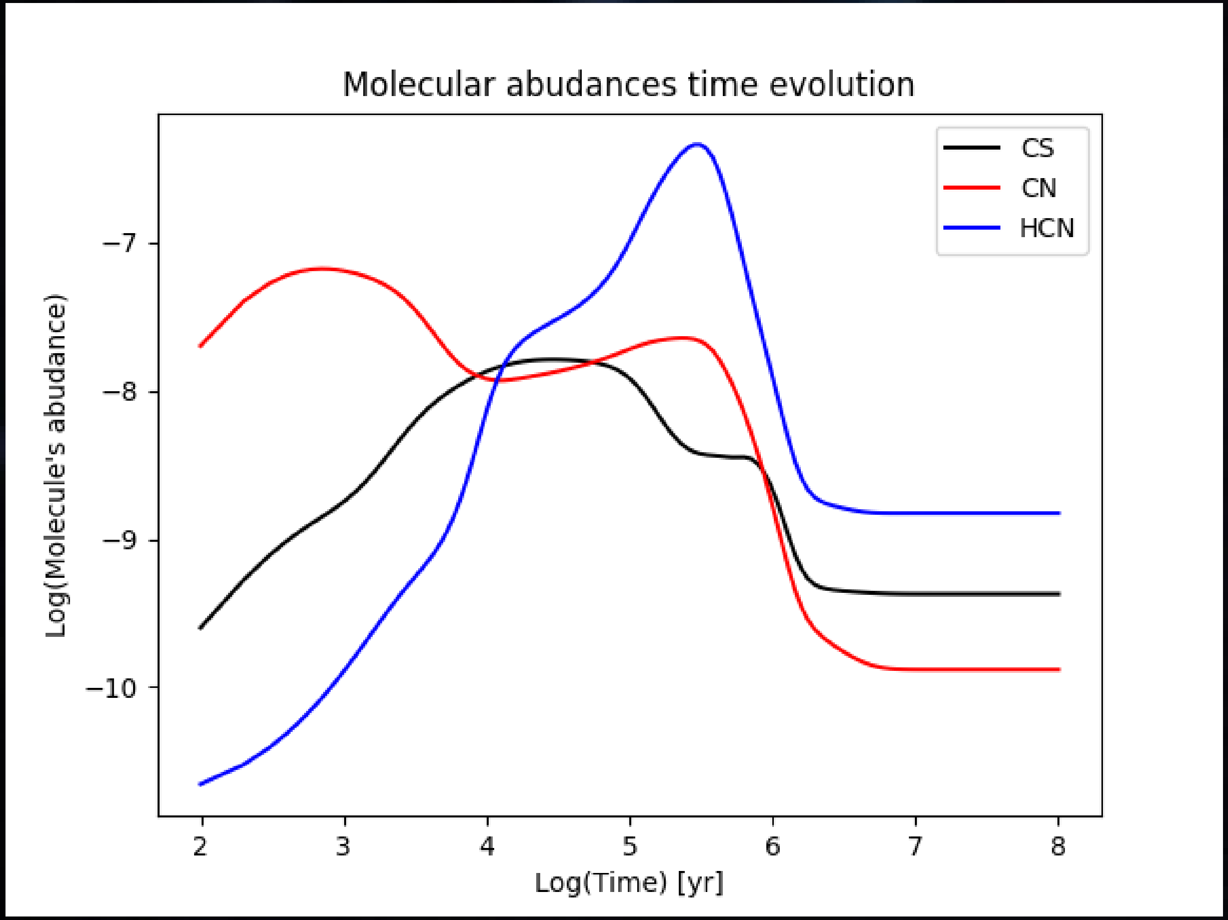
- Developed by community of astrochemists and chemist
- **6090 reactions** involving 474 species
- gas-phase reactions and gas-grains reactions with rate coefficients
- **Code Nahoon** - solving kinetic equation for reaction chains
- Used for modelling ISM and planetary atmospheres

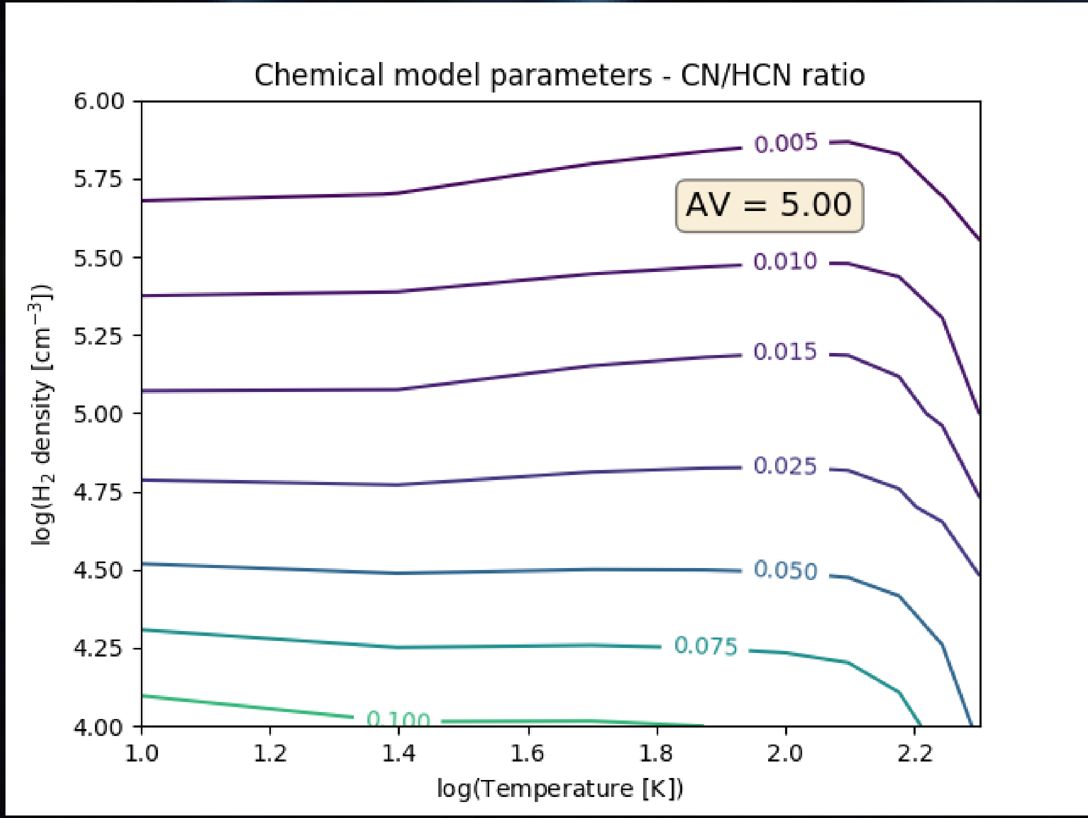
Input
- ❑ Cloud temperature
- ❑ Total density of H_2
- ❑ Visual extinction

→

Output
- ❑ Species and molecules abudances

STARLESS CLOUD AND PROTOSTARS ENVELOPE MODELS



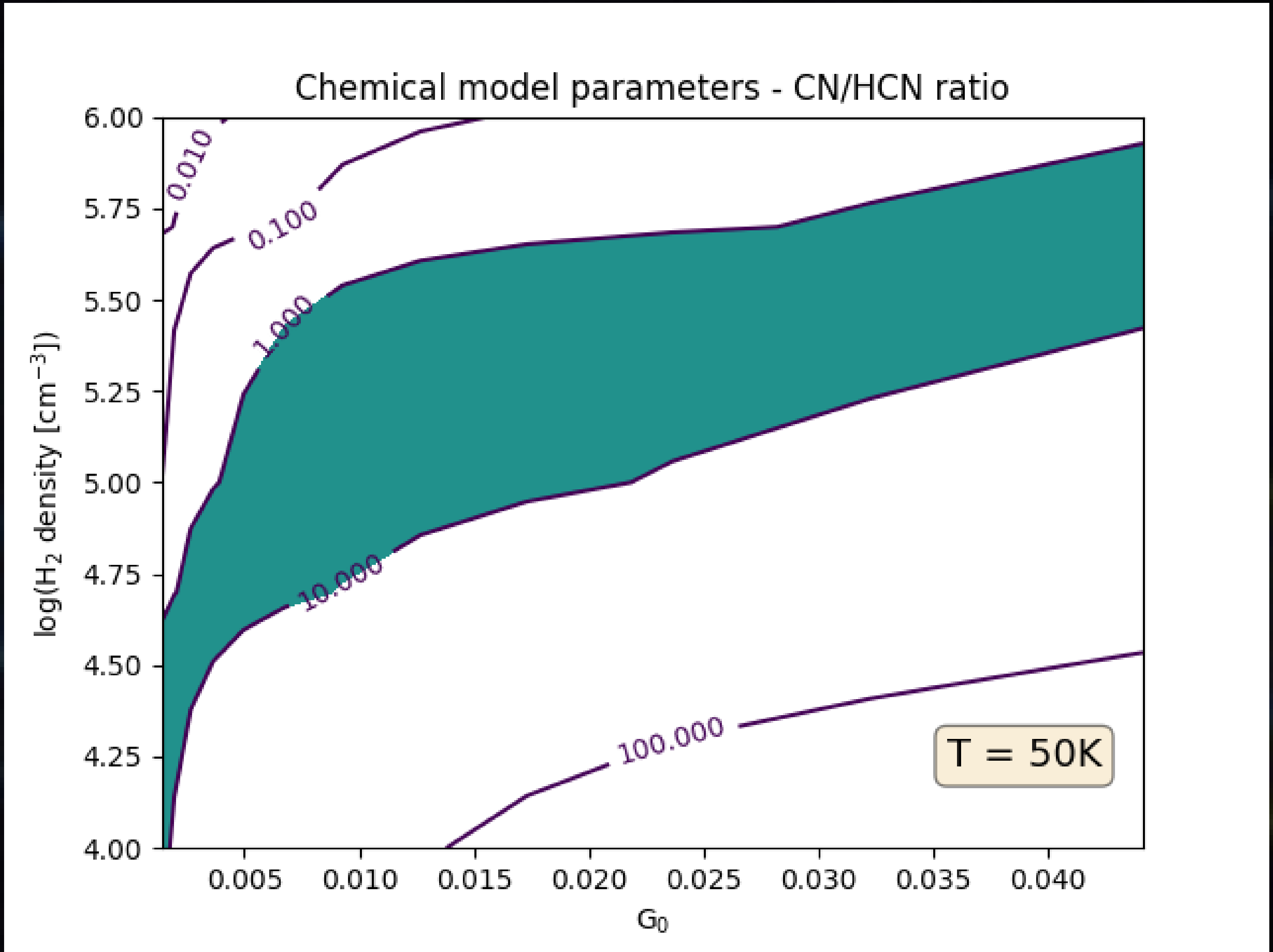


In low temperature regime CN/HCN ratio does not depend strongly on temperature

Final results

PDRs: G_0 = 10-10^4
(Harworth et al. 2018)

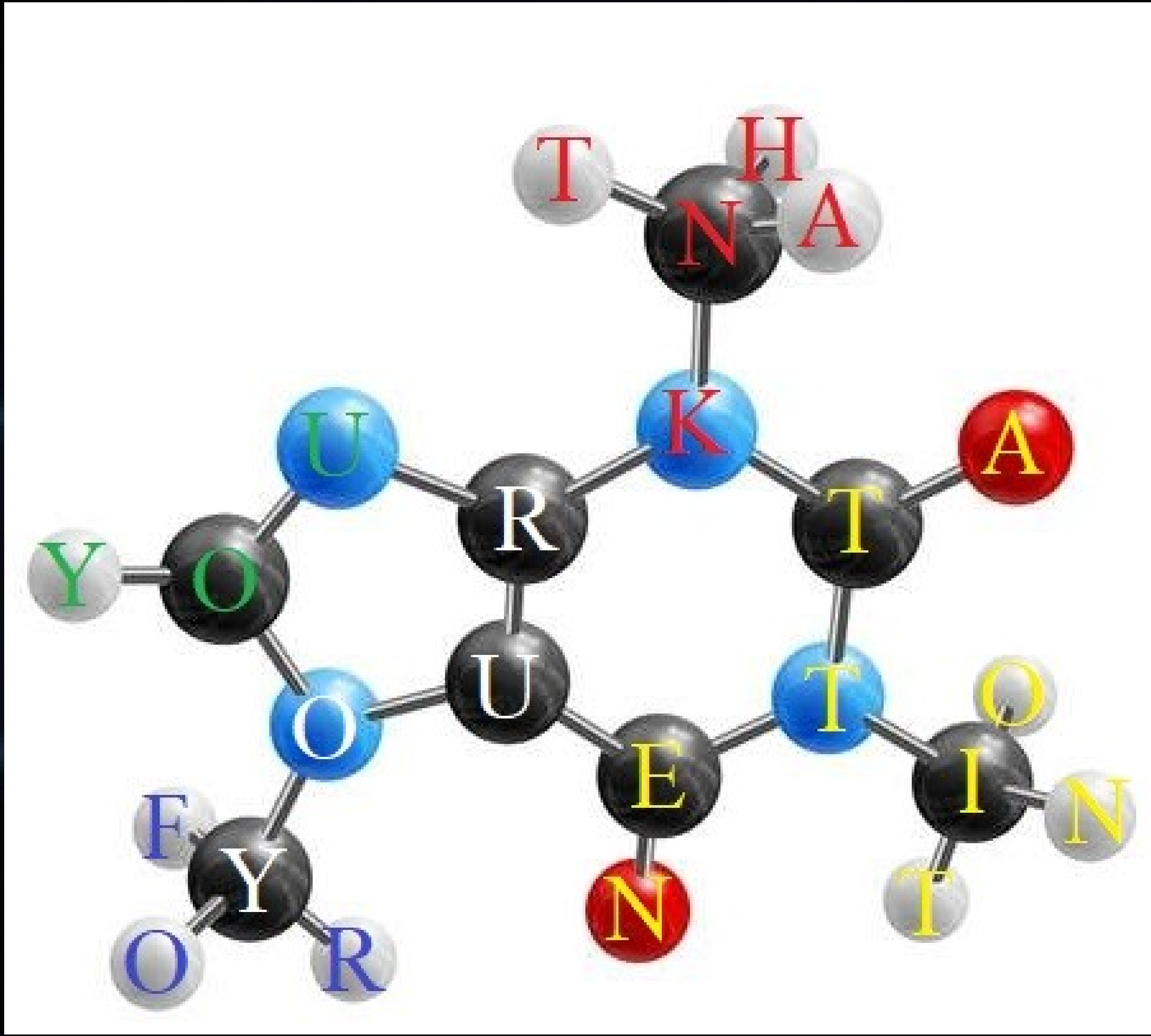
High-mass protostars:
G_0 = 20-600
(Benz et al. 2016)



There is non-zero G_0 parameter around low-mass protostars in the Serpens Main

CONCLUSIONS

- CN/HCN ratio can be used as a tracer for the UV radiation around low-mass protostars
- CN/HCN ratio is higher around more evolved low-mass protostars
- Column density ratio covers the range of 1-10, irrespectively of the gas parameters
- Up to 150K molecules abundances ratio does not depend strongly on temperature
- Nahoon astrochemical model shows that the **UV radiation cannot be neglected in models of low-mass star formation**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