Multiplicity in the earliest phases

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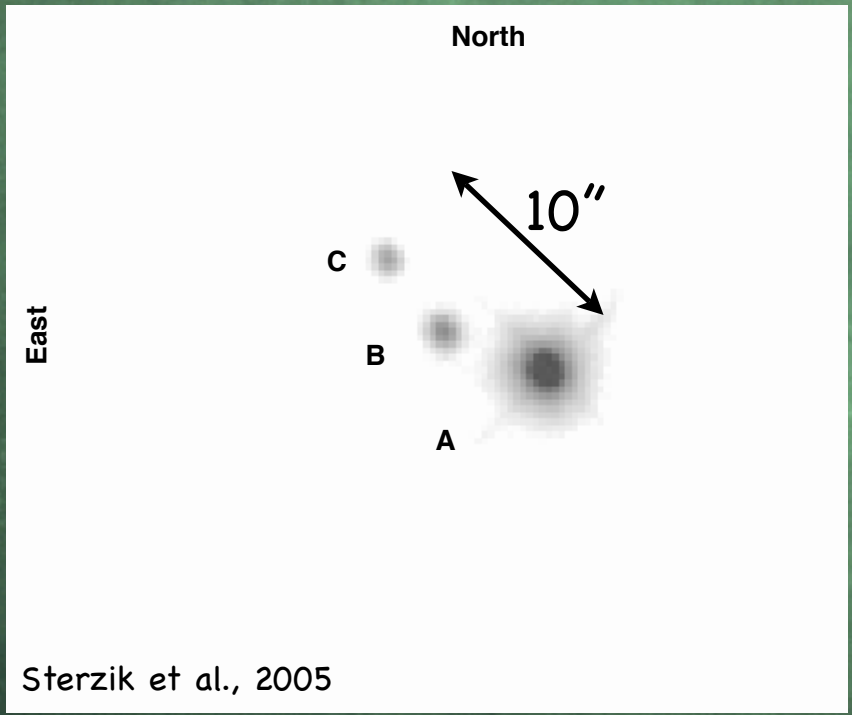
- When is it established?
- On what spatial scales?

What are the physical processes that shape MF, P, A, q, e ...

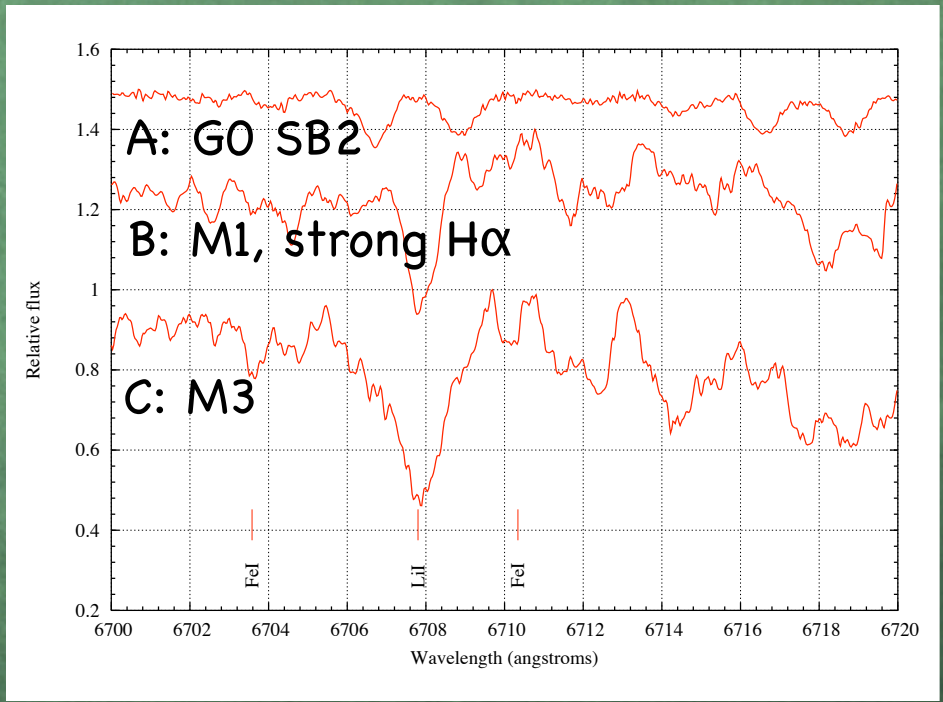
Note the observational difficulties and biases

Examples

HD 34700



Sterzik et al., 2005



… 3 Myr old c+wTTS hierarchical quadruple

... there are many!

Table 3. Multiple TTSs with SBs having a known orbit. The periods of spectroscopic binary P_{in} (in days) and the angular distances (or periods) of outer components are listed.

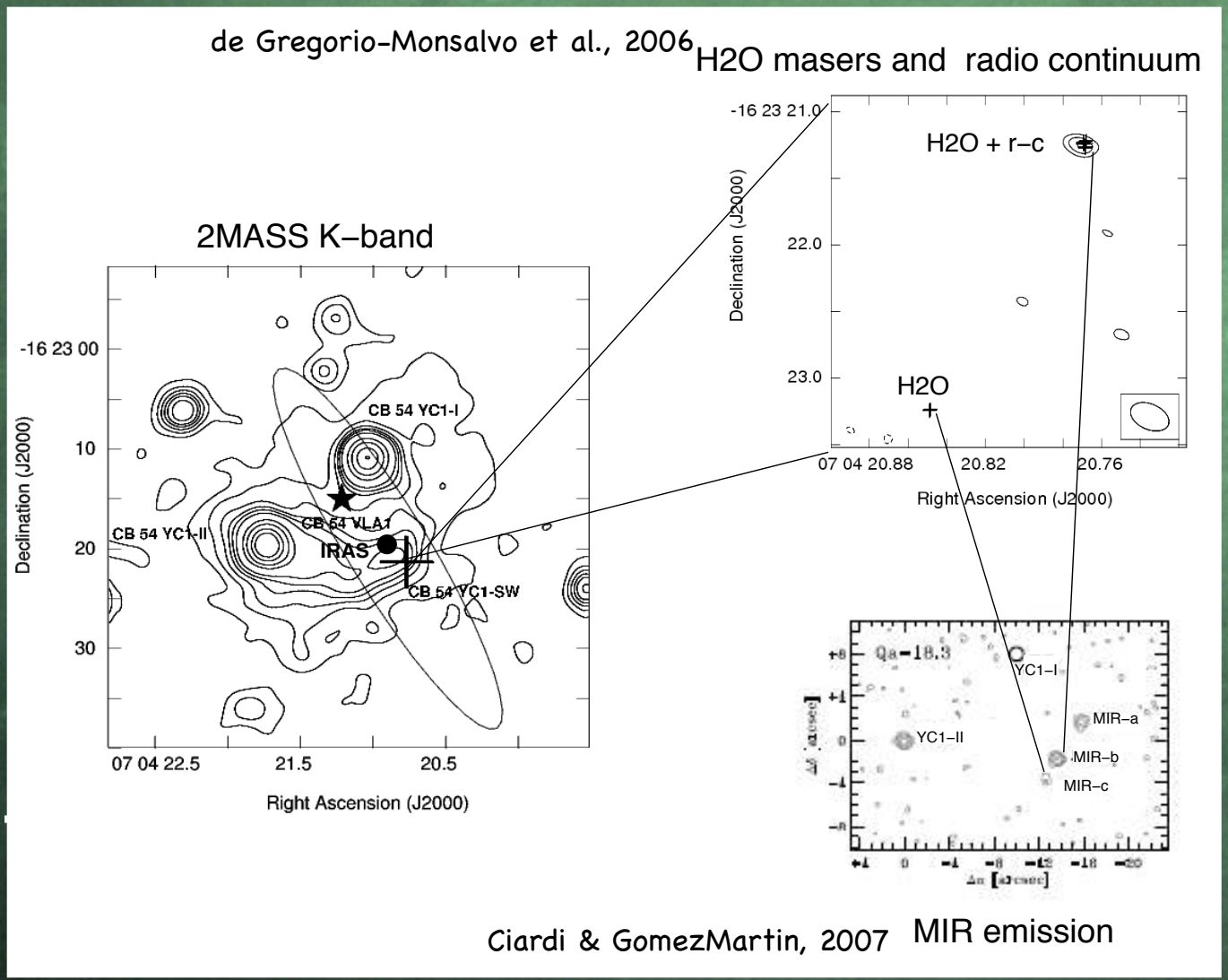
Source	P_{in}	d_{out}	Remark
HD155555	1.7	33″	
V1154 Sco	2.4	0.″288	
RW Aur	2.77	0.″12 + 1.″39	Quad.
RXJ0529.4+0041	3.03	1.″3	eclips.
RXJ0541.4-0324	4.98		SB3
RXJ1301.1-7654	13	1.″44	
UZ Tau	19.1	0.″368 + 3.″54	Quad.
HD 34700	23.5	5″+ 10″	Quad.
ROXs 42C	36	0.″157	
RXJ0532.1-0732	46.9		SB3
V773	51.1	0.″2 + 0.″2	Trap.
Crux-3	58.3	4.6yrs	SB3
ROXs 43A	89.1	6″	
HD98800	262 + 315	0.″8	Quad.
Haro 1-14	591	12.″9	

- 40 TTS w/ SB orbits
- 15 triples or higher
- higher MF for P<10d (cp A. Tokovinin's talk)

- 25% of all SB are higher order (Mayor & Mazeh 1987)

More Examples

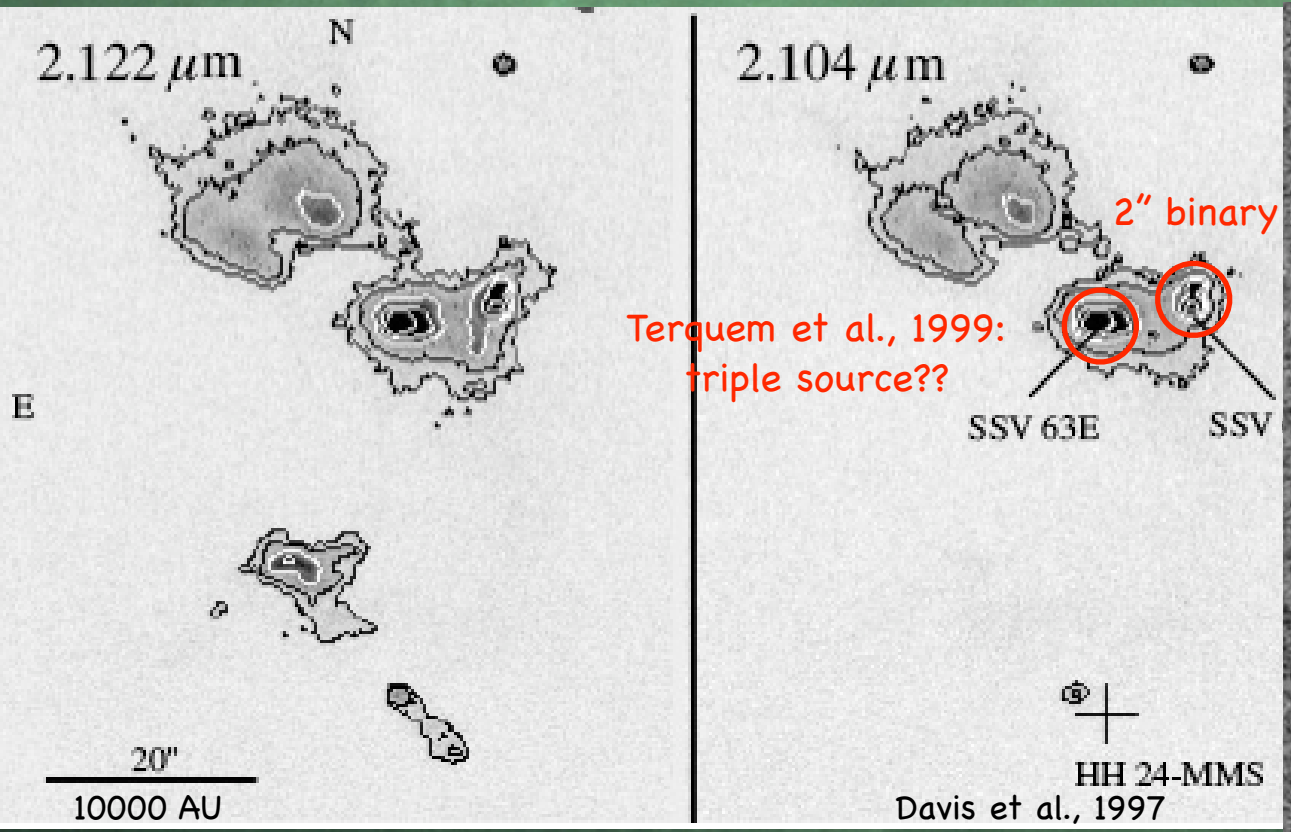
CB54

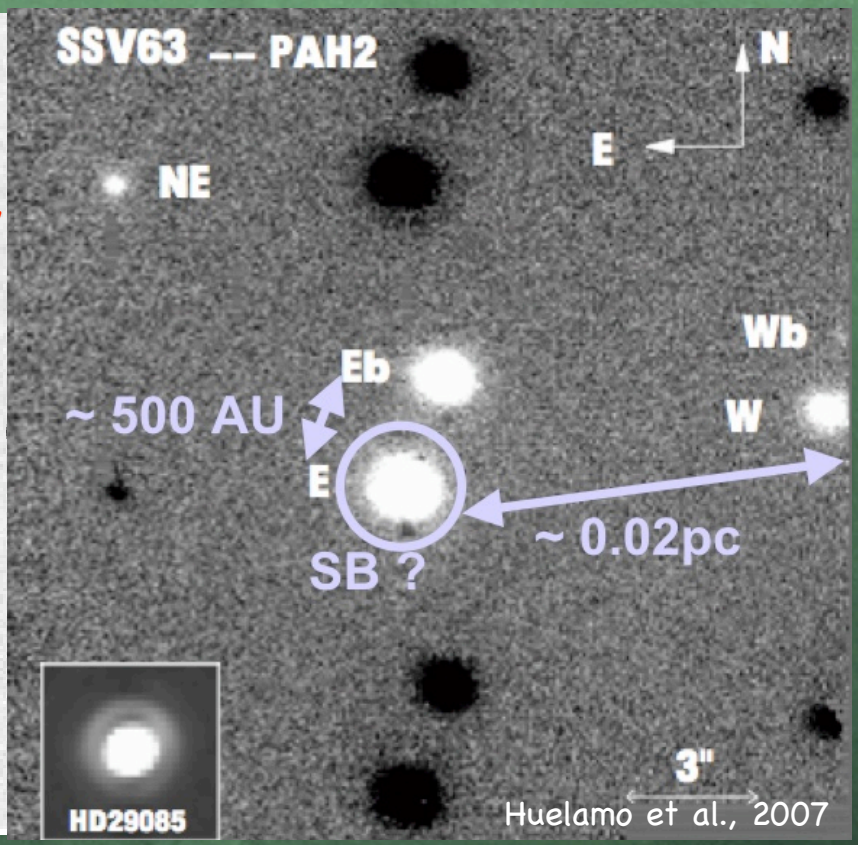


- Bok globule
- multiple outflows
- twisted jets
- masers / class 0
- multiple stellar sources @ 100 AU

More Examples

SSV63

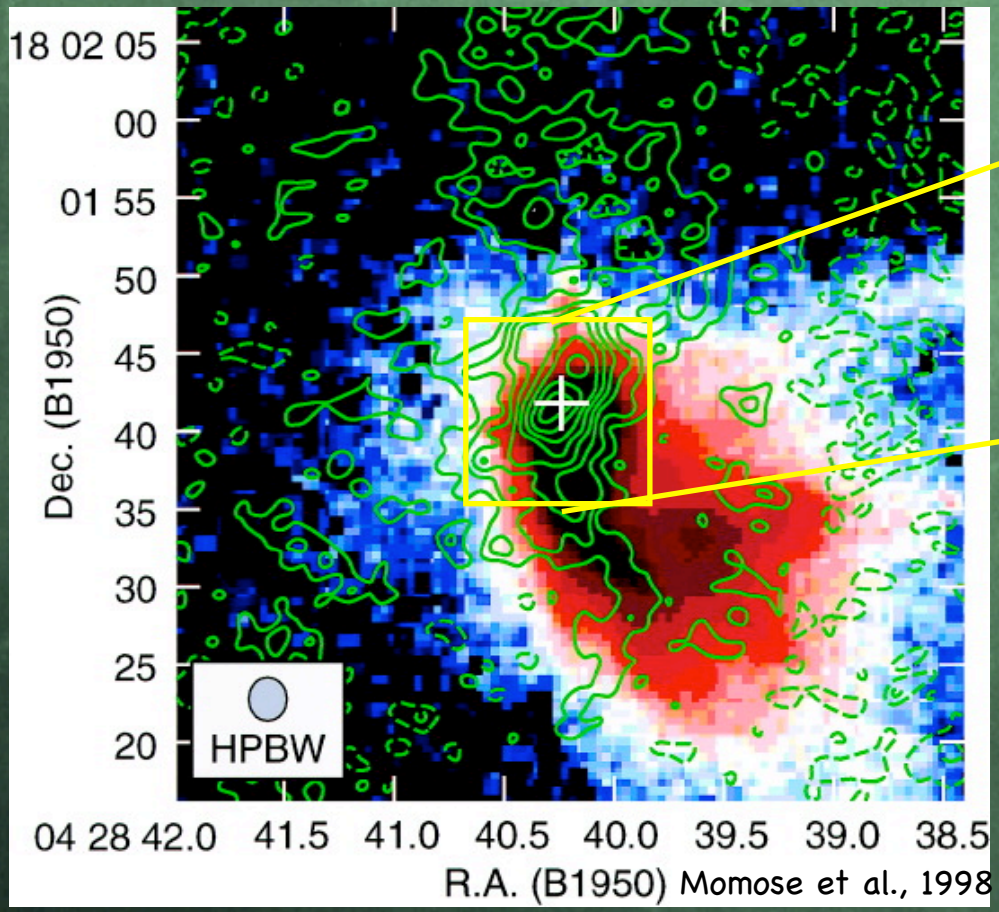




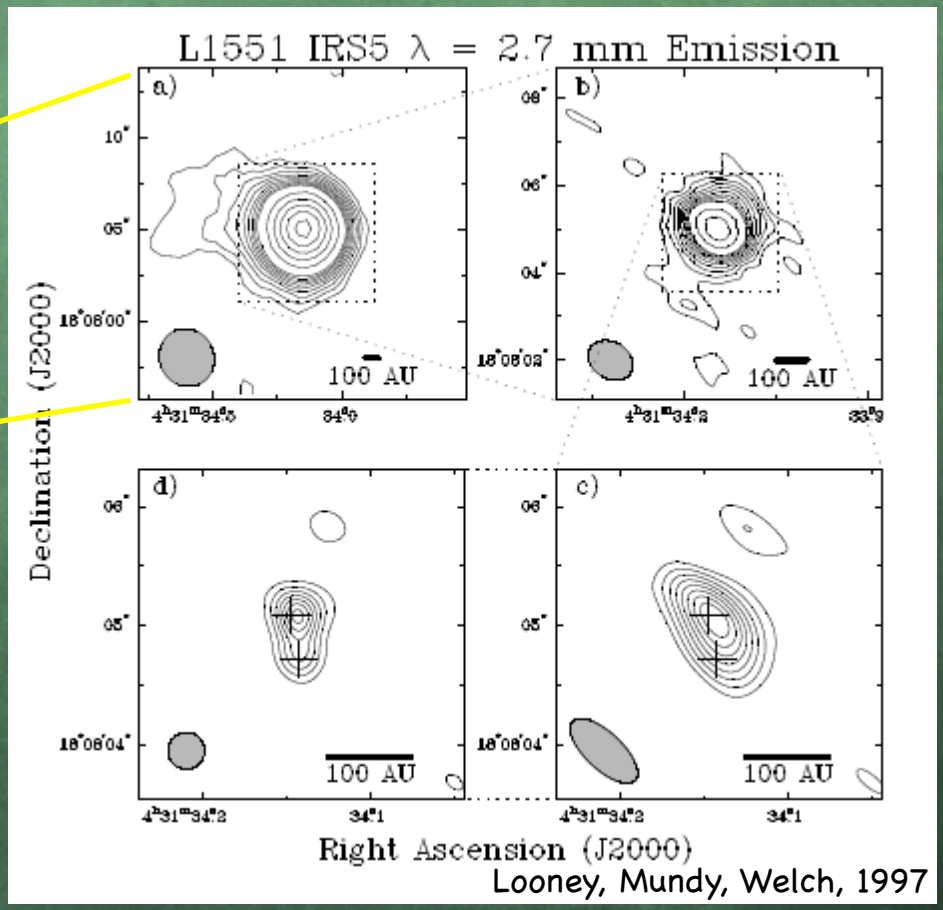
More Examples

L1551 IRS5

- prototypical class I source
- outflow, jets, HH, envelope, disk
- 50 AU binary + cb disk ??



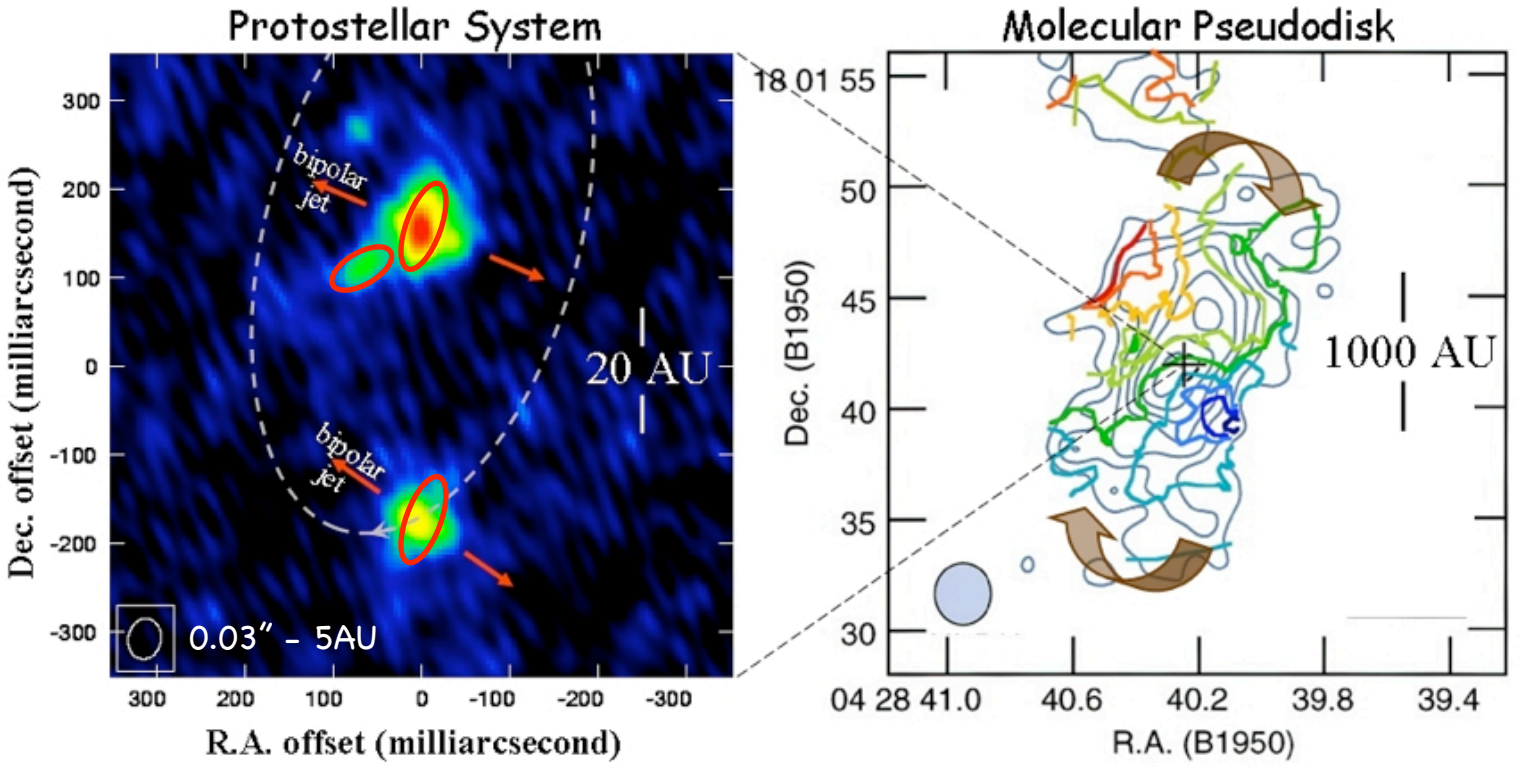
Momose et al., 1998



Looney, Mundy, Welch, 1997

More Examples

L1551 IRS5

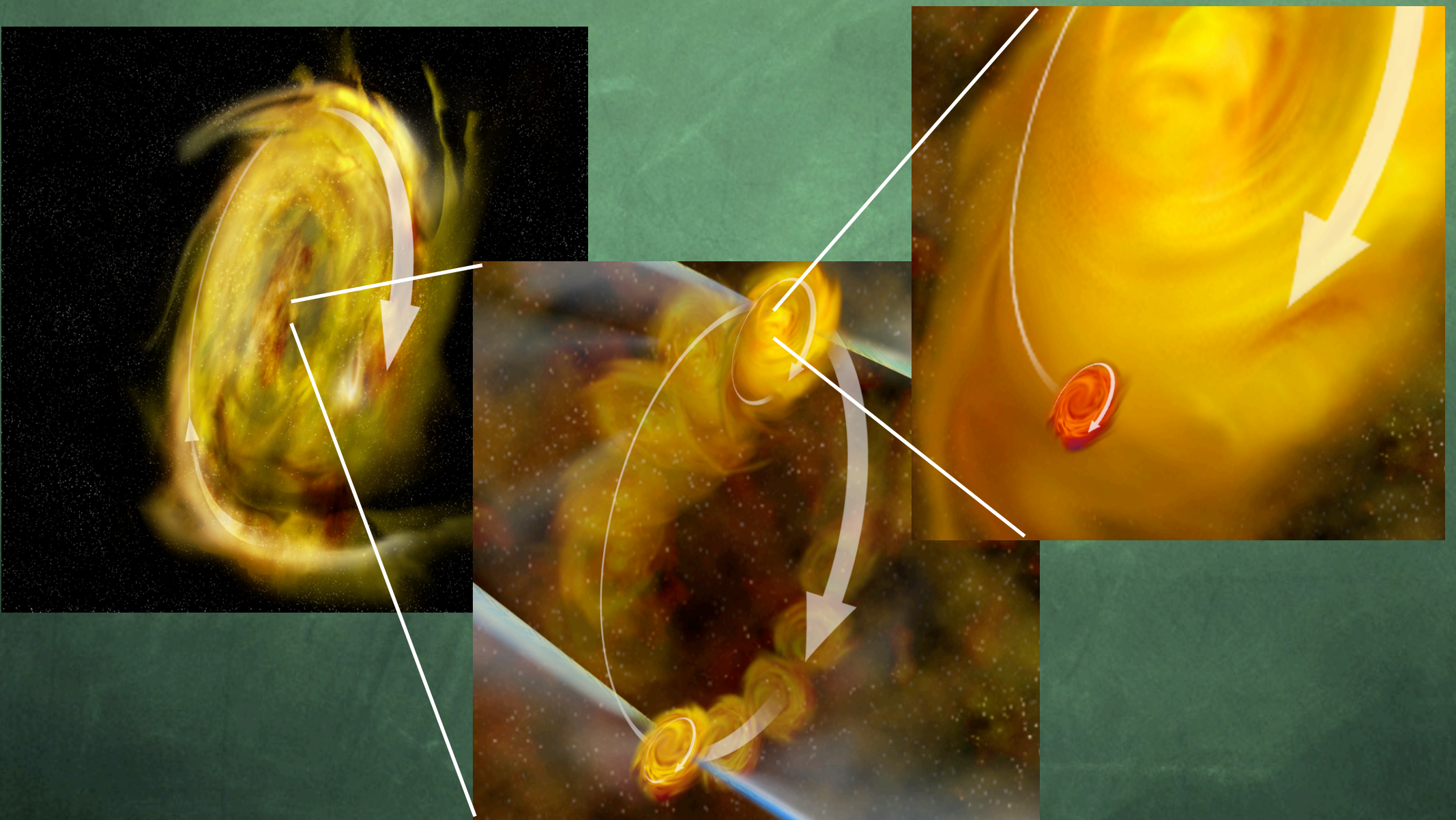


Lim & Takakuwa, 2006

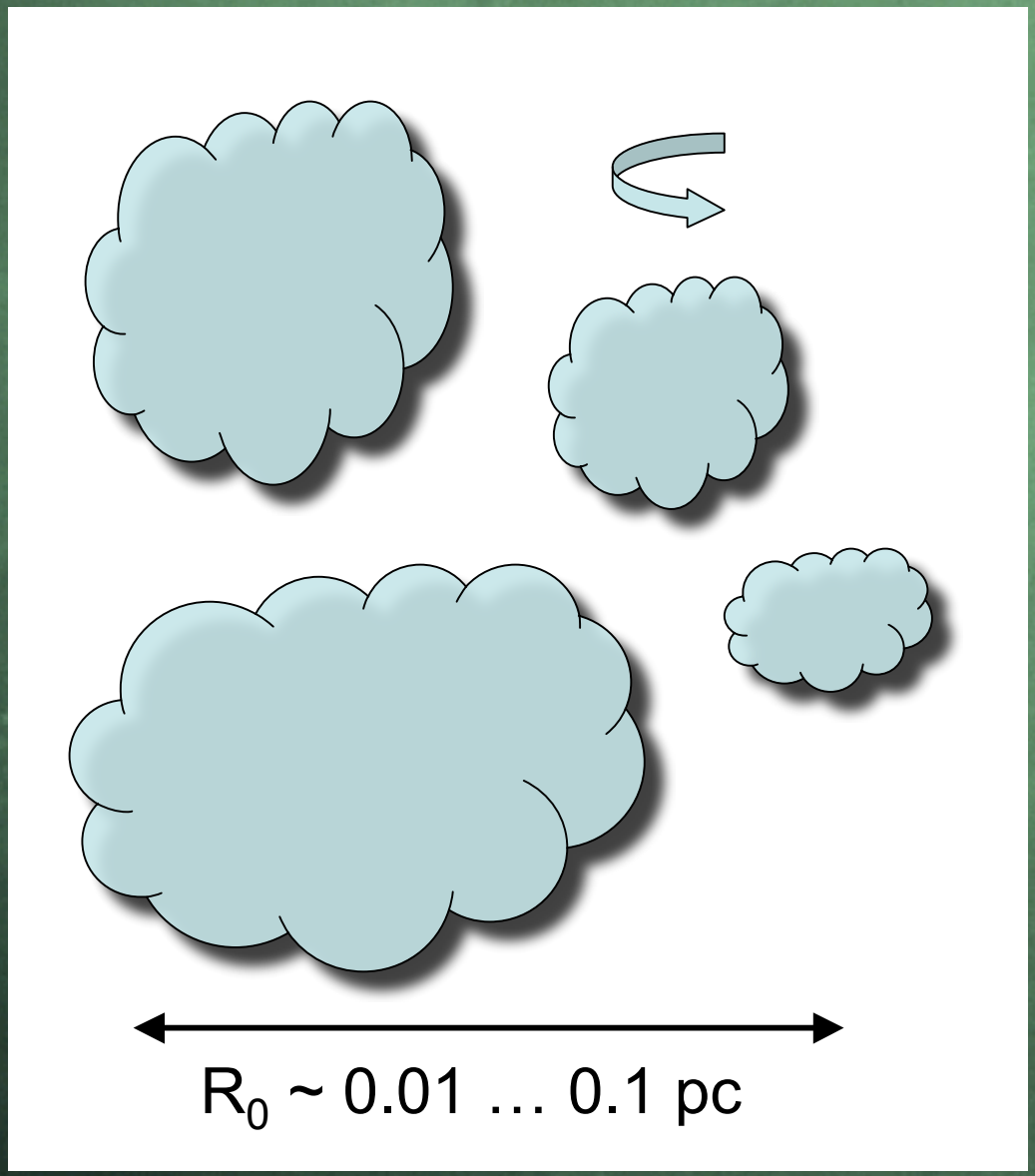
- VLA 7mm hierarchical triple
- aligned jets
- NS: coplanar
- NS: low e
- 3rd disk is misaligned

fragmentation...

NRAO (Dec 2006) PR: "Smoking Gun" for Multiple Star Formation

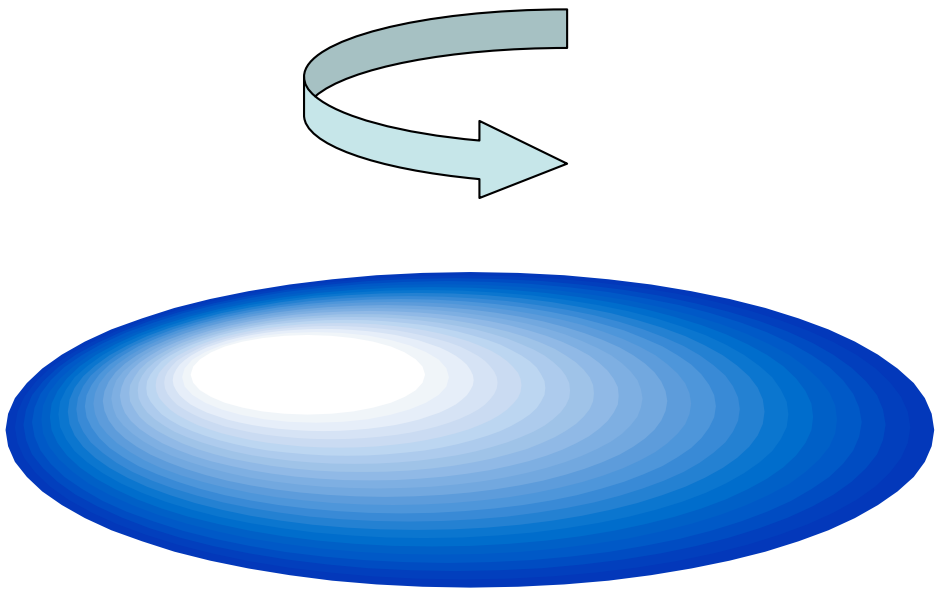


Pre-Stellar Cloud Cores



- M_0 ~ 0.5 - 5 M_{sol}
- $dN/dM_0 \sim M_0^{-\gamma}$
- $R_0 \sim M_0$
- T_0 ~ 10 … 30 K
- $\rho_0 \sim 10^{-18}$ g/cm^3
- grav. bound: $\alpha_0 + \beta_0 < 1/2$
- turbulent/magnetic support

Isothermal Homolgous Collapse



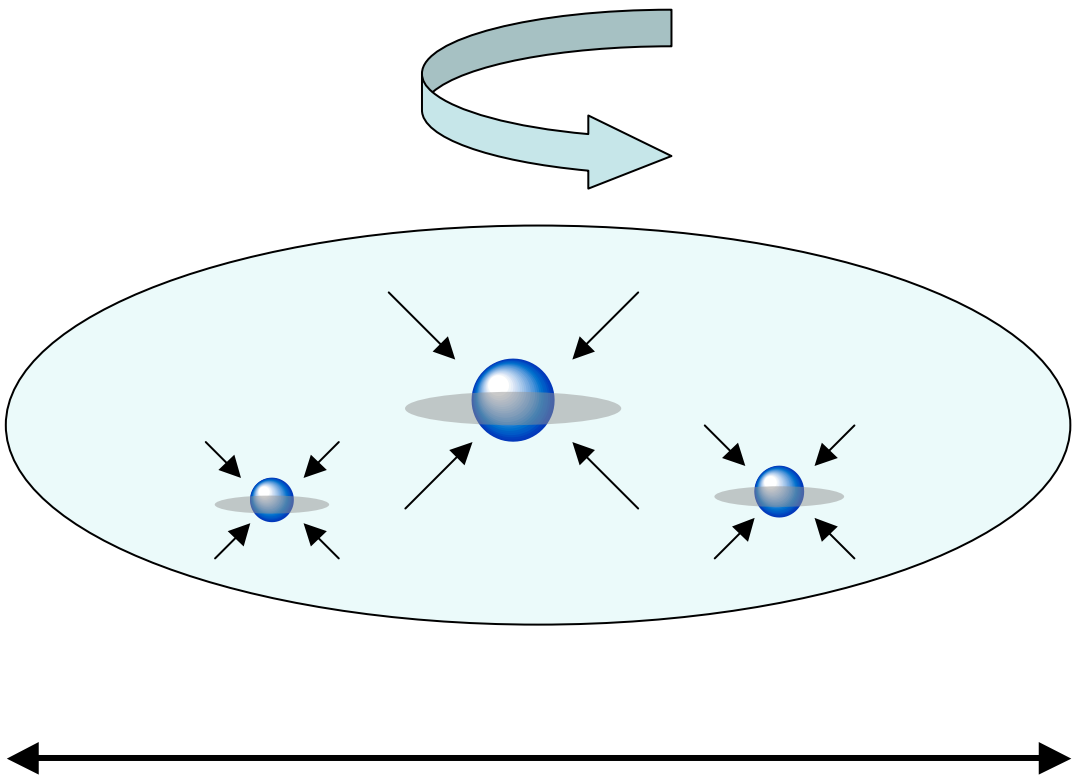
R_c ~ 100's A.U.

- $R_c \sim \beta_0 R_0$
- $M_c \sim M_0$
- $\tau_{ff} \sim 10^{4...5}$ yrs
- rotationally flattened "pseudodisk"
- $\rho_c \sim 10^{-13}$ g/cm^3

prone to fragmentation ?

- $\alpha_0\beta_0$ (e.g. $\alpha_0 * \beta_0 < 0.12$)
- initial perturbations
- $\beta > \beta_{crit} \sim 0.02$

Fragmentation & 2nd Collapse



Sterzik, Durisen & Zinnecker, 2003

- $T_{ff} \sim 10^{2...3}$ yrs
- $\rho \sim 10^{-5...0}$ g/cm^3
- "protostars": class 0
- non-hierarchical configurations

Fragmentation Scale

$\alpha_0 = 5kT_0R_0/2\mu GM_0$

$\beta_0 = R_0^3\Omega_0^2/3GM_0$

fragmentation condition: $\beta_0 > \beta_{crit} \sim 0.02$

isothermal collapse scale: $R_C \sim R_0 * \beta_0$

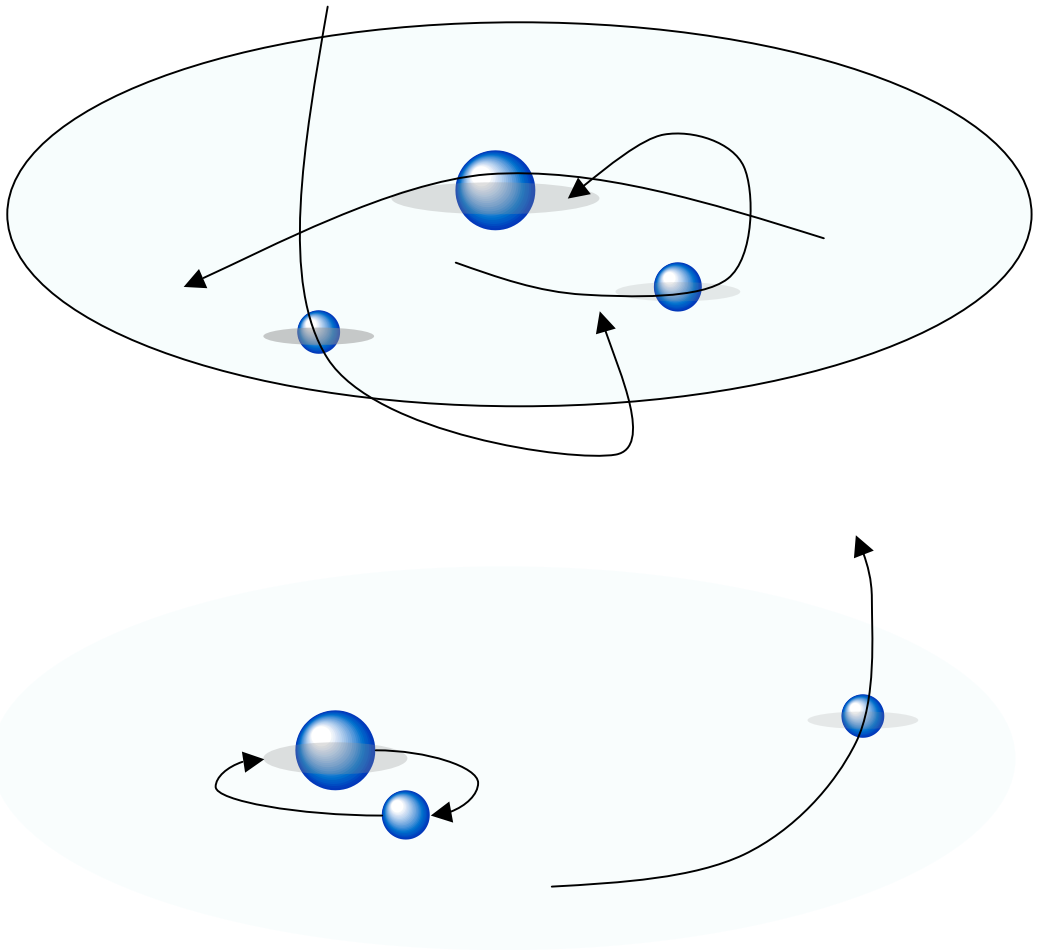
$R_C > 130AU\ (\alpha_0/0.5)\ (\beta_0/0.02)\ (M_0/M)\ (10K/T_0)$

$a \sim R_C \approx O(100\ A.U.)$

$a \sim M_0$

$a \sim 1/T_0$

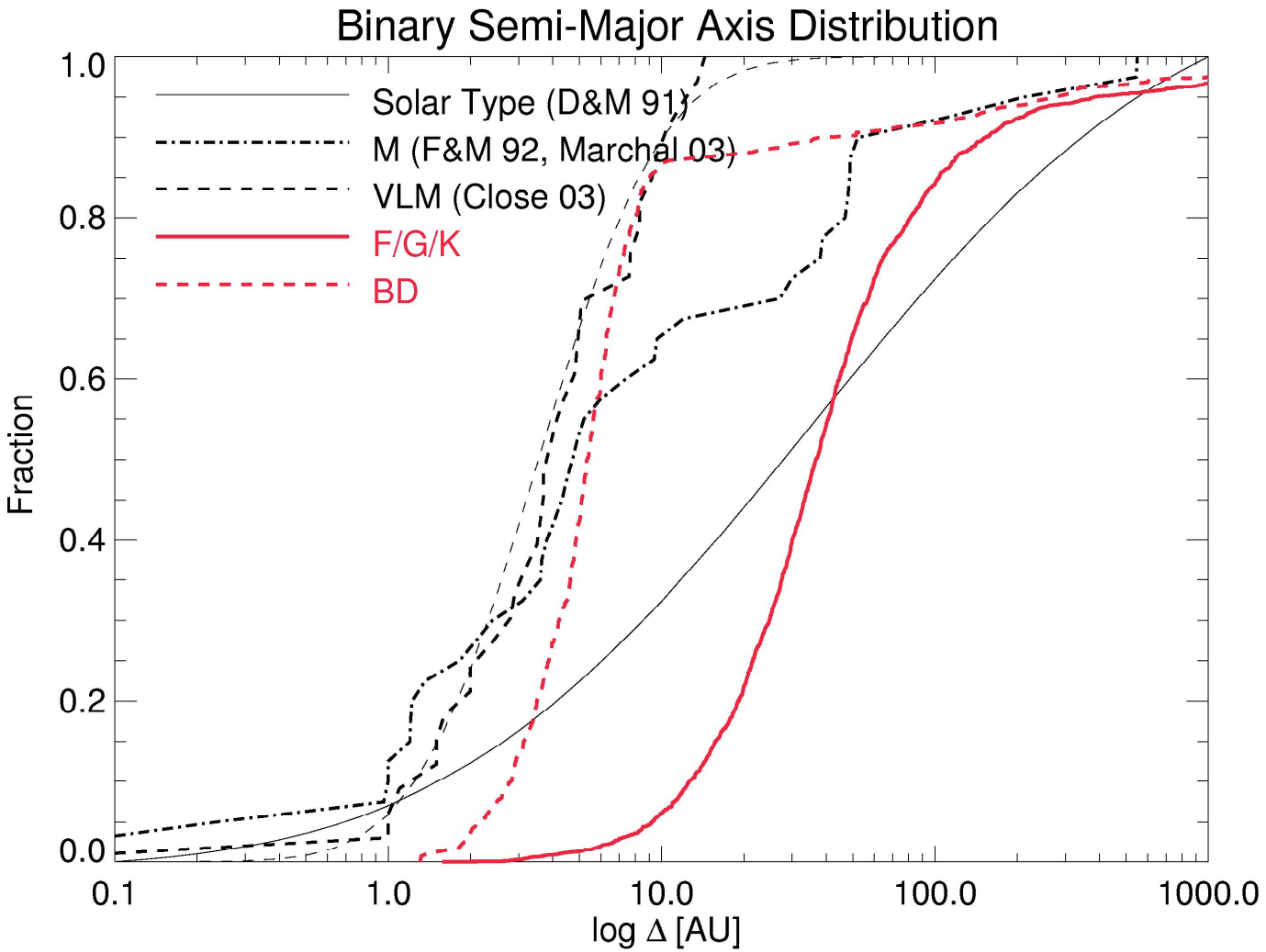
Dynamical Evolution



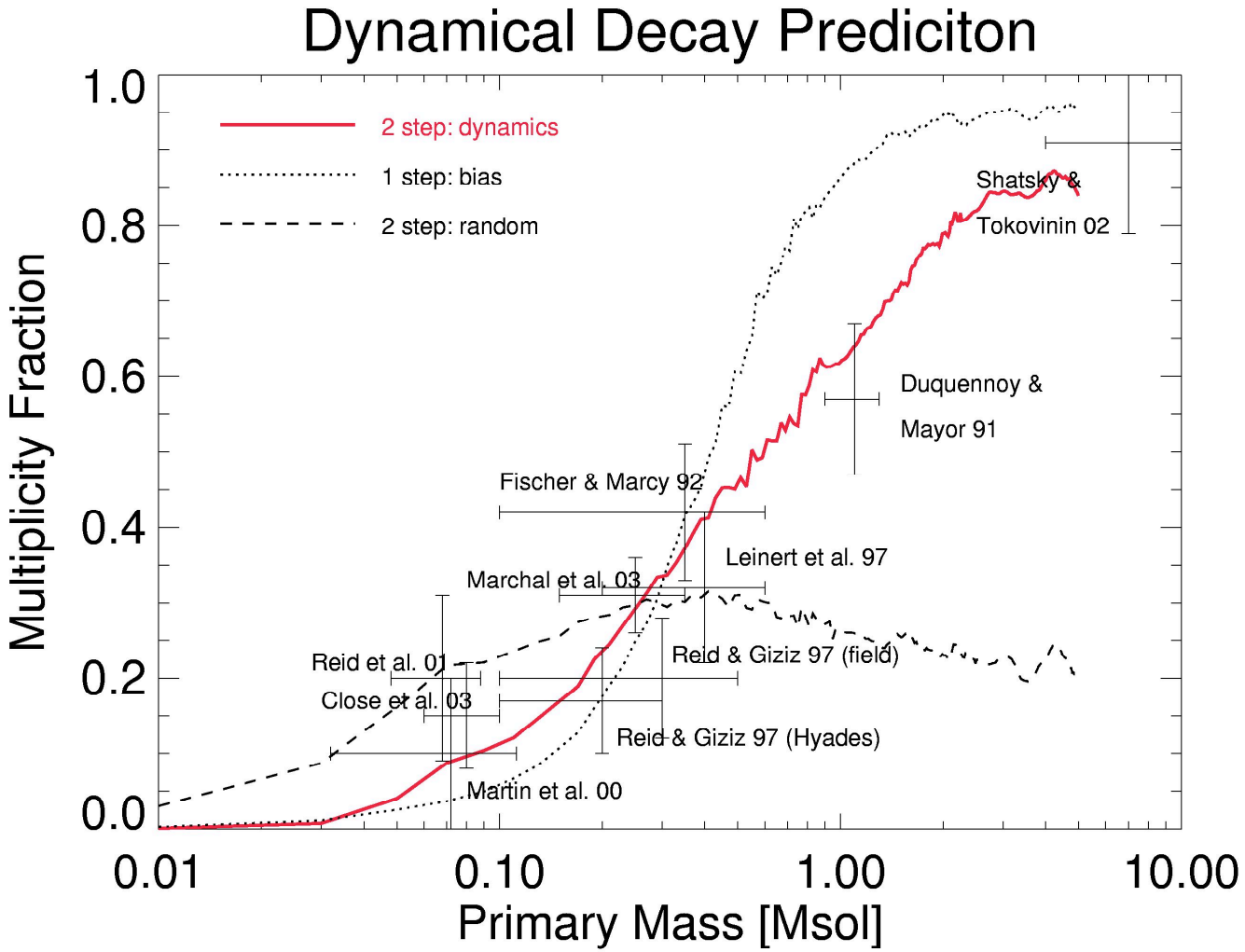
R_{bin} ~ 40 A.U.

- T_{dyn} ~ $10^{3...4}$ yrs
- chaotic dynamic
- system decay
- hierarchical configurations
- scale: R_{bin} ~ 0.1 * R
- broad distributions

Dynamical Evolution: a

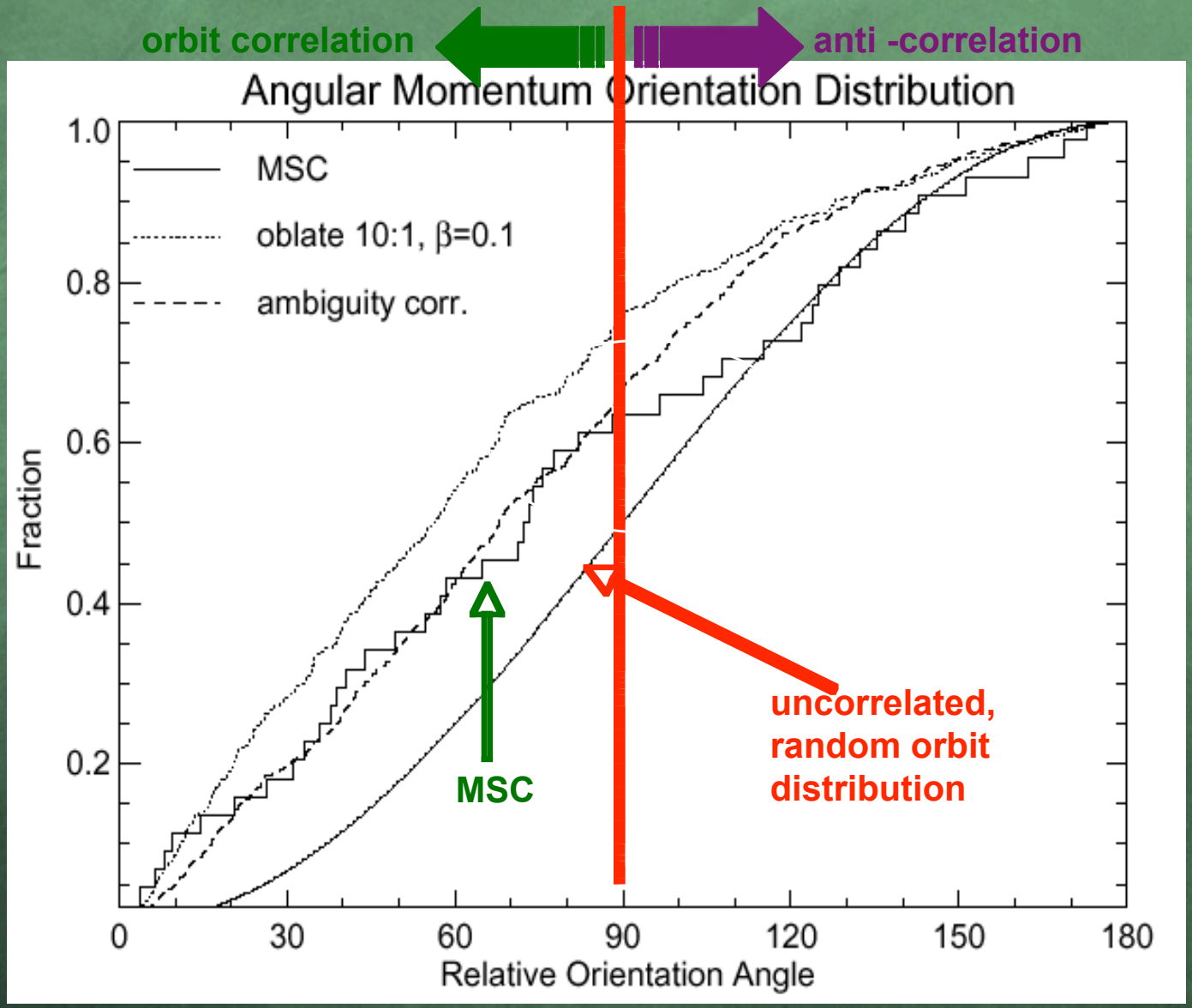


Dynamical Evolution: MF ver. M



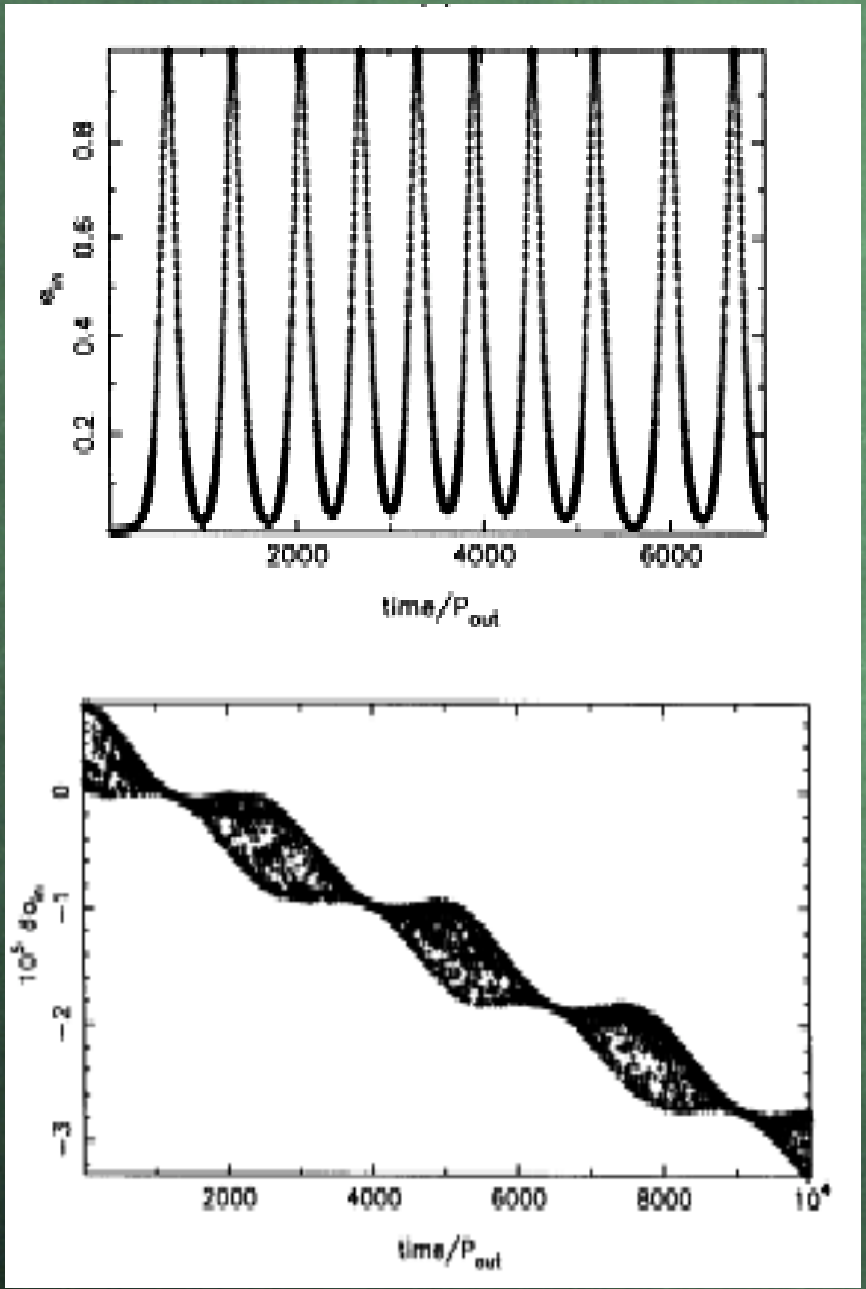
Sterzik & Durisen, 2003

Dynamical Evolution: Orbit Orientation



Sterzik & Tokovinin, 2002

Close Binary Formation



- dynamical decay produces a significant number of perpendicular orbits
- some of them likely generate Kozai-cycles (eccentricity pumping) and tidal friction (Kiseleva, Eggelton, Mikkola, 1998)
- inner orbits shrink, outer orbits circularize

Conclusions

- primordial multiples are observable
- scales 10-100's A.U.
- embedded SBs likely exist
- hierarchical systems frequent

- fragmentation after isothermal collapse
- gravitational few-body dynamics
- quantitative distribution functions