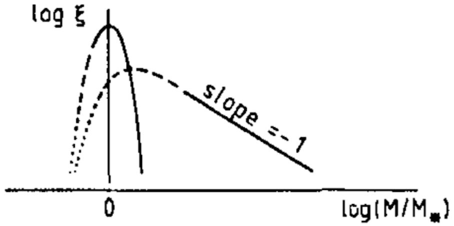
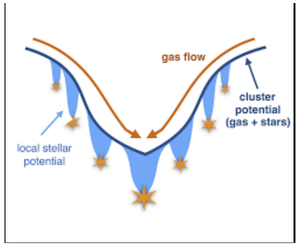
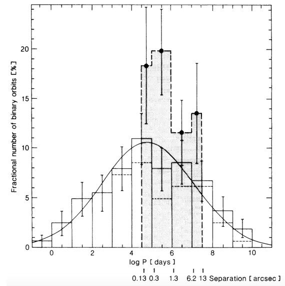


Zinnecker 1982
Zinnecker 1984

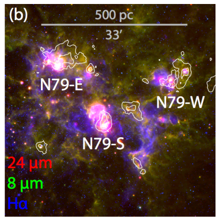


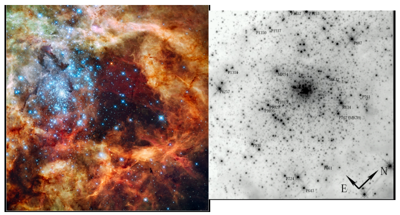
Bonnell, Bate & Zinnecker 1998; Bally & Zinnecker 2005

Leinert, Zinnecker et al 1993

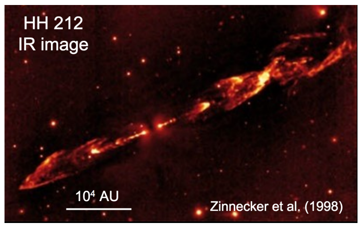


Ochsendorf, Zinnecker et al 2017

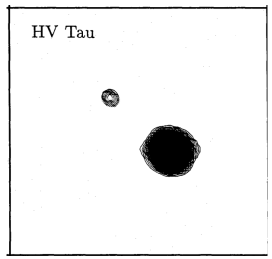




Andersen, Zinnecker et al 2009



Zinnecker et al 1998



Reipurth & Zinnecker 1993

PREDICTION OF THE PROTOSTELLAR MASS SPECTRUM IN THE ORION NEAR-INFRARED CLUSTER

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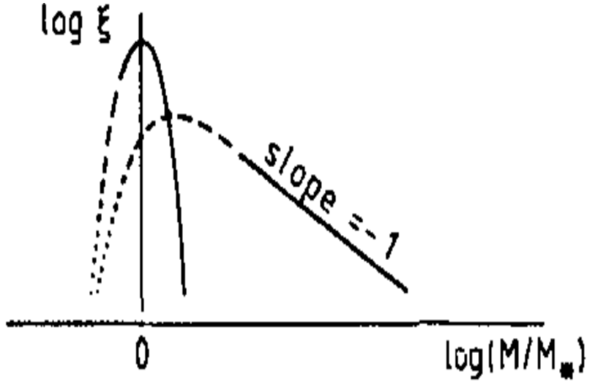
FIGURE 2. The evolution of the mass spectrum, $\zeta \equiv dN/d \log M$, of gravitating point masses for an accretion rate $\dot{M} = \alpha M^2$ (a narrow symmetric distribution evolves into a broad asymmetric distribution).



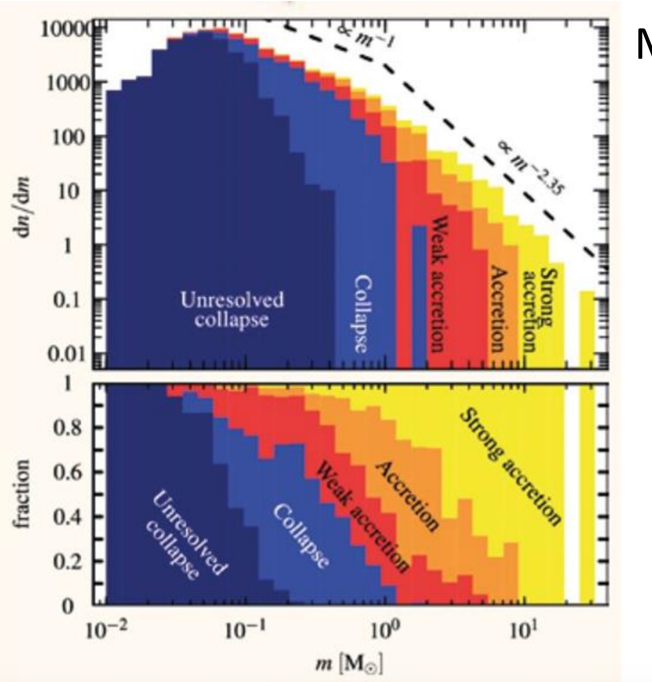
Cambridge University Exam. Q:

➔

10. A spherical inflow of gas onto a point mass M_0 undergoes a sonic transition at a radius $R_B = GM/2c_s^2$, where c_s is the sound speed of an isothermal medium of density ρ. Write down an expression for the accretion rate onto the object and hence derive an expression for $M(t)$, the mass of the object at time t, if it grows by accretion from an initial mass of $M(0) = M_0$.

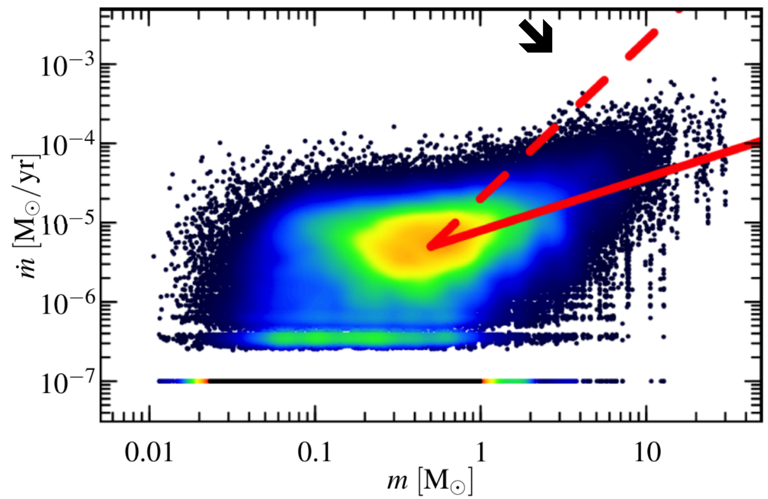
    A population of stars grows in this way from a range of initial M_0 values. Derive an an expression for dM/dM_0 at given time and express your answer in terms of M_0 and M. If the distribution of masses is initially flat over a small range of M_0, derive an expression for the form of the IMF that is expected following accretional growth and comment on your answer.

Simulations generate Salpeter like tail in regimes where stars acquire most of mass by accretion



Maschberger et al 2014

quadratic

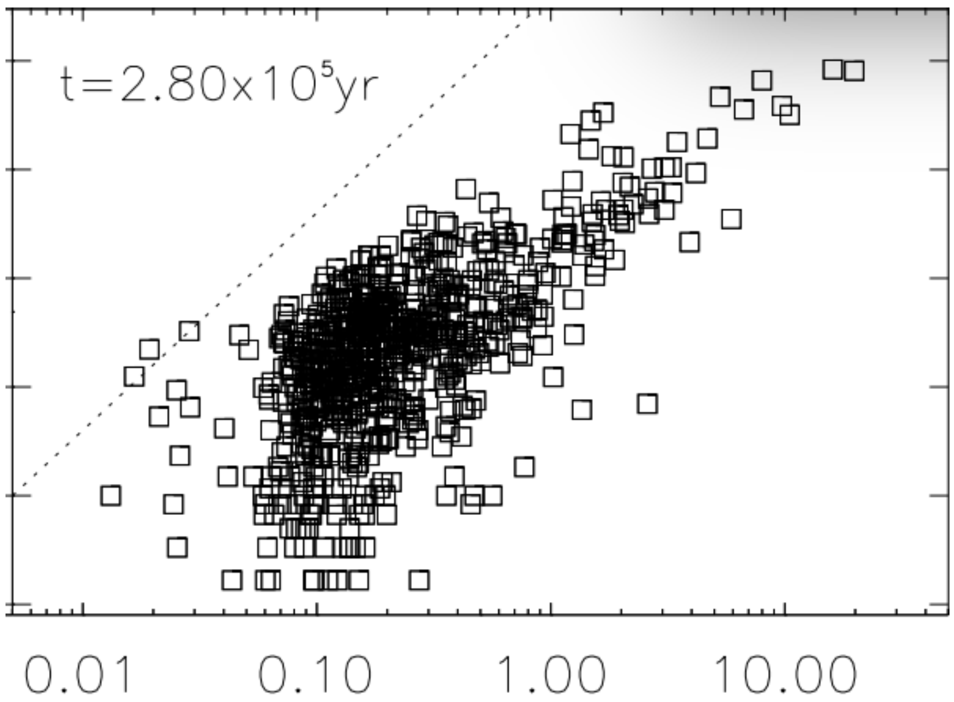


….yet apparently accretion rate does *not* scale quadratically with M_* in the simulations!

M14 argued for a complex combination of stochastic accretion and spread in initial masses and growth times

Back to simplicity?

Quadratic dependence



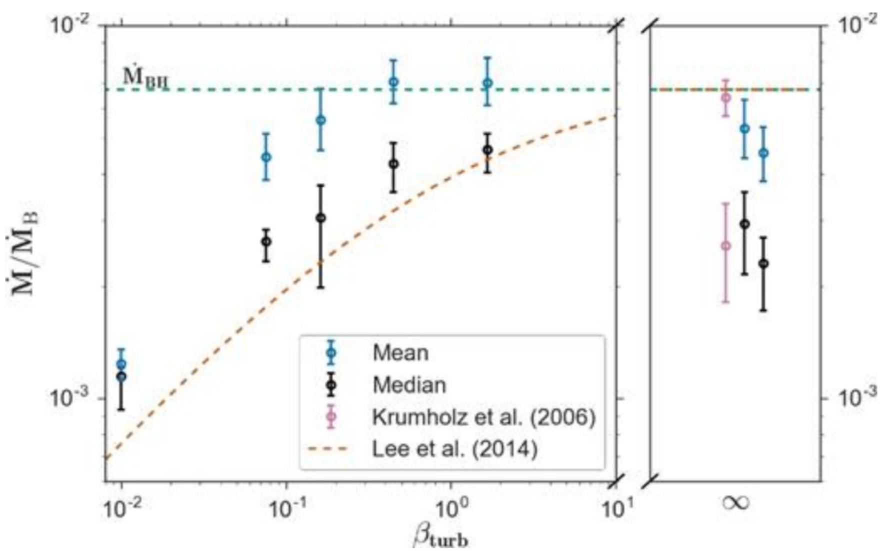
$\dot{M}$

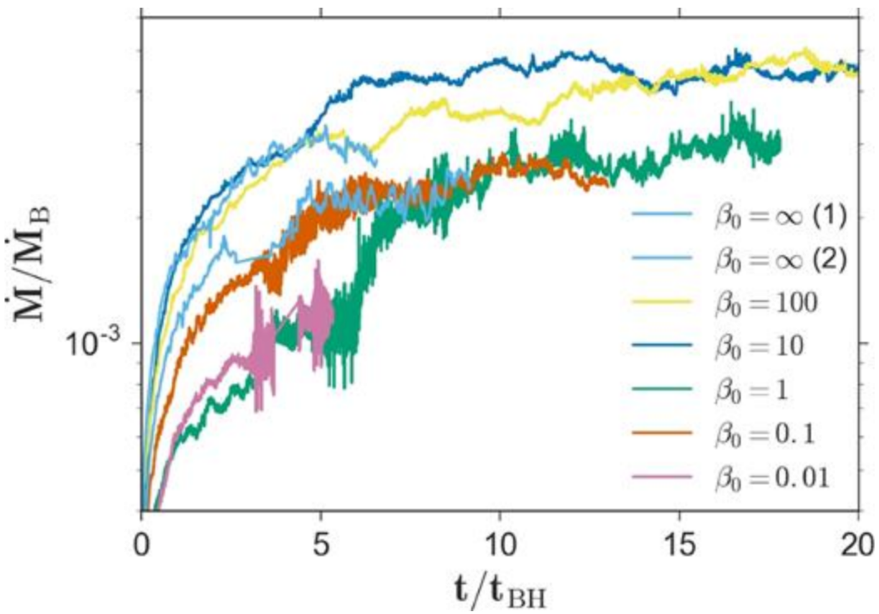
M

Ballesteros-Paredes et al 2016

What about turbulence and B fields?

- See e.g. Krumholz et al 2005, Lee et al 2014, Burleigh et al 2017 for idealised Bondi Hoyle experiments in turbulent magnetised media



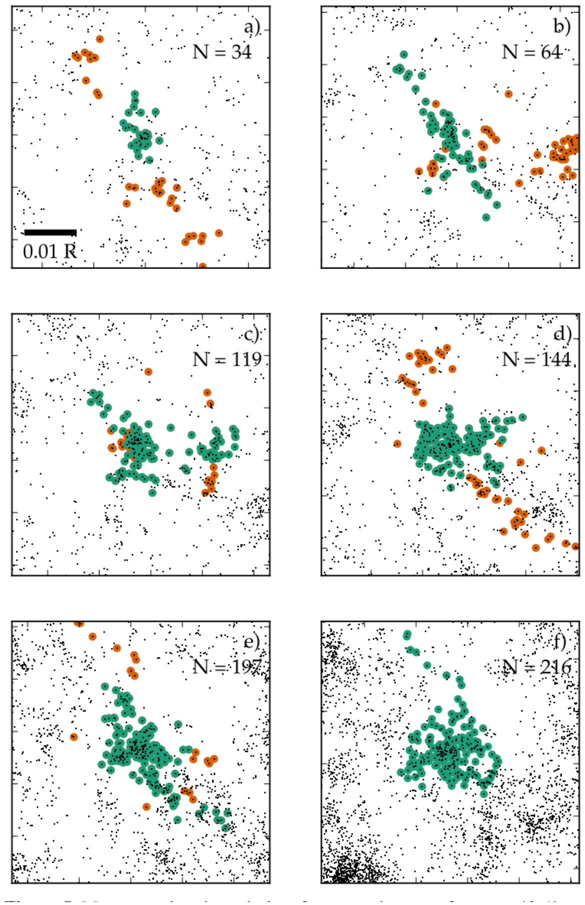


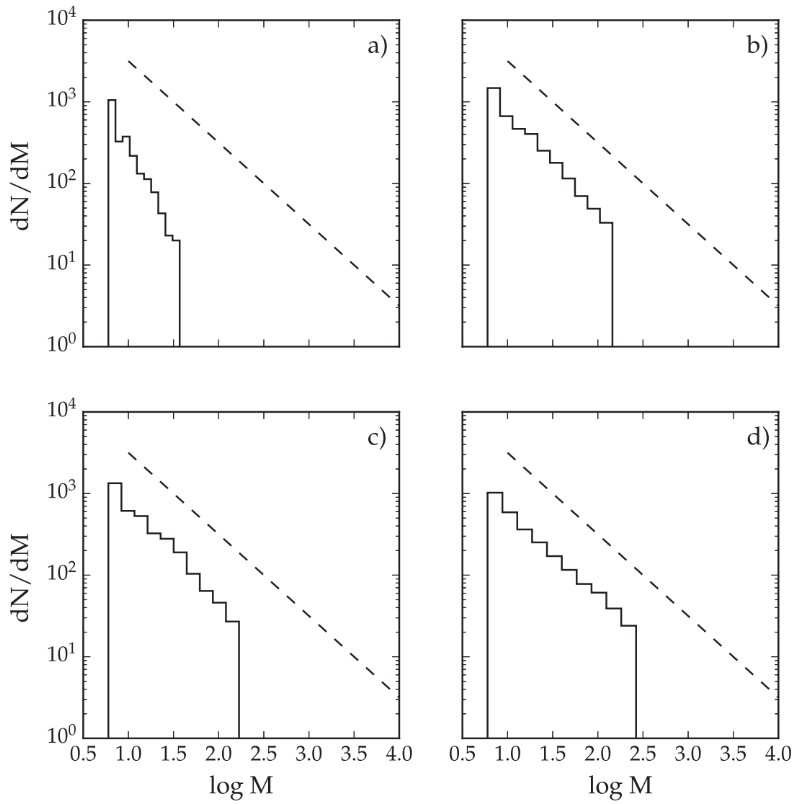
← increasing B field

Suppresses accretion cf pure Bondi Hoyle

Quadratic dependence on M preserved

Can the idea extend to star cluster formation?





See Kuznetsova, Hartmann & Burkert 2017 for simulations of sub-virial cluster formation

`What about the massive stars?’

Toward Understanding Massive Star Formation*

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0066-4146/07/0922-0481$20.00

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Key Words

accretion, circumstellar disks, HII regions, massive stars, protostars, star formation

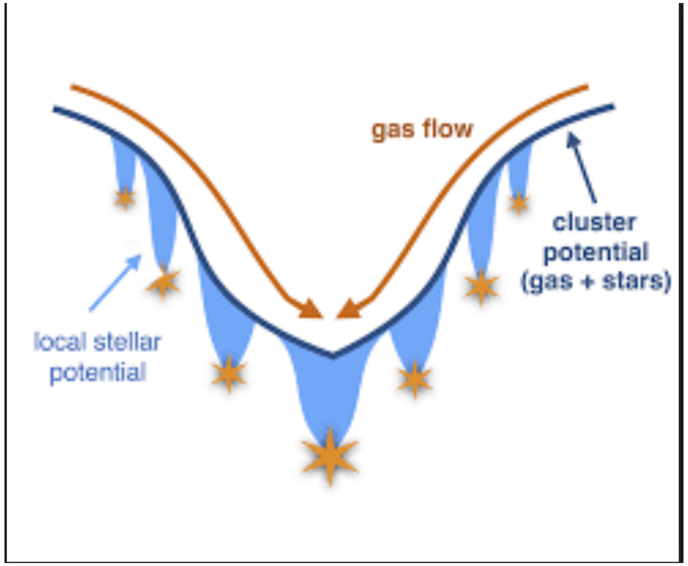
Abstract

Although fundamental for astrophysics, the processes that produce massive stars are not well understood. Large distances, high extinction, and short timescales of critical evolutionary phases make observations of these processes challenging. Lacking good observational guidance, theoretical models have remained controversial. This review offers a basic description of the collapse of a massive molecular core and a critical discussion of the three competing concepts of massive star formation:

- monolithic collapse in isolated cores
- competitive accretion in a protocluster environment
- stellar collisions and mergers in very dense systems

We also review the observed outflows, multiplicity, and clustering properties of massive stars, the upper initial mass function and the upper mass limit. We conclude that high-mass star formation is not merely a scaled-up version of low-mass star formation with higher accretion rates, but partly a mechanism of its own, primarily owing to the role of stellar mass and radiation pressure in controlling the dynamics.

Formation of massive stars by stellar collisions following accretion driven contraction of cluster cores
Bonnell, Bate & Zinnecker 1998



T_M > T_2r => max. density set by stellar dynamical effects

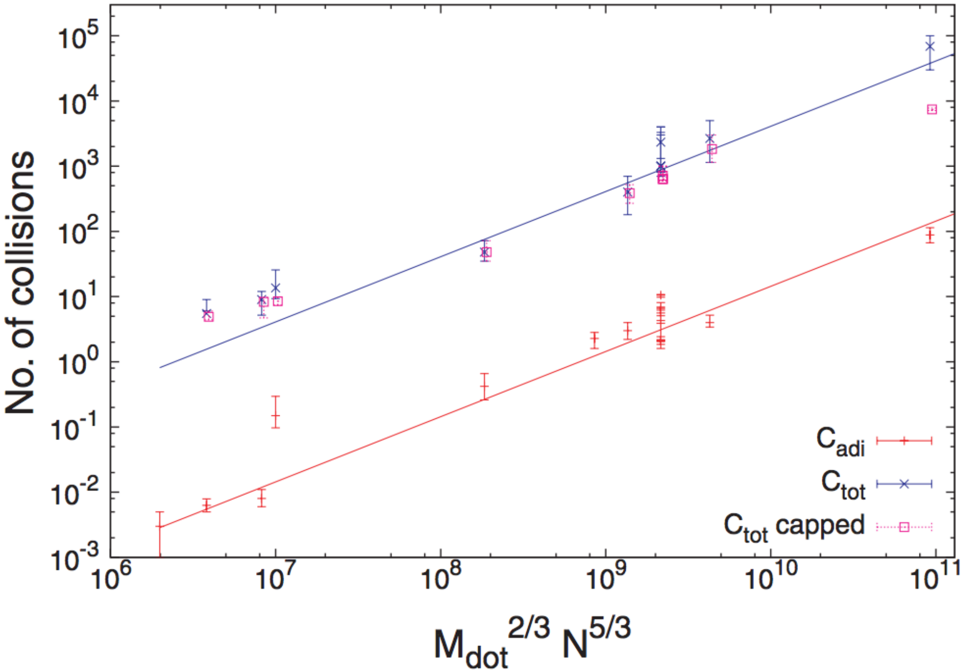
T_M < T_dyn => radius shrinks by factor ~ 2

T_dyn < T_M => contracts adiabatically R ~ M^-3, ρ ~ M^10 !

- => expect accretion induced collisions to be important at high N…

No. collisions ~ $M_{dot}^{2/3}\ N^{5/3}$ Clarke & Bonnell 2008

Where are accretion induced core collapse + stellar collisions likely to be important?



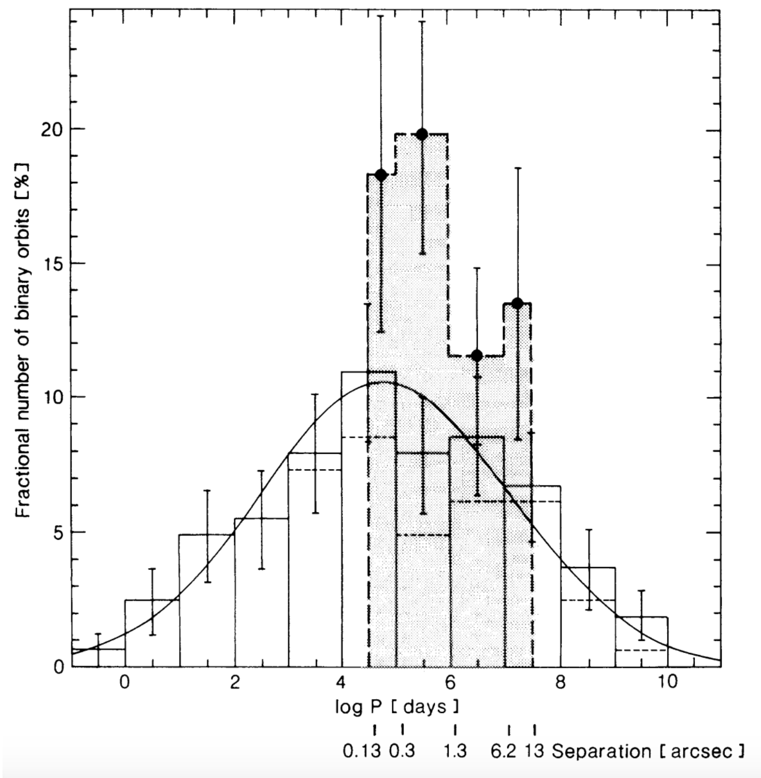
Monte Carlo dynamical modeling:
Davis et al 2010

•

- Arches ? Not in past… Baumgardt & Klessen 2011; Moeckel & Clarke 2011
- Primordial clusters: promising route to IMBHs

Reinoso et al 2018; Boekholt et al 2018

`What about the binaries?'



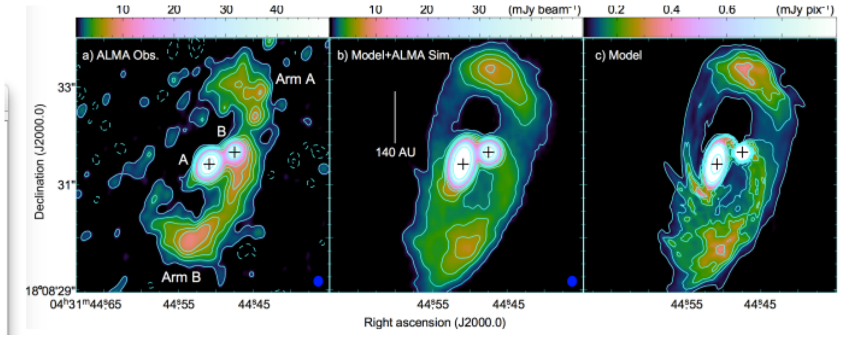
Leinert , Zinnecker et al 1993

- Taurus binary data established central role for multiplicity in star formation

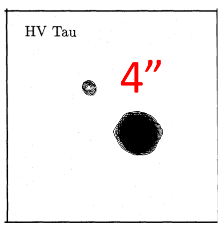
Now is a golden time for young binary characterisation

- The ALMA opportunity: interest in circumbinary disc structure re-ignited by circumbinary planets

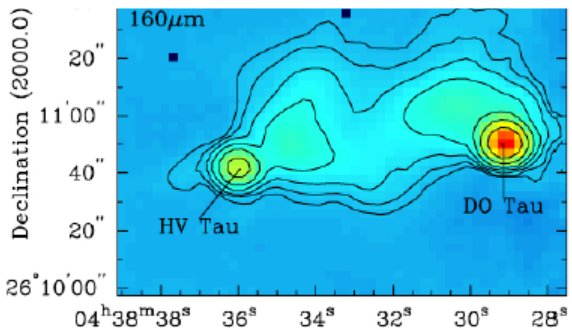
Takahuwa et al 2017



- The GAIA opportunity: kinematic substructure in star forming regions



Reipurth & Zinnecker 1993

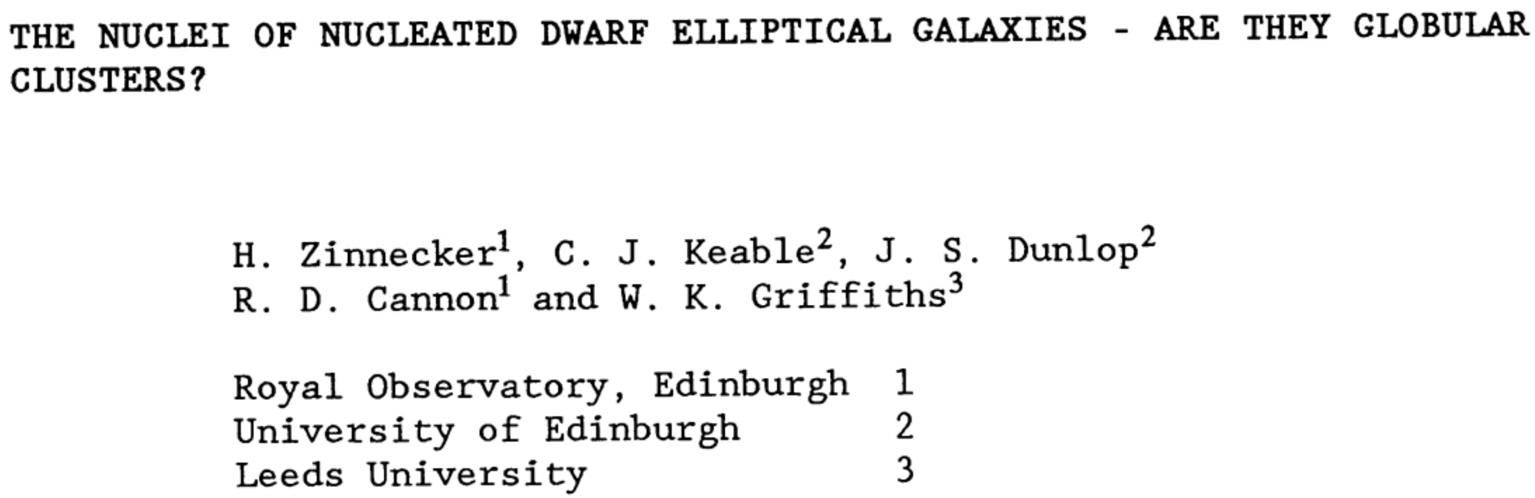


Howard et al 2013

Kinematics and extended structure can be modeled as disintegrating quadruple: *Winter et al 2018*

There is much, much more..

Including…


THE NUCLEI OF NUCLEATED DWARF ELLIPTICAL GALAXIES - ARE THEY GLOBULAR CLUSTERS?

H. Zinnecker[1], C. J. Keable[2], J. S. Dunlop[2]
R. D. Cannon[1] and W. K. Griffiths[3]

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FROM STARS TO MASSIVE STARS
Theory
Observation