EVOLUTION OF ACCRETION DISKS WITH DEAD ZONES

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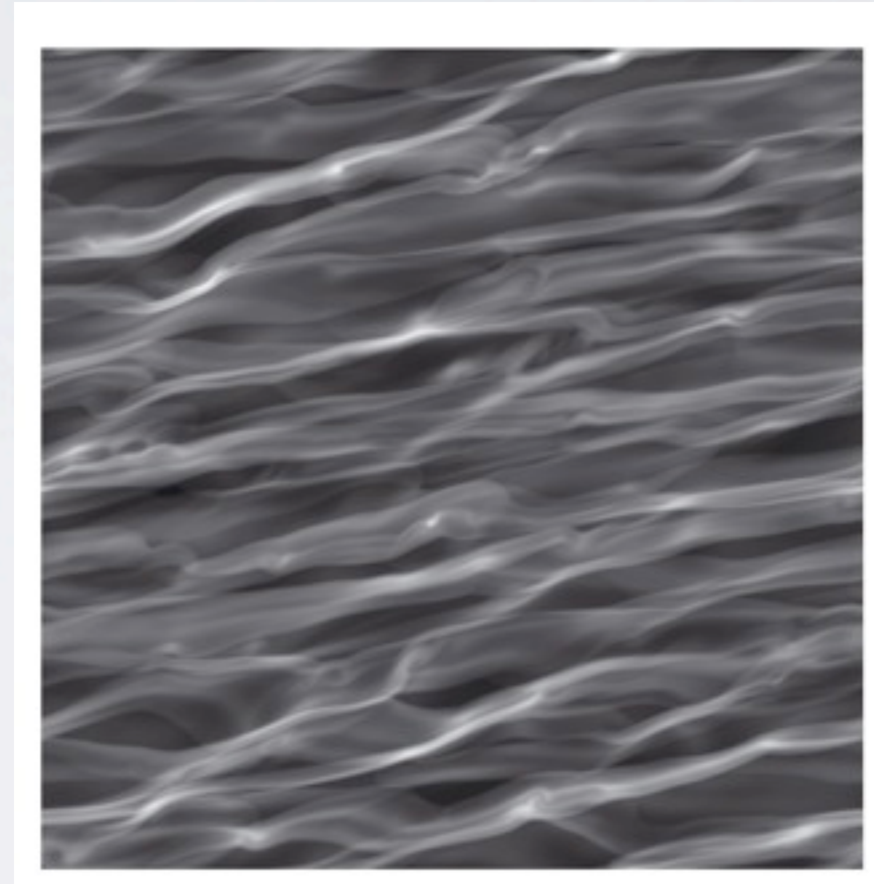
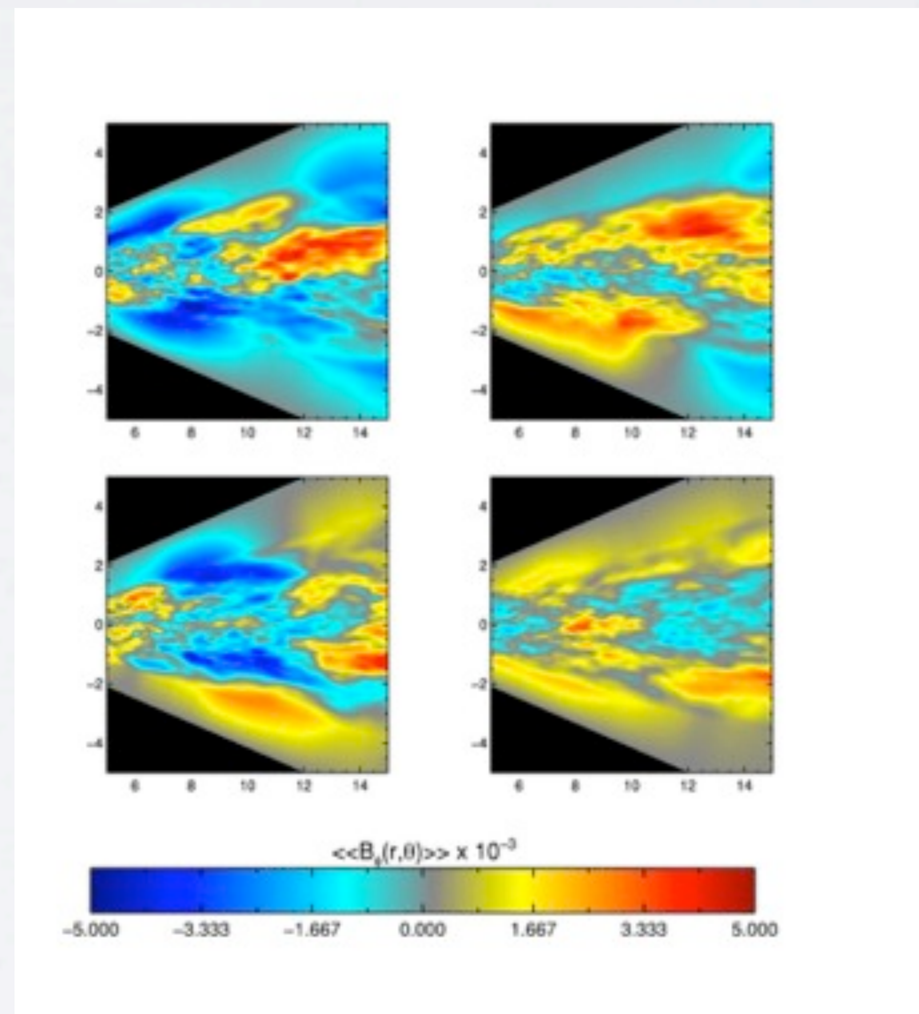
WHAT DRIVES ACCRETION?

- Gravitational Instability, Q ~ 2, $M_d \sim (H/r) M_*$
- Magnetic Fields (MRI), gas ionized
- Magnetic more powerful



Rice et al. 2011



Simon et al. 2011

PROTOSTELLAR DISKS

- Need ionization for MRI
  - Thermal (internal)
  - X-rays
  - UV
  - Cosmic Rays
- Recombination effects ions, PAHS, Dust

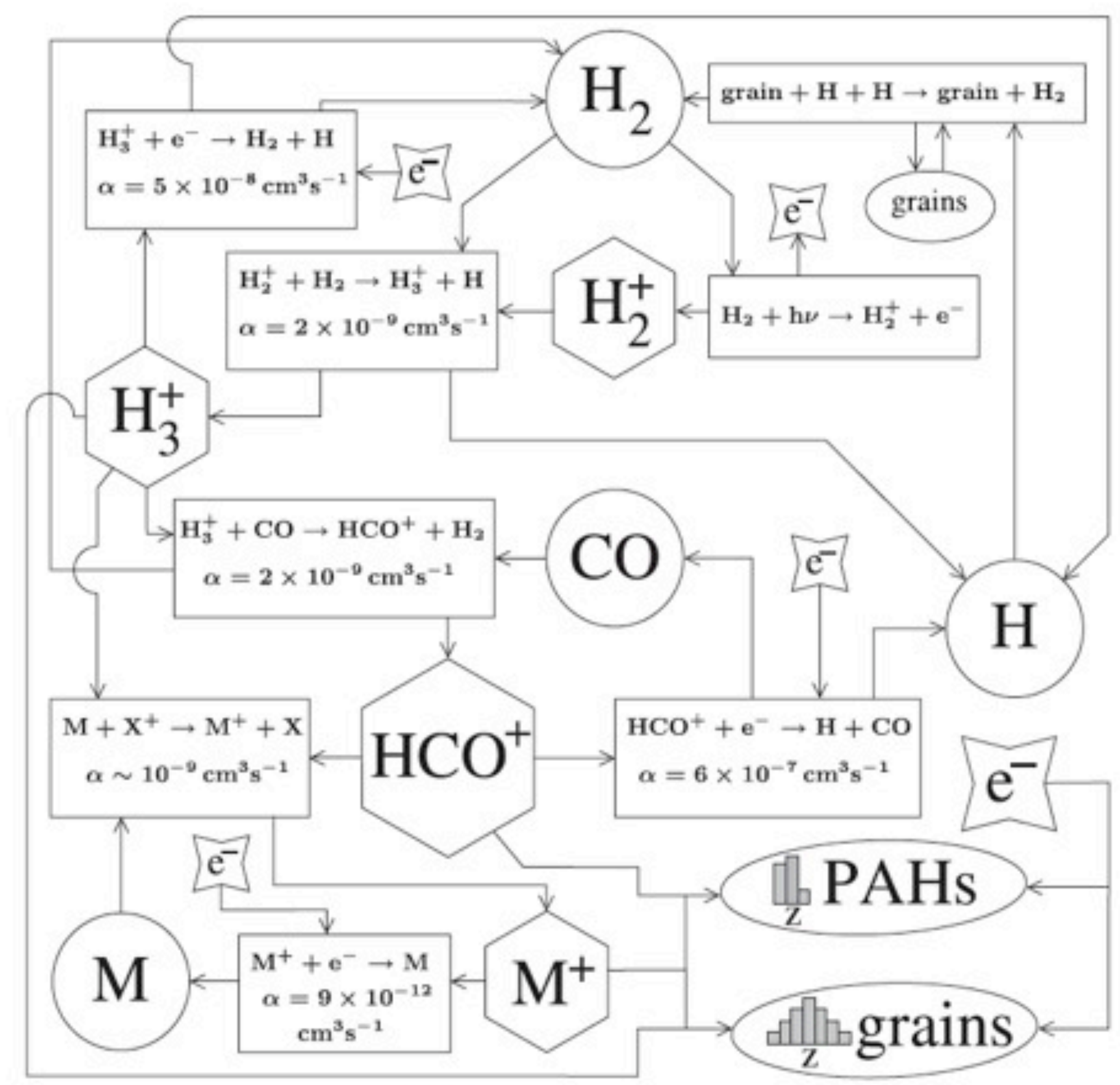
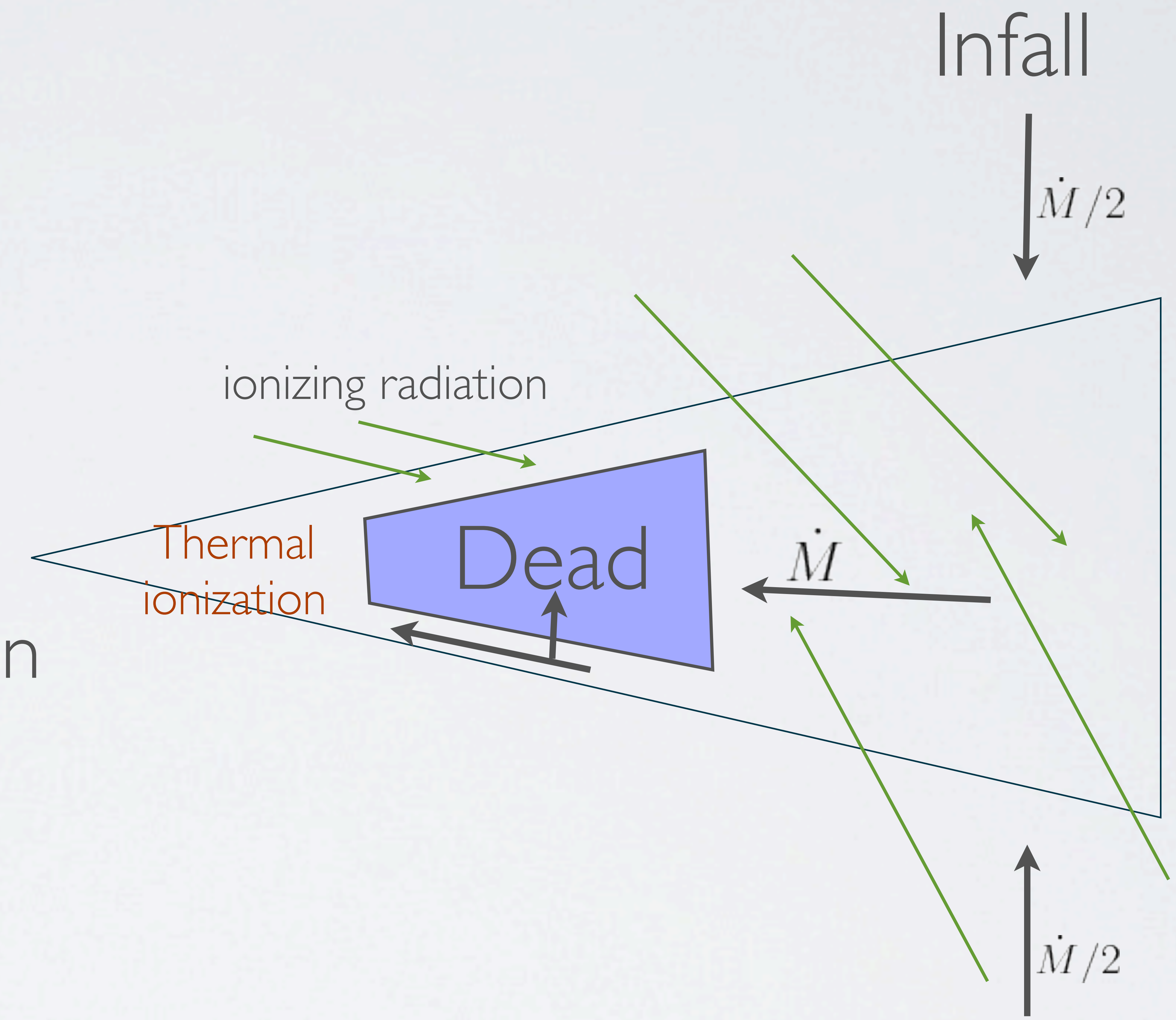


Figure 2. Our chemical reaction network, derived from Oppenheimer & Dalgarno (1974). Rate coefficients as shown in this figure are evaluated at $T = 80$ K. See Table 2 for a comprehensive list of all modeled reactions and precise rate coefficients.

Perez-Becker & Chiang 2011

DEAD ZONE

- Turbulent (active) outer layers
- Nonturbulent midplane layer in certain radial range (Gammie 1996)
- Dead zone gains mass



OUTBURSTS

- Long term evolution (Gammie 1996, Armitage et al. 2001, Zhu et al 2010)
- Dead zone becomes gravitationally unstable.
- Dead zone heated to thermal ionization threshold
- Suddenly turns on MRI: Outburst

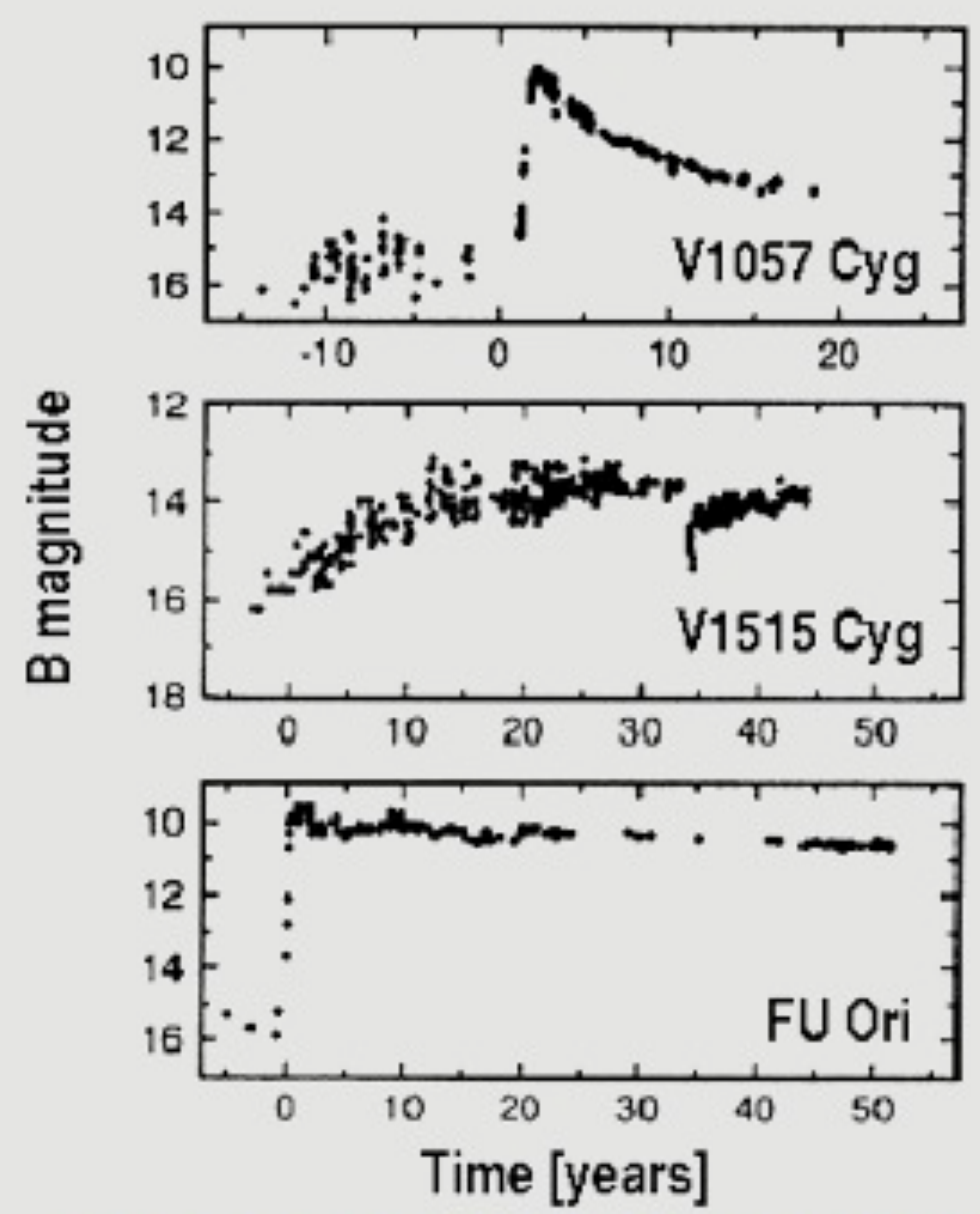


*Figure 1: Light curve of three FUor-type object. (From L. Hartmann and S.J. Kenyon: The FU Orionis phenomenon, Annu. Rev. Astron. Astrophys. **34**, 1996, pp. 211)*

MODEL FOR OUTBURSTS

- Infall accretion onto disk
- Two layer model: upper and midplane
- Assumes some level of external ionization
- Gravitational instability near midplane when Q~2

MODEL RESULTS

- Outbursts for $\dot{M} > 10^{-7}$ solar masses/yr
- Outburst rise rapid
- Outburst duration ~10-100 years

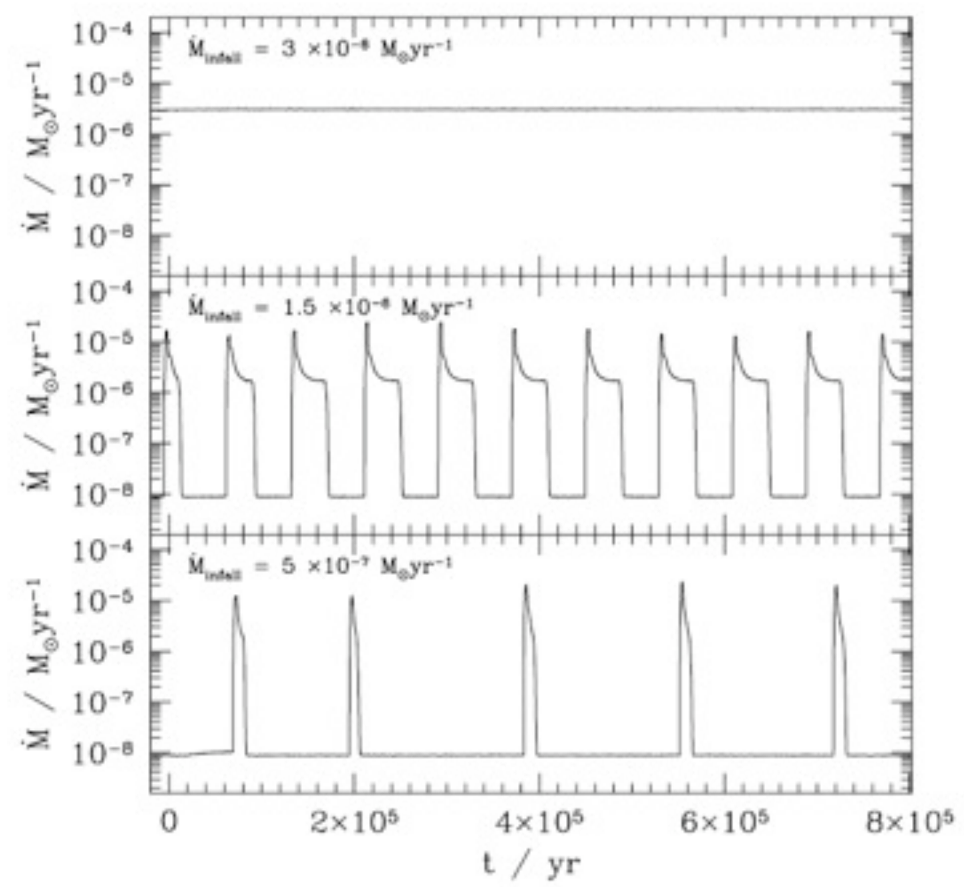


Figure 2. Protostellar accretion for models with a constant rate of infall on to the outer disc. From top down, the panels show models with $\dot{M}_{\rm infall} = 3 \times 10^{-6}$, $1.5 \times 10^{-6}\, M_\odot\, yr^{-1}$, and $5 \times 10^{-7}\, M_\odot\, yr^{-1}$ respectively. All models are shown after initial transients have decayed. Steady accretion occurs for sufficiently high accretion rates through the outer disc. At lower accretion rates, the mass flow on to the star is strongly time-dependent.

Armitage, Livio, & Pringle 2001

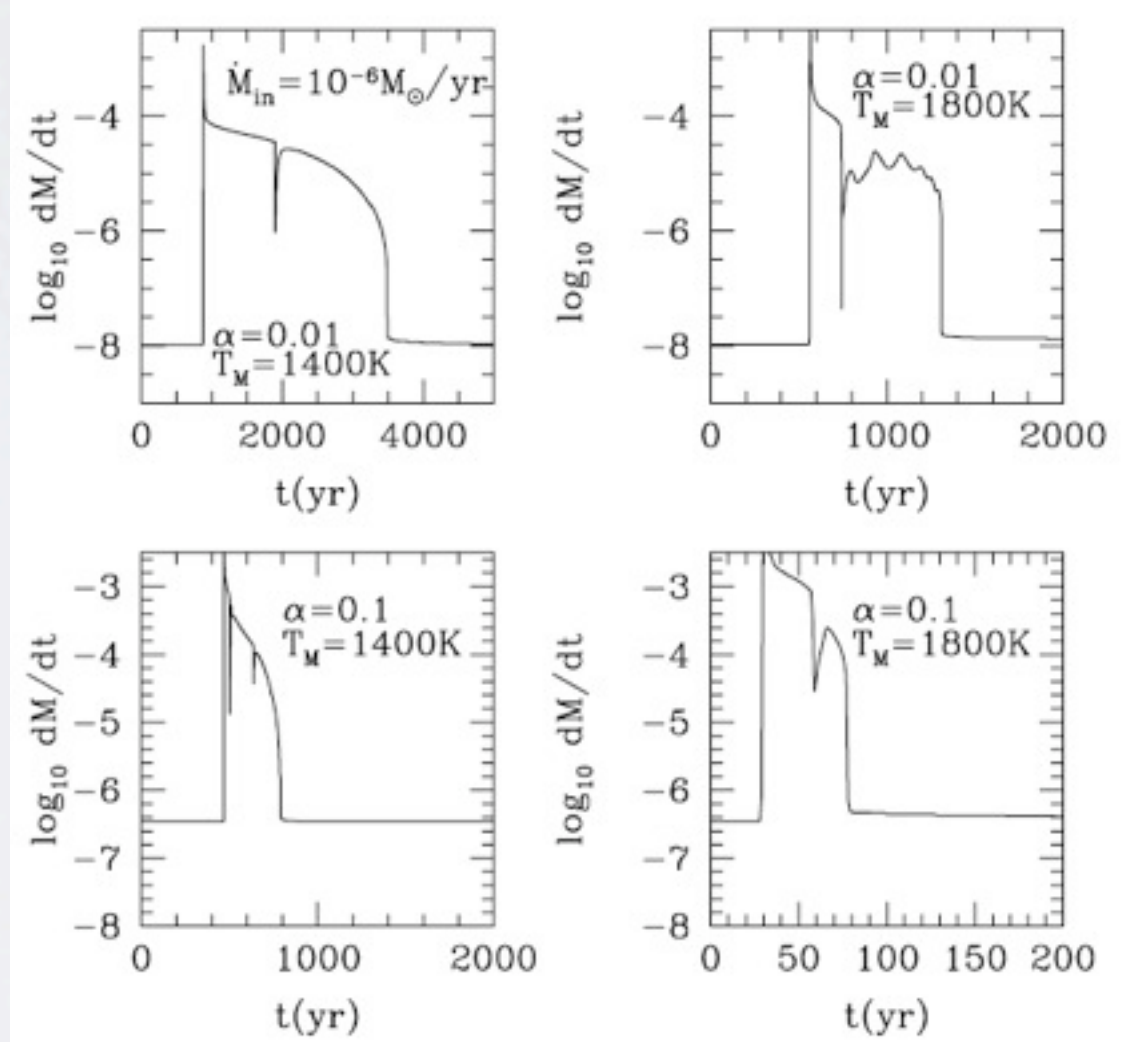
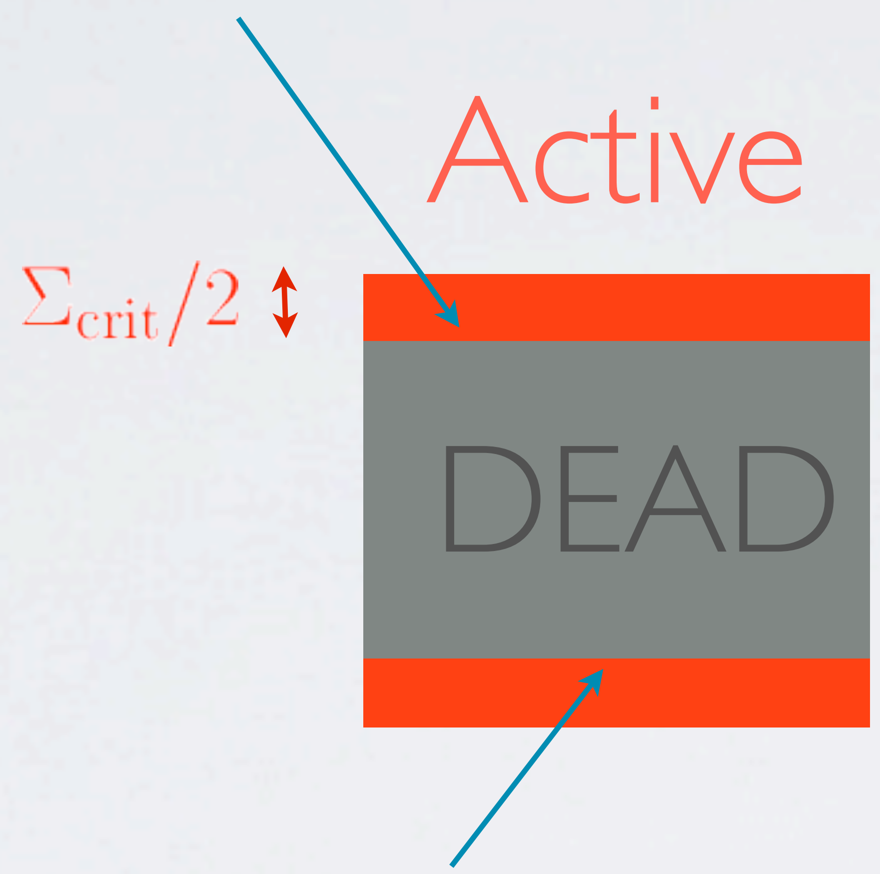


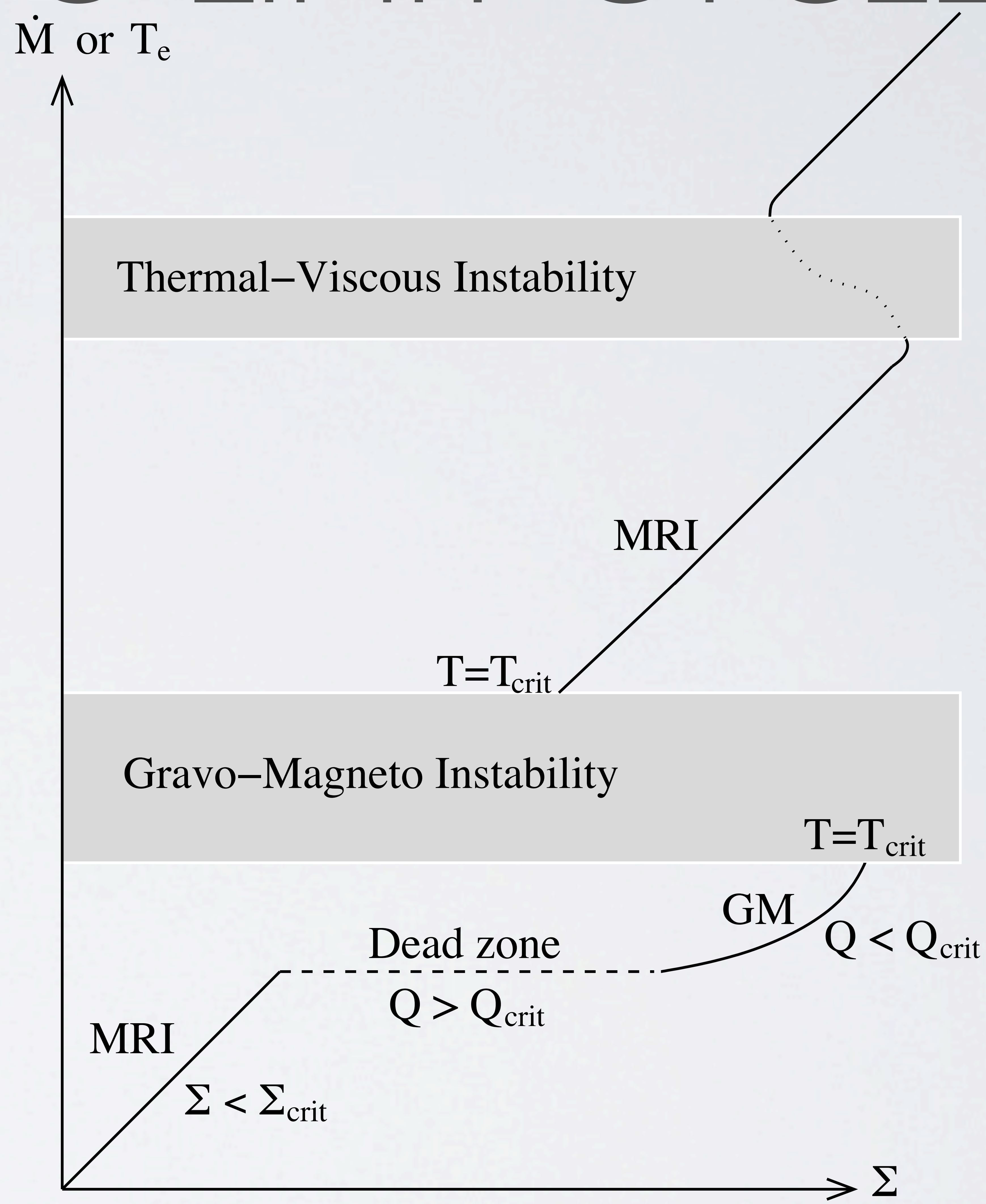
Figure 4. Mass accretion rate with time for different α_M and T_M for the mass infall rate of $10^{-6}\, M_\odot\, yr^{-1}$.

Zhu, Hartmann, & Gammie 2010

GRAVO-MAGNETO LIMIT CYCLE



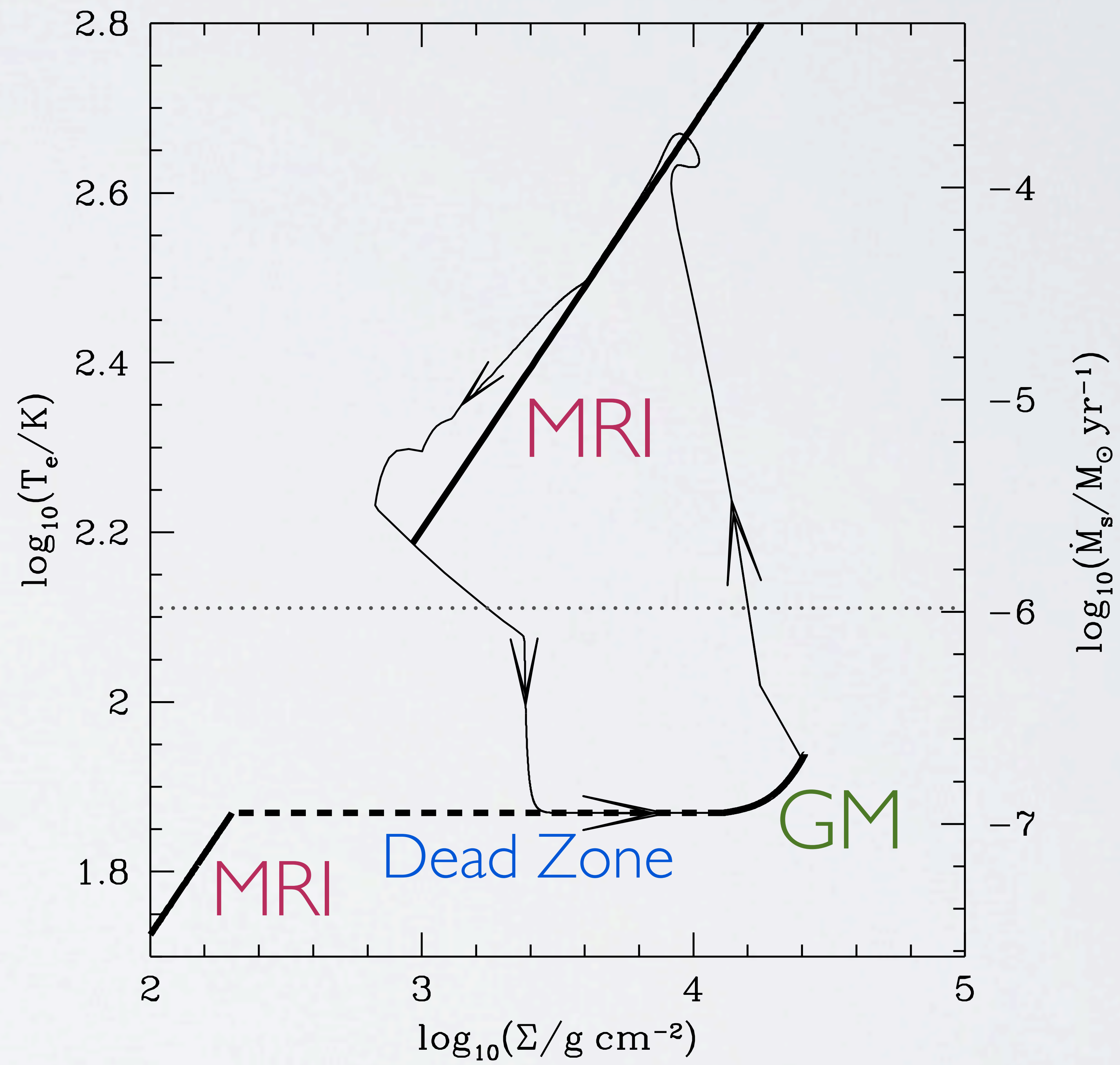
- Fixed radius
- Consider Teff or Mdot versus Sigma on log-log plot
- Disconnected branches
- Transitions through GM instability



Martin & Lubow 2011

SIMULATION

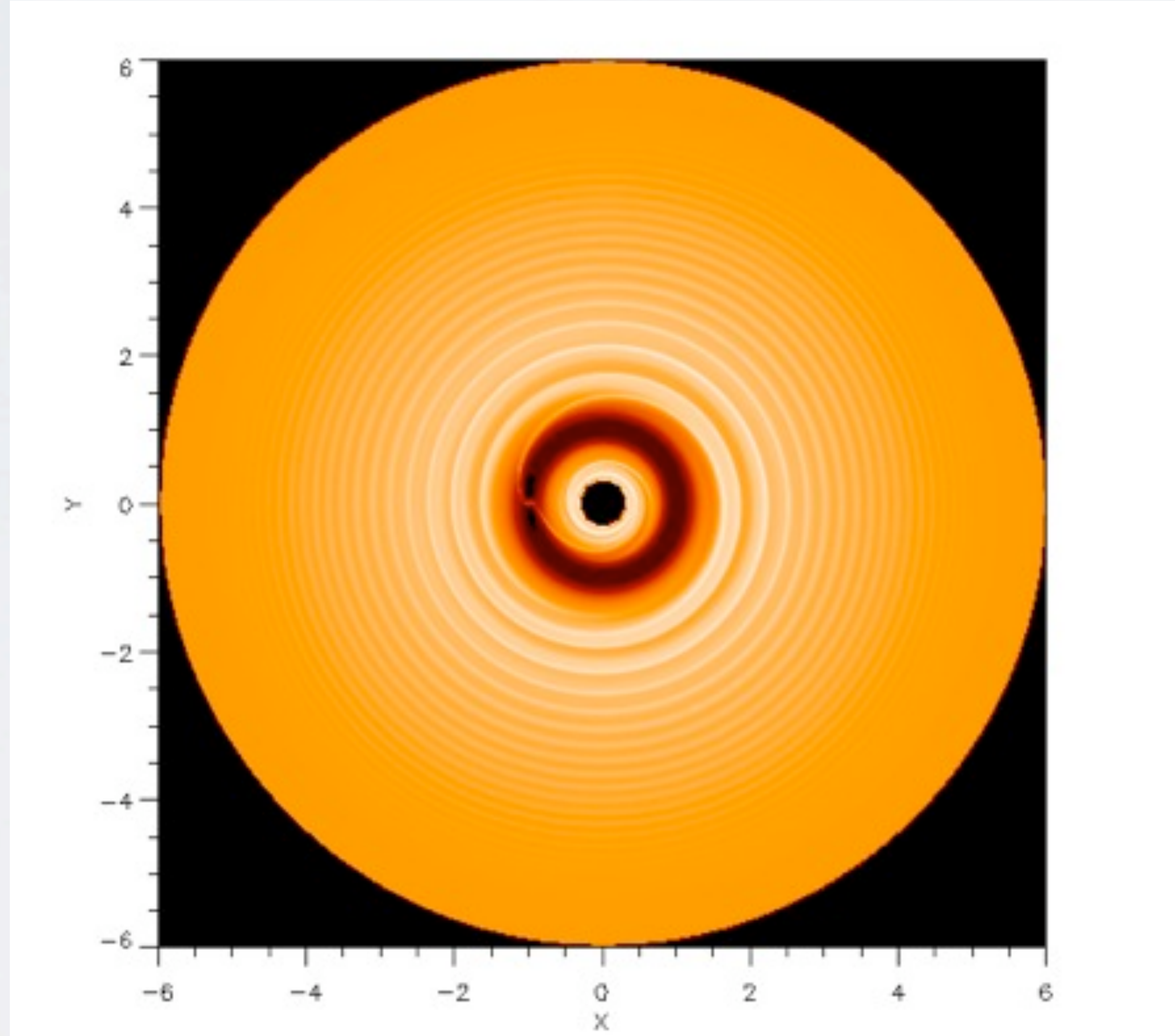
- Follow time-dependent evolution (simulation) of global model
- Compared simulation with analytic model at some radius for $\dot{M} = 10^{-6}$ solar masses per yr

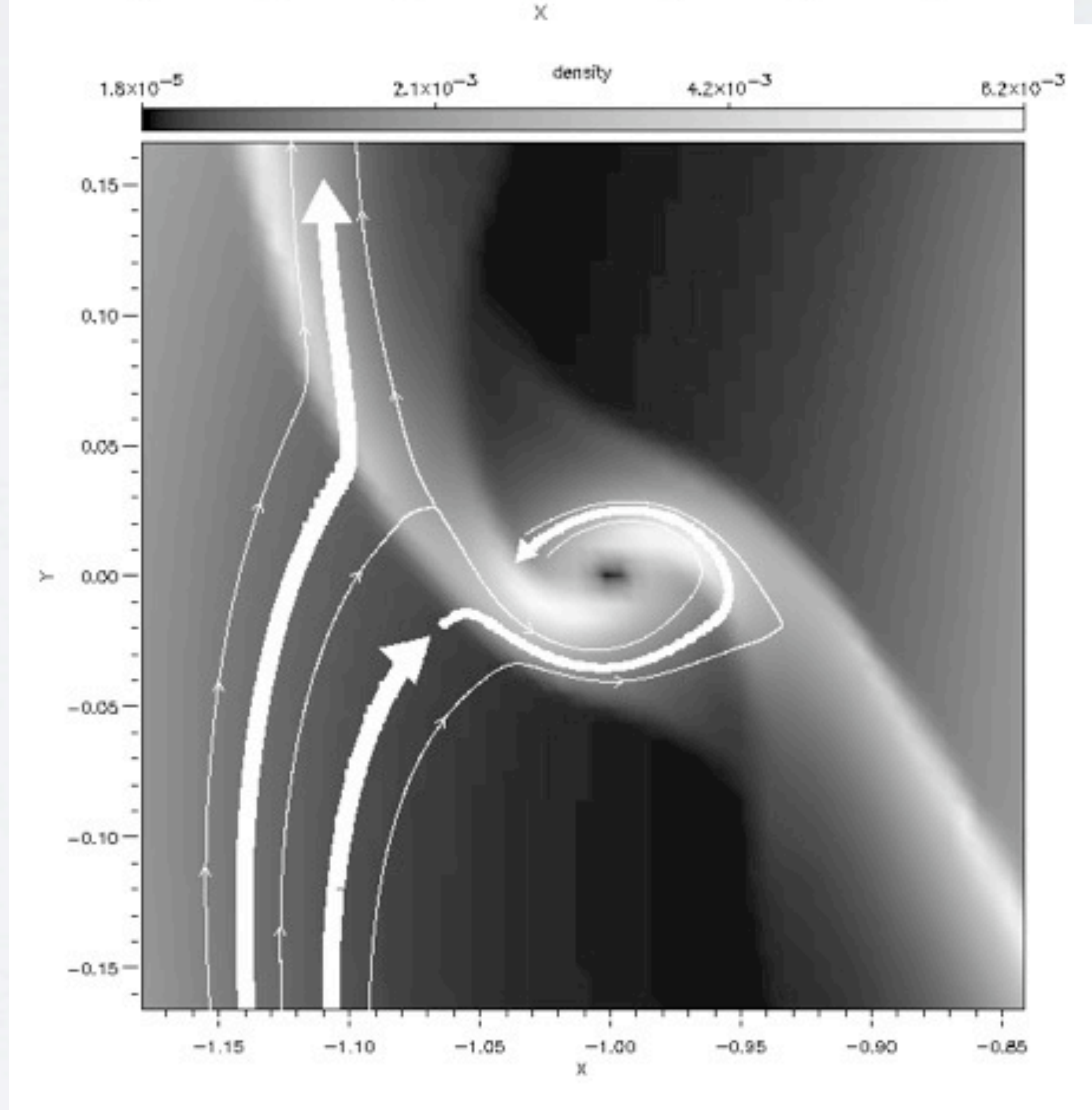


Martin & Lubow 2011

CIRCUMPLANETARY DISKS

- Gas accretes through gap onto giant planet
- Carries angular momentum and forms disk
- Can be GM unstable during T Tauri phase Lubow & Martin 2012
- Hot gas accreted
- Implications to satellite formation





Thursday, July 26, 2012

SUMMARY

- Long term evolution of dead zones involves effects of magnetic fields and self-gravity
- Outbursts can result from transition of GI to MRI
- GM limit cycle