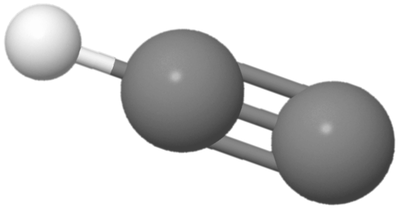
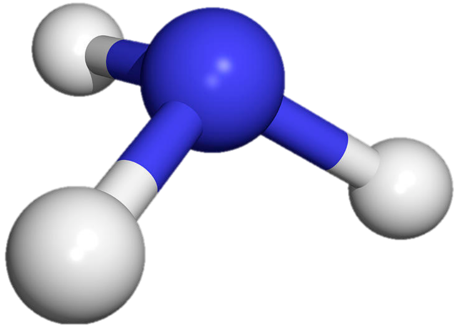
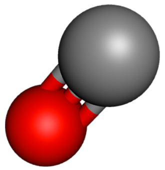




Synthetic molecular line observations of the first hydrostatic core



ALISON YOUNG & MATTHEW BATE

Early star formation

Molecular cloud begins to collapse (First collapse)

→

First hydrostatic core forms

Thermal pressure balances gravitational collapse

→

Second Collapse

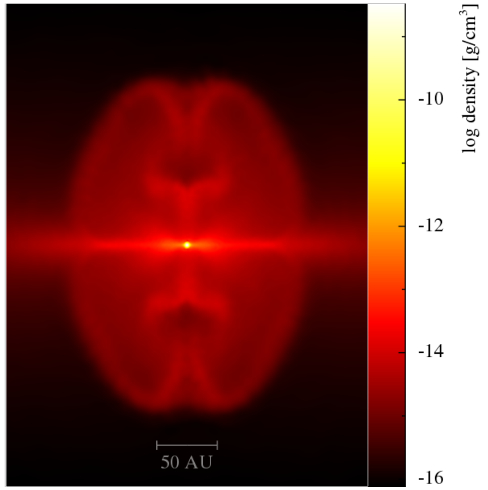
→

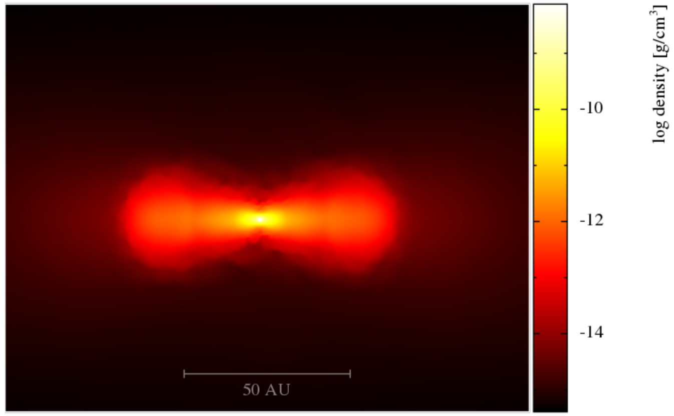
Stellar core forms

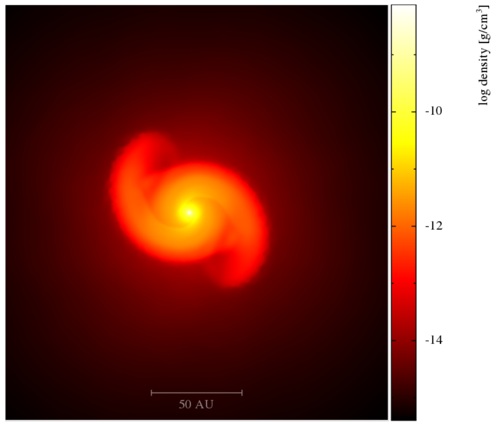
Central density and temperature increase →

Predictions

- Rotationally supported disc (e.g. Bate 2011, Tomida+ 2015)
- Compact, slow, warm outflow (e.g. Tomida+ 2010)
- Low luminosity < 0.1 $L_{\odot}$ (e.g. Young+ 2004)
- SEDs peak ~200μm (e.g. Omukai 2007, Young & Evans 2005)
- CS linewidth increases after FHSC formation, blue asymmetry (Tomisaka & Tomida 2011)



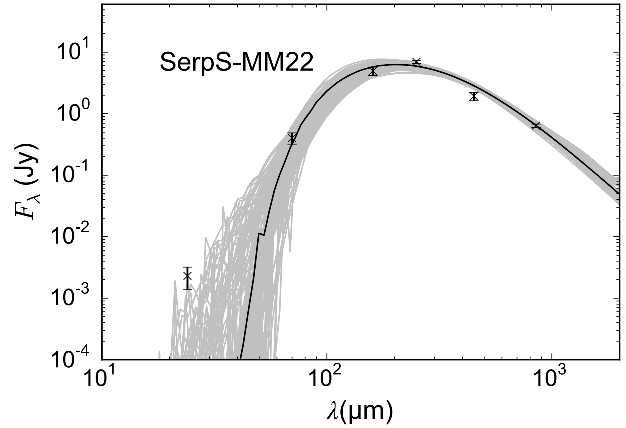




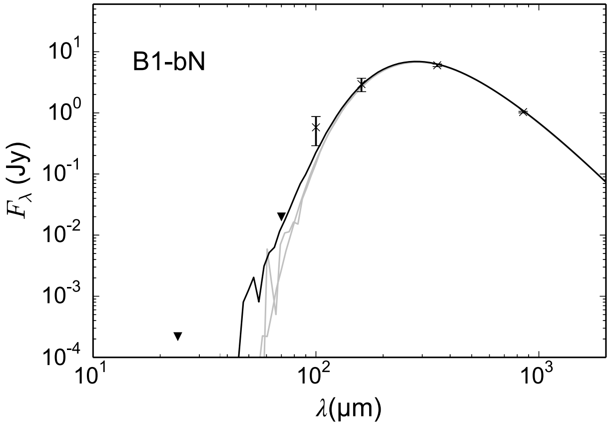
Young+ 2018

FHSC candidates

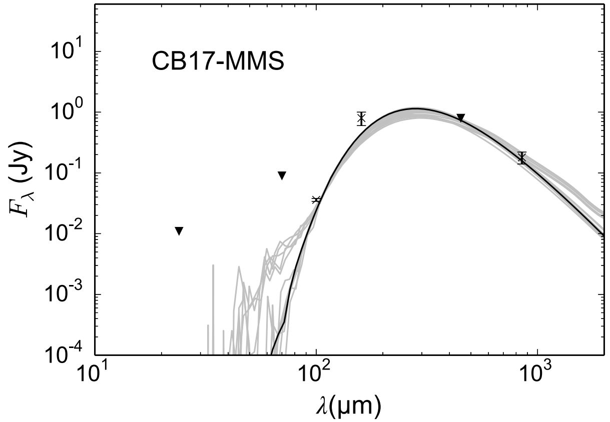
- Between "starless cores" and Class 0 protostars
- Can use SEDs to predict which sources are most likely to contain a FHSC (Young+ 2018)



Not a FHSC



Fast rotation, high inclination



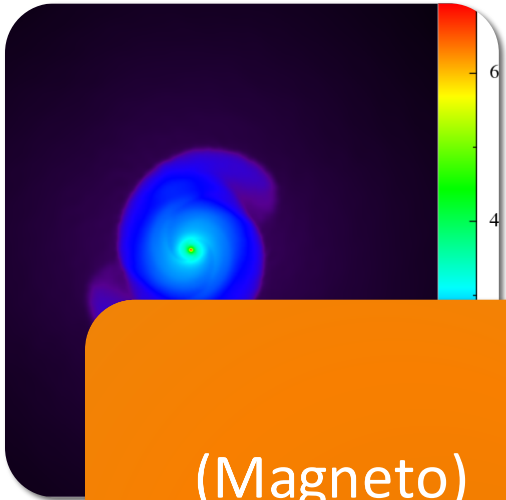
Moderate rotation, high inclination

We also fitted SEDs of B1-bS, Per-Bolo 58, Cha MMS-1, Aqu-MM2, SerpS-MM19 & Aqu-MM1 – see Young+ (2018)

Aims

- Which molecules and transitions might be observable and useful?
- Are there any distinctive characteristics of FHSC line emission?
- Could we measure the kinematics?

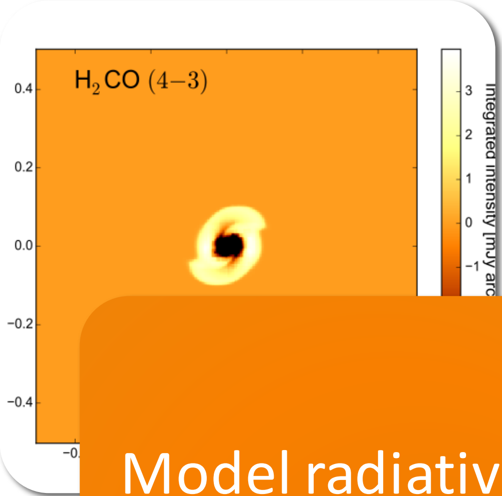
Method



(Magneto) hydrodynamical models

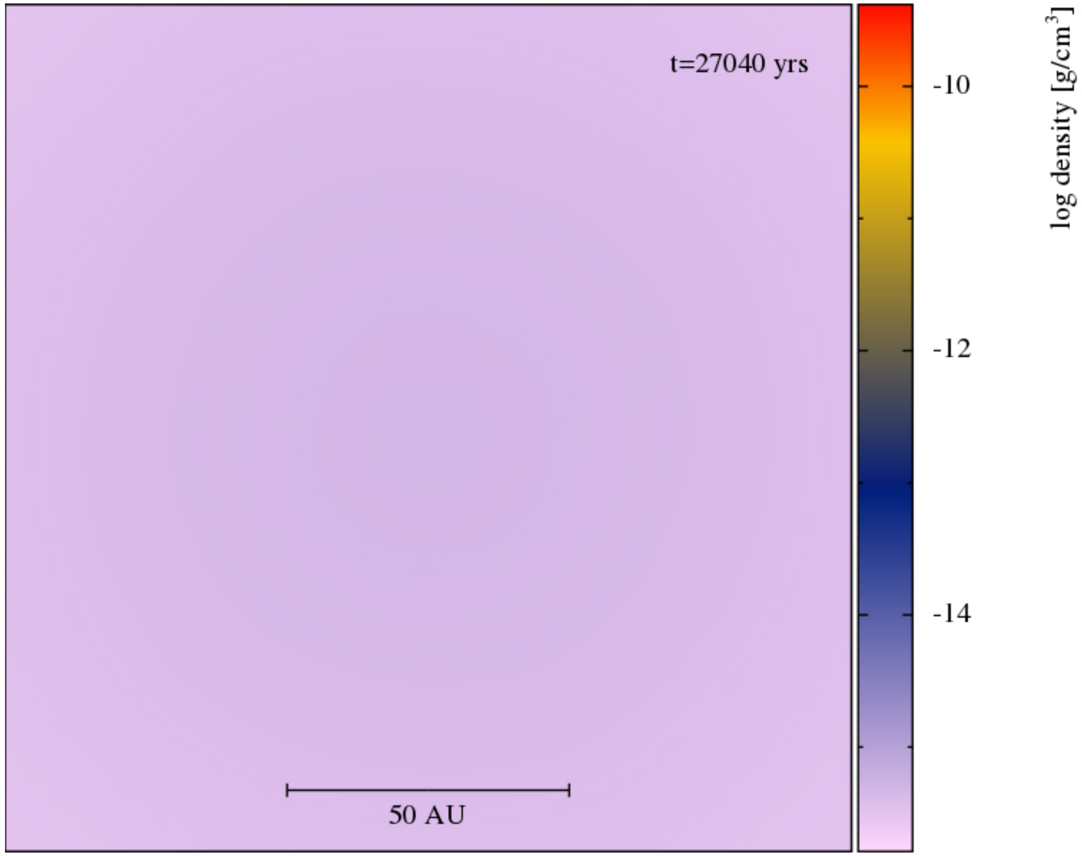
KROME
better science through chemistry

Calculate chemical reactions



Model radiative transfer for snapshots

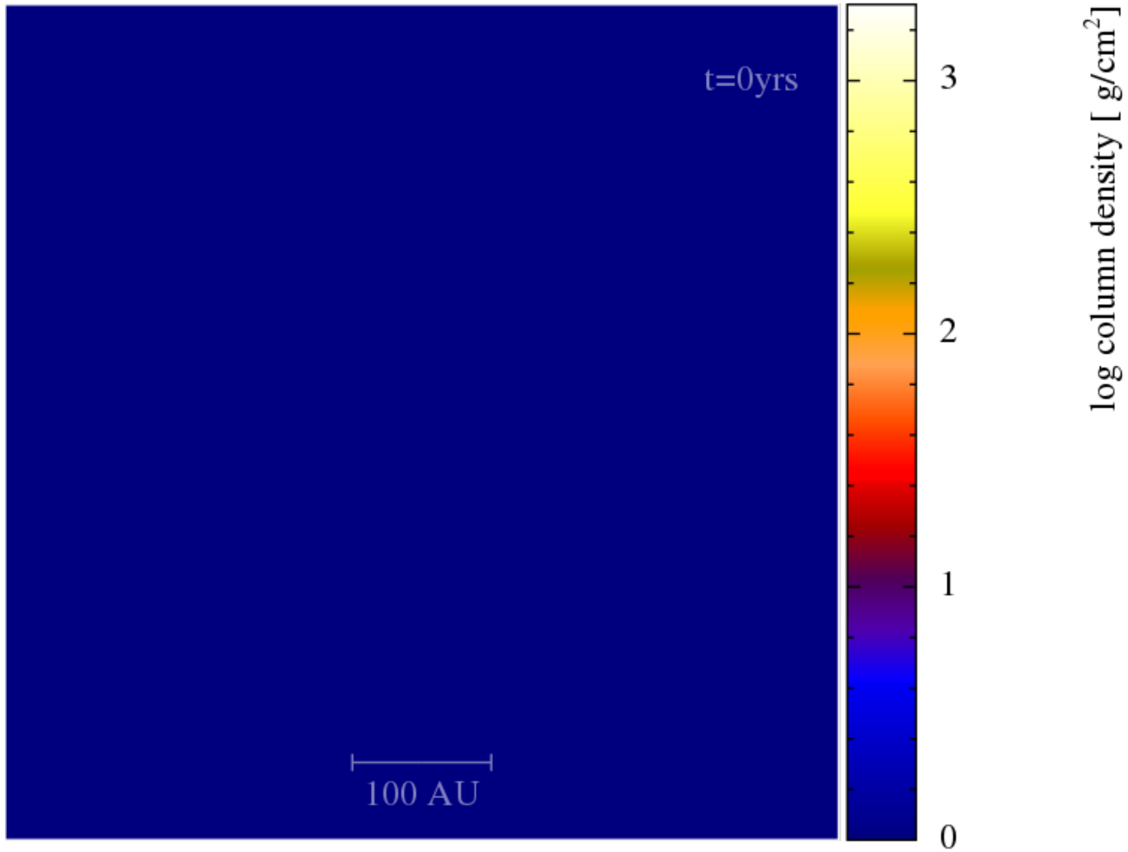
Hydrodynamical models



SPH calculation: 3×10^6 particles

- 1 $M_\odot$, $\boldsymbol{\beta}_{rot}$ = 0.02
- 1 $M_\odot$, $\boldsymbol{\beta}_{rot}$ = 0.05, μ=5
- hydrodynamics, gravity, radiation, ISM heating/cooling processes, (ideal MHD)
- Follows collapse of cloud core until after stellar core formation ~35 kyr

Hydrodynamical models



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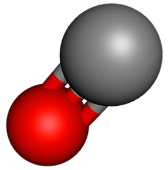
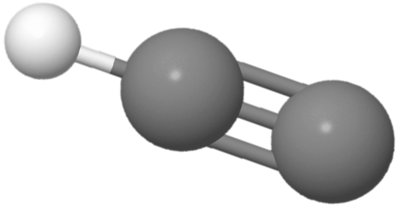
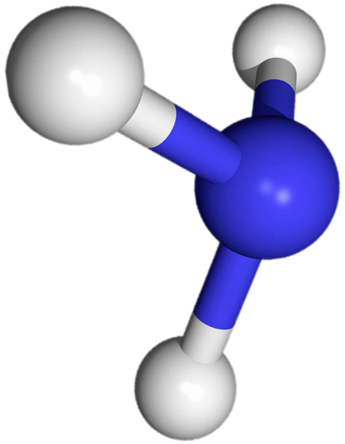
Chemistry

- KIDA 2011 network (Wakelam+ 2012) + gas-grain reactions (Garrod+ 2007, Reboussin+ 2014)
- Initial abundances calculated from standard ISM conditions
- KROME solver (Grassi+ 2014) called for each particle
- Initial conditions run for 60kyr, then for successive hydro timesteps.

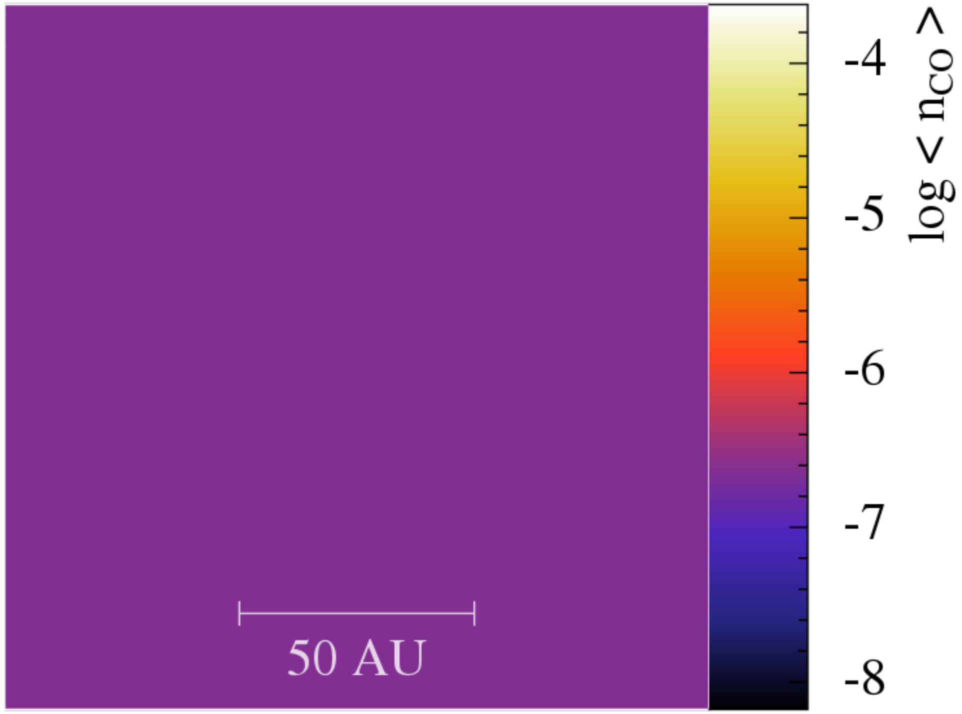




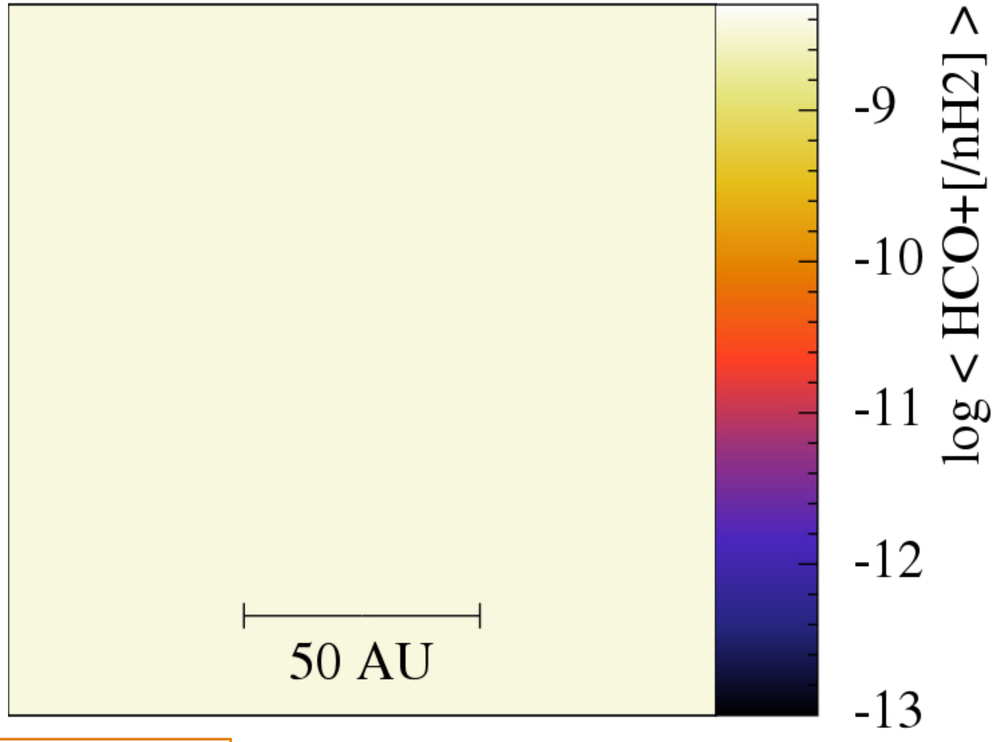


Chemical evolution

CO



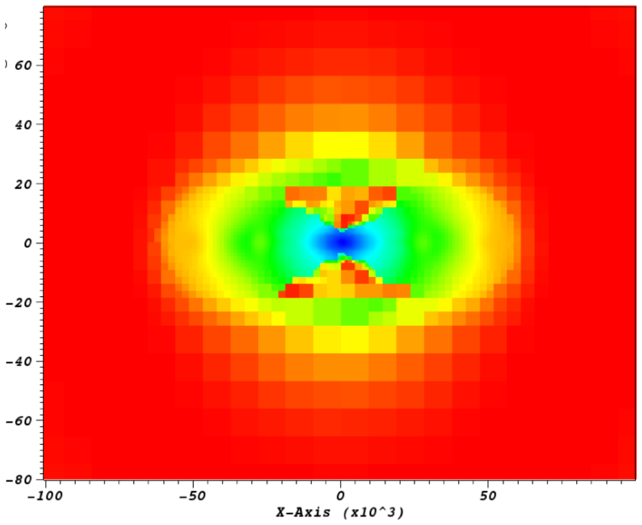
HCO+



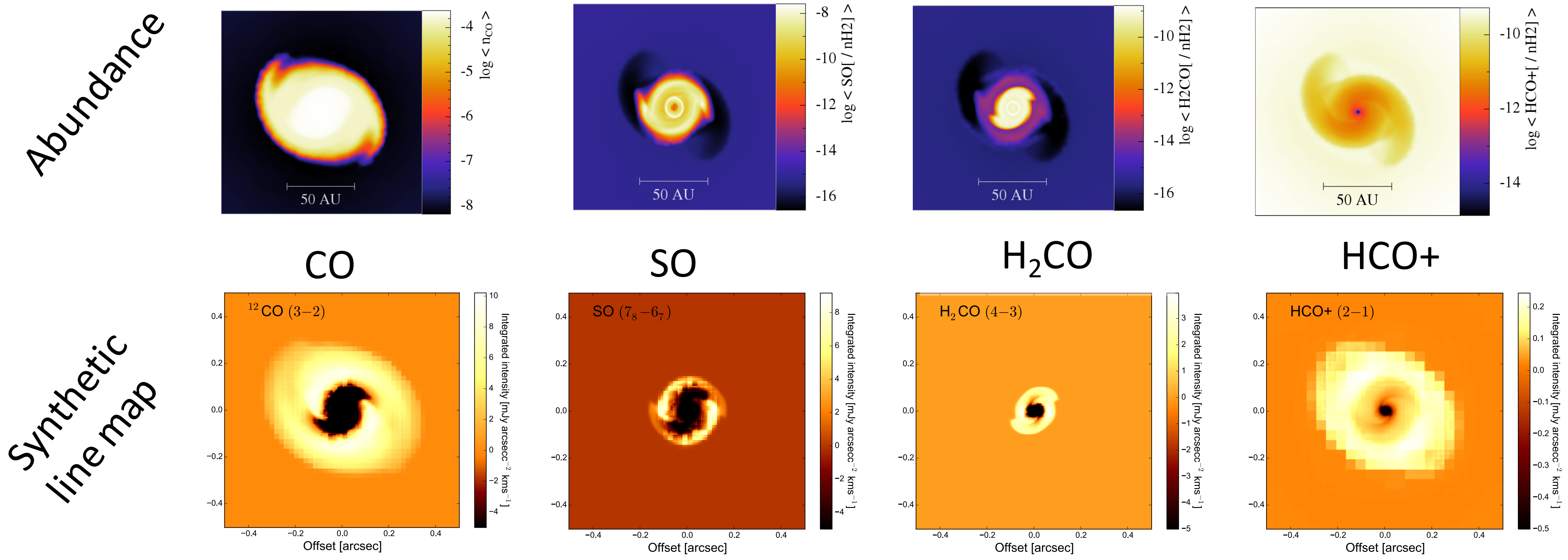
No significant chemical changes soon after stellar core formation

Radiative transfer

- TORUS (Harries 2000) Monte Carlo radiative transfer
- 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

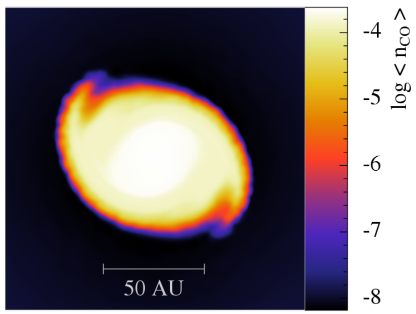


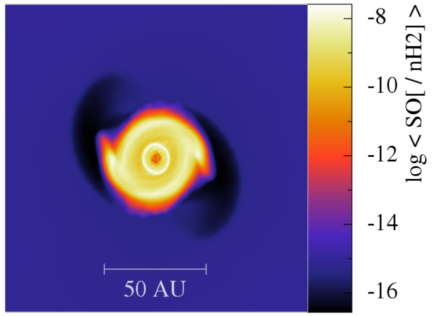
Integrated Intensity



Integrated Intensity

Abundance

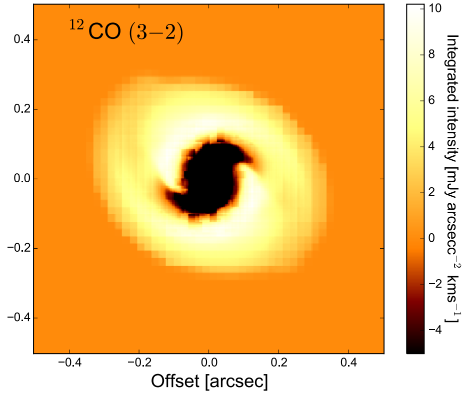


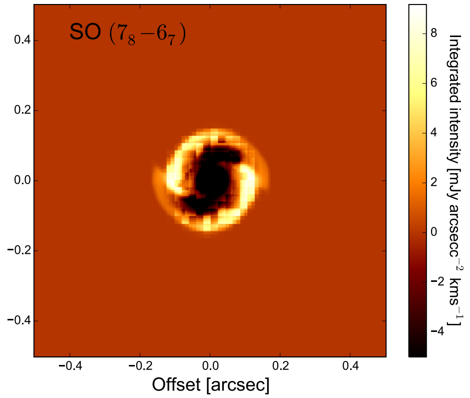


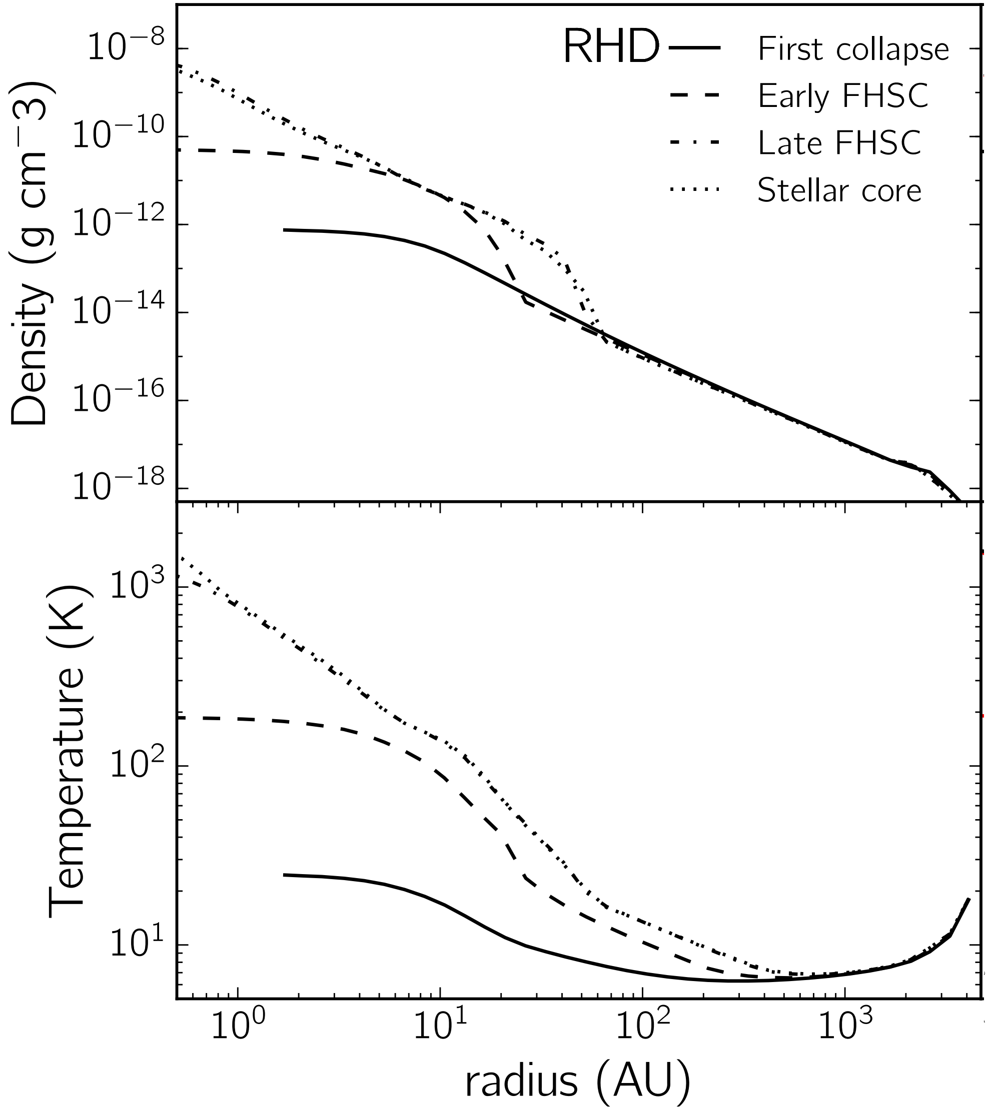
CO

SO

Synthetic line map

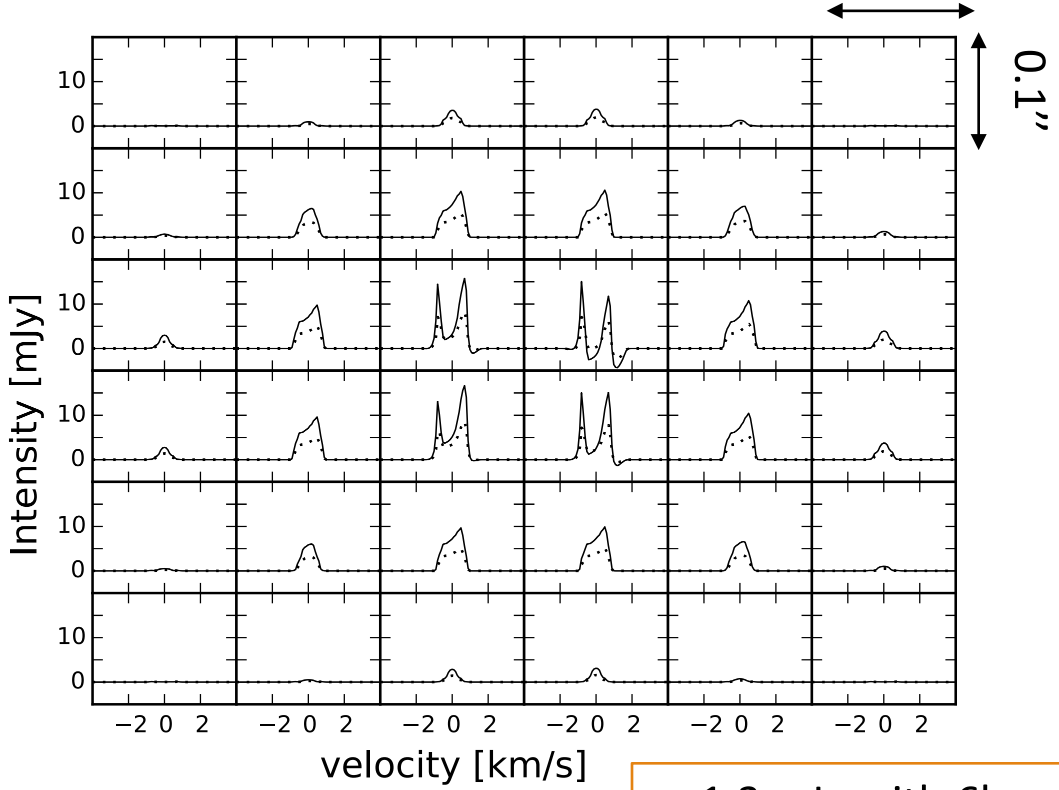


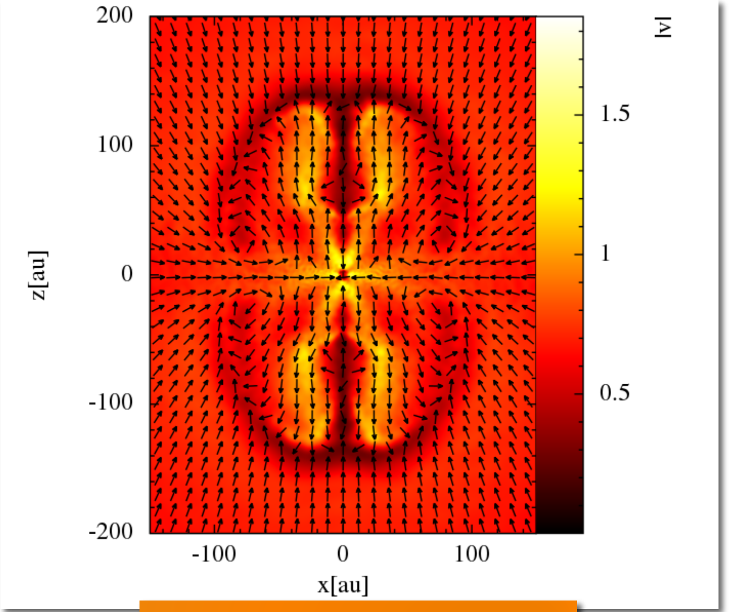




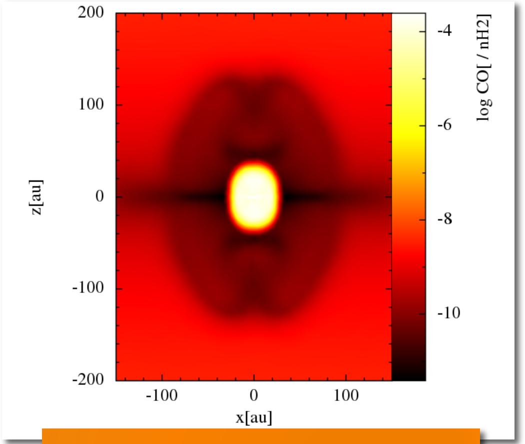
Synthetic spectra

CO (3-2) Late FHSC, outflow, face-on





Velocity

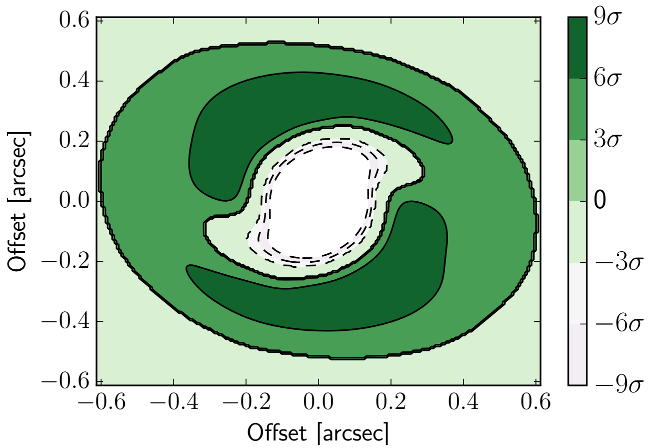


CO abundance

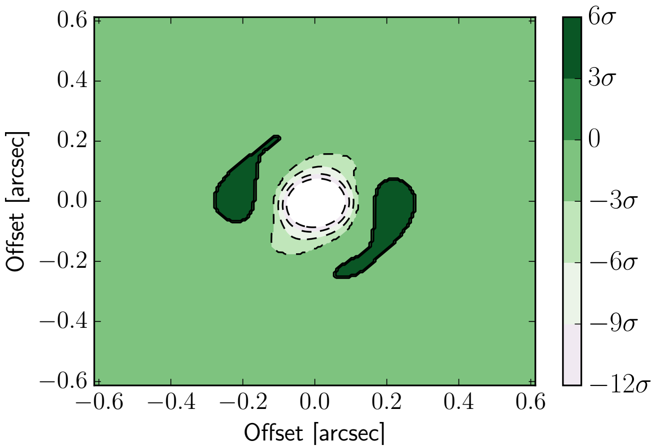
σ=1.3 mJy with 6hrs ALMA, Δv=0.4 km/s

Outlook

6hrs ALMA 0.05'' resolution



CO (3-2) σ= 2.7 mJy



SO (7_8-6_7) σ=3.0 mJy

Summary

- Produced synthetic line observations from hydro + chemistry simulations
- No significant changes in chemical abundance soon after second collapse
- CO, SO bright enough for kinematics with several hours integration
- These observations will be challenging!