UC SANTA BARBARA

THE Current

August 6, 2025

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Some young suns are aligned with their planet-forming disks, others are born tilted

Researchers at UC Santa Barbara, The University of Texas at Austin, Yale University and National Taiwan Normal University have found that a fair number of sun-like stars emerge with their rotational axis tilted with respect to their protoplanetary disks, the clouds of gas and dust from which solar systems are born.

“All young stars have these disks, but we’ve known little about their orientations with respect to the spin axis of the host stars,” said UCSB associate physics professor Brendan Bowler, who studies how planets form and evolve through their orbits and atmospheres, and is senior author of a study in the journal Nature. Based on the general alignment of our own sun’s rotational axis with those of the planets in our solar system, the assumption was that stars and their planet-forming disks emerge and rotate in or very close to alignment, he explained.

“This work challenges these centuries-old assumptions,” Bowler said.

Ever since exoplanets — planets that orbit other stars — were discovered in the early 1990s, the variety of spin orientations of host stars relative to the orbits of the planets closest to them had astrophysicists scratching their heads.

“It came as quite a surprise that some planets were on orbits that were extremely inclined relative to the spin axis of the host star,” said Lauren Biddle, a postdoctoral

researcher at UT Austin, and lead author of the study. Since then, there have been efforts to explain the dynamics that could lead to this planetary system architecture.

“One idea is that after planets form, gravitational interactions with a passing star or maybe a companion star could incline the orbit of the planet relative to the host star,” Biddle said. “Or maybe after planets form, a particularly massive one on the outer edge of the system could gravitationally interact with planets closer to the star.” The leading idea has been that planetary systems and their suns begin life aligned but through interactions over billions of years, systems can become misaligned, she said. “But there was also this question about whether these orbits were inherited from their formation process.”

To find out, the researchers took data from the Atacama Large Millimeter/submillimeter Array (ALMA), the Transiting Exoplanet Survey Satellite (TESS) and the repurposed exoplanet-seeking Kepler Mission (K2) to measure stellar and disk inclinations and obtain star-disk obliquity for a sample of 49 young isolated stars and their planet-forming disks.

The result of their survey? About two-thirds of the stars and protoplanetary disks were found to be in alignment, while a third of them were misaligned. The modest number of misaligned stellar and planet-forming disk orientations hints at a more elegant model of the origin of planetary system tilts: some are just born that way.

“It changes our interpretation,” Bowler said. “It means that we don’t need a ton of post-formation dynamics and interactions and planet-scattering events.” Certainly, there are suns and planetary systems that do undergo significant interactions, and can only be explained by complex dynamics, according to him. And, he added, studying other stars and their solar systems gives context to our own six-degree misalignment between our own sun and solar system.

“If we think of science as kind of an Occam’s razor where the least complex model ends up winning out, given the data, this is a nice example of the sun simply just fitting into this primordial, stellar obliquity distribution,” Bowler said.

Future work in this realm may include further investigations into just how these sun-like stars and their protoplanetary disks create these tilted orientations during the earliest stages of solar system formation.

“Now we know that at least a third of them are tilted,” said Bowler, but why this is the case remains unanswered.

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