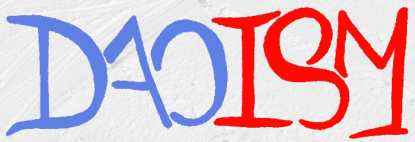
Turbulence, morphology and feedback-driven star formation in Orion B?

Jan H. Orkisz

DAOISM week, January 23th 2024

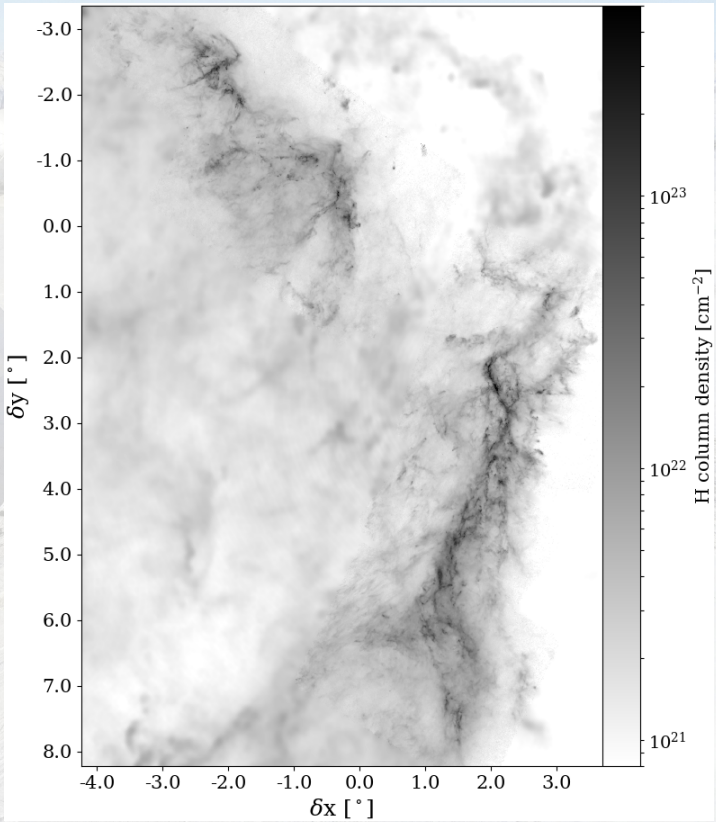
with J. Pety, M. Gerin, E. Olivier, M. Gaudel
and the rest of the ORION-B/DAOISM collaboration,
as well as J. Kainulainen, A. Spilker, and S. Rezaei-Kh.



Orion B and its family

Orion clouds: Part of the Orion complex (Orion-Eridanus super-bubble)

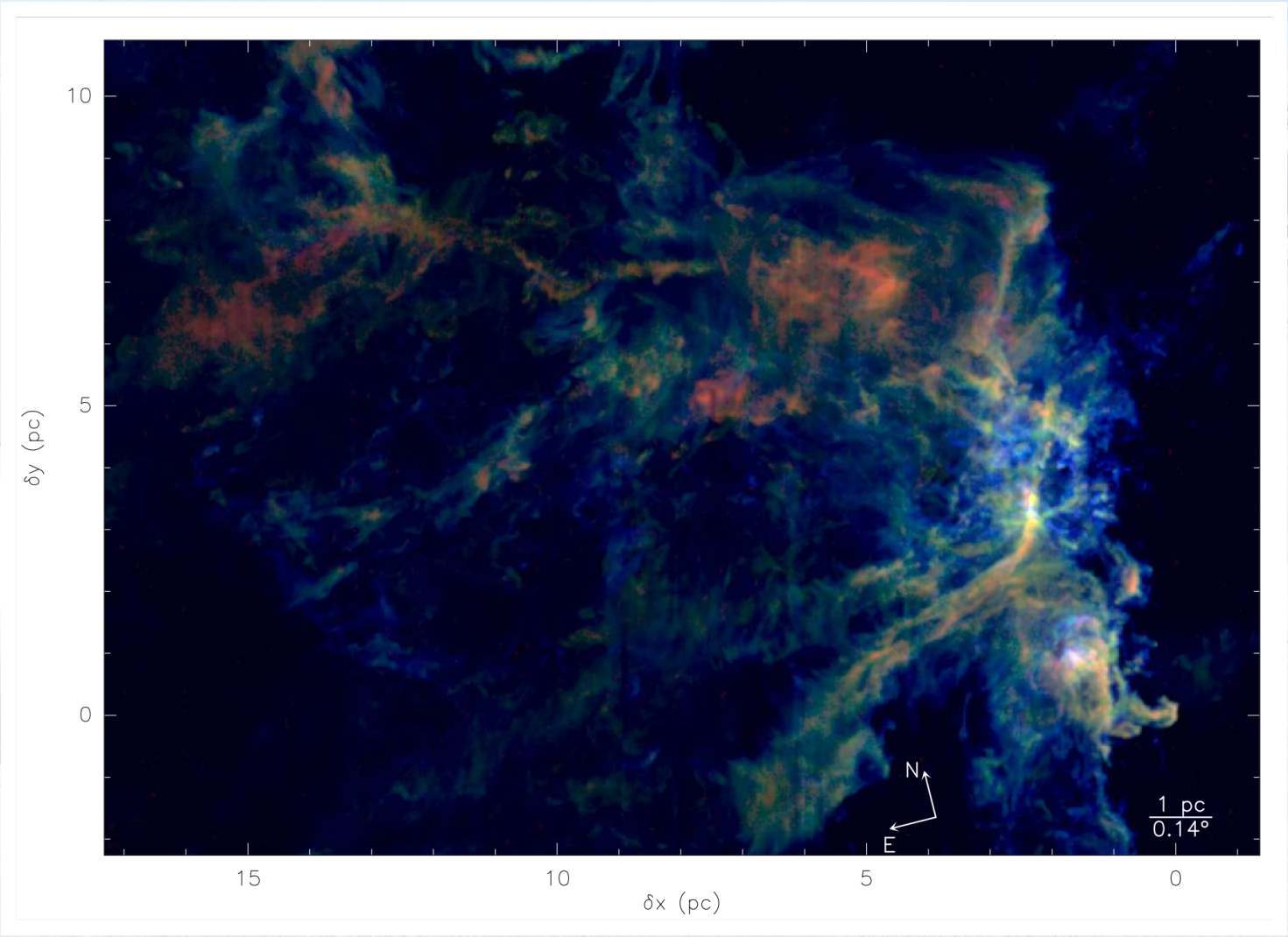
- Our target: Orion B
  - Mass: $6 \times 10^4 M_\odot$
  - Distance: 420 pc
  - Distinctive signs:
    Horsehead nebula
    Boring star formation
- The big brother: Orion A
  - Mass: $9 \times 10^4 M_\odot$
  - Distance: 430 pc
  - Distinctive signs:
    Very active star formation
    Beautiful nebula M42
    In general the cool, trendy GMC



Based on *Lombardi et al. 2014*

Orion B seen by the IRAM-30m

$C^{18}O$ ^{13}CO ^{12}CO $(J = 1 - 0)$



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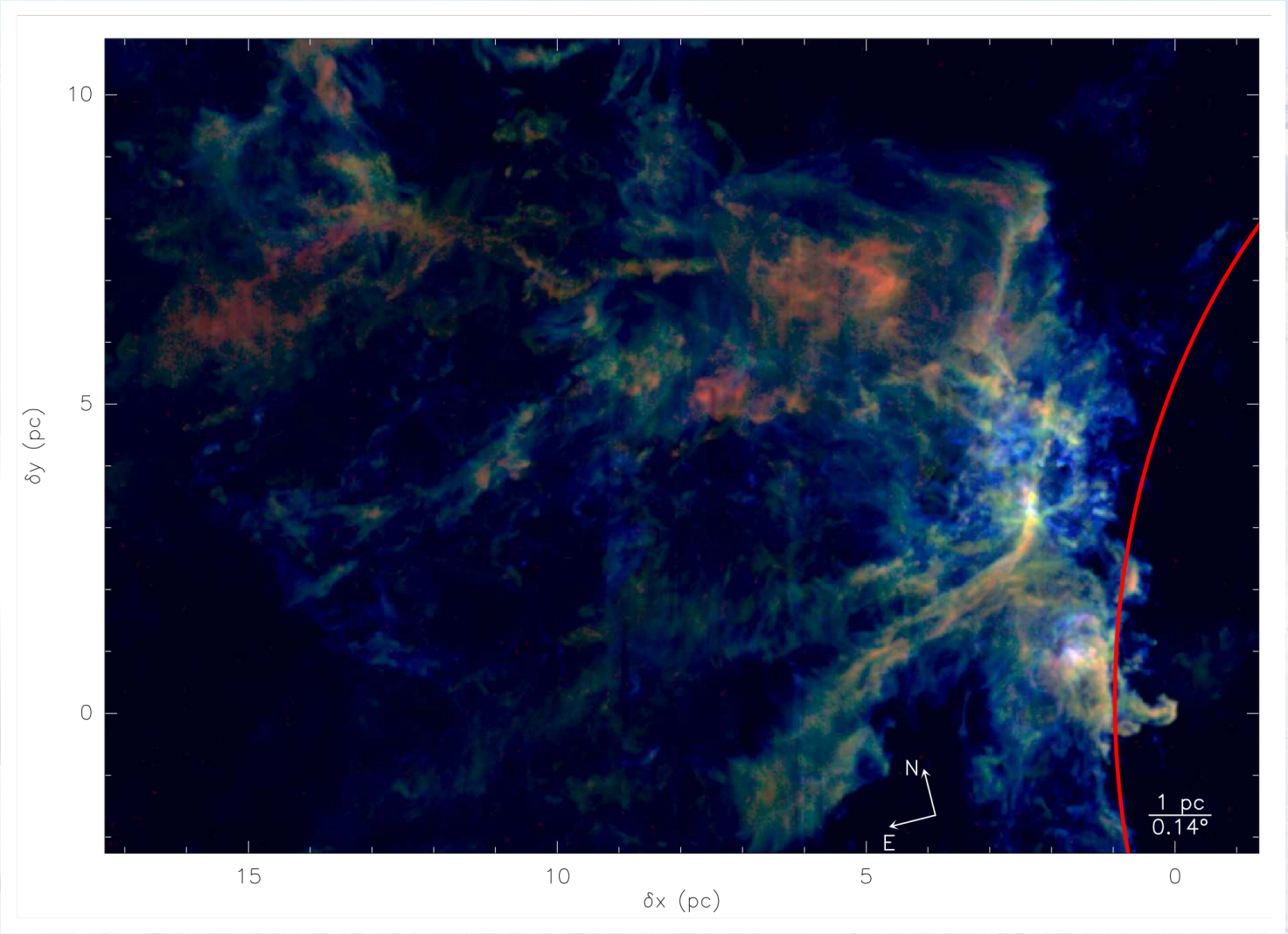

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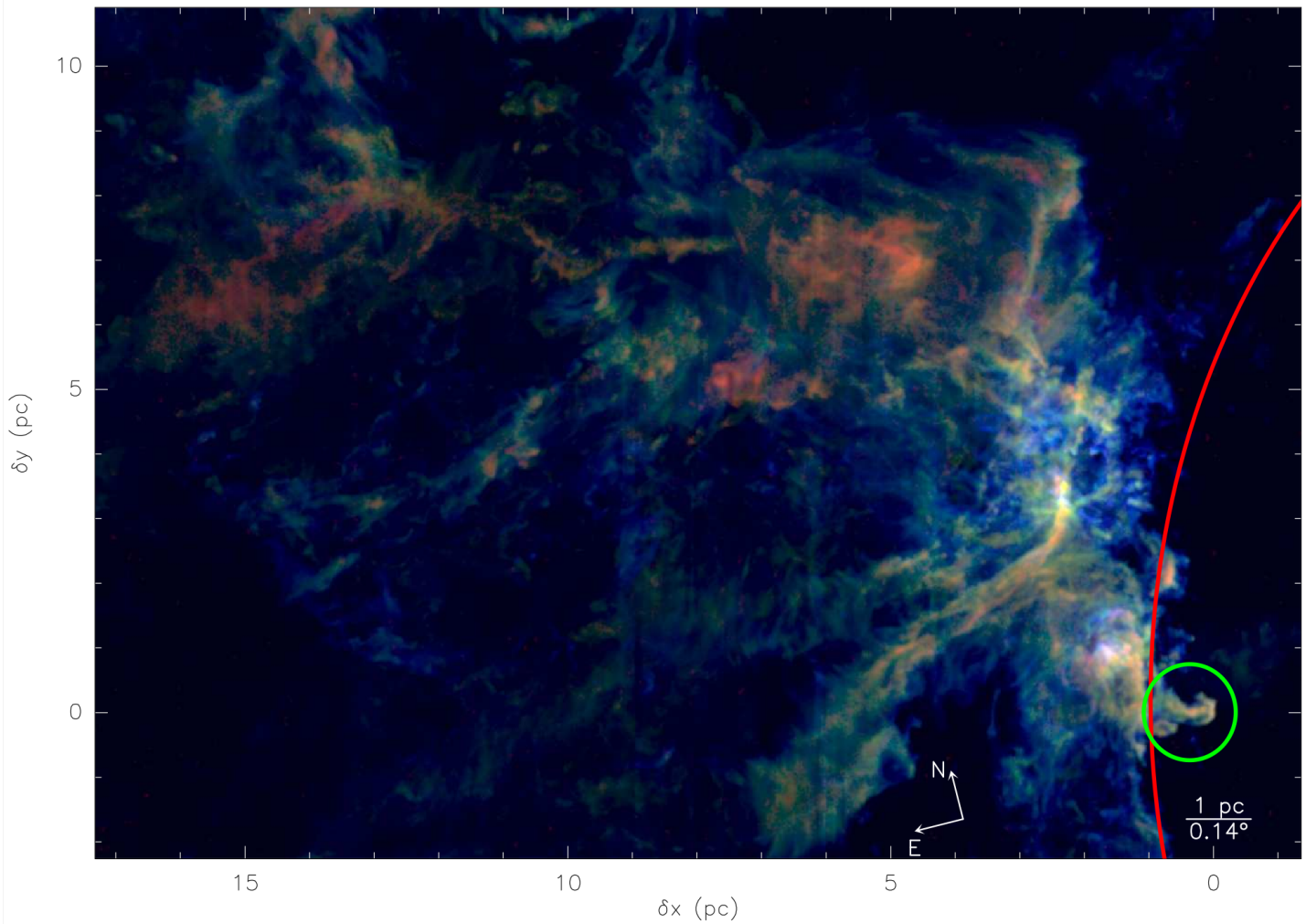

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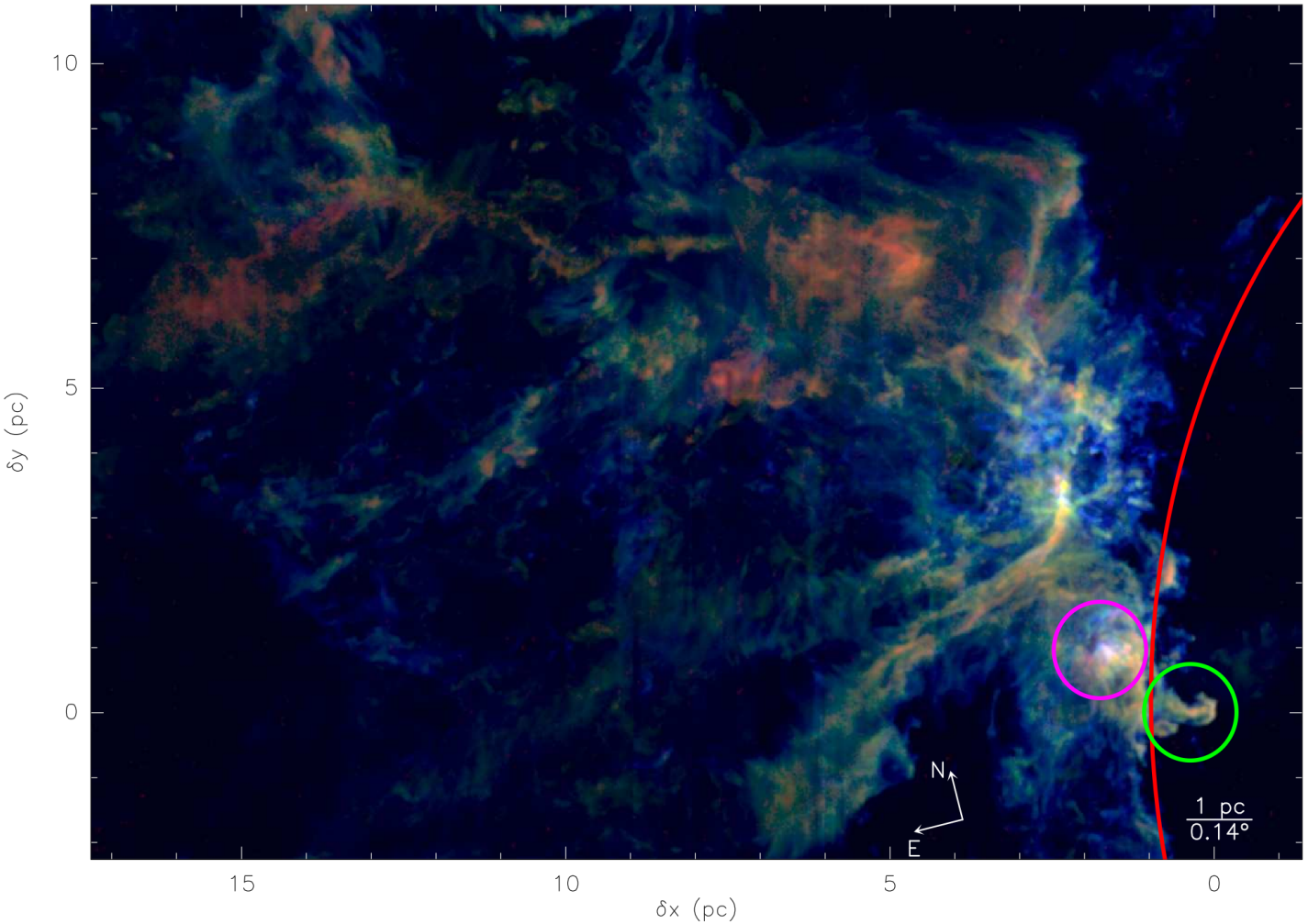

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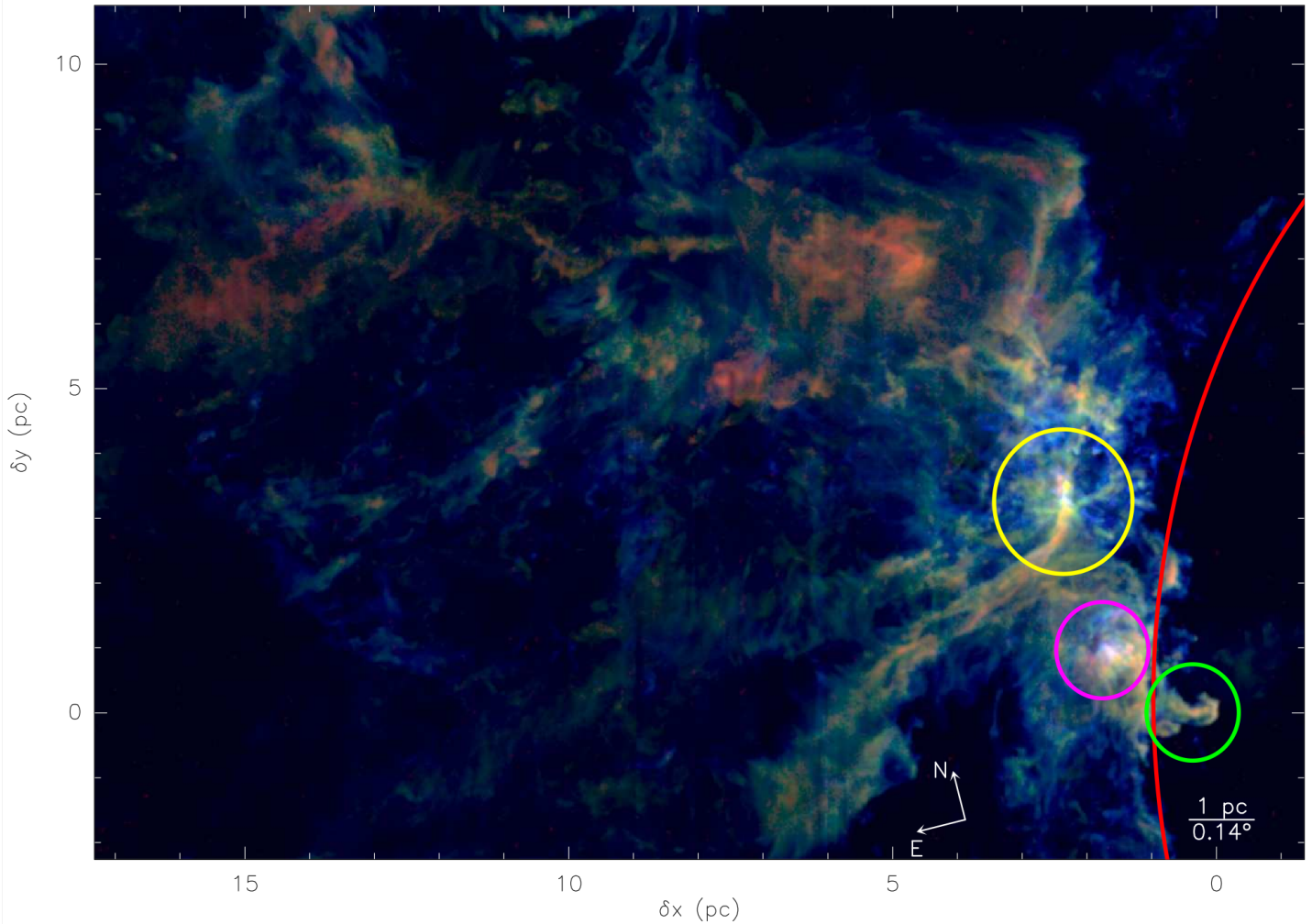

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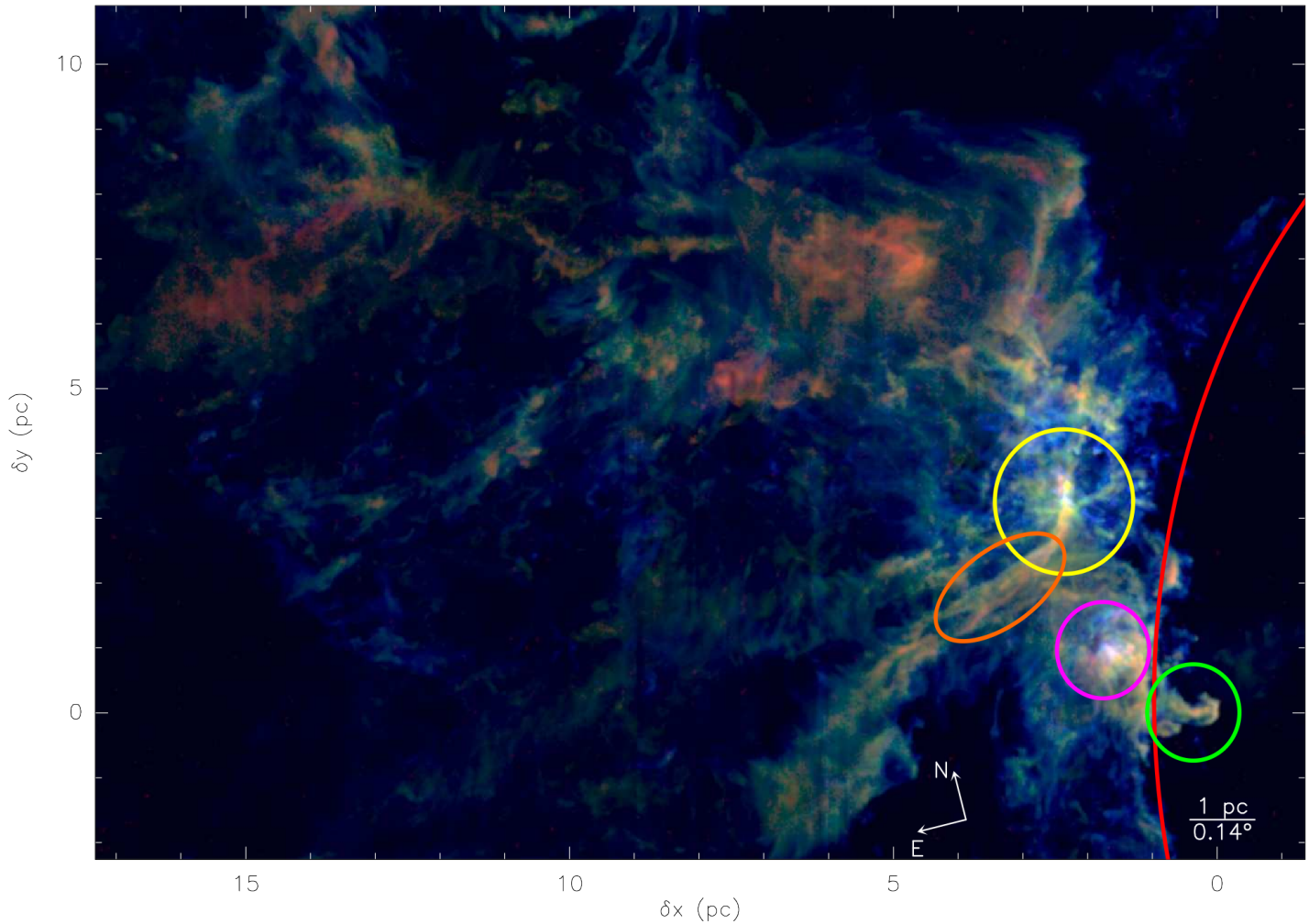

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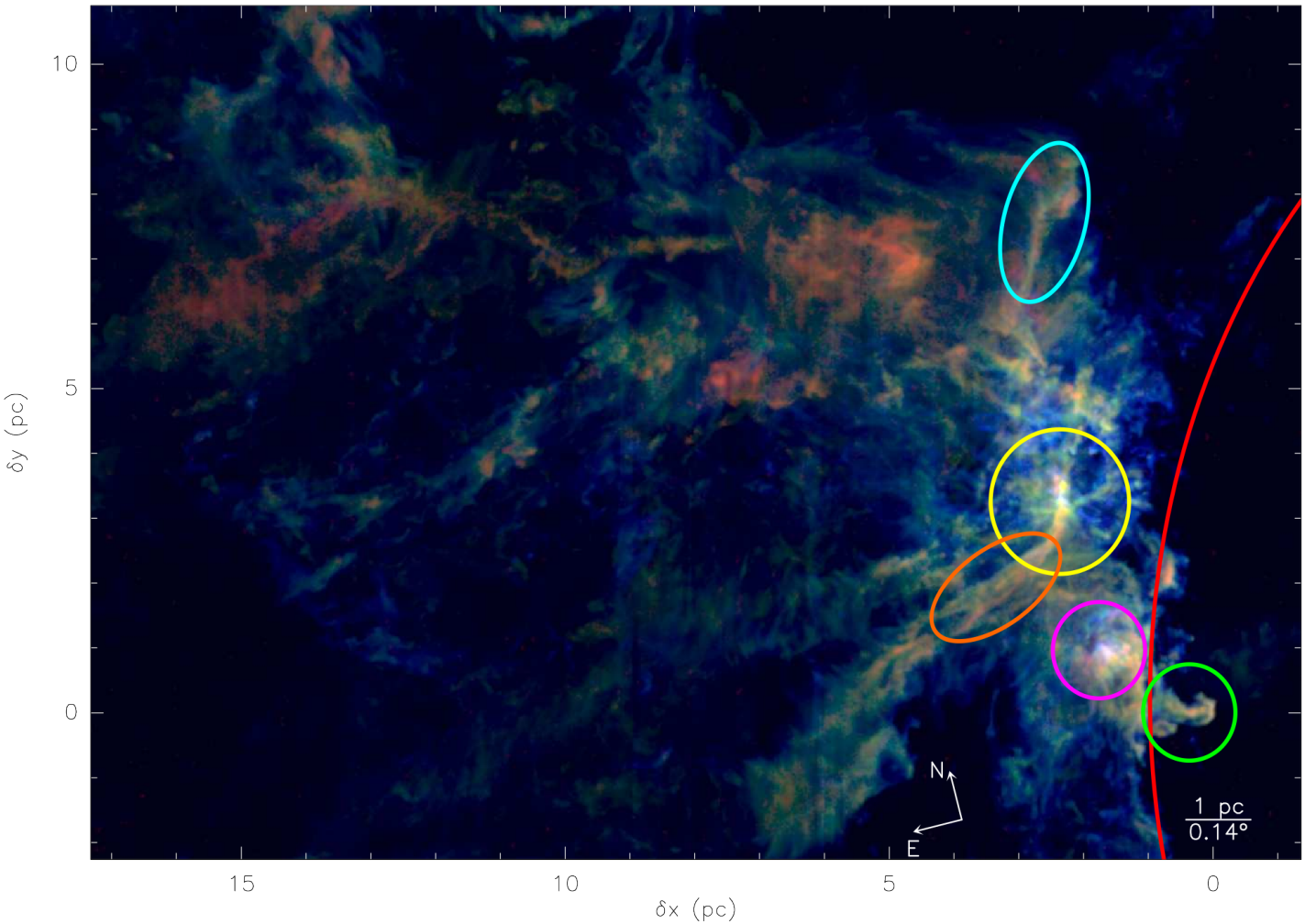

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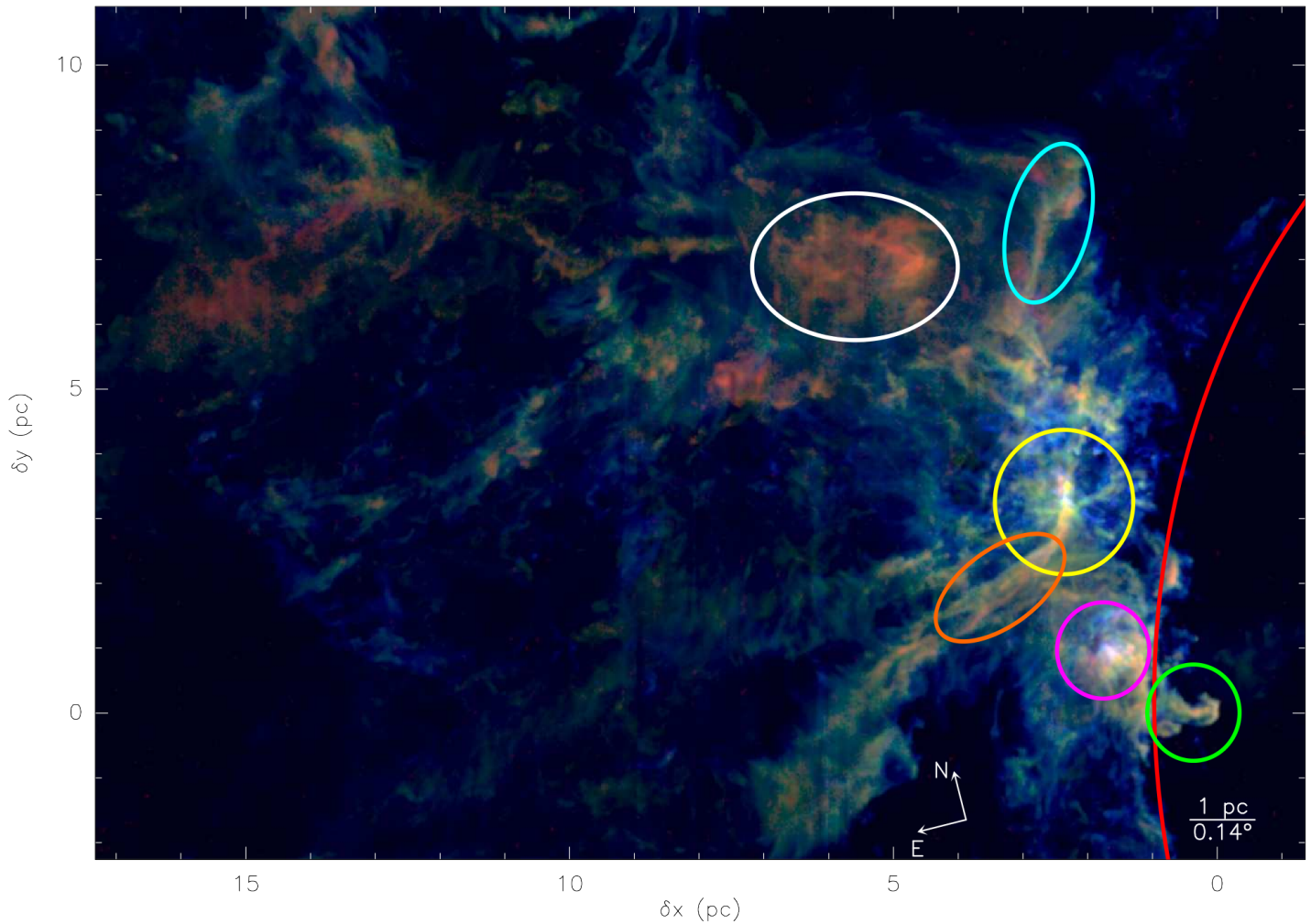


A bit of family history

- The complex is carved by the Orion OB association

  Bally et al. 1987, Bouy & Alves 2015

- Several generations of OB stars, from OB1a to OB1d
  - Activity started 8 – 12 Myr ago
  - σOri and oldest Orion A stars belong to OB1c
  - NGC 2024 and ONC belong to OB1d
  - OB1d is less than 2 Myr old

  Bally et al. 2008

- Cloud destruction or gas accumulation?
- Feedback vs. star formation

Image by *R. Bernal Andreo*

Measuring turbulence driving

Statistical reconstruction of compressive vs. solenoidal modes in Orion B

A quiet cloud with active star-forming regions?

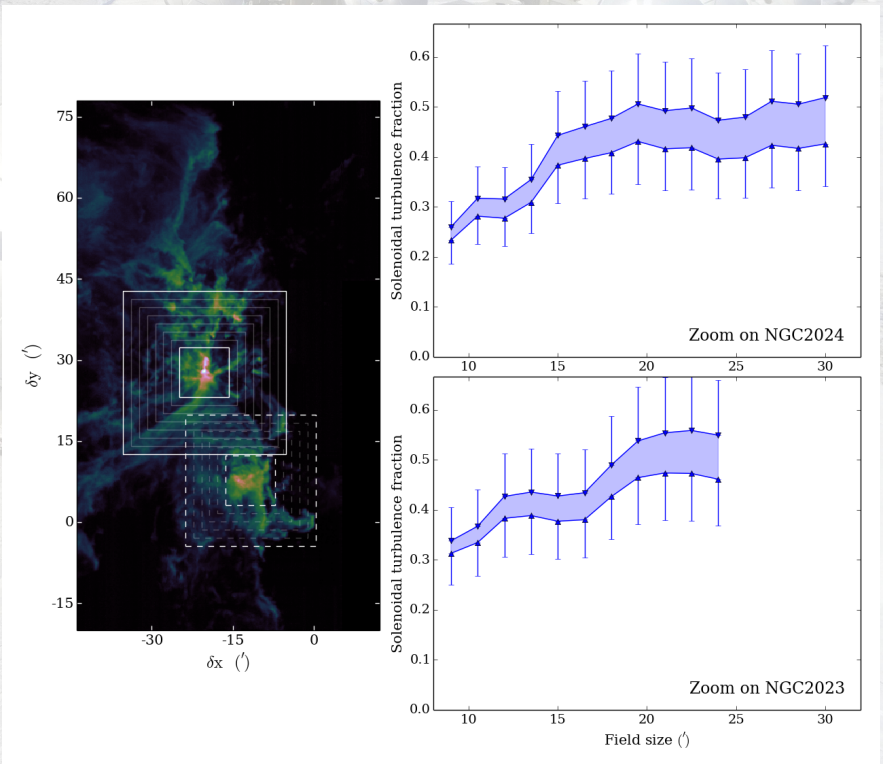
Large scale:

$$0.72^{+0.09}_{-0.09} < R_{^{13}\mathrm{CO}} < 1^{+0.0}_{-0.09}$$

- Lowest SFE among all nearby GMCs

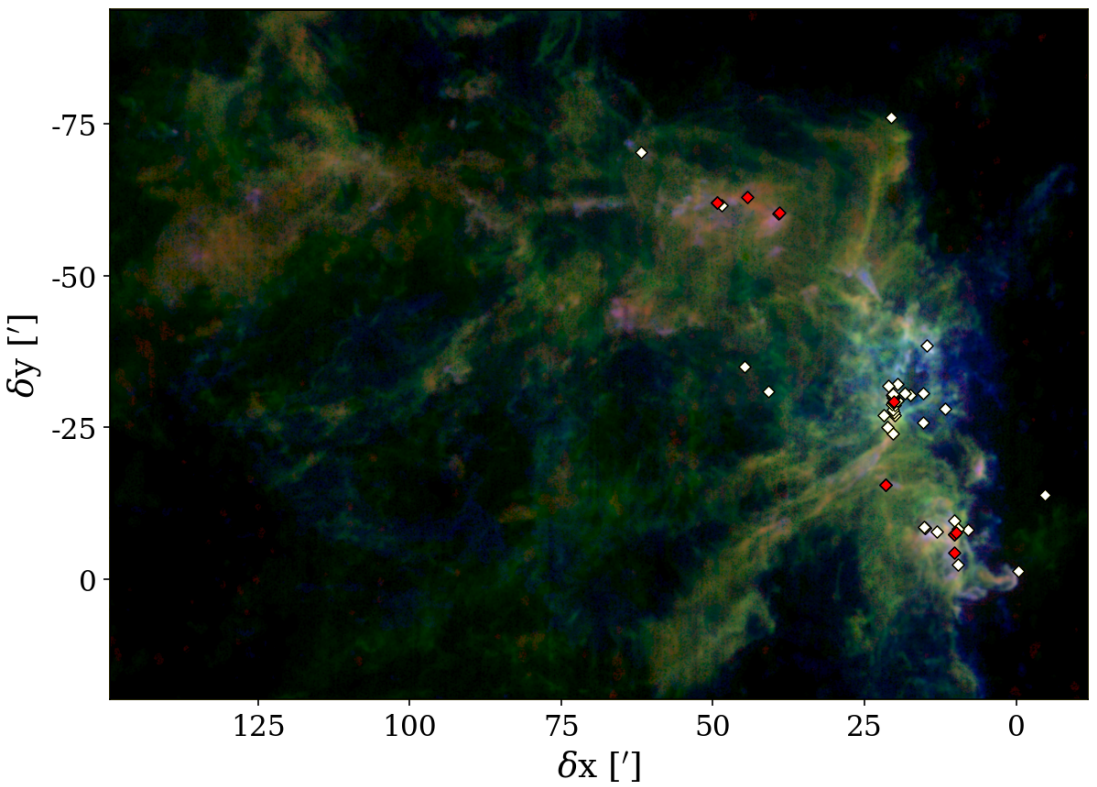
Lada et al. 2010
Megeath et al. 2016

Zooms towards star forming the regions NGC 2023 / NGC 2024:
$R_{^{13}\mathrm{CO}} < 0.4$
$\Rightarrow$ strongly compressive



Orkisz et al. 2017

A larger, multi-tracer study



YSOs from *Megeath et al. 2016* and *Furlan et al. 2016*

$C^{18}O$ ^{13}CO HCO^+ $(J = 1 - 0)$

Orkisz, Olivier et al., in prep.

- More solenoidal from West to East
- Orion B9 less compressive than NGC 2023 & NGC 2024
- Tracers qualitatively consistent
- Inter-tracer differences?

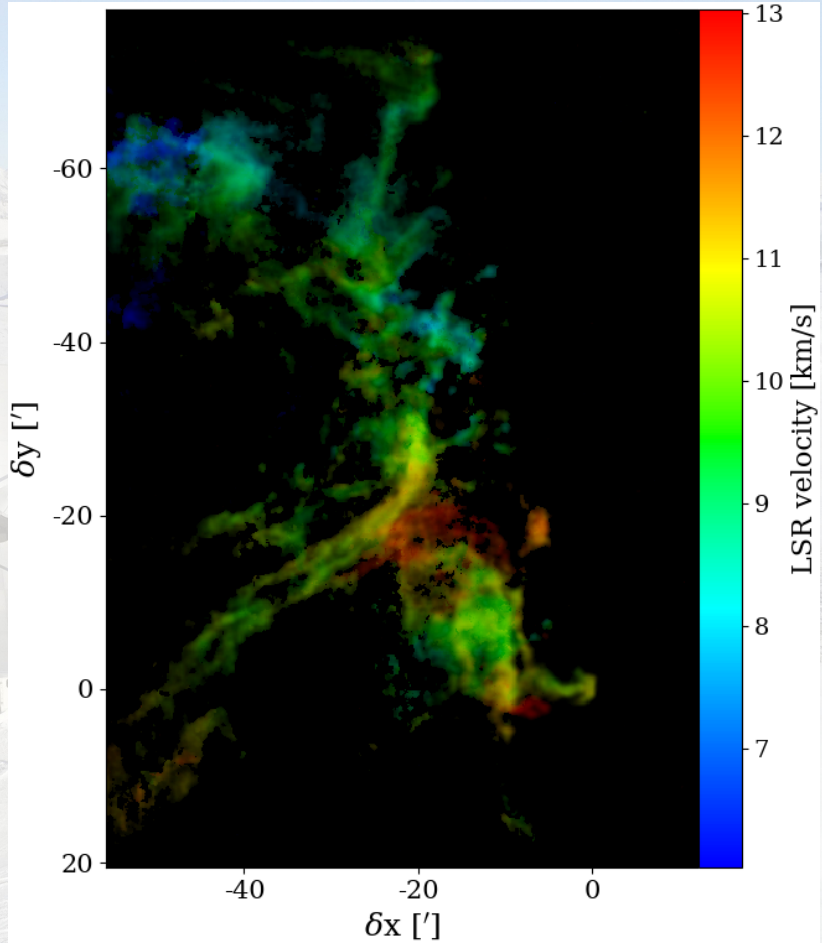
Characterising $C^{18}O(J = 1 - 0)$ filaments

- $C^{18}O(J = 1 - 0)$ is a good tracer of the densities expected for filaments

- Typical width 0.12 ± 0.04 pc
- Turbulence dissipation
- Mass consistent with SFE

BUT

- Low filament densities
- Supersonic turbulence
- $\Rightarrow$ filaments are stable against gravitational collapse



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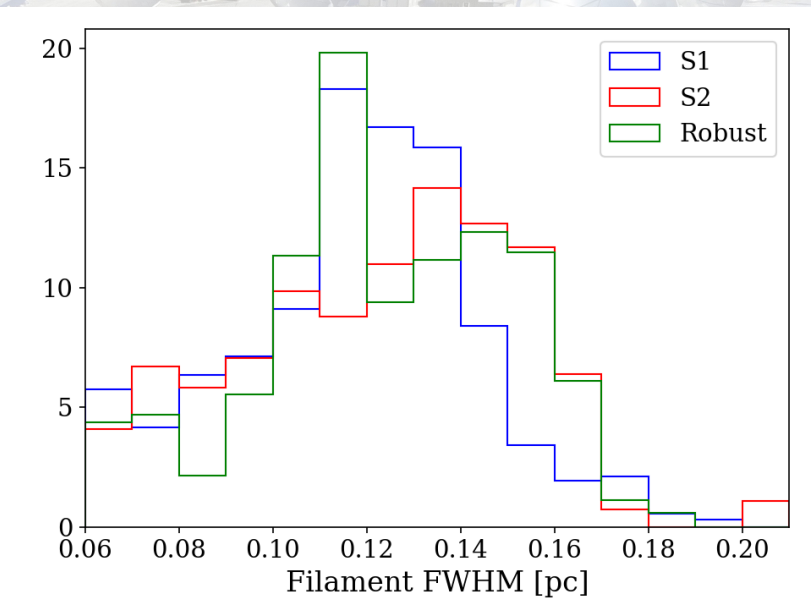

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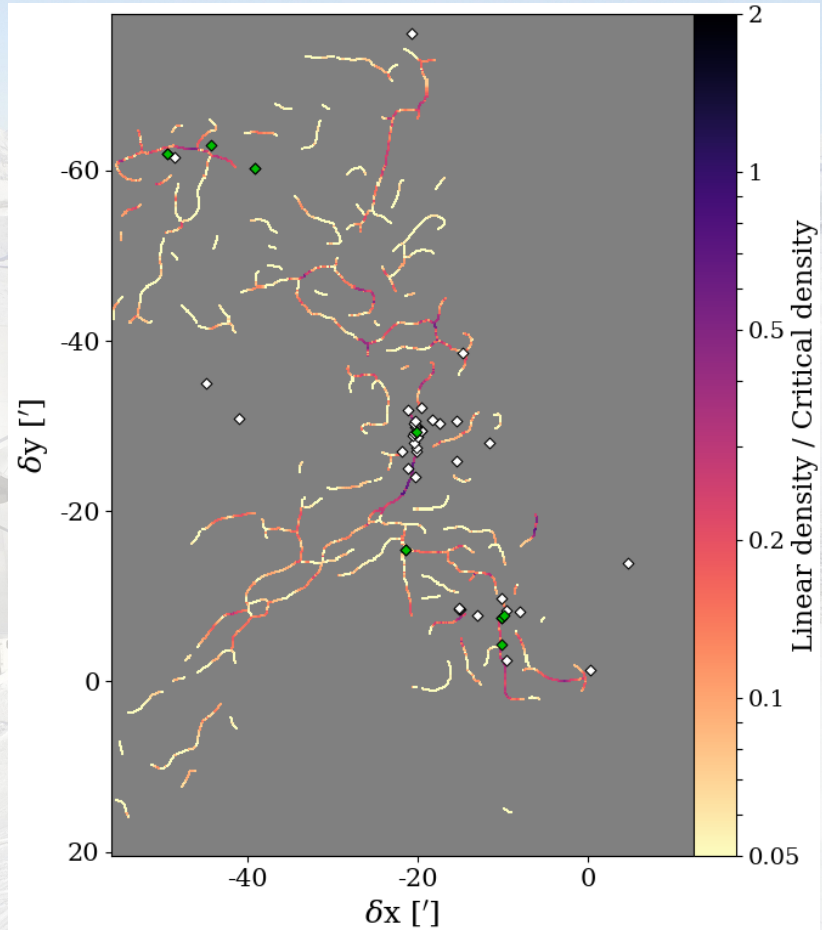

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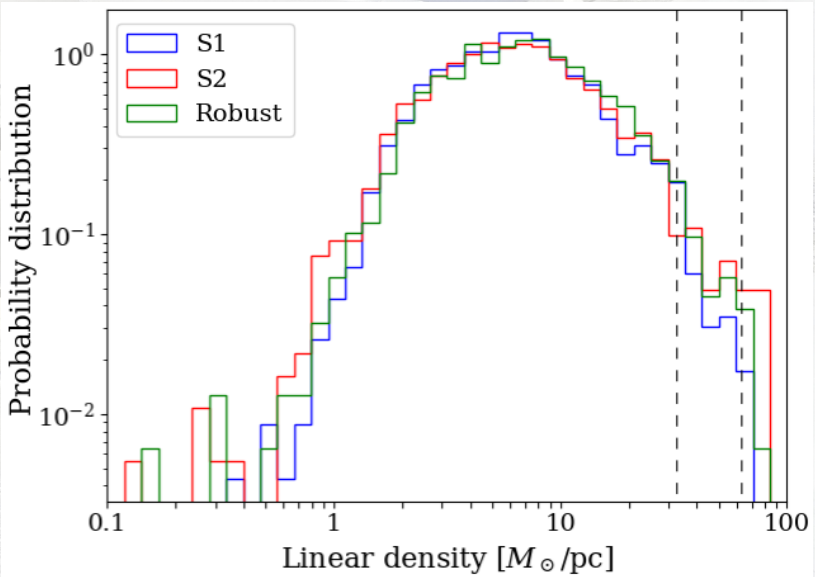
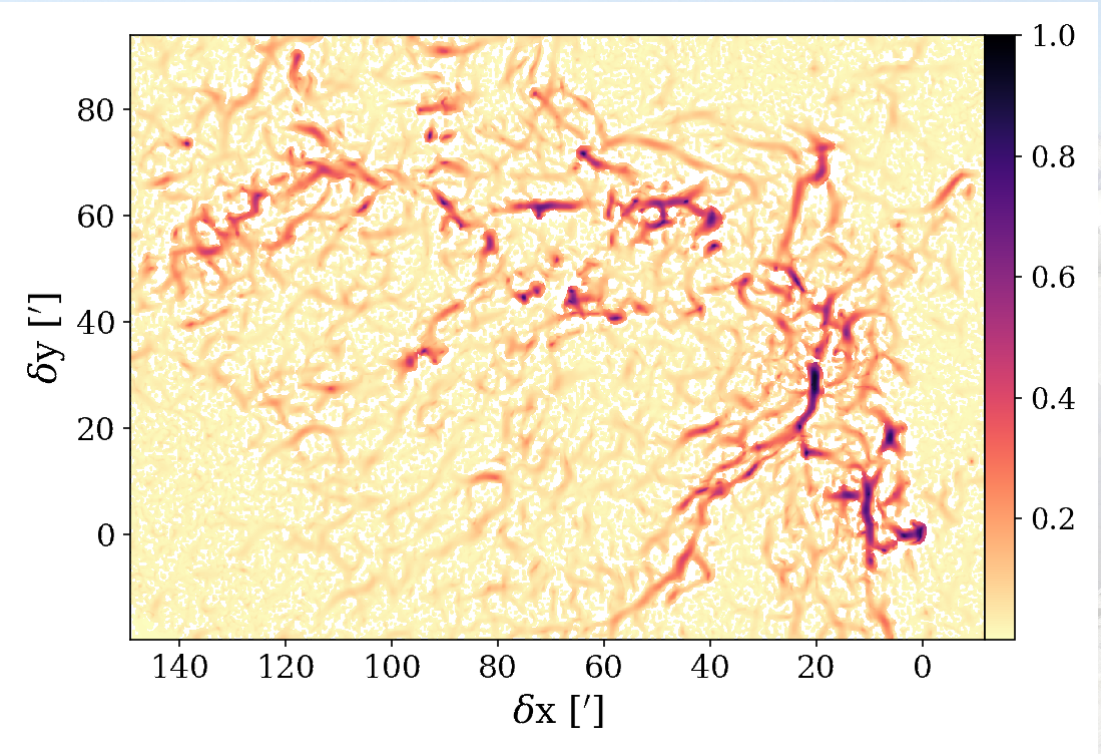


Orkisz et al. 2019

Kinematics of filament formation



Gaudel et al., 2023

- The cloud is more filamentary in the West?

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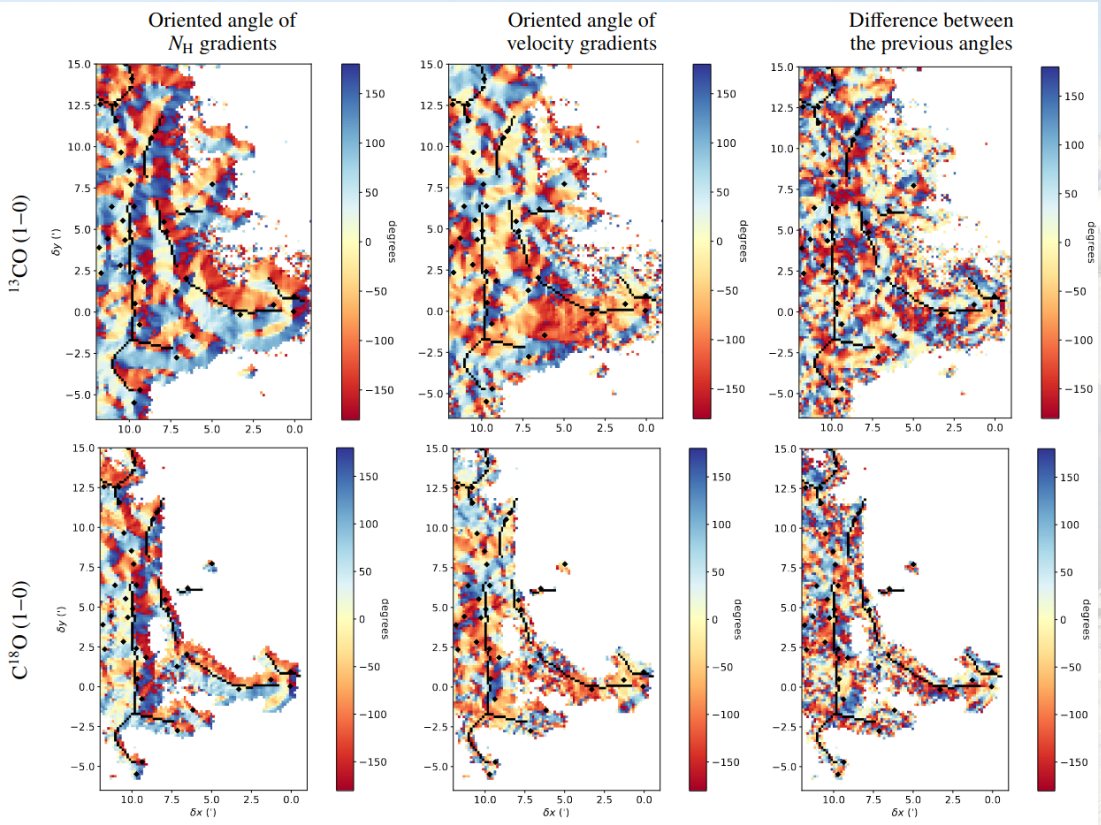
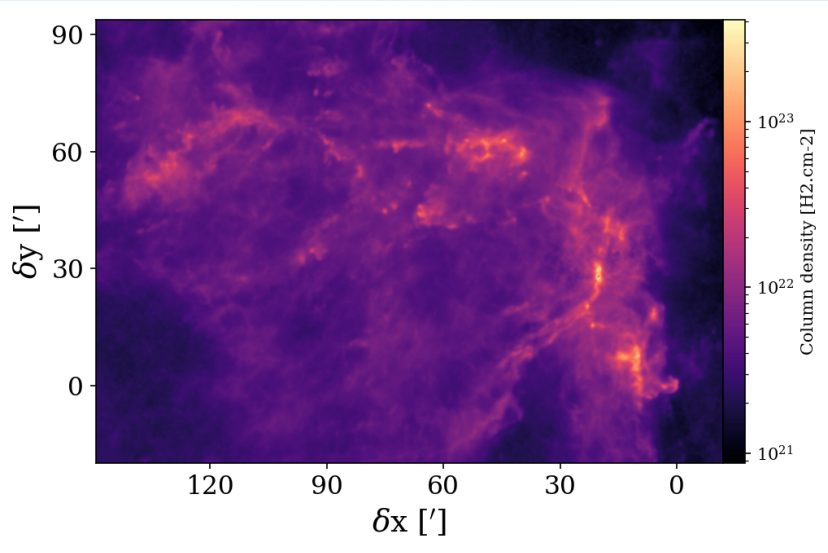


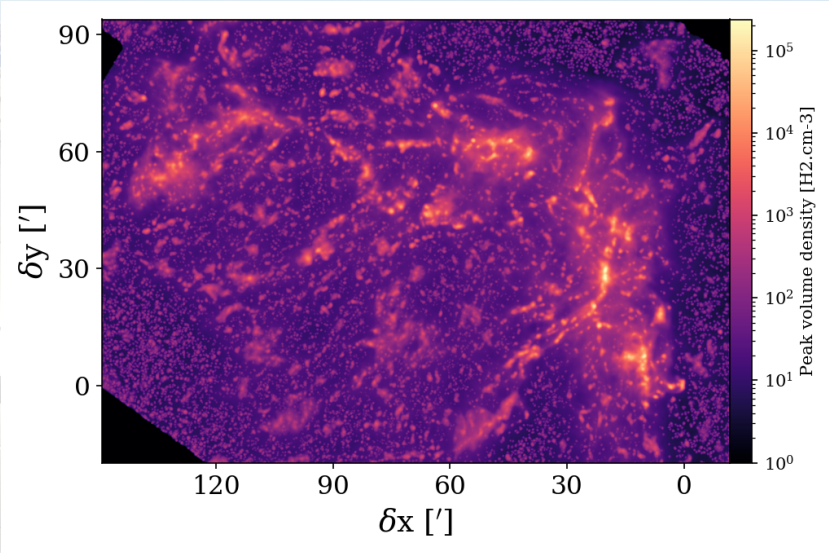
Gaudel et al., 2023

- The cloud is more filamentary in the West?
- HII regions generate a lateral pressure which favours the formation of filaments
- Kinematics around other filaments are dominated by infall

Volume densities from cloud to core scales?

Statistical reconstruction of the volume density in molecular clouds

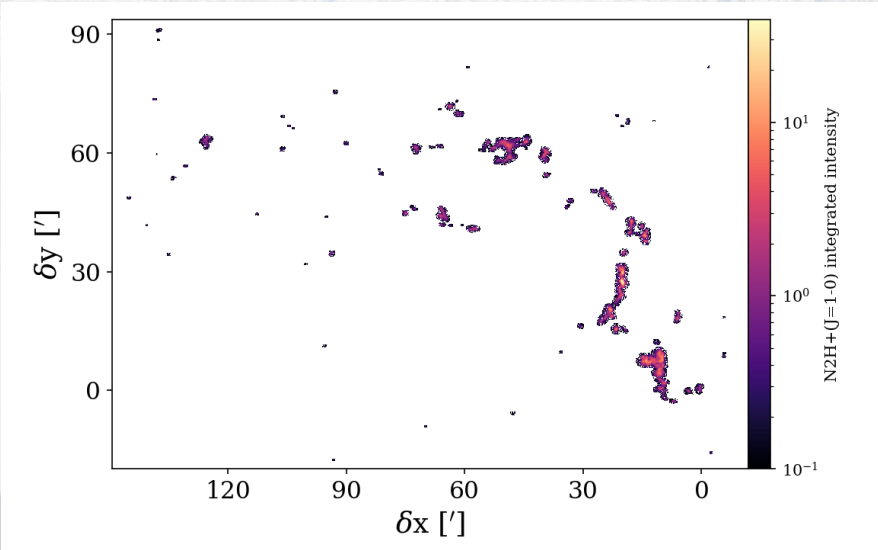




Orkisz & Kainulainen, subm.

- Higher peak volume densities in the West than in the East
- Higher dense gas fraction ($> 2 \times 10^4 \mathrm{H_2.cm^{-3}}$) West vs. East

Chemistry, HII regions, YSO population



- little N_2H^+ detected
  even less in the East

- very young HII regions:
  NGC 2023: 0.1 Myr
  NGC 2024: 0.2 Myr
  Tremblin et al. 2014, Orkisz et al. 2019

- SFE 3-4 times lower than in Orion A

- very high fraction of very young YSOs:
  S-W Orion B: 24%
  Orion A: 1.5%
  Stutz et al. 2013

Evolution of the molecular cloud?

Orion B has a consistent West-East gradient of

- Compressive fraction of turbulence
- Filamentarity of the gas?
- Volume density
- Star formation age

and

- Star formation activity

Compression from HII regions: feedback-driven star formation?

Will Orion B become the next Orion A?