14 Stars notes 2017/09/- supplementary - Star formation, protostar accretion

14.1 Star formation and Jean's mass

Take a piece of the ISM with density ρ and T which has mass M over radius R. the gravitational energy is

$$|E_{GR}| \sim \frac{GM^2}{R}$$

Typical densities in a star forming clound are $n \simeq 100/\mathrm{cc}$.

Total KE content of that region is

$$E_{th} \simeq \frac{3}{2}\frac{M}{m_p}kT$$

critical condition (Jeans length or Jeans mass) set by

$$\frac{GM^2}{R} > \frac{3}{2}\frac{M}{m_p}kT$$

Rewrite in terms of density

$$M = \frac{4\pi}{3}R^3\rho$$

so

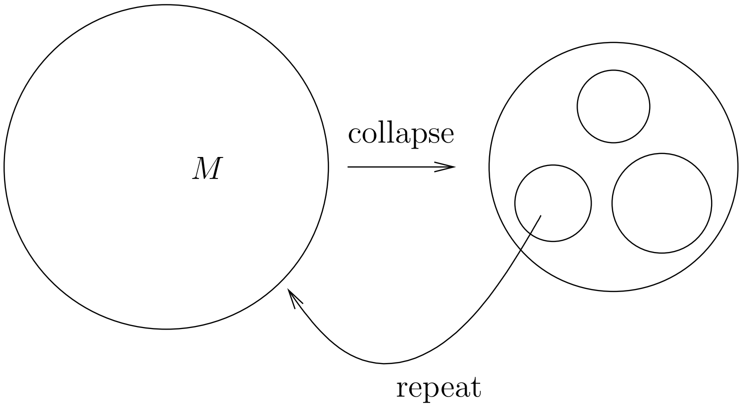
$$\frac{GM}{\left(\frac{3M}{4\pi\rho}\right)^{1/3}} > \frac{3}{2}\frac{kT}{m_p}$$

this gives a threshold for instability of $M > M_J$, where the "Jeans mass" is

$$M_J = 500M_\odot \left(\frac{T}{10^4}\right)^{3/2}\left(\frac{1}{n}\right)^{1/2}$$

where $n = \rho/m_p$. In a region with T, ρ a mass in excess of this can collapse.

The problem is this is big. How do we get from this to the distribution of stellar masses from this? How does a collapsing mass fragment into $M_\odot$ chunks? We will simply try to answer why would it fragment at all? The Jean's mass scales as $M_J \propto T^{3/2}\rho^{-1/2}$. Imagine that the region keeps it's same temperuture as it collopses. Then M_J decreases during the collapse. Then as the jeans mass decreases this can allow for "fragmentation" or the subsequent collapse of less massive regions.



So what halts the fragmentation? As density is rising in the fragments, they eventually become optically thick and so can't necessarily radiate on the collapse time. Presume that then it becomes adiabatic. Then $T \propto \rho^{2/3}$. Then the Jeans mass, $M_J \propto \sqrt{\rho}$, which is increasing as collapse continues. This shuts off fragmentation.

Halting of fragmentation is then due to the isothermal-adiabatic transition. Hard because you have to do both the dynamics and radiative transfer.

14.2 Star formation continued

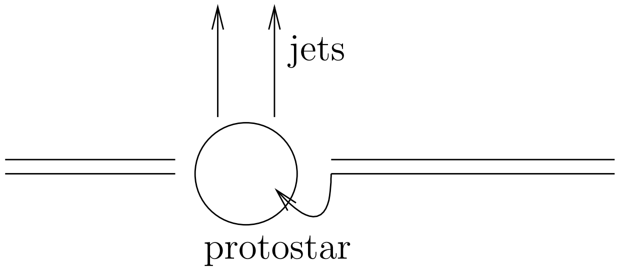
What's a characteristic timescale? The dynamical time, which is

$$t_{dyn} = \frac{1}{\sqrt{G\rho}} \simeq \frac{10^7 yrs}{(n/100)^{1/2}}$$

on this same timescale there is evidence that the "protostar" accretes more material from the surrounding cloud. The luminosity that such an object has is

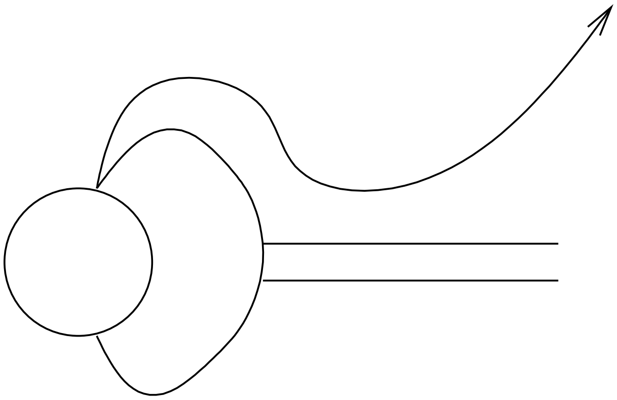
$$L = \dot{M}\frac{GM}{R}$$

just accretion luminosity. The picture is a disk with a jet.



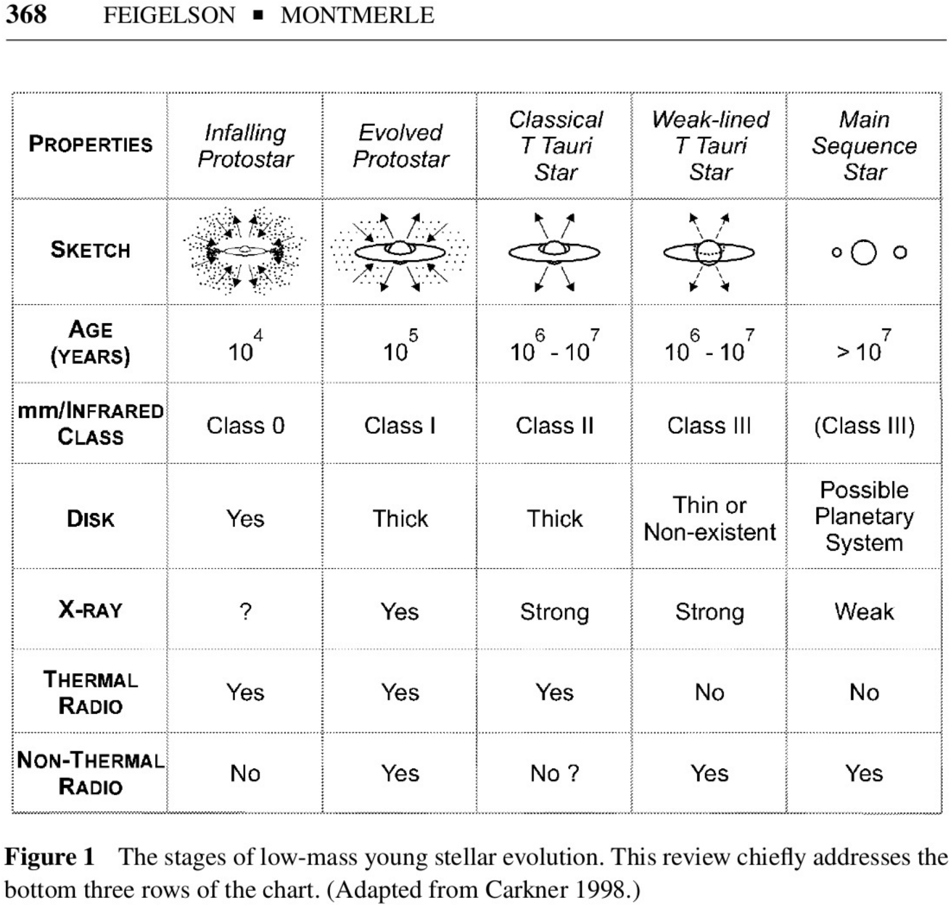
For $M \simeq M_\odot$ the first $\sim (1-5)$ Myrs is this accretion stage.

Why the jets? Two questions: what launches them, and what collimates them. The resulting stars are NOT spinning very fast. The field lines truncate the disk, and then those further out go to infinity.



The problem is figuring out how incoming material chooses between the closed field line and the open one.

See figures in Feigelson & Montmerle 1999, ARA&A, 37, 363



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PROPERTIES	*Infalling Protostar*	*Evolved Protostar*	*Classical T Tauri Star*	*Weak-lined T Tauri Star*	*Main Sequence Star*
SKETCH					
AGE (YEARS)	10^4	10^5	$10^6 - 10^7$	$10^6 - 10^7$	$> 10^7$
mm/INFRARED CLASS	Class 0	Class I	Class II	Class III	(Class III)
DISK	Yes	Thick	Thick	Thin or Non-existent	Possible Planetary System
X-RAY	?	Yes	Strong	Strong	Weak
THERMAL RADIO	Yes	Yes	Yes	No	No
NON-THERMAL RADIO	No	Yes	No ?	Yes	Yes

Figure 1 The stages of low-mass young stellar evolution. This review chiefly addresses the bottom three rows of the chart. (Adapted from Carkner 1998.)

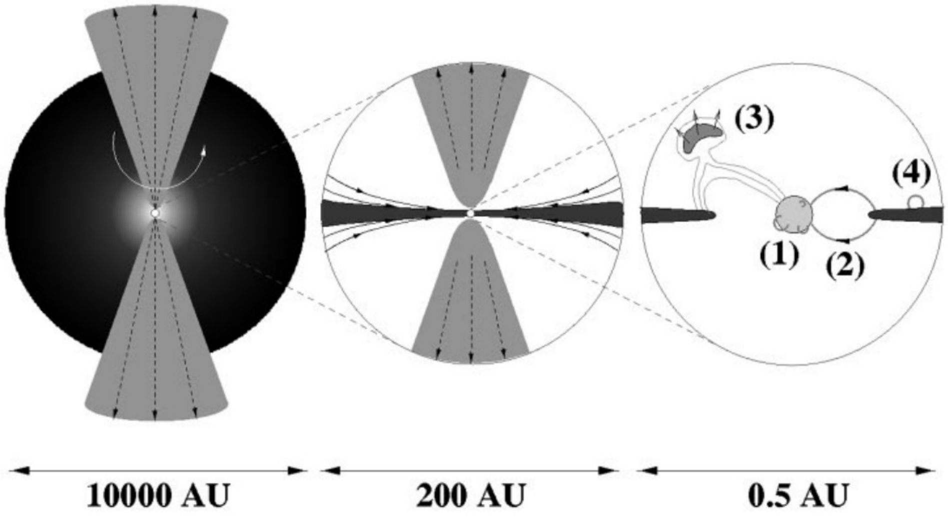

Figure 2 Four magnetic-field configurations that may be responsible for the magnetic activity of Class I protostars. The X rays come from the inner region of a complex structure comprising a collapsing extended envelope (*left*), an inner disk and outflow (*center*), and a star-disk magnetic-interaction region (*right*). (Courtesy of N. Grosso.)

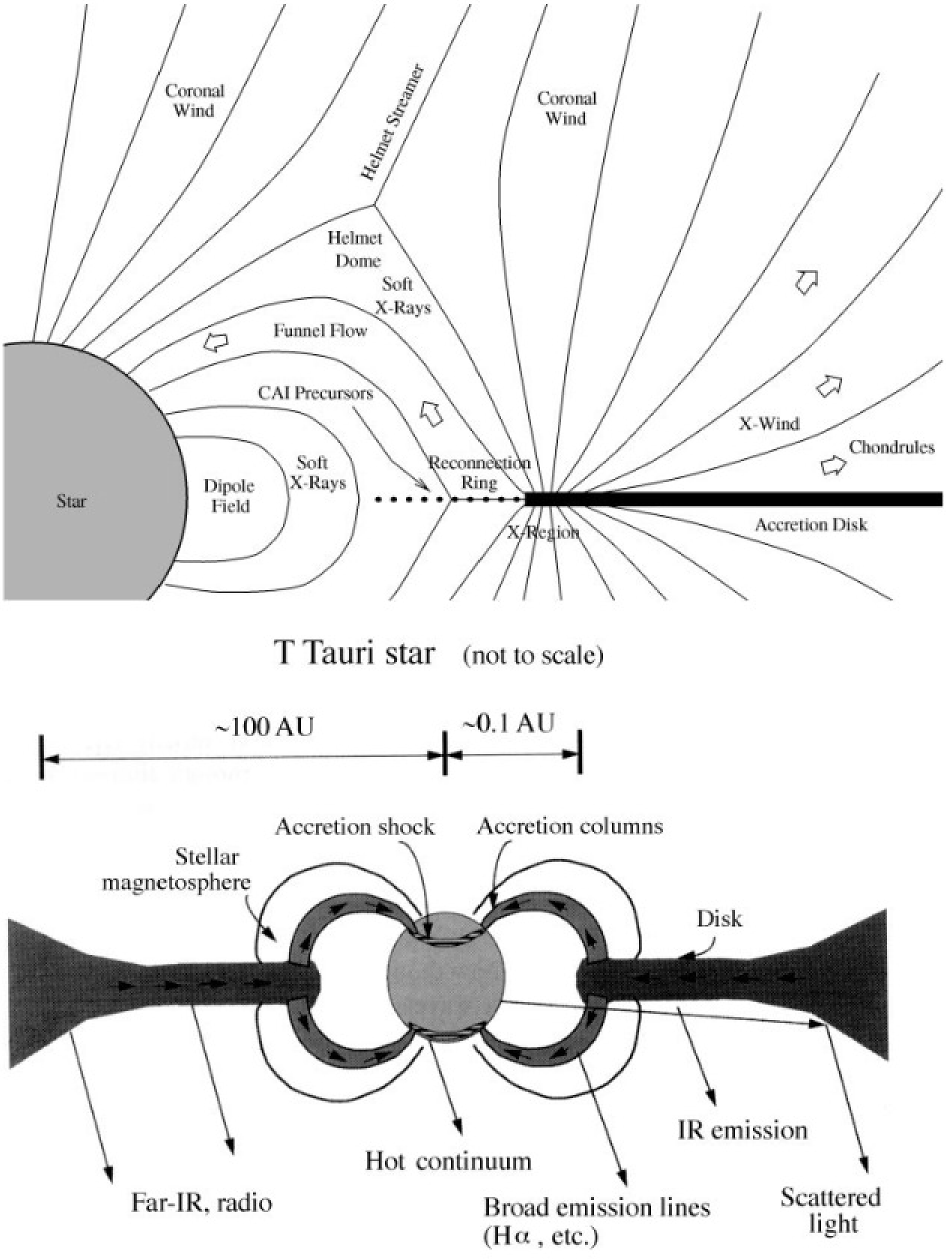

Figure 3 Two contemporary models for Class I–II YSOs, in which magnetic fields play crucial roles: (*top*) the x-wind model of YSOs showing magnetically collimated accretion and outflows with irradiated meteoritic solids (Shu et al 1997); (*bottom*) magnetically funneled accretion streams producing broadened emission lines (Hartmann 1998).