Chemical evolution in low-mass star formation

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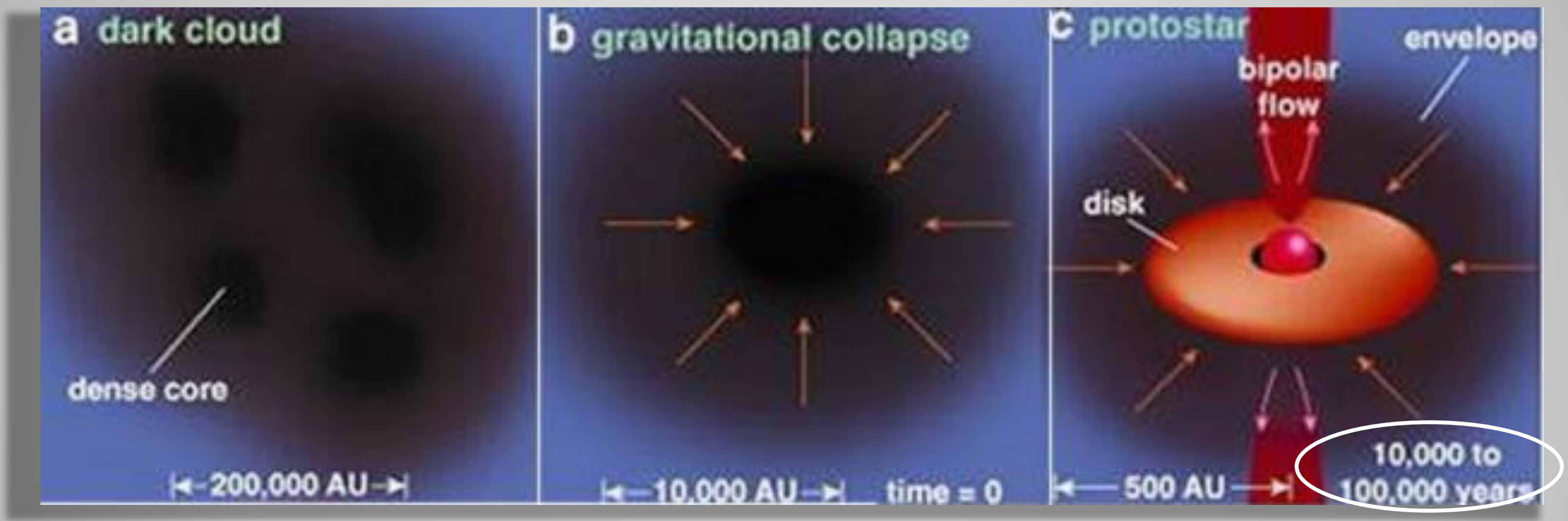
Contents

Introduction

- Dynamical process of star formation alters the physical conditions of surrounding material by orders of magnitude within relatively short timescales.



Introduction

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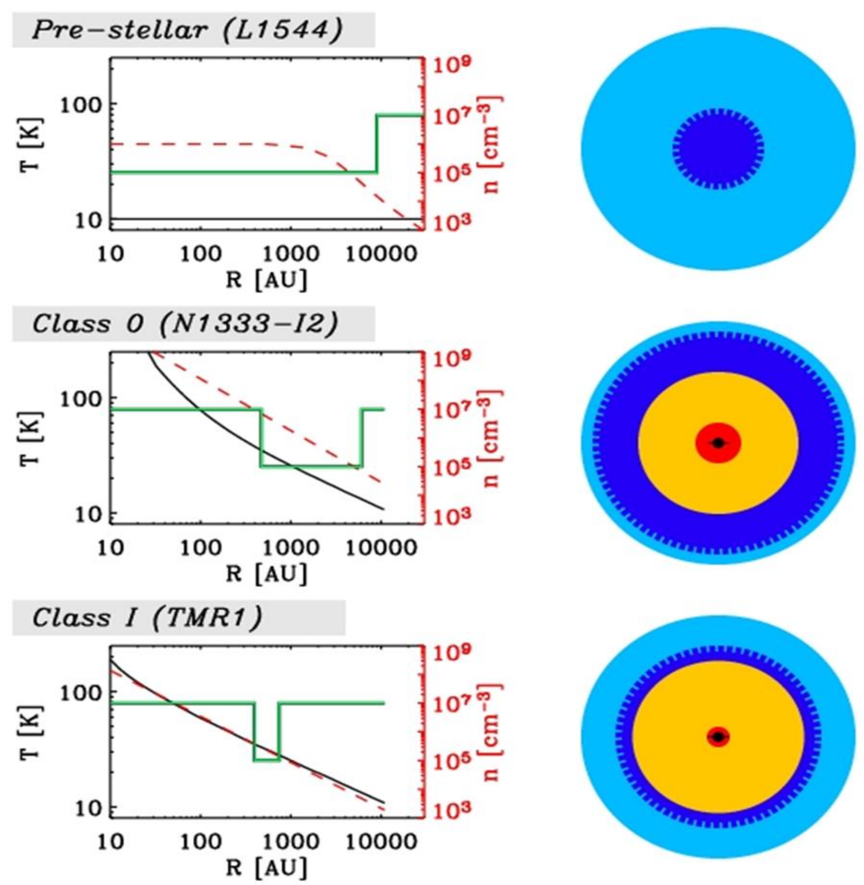
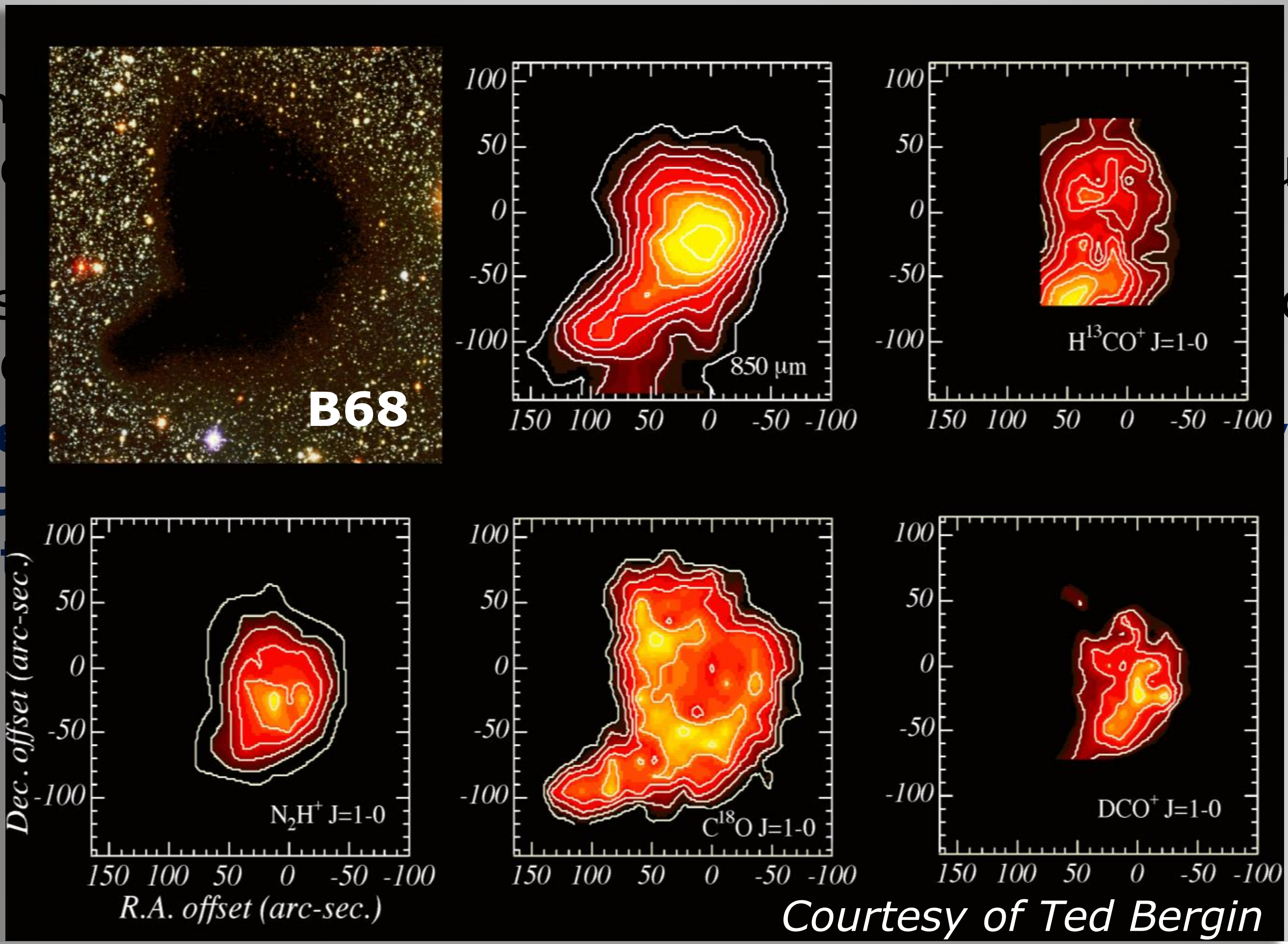


Jørgensen, Schöier & van Dishoeck, 2005

Introduction

- Dynam… conditi… within… …ude
- Chemis… conditi… …cal
- **As a re… conditi… forma… …sical**



Introduction

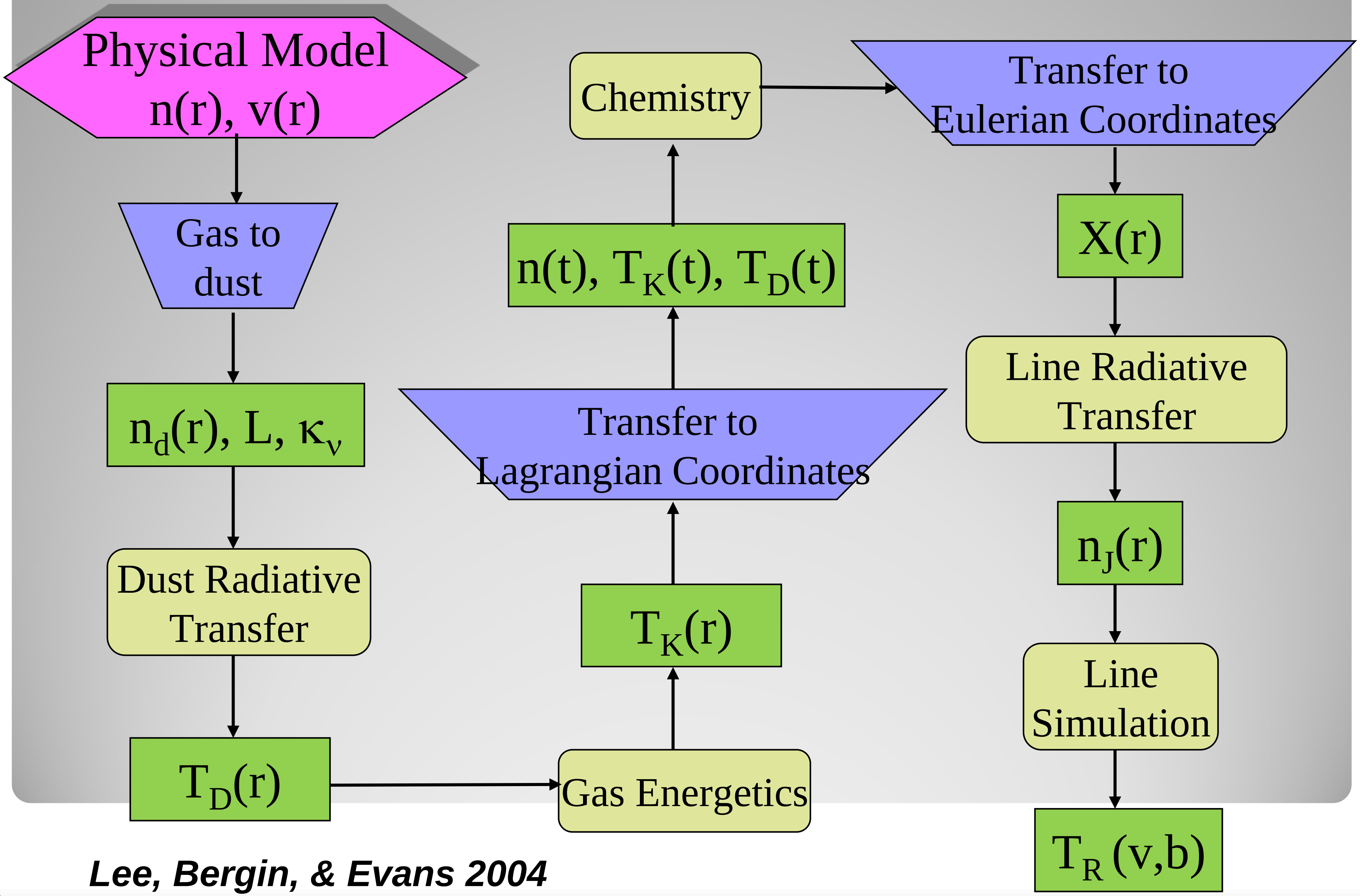
- Dynamical process of star formation alters the physical conditions of surrounding material by orders of magnitude within relatively short timescales.
- Chemistry changes responding to the variation of physical conditions.
- As a result, chemistry can be a good tracer of physical conditions (i.e. dynamics) associated with star formation.

- However, these two processes are tangled to make the interpretation of observations difficult.
- Therefore, **we need a self-consistent model to deal with dynamics and chemistry simultaneously.**

Chemo-Dynamical Model

- Combine chemistry, dynamics, gas energetics, and radiative transfer in a self-consistent way
  - to compare with observations of dust continuum and molecular line emission
  - to understand chemical and dynamical conditions in low-mass star forming cores through the pre-stellar stage to later evolutionary stages after a central protostar forms

Chemo-Dynamical Model

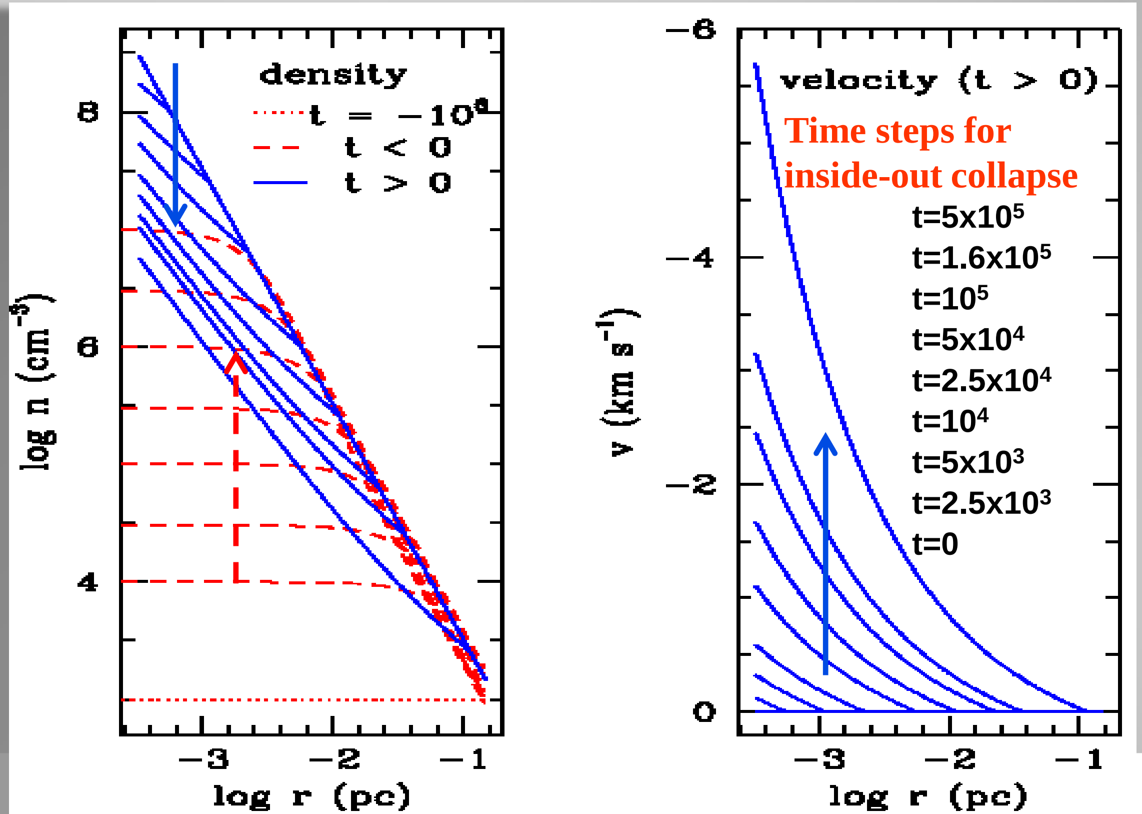


Lee, Bergin, & Evans 2004

Dynamics for the envelope

- Shu's inside-out collapse model combined with Bonnor-Ebert spheres

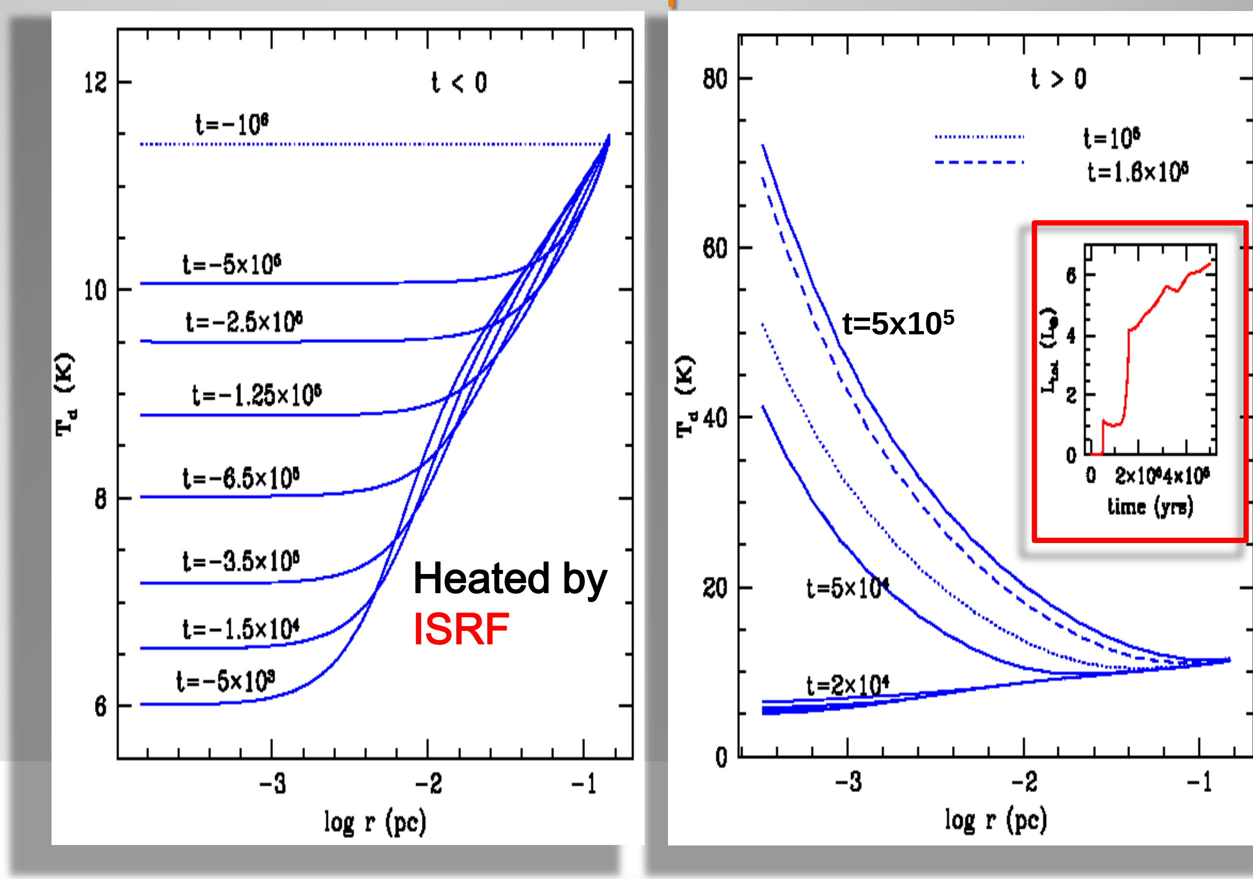
a=0.22 km/s
r_{out}=0.15 pc



Standard accretion model

- continuous accretion from envelope to disk, and to protostar

Dust Temperature

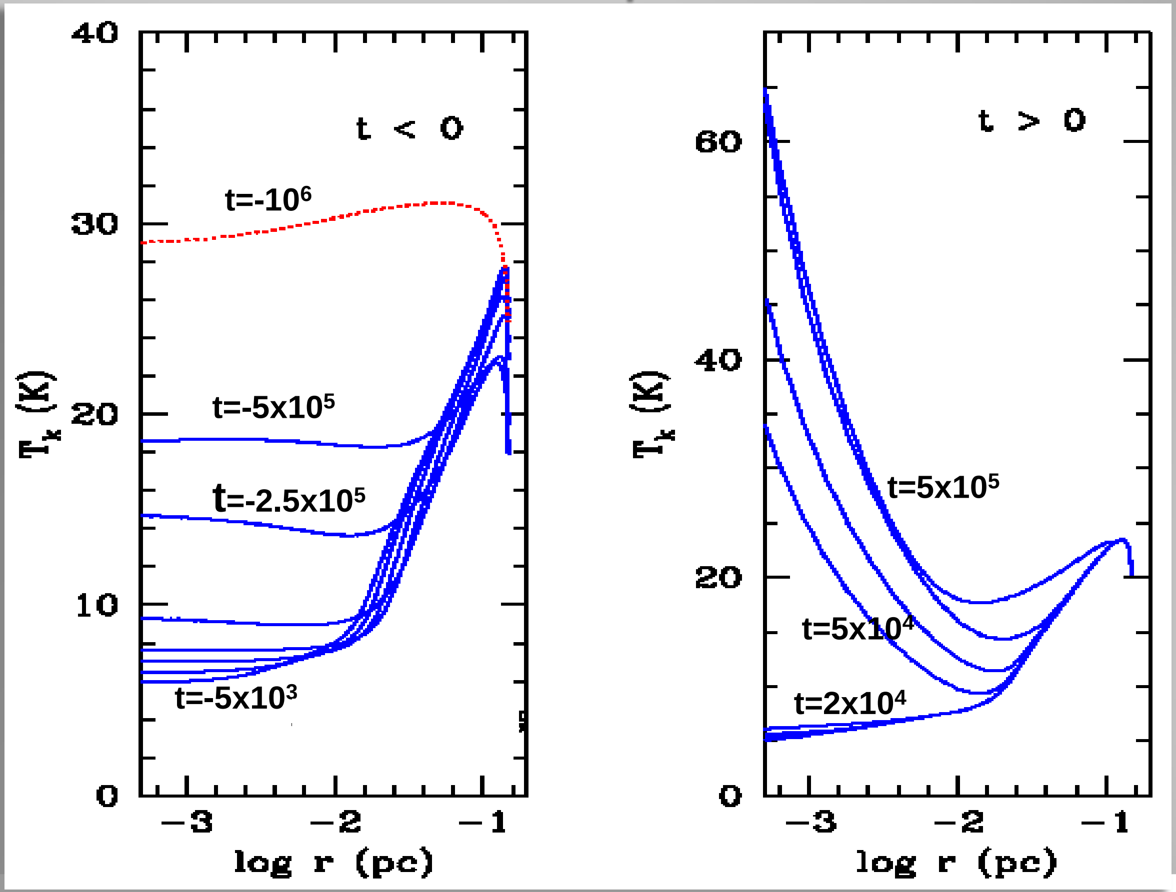


ISRF attenuated by $A_{v,e}$=0.5 mag

Young & Evans 2005

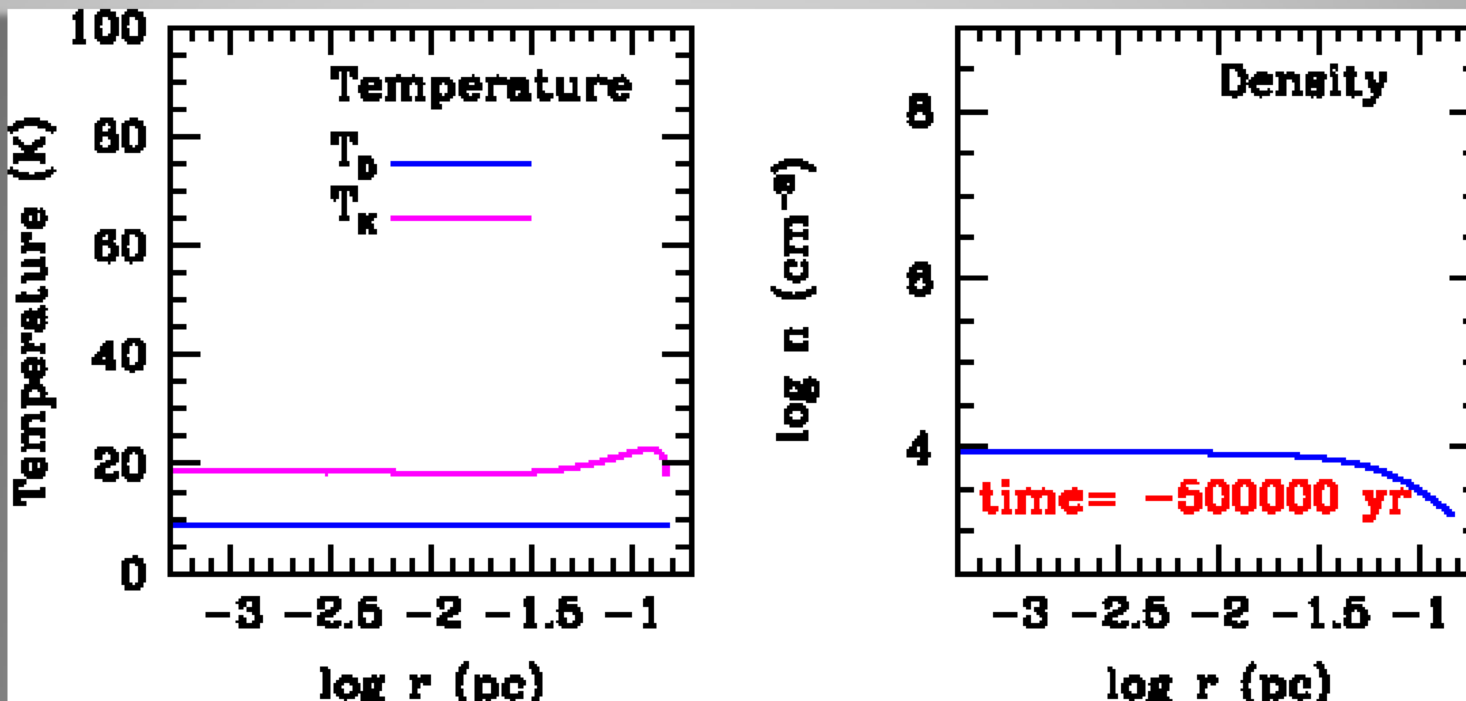
Standard accretion model

Gas Temperature

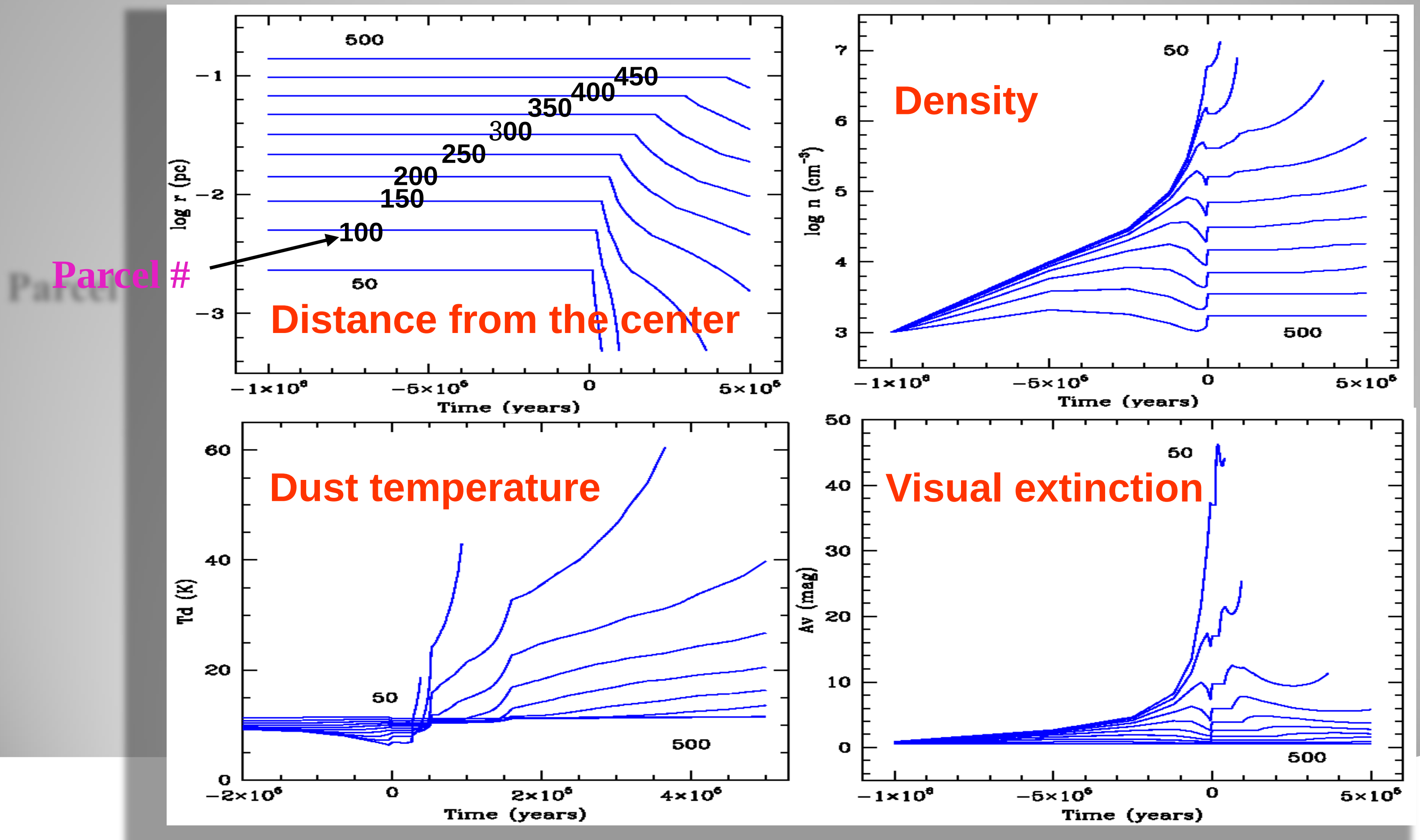


G_o=0.4

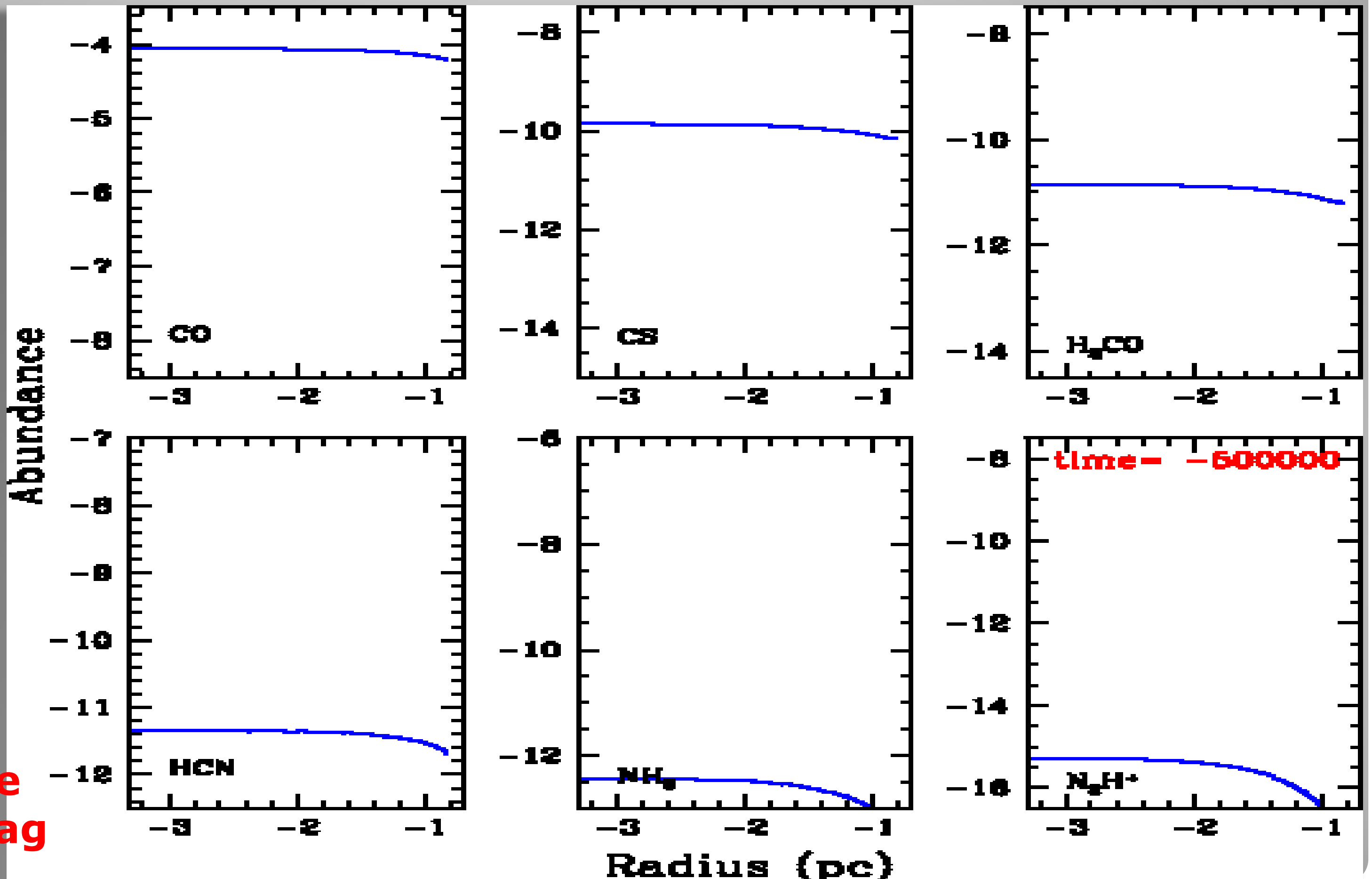
Evolution of Temperatures and density Profiles



Chemical evolution in Lagrangian coordinates

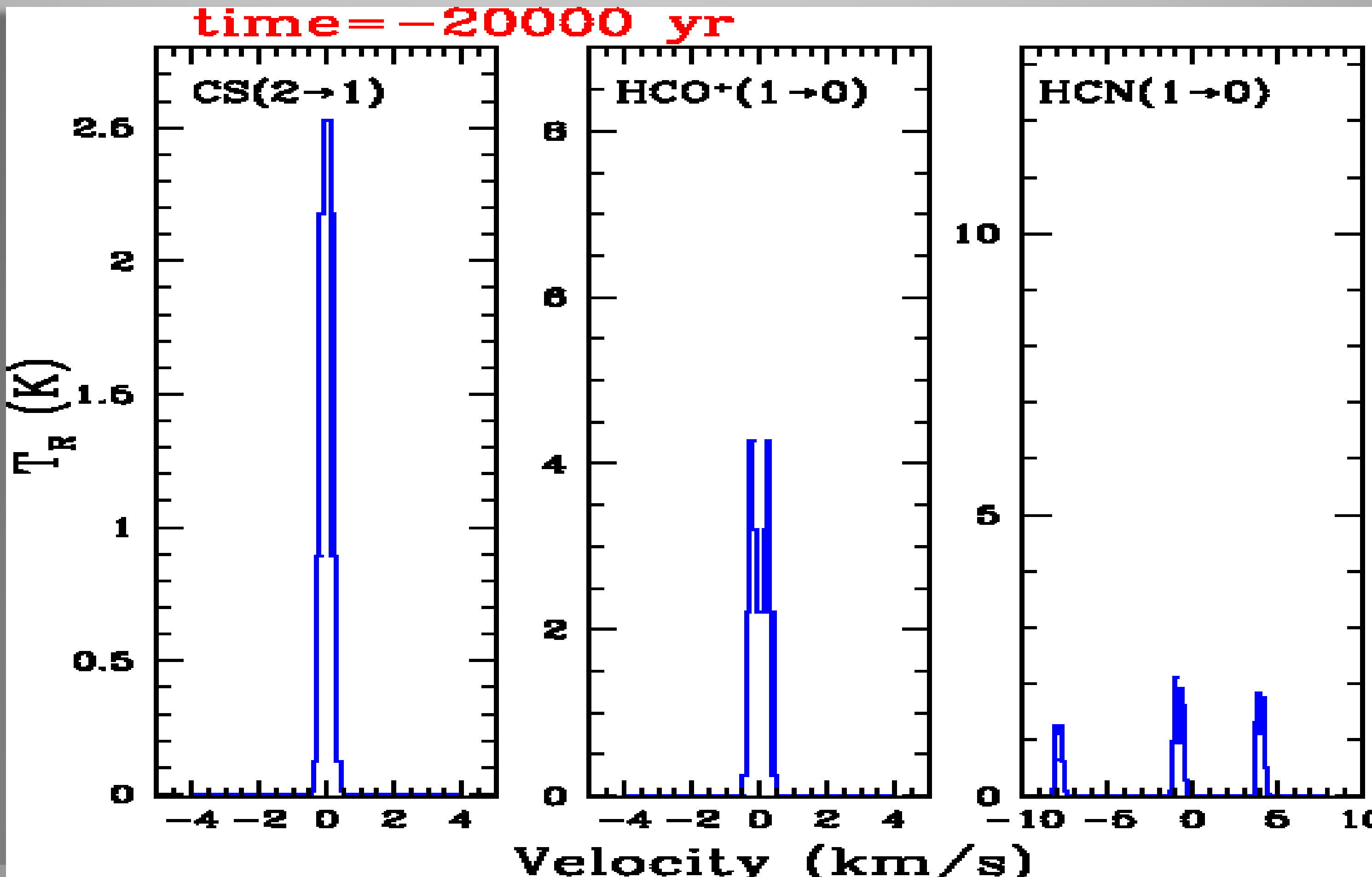


Evolution of Abundance Profiles

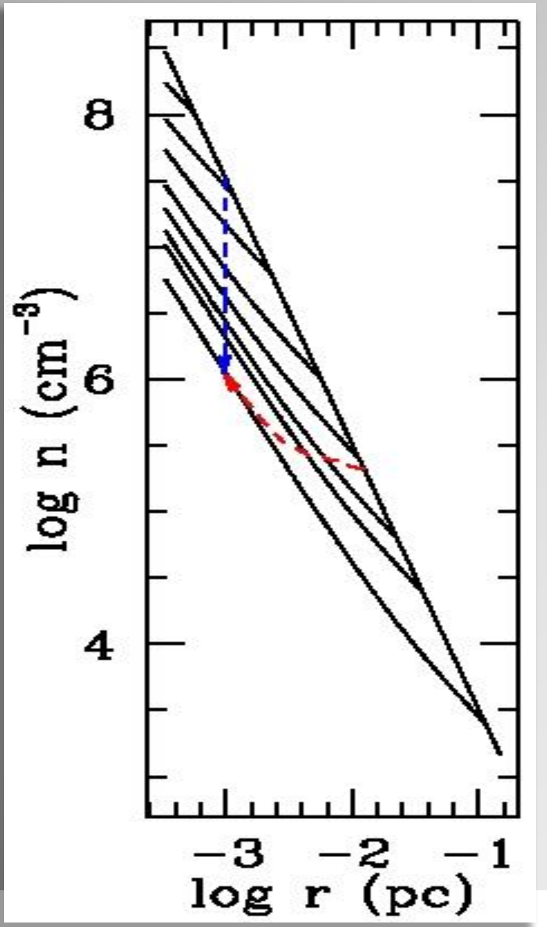


SiO_2 mantle
$A_{v,e}$=0.5 mag

Evolution of Line Profiles

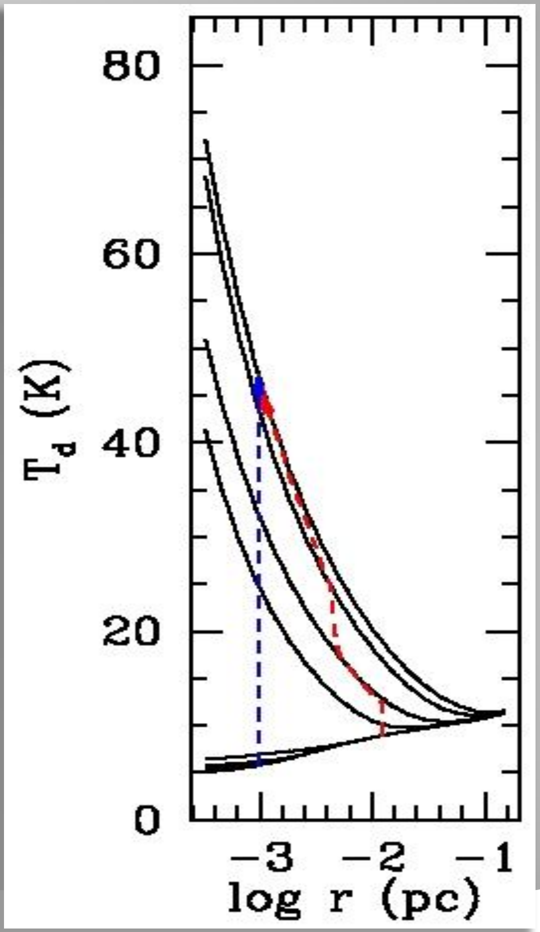


Comparison of evolutionary model with static model



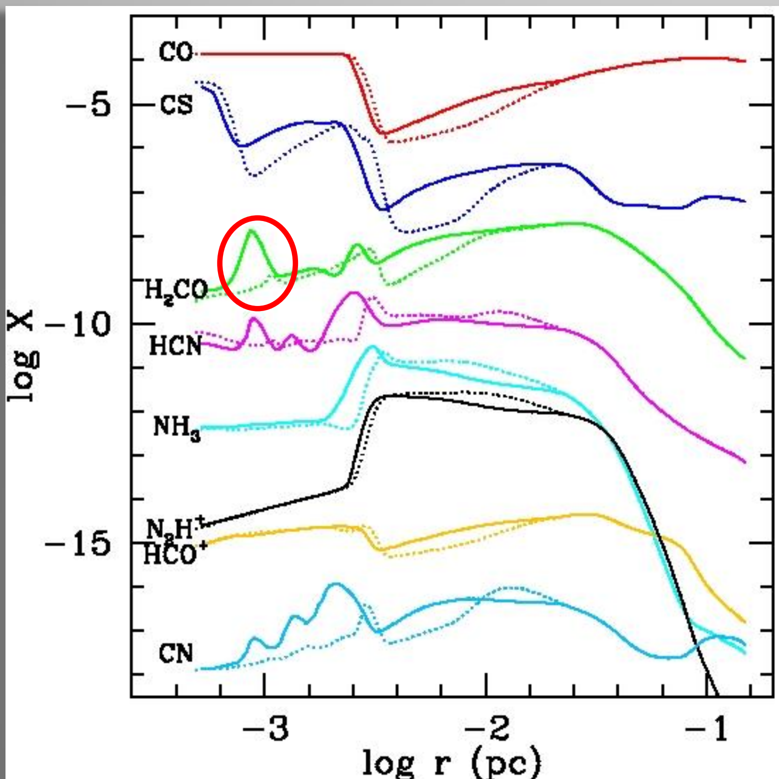
Different histories of physical conditions in the static model and the evolutionary model result in different chemical distributions in a given timestep.

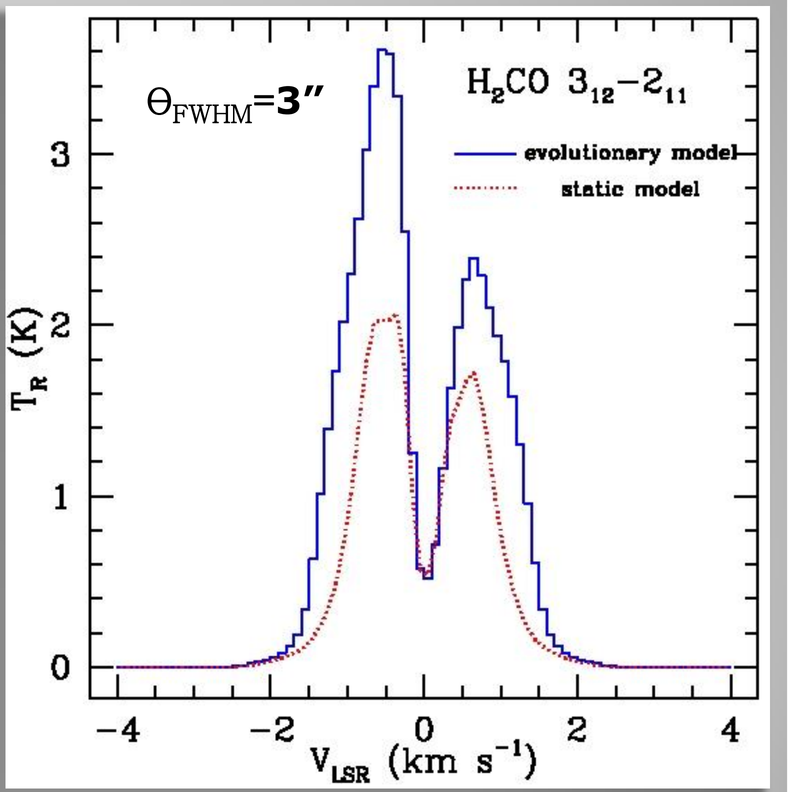
Static model: n↓ T↑
Evolutionary model: n↑ T↑



Lee, Evans, & Bergin 2005

Comparison of evolutionary model with static model



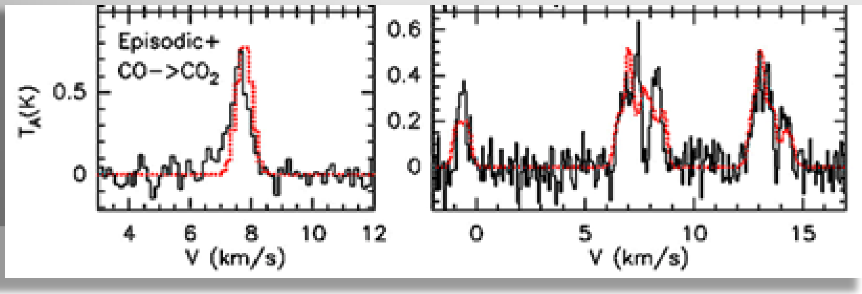


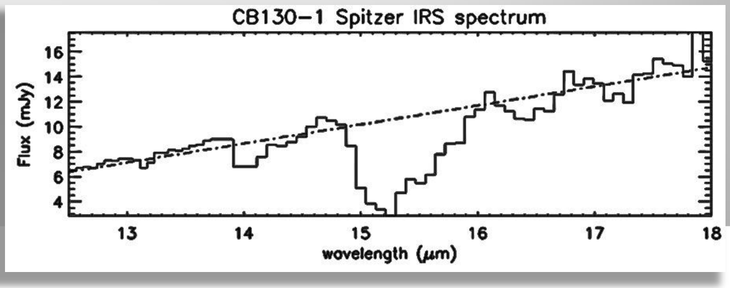
Abundance profiles at $t=10^5$ yrs

Applications to specific sources:

- L1544, L1512, L1498 (Young et al. 2004)
- B335 (Evans et al. 2005)
- L1251B (Lee et al. 2007)
- L43 (Chen et al. 2009)
- CB130 (Kim et al. 2011)

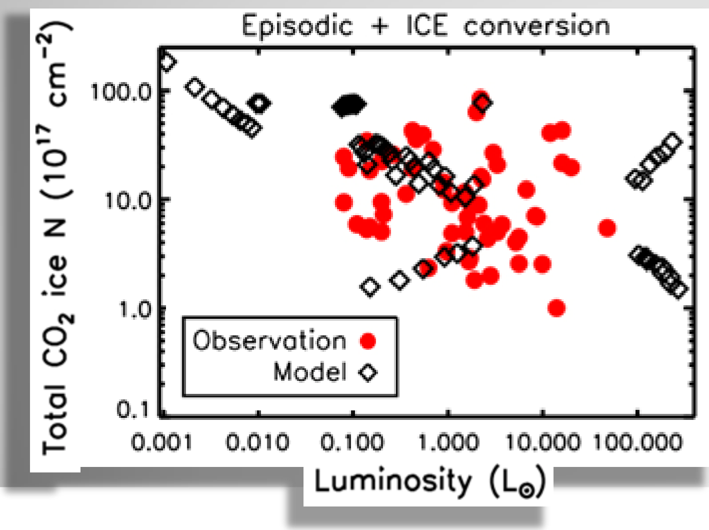
CO_2 ice formation from CO ice during the quiescent phase in the episodic accretion

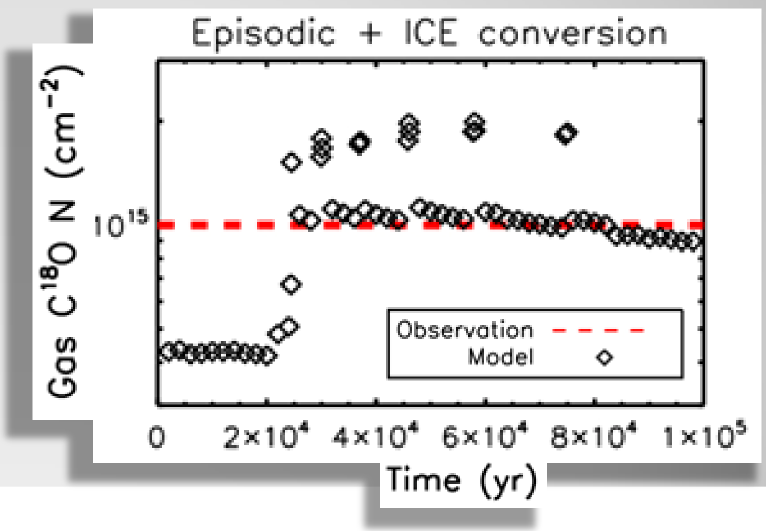




Episodic accretion model
- a statistical study

- *Kim et al. (2012)*
  - Dunham et al. (2010) + Lee et al. (2004)
    Episodic accretion model Chemo-dynamical model
  - fit the column densities of CO_2 ice and $C^{18}O$ gas simultaneously in a wide range of YSO luminosities





Episodic accretion model

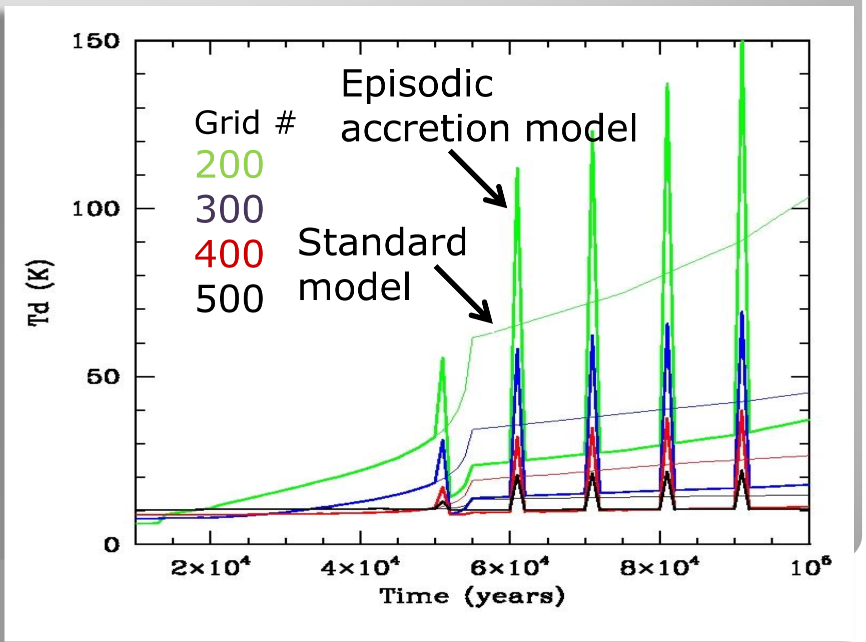
- continuous accretion from envelope to disk,
- but episodic accretion from disk to protostar
  (accretion event every 10^4 yrs for 10^3 yrs)

normal accretion rate = 4.8 x 10^{-6} M_{sun}/yr

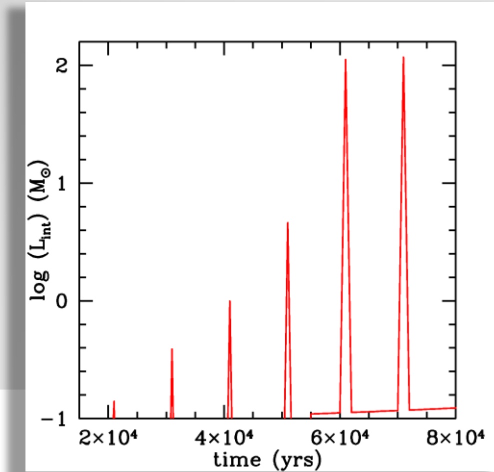
accretion rate (accretion phase) = 10 x normal rate

accretion rate (quiet phase) = 0.01 x normal rate

Temperature evolution of infalling grids

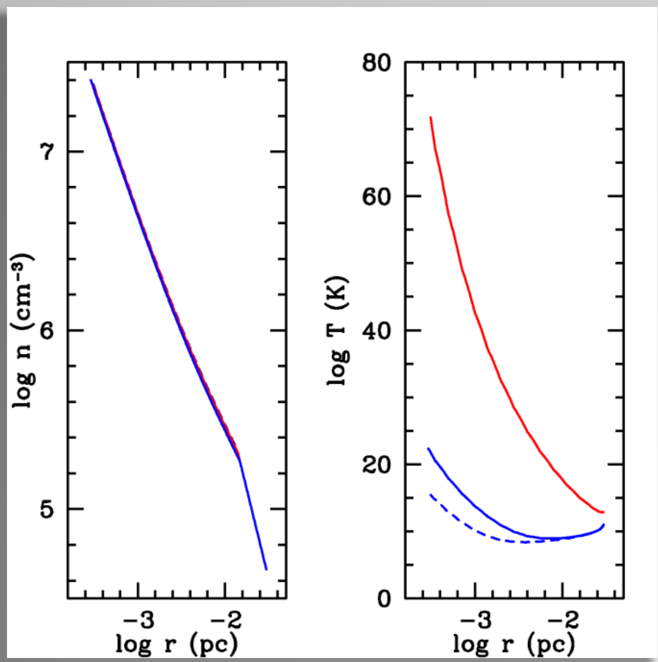


evolution of internal luminosity (Lee 2007)

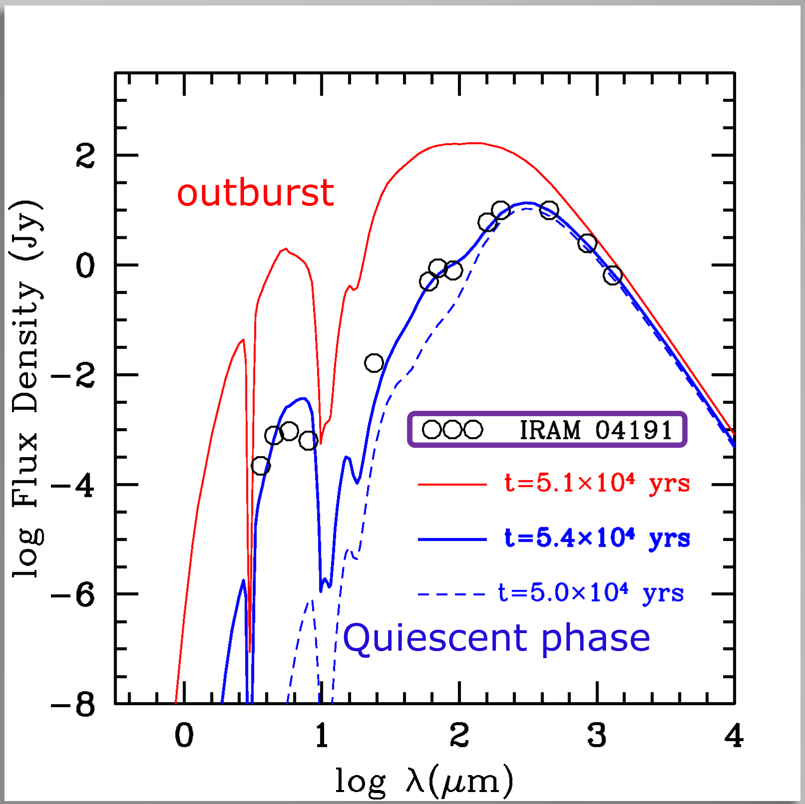


Episodic accretion model

- *Lee 2007*



Density and temperature profiles around an accretion burst

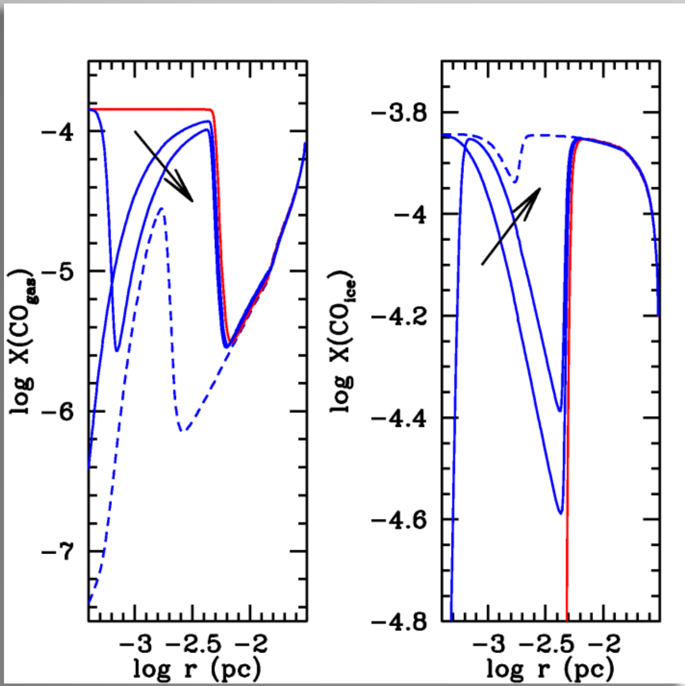


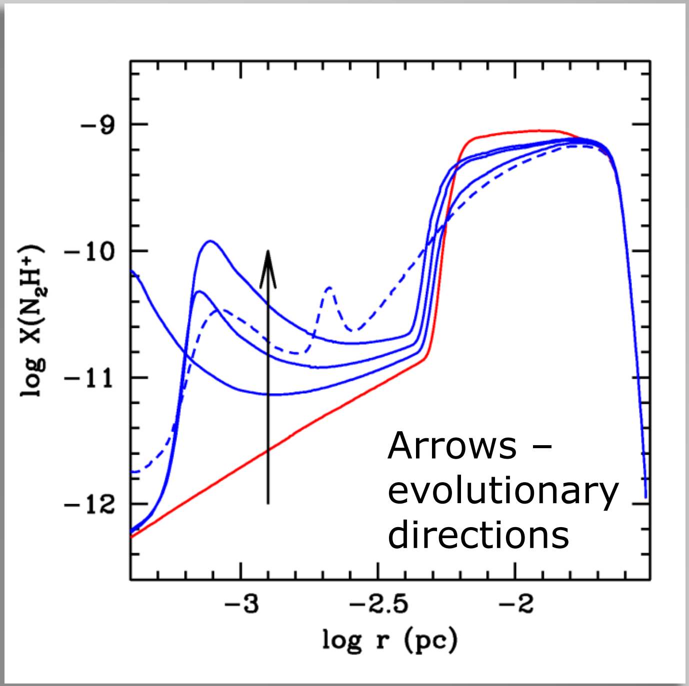
M_{core} = 1 M_{sun}

R_{core} = 6200 AU

Episodic accretion model

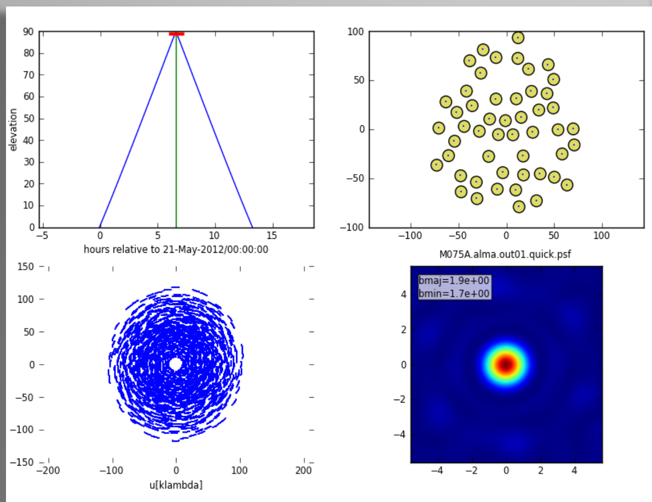
- *Lee 2007*





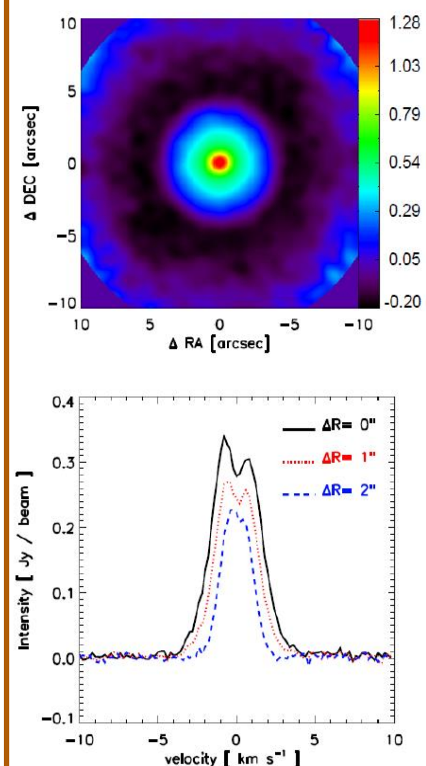
Abundance profiles around an accretion burst

ALMA Observation

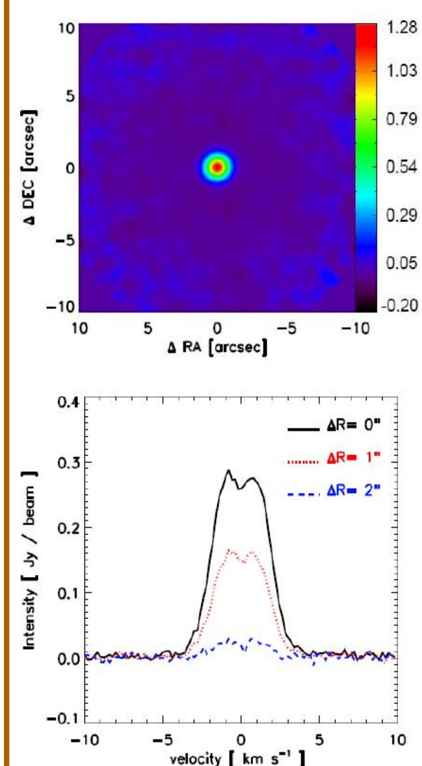


ALMA observation:
UV coverage and
synthesized beam

Episodic



Continuous



Simulation of ALMA observation of $C^{18}O$ 2-1

Summary

- One needs to use a self-consistent chemical model to understand the physical conditions of a star forming core correctly.
  - Ice and gas components must be considered together to constrain the chemical process ongoing in star forming regions.
  - High resolution observations are necessary to constrain the dynamical process entangled with chemistry in star formation.