MHD Simulation of Jets & Flares of Pre-Main Sequence Stars

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Observation from the solarsystem

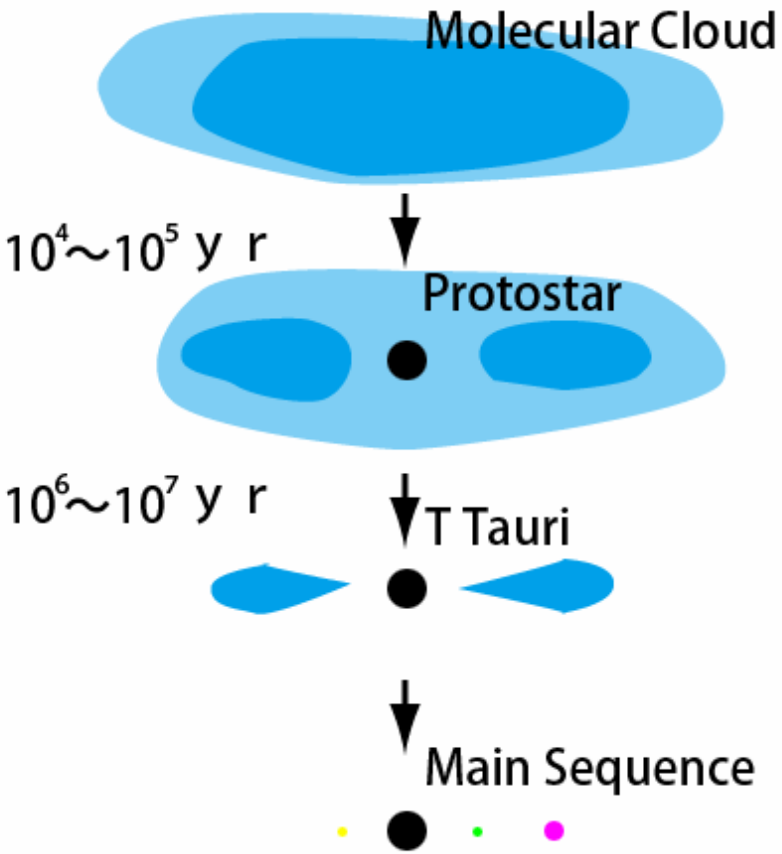
Nobeyama 45m

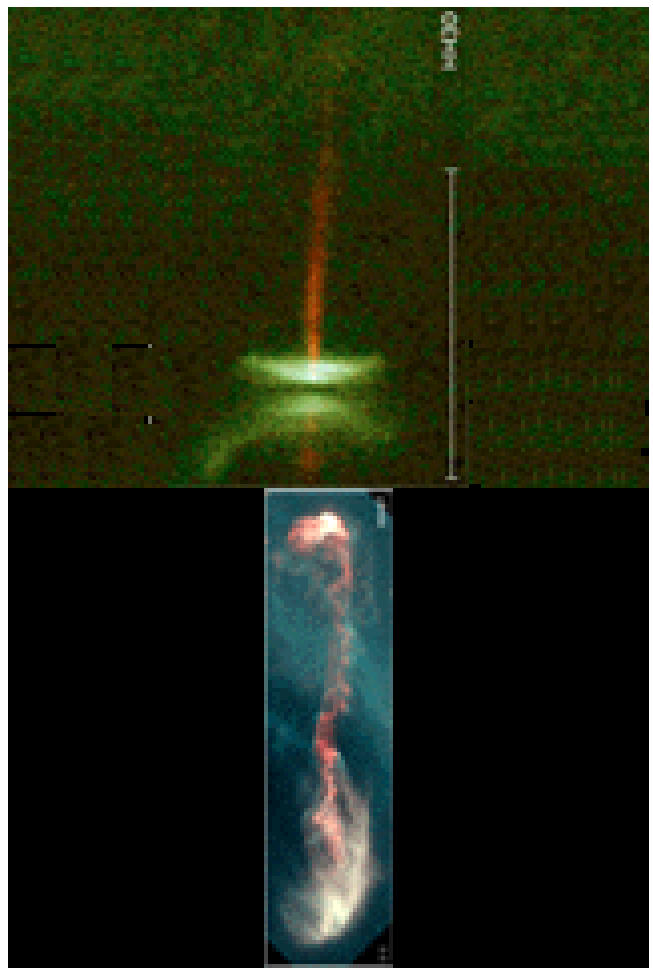
ASCA

Chandra

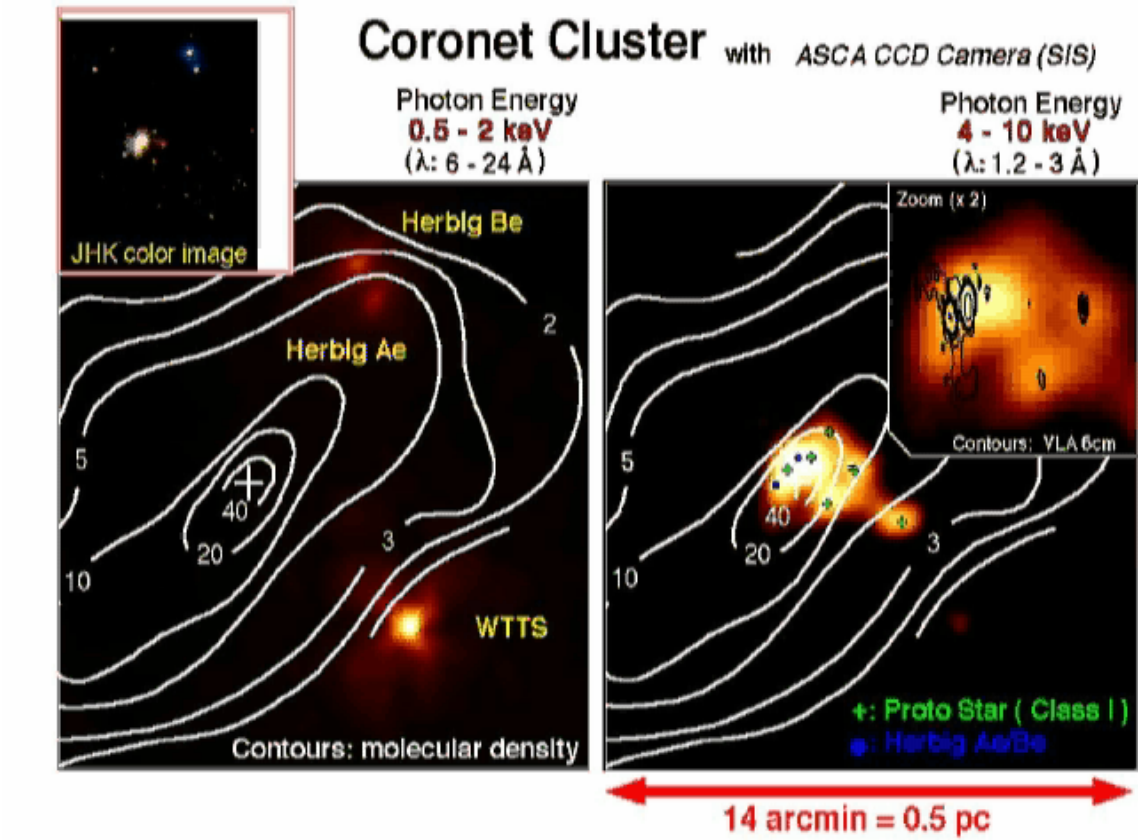
Newton

Remarkable aspects of YSO's (Mass outflows)



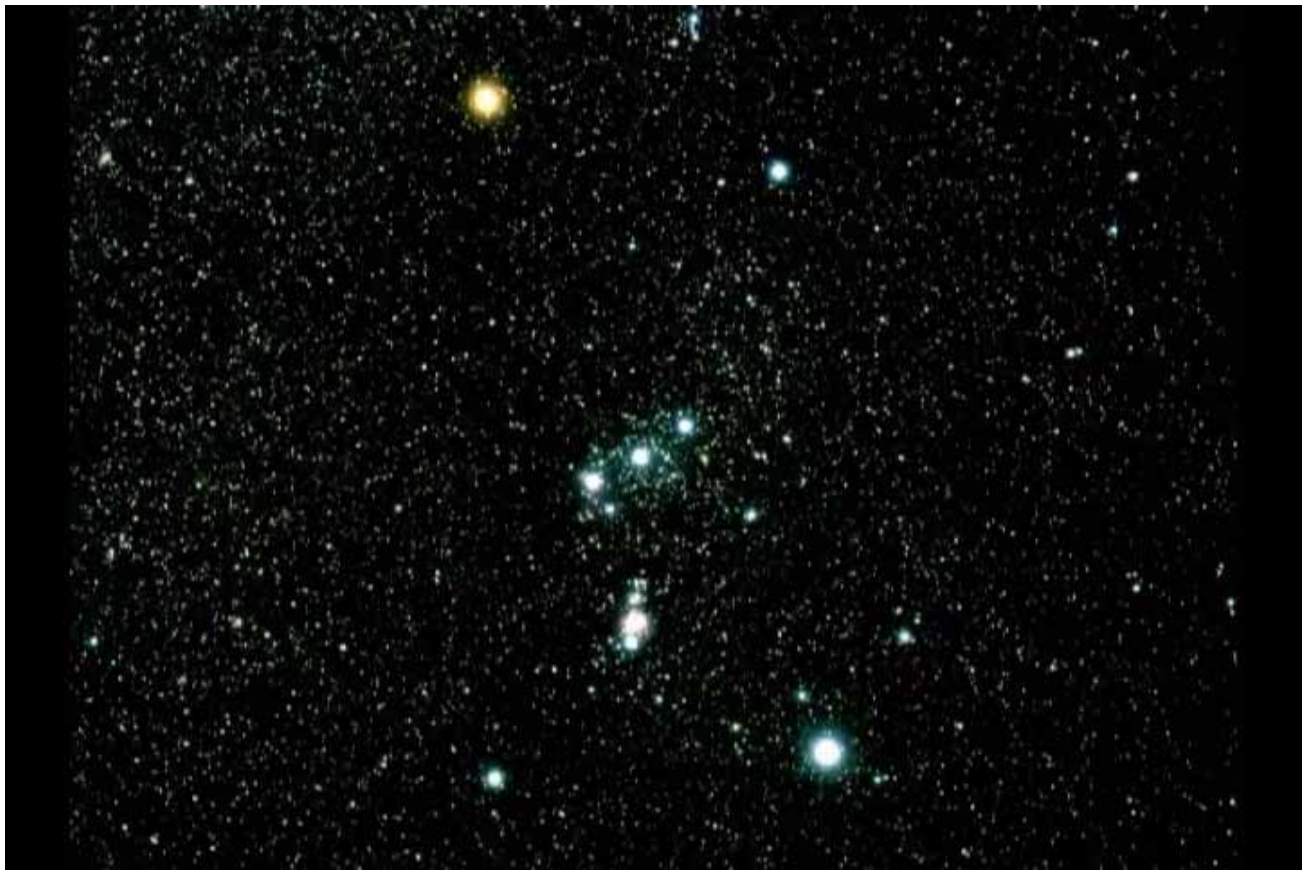


Remarkable aspects of YSO's (X-ray emission)



Movie Credit:K.,Hamaguchi

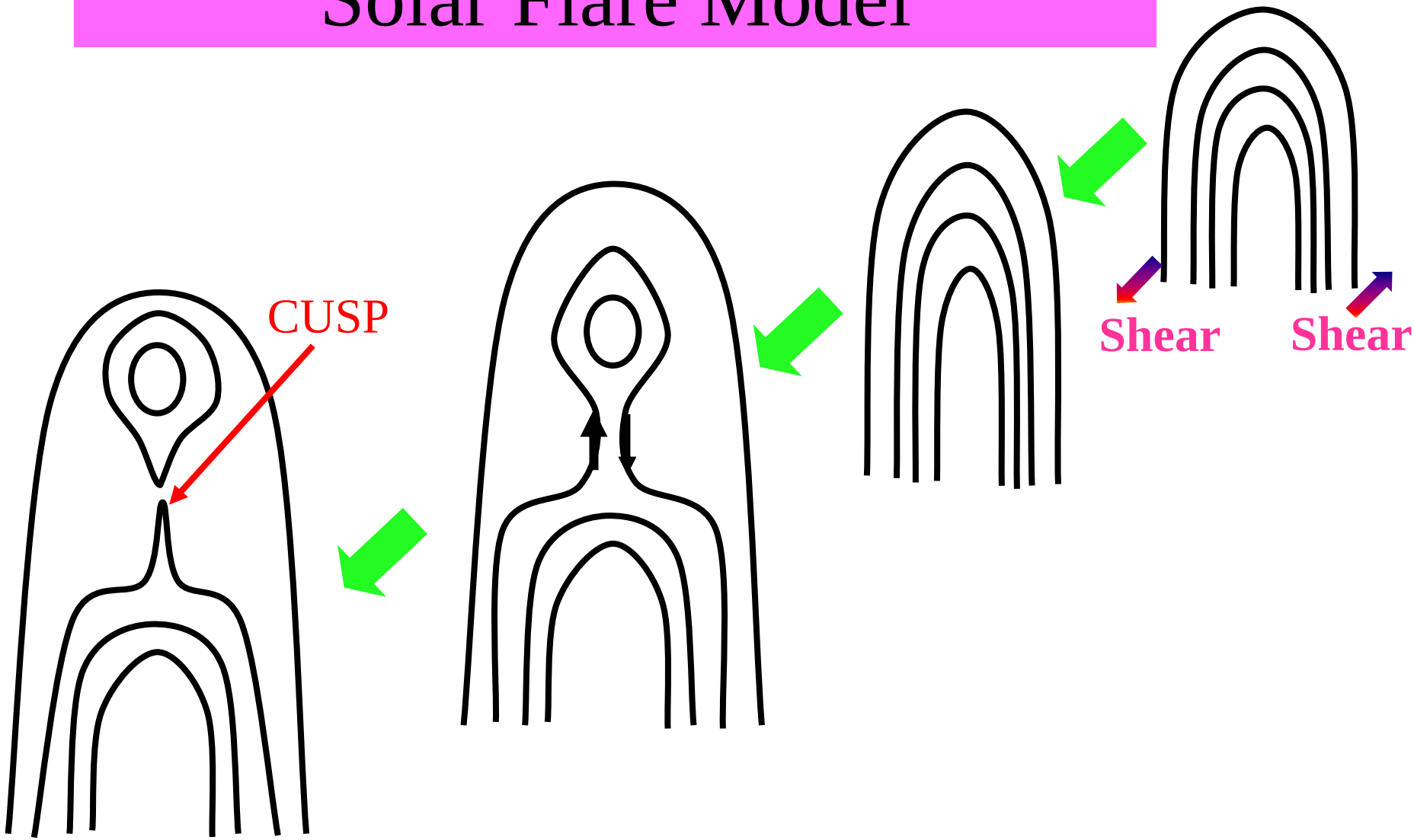
Chandra(COUP)



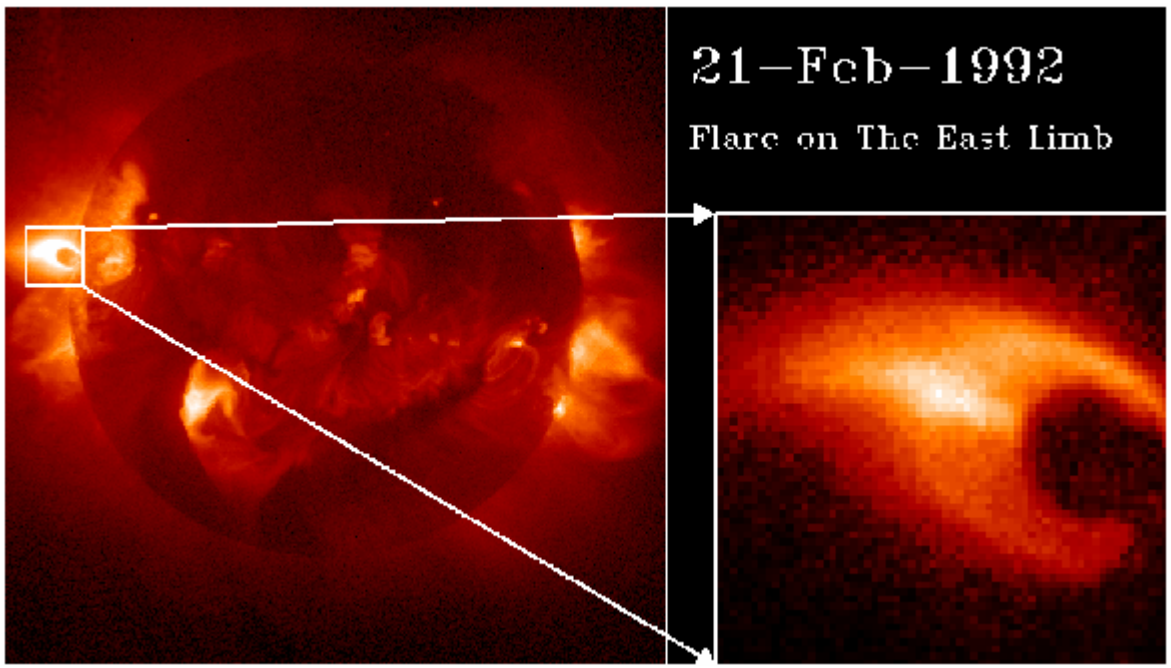
The Flare is Large and Hot

- **Several times larger than the radius of the central star**
- **Hard X-ray(several keV)**

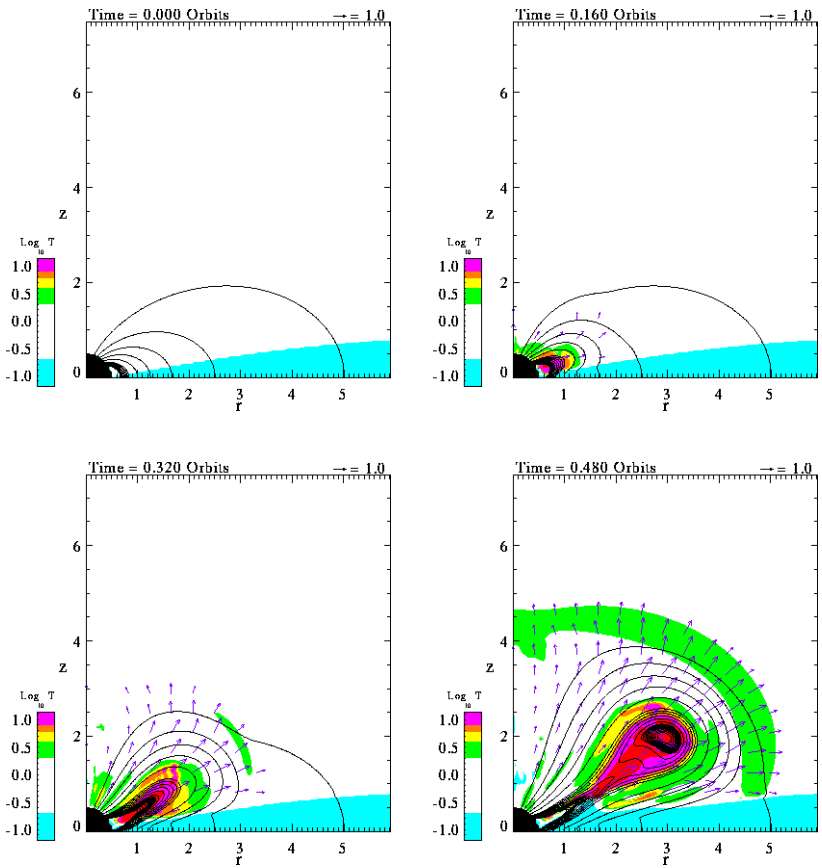
Solar Flare Model



Magnetic Reconnection

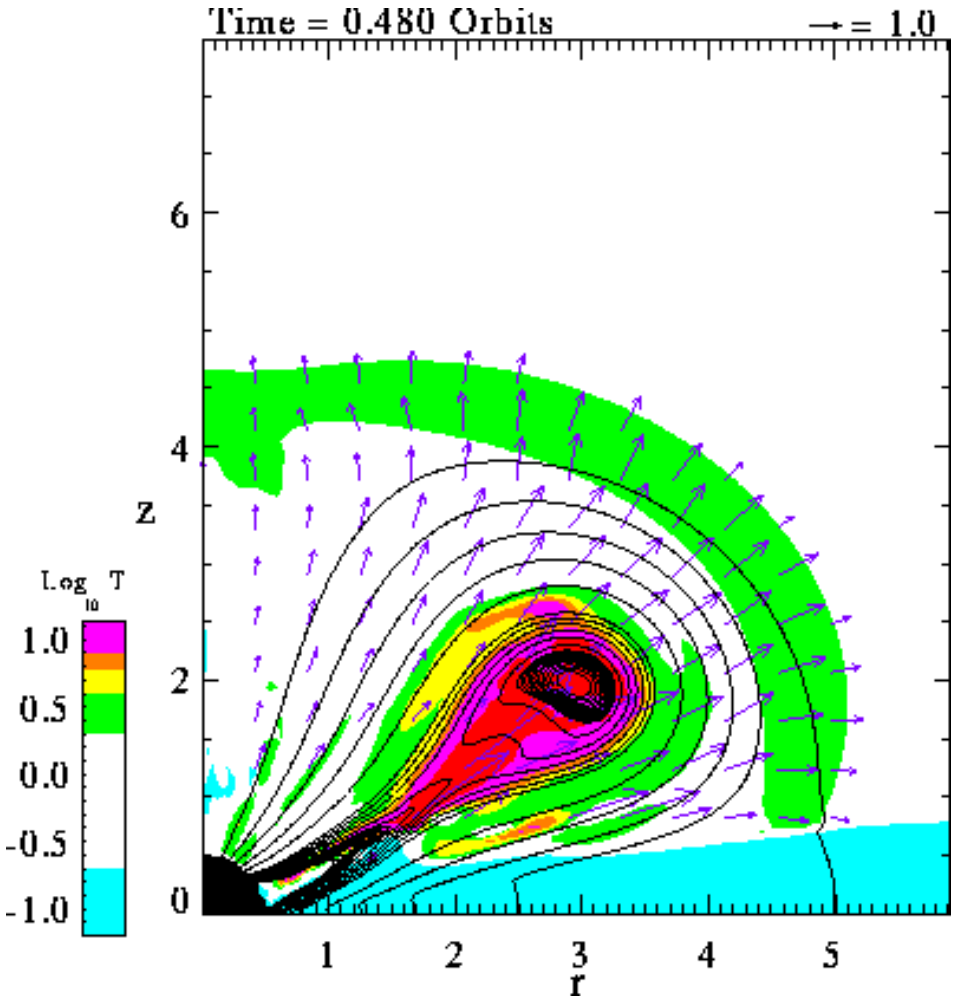


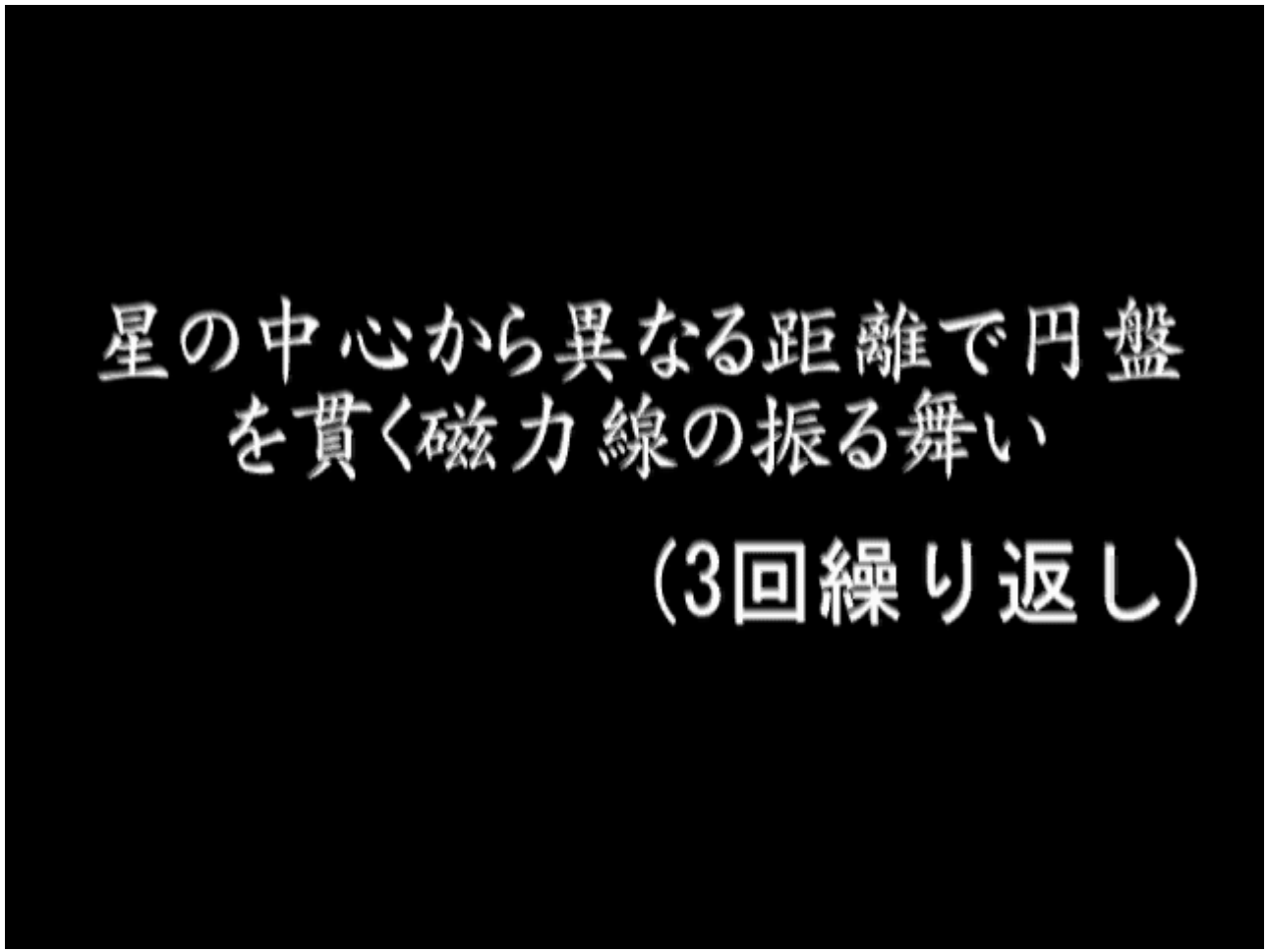
The interaction between magnetosphere and accretion disk

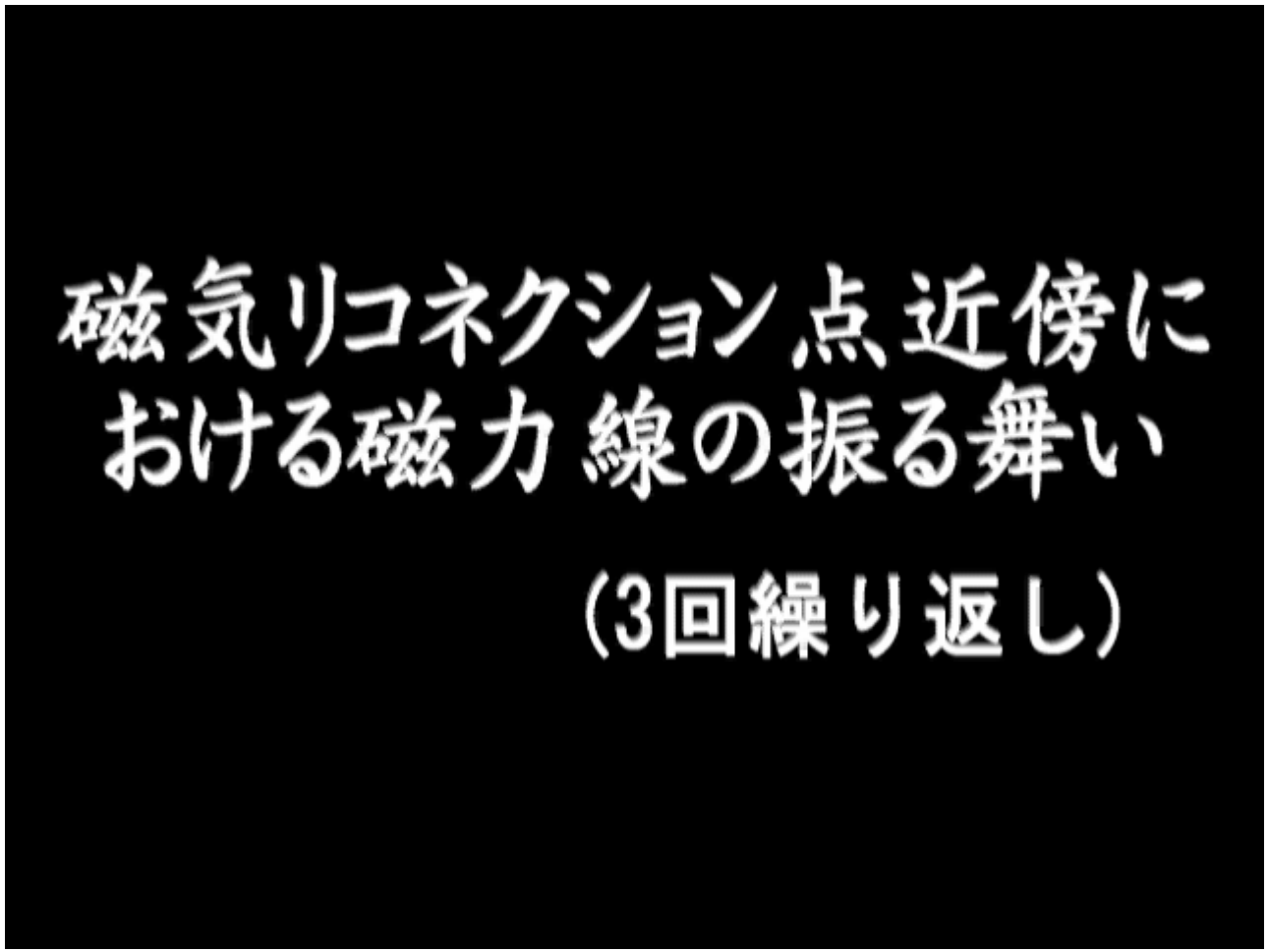


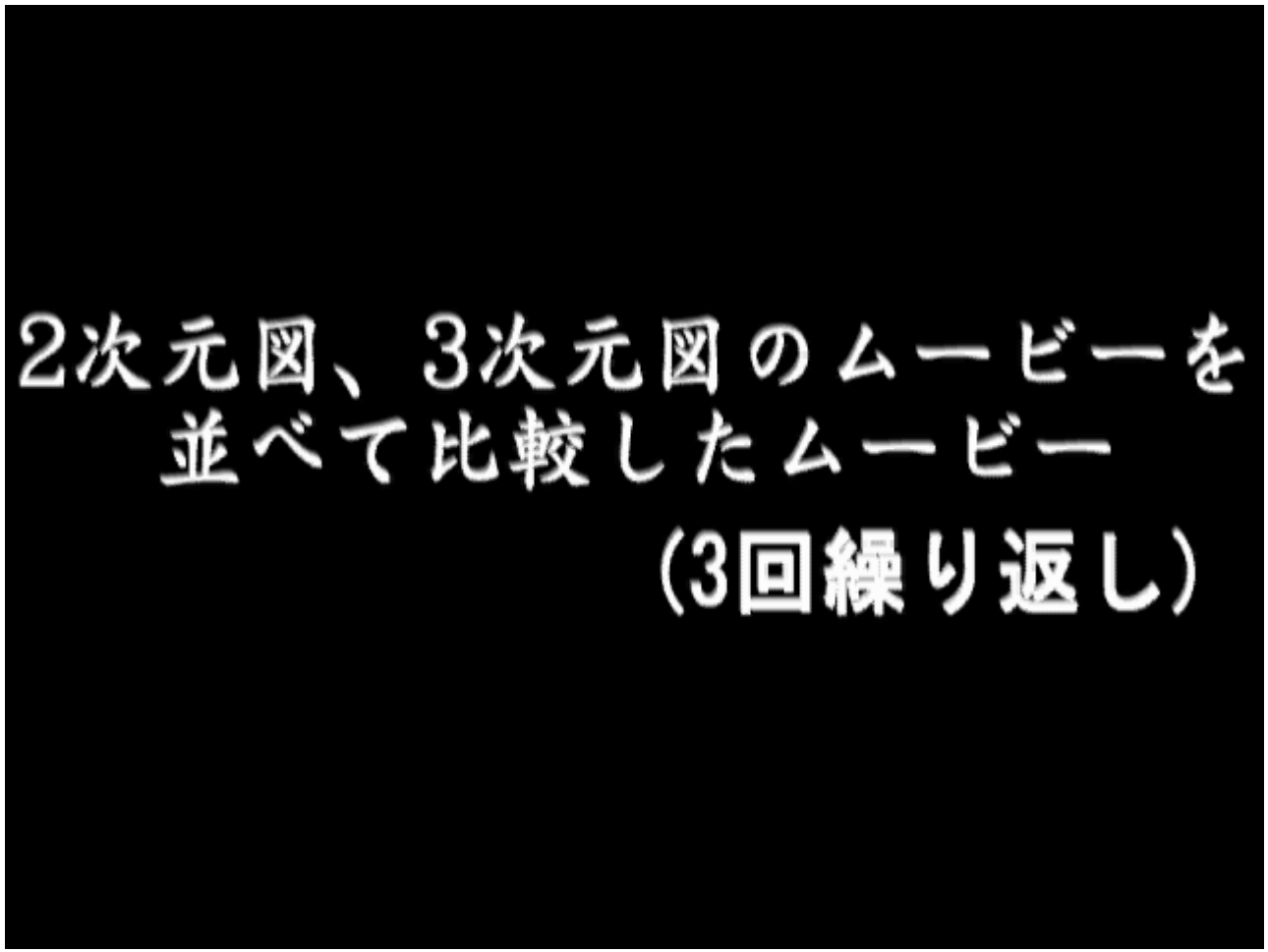
- **High temperature plasma flow by magnetic reconnection**
- **High temperature plasma(Kev)**
- **Reconnection jet (several hundred km/s)**

Slow MHD shock wave created by magnetic reconnection





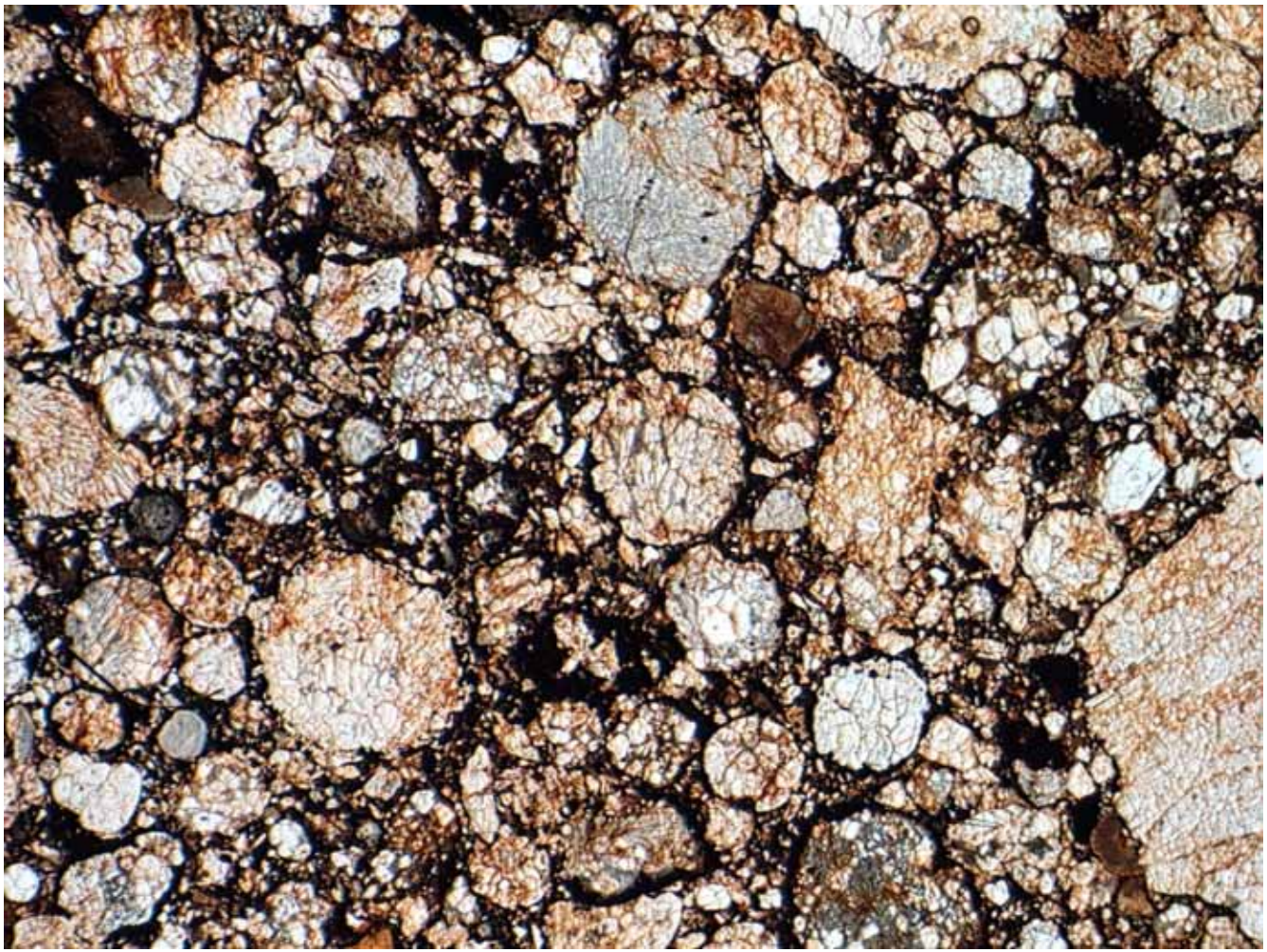




Results and Discussion

- Interaction between
  magnetosphere and accretion disk
  can form high temperature (keV) plasma flow
- The velocity of the plasma flow is
  about several hundred km/s
- The model can explain
  mass outflows and x-ray emission from YSO's
  qualitatively and quantitatively

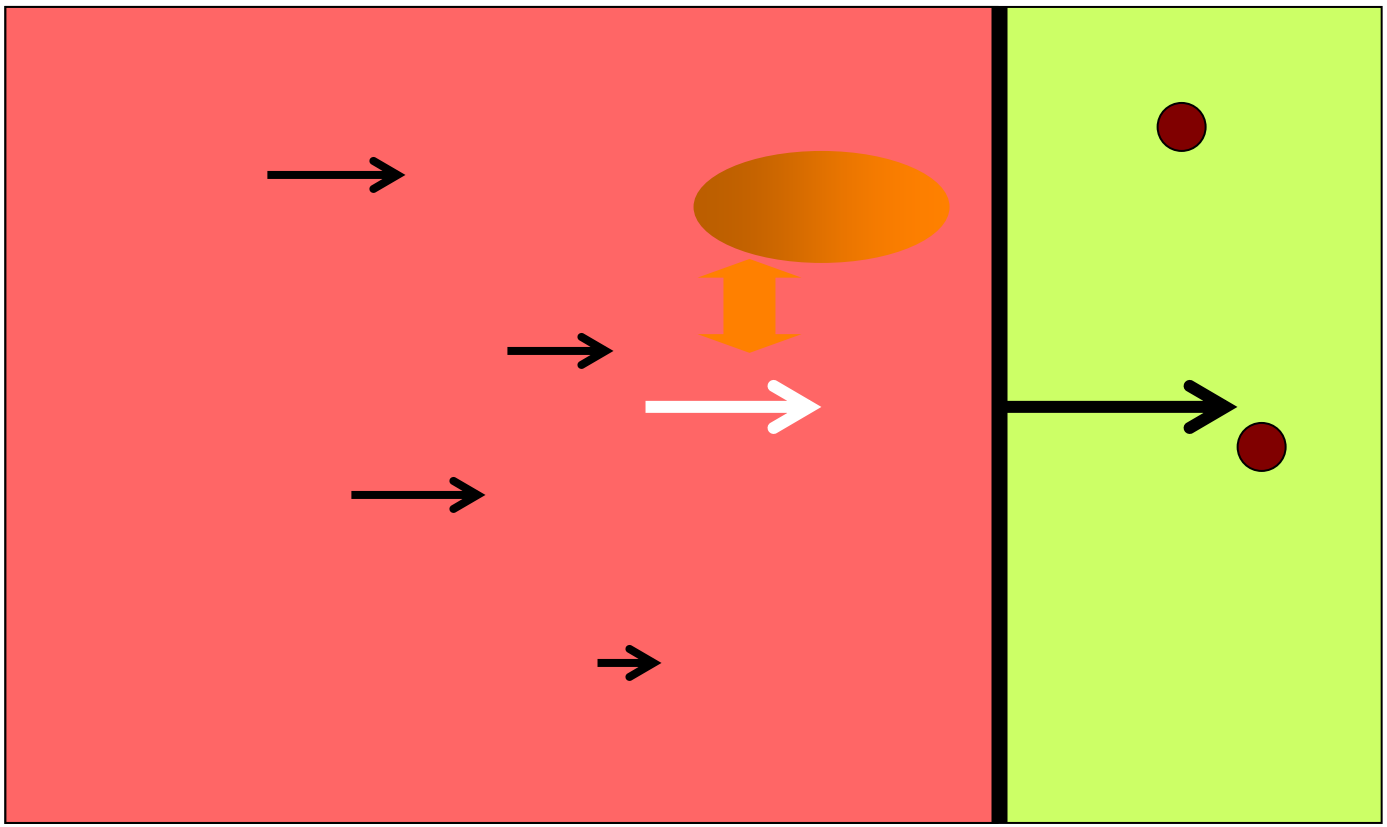
Ordinary Chondrite



Chondrule Formation(Models)

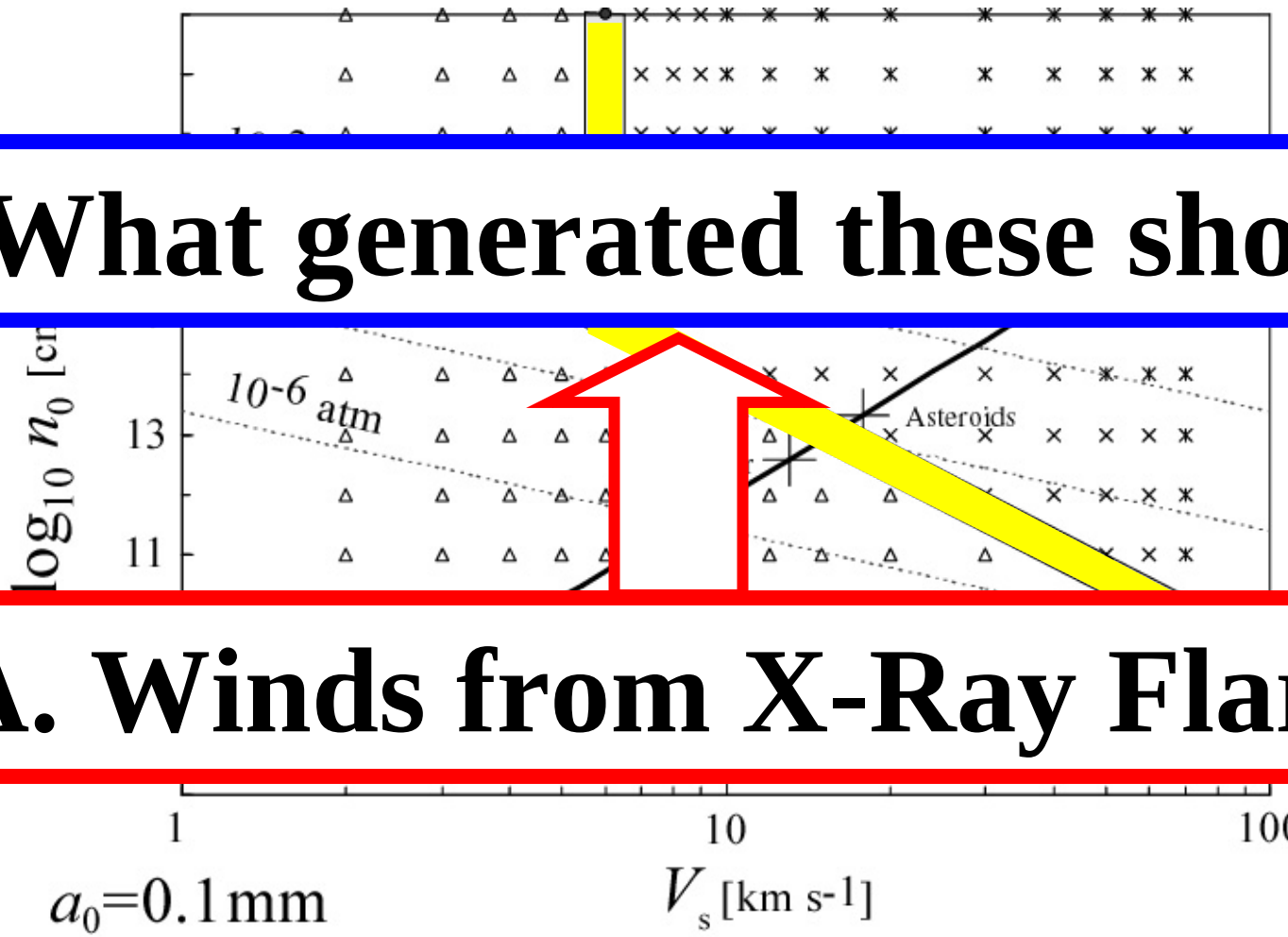
- Shock Wave Model
- X-Wind model
- Nebular Lightning
- ...

Shock Wave Heating for Dust Particles



Chondrule Forming Shock Waves: Peak Temperature

Q.What generated these shocks?

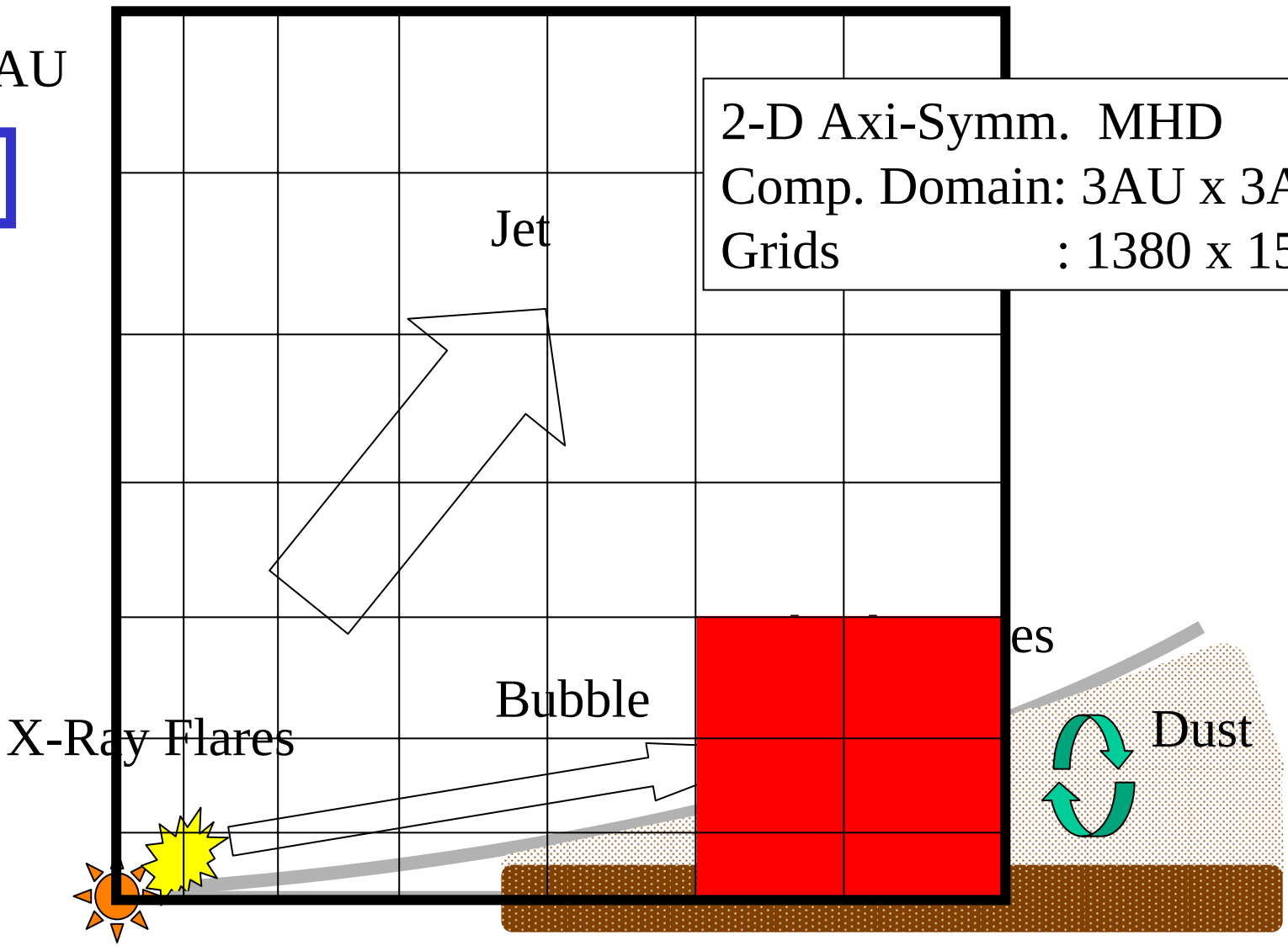


A. Winds from X-Ray Flares

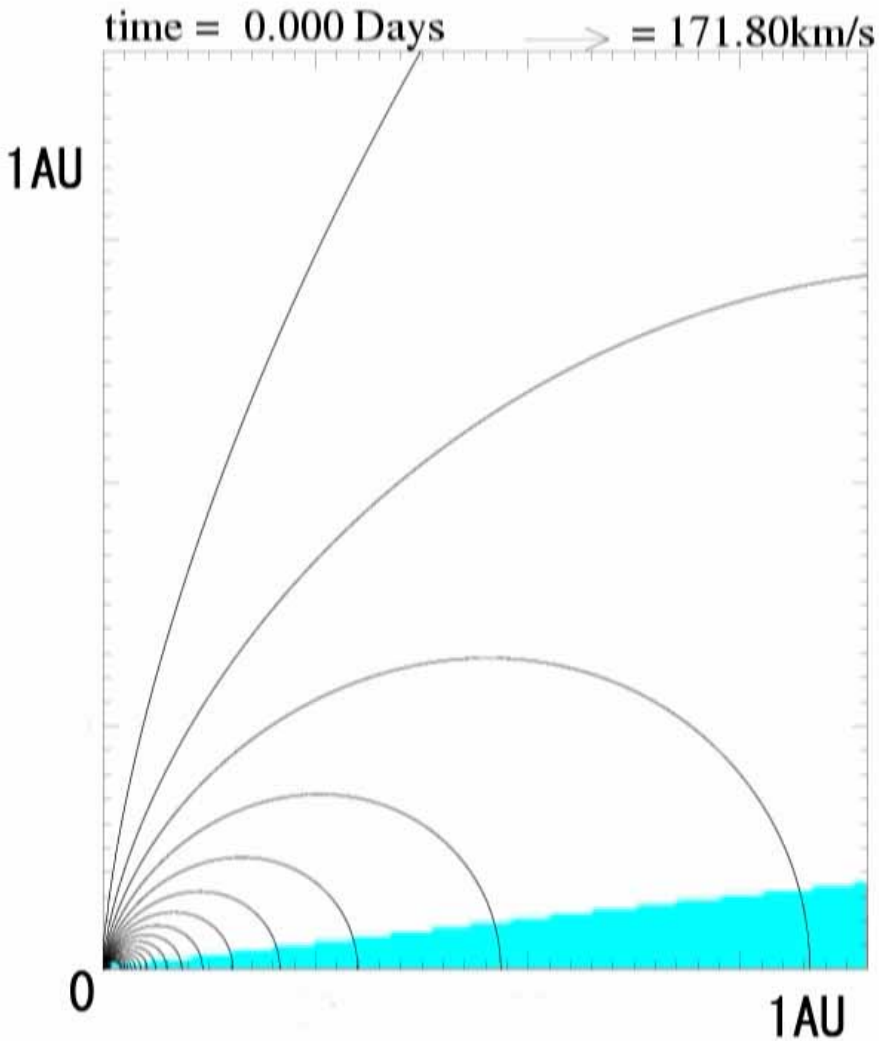
Iida, Nakamoto, Susa, & Nakagawa (2001) Icarus

3AU

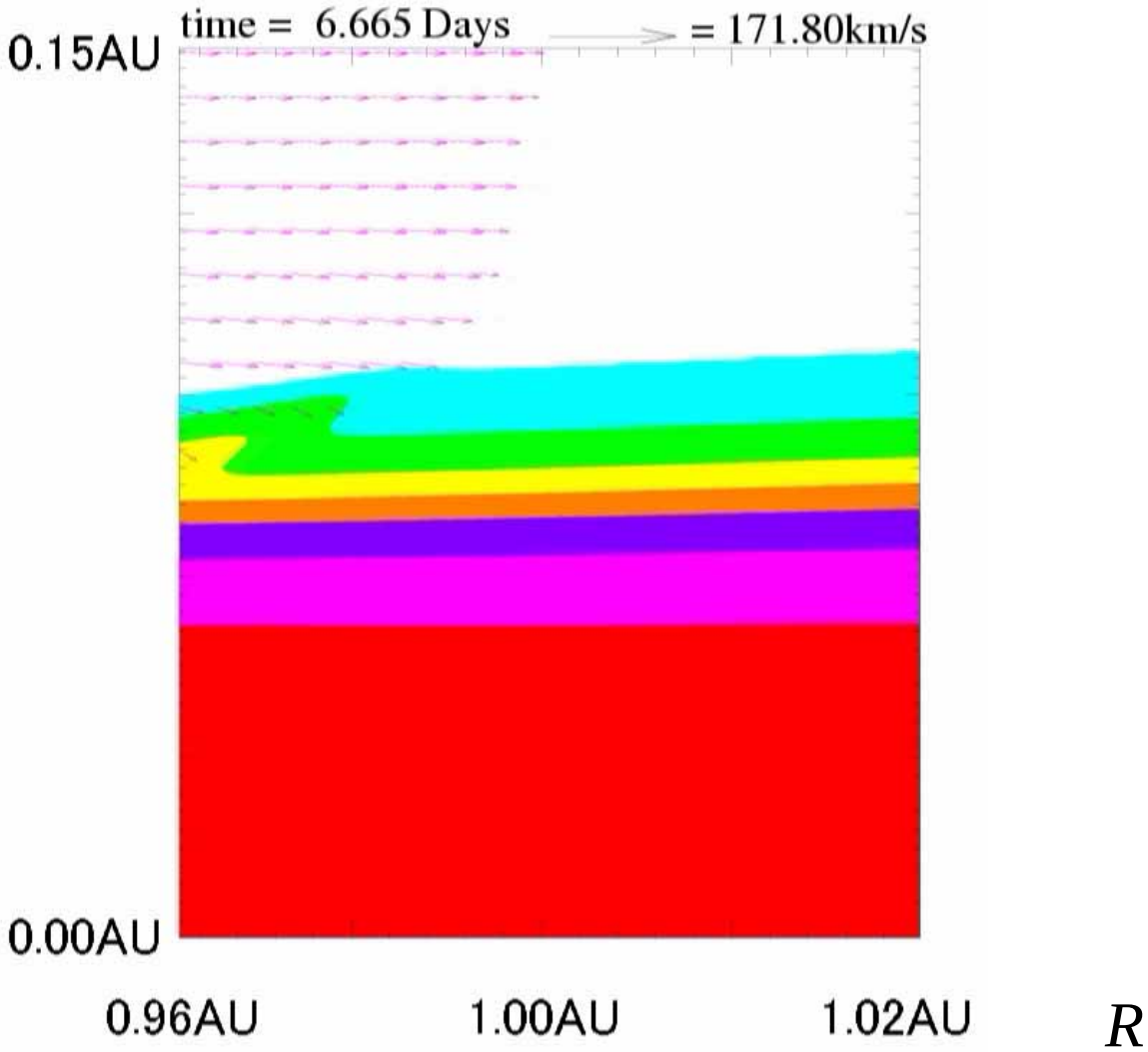
Model



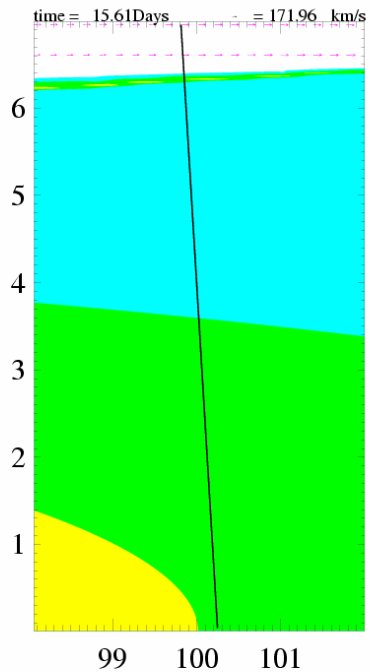
Temperature & Velocity

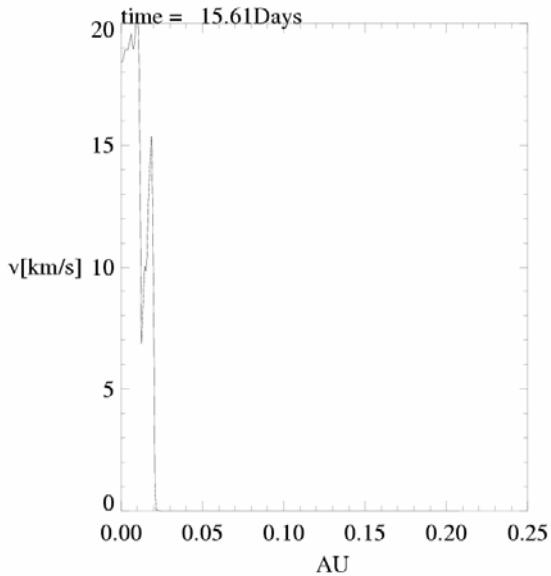


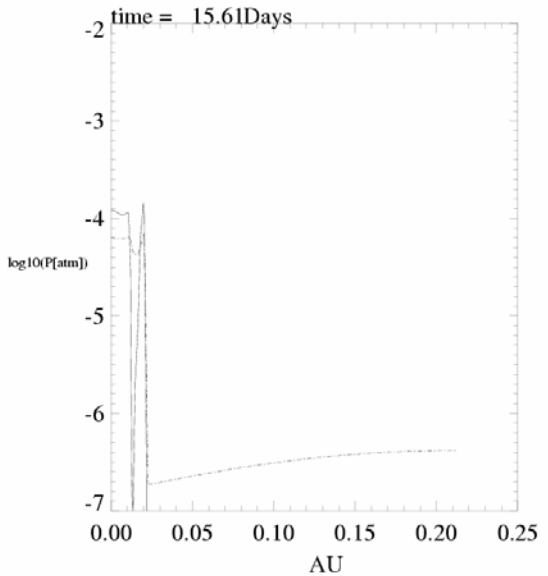
Density & Velocity



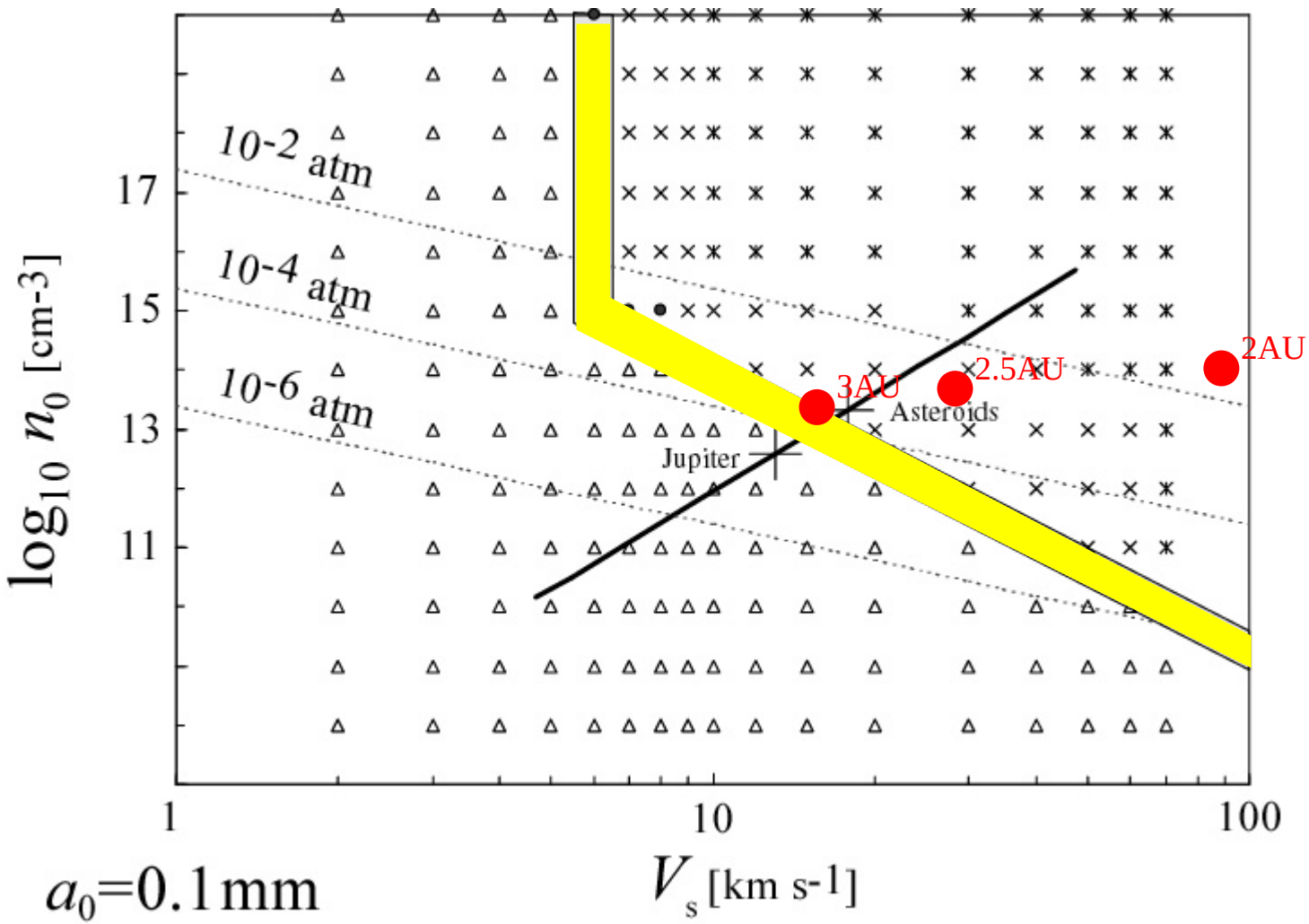
Shock Wave Formed at 3AU



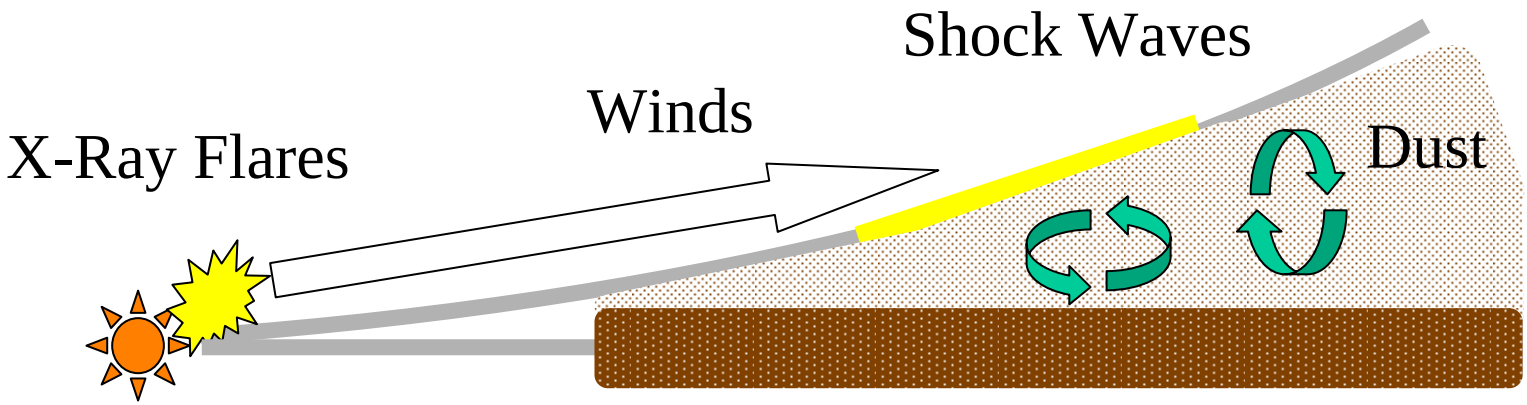




Chondrule Forming Shock Waves: Peak Temperature



“Shock Wave Heating at Upper Disk by X-Ray Flare Winds”



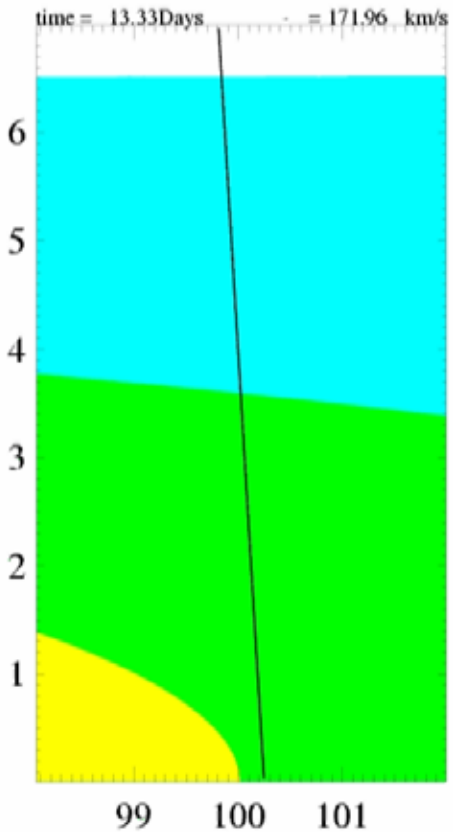
- MHD simulations
- Shock Waves for Ch. Formation are generated in

  Upper Layer: Z<1 *h*

  2AU<*R* < 3 AU region.

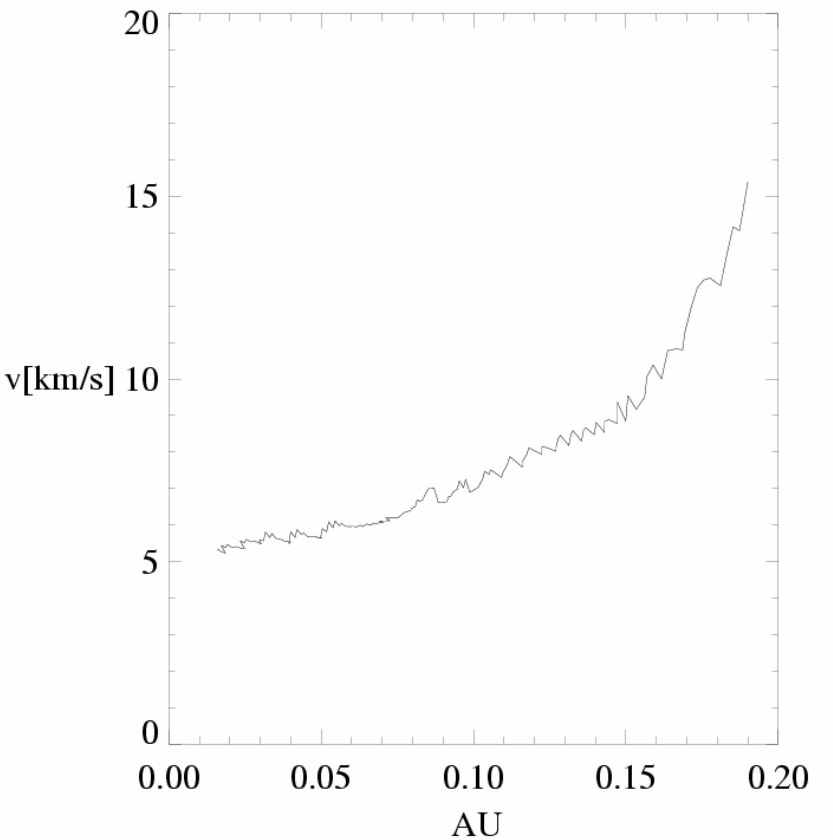
Propagation of the shock wave (from the surface to the equatorial plane)

(0.18AU)



(3AU)

Vertical distribution of the velocity



Results and Discussion

- Shock wave is formed on the surface of the accretion disk by the magnetic bubble of the X-ray flare
- The velocity of the propagation is about 15km/s at 3AU
- Shock wave which can make chondrule is formed on the surface of the disk at 2AU-3AU