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The escape of the Sun's fraternal twin

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Roughly half of all stars are in multiple systems (binaries, triples etc), which means that two or more stars orbit each other because of their mutual gravitational pull. For stars of about the mass and age of the Sun, the average separation between companion stars is 50 times the Earth-Sun distance. Such companions are close enough to have affected each others' formation and evolution. Thus, understanding how multiple star systems form is a key question in astronomy.

The past decade has seen much progress on this issue. Observational and theoretical studies indicate that multiple systems should form early in the star's life, but not all of the companions are retained. Computer simulations find that companion stars can be ejected or the stars may move closer together due to the interplay of the stars and their gaseous environment within a million years. Nevertheless, previous studies mostly focused on multiple systems that are over a million years old. As such, we expect many of these multiple systems to have different properties than when they first formed. Therefore, we need to focus on much younger multiple star systems so that we can observe their properties before they have had time to change.

Observing these young multiple systems is difficult. Stars stem from egg-shaped gas clouds called "dense cores". The youngest stars are still buried inside these cores, whose dust grains absorb all visible light. Therefore, we cannot observe these cores with optical telescopes. To detect these dense cores, we must observe them using infrared telescopes and radio telescopes.

We based our study on the results from two recent surveys of the Perseus molecular cloud, which is a typical nearby star-forming region. The first was a radio survey that located all the young stars, both single and binary. This survey used a collection or radio telescopes (known as an array of telescopes) called the Very Large Array to identify compact sources of energy associated with young stars. While these radio observations could detect the young stars, they could not detect the dense core surrounding them. Thus, we used a second survey that observed dust in the Perseus cloud as a whole rather than the material associated directly with the stars. This study used the new SCUBA-2 detector on the James Clerk Maxwell Telescope. We used the SCUBA-2 data to examine the dense cores around each of the young stars in the Perseus cloud. With both of these surveys, we could examine the properties of those dense cores with multiple star systems to see if their features are different from the dense core with only single stars. Such a comparison has only recently become possible, because of these and similar, large-scale surveys.

Combining data from these two studies, we found that the most widely separated binaries were primarily aligned with the long axis of their dense, egg-shaped cores. The widely separated binaries are also the youngest systems. The slightly older binaries stars are closer together by comparison and they show no such alignment. Instead, the tight binary orbits are randomly oriented with respect to the dense cores.

We created several models to try and understand how the wide and tight binaries may evolve. In the model that best reproduced our observations, dense cores initially produce only wide binaries. These binaries then either shrink in separation as they age, or else break apart into two single stars that go their separate ways. We also find that most of the wide binaries break up, with only some of them shrinking. Our best model agrees well with observations, which show that there are fewer binary stars in older systems than in younger systems.

In summary, we propose that young stars initially form as wide binary systems that are aligned with their dense, egg-shaped cores. How these systems form is still an open question. In any case, the binaries then either drift together as they age or break apart. Both processes occur over a time of less than a million years, in agreement with previous theoretical simulations. If our analysis is correct, it follows that any single star, including the Sun, is the product of a dissolved binary. The Sun's "fraternal twin" must have left it at near birth, over four billion years ago, and has now drifted far away.