Discs in the first hydrostatic core stage

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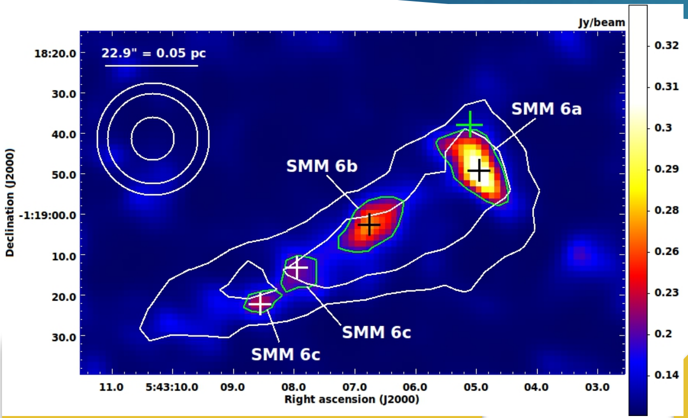
Early star formation

Molecular cloud collapse starts (First collapse) → First hydrostatic core forms → Second Collapse → Stellar core forms

Central density and temperature increase

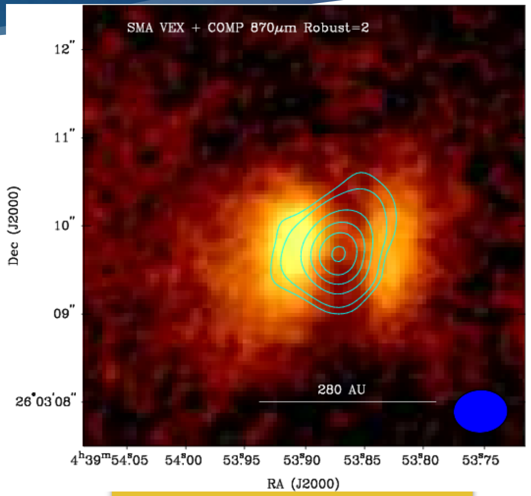
Early star formation

Miettenen+ 2013



?

Tobin+ 2013



Molecular cloud collapse starts (First collapse)

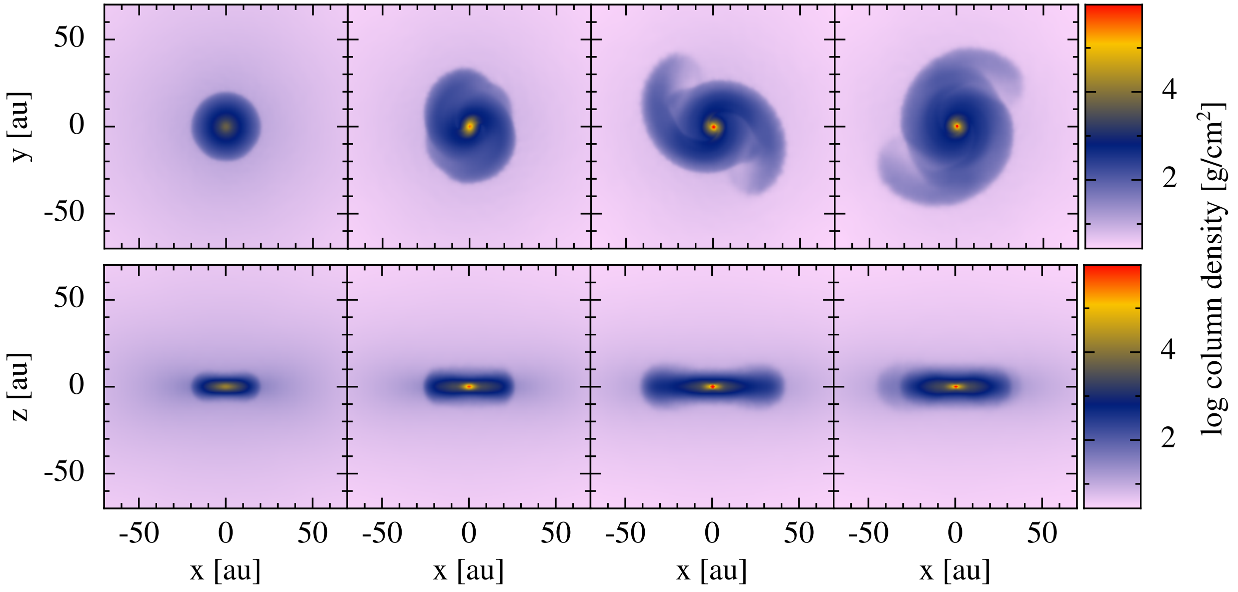
First hydrostatic core forms

Second Collapse

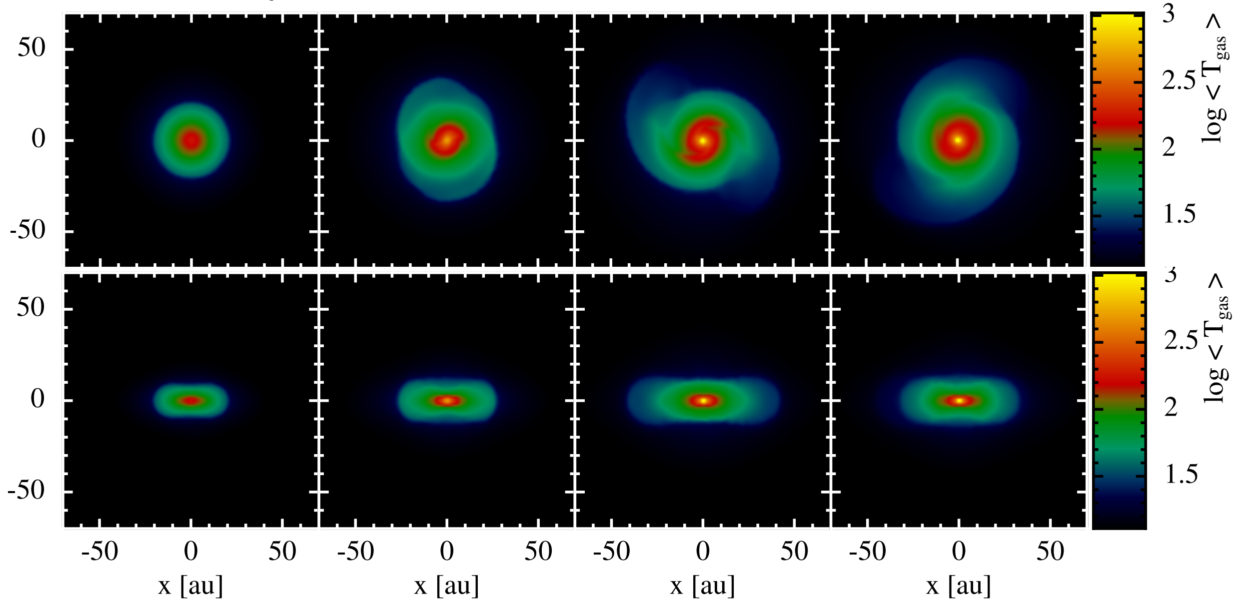
Stellar core forms

The first hydrostatic core

Column density



Gas temperature

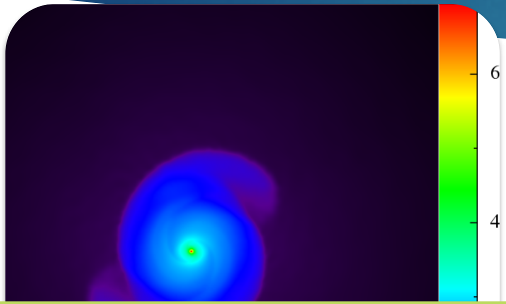


The first hydrostatic core

How to identify the FHSC – chemistry and/or kinematics?

- Could we detect the rotational structures?
- Chemical differences?
- What are the best tracers of different structures?

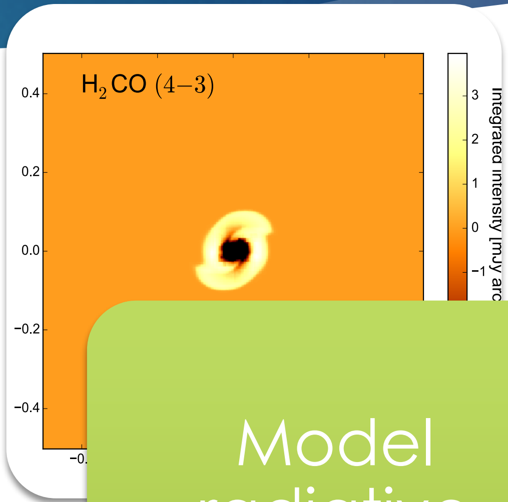
Method: Molecular line emission



(Magneto) hydrodynamical models

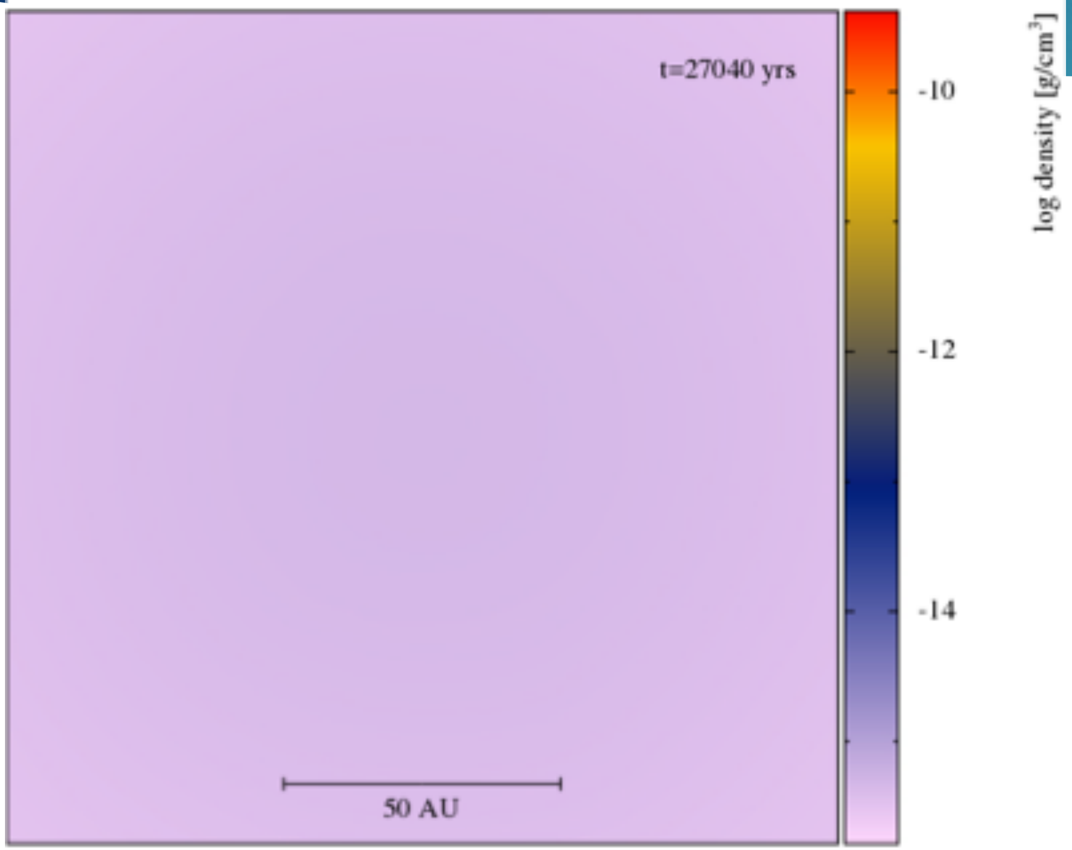
KROME
better science through chemistry

Calculate chemical reactions



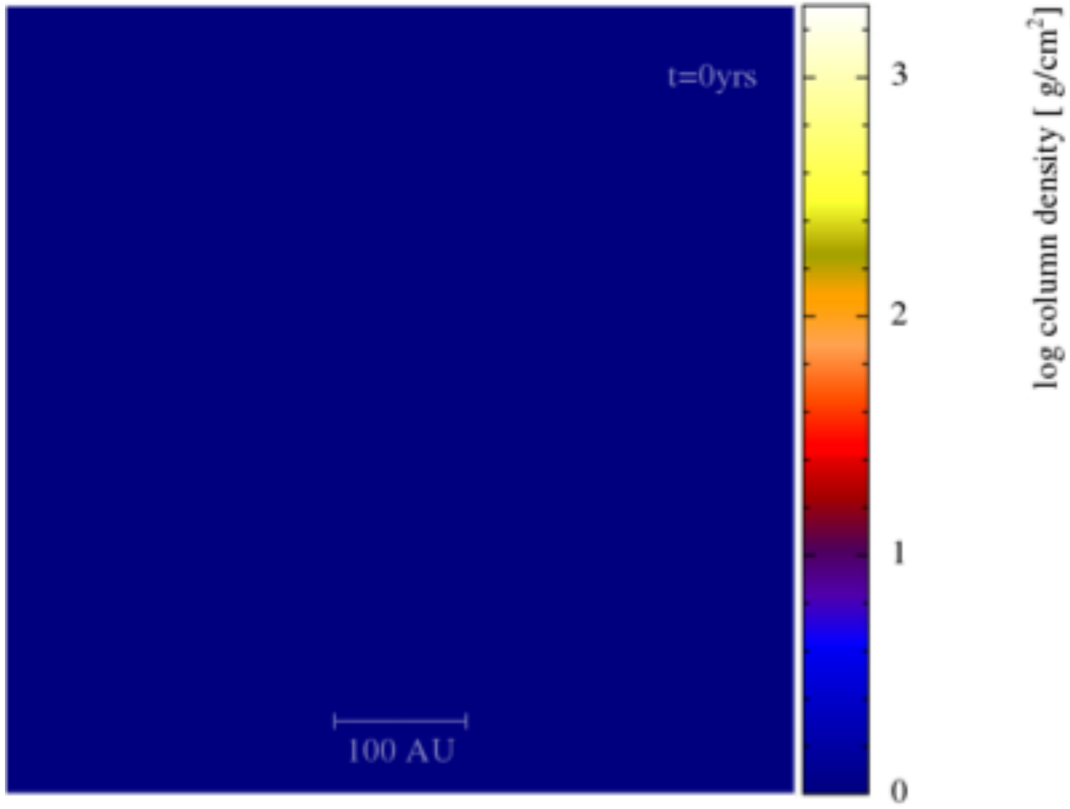
Model radiative transfer for snapshots

Hydrodynamical models



- **SPH calculation**: $3{\times}10^6$ particles
- **β_{rot} = 0.02, RHD only**
- β_{rot} = 0.05, μ=5
- 1 $M_\odot$ Bonnor-Ebert sphere
- hydrodynamics, gravity, radiation, ISM heating/cooling processes (Bate & Keto 2015)
- Follows collapse of cloud core until after stellar core formation ~35 kyr

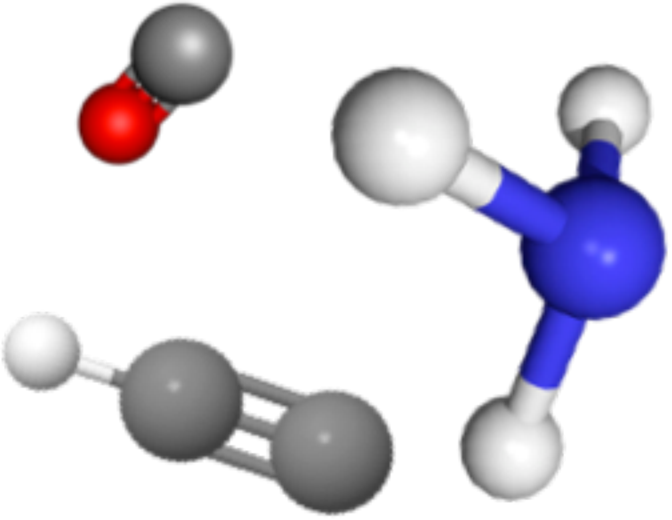
Hydrodynamical models



- **SPH calculation**: 3×10^6 particles
- β_{rot} = 0.02, RHD only
- **β_{rot} = 0.05, μ=5 (ideal MHD)**
- 1 $M_{\odot}$ Bonnor-Ebert sphere
- hydrodynamics, gravity, radiation, ISM heating/cooling processes (Bate & Keto 2015)
- ideal MHD
- Follows collapse of cloud core until after stellar core formation ~35 kyr

Chemistry

- Non-equilibrium, time-dependent chemistry
- KIDA 2011 network (Wakelam+ 2012) + gas-grain reactions (Garrod+ 2007, Reboussin+ 2014)
- 600 species, ~7000 reactions
- Pre-calculated initial abundances in 0-D from standard dense ISM conditions
- KROME solver (Grassi+ 2014) called for each particle using $\boldsymbol{\rho}$, T_{gas}, T_{dust}, A_v
- Initial conditions run for 60kyr, then for successive hydro timesteps.



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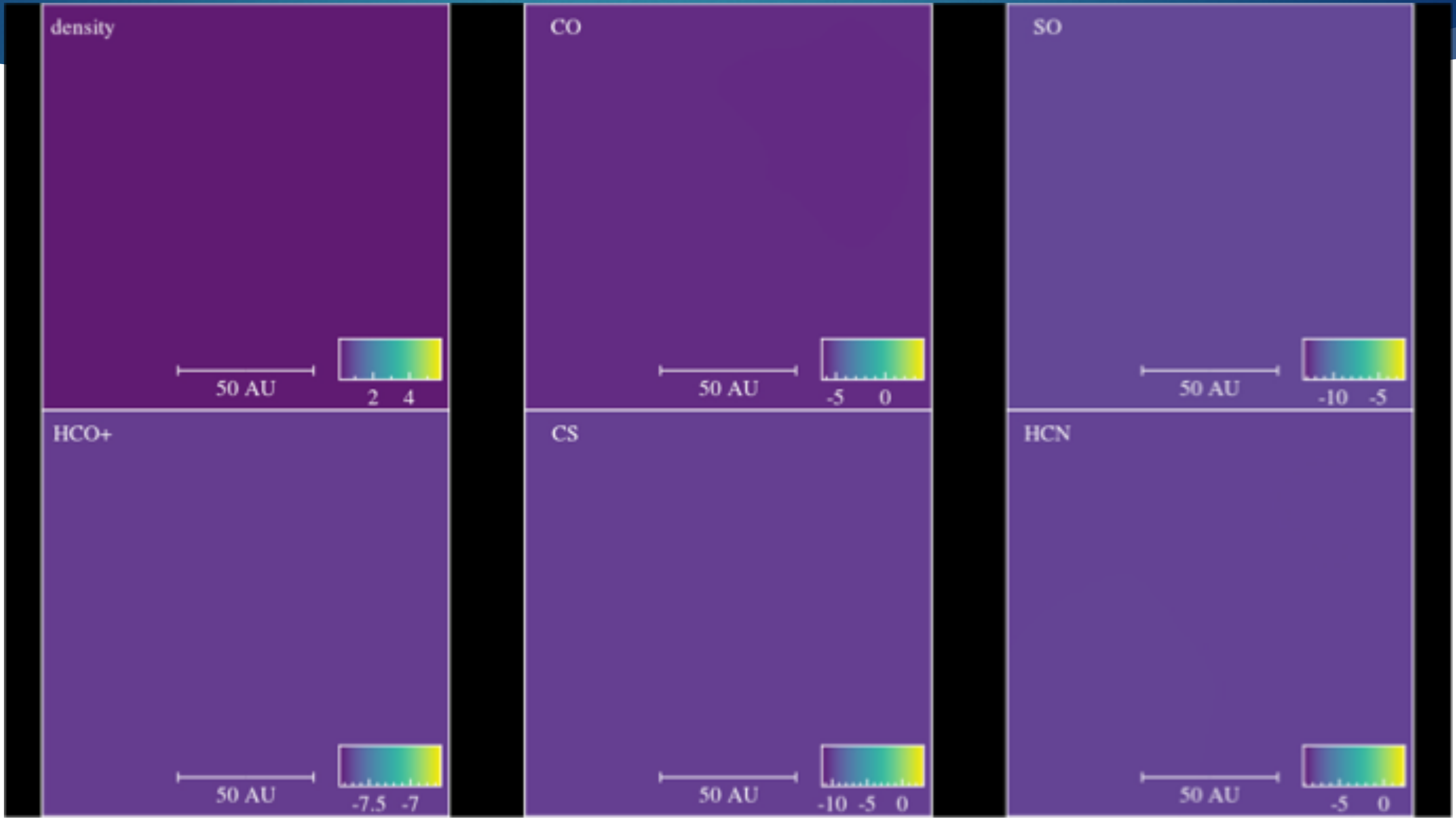
Chemical evolution

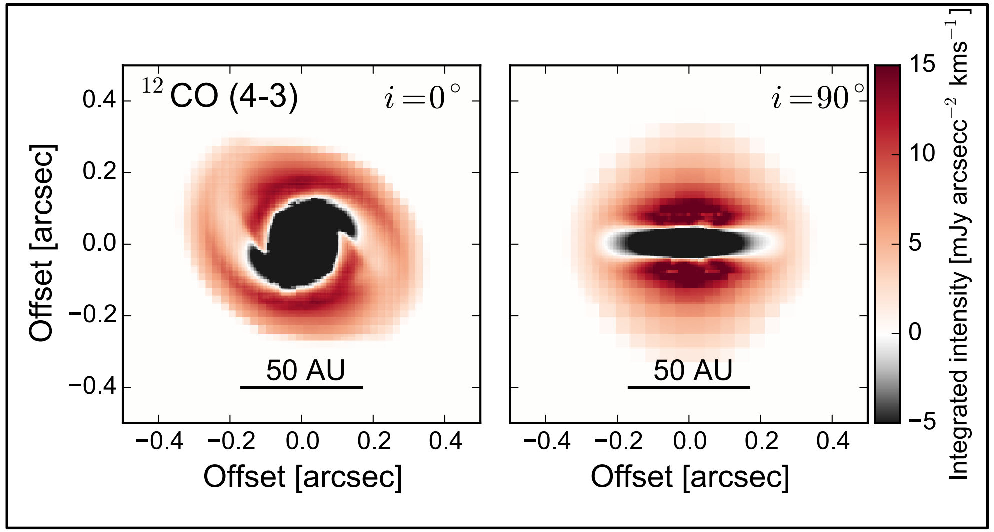


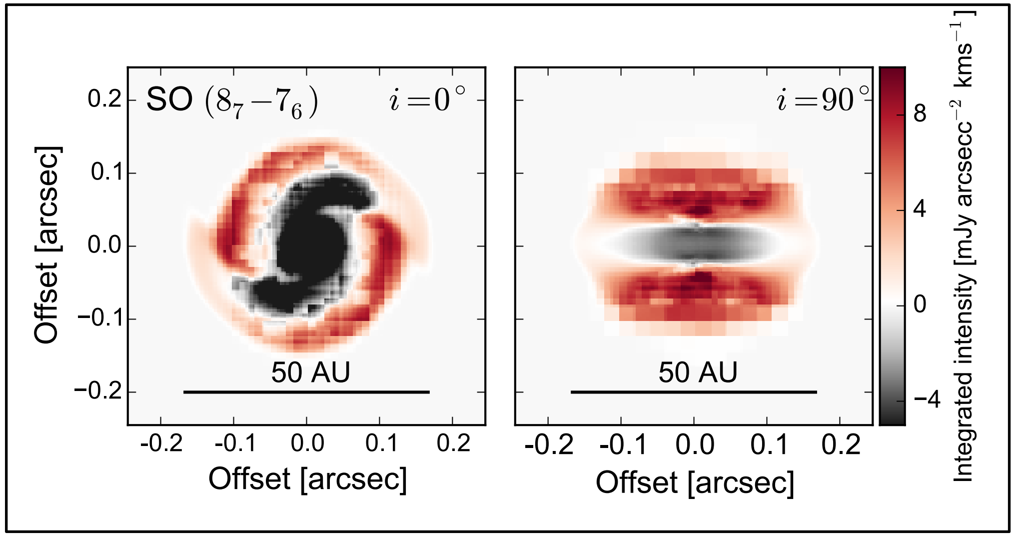
Radiative transfer

- TORUS (Harries 2000) Monte Carlo radiative transfer
- Level populations calculated assuming LTE
- Observer @ 150 pc
- 5'' × 5'' image (=750 AU)
- v = -- 4 km/s to +4 km/s, 0.1 km/s resolution
- -> FITS velocity cube for CO, CS, SO and HCO^+

Integrated Intensity: rotational structures

Synthetic line map





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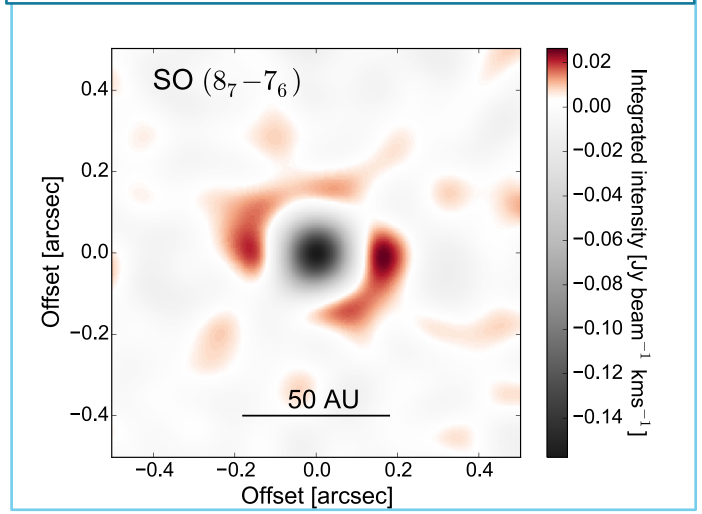
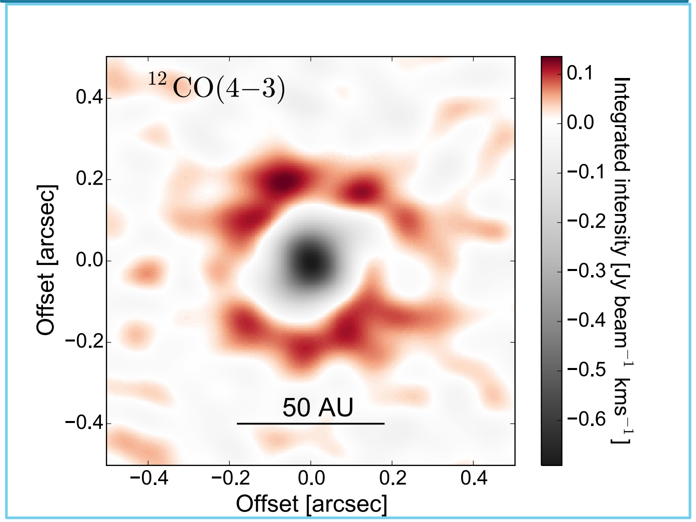
Rotational structures

What about ALMA?

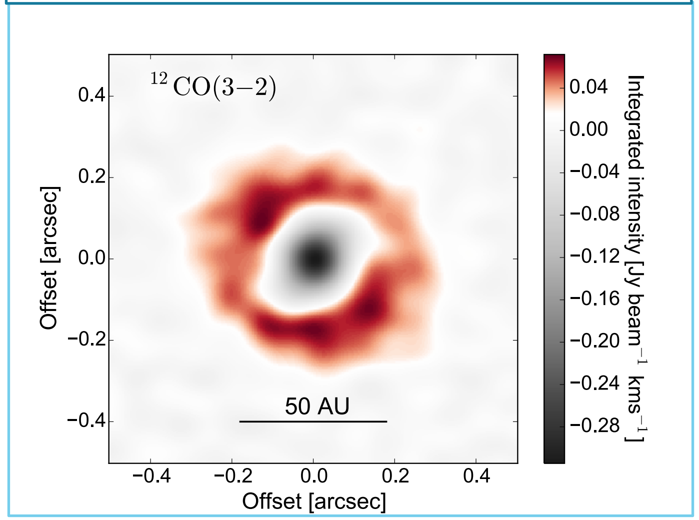
SO ($8_7 - 7_6$) 340 GHz, 8h, ~0.14'' beam



CO (4 – 3) 461 GHz, 8h, ~0.1'' beam



CO (3 – 2) 345 GHz, 4h, ~0.1'' beam



- Non-axisymmetric structure detectable
- Noise reduction important consideration

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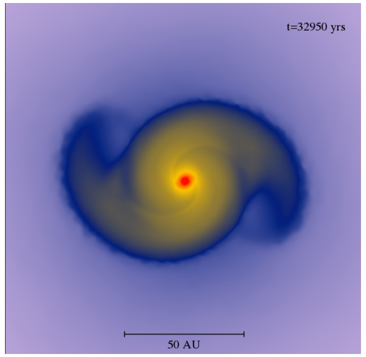
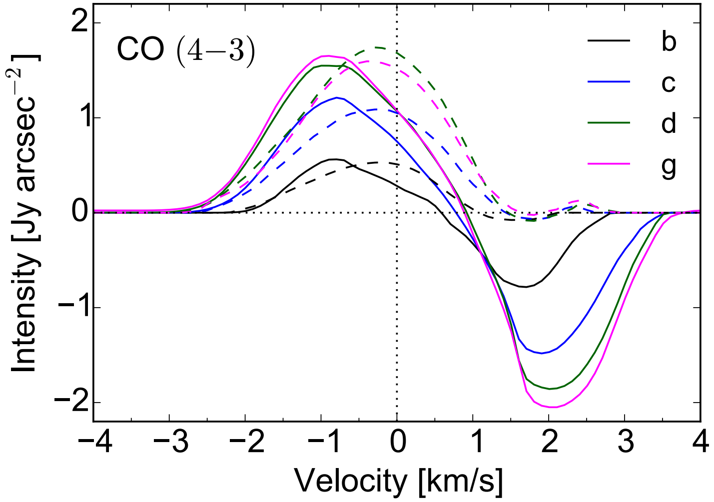
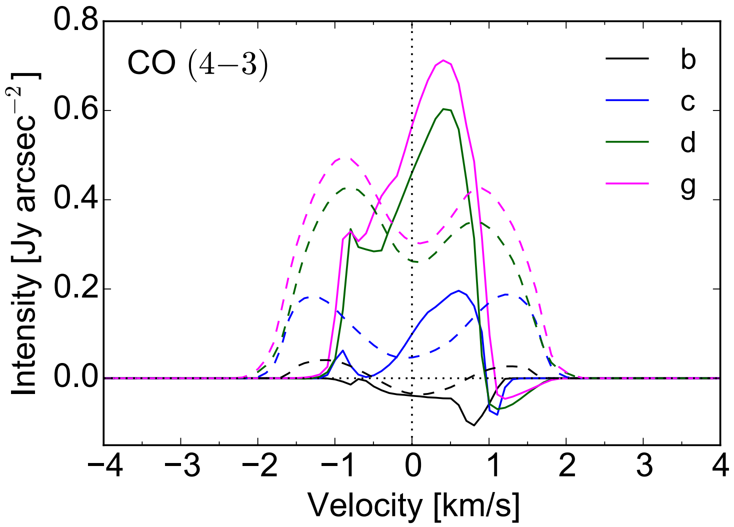
Kinematic signatures?

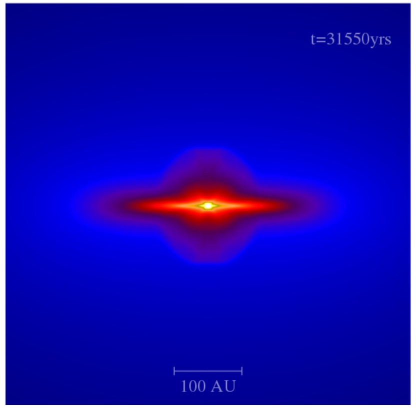
RHD (with disc)





RMHD (with outflow)





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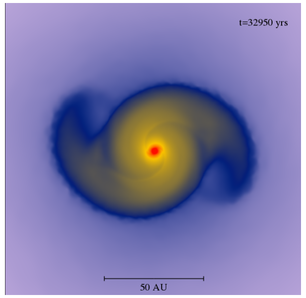
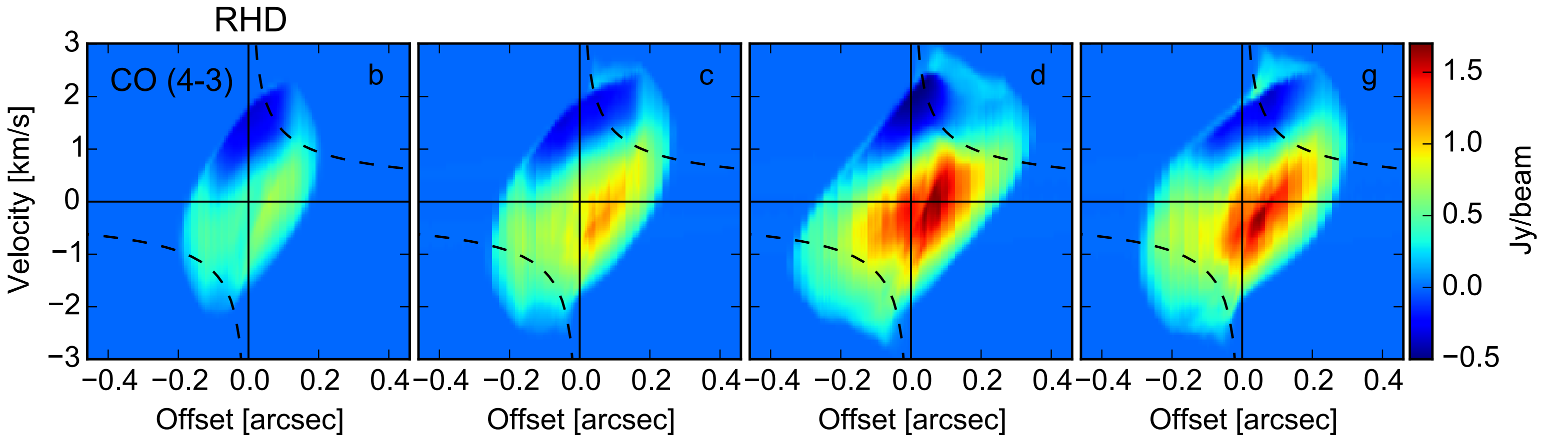
Kinematic signatures?

RHD (with disc)





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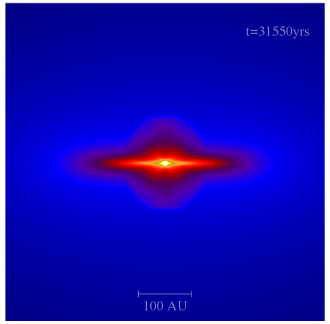

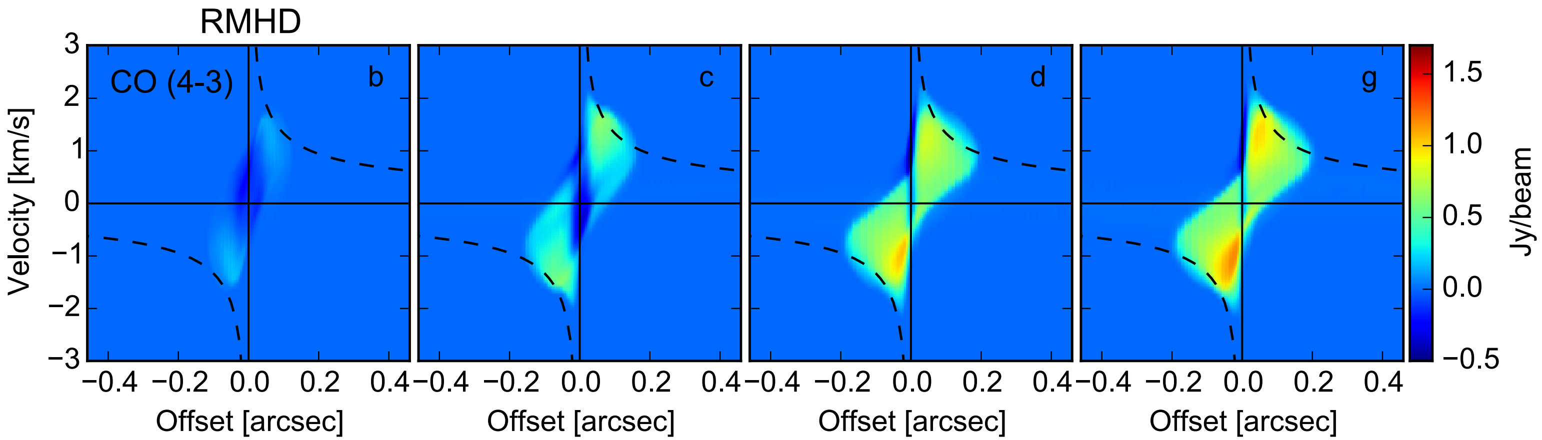

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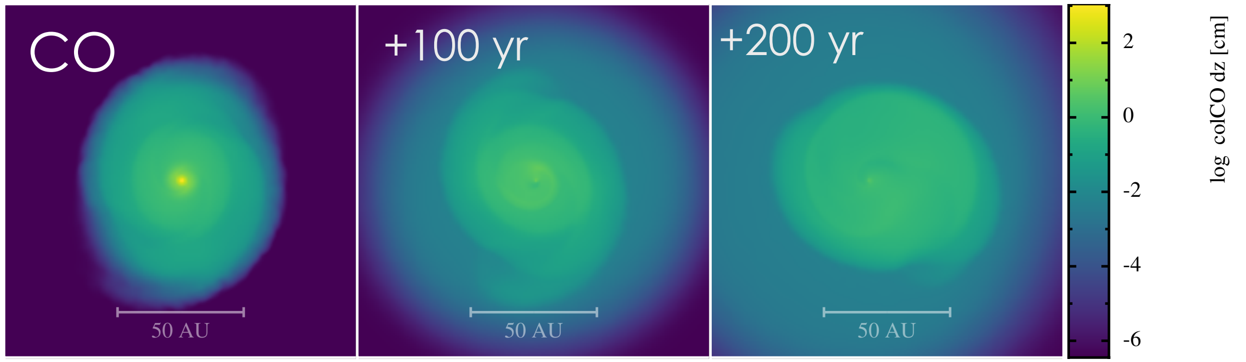
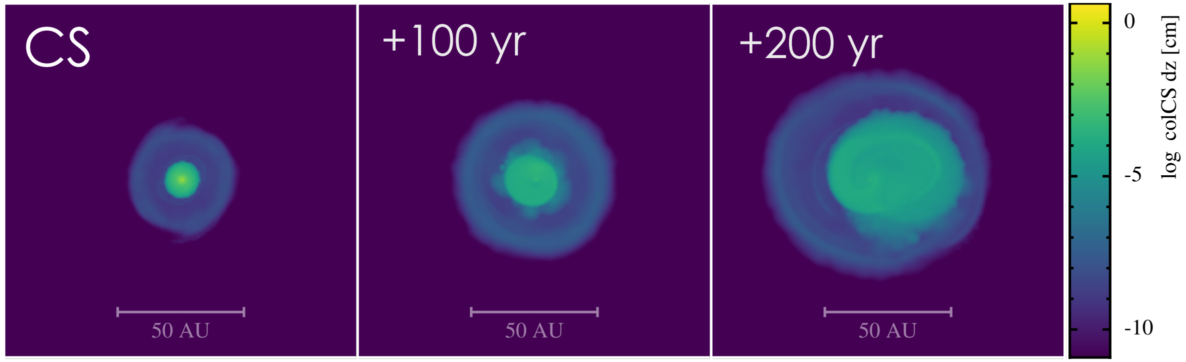
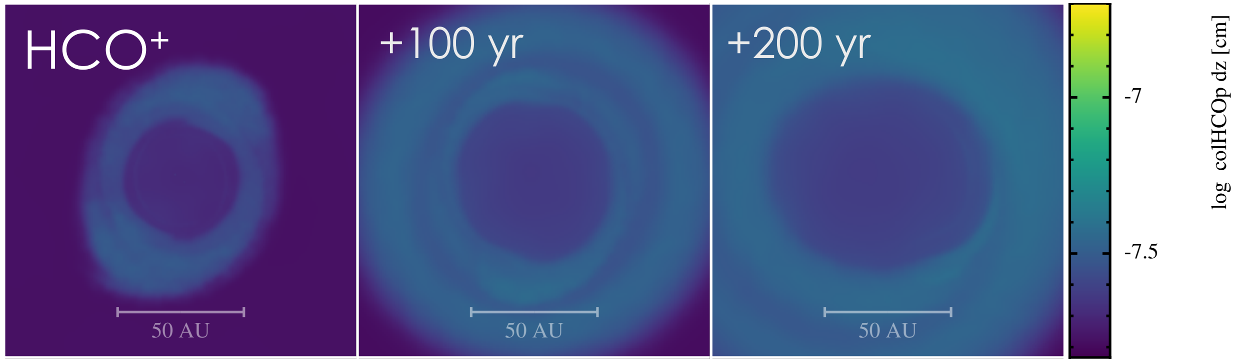
Beyond stellar core formation?

- With thermal feedback due to accretion luminosity







Summary/What next?

- Rotational structures should be detectable with ALMA
- Kinematic signatures of disc not clear as disc optically thick and seen in absorption

- Adapt chemistry calculations for protoplanetary discs