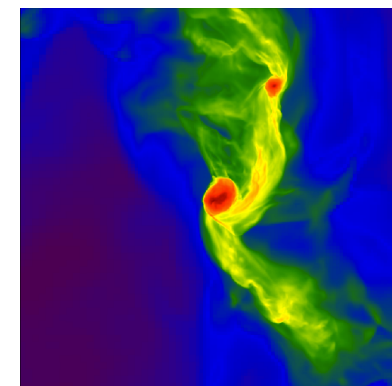
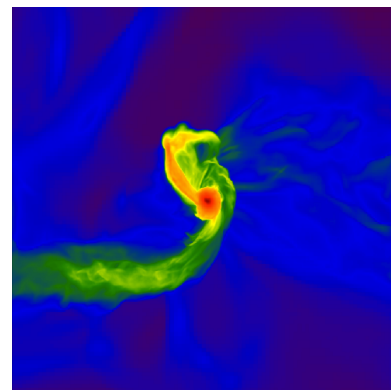
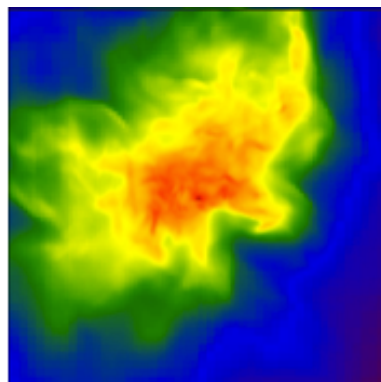
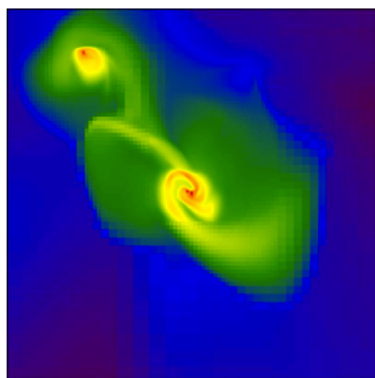
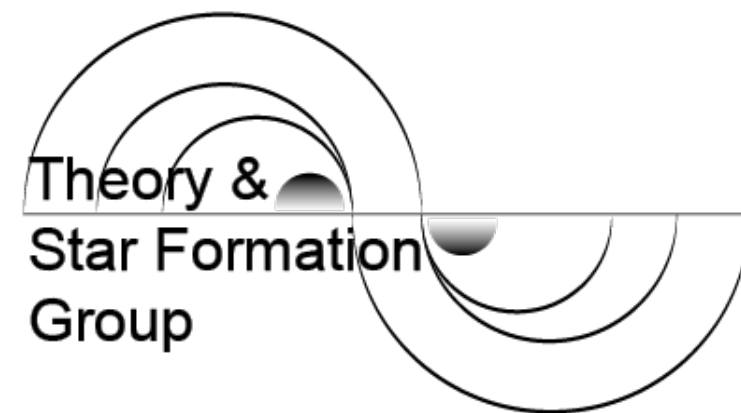




Publication Year	2017
Acceptance in OA	2020-09-09T06:57:07Z
Title	Can Deuteration be Used as A Chemical Clock in Protostellar Cores
Authors	Schleicher, Dominik, Banerjee, R., Boekholt, T., Bovino, S., Fellhauer, M., GALLI, Daniele, Grassi, T., Grete, P., Haugboelle, T., Koertgen, B., Latif, M., Riaz, R., Stutz, A.
Publisher's version (DOI)	10.5281/zenodo.808655
Handle	http://hdl.handle.net/20.500.12386/27229

Can deuteration be used as a chemical clock in protostellar cores

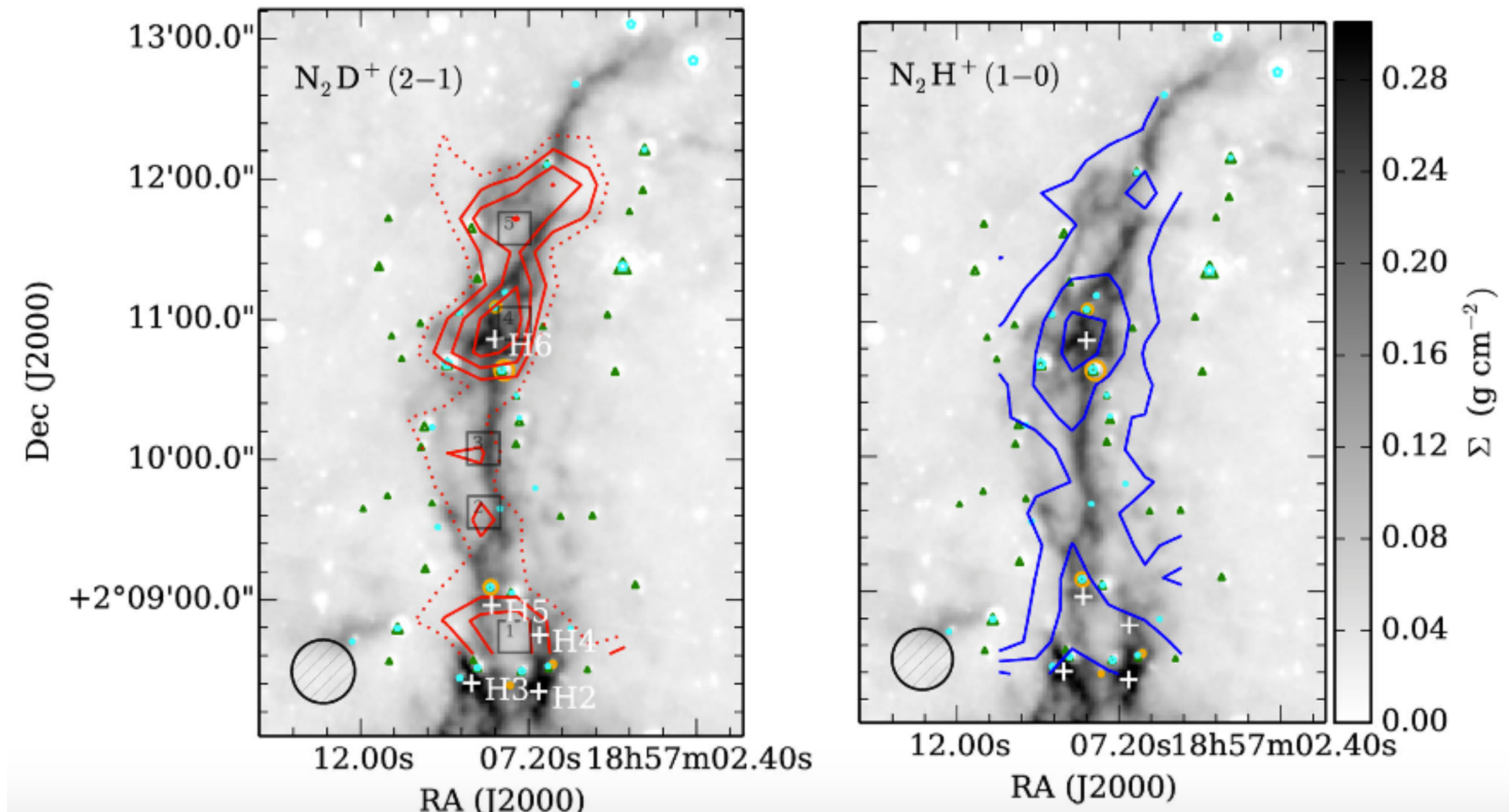
Dominik Schleicher
Astronomy Department
Universidad de Concepción



Collaborators:

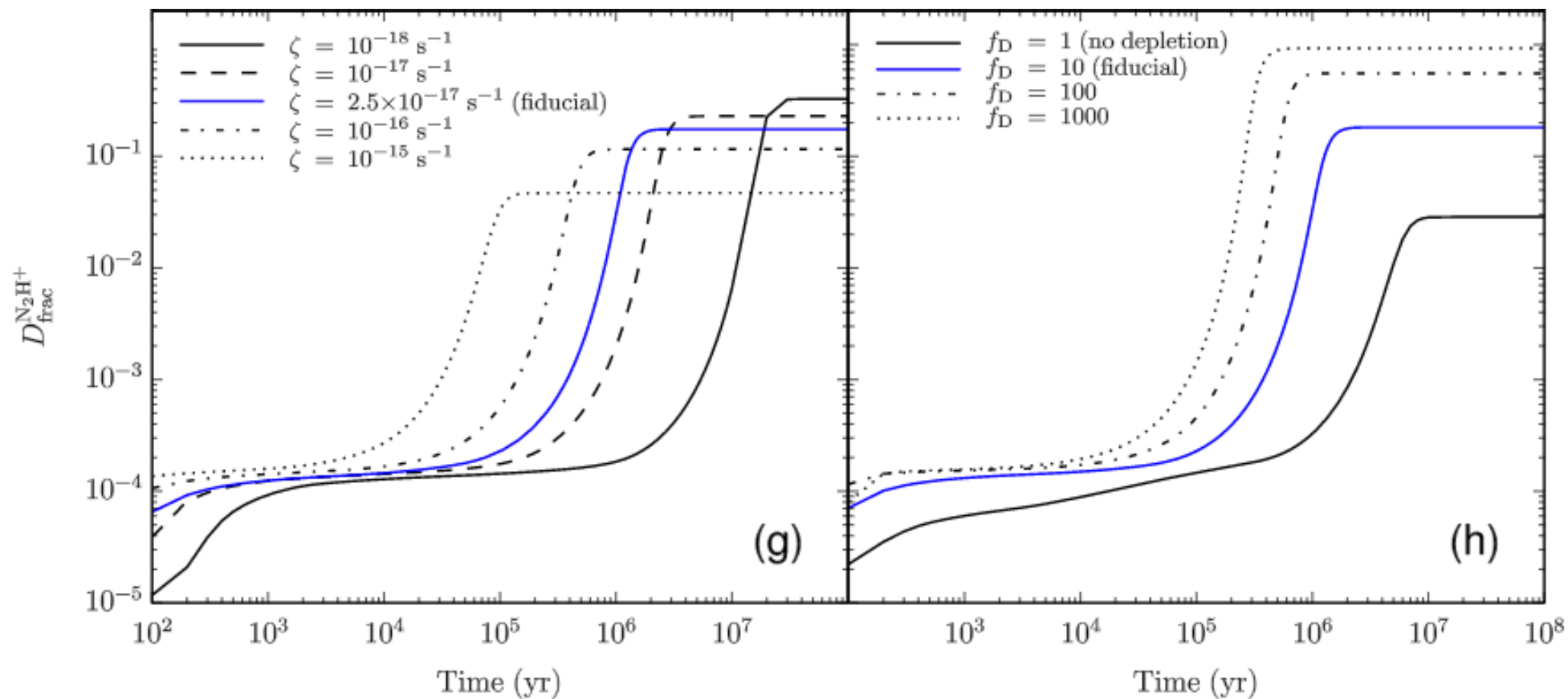
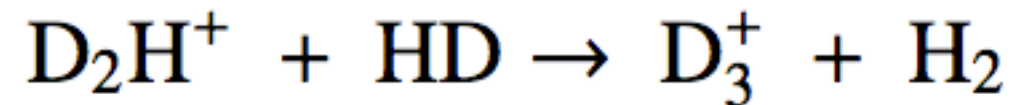
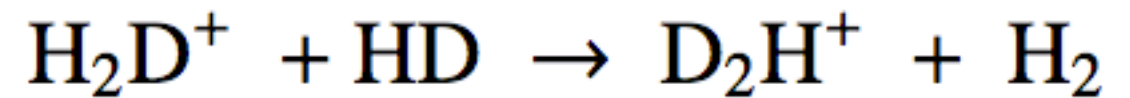
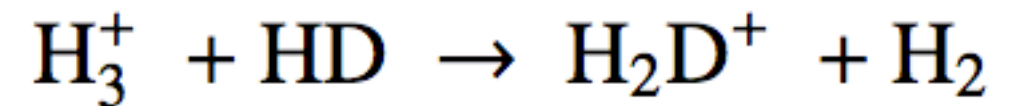
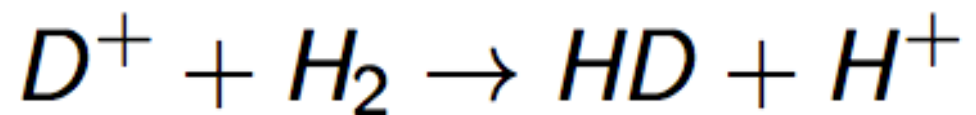
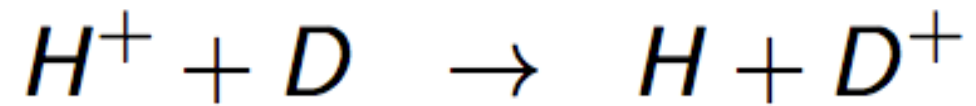
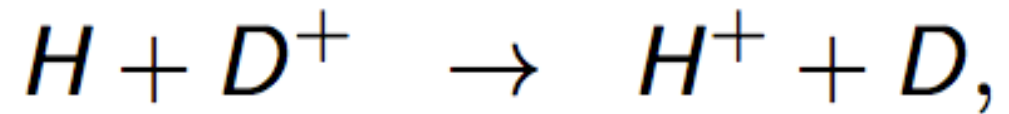
Robi Banerjee (Hamburg), Tjarda Boekholt (Concepción), **Stefano Bovino** (Hamburg), Michael Fellhauer (Concepción), Daniele Galli (Florence), Tommaso Grassi (Copenhagen), Philipp Grete (Michigan), Troels Haugboelle (Copenhagen), **Bastian Koertgen** (Hamburg), Muhammad Latif (Islamabad), Rafeel Riaz (Concepción), Amelia Stutz (Concepción)

Deuteration in IRDC G035.39–00.33



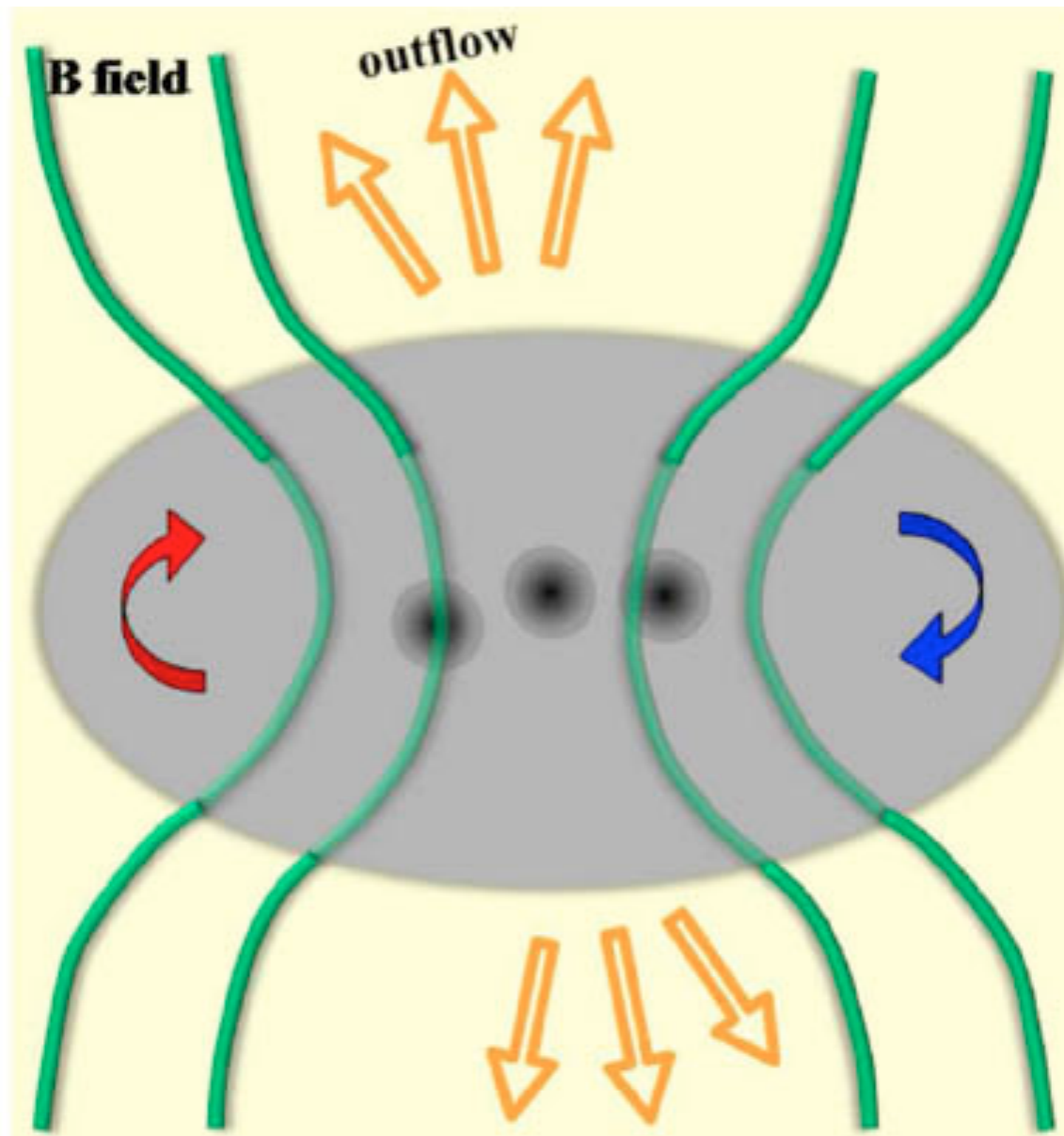
Barnes et al. (2016)

Deuteration of molecules



Kong et al. (2015)

High deuteration fractions: magnetically dominated star formation?



Magnetic flux = $\Phi = B A$

Magnetic field

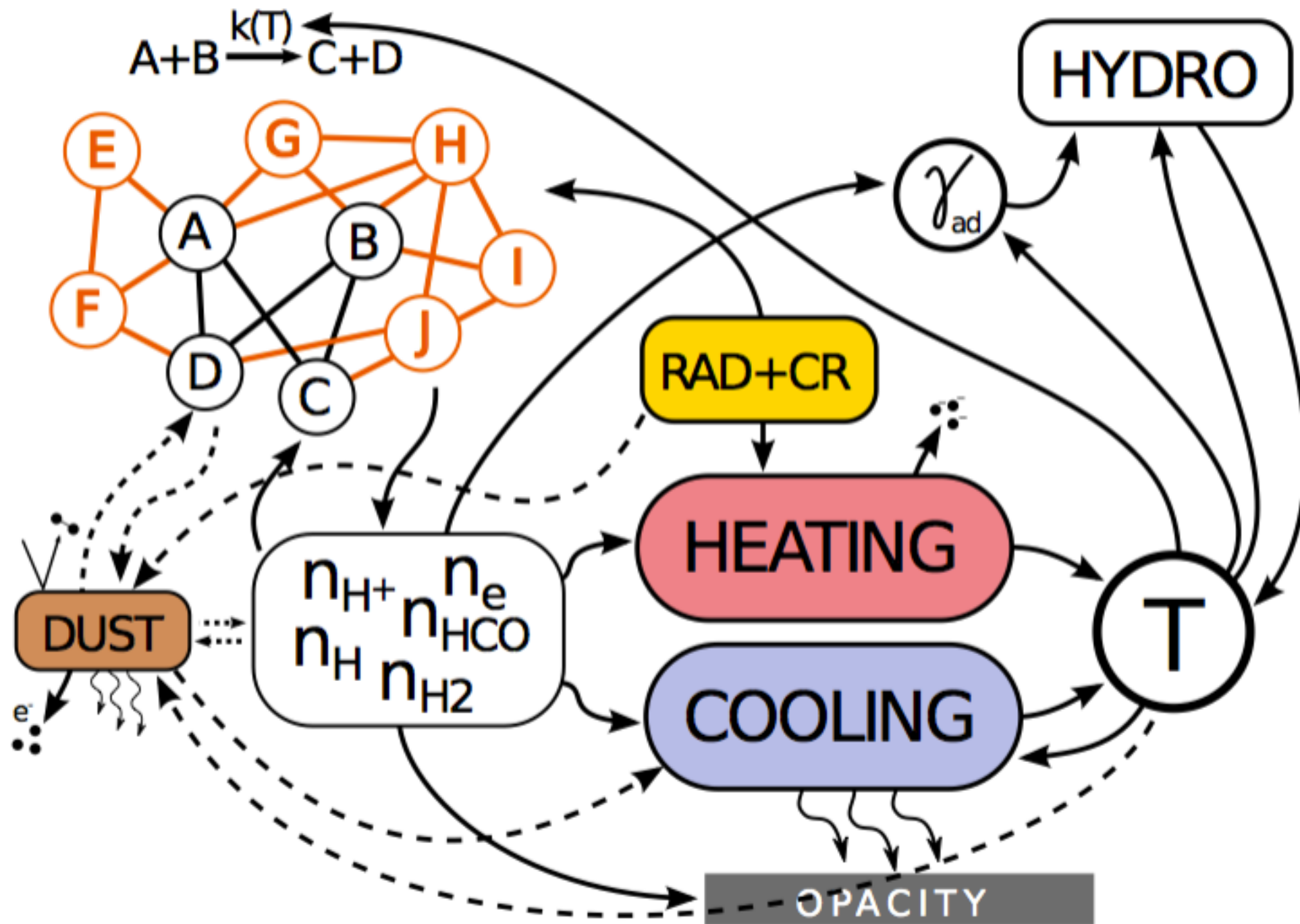
Area perpendicular to magnetic field B

critical mass to
collapse:

$$M_J^B = \frac{\Phi}{2\pi\sqrt{G}}$$

magnetic field -> slow collapse -> time for deuteration?

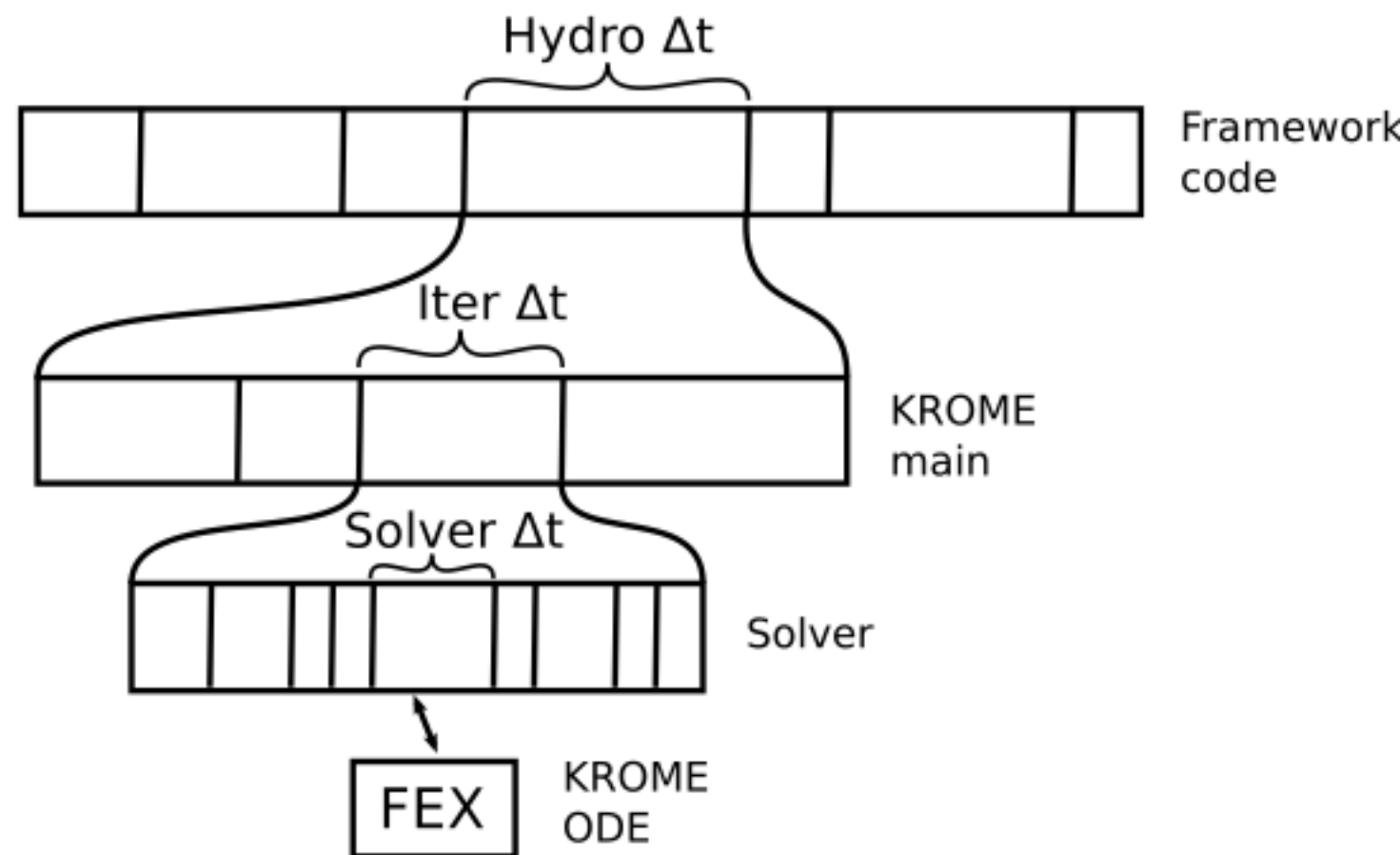
Chemical complexity



Grassi, Bovino, Schleicher et al. (2014)

The chemistry package KROME

- KROME:
python module to **create Fortran subroutine**
for existing chemical networks.
- The subroutine is then included in the framework code.
- Existing **interfaces for Enzo, Flash, Gasoline, Ramses**
(plus wrapper for C++).
- Several example networks
as well as user-defined
networks.
- **Publicly available:**
www.kromepackage.org



Grassi, Bovino, Schleicher et al. (2014)

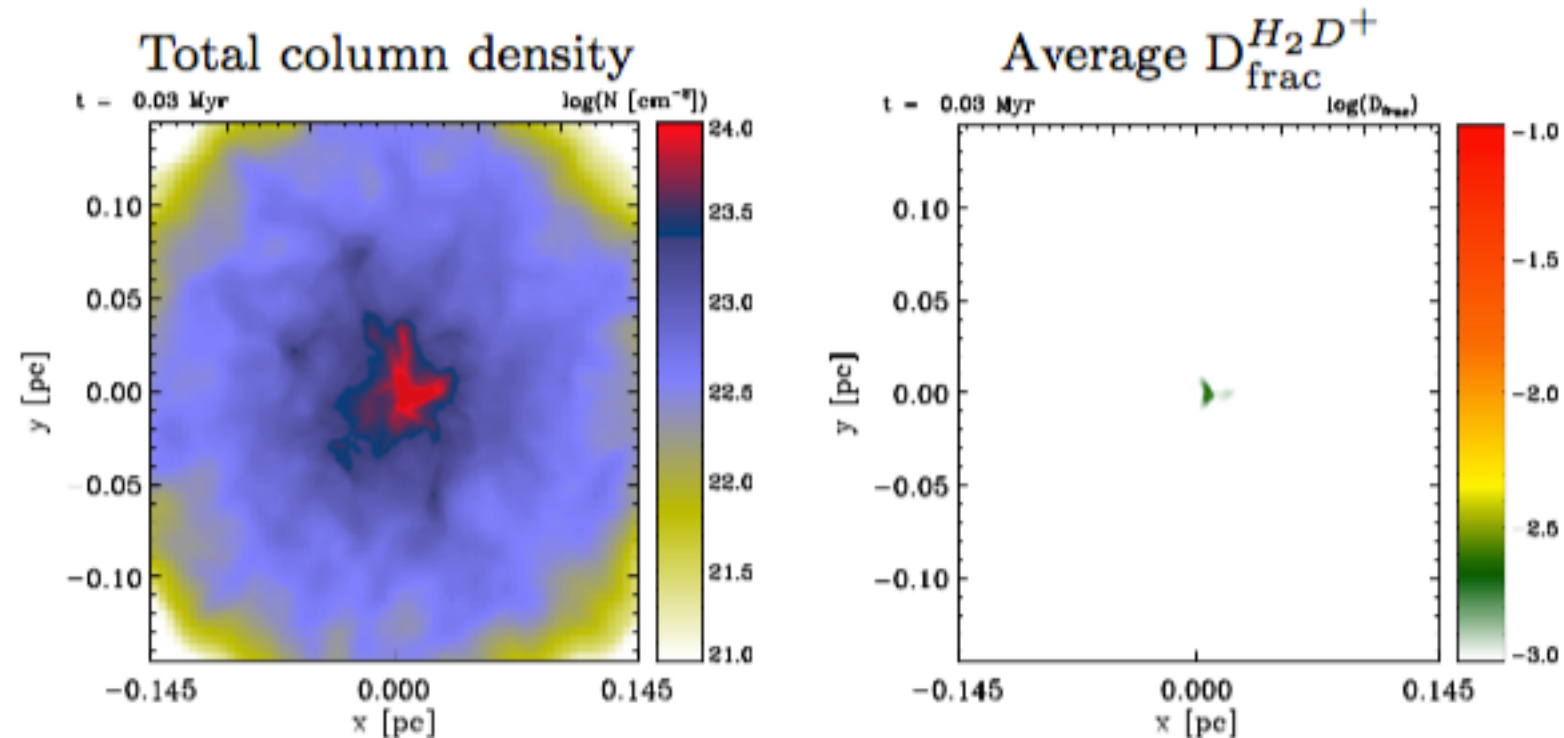
Test with 3D numerical simulations

- 60 solar mass core, 0.17 pc, 15 K, turbulent Mach number of 2
- mass to flux ratio: ~ 10 above critical value
- maximum resolution: 235 AU
- magneto-hydrodynamics + self-gravity solved with the FLASH code
- network for deuteration chemistry based on Walmsley et al. (2004)

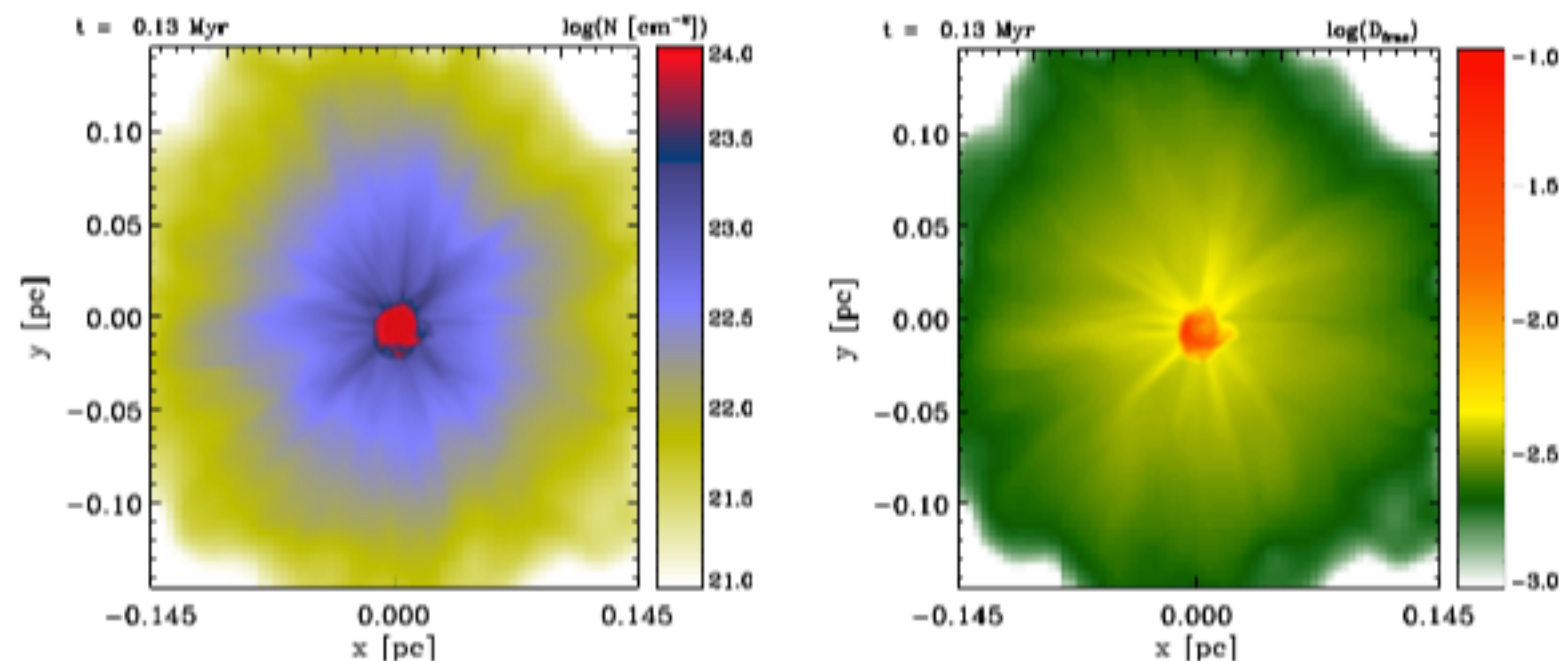
Koertgen, Bovino, Schleicher et al., submitted
(arXiv:1703.01201)

Results reference run

30 kyrs:



130 kyrs:



Koertgen, Bovino, Schleicher et al., submitted
(arXiv:1703.01201)

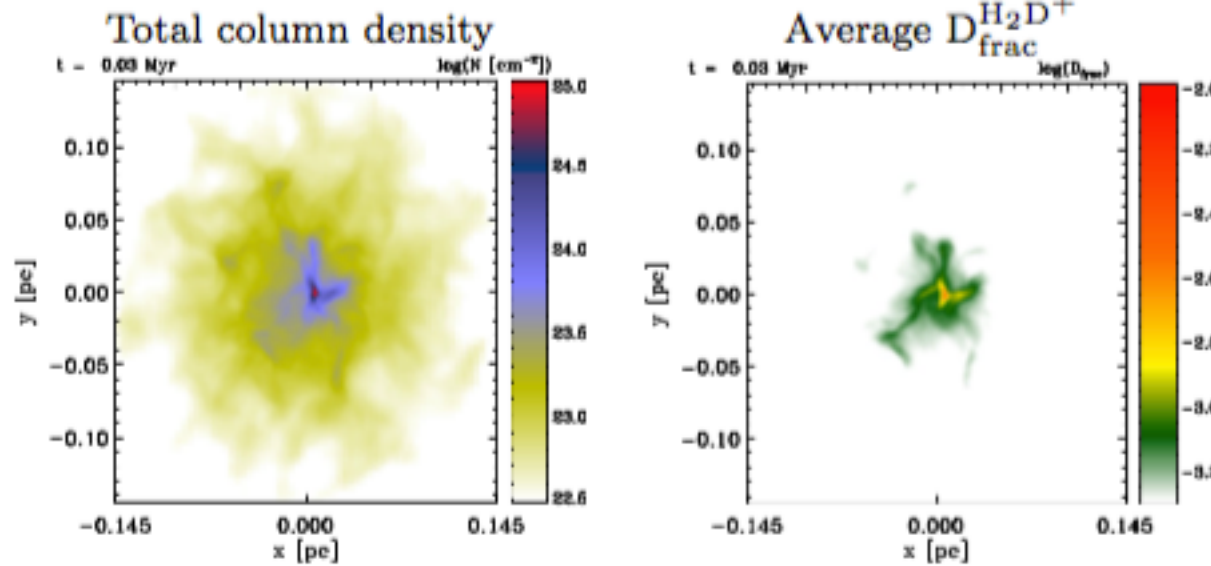
Total number of simulations

Surface density (g/cm^2)	Core radius (pc)	Core mass ($M_\odot$)	Av. Field strength (μG)	Mass-to- flux ratio ^a μ/μ_{crit}	Mach number $\mathcal{M}_{\text{turb}}$	Virial parameter α_{vir}
0.14	0.17	60	27	10	1	0.16
0.14	0.17	60	27	10	2	0.64
0.14	0.17	60	27	10	2	0.64
0.14	0.17	60	27	10	2	0.64
0.14	0.17	60	27	10	2	0.64
0.14	0.17	60	27	10	4	2.56
0.14	0.17	60	27	10	6	5.76
0.14	0.17	60	27	10	12	23.04
0.14	0.17	60	54	5	2	0.64
0.14	0.17	60	54	5	4	2.56
0.14	0.17	60	108	2.5	0.5	0.04
0.14	0.17	60	108	2.5	2	0.64
0.14	0.17	60	108	2.5	6	5.76
0.24	0.08	27	49	10	2	0.71
0.24	0.08	27	98	5	2	0.71
0.39	0.1	60	76	10	0.5	0.03
0.39	0.1	60	76	10	2	0.48
0.39	0.1	60	76	10	2	0.48
0.39	0.1	60	152	5	2	0.48
0.39	0.1	60	304	2.5	2	0.48
0.39	0.1	60	304	2.5	4	1.92

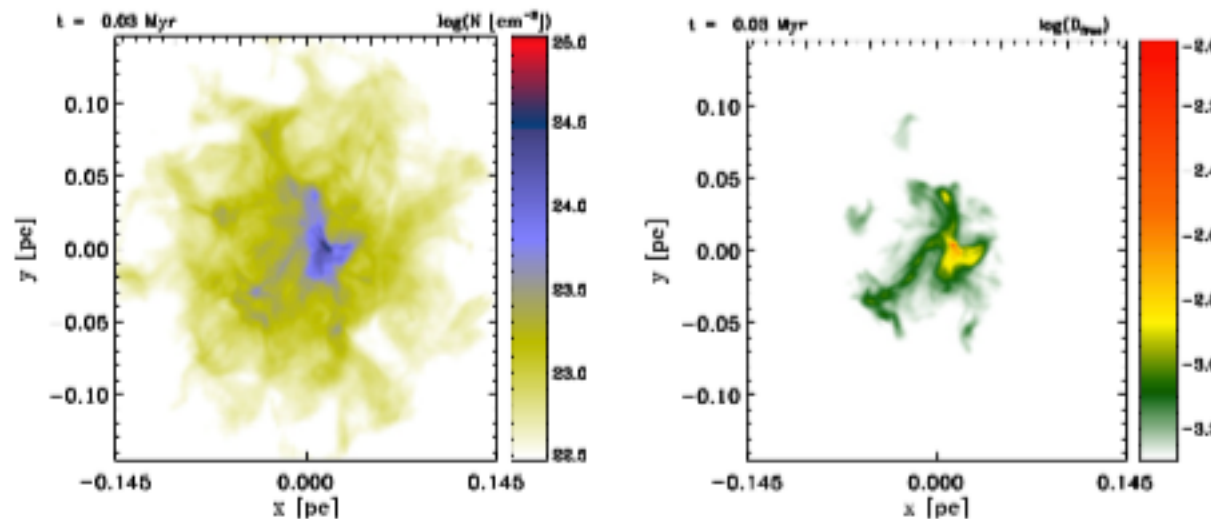
Koertgen, Bovino, Schleicher et al., submitted
(arXiv:1703.01201)

Dependence on turbulent Mach number

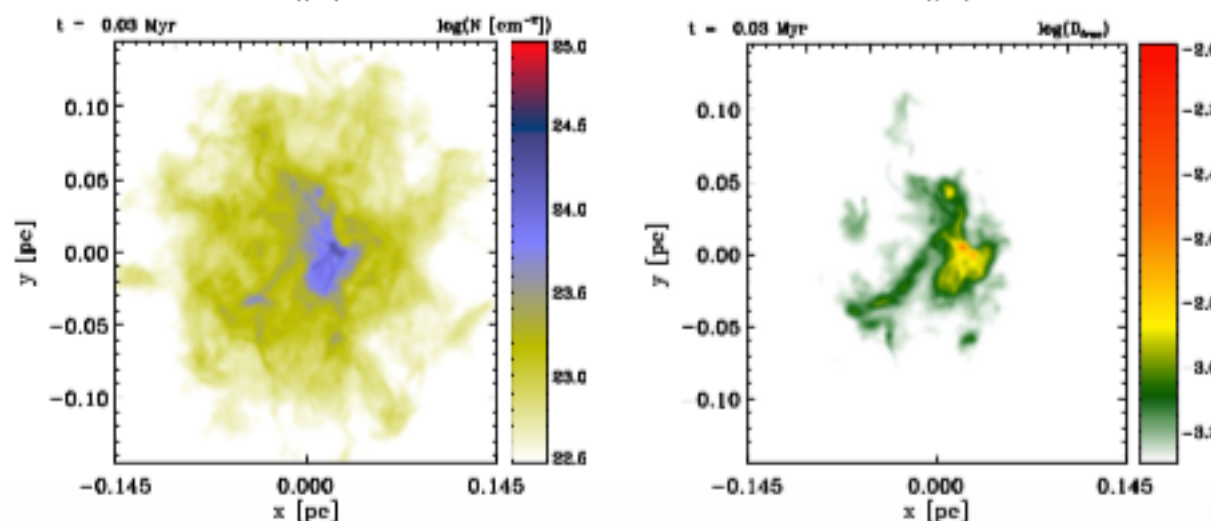
M=2



M=4

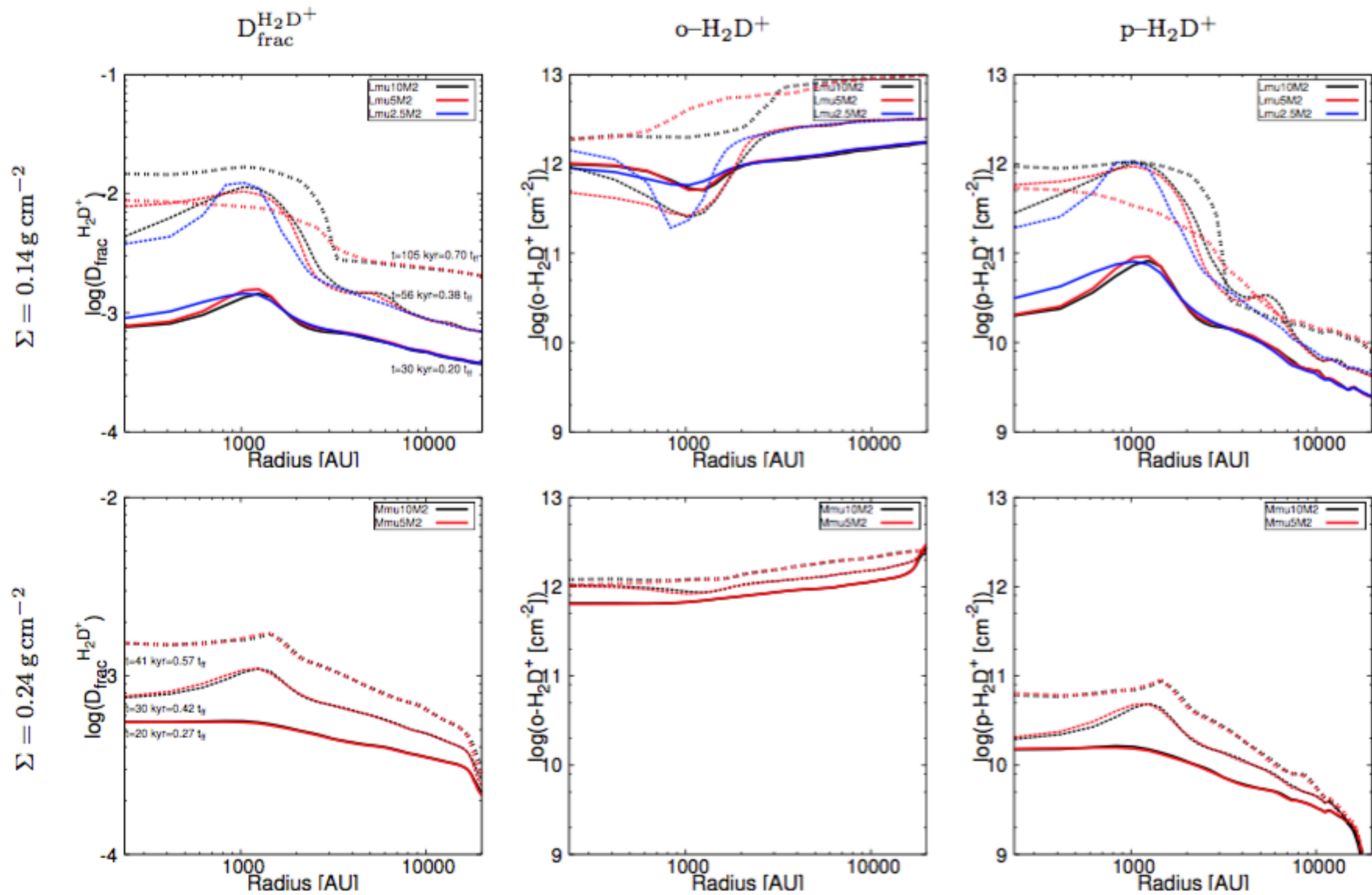


M=6



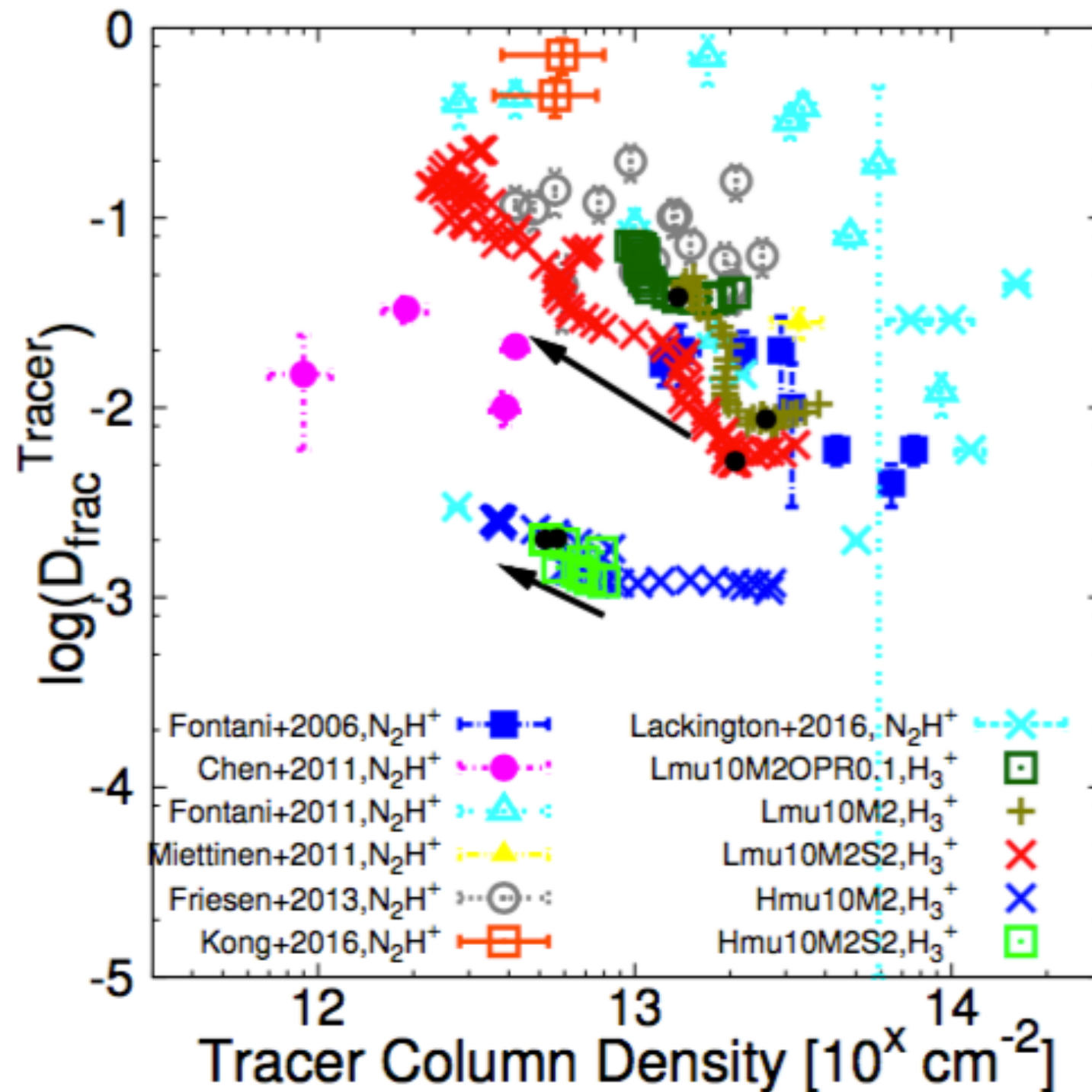
Koertgen et al., submitted

Dependence on mass-to-flux ratio



Koertgen, Bovino, Schleicher et al., submitted
(arXiv:1703.01201)

Comparison with observational data



Koertgen, Bovino, Schleicher et al., submitted
(arXiv:1703.01201)

Summary

- Observed deuteration fraction can be readily reproduced in numerical simulations.
- The deuteration fraction is roughly independent of the magnetic field, and depends weakly on the initial surface density and turbulent Mach number.
- Important to explore chemical uncertainties like incomplete depletion both with high-resolution observations as well as chemical investigations.
- Need to better understand the initial conditions:
What is the ortho-to-para ratio on large scales? How good is the approximation of high depletion?