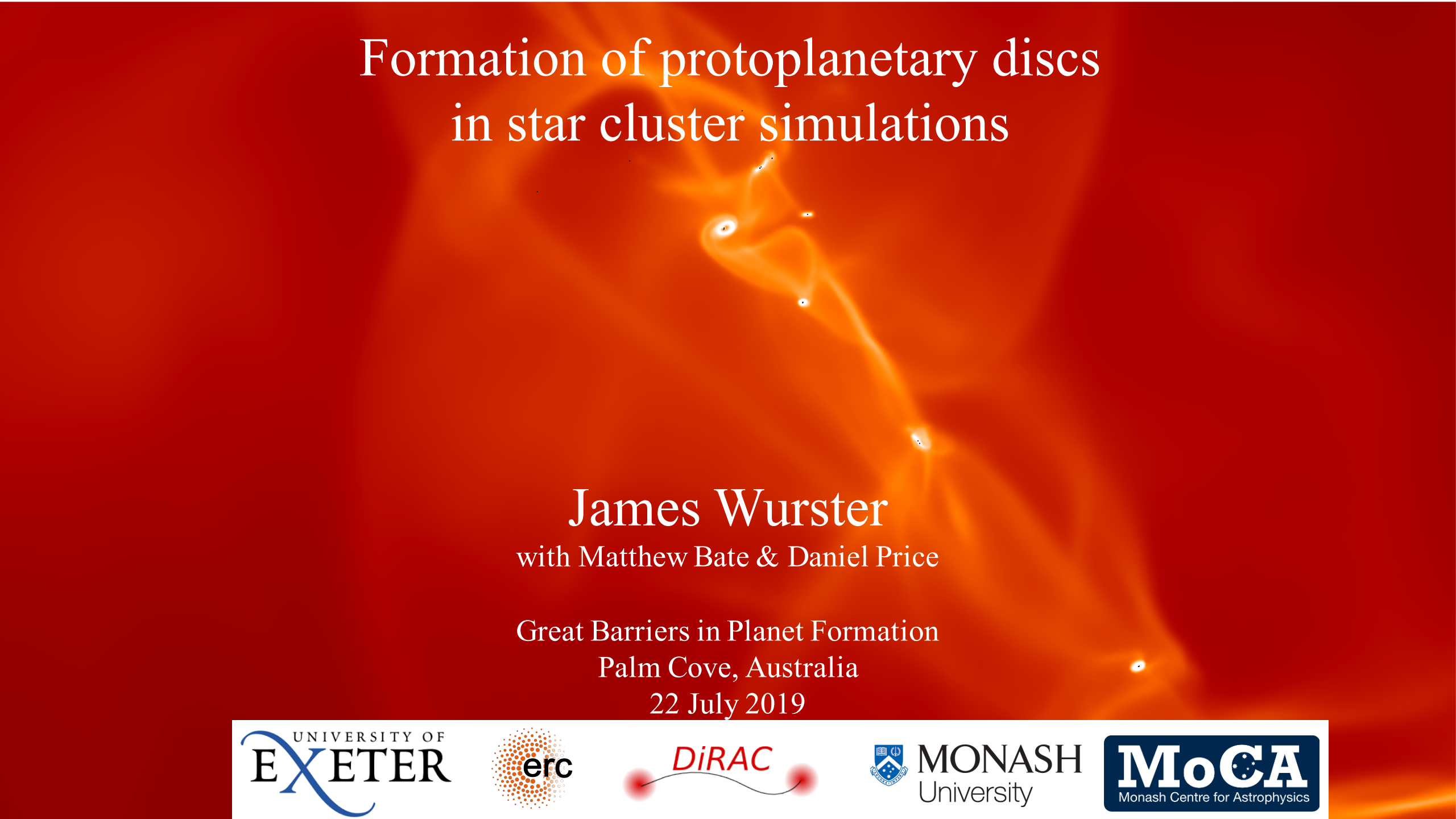
Formation of protoplanetary discs in star cluster simulations



James Wurster

with Matthew Bate & Daniel Price

Great Barriers in Planet Formation

Palm Cove, Australia

22 July 2019

UNIVERSITY OF EXETER

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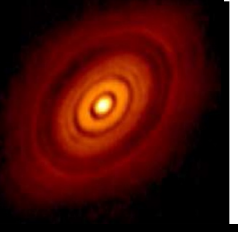
DiRAC

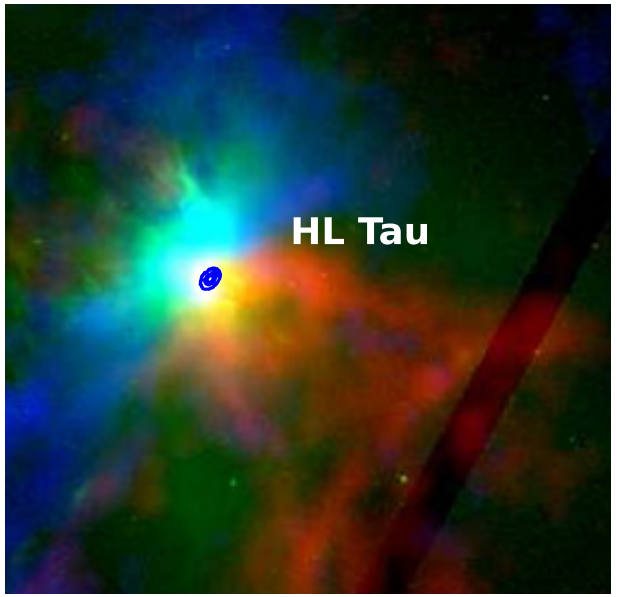
MONASH University

MoCA Monash Centre for Astrophysics

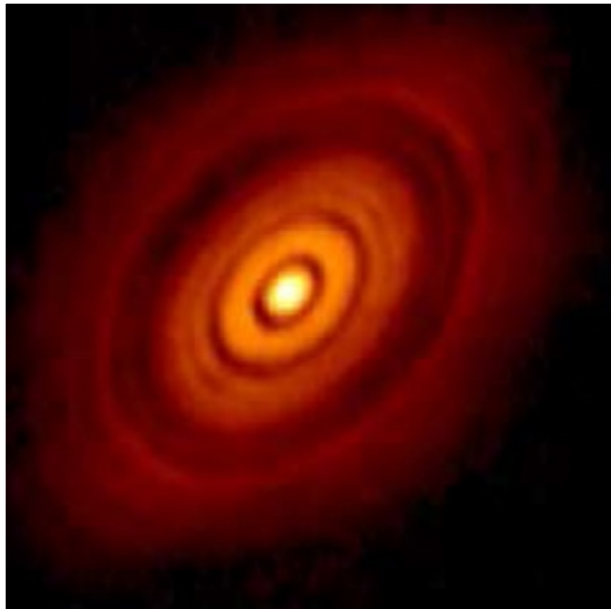


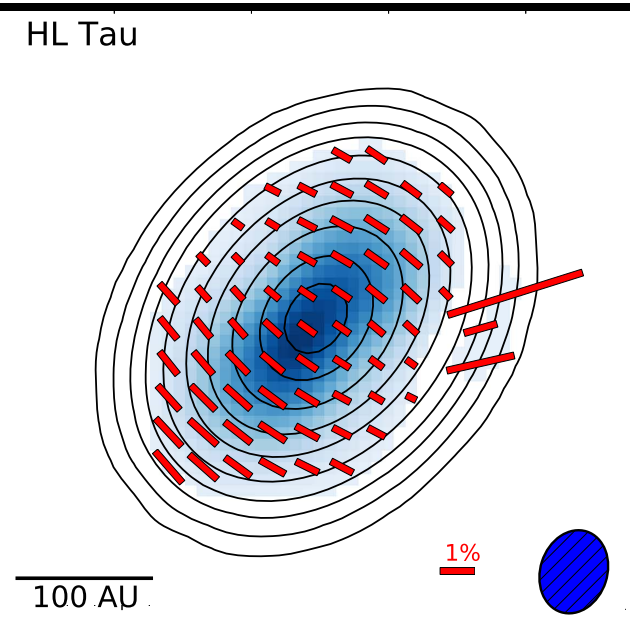
What's in a disc?

Gas!

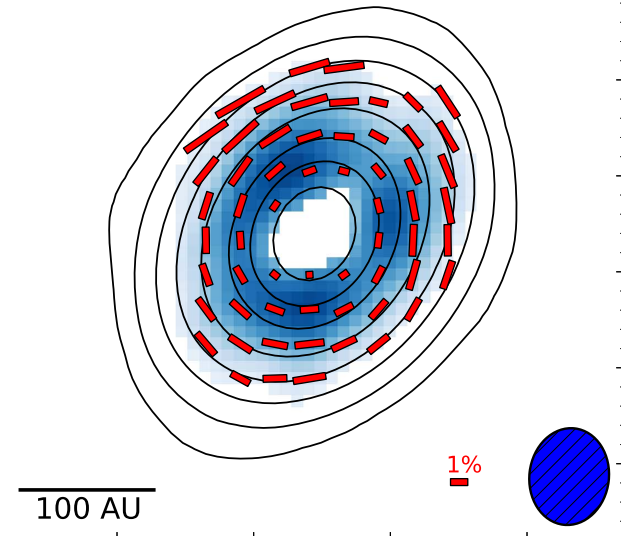


Dust!

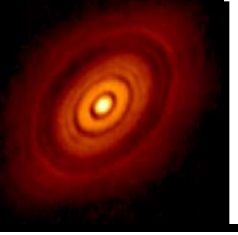




Magnetic fields!

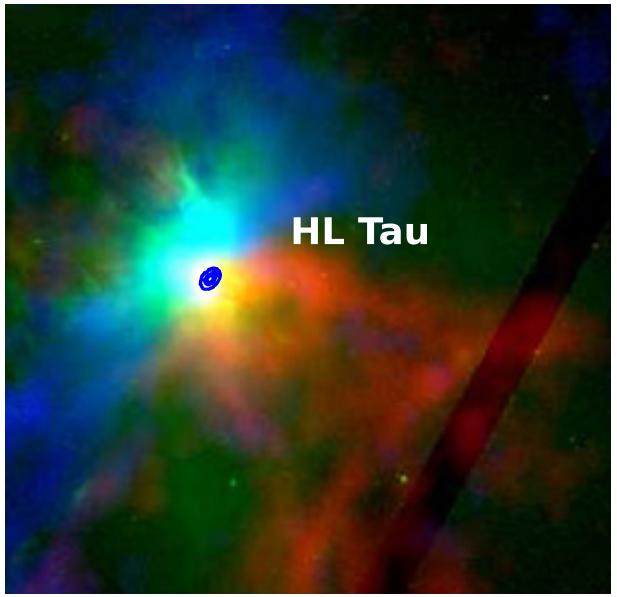


Left: Gas around HL Tau disc (ALMA Partnership, 2015)
Centre: HL Tau dust disc (ALMA Partnership, 2015)
Right: polarisation in HL Tau (Stephens+ 2017)

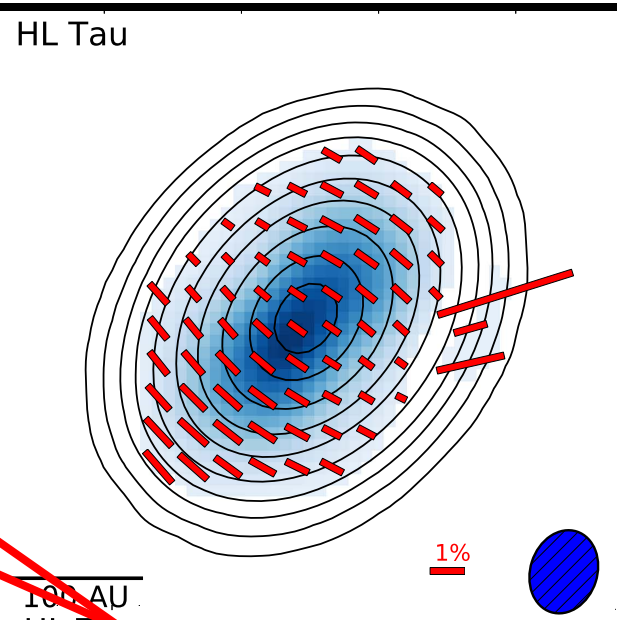


What's in a disc?

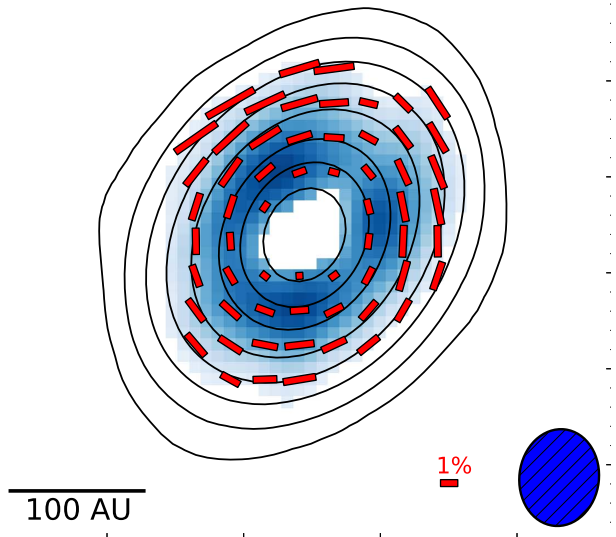
Magnetised Gas!



Magnetised Dust!



HL Tau **Magnetic fields!**



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Centre: HL Tau dust disc (ALMA Partnership, 2015)
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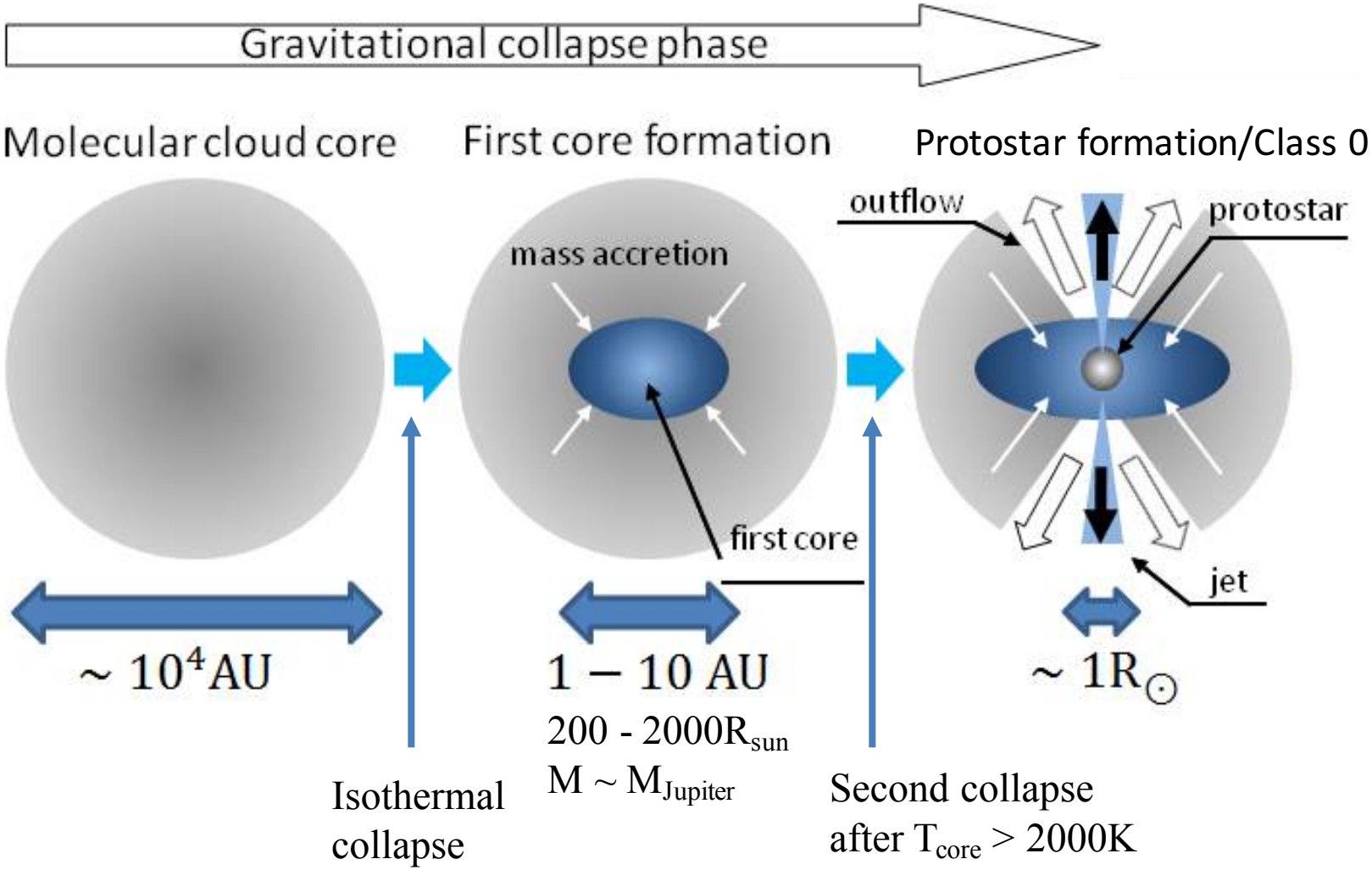
Disc formation & evolution



Larson (1969); Illustration by Y. Tsukamoto

The birth of discs

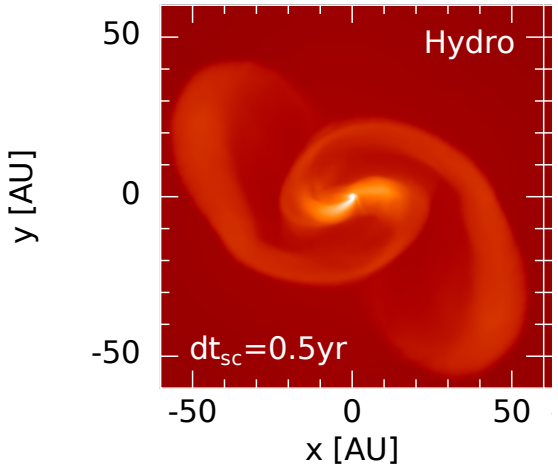
➢Using idealised initial conditions:

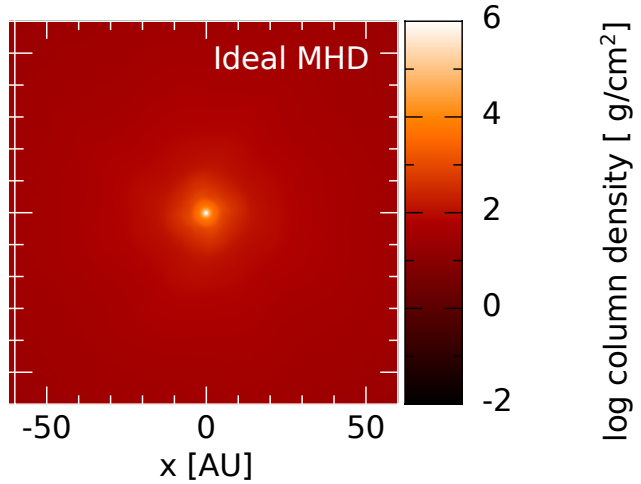
➢ Hydro: forms a 50au disc early during the first hydrostatic core phase

Wurster, Bate & Price (2018a,c)

The birth of discs

➢Using idealised initial conditions:





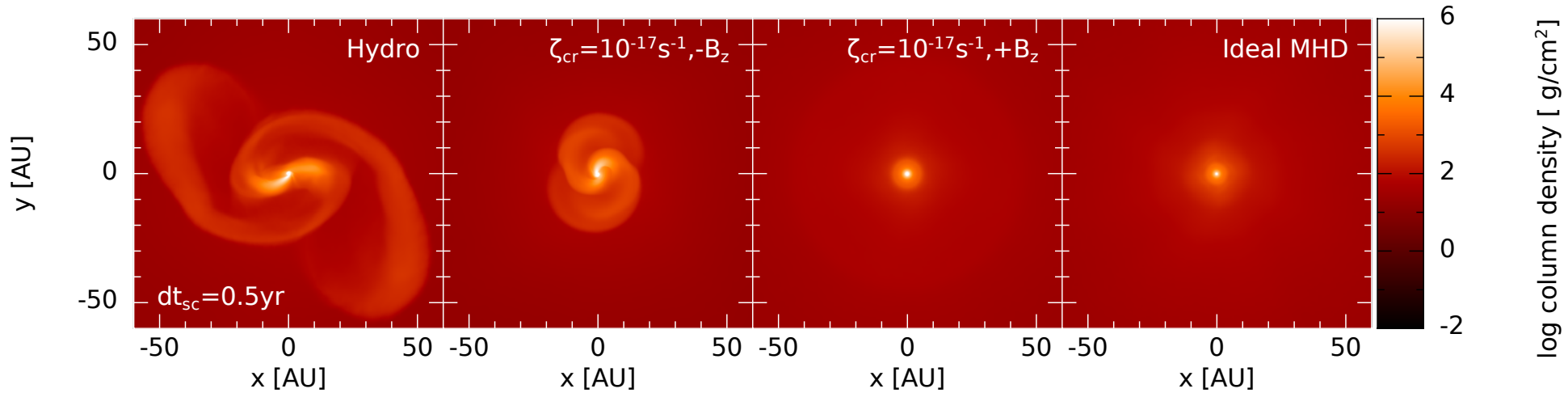
➢ Hydro: forms a 50au disc early during the first hydrostatic core phase

➢ Ideal: never forms a rotationally supported disc
(the Magnetic Braking Catastrophe; Allen, Li & Shu, 2003)

Wurster, Bate & Price (2018a,c)

The birth of discs

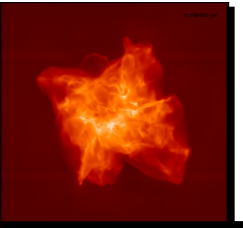
➢Using idealised initial conditions:



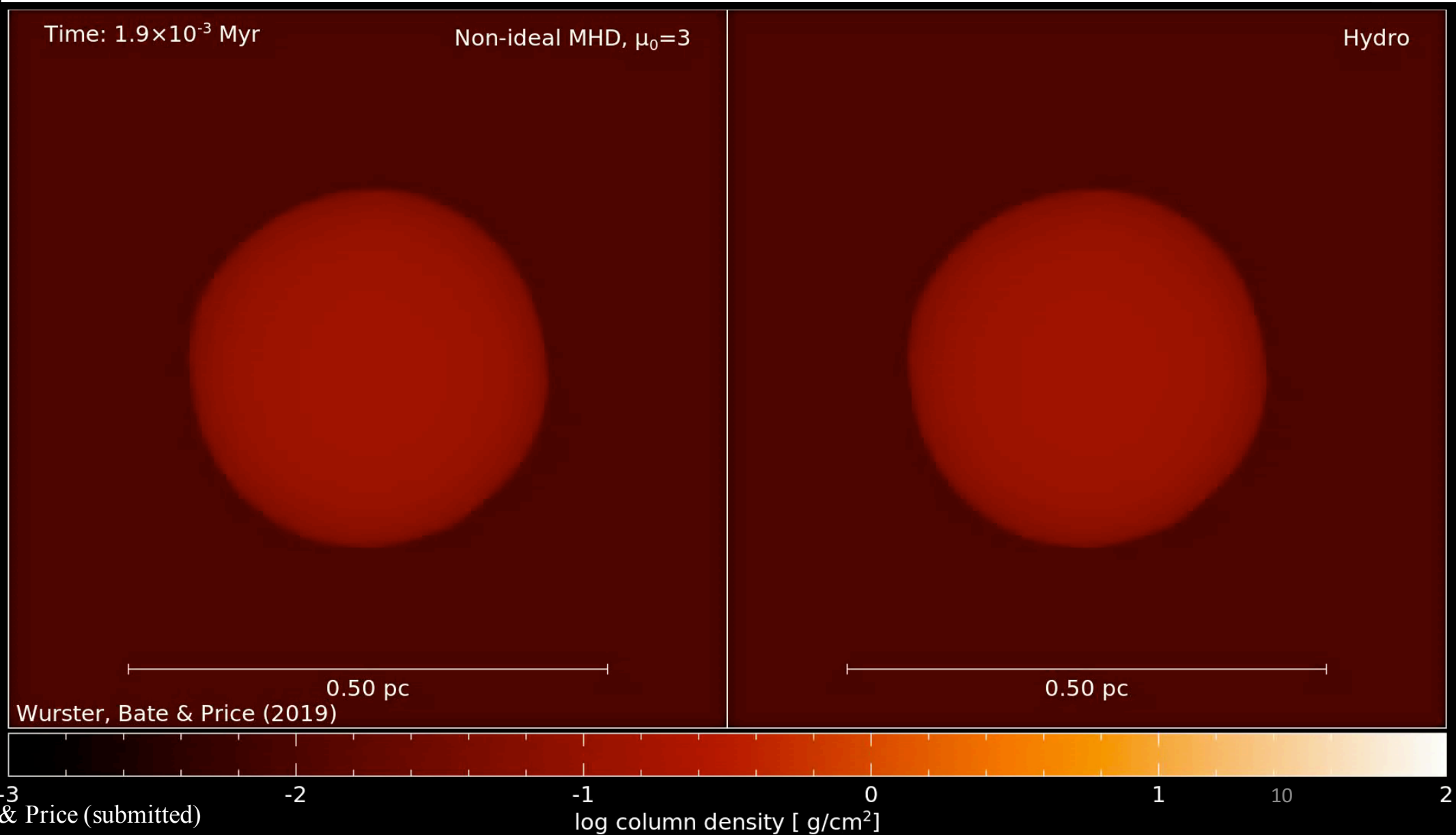
- Hydro: forms a 50au disc early during the first hydrostatic core phase
- Non-ideal with $-B_z$: forms a 25au disc during the first hydrostatic core phase
- Non-ideal with $+B_z$: forms a 1au disc by the stellar core phase
- Ideal: never forms a rotationally supported disc
  (the Magnetic Braking Catastrophe; Allen, Li & Shu, 2003)

See me or Alison Young for details about first hydro static cores (incl. disc formation and/or outflows)

Wurster, Bate & Price (2018a,c)



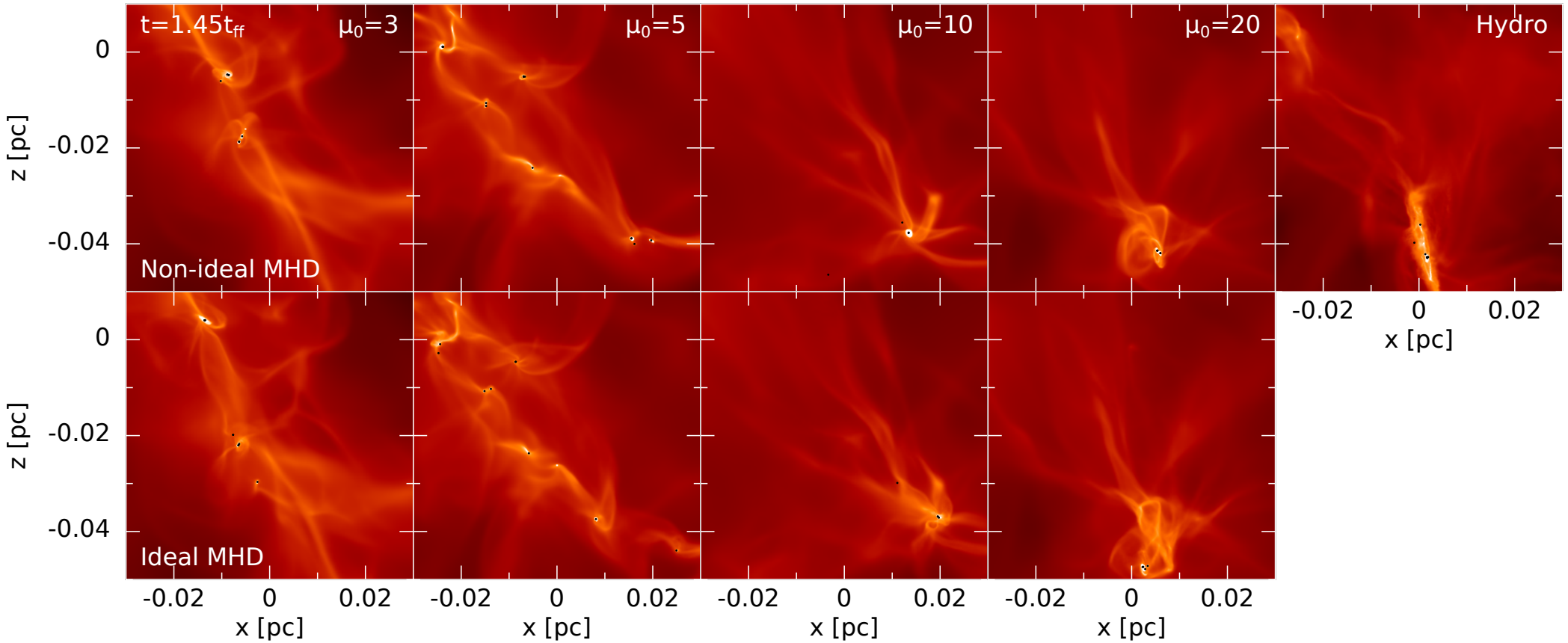
Cluster formation: effect of non-ideal MHD



Wurster, Bate & Price (submitted)

Cluster formation: effect of magnetic fields

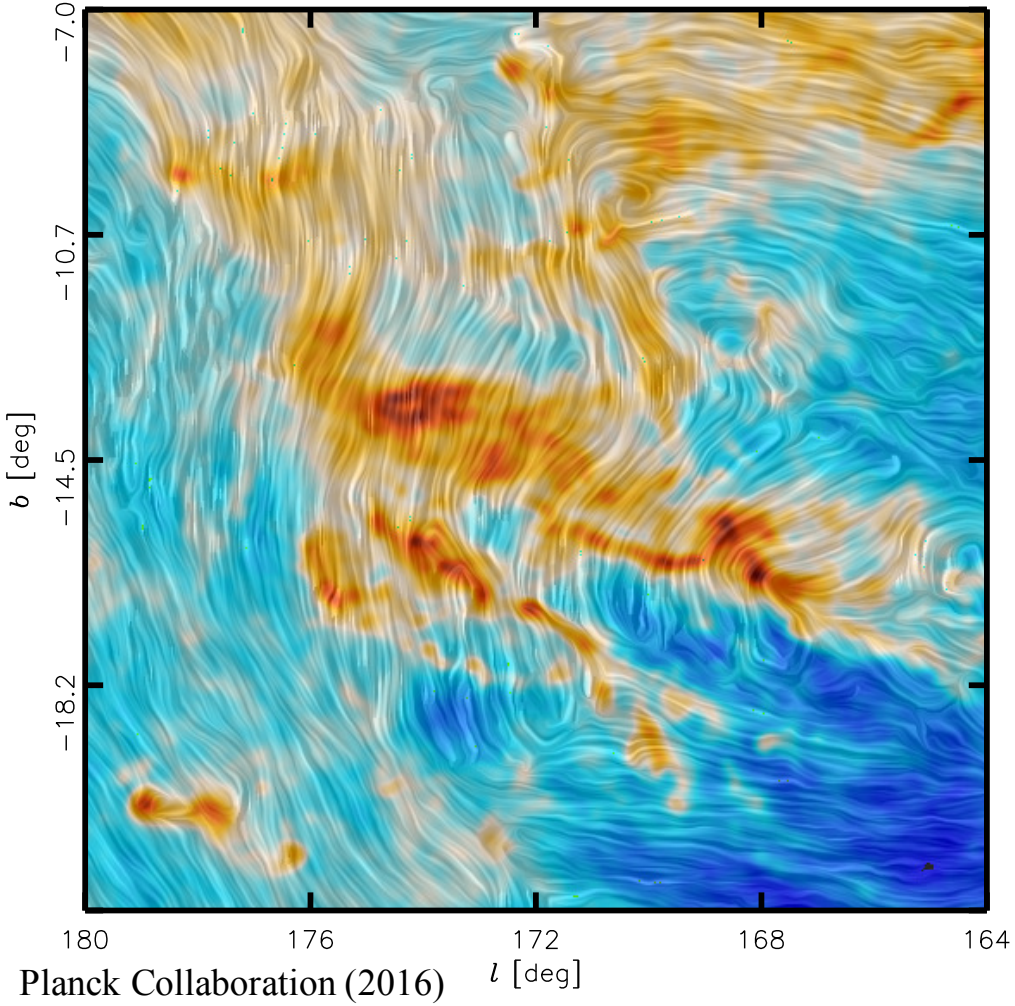
Decreasing magnetic field strength →



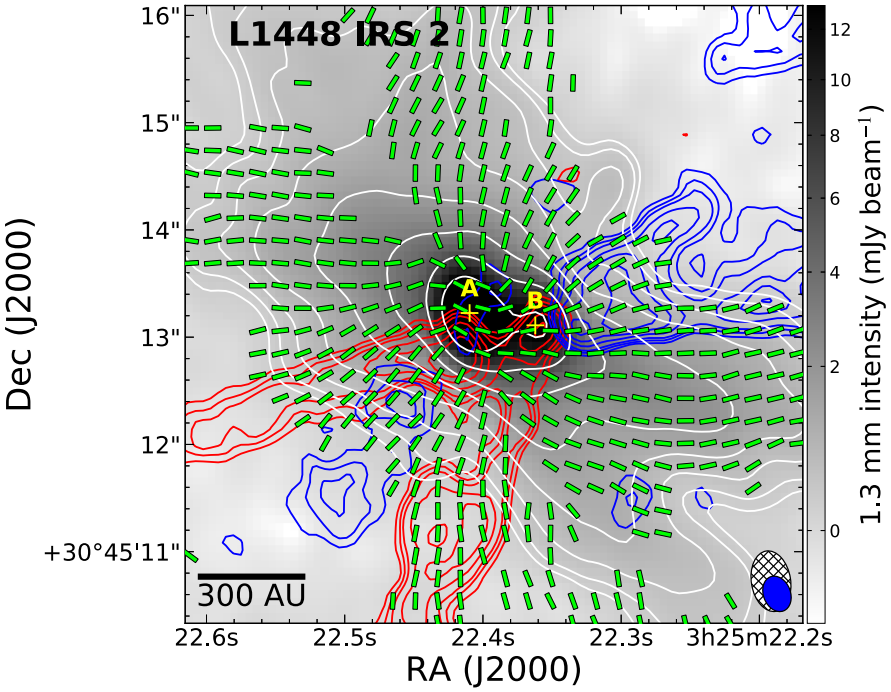
Wurster, Bate & Price (submitted)

Cluster formation: magnetic field structure

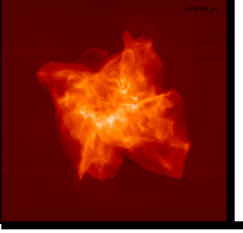
- Large-scale magnetic fields are perpendicular to dense structures
- Large-scale magnetic fields are parallel to low-density structures
- Small-scale magnetic fields get pinched into dense regions, creating an hour-glass shape



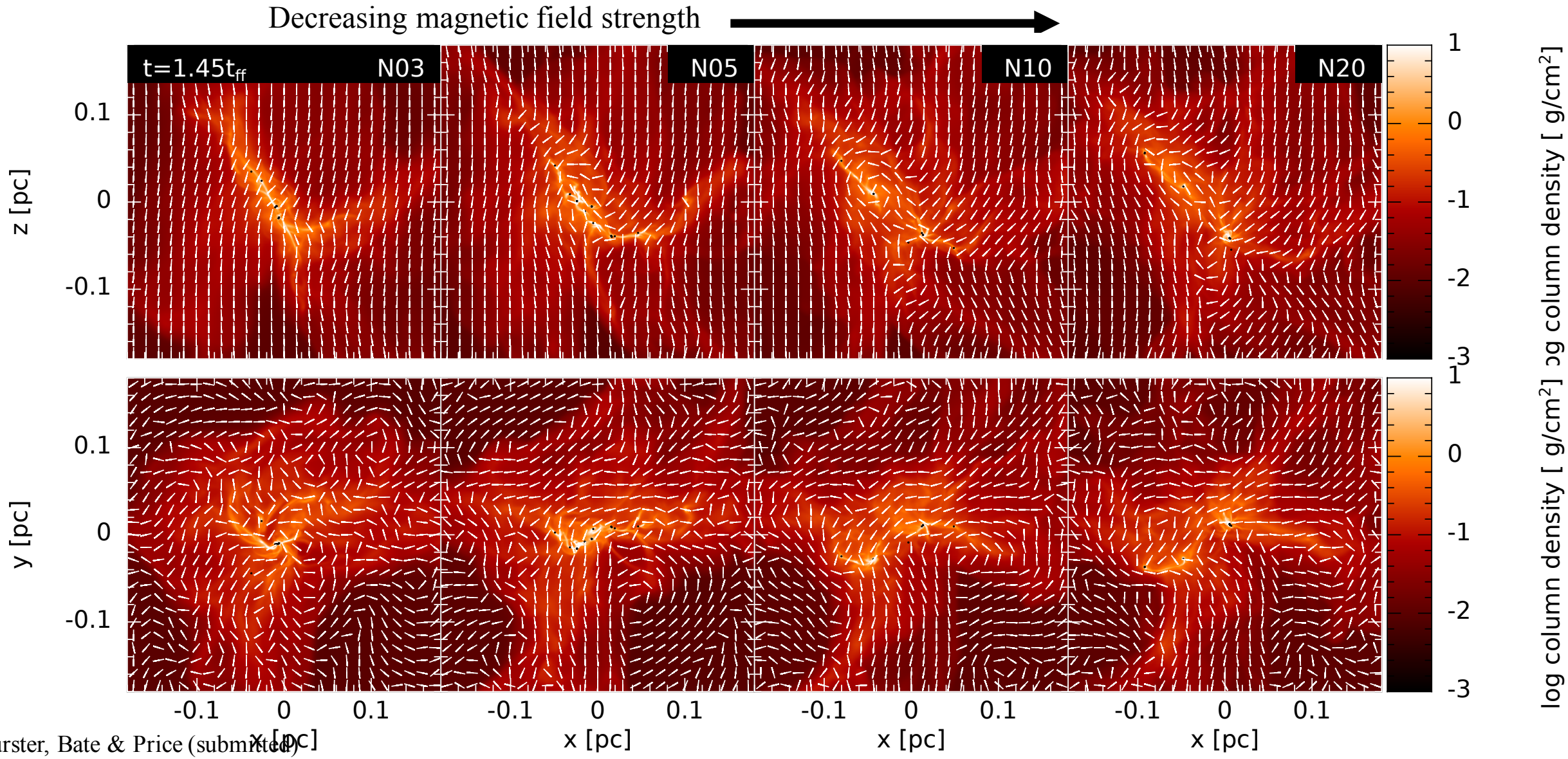
Planck Collaboration (2016)



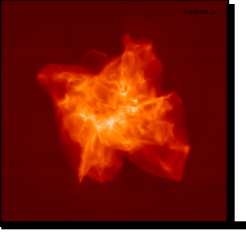
Kwon+ (2019)



Cluster formation: magnetic field structure

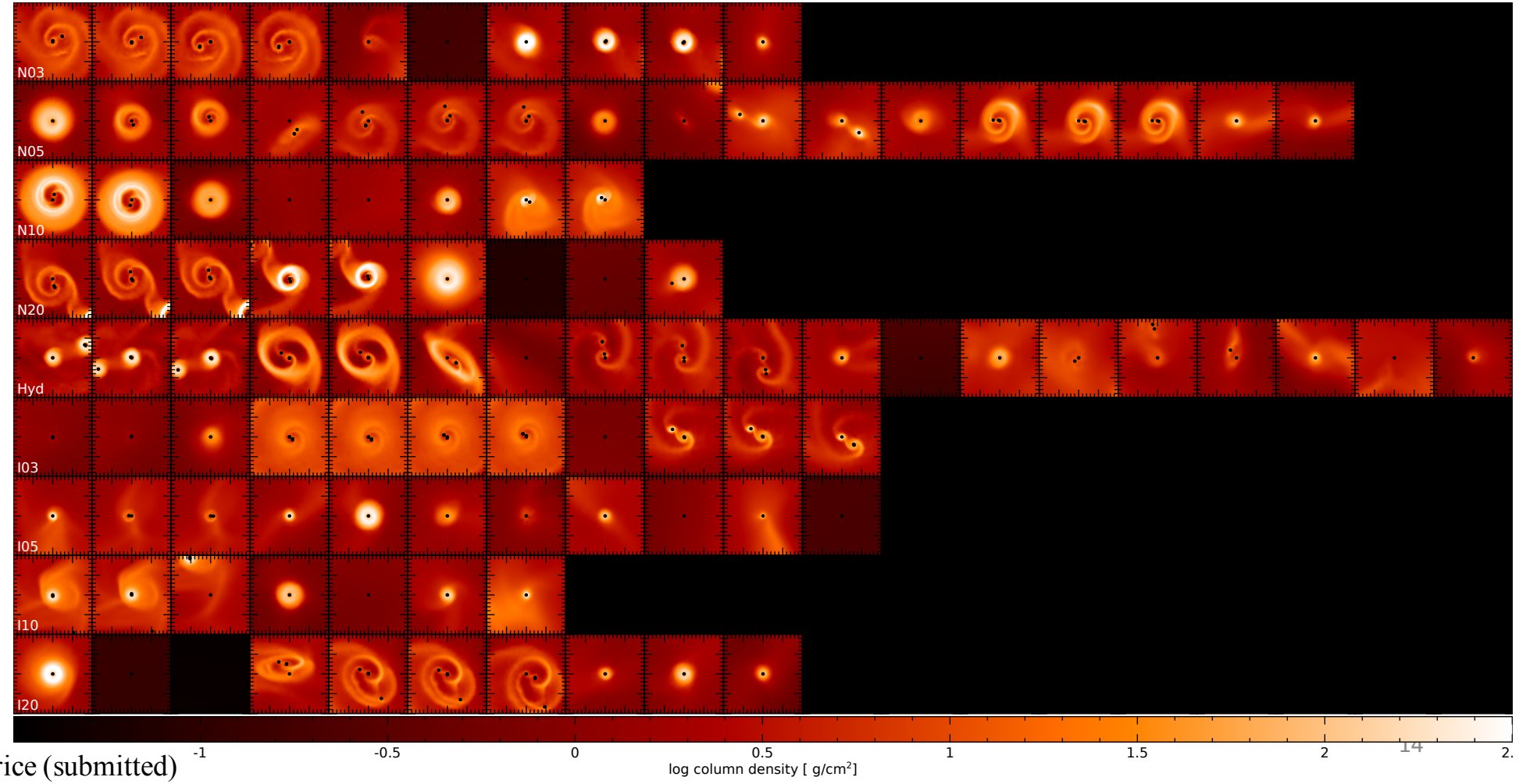


Wurster, Bate & Price (submitted)

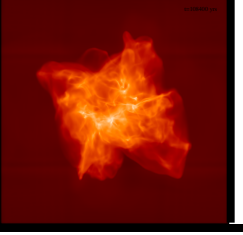


Cluster formation: protostellar discs

- Discs form in *every* model
- Discs surround 1-4 stars
- Evolution is very dynamic given multiple interactions

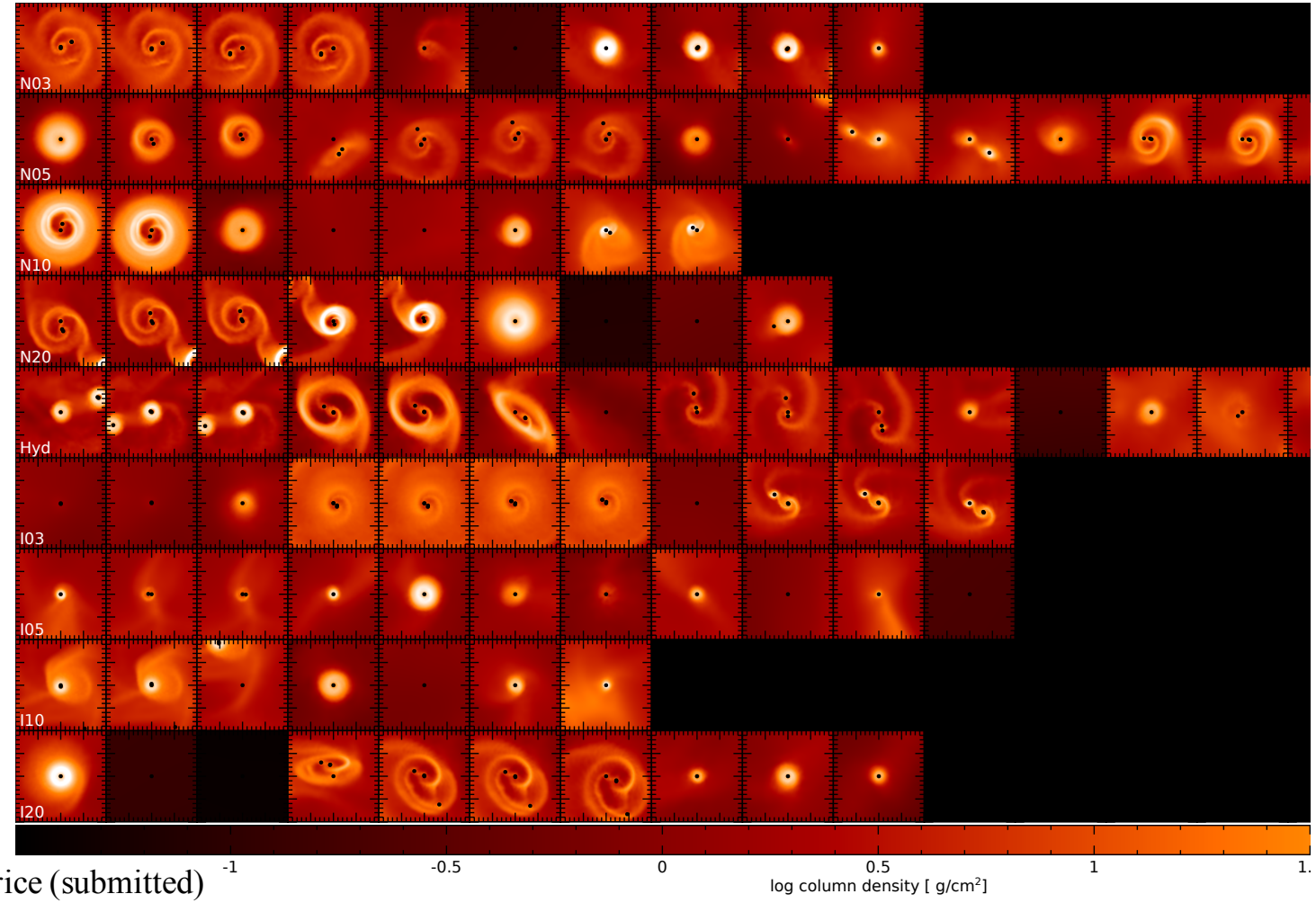


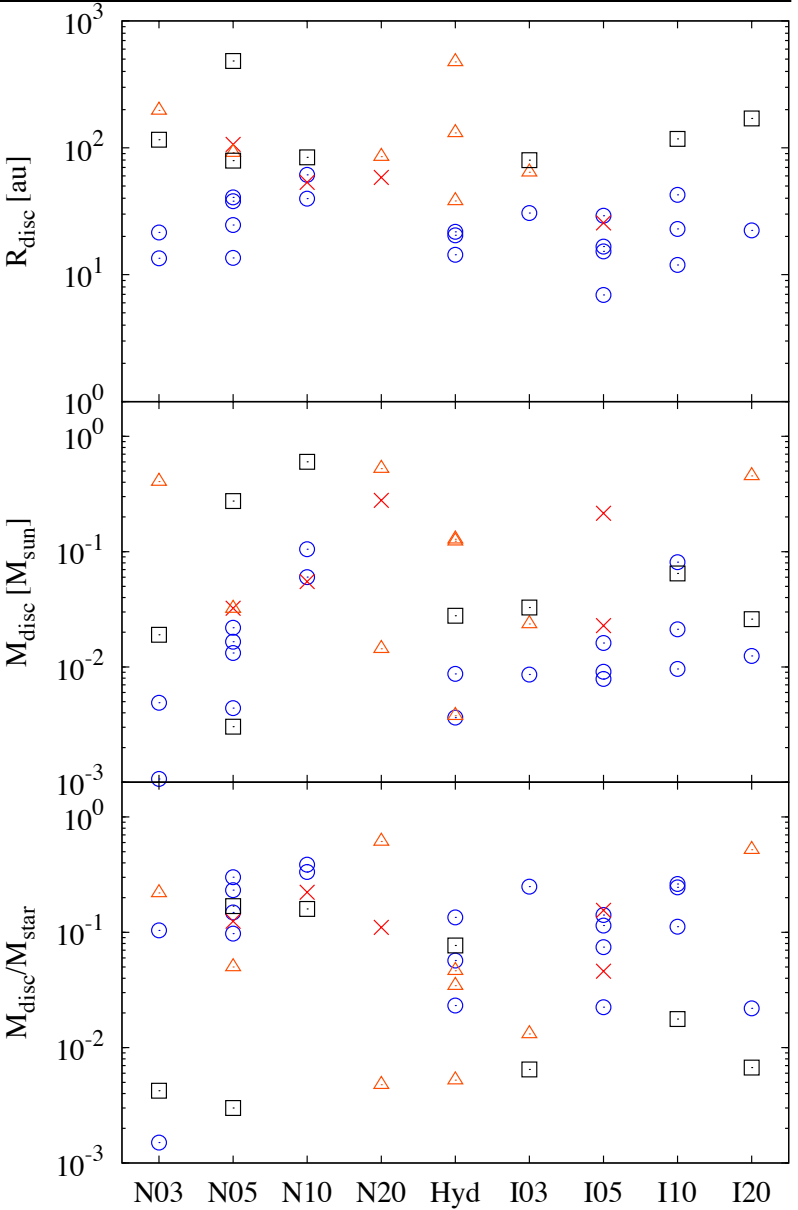
Wurster, Bate & Price (submitted)



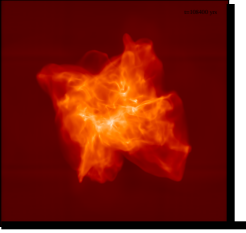
Cluster formation: protostellar discs

- Circumstellar discs of 5-80au form
- Circumsystem discs of up to 500au form
- Evolution is very dynamic given multiple interactions



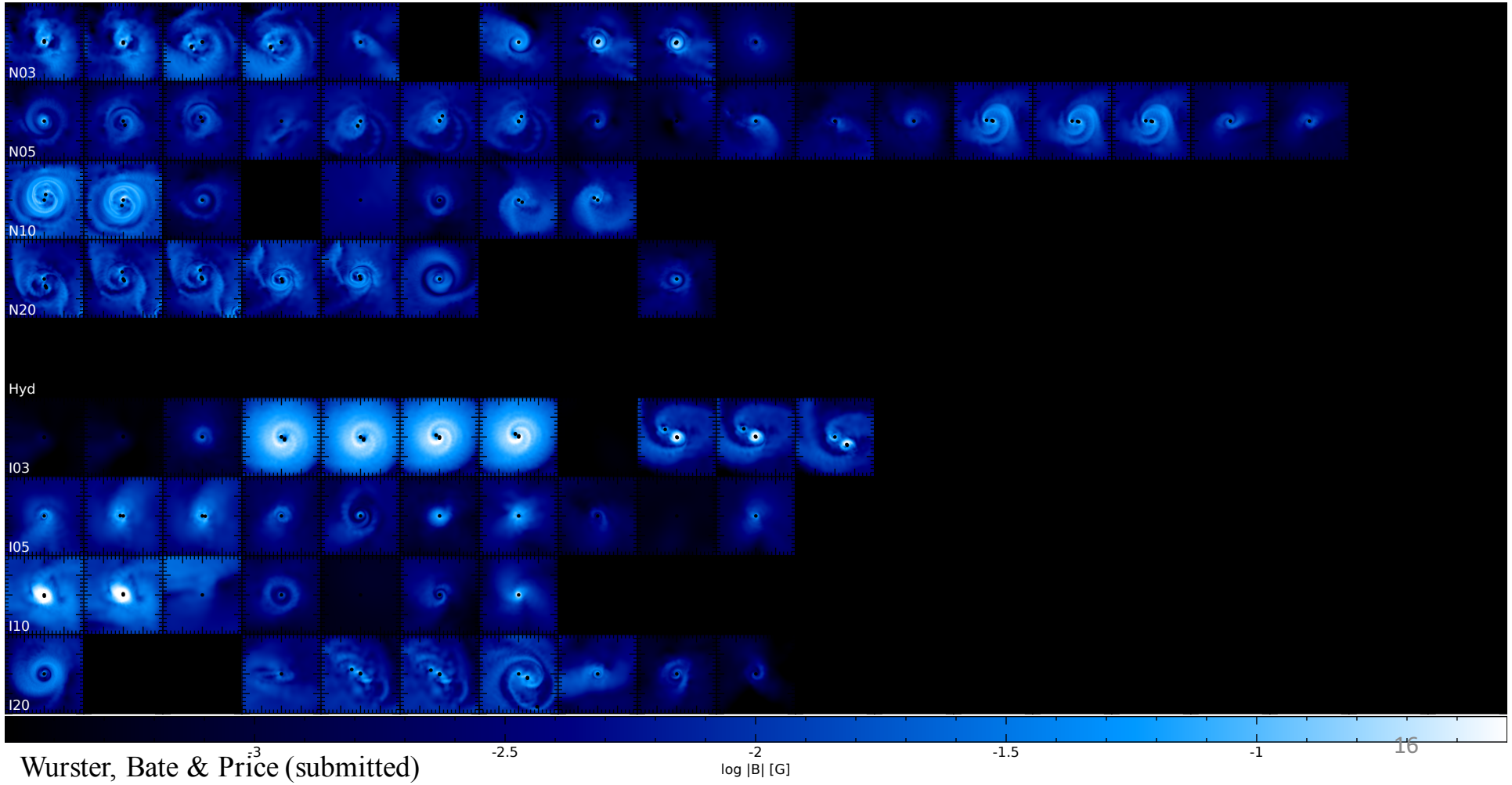


Wurster, Bate & Price (submitted)



Cluster formation: protostellar discs

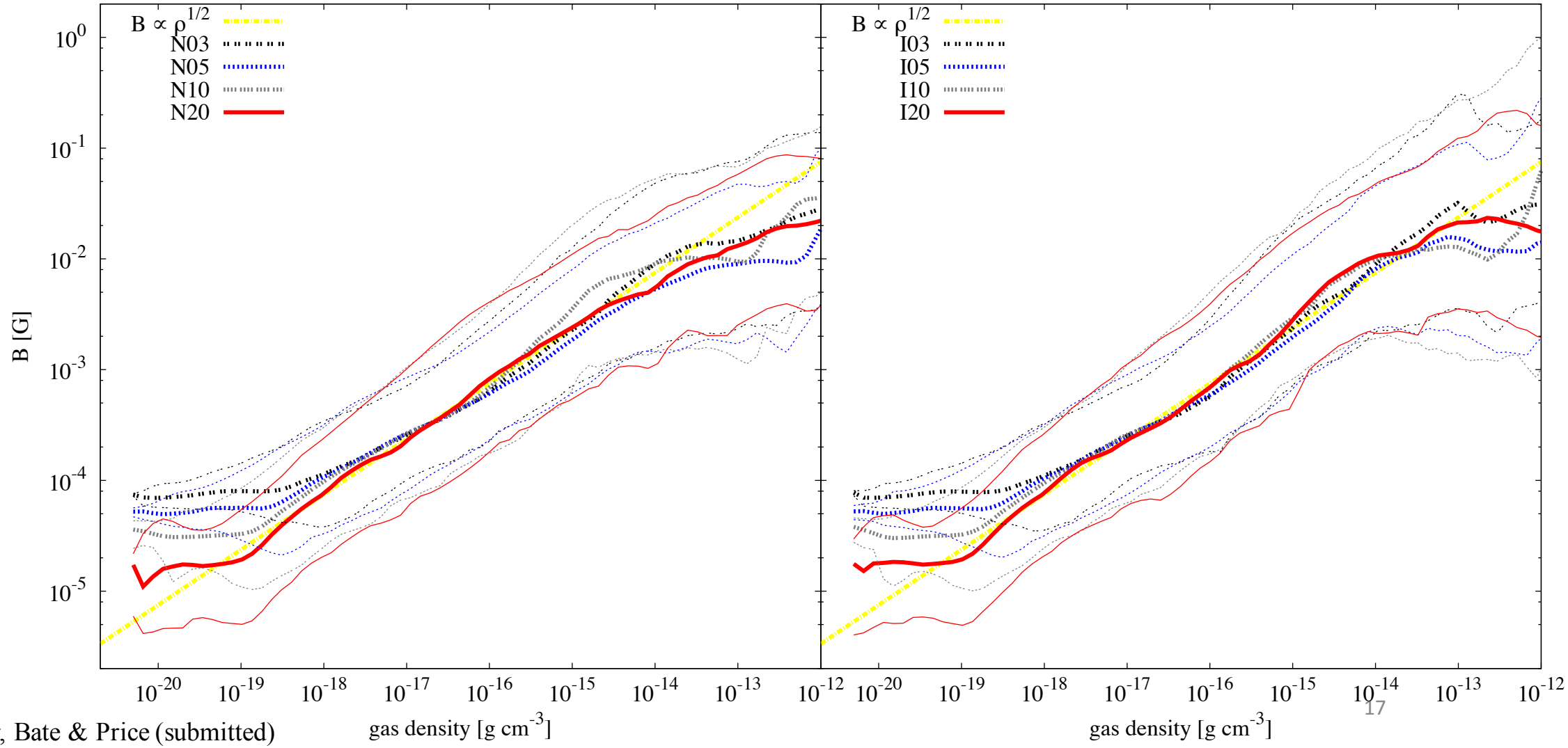
- There is a wide range of magnetic field strengths in the discs



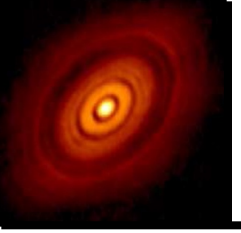
Wurster, Bate & Price (submitted)

Cluster Formation: Star forming regions

➢Star forming regions have a wide range of initial magnetic field strengths, that are approximately independent of the global environment



Wurster, Bate & Price (submitted)



Conclusions

- When modelling the formation of an isolated star
  - Large, rotationally supported discs form in pure hydrodynamics
  - No discs forms when using ideal MHD
  - Large and small discs form when using non-ideal MHD
  - Non-ideal MHD solves the magnetic braking catastrophe

- When modelling the formation and evolution of a low-mass star cluster
  - Magnetic fields affect the large-scale structure of the cloud
  - Non-ideal MHD processes only affect small-scale structure
  - Protoplanetary discs form in *every* model, even those with initially strong magnetic fields
  - There is no magnetic braking catastrophe

- TAKE-AWAY MESSAGE: *MAGNETIC FIELDS CANNOT BE IGNORED! (and need further investigation)*

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