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Research Note

How do binary separations depend on cloud initial conditions?

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Abstract. We explore the consequences of a star formation scenario in which the isothermal collapse of a rotating, star-forming core is followed by prompt fragmentation into a cluster containing a small number ($N \lesssim 10$) of protostars and/or substellar objects. The subsequent evolution of the cluster is assumed to be dominated by dynamical interactions among cluster members, and this establishes the final properties of the binary and multiple systems. The characteristic scale of the fragmenting core is determined by the cloud initial conditions (such as temperature, angular momentum and mass), and we are able to relate the separation distributions of the final binary population to the properties of the star-forming core. Because the fragmentation scale immediately after the isothermal collapse is typically a factor of 3−10 too large, we conjecture that fragmentation into small clusters followed by dynamical evolution is required to account for the observed binary separation distributions. Differences in the environmental properties of the cores are expected to imprint differences on the characteristic dimensions of the binary systems they form. Recent observations of hierarchical systems, differences in binary characteristics among star forming regions and systematic variations in binary properties with primary mass can be interpreted in the context of this scenario.

Key words. stars: binaries: general – stars: binaries: close – stars: binaries: visual – stars: formation – stars: low-mass, brown dwarfs

1. Introduction

A comprehensive theory of binary star formation is still lacking, including explanations for the observed statistical properties of binary and multiple systems – such as multiplicity fractions, periods, eccentricities and mass ratios. For instance, the distribution of binary separations, at least for solar-type stars (Duquennoy & Mayor 1991), is known to be very broad, almost flat in logarithmic separation intervals, with a median separation of about 40 AU. Lower-mass binaries apparently prefer even smaller separations and narrower separation distribution functions (Close et al. 2003; Sterzik & Durisen 2003b).

The most promising process for the formation of wide binaries is fragmentation during the collapse of a rotating cloud. Modern collapse calculations having initial conditions appropriate to dense molecular cores tend to agree in this main conclusion (Boss 1998; Bodenheimer & Burkert 2001; Bonnell 2001; Matsumoto & Hanawa 2003; Nakamura & Li 2003). More detailed predictions, however, depend critically on the choice of the initial conditions, such as the density and rotation profiles, the geometry of the cloud, its temperature, and the properties of any initial perturbations in density, shape, and velocity. The typical separation scale of binaries produced via this mechanism is approximately one order of magnitude too large, and so additional processes must be invoked to reduce the final characteristic scale of the binaries (Boss 1992).

In this Research Note, we explore the consequences of a star formation scenario in which isothermal collapse of a rotating, star forming core is followed by fragmentation and subsequent dynamical evolution of a small cluster ($N \lesssim 10$) of protostars. Our main conclusions are based on scaling arguments implicit in the literature. In a previous work (Durisen & Sterzik 1994), we have shown that the parameter space available for fragmentation and hence binary formation is expected to vary with the cloud temperature at which star formation occurs. A similar argument can be made to infer that the specific angular momentum required for fragmentation and therefore the mean separations in forming binary systems are expected to be lower in higher temperature environments.

However, fragmentation into a binary after the first collapse can probably not explain the characteristic separation scales observed. We therefore conjecture that fragmentation typically leads to protostellar systems having more then two components. These components will then dynamically evolve by gravitational interactions (Sterzik & Durisen 1998), and/or orbital decay (Bate et al. 2002) and the final stable end-products

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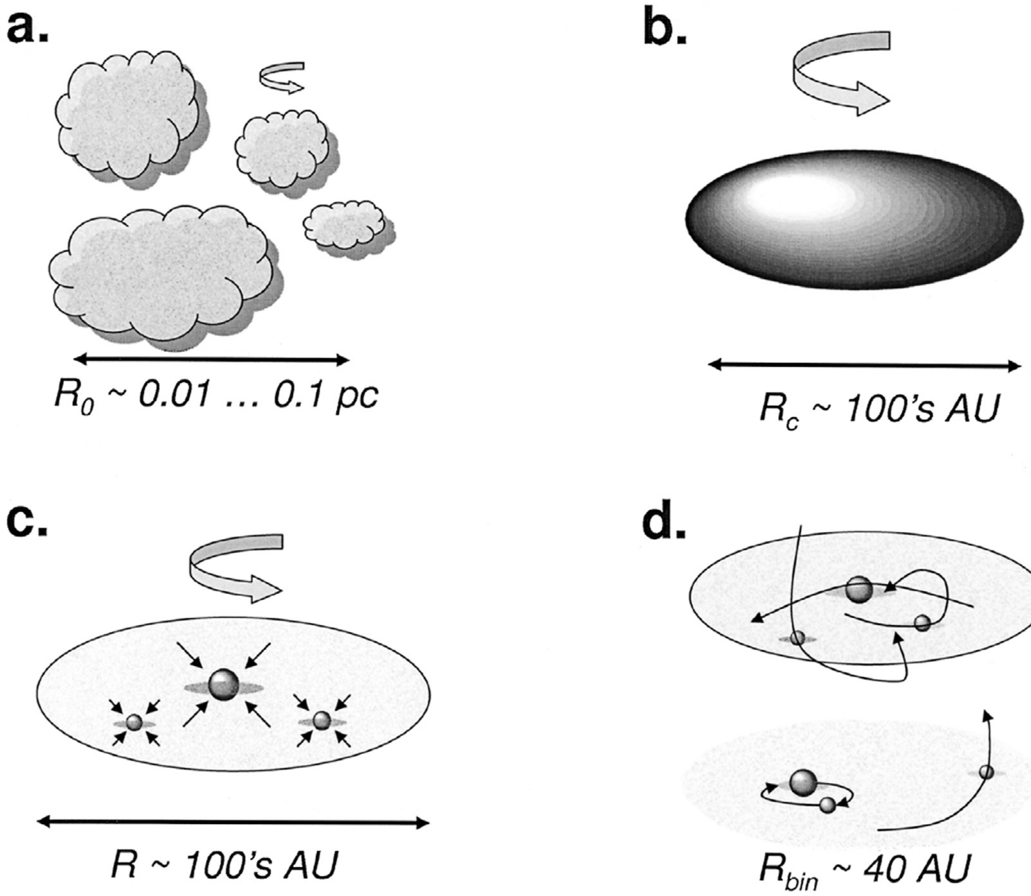

Fig. 1. Evolutionary stages from molecular cloud cores toward final binary and multiple stellar systems. Typical system scales are indicated. **a)** Molecular cloud cores. **b)** Isothermal collapse of one core. **c)** Fragmentation and accretion to form protostars. **d)** Dynamical evolution of a small multiple stellar system. Stages **b)** and **c)** and stages **c)** and **d)** may overlap to some extent.

represent, on a statistical basis, the dominant component of the observed binary and multiple system population.

With this research note we present a coherent framework that relates these different physical mechanisms during the various stages of star formation and leads to a qualitative derivation of the characteristic scale for the resulting binary and multiple systems. We also speculate on the evolution of inner binaries in hierarchical systems due to the combined action of the Kozai effect and tidal friction as a way to populate the short-period part of the binary distribution. In this "unified theory of binary formation", dynamical interactions within multiple systems are an essential ingredient to explain the whole range of observed binary separations.

2. Evolution of fragmenting clouds

In the following we will use Fig. 1 as a schematic sketch of the evolutionary stages from pre-collapse cloud cores to multiple and binary stellar systems.

2.1. Stage a: Pre-collapse cloud cores

Pre-collapse cloud cores (stage **a**) are characterized by observations that reveal typical scales of the order of $R_0 \approx 0.01{-}0.1$ pc, densities of $\varrho_0 \approx 10^{-18}$ g/cm^3, and temperatures $T_0 \approx 10$ K (in the following, the index 0 denotes initial conditions). Star-less cores typically have inner density profiles that are moderately increasing ($\varrho(r) \propto r^{-1}$), or even flattish, as observed in isolated Bok globules (Alves et al. 2001). Pre-collapse cores span a range of masses similar to those of stellar masses, and their mass function is reminiscent of a stellar initial mass function with similar power-law exponents. A linear mass versus size relation is observed (Motte et al. 2001)

$$M_0 \propto R_0. \tag{1}$$

The cores show a trend for slight differential rotation.

Using expressions strictly valid only for uniform spherical cloud cores, the typical ratios of the *rotational to gravitational energy* $\beta = R^3\Omega^2/3GM$ are around $\beta_0 \approx 0.02$ (Goodman et al. 1993). The *thermal to gravitational energy* $\alpha = 5kTR/2\mu GM$ is likely to be such that $\alpha_0 + \beta_0 < 1/2$, implying that cores are gravitationally unstable. Probably magnetic fields and/or supersonic turbulence contribute to the support of cores against immediate gravitational collapse. If so, then we expect $\alpha_0 \ll 1$. For a uniform spherical cloud, the number of Jeans masses in the cloud is roughly $1/2\alpha$.

2.2. Stage b: Scaling properties during isothermal collapse

Given the observed relatively flattish density profiles, and their tendency to contain several Jeans masses, a nearly homologous isothermal collapse (see, e.g., Tohline 2002) might represent an appropriate description of the first collapse phase (stage **b**). Then, conservation of angular momentum evolves the object into an oblate, compact, fast rotating spheroid. Essentially all the cloud mass reaches the final flattened configuration after one free-fall time of $\tau_{\rm ff} \approx 10^5$ yrs (Nakano 1998; Boss 2002), almost simultaneously, and densities at the end of the isothermal phase reach $\varrho_{\rm c} \approx 10^{-13}$ g/cm^3.

Analytic solutions for the collapse of rotating uniform spheroids have been derived in the classic work of Tohline (1981). He relates the initial cloud geometry and virial status to a final equilibrium state by relatively simple analytic formulae. In particular, the relationship of the collapsed core radius $R_{\rm c}$ to the initial cloud radius R_0 reduces to

$$R_{\rm c}/R_0 \approx (4/\pi) \cdot \beta_0 \qquad (2)$$

for the case of an initial sphere. With typical values of $\beta_0 \approx 0.02$, the ratio of the initial cloud scale to stage **b** scale should be typically ~40, as shown in Fig. 1. Equation (1) applies to the case where collapse is stopped by rotation at a high value of β before the cloud goes into the adiabatic phase of collapse.

On these grounds we conclude that dense, collapsed, "prestellar" cores at the end of the isothermal phase will have – before fragmentation (Tohline 2002) – a typical radial extent of 100's AU, if they originate from typical pre-collapse core sizes having $\beta_0 \approx 0.02$. If β_0 is independent of M_0, then we find that the size of the collapsed structure is linearly related to its mass by combining Eqs. (1) and (2). Although Eq. (2) only applies precisely to an idealized case, it will always be generally true that, by the time the bulk of the cloud has collapsed, the system of gas and/or fragments will have a size of the order given by Eq. (2) as long as the system mass and angular momentum are approximately conserved. So our scaling arguments are not strictly dependent upon the collapse being nearly homologous.

2.3. Stage c: Fragmentation

When, and under what conditions, does the collapsed core then fragment? The classical fragmentation criterion following Tohline (1981)

$$\alpha_0\beta_0 \leq 0.12 \qquad (3)$$

applies, if at all (Bodenheimer & Burkert 2001), only to idealized configurations. Modern 3D-hydrodynamical collapse calculations with enough numerical resolution to resolve the Jeans length find that no such simple criterion exists to predict the outcome of specific initial configurations in detail (Bodenheimer & Burkert 2001; Bonnell 2001; Tohline 2002). For example, Tsuribe & Inutsuka (1999) find that fragmentation is rather independent of β_0, as long as α_0 is sufficiently small, meaning that a roughly homologous collapse is likely to fragment, both with uniform density (Bate & Burkert 1997; Truelove et al. 1998) and with Gaussian initial density profiles (Boss 1998; Burkert & Bodenheimer 1996). This low-α-driven fragmentation occurs basically because the cloud contains many Jeans masses. On the other hand, rotationally-driven fragmentation occurs when a core collapse achieves a high value of β during isothermal collapse, as explained in the next subsection.

The *number of fragments* is even harder to predict, because collapse calculations usually cannot follow the orbital and accretion evolution of the fragments long enough to unambiguously infer their survival as individual entities. No a priori argument can be made that determines the distribution of N's in the progenitor cluster, except that one might expect an $\alpha \ll 1$ collapse to produce a number of fragments on the order of the number of Jeans masses in the cloud. There seems to be consensus that the strength and nature of initial perturbations in shape (prolate or oblate), density structure ($\cos m\phi$, turbulent, or random), or velocity field, together with the degree of flatness at the end of the isothermal phase, determine the degree of sub-fragmentation (Tsuribe & Inutsuka 1999).

Albeit with poor statistics, binary and multiple embedded protostars have actually been observed. This strengthens the notion that multiplicity begins at birth. The typical separation range is of the order of a few 100's to 1000's AU (Looney 2000; Launhardt et al. 2000). This roughly agrees with the collapse scale expected from Eq. (2).

2.4. Stages a to c: Temperature dependence

If fragmentation occurs at all, one can immediately infer a number of important scaling properties.

Rotationally-driven fragmentation occurs when a cloud achieves a high value of β during isothermal collapse, before the onset of adiabatic evolution. As shown numerically for clouds with masses of one to a few $M_\odot$, the condition for rotational fragmentation is (Boss 1993)

$$\beta_0 \geq \beta_{\rm crit} \approx 0.02. \qquad (4)$$

This result is easy to understand. Few $M_\odot$ clouds will collapse over about 10^5 orders of magnitude in density before reaching the optically thick conditions which usher in the adiabatic phase (see Fig. 2 of Tohline 2002). Such a compression factor corresponds to a radial shrinkage by a factor $10^{5/3} \sim 50$. Because β during collapse scales inversely as R (Tohline 2002) and because rotationally-driven fragmentation requires that β become ~1 during collapse prior to the onset of adiabaticity, we expect $\beta_{\rm crit} \approx 0.02$.

Durisen & Sterzik (1994) pointed out one consequence of Eq. (4), namely that the amount of parameter space available for rotationally-driven cloud fragmentation increases as cloud temperature decreases. This is a possible explanation for observing different binary fractions in different star forming regions. A simple extension of their argument, which they did not point out, is that the typical spatial separation of the multiple systems produced by fragmentation also depends on the temperature of the star forming region. To see this, we can combine Eqs. (2) and (4) to get

$$R_c \geq 130\ \mathrm{AU} \cdot \left(\frac{\alpha_0}{0.5}\right)\left(\frac{\beta_{\mathrm{crit}}}{0.02}\right)\left(\frac{M_0}{M_\odot}\right)\left(\frac{10\ \mathrm{K}}{T_0}\right), \quad (5)$$

which is equivalent to Eq. (3) of Durisen & Sterzik (1994). Note that, for the same scalings,

$$R_0 = 0.025\ \mathrm{pc} \cdot \left(\frac{\alpha_0}{0.5}\right)\left(\frac{M_0}{M_\odot}\right)\left(\frac{10\ \mathrm{K}}{T_0}\right). \quad (6)$$

Similarly, Eq. (3) leads to a crude upper limit on the expected scale of separations

$$R_c \leq 1500\ \mathrm{AU} \cdot \left(\frac{M_0}{M_\odot}\right)\left(\frac{10\ \mathrm{K}}{T_0}\right). \quad (7)$$

Recall, however, that Eq. (3) may only have limited applicability.

Equations (5) and (7) bracket a probable range of scales expected for fragmentation after isothermal collapse. They reflect the fact that – all else being equal – higher temperature cores reach their critical specific angular momentum for fragmentation earlier then lower temperature cores. We speculate that this could be the reason why Brandner & Köhler (1998) find differences in the separation distributions for weak-line T-Tauri stars in two regions of Upper Scorpius. Their distribution is tweaked towards larger separations in UpperSco B, a region solely populated by low-mass stars, relative to UpperSco A, where more massive stars are present and potentially heat the environment, including the lower-mass pre-collapse cores.

For any individual cloud which follows a rotationally-driven fragmentation, Eq. (2) gives the scaling from initial cloud dimensions to scale of the resultant binary or multiple system. In terms of α_0, β_0, M_0, and T_0, Eq. (2) becomes

$$a_{\mathrm{bin}} \approx R_c \approx 130\ \mathrm{AU} \cdot \left(\frac{\alpha_0}{0.5}\right)\left(\frac{\beta_0}{0.02}\right)\left(\frac{M_0}{M_\odot}\right)\left(\frac{10\ \mathrm{K}}{T_0}\right), \quad (8)$$

where a_{bin} is the semi-major axis of any binary resulting from the fragmentation. There is a significant formal difference between Eq. (8) and Eq. (5) in that β_0 is the initial condition for a particular cloud, while β_{crit} is a critical β-value which might itself depend on M_0 and T_0 through its dependence on the transition from isothermal to adiabatic conditions.

Equation (8) shows that characteristic lengths, i.e., separations, should vary linearly with system mass – as expected from isothermal scaling laws. We discuss the implications in more detail below. The superficial similarity of Eqs. (5) and (8) lies in the numerical coincidence that typical cloud β_0's and the value of β_{crit} are both about 0.02. This suggests that rotationally-driven fragmentation occurs fairly often but is not the only mode of fragmentation.

Notice that the characteristic (median) separations observed for nearby solar-type stars ($\approx$40 AU) are *a factor ~3–10 times less* then inferred from the isothermal scaling laws as expressed in Eqs. (5), (7), and (8). We conclude that separations of binaries and multiples that form directly as the outcome of an isothermal fragmentation process will have larger separations than observed on the main sequence. Additional processes must then be involved that reduce the characteristic scale.

Let us also point out that we do not consider Eq. (8) to be an exact mapping. As argued by Larson (2002), star formation in general and fragmentation in particular are likely to be a highly chaotic processes which are best treated in a statistical way. All that is required for our arguments to be valid is that Eq. (8) is a relation followed by the modal or most typical cloud collapse and fragmentation. Given that the observed separation distribution of binaries on the main sequence is very broad, one hopes that the distribution of separations about this mode resulting from collapse and fragmentation is also actually quite broad.

2.5. Stage d: Dynamical Interactions

As a working hypothesis, we will assume that the collapse proceeds into the adiabatic phase with a few ($N \lesssim 10$) fragments that will survive independently and form protostars. The contraction time scale is expected to be very rapid during this phase. Due to the pre-compression during isothermal collapse, the free-fall time is now more then two orders of magnitudes smaller, only between 10^2 and 10^3 yrs. Stellar densities ($\varrho(r) > 0.01$ g/cm^3) within the collapsing fragments are rapidly reached with the formation of the second, hydrostatic, central cores, and the initial accretion rates can exceed $10^{-4}\ M_\odot$/yr. The spatial distribution of the individual protostars is, initially, confined by the volume of the isothermal core, i.e. $R_c \approx$ 100's AU. Numerical simulations show that these *protostars* are usually surrounded by massive circumstellar disks (Bate 1998; Matsumoto & Hanawa 2003). Multiple protostars will also compete with each other for the accretion from the common gas reservoir, which can imprint the expected mass spectrum (Bonnell et al. 1997; Klessen 2001). In the case where the protostellar collapse is triggered by external compression waves, even higher initial accretion rates are expected, and it seems safe to say that the time to build up most of the final stellar masses (i.e. the time to evolve a protostar from class 0 into class I) takes no more then a few 10^4 yrs (Hennebelle et al. 2003). By that time, dynamical interactions between the individual protostars become important, as the crossing time for dynamical systems in such configurations is only of the order of a few $\tau_{\mathrm{cross}} \approx 10^3$ yrs (Sterzik & Durisen 1995, 1998).

Because accretion probably occurs even after strong dynamical interactions commence, stages **c** and **d** of our scenario may significantly overlap. Reipurth & Clarke (2001) have qualitatively explored the consequences of the evolution of a newborn multiple systems under the simultaneous action of mass accretion and dynamical interactions. The disintegration of the multiple systems can then cause the formation of brown dwarfs as stellar embryos that have been ejected before accretion has stopped. Bate et al. (2002) demonstrate in their hydrodynamical star formation calculations that relatively close binary systems with separations between 1 and 10 AU can be produced through a combination of dynamical interactions in non-hierarchical multiples, and orbital decay of initially wider binaries. Orbital decay due to infalling gas accretion, and star-binary-disk interactions lead to a preponderance of equal-mass close binaries, in general agreement with observations. The complexity of their numerical scheme, however, restricts the statistical robustness of their results. Also Delgado-Donate et al. (2003) simulate the combined effects of competitive accretion and close dynamical interactions between individual protostars in detail. With respect to pairing statistics, escape speeds, and binary properties, they corroborate the results of pure point-mass calculations (Sterzik & Durisen 1995, 1998, 2003a; Kiseleva et al. 1998a; Rubinov et al. 2002) that neglect the effects of remnant molecular gas and disk accretion. By focusing on the stellar dynamical effects alone, the point-mass treatments provide predictions with highest statistical significance.

A robust result independent of the detailed accretion history is that the dynamical evolution drives an initially non-hierarchical system into singles, binaries, and stable or metastable hierarchical configurations. Typical binary separations are found to be a factor 3−10 below the initial cluster scale (Sterzik & Durisen 1998; Bonnell 2001), and the distribution is broadened with respect to the input distribution. *We conjecture that a phase of dynamical evolution and hierarchical rearrangement within multiple systems stemming from fragmentation after isothermal collapse is a prerequisite to establish the typical separation scales observed in binary systems.* Fragmentation into $N > 2$ protostellar systems is required and could be due to randomness in the initial cloud core conditions and perturbations and/or to a possibly chaotic nature of the fragmentation process itself (Larson 2002). Some primordial $N = 1$ and $N = 2$ systems which do not undergo further dynamical interactions can be incorporated into such a scenario. But the primordial binaries will then populate only the wider end of the separation distribution.

2.6. Outcome: Mass dependences

A linear pre-protostellar core mass versus size relation like Eq. (1) implies that the specific energy of star forming cores is constant over the observed mass and size ranges. We may further assume that the total core mass and the total stellar masses are related via a (relatively) constant star formation efficiency. Finally, the scaling properties of the isothermal collapse allow us to relate the pre-collapse size to the system scale of the core at the end of the isothermal collapse via Eq. (2). This size defines roughly the scale of the protostellar cluster. Altogether this means that the validity of a linear mass versus size relation Eq. (1) can be extended to stellar few-body clusters and that the specific energy in these clusters should be more or less constant. If this is true, the final binary separation distributions following dynamical decay are roughly proportional to the system mass (Sterzik & Durisen 1998, 2003a).

It is striking that binaries among very low mass stars and brown dwarfs (with typical masses of $\sim 0.1\ M_\odot$) are observed be 10 times tighter than for stars $\sim 1\ M_\odot$ (Close et al. 2003; Sterzik & Durisen 2003b). This observation apparently supports the view that the linear mass-radius relation expected from isothermal collapse holds down to the stellar separation scale.

Combining dynamical calculations with a statistical approach to assigning stellar masses to the fragment clusters, Durisen et al. (2001) find that the resulting multiplicity fractions for stable stellar systems after dynamical decay agree with observations in showing a distinct increase in multiple fraction with primary mass. This general agreement survives extension of such calculations to substellar masses (Sterzik & Durisen 2003a), although some aspects of brown dwarf binary properties remain poorly understood.

3. Formation of very close binaries

The formation of close O(1 AU), or even spectroscopic binaries ($\ll$1 AU), which contribute a significant fraction to the observed binary populations, is less clear. One proposed mechanism is angular momentum exchange in a circumbinary disk (Artymowicz et al. 1991), but the direction of the orbital migration is sensitive to the detailed configuration and properties of the disk material (Goldreich & Tremaine 1980; Bate 2000). Tidal interaction with a hypothetical disk is expected to diminish during the evolution. The disk itself loses mass due to accretion. Repeated star-disk interactions disrupt the disk and weaken the frictional forces that could lead to orbit shrinkage (Hall et al. 1996).

Fragmentation during the second collapse phase naturally leads to more compact configurations, but the viability of the process is not established (Boss 1989; Bate 1998; Bonnell 2001). Finally, fission of a rapidly rotating pre-main sequence configuration is unlikely (Tohline & Durisen 2001), although it cannot yet be ruled out entirely (Tohline 2002).

Random processes arising from the chaotic dynamics of fragmenting systems can in principle provide the necessary decelerating torques to broaden an initially narrow separation (or angular momentum) distribution function (see, e.g., Larson 1978, 11997, 2002). However, it has also been shown that dynamical interactions within star clusters alone cannot sufficiently broaden initially narrow separation distributions (Kroupa & Burkert 2001). Additional processes and higher stellar densities, such as those within bound, small-N multiple systems, are required.

Under certain conditions, stellar tidal interactions will play a crucial role in the evolution of hierarchical multiple systems. For instance, tidal friction in triples can dramatically reduce the inner orbital periods by orders of magnitude over moderately short time intervals through secular transfer of angular momentum (Kiseleva et al. 1998b). In order to cause significant deformation and friction on the stars, they must approach each other very closely. Cyclic variations and high eccentricities of the inner binary orbit can be induced by the presence of an inclined, outer orbit (Kozai 1962). Researchers have started to model the combined action of the Kozai-cycle and stellar tidal interactions in detail, and some applications include the complex orbital evolution in specific binary and triple stars (Eggleton & Kiseleva-Eggleton 2001), open star clusters (Mardling & Aarseth 2001) and the dynamical evolution of extrasolar planetary systems (Mardling & Lin 2002).

For the dynamical Kozai-cycles to become effective, the orbits of newborn multiples should be preferentially orthogonal. Is this the case? The relative orientations of orbits in triple stars resulting from dynamical decay have been compared to the statistics of real multiple stars (Sterzik & Tokovinin 2002). The observed distribution of orbit orientations exhibit only a slight trend for orbital correlation, and can be fairly well reproduced by the decay simulations if the initial cluster properties correspond on average to moderate geometrical oblateness (∼10:1) and moderate β (∼0.1).

The majority of triple systems, both in observations and in the simulations, have relatively high inclinations angles, and *are therefore likely subject to the Kozai effect*. Probably many of these systems evolve into very close binaries by Kozai-cycles and stellar tidal effects. Empirically, an overabundance of close binaries in hierarchical systems has been found (Tokovinin & Smekhov 2002). This can be explained quite naturally within this framework (Tokovinin 2003), but more detailed modelling is required to quantify the viability of this effect to explain observations of all spectroscopic binaries in a satisfactory way.

4. Discussion and summary

We have sketched a scenario in which the isothermal collapse of a rotating cloud core produces few-body proto-stellar systems. The stochastic stellar dynamical interactions which occur subsequently in the evolution of these small-N clusters appear to be necessary to establish realistic binary separation distributions. One critical requirement in the chain of arguments is that pre-collapse cores containing a few Jeans-masses are realistic initial conditions. The classic theory of star formation, in which stars build up from an "inside-out" (non-homologous) collapse of singular, isothermal spheres (Shu et al. 1987), will build up a density profile that will not lead to fragmentation.

Alternative approaches have been proposed in which interstellar turbulence leads to transient, shock-generated density fluctuations, such as sheets, filaments, voids, and cores. This process, sometimes referred to as turbulent fragmentation, produces a spectrum of cores with masses reminiscent of the stellar mass function (Klessen 2000; Klessen & Burkert 2001; Padoan & Nordlund 2002). Depending on the amplitude of these density fluctuations, some of the cores may exceed the threshold of gravitationally stability, and collapse. The stochastic nature of these fluctuations will then also determine how gravitationally super-critical the forming core will be, in other words, how likely a subsequent homologous collapse with fragmentation will be. In this context, fragmentation of a core into one or more stars is ultimately a consequence of the stochastic properties of the underlying turbulence the molecular cloud, and its ability to generate gravitational unstable cores.

If, however, the collapse satisfies Eq. (2), scaling relations hold that constrain basic system scales, and relate them to cloud initial properties like mass and temperature. Different star forming environments are then expected to imprint variations in observables such as the properties of multiple systems or the shape of the IMF. Kroupa et al. (2003) have recently argued that stellar-dynamical evolution in different young clusters alone can explain the binary properties of stellar systems ranging from loose associations to dense clusters, provided that *brown dwarfs* are a part of a separate population whose properties might vary with star-forming conditions. If isothermal fragmentation of pre-stellar cloud cores into small-N systems is a major decay channel of star formation, then even the initial properties of the *stellar* population will vary in the way described in this paper.

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