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Osservatorio Astrofisico
di Arcetri (INAF-OAA)

INAF-OA Arcetri
Department of Physics and Astronomy
(Florence, 22nd-24th October 2024)

The **ALMA-UNIC** *Large Program:* a new frontier for the CRs study in massive star-forming regions

Giovanni Sabatini [1]

The whole UNIC-team:
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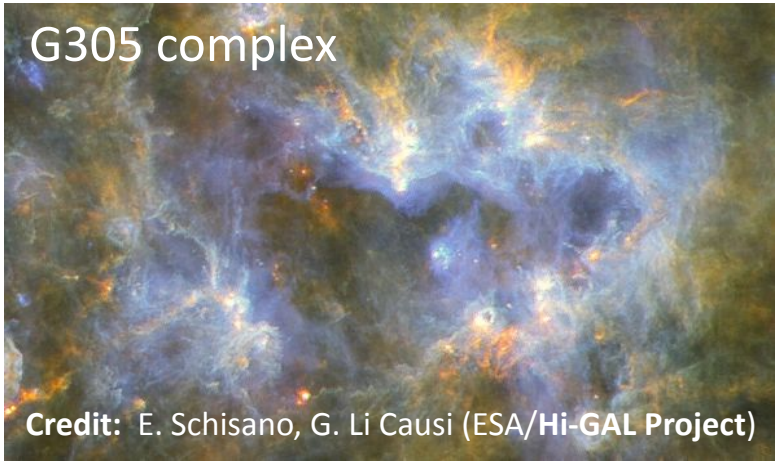
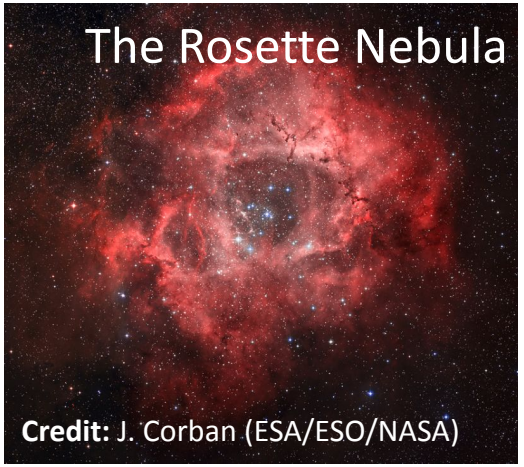
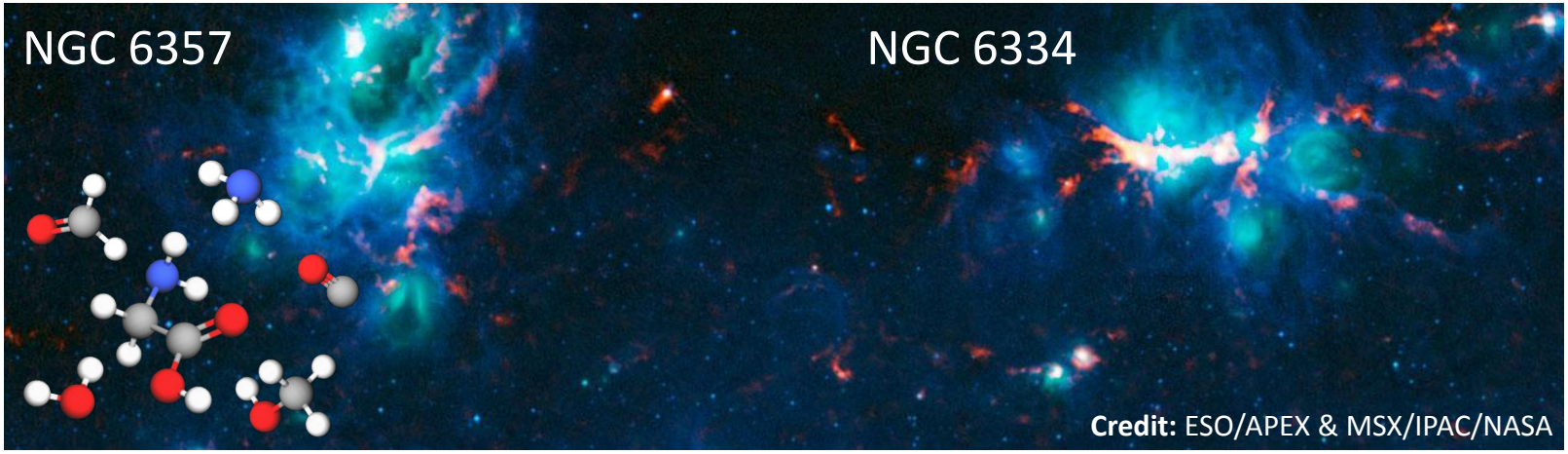
[1] INAF – Osservatorio Astrofisico di Arcetri, Firenze, IT;







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High-mass stars - ATLASGAL overview

- **Why HMS are difficult to be observed?**

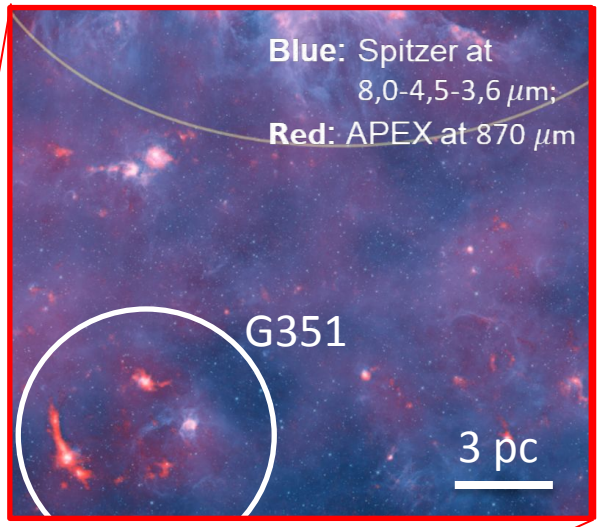
(*i*) Rare $N(1M_\odot)/N(15M_\odot) \sim 60$

(*ii*) Formed in clusters

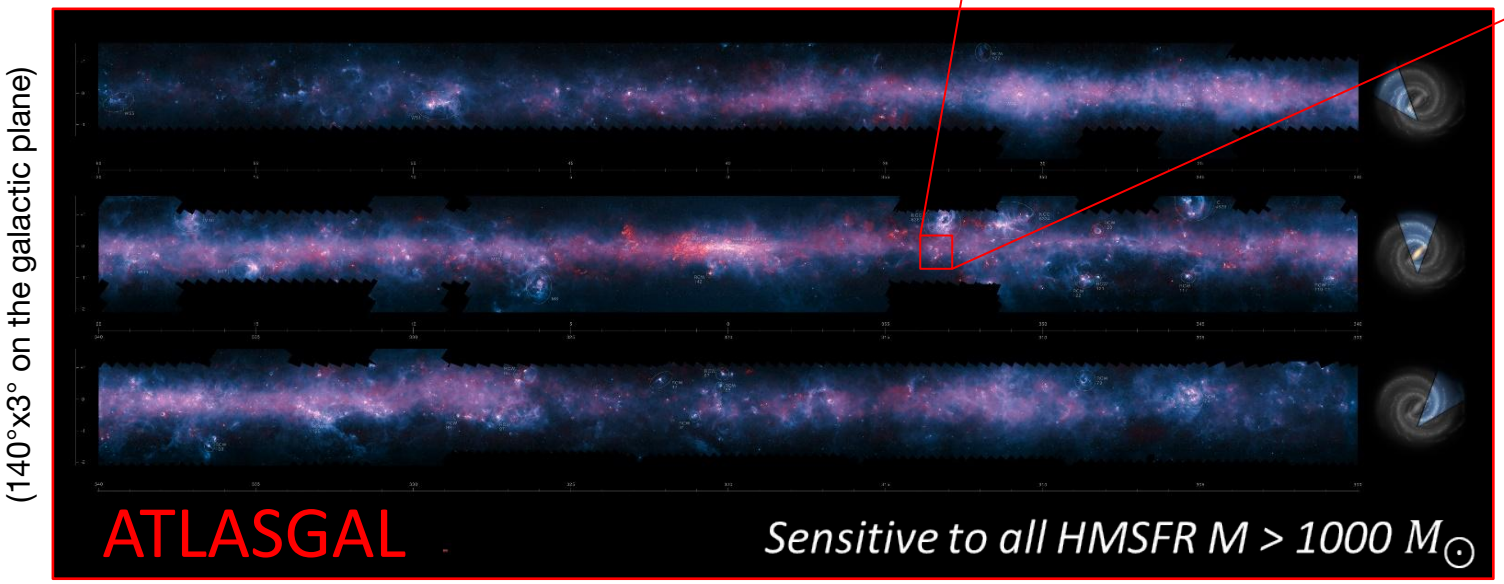
(*iii*) Fast evolution

$t_{MS,1M_\odot} / t_{MS,15M_\odot} \sim 10^3$;

(*iv*) Embedded in dusty envelopes ($A_V > 10$)



(Schuller+09)

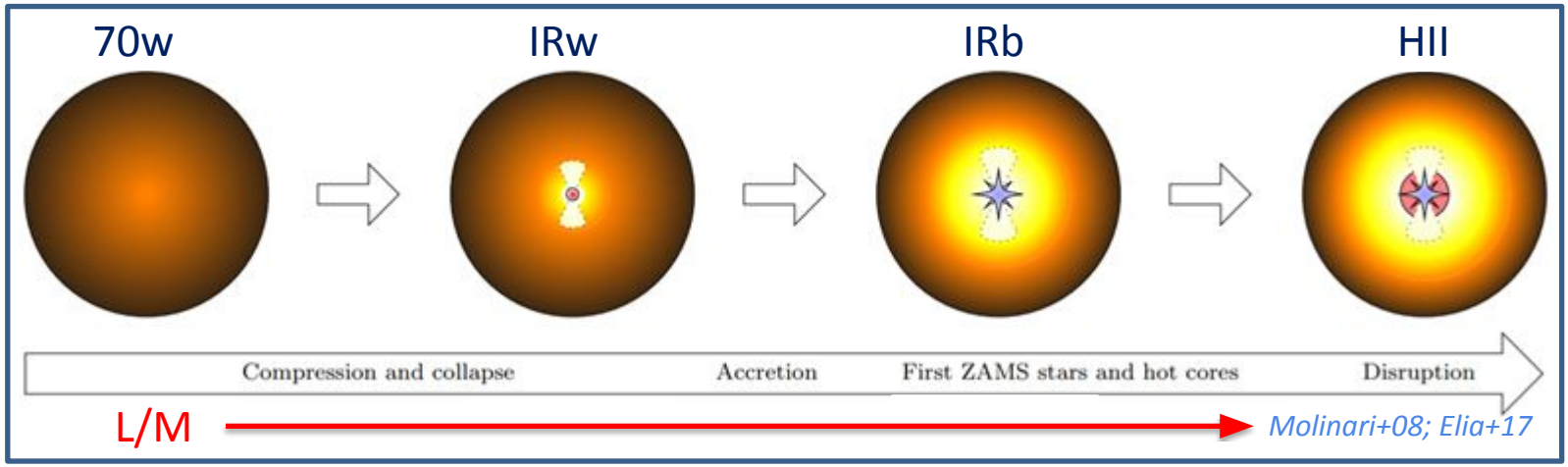


APEX *Telescope Large Area Survey of the Galaxy*

ATLASGAL: evolutionary stages

Observational evolutionary sequence

(Giannetti+17; König+17)



1. 70μm-weak stage

clumps are formed

- Dark at 70 and 24 μm;
- L/M $\lesssim 2\ L_\odot\ M_\odot^{-1}$;

2. IR-weak stage

forming massive YSO embryos

- Bright at 70 μm and dark at 24 μm;
- $2 \lesssim$ L/M $\lesssim 10\ L_\odot\ M_\odot^{-1}$;

3. IR-bright stage

contraction and nucleosynthesis

- Bright at 70 and 24 μm;
- $10 \lesssim$ L/M $\lesssim 40\ L_\odot\ M_\odot^{-1}$;

4. HII stage

Dispersion of the parent clump

- Also detected in radio continuum
- L/M $\gtrsim 40\ L_\odot\ M_\odot^{-1}$;

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ATLASGAL: evolutionary stages

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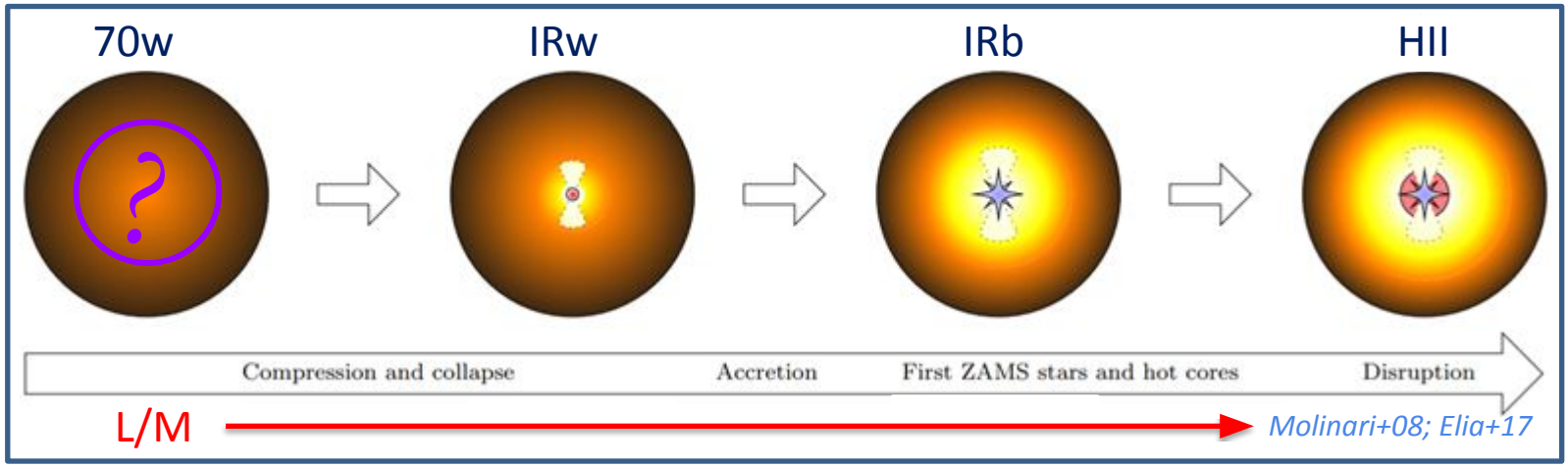

1. 70μm-weak stage

clumps are formed

- Dark at 70 and 24 μm;
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(Some) Relevant open questions

- ❑ How/when/where are HMSs formed?
- ❑ Are there any observational evidence for HMPCs?

- ❑ Typical chemical/physical properties of the core population in high-mass clumps? e.g. M_{core}, R_{core}, $N(H_2)$, $n(H_2)$, α, PPV structures, ζ^{ion}…)
- ❑ Can we reproduce these properties with cutting-edge simulations?

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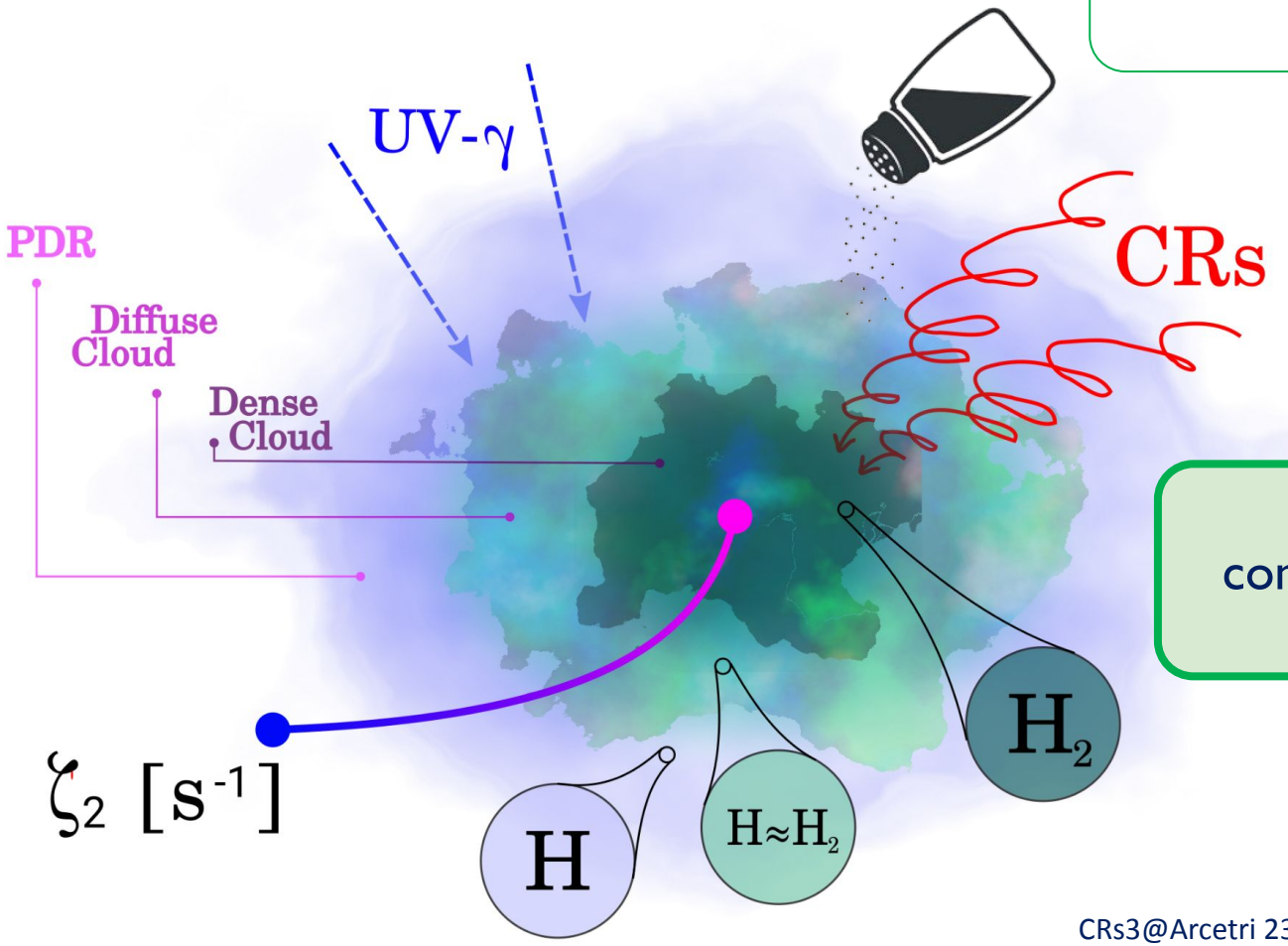
CRs and Star Formation

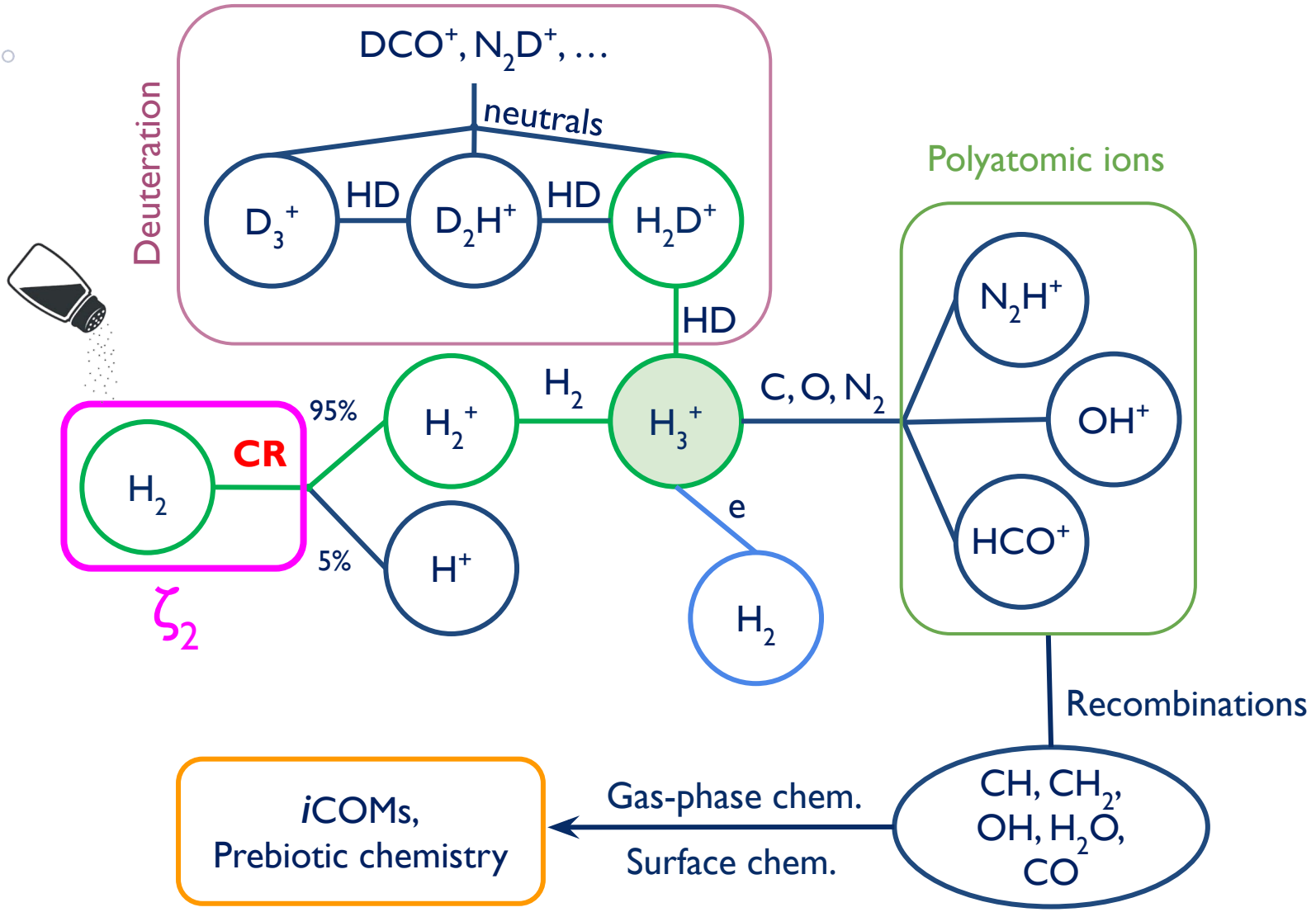
Mechanisms driving the cloud collapse

Dust physics



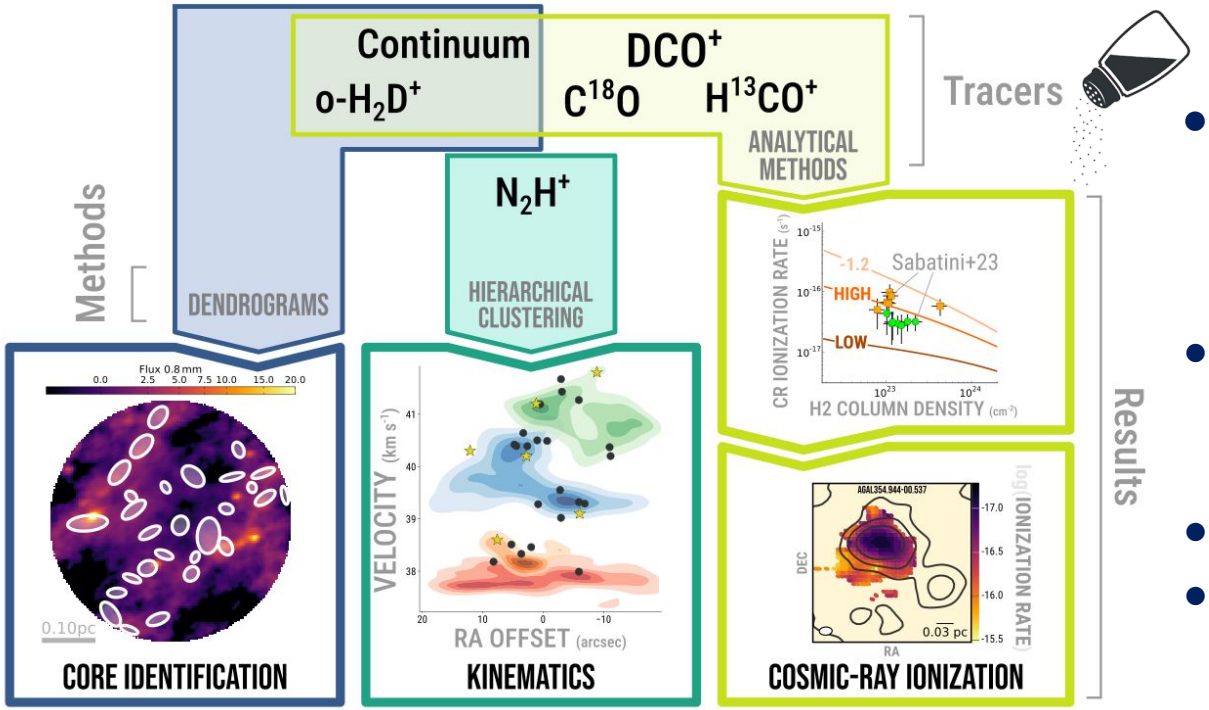
Chemical complexity in the ISM

CRs: the dawn of chemistry



(e.g. *Ceccarelli*+14, +22 and refs therein)

ALMA UNIC Large Programm



- **Targets**: 10 massive (>300 $M_\odot$) young (70μm-dark or weak) ATLASGAL clumps
- 82h of Main Array
  320h of ACA
  650h of ALMA-TP
- **Bands**: 3, 6 & 7
- **Resolution**: 2000-3000 AU

UNveiling the Initial Conditions of high-mass star formation (UNIC) - ALMA Cycle-10

PI: E. Redaelli

Co-PIs: S. Bovino, V. Chen, R. Friesen, P. Sanhueza

ALMA UNveiling the Initial Conditions of High-mass Star Formation UNIC

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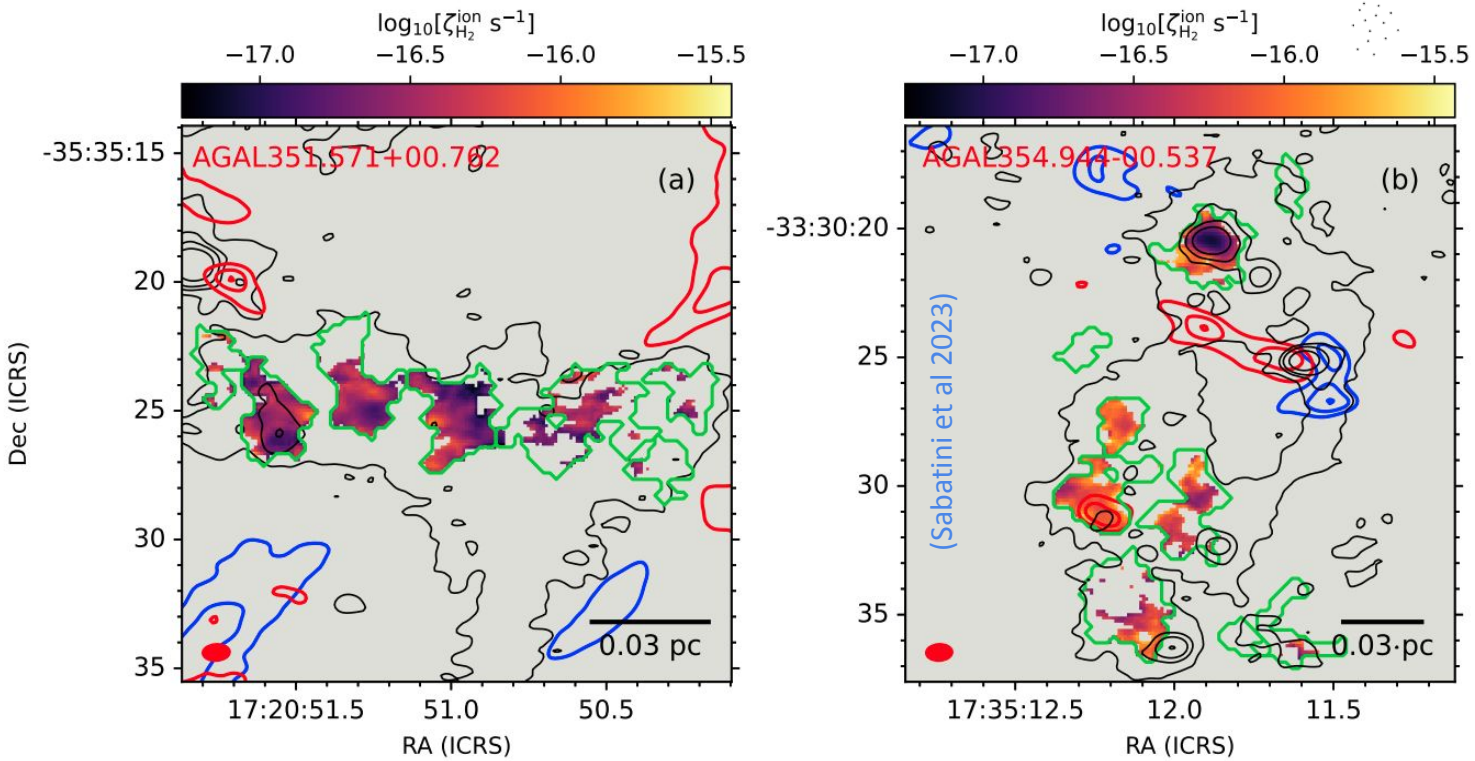
ζ_2 maps with ALMA-UNIC



CR ionization rate of H_2 molecule

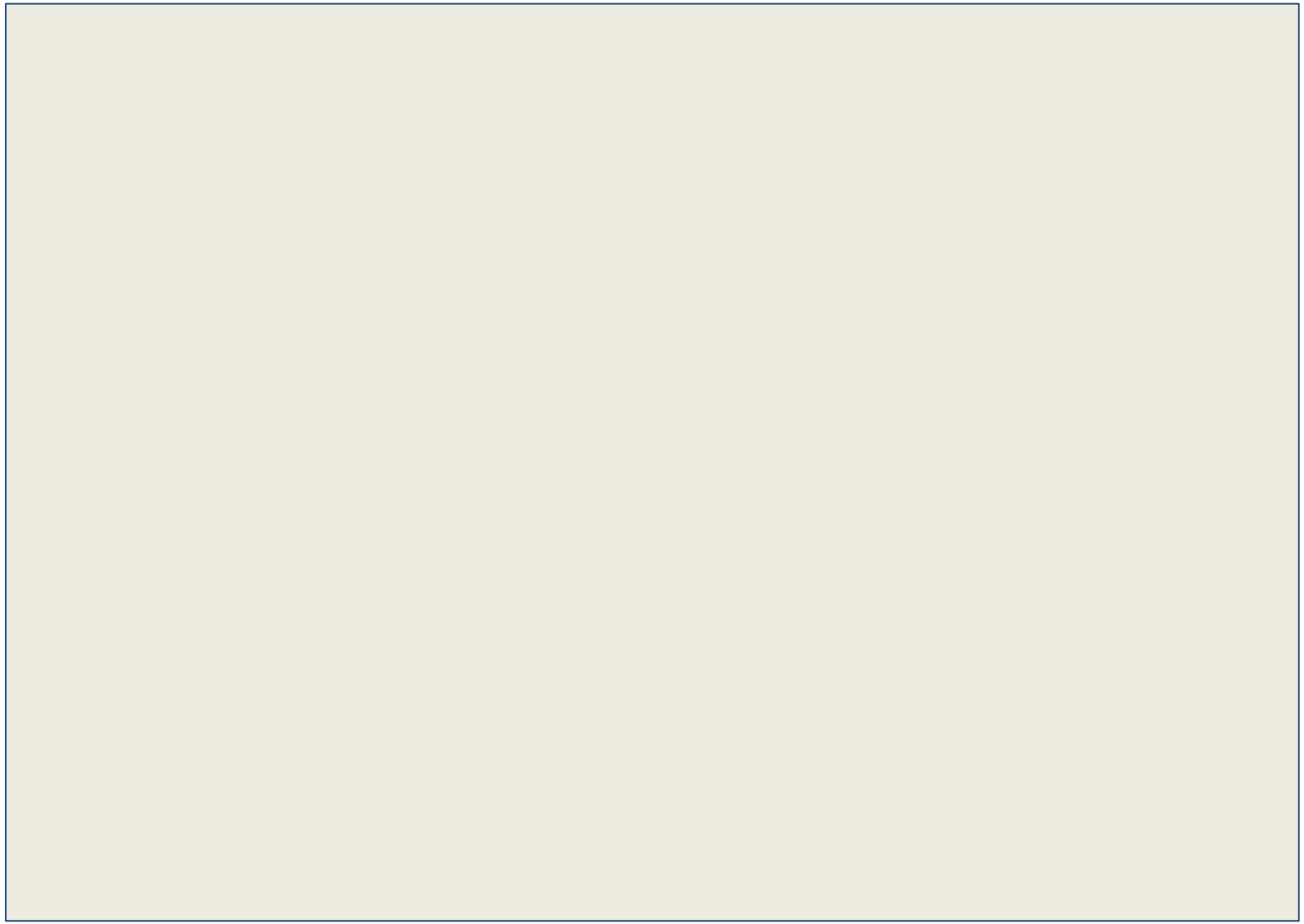
$$\zeta_{H_2}^{ion} = k_{CO}^{o-H_3^+} \frac{X(CO)\, N(o - H_2D^+)}{3\, R_D\, \ell}$$

path-length used to estimate *N*

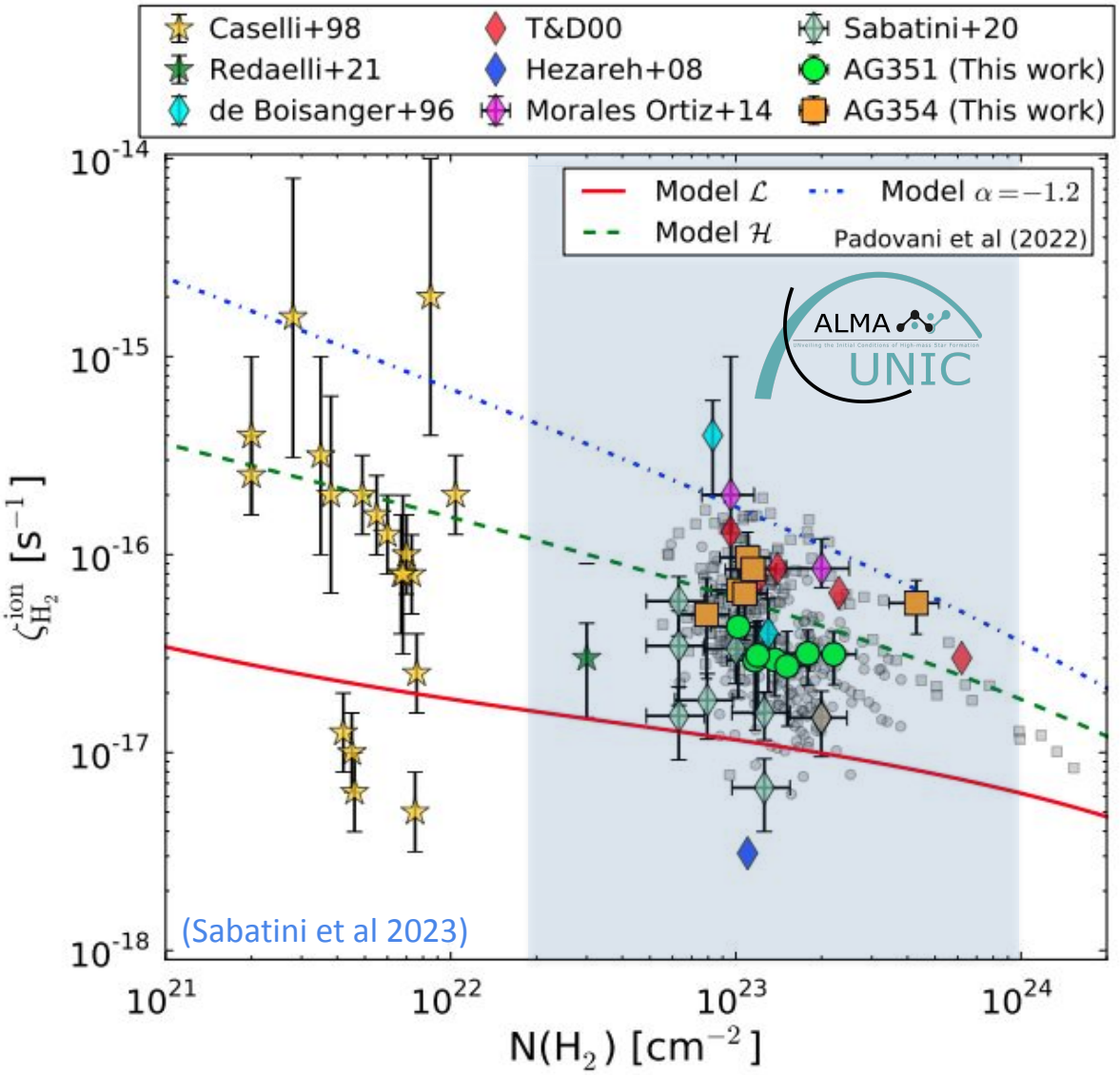
(Bovino et al. 2020) **see also**: *Sabatini+20, +23, Redaelli+24 and Socci+24a*

➢ **More methods by**: *Guélin+77, Caselli+98,* Pineda+24a (DCO^+, HCO^+, CO), *Ceccarelli+14, Redaelli+21b* (HCO^+, N_2H^+, N_2D^+), *Luo+24* (HCO^+, N_2H^+, CO), *Fontani+17* (HC_3N, HC_5N), *Favre+18* (c-C_3H;), *Bialy+20, Padovani+22* (H_2 NIR-lines)

ALMA-UNIC core properties

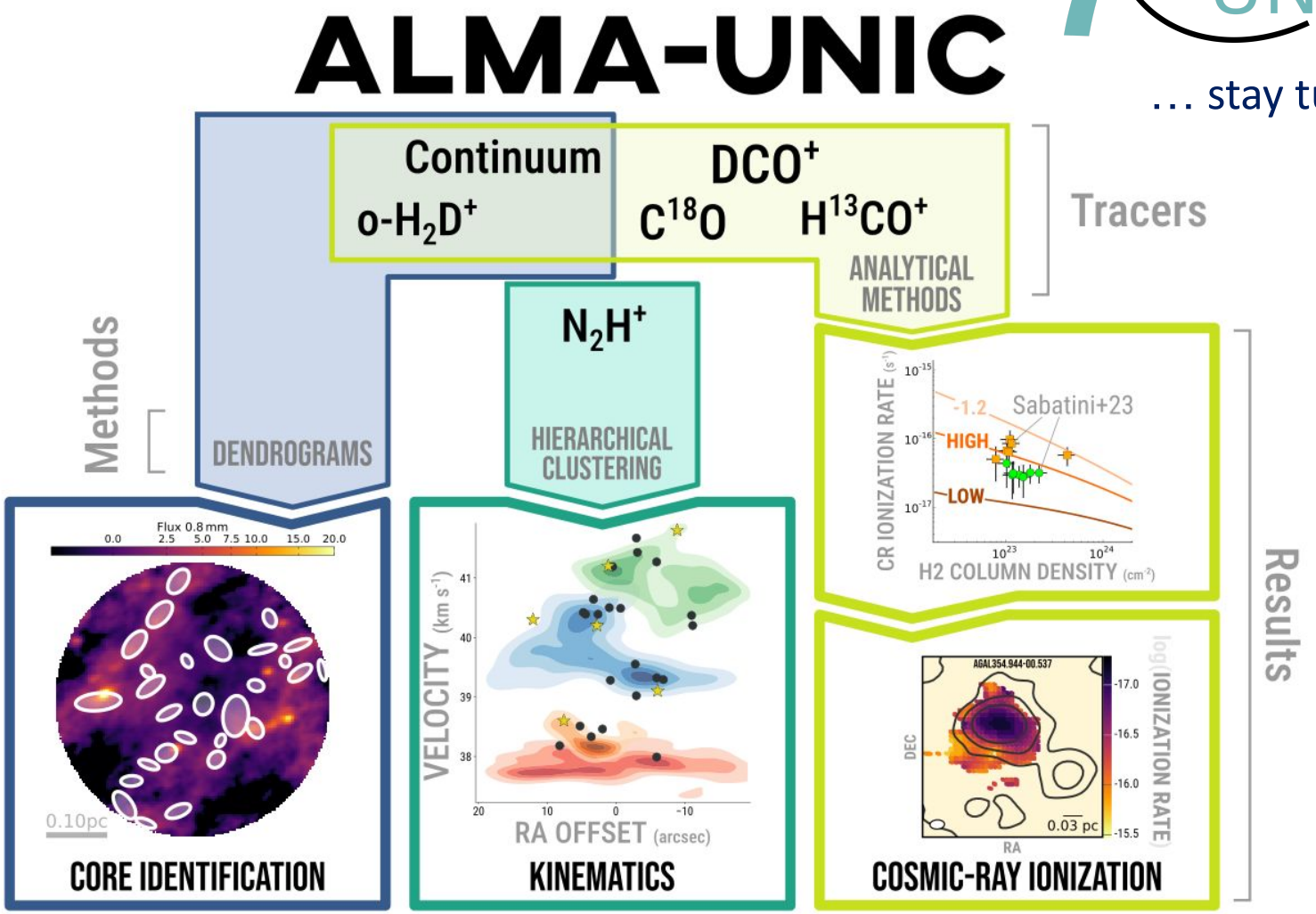


ζ_2 vs $N(H_2)$ with ALMA-UNIC



(see *Padovani* et al 2020 and *Gabici* 2022 reviews)

Summary



… stay tuned!

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Thank you

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