The state of our knowledge

What we understand about star formation

Some things we’d like to understand that studies with the great observatories might clarify

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Star formation “theory”

How do protostellar cores form?

Why do disks accrete? - gravity early... Then Magnetorotational Instability ??

Planet formation ?

Rapid collapse with angular momentum conservation; OK
The brown dwarf “problem”

\[ M_J = (\pi c_s^2/G)^{3/2} \rho^{-1/2} \sim 5.4 T_10^{3/2} (N_{H_2}/10^4)^{-1/2} M_\odot; \]

\[ M = 0.05 M_\odot, T=10K, \Rightarrow N_{H_2} \sim 10^8 \text{ cm}^{-3} \]

or \[ M_J = 17 T_10^2 (P/k/10^4)^{-1/2} M_\odot; \]

\[ M = 0.05 M_\odot, T=10K, \Rightarrow P \sim 10^5 <P>_{\text{ISM}} \]

Form BDs in (dense) disks, then eject (Reipurth & Clarke)?

but:

BDs with disks (Luhman, Mohanty, Jaywardhana, etc.); can they survive ejection? young binary BDs? (Luhman)

If BDs form in the same way as stars:

⇒ DYNAMIC CONDITIONS IN MOLECULAR CLOUDS!

Spitzer, HST, ground studies
Ejection or independent formation?

Fragmentation in disk (ring) plus ejection? (e.g., Reipurth & Clarke) and/or independent core (dynamic formation)? (Bate, Bonnell, & Bromm)

04325+2402 (protostar)

2μm IRTF
(Hartmann, Calvet, Allen, Chen, Jayawardhana 1999)

2μm NICMOS

Disk+envelope

1000AU
Proto(stellar, planetary) disks accrete

dM/dt \propto M^2 \text{ approximately; why??}

some weak evidence that M(disk) \propto M_*; what is the other factor??

Calvet, Muzerolle et al. 2004
What drives disk accretion?

If $M(\text{disk}) > 0.1 M(\text{star})$, then self-gravity can drive angular momentum transport by spiral waves
$\Rightarrow$ build up star by gravity

What drives accretion in lower-mass disks?

MRI - needs (low) ionization to couple $B$ to gas
$\Rightarrow$ X rays (?)

Grady et al. 1999; STIS 0.2-1.1\text{$\mu$m} coronagraphic image of AB Aur (two position angles)
COUP - Xray ionization of disks

Magnetorotational instability (MRI); X-ray ionization? but highly time-variable...

Tsujimoto et al
Inner disk; dust settling, grain growth \(\implies\) first stage of planet formation (core acc.)

Sicilia-Aguilar et al. 2005; Spitzer results
Inner disk clearing

Spectra from IRS on SPITZER

TW Hya, ~ 4 AU
~ 10 Myr

CoKu Tau 4, ~ 10 AU
~ 2 Myr

Uchida et al. 2004

Forrest et al. 2004; D’Alessio et al. 2004

Inner disk

No inner disk, WTTS
Some problems...

- Formation of protostellar cores - BD formation (Spitzer); high-mass stars (HST) \( \Rightarrow \text{IMF} \)
- Disk accretion \( \Leftrightarrow \) ionization by X-rays? (Chandra)
- Disk evolution; dust settling/growth; planet formation(?) (Spitzer, HST)
T Tauri star - magnetospheric accretion

- Stellar magnetosphere
- Accretion shock
- Accretion columns
- Far IR emission
- Gas Disk
- Dust Disk
- X-ray emitting coronal gas

~0.1 AU
Disk frequencies

Haisch et al. 2001; Sicilia-Aguilar et al. 2005

likely to have outer disks not detected at short $\lambda$ (eta Cha?)