How can the 3D shapes of the local molecular clouds help us better understand star formation?

Sara Rezaei Kh.

Chalmers-MPIA Cosmic Origins Fellow

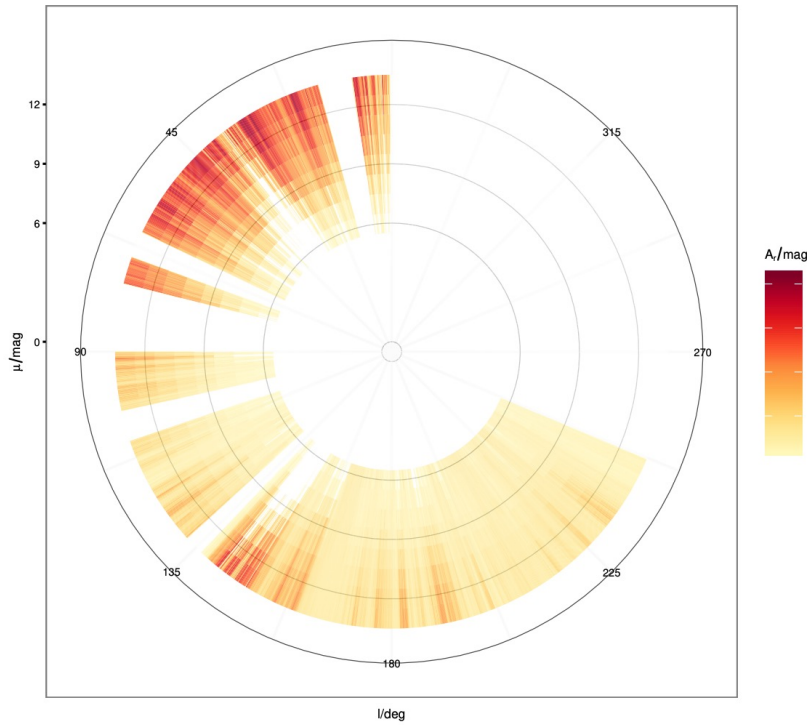sara@mpia.de

Puzzles of star formation
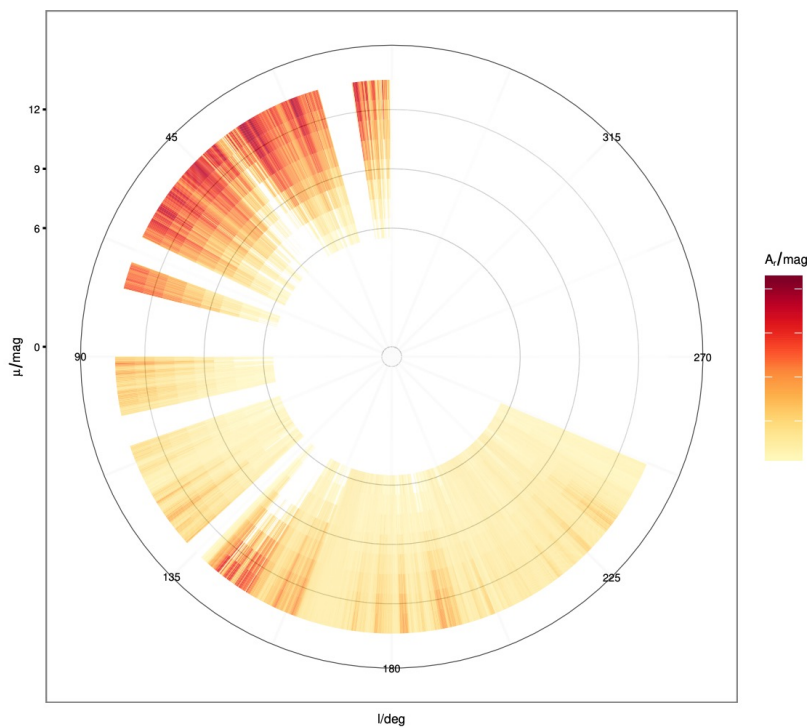
Puzzles of star formation
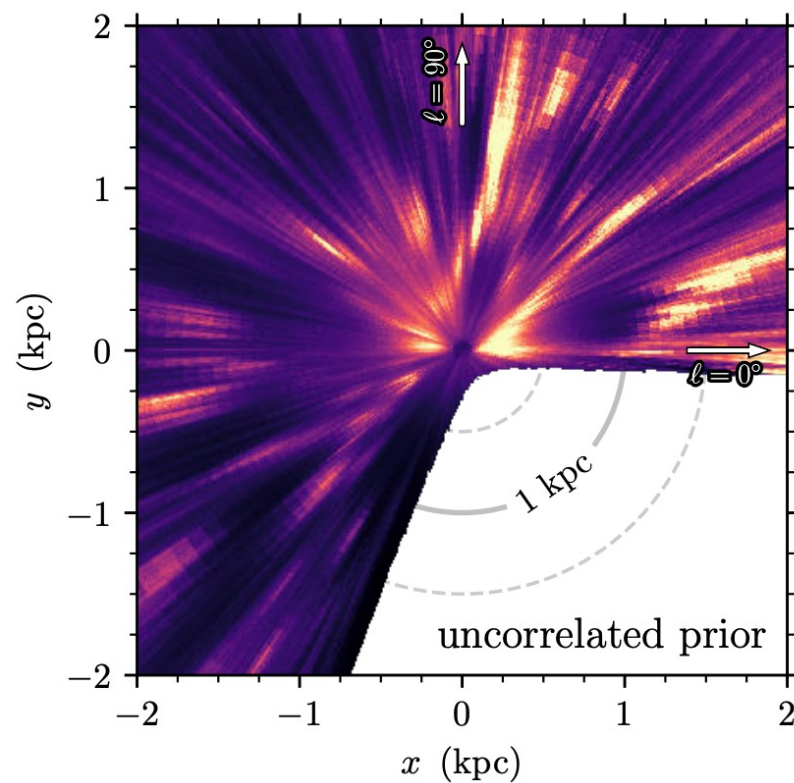
3D maps

An extinction map

Hanson et al. (2016)

3D maps

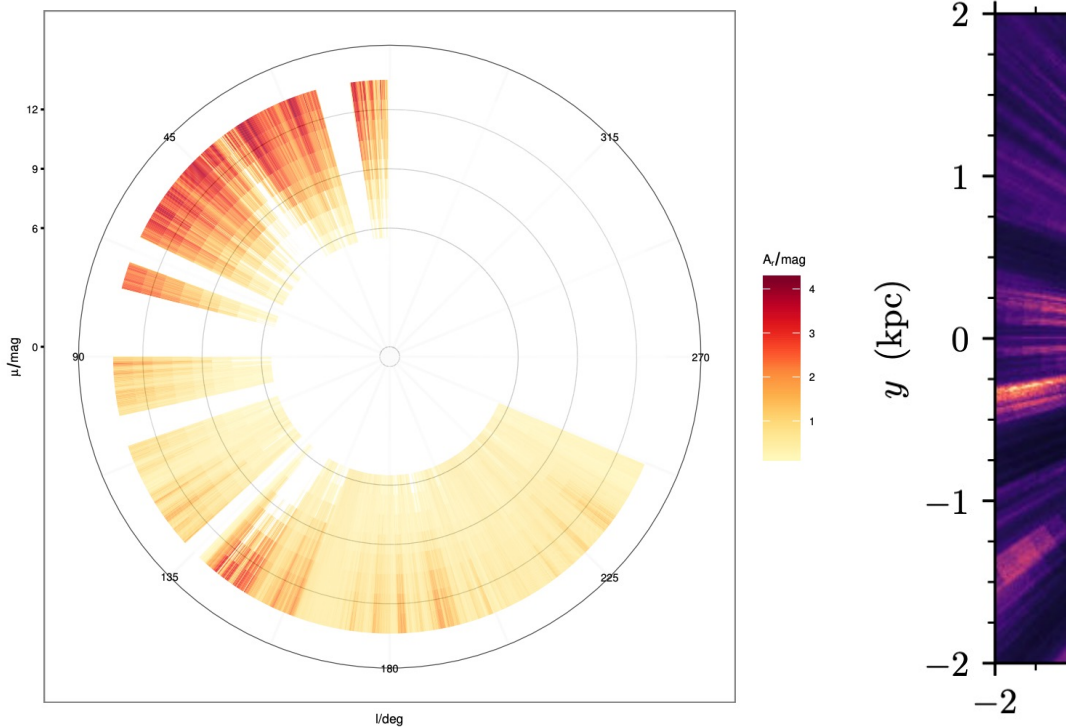An extinction map

Derivative of an extinction map

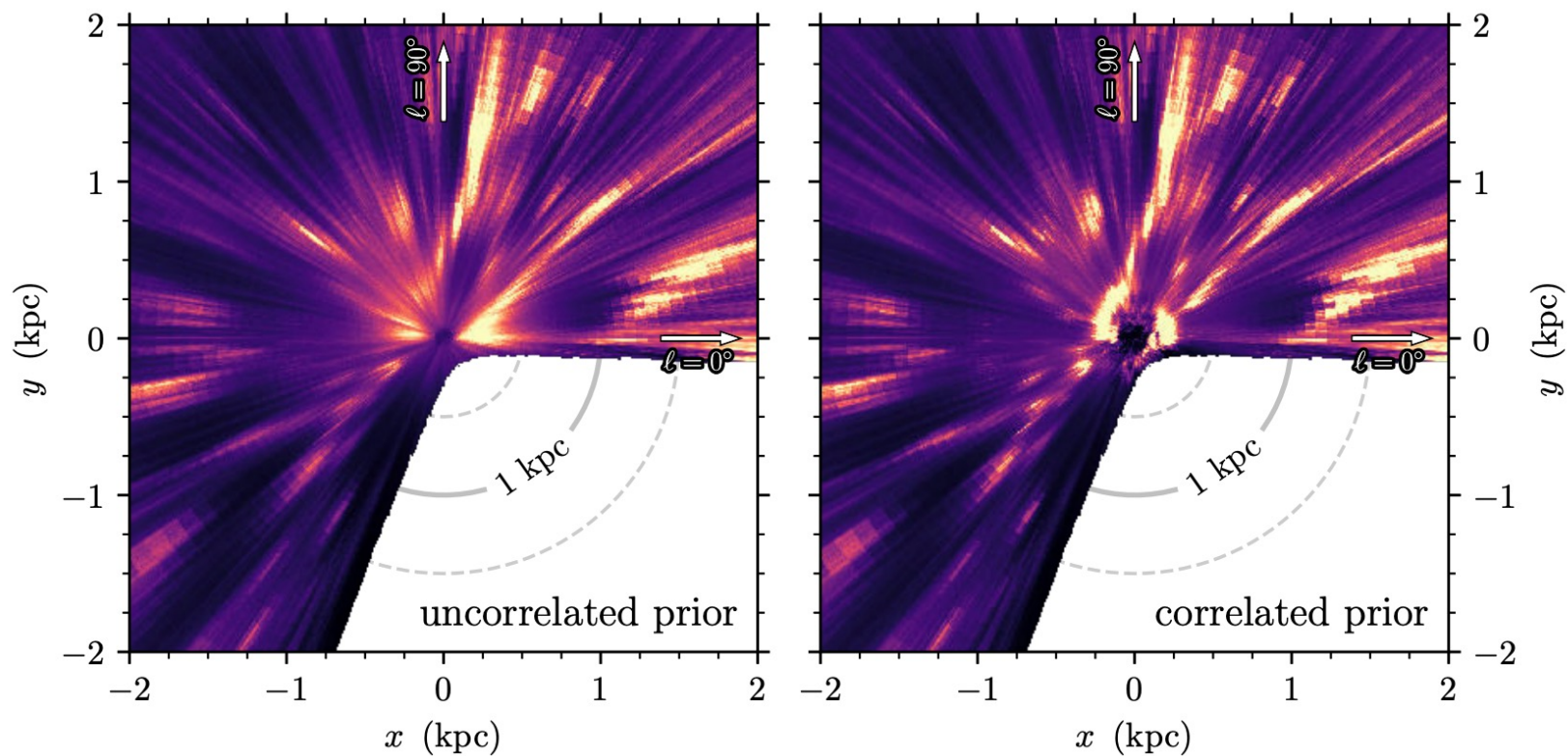Hanson et al. (2016)

Green et al. (2019)

3D maps

An extinction map

Hanson et al. (2016)

Derivative of an extinction map

Green et al. (2019)

How about 3D structure of the molecular clouds?

- Distance uncertainty
- Underlying methods
- Treating each l.o.s individually

Our 3D dust mapping technique
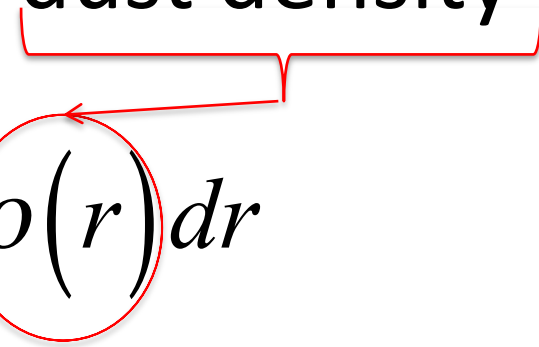
- Directly infer dust density

Our 3D dust mapping technique

- Directly infer dust density

$$A_n \propto \int_0^{r_n} \rho(r)\,dr$$

Our 3D dust mapping technique

- Directly infer dust density

$$A_n \propto \int_0^{r_n} \rho(r) \, dr$$

Our 3D dust mapping technique

- Directly infer dust density

- Non-parametric

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- Neighbouring correlation (Gaussian Process)

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- Distance and extinction uncertainties

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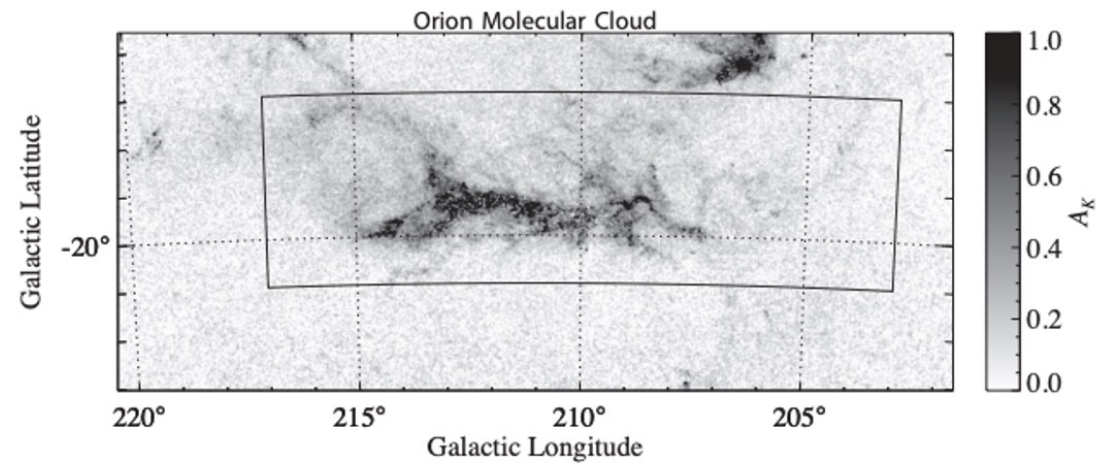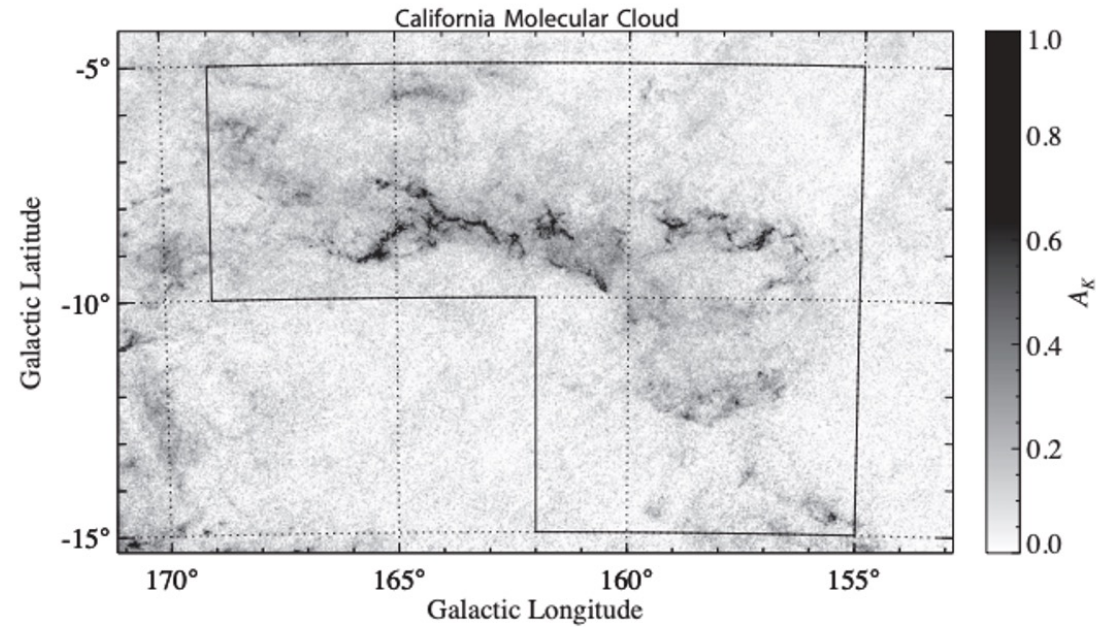Detailed 3D structure of the molecular clouds for the first time

Orion A vs California

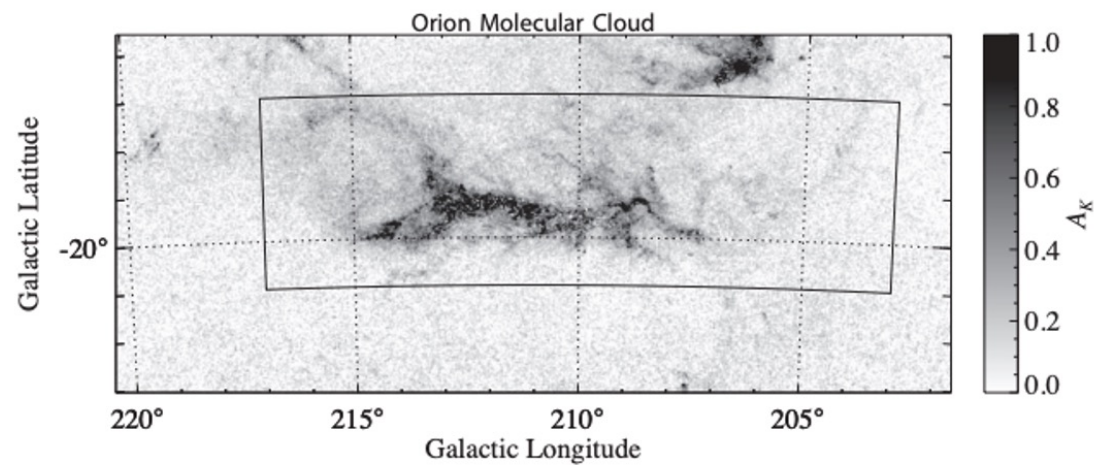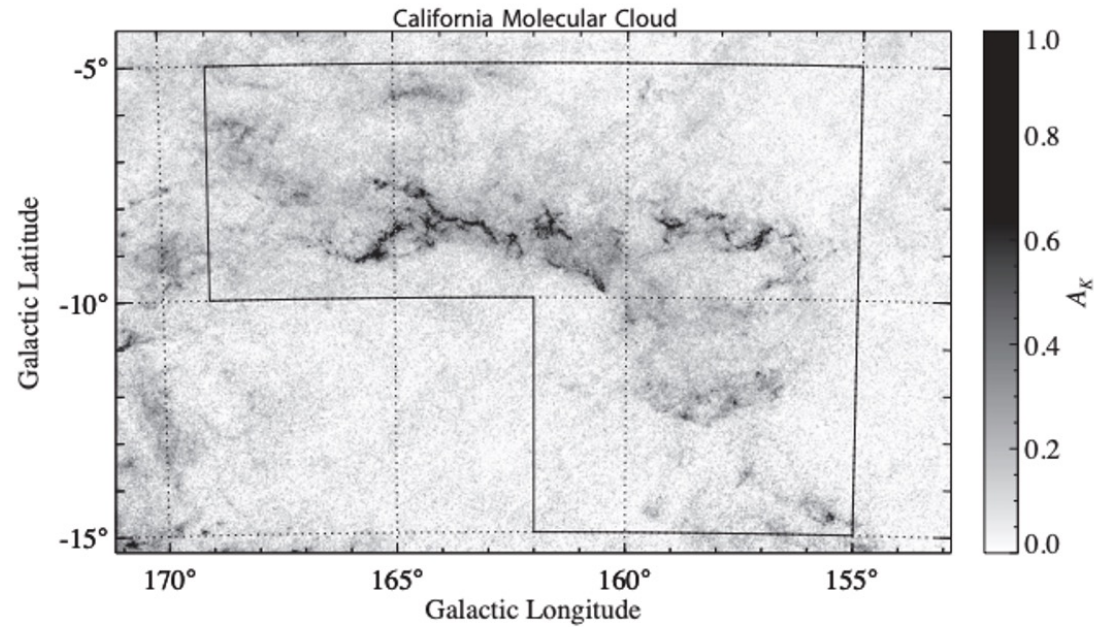

Size

Shape

Kinematics

Mass

Lada+2009

Orion A vs California

Size

Shape

Kinematics

Mass

Star formation

Lada+2009
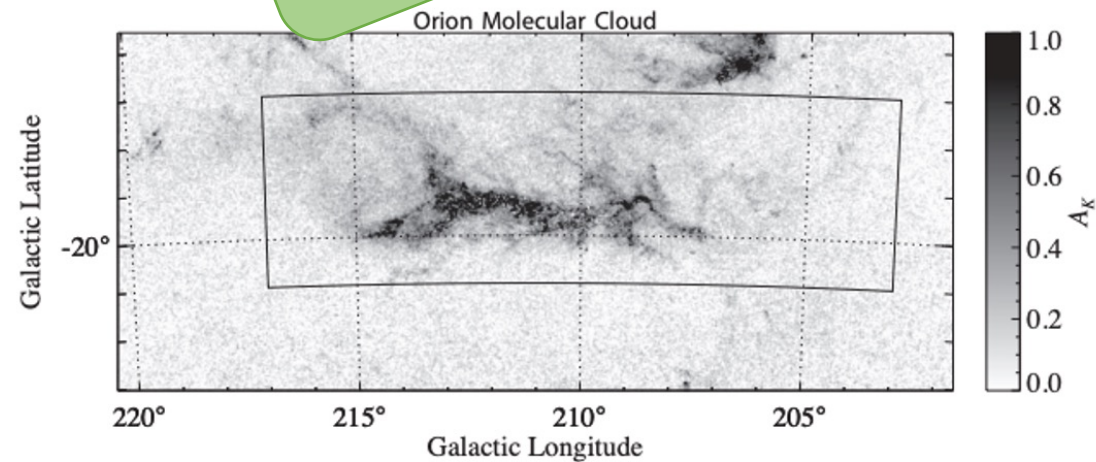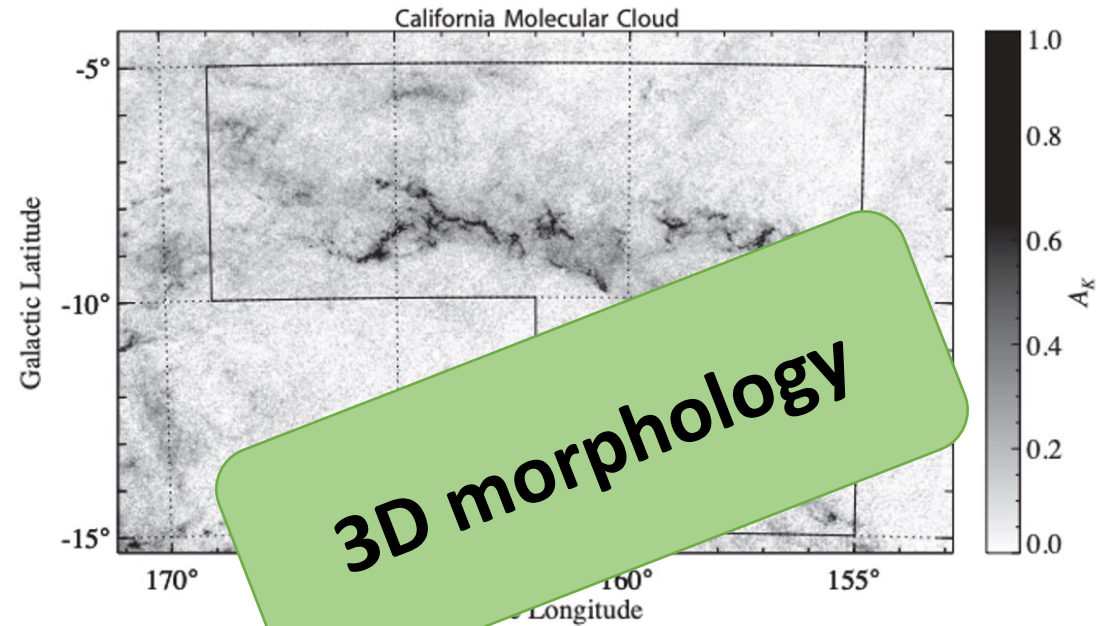
Orion A vs California

Size

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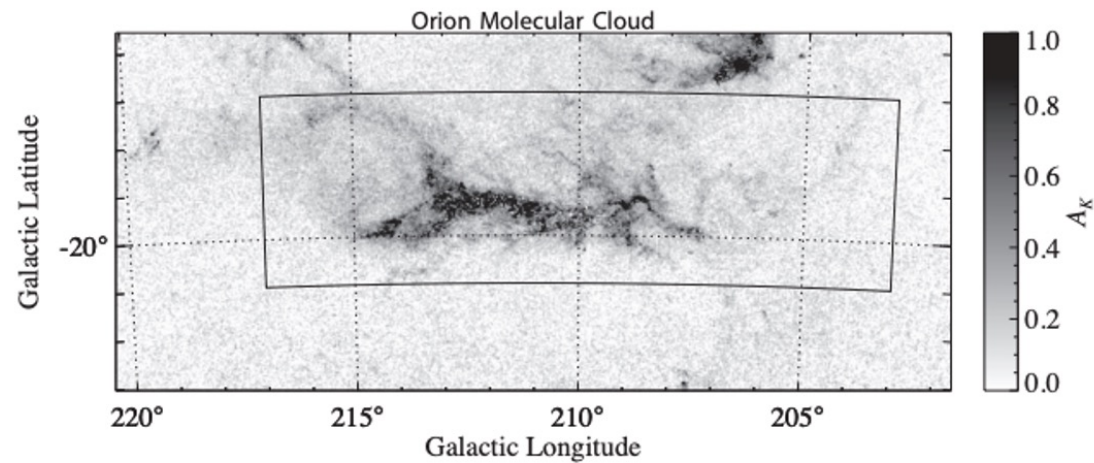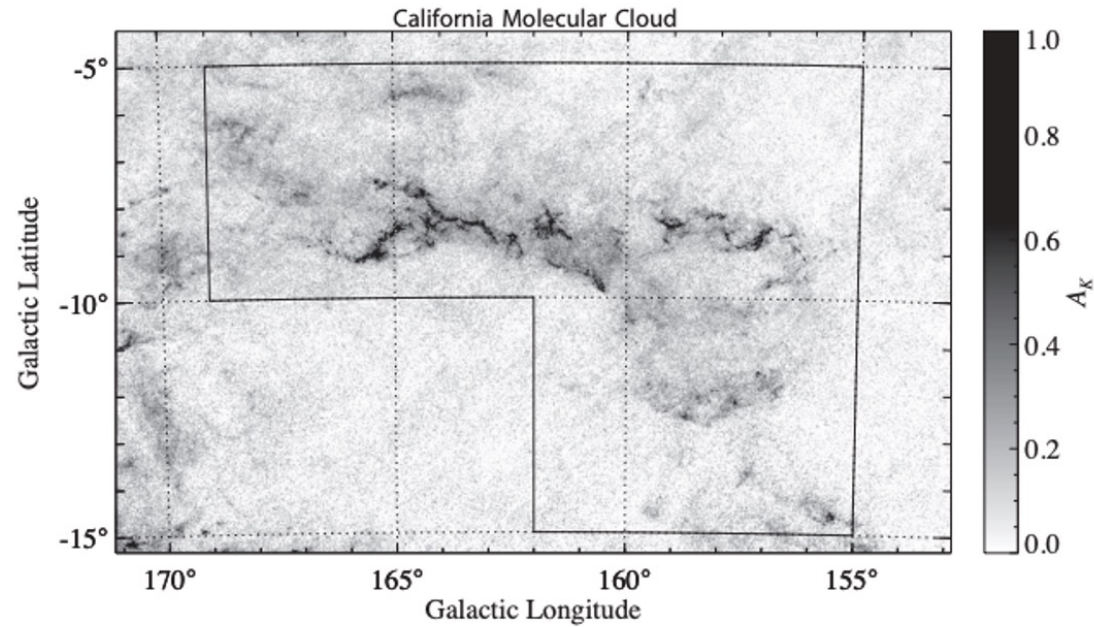3D morphology
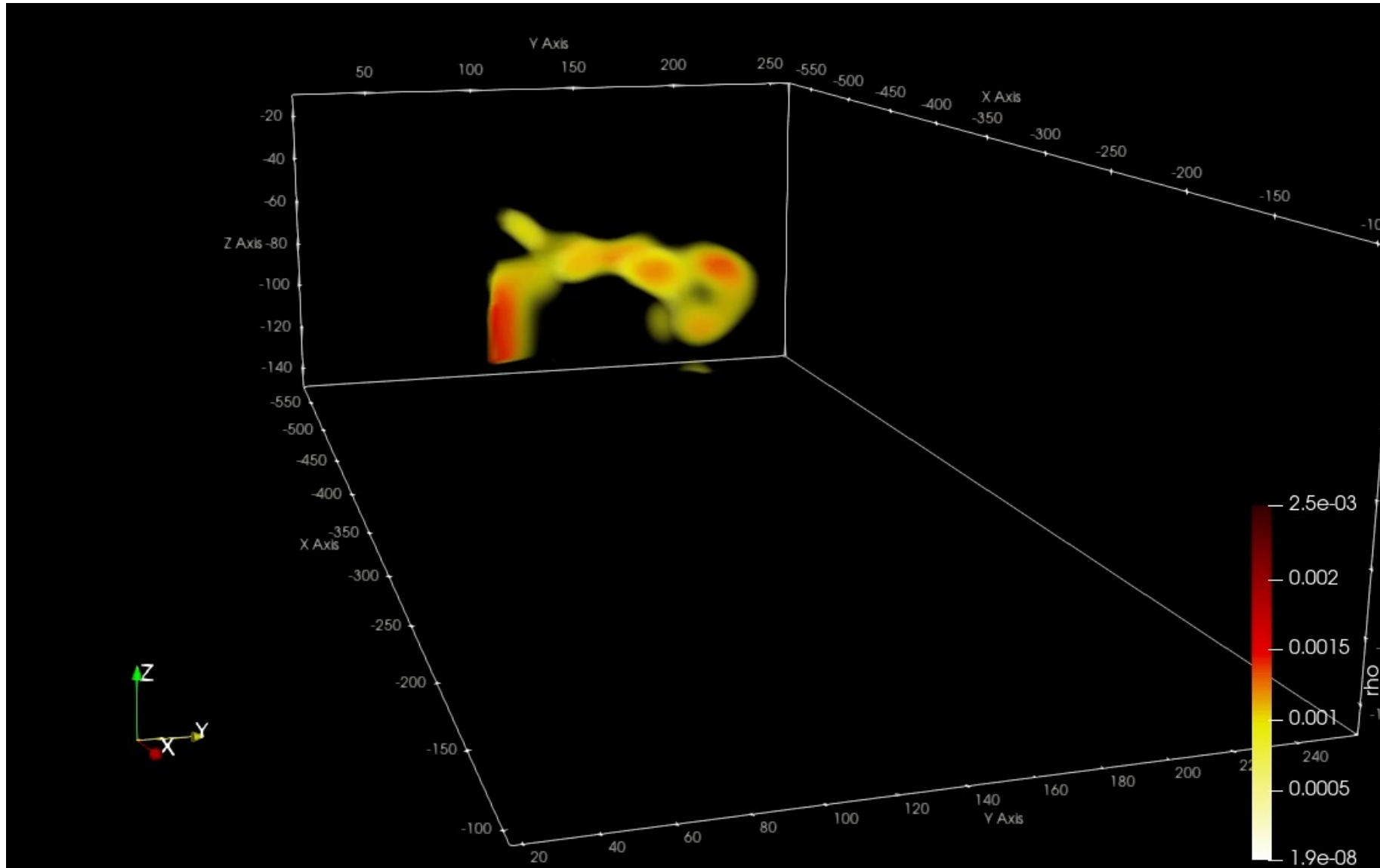
Star formation

California Molecular Cloud

Orion Molecular Cloud

Lada+2009

Orion A – 3D dust distribution

Rezaei Kh. et al. 2020

Animation Credit: T.Müller, MPIA

Orion A vs California

Lada+2009
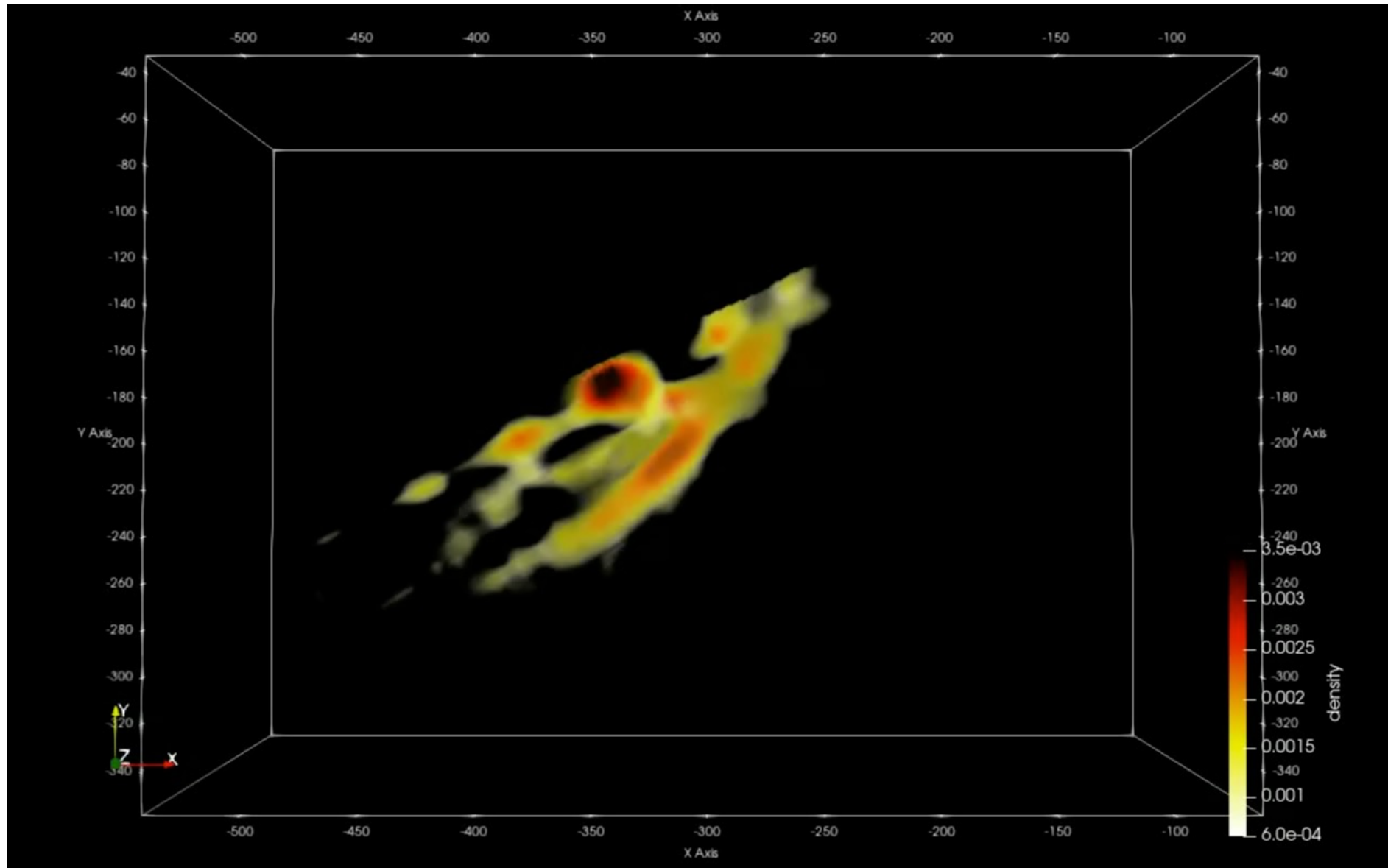
California – 3D dust distribution

Rezaei Kh.+ in prep.

Z

X

Bubble

Z

X

Foreground cloud

Orion B

Orion A - Tail

California Molecular Cloud

Galactic Latitude

$-5°$

$-10°$

$-15°$

Galactic Longitude

$170°$ $165°$ $160°$ $155°$

A_K

1.0

0.8

0.6

0.4

0.2

0.0

Orion Molecular Cloud

Galactic Latitude

$-20°$

Galactic Longitude

$220°$ $215°$ $210°$ $205°$

A_K

1.0

0.8

0.6

0.4

0.2

0.0

Lada+2009
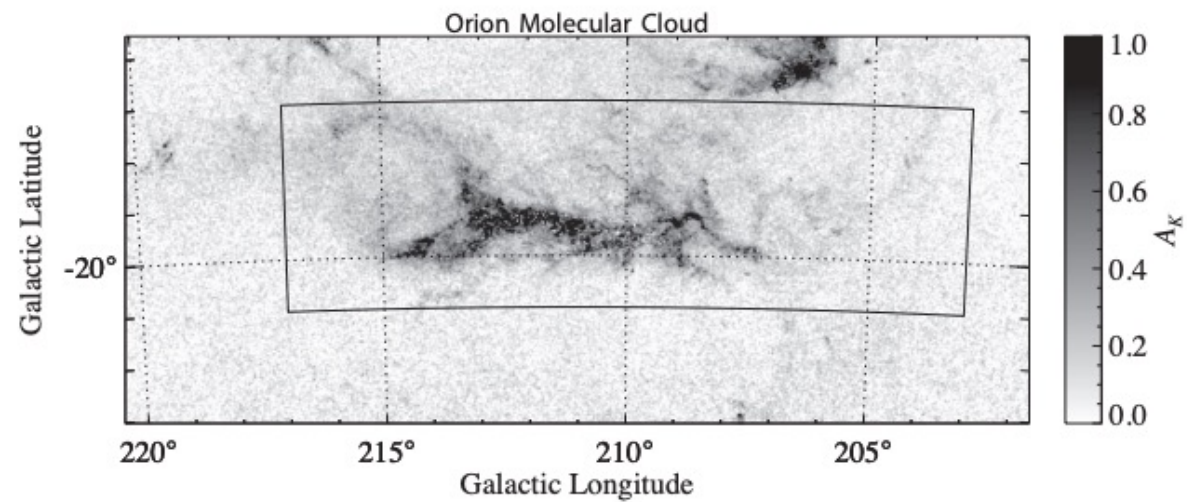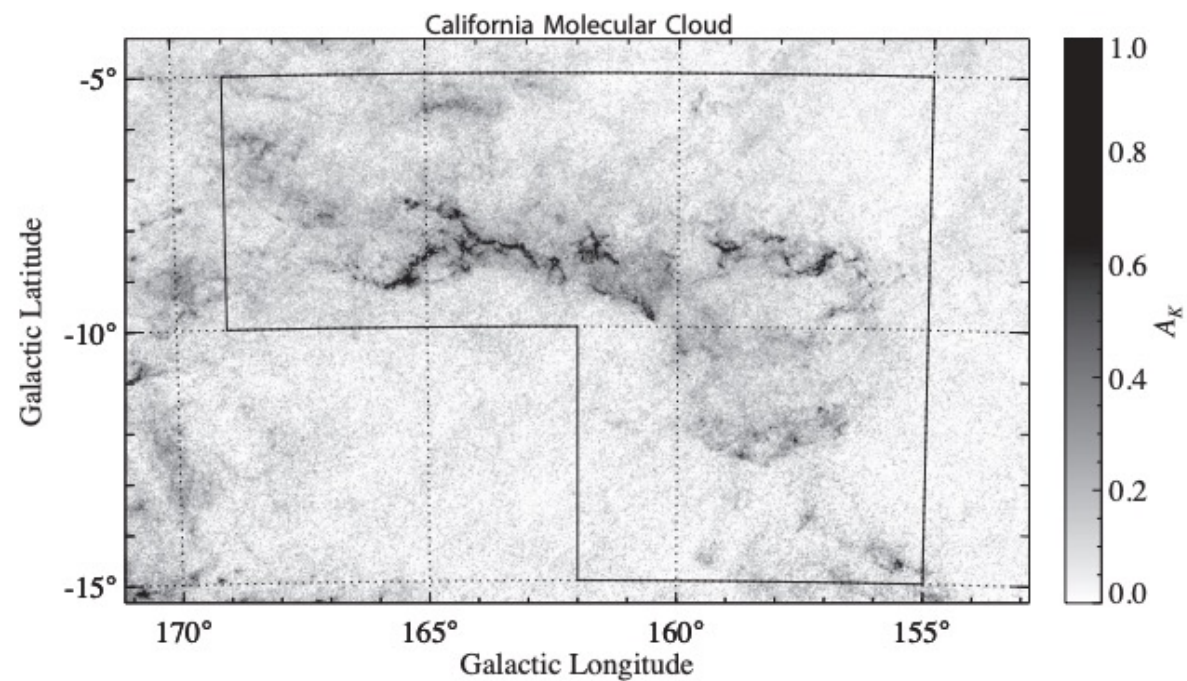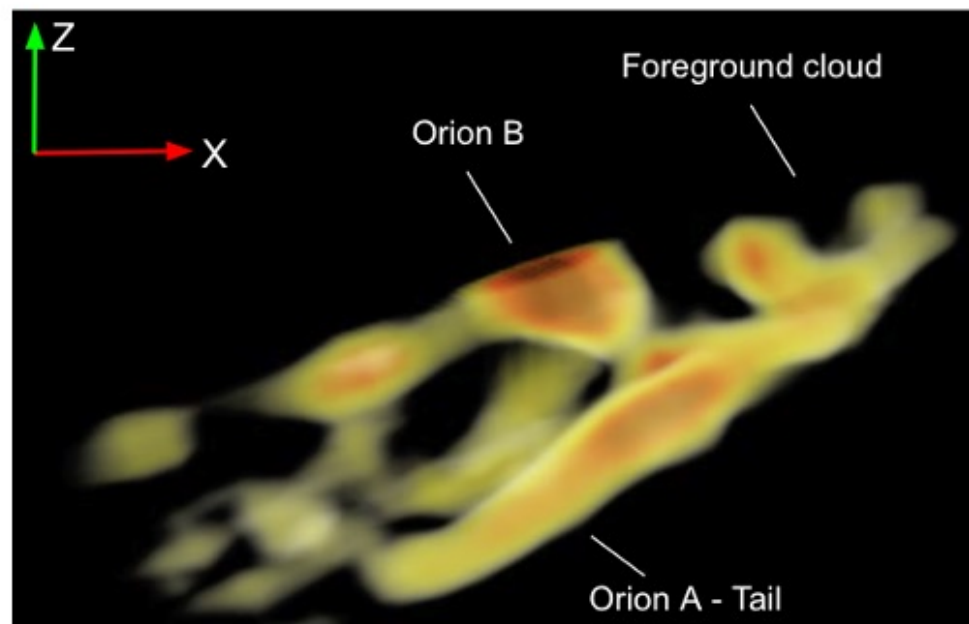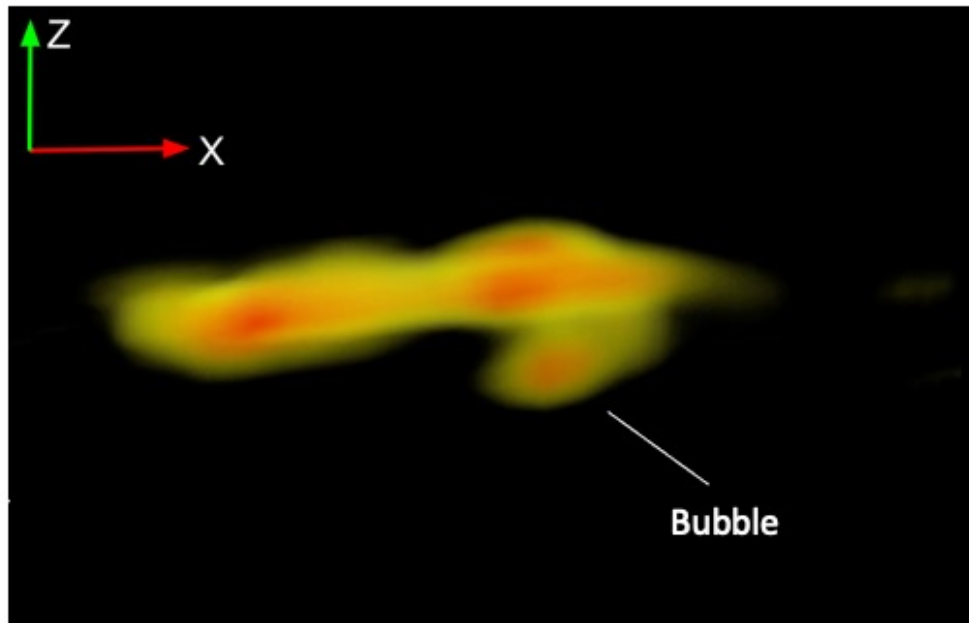
Orion A vs California

Orion A vs California

- Not similar in shape;
  - Orion A: filamentary, feedback
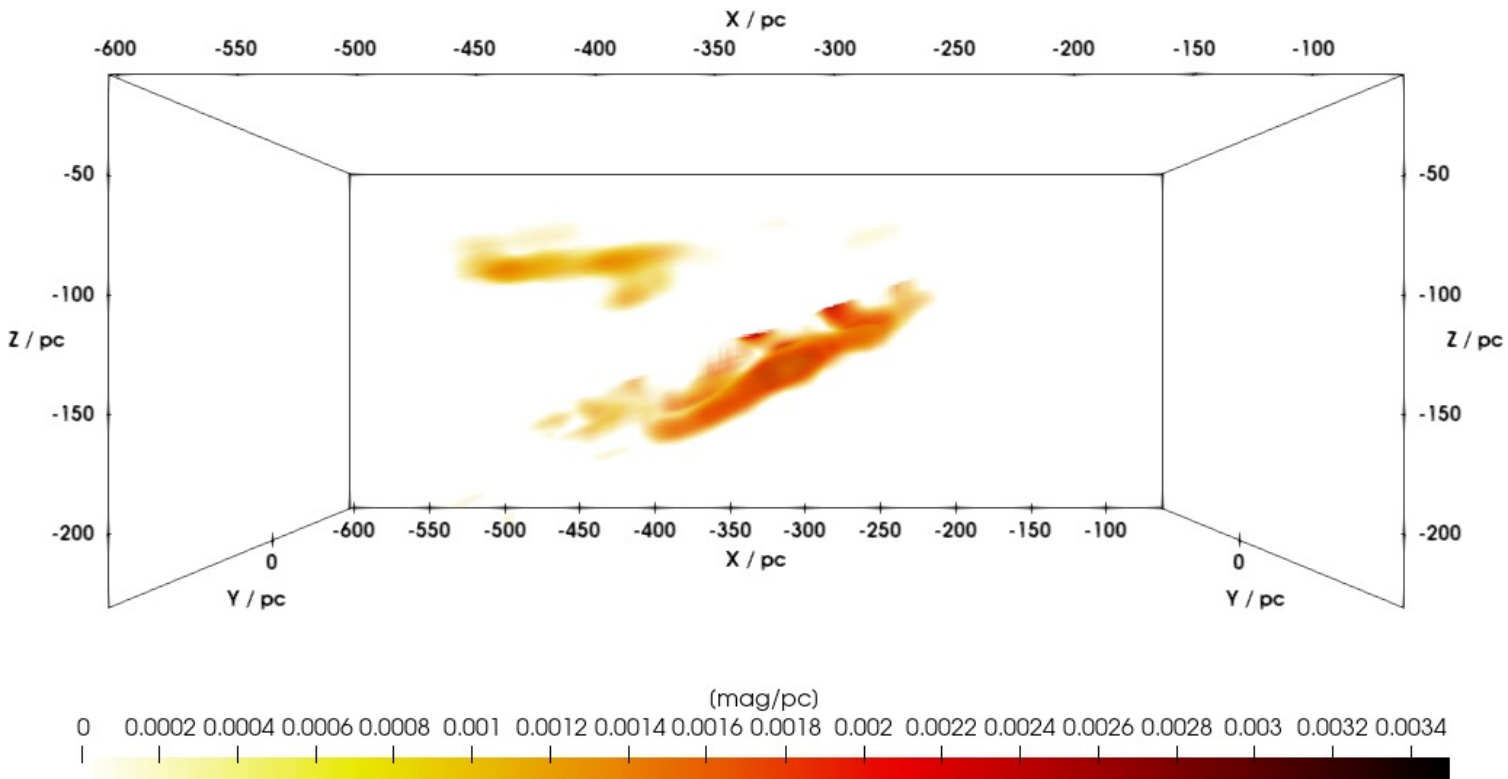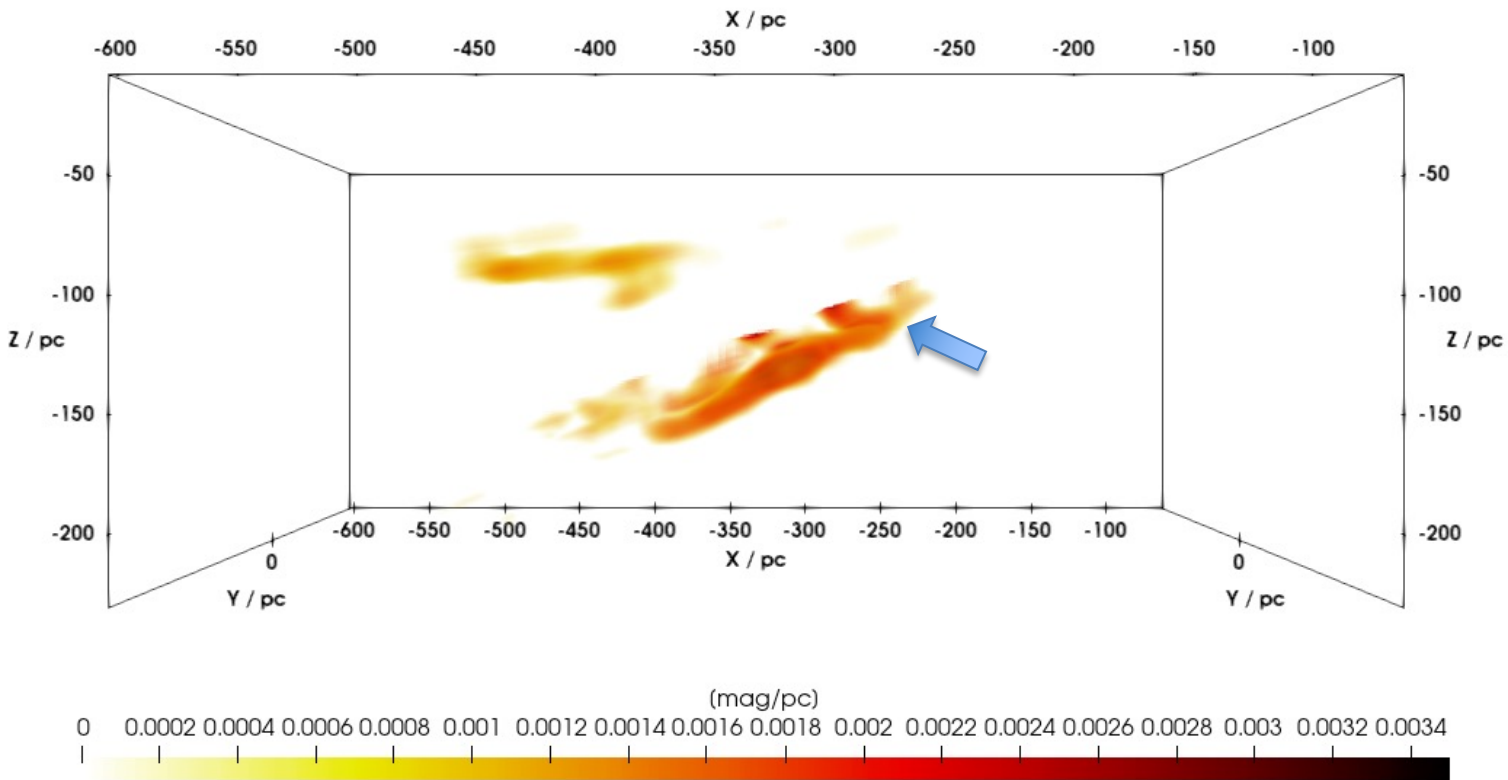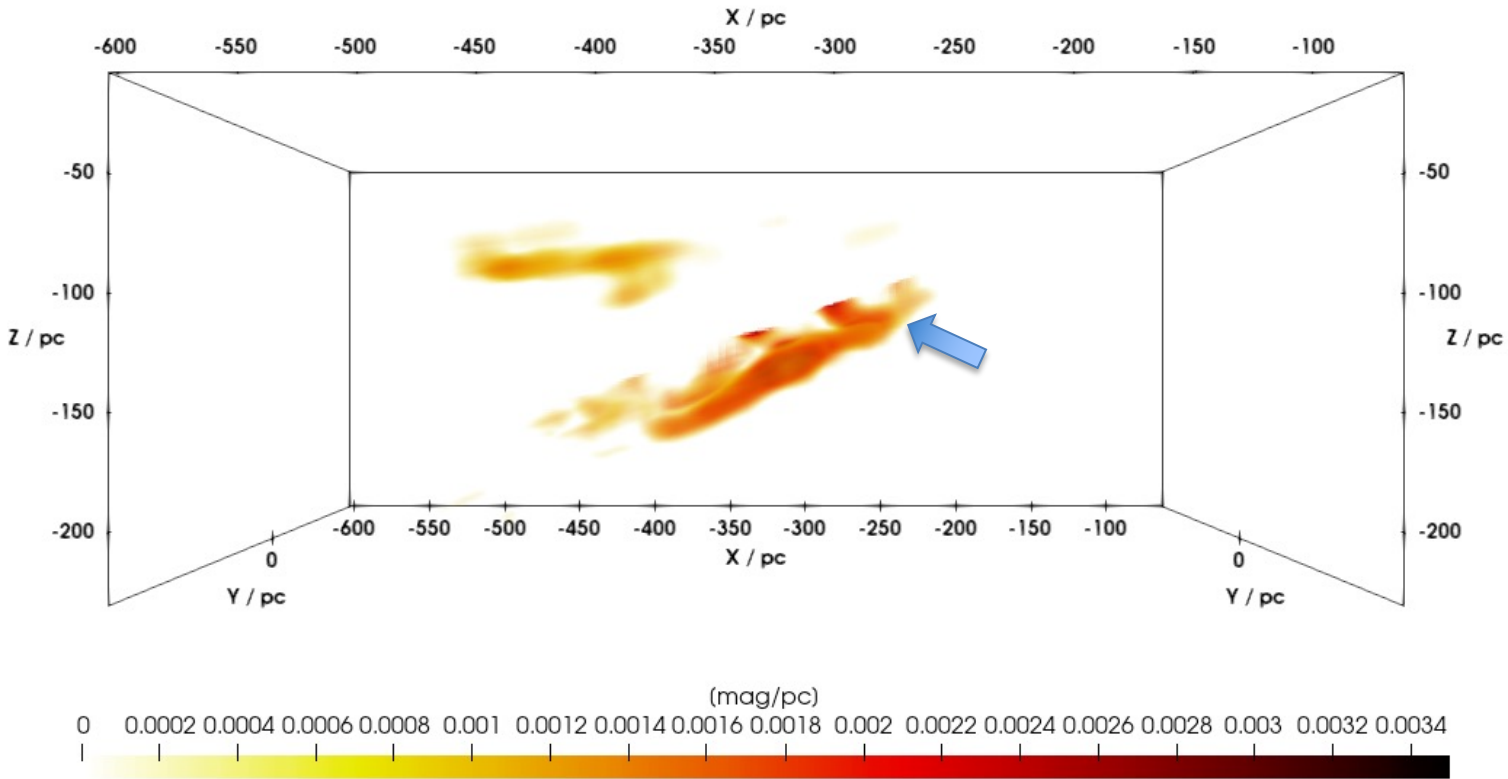   California: sheet

- Higher density substructures in Orion A

Orion A vs California

- Not similar in shape;
  - Orion A: filamentary, feedback California: sheet

- Higher density substructures in Orion A

- Age difference (Orion A foreground older populations)

Rezaei Kh.+ in prep.

Orion A vs California

(mag/pc)
0   0.0002 0.0004 0.0006 0.0008 0.001 0.0012 0.0014 0.0016 0.0018 0.002 0.0022 0.0024 0.0026 0.0028 0.003 0.0032 0.0034
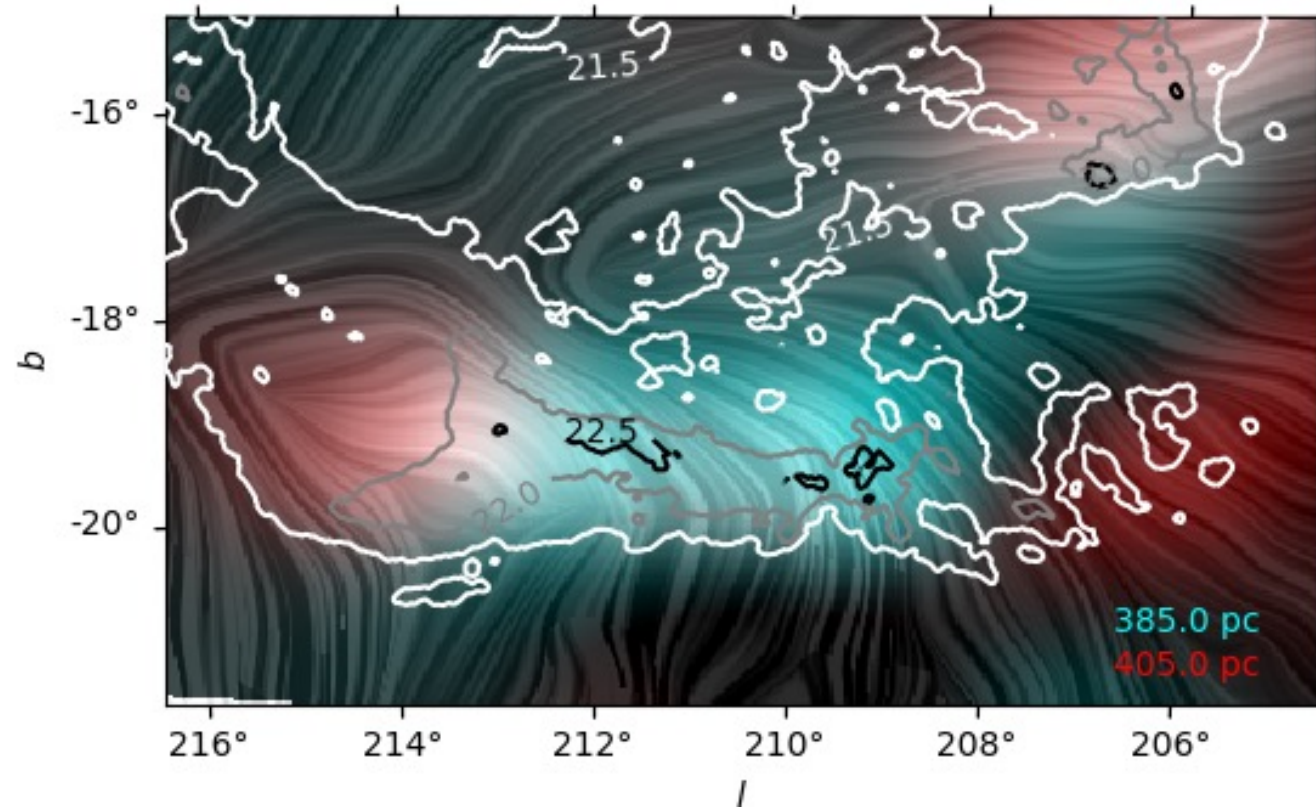
SFR ✔

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Rezaei Kh.+ in prep.

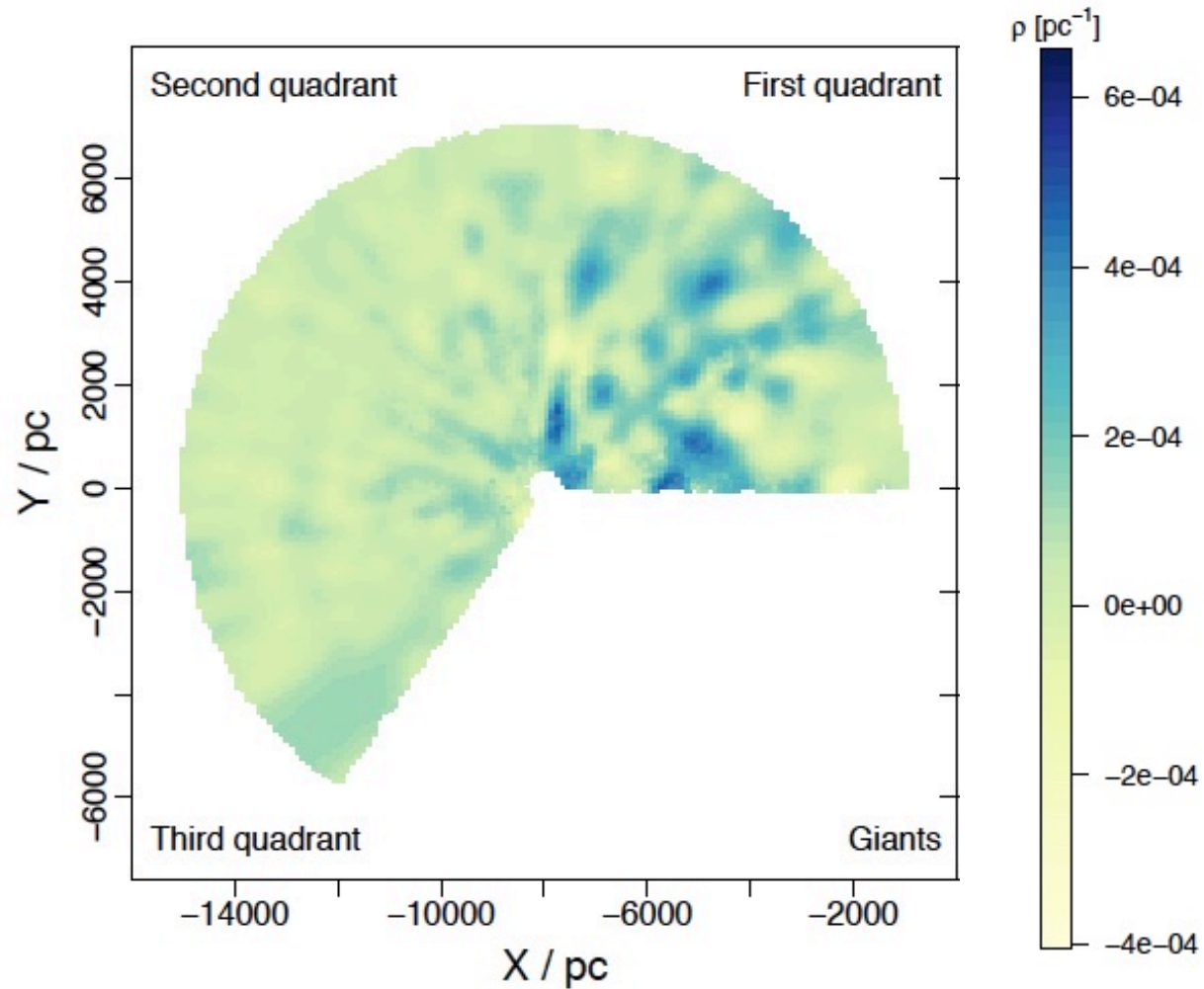# 3D dust map and Magnetic fields

Rezaei Kh. et al. 2020

Contours: dust column density from Planck
Drapery pattern: magnetic field orientation
(Planck 353-GHz polarization)

Galactic structure

Galactic structure

Rezaei Kh. et al. 2018 b

Questions!

- Are filaments filaments?

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- K-S relation in the MW?

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- Cloud structure; self-regulated / environment?

Questions!

- Are filaments filaments?

- K-S relation in the MW?

- Cloud structure; self-regulated / Galactic potential?

- Connecting gas and dust and stars?