The Critical Role of Galactic Dynamics in Regulating the Spatial Structure, Kinematics, and SFR

P22

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Emmy Noether-Programm DFG
DFG Deutsche Forschungsgemeinschaft
SFB 881

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Defining features of Central Molecular Zone (CMZ): a unique laboratory

- ✦ Gas occupies a stream on an eccentric orbit of R ~ 60-120 pc

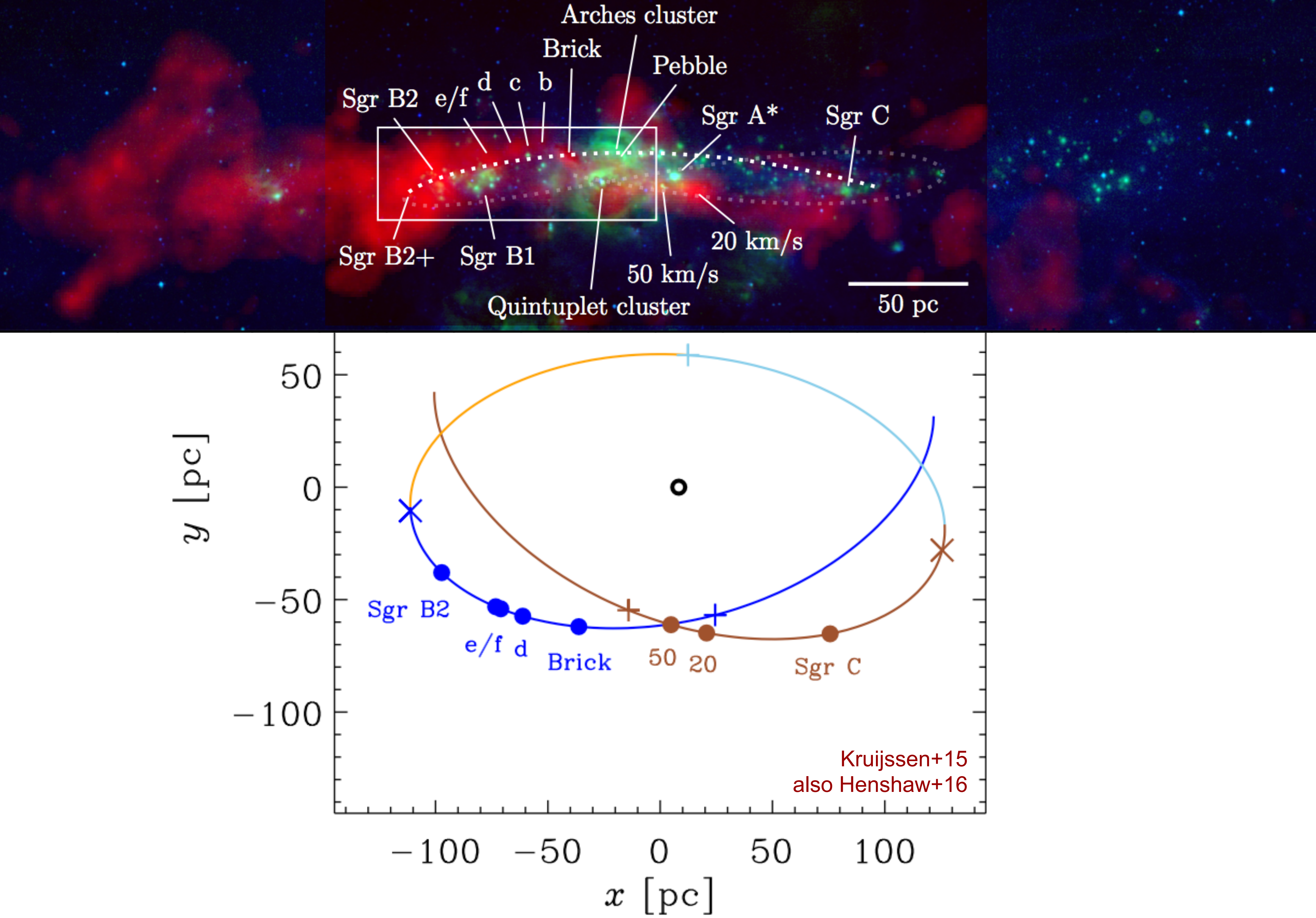
  Molinari+11; Longmore+13b; Kruijssen+15; Henshaw+16

- ✦ Fully compressive tidal field at R = 40-120 pc

  Kruijssen+15; Lucas 15; Kruijssen+18

- ✦ Strong shear with V/R ~ 1.7 Myr^{-1} (~100x higher than at solar radius)

  Krumholz & Kruijssen 15; Krumholz+17; Jeffreson+18


Arches cluster
Brick
Pebble
Sgr B2
e/f
d
c
b
Sgr A*
Sgr C
Sgr B2+
Sgr B1
20 km/s
50 km/s
Quintuplet cluster
50 pc
y [pc]
50
0
−50
−100
Sgr B2
e/f
d
Brick
50
20
Sgr C
Kruijssen+15
also Henshaw+16
−100
−50
0
50
100
x [pc]

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In the CMZ, galactic dynamics affect cloud evolution

$$\sigma_{\rm virial} = 0.52\,{\rm km\,s^{-1}} \left(\frac{\Sigma_{\rm GMC}}{10^2\,{\rm M_\odot\,pc^{-2}}}\right)^{1/2} \left(\frac{R}{1\,{\rm pc}}\right)^{1/2}$$

Heyer+09

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$$\sigma_{\rm shear} = 0.67\,{\rm km\,s^{-1}} \left(\frac{\Omega_{\rm rot}}{1.7\,{\rm Myr^{-1}}}\right) \left(\frac{R}{1\,{\rm pc}}\right)\ ({\rm CMZ})$$ Kruijssen+18

$$\sigma_{\rm shear} = 0.30\,{\rm km\,s^{-1}} \left(\frac{\Omega_{\rm rot}}{0.026\,{\rm Myr^{-1}}}\right) \left(\frac{R}{10\,{\rm pc}}\right)\ ({\rm solar\ neighbourhood})$$

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$$\left(\frac{n_{\rm GMC}}{3.0\ {\rm cm^{-3}}}\right)^{1/2} < \left(\frac{\Omega_{\rm rot}}{0.026\ {\rm Myr^{-1}}}\right)\ \text{(solar neighbourhood)}$$

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dense GMC

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warm neutral medium

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galactic dynamics affect 50 cm^{-3} cloud for R < 2 kpc (within Galactic bar!)

Role of Galactic Dynamics in Shaping CMZ Clouds

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The dynamical evolution of molecular clouds near the Galactic Centre – II. Spatial structure and kinematics of simulated clouds

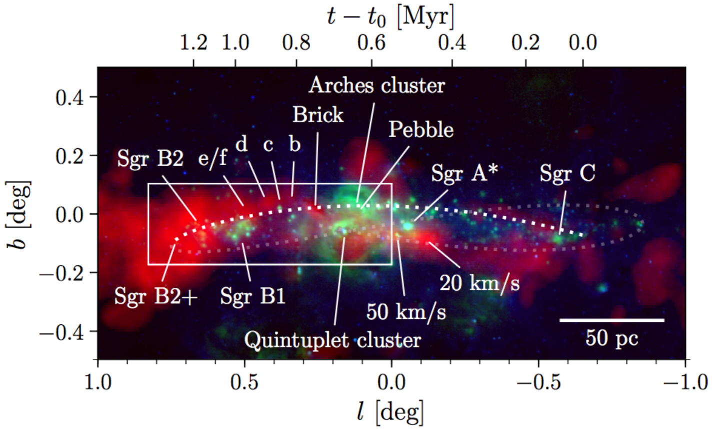
MNRAS submitted

J. M. D. Kruijssen,[1,2★] J. E. Dale,[3] S. N. Longmore,[4] D. L. Walker,[5,6] J. D. Henshaw,[2] A. Ginsburg,[7] S. M. R. Jeffreson,[1] A. T. Barnes,[4,8] C. D. Battersby,[9] K. Immer,[10] J. M. Jackson,[11] E. R. Keto,[12] N. Krieger,[2] E. A. C. Mills,[13] Á. Sánchez-Monge,[14] A. Schmiedeke,[8] S. T. Suri[14] and Q. Zhang[12]

The dynamical evolution of molecular clouds near the Galactic Centre – III. Tidally–induced star formation in protocluster clouds

MNRAS submitted next week

James E. Dale[1], J. M. Diederik Kruijssen[2] and S. N. Longmore[3]



$t - t_0$ [Myr]
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.4
0.2
0.0
−0.2
−0.4
b [deg]
Arches cluster
Brick
Pebble
d
c
b
Sgr B2
e/f
Sgr A*
Sgr C
20 km/s
Sgr B2+
Sgr B1
50 km/s
Quintuplet cluster
50 pc
1.0
0.5
0.0
−0.5
−1.0
l [deg]

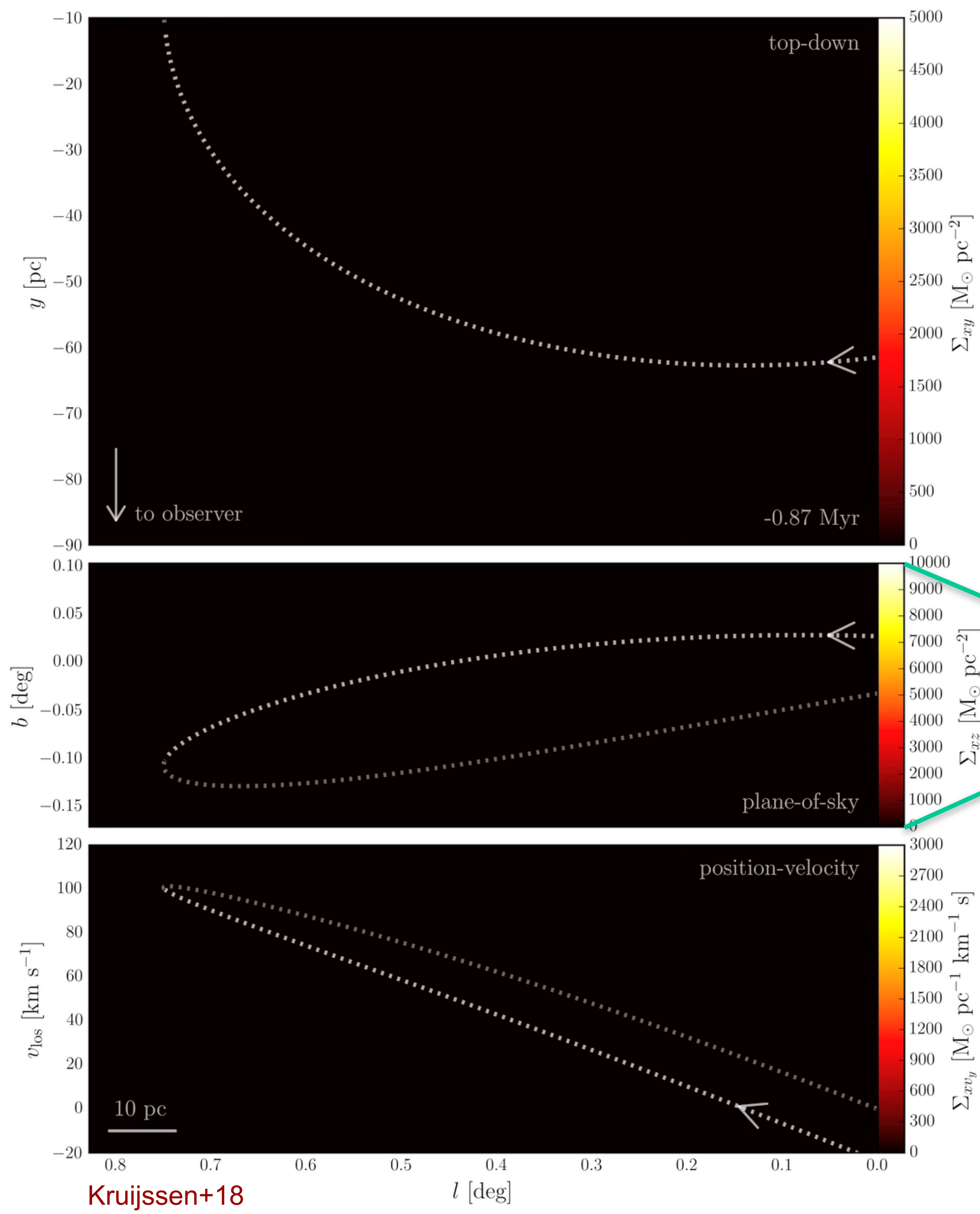
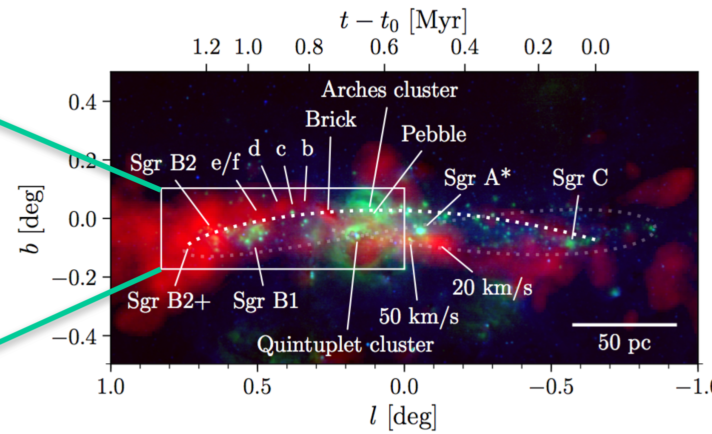
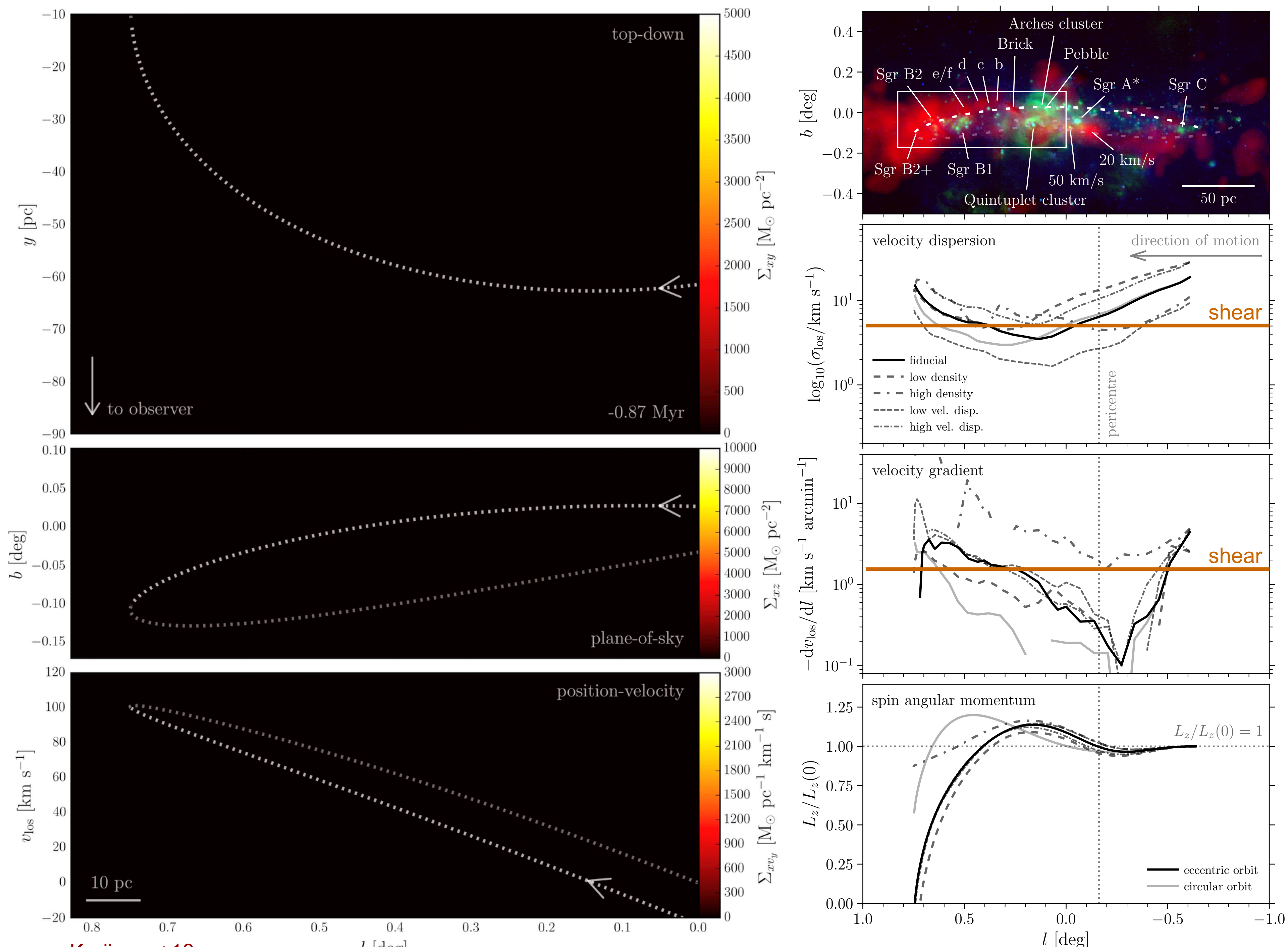


Table 1. Initial conditions of the simulations.

Simulation	M	R_t	σ	α_{vir}	ρ	Σ	t_{ff}
fiducial	7.7	13.6	24.1	9.4	1.3	1.3	0.94
low density	13.4	23.5	41.2	27.4	0.4	0.8	1.63
high density	4.5	7.8	13.9	3.1	3.8	2.3	0.54
low vel. disp.	1.0	6.8	12.1	9.4	1.3	0.7	0.94
high vel. disp.	26.1	20.4	36.2	9.4	1.3	2.0	0.94

Note: All listed quantities are evaluated over the full volume of the clouds, i.e. out to the truncation radius R_t, which is about 1.7 times the half-mass radius. Units: M in 10^5 $M_\odot$, R_t in pc, σ in km s^{-1}, ρ in 10^3 cm^{-3}, Σ in 10^3 $M_\odot$ pc^2, and t_{ff} in Myr.





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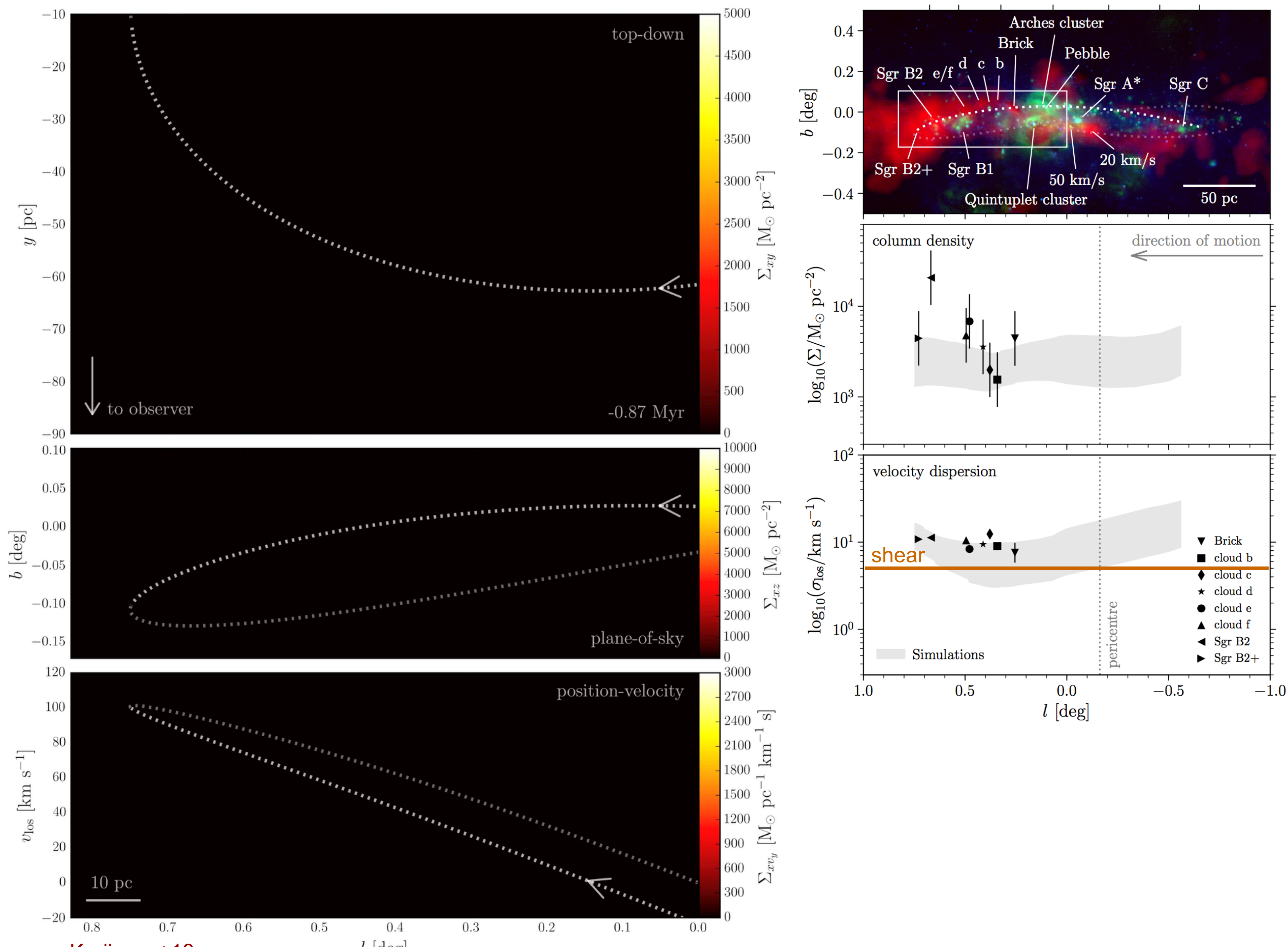

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Role of Galactic Dynamics in Shaping CMZ Clouds

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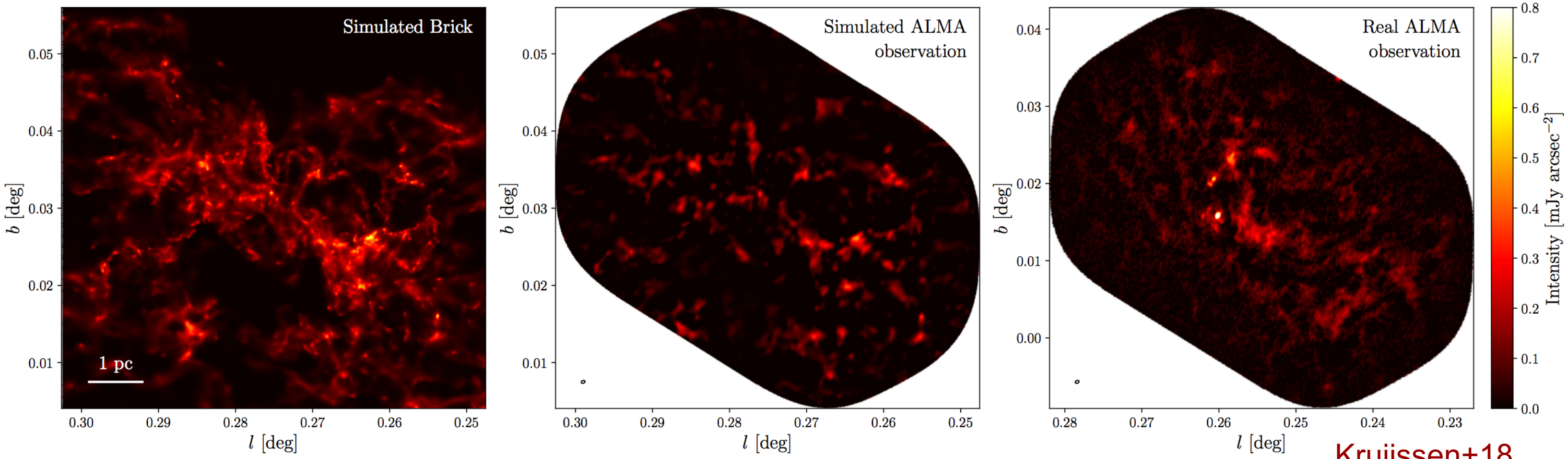
Structure of simulation at position of the Brick resembles observed cloud

✦ Peak brightness, fragmentation length, morphology similar



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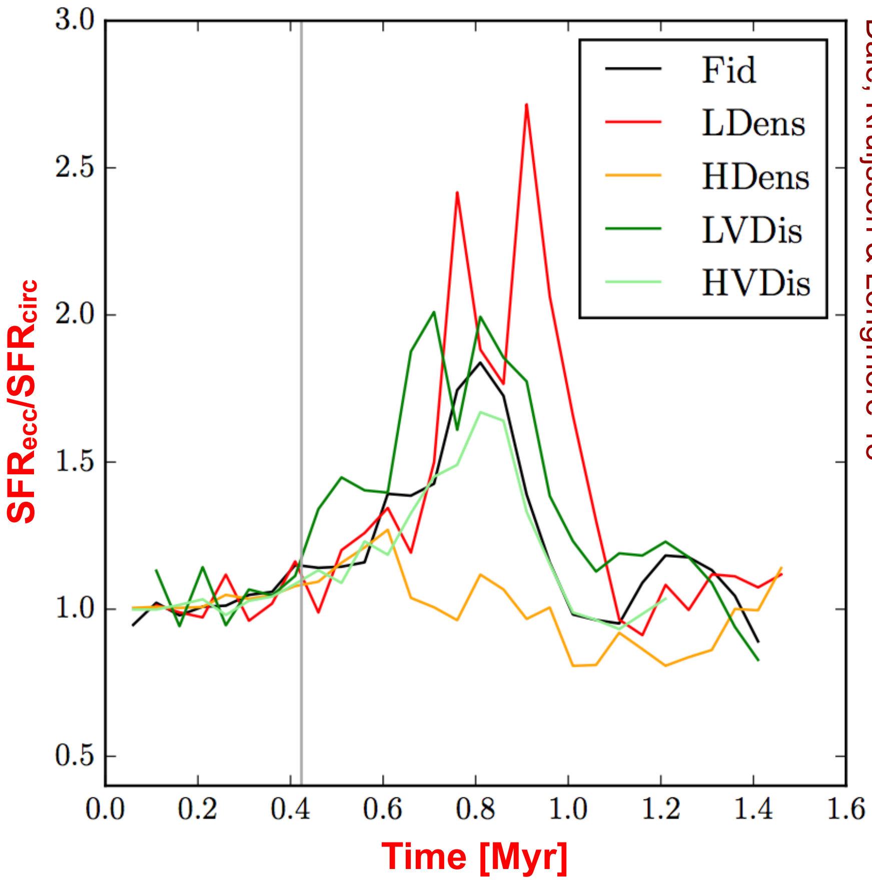
Pericentre passage enhances SFR by factor ~2

- ✦ Star formation rate in clouds on eccentric orbits is enhanced post-pericentre



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Conclusions

- ✦ CMZ clouds shaped by shear, tidal/geometric deformation, pericentre passage
- ✦ *Shear* is an important turbulence driver in the CMZ ➔ solenoidal turbulence
- ✦ Conservation of angular momentum during *gas accretion onto the cloud* and *gravitational collapse* drives large velocity gradients
- ✦ *Compressive tidal field* turns clouds into spinning pancakes
- ✦ Tidal perturbation by *pericentre passage* enhances SFR by factor of 2
- ✦ *All galaxies* have central tidally compressive regions driving nuclear starbursts
- ✦ Understanding variety of turbulence drivers enabled by *ALMA LP* of the CMZ

  see Jonathan Henshaw's talk on Monday