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vention for nine 14- to 20-year-olds who had been recently diagnosed with mild to moderate depression or anxiety and were recruited through their clinicians. After 30 hours of volunteer work at animal shelters, food banks, and other community organizations, the average reduction in depressive symptoms among participants was 19 percent.

Everyone in the study enjoyed the work and reported a sense of pride and accomplishment. "Young people who were struggling with anxiety said that they were pretty anxious before doing it but then felt so much better after," Ballard says. Although volunteering should not replace mental health treatment, she says, it could help in conjunction with other forms of therapy. She is pursuing that hypothesis in a larger study.

What accounts for the benefits? Helping others improves mood and raises self-esteem. It provides fertile ground for building social connections. It also shifts people's focus away from negative things and can change how they see themselves. Many teens say they don't feel important, Ballard says. "Volunteering can give people a different sense of themselves, a sense of confidence and efficacy." Lanza thinks of it as "a health pipeline." He adds that "it equips you with certain types of skills that better control anxiety."

There may be a potential downside to volunteering, however. Fuligni and his colleagues have found that young people's mental health can suffer if they feel their contributions are devalued because of their gender, racial or ethnic identity. And if they feel like they are being forced to participate or are not doing much, the experience can be harmful, Ballard says. One report found that people who were required to volunteer when they were young were less likely to do such work when they were older. "Young people have to choose something that feels meaningful to them," Ballard says. Adults can help by offering choices and by vetting volunteer opportunities to be sure that organizations are well run and equipped to offer a good experience.

When these situations are carefully thought out, volunteering doesn't just help the volunteers. It also helps the people and communities on the receiving end. "Volunteering could be a win-win," Lanza says. ●

Planetary Baby Pics

Snapshots of planet-forming disks reveal secrets of how worlds are born

BY PHIL PLAIT

FOR CENTURIES—and, frankly, until quite recently—astronomers were baffled by planet formation. They saw points of light in the sky moving in a neat, orderly fashion, but many crucial details about how those worlds got there in the first place were a mystery.

We've come a long, long way since those times—and with remarkable speed. With the help of bigger telescopes, more precise instruments and advanced digital image-processing techniques, answering the question of how planets form has gone from speculative guesswork to a robust field of study. And, like most new scientific disciplines, it's evolving rapidly. We used to have just a few observations of embryonic planetary systems but now have hundreds thanks to the breathtaking pace of discovery.

In fact, astronomers recently delivered detailed observations of 86 nascent planetary families, adding a staggering number of objects for researchers to gleefully analyze. And with that analysis will come a better understanding of how stars and planets are born.

In Ye Olden Days—such as when I was a kid—the scientific understanding of planetary formation was weak, and a lot of the ideas that were tossed around could safely be called "wacky." For example, one was that a star passed so close to our sun that it drew strands of material out of it, and those strands coalesced to form planets. This is a pretty cool idea—at least its proponents were "thinking big"—but it's a stretch, to say the least. For one thing, such close near-collisions between stars in this part of the galaxy are so rare as to be virtually nonexistent. And that kind of superheated solar streamer would dissipate to nothingness, not collapse into tidy, enduring worlds.

But as time went on and the observations got better, so did the hypotheses. Now we know that stars form in gigantic clouds of gas called nebulae when overly dense clumps of material collapse under their own gravity. The material flattens into a protostellar disk, with matter swirling around the center and feeding the young star forming there. Eventually the disk—now called a protoplanetary disk—cools and can truly begin the planetary-formation process. Planets grow either as small objects, such as pebbles and rocks, stick together to make bigger ones or as huge chunks of the disk collapse to directly create large objects.

These disks were theorized for decades, but no one actually detected any until the 1980s, when observations of the bright star Vega revealed it to be surrounded by a ring of starlight-warmed dust. More were quickly found, although the observations were short on diagnostic detail.

That changed when a crew of astronauts installed the Space Telescope Imaging Spectrograph (STIS) on the Hubble Space Telescope in 1997. STIS was able to block most of a target star's brilliant glare and deliver high-resolution images of any sizable circumstellar disk. Many of the disks discovered with STIS bore spiral arms—an indication of unseen planets that were setting the disks aswirl with their gravity. In others, scientists saw clear gaps in the disk where planets were either plowing through material and sweeping it up or pumping orbital energy into the particles there and changing their trajectory. (Full disclosure: I worked on STIS and was part of the project that looked at these disks. In that research, I helped to digitally remove the star's light. Being one of the first people to ever see these structures in detail was an honor and a joy.)

The study of these disks has, of course, moved on since then and, incredibly, has gotten even better. The Atacama Large Millimeter/submilli-

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meter Array (ALMA) observatory in Chile has scrutinized dozens of such structures and revealed previously unseen details in wavelengths of light near the radio range. And now astronomers are bridging the gap between visible light and radio with the European Southern Observatory's immense Very Large Telescope (VLT), also in Chile. It's composed of four gigantic 8.2-meter telescopes, and on one of these beasts sits SPHERE, the Spectro-Polarimetric High-contrast Exoplanet REsearch instrument. It's a phenomenally high-resolution camera that takes images with such exquisite detail that, no joke, when I first saw its astonishing pictures of asteroids in our solar system, I thought I was being pranked.

Each of the VLT's four telescopes is so big that it can collect a lot of light and see fine detail, so it's able to observe many stars in the throes of creation and discern structures in the surrounding material—features created by massive objects such as protoplanets forming in a disk. In three papers in the journal *Astronomy & Astrophysics,* astronomers report findings from their observations of planetary systems emerging in three nearby nebulae in the constellations of Orion, Taurus and Chamaeleon. Each of these star-forming factories is close enough to Earth that the powerful VLT-SPHERE combo reveals myriad details. Many of the observed disks have gaps and spiral arms, signaling the growth of planets and, more important, putting the disks in context with their immediate astrophysical surroundings.

The study of planetary birth is at an inflection point. In the past, these objects were found only rarely, but now observations are sweeping them up.

For example, in the Taurus cloud, SPHERE observed roughly 20 percent of the nebula's Class II objects (those where the light from the newly born star is just emerging from the protostellar murk), representing a complete sample of all stars with more than 0.4 times the sun's mass—the rest were too faint to be reliably detected. Of these, nearly two thirds had faint disks that had been neither seen nor documented before.

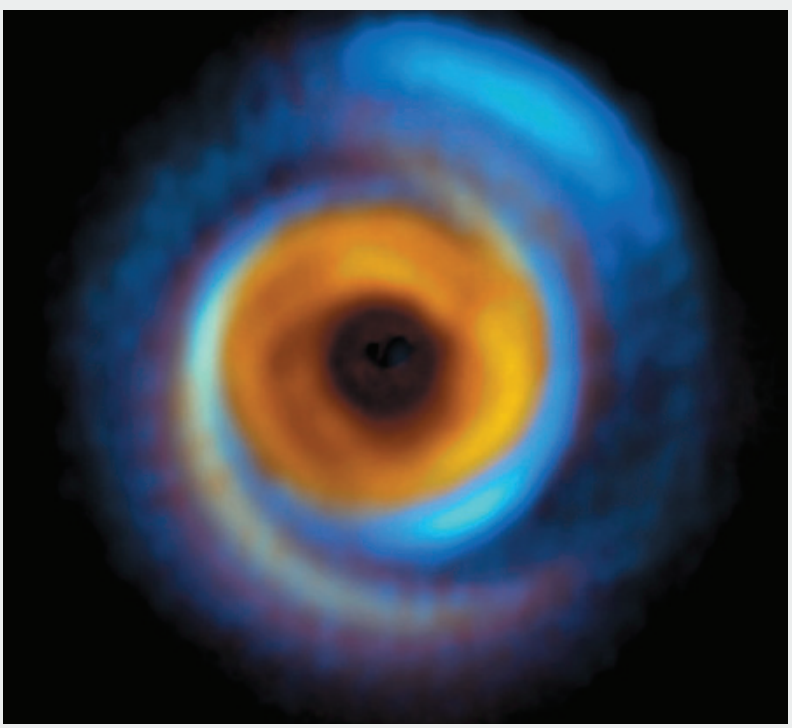
Nearly a third of the systems observed in the Taurus cloud were multiple-star systems, in which two or more stars orbit one another. Statistics show that about half of all stars are—unlike our sun—in multiple systems, so studying planetary formation in these Tatooine-like environments will yield a lot of interesting data on how stellar multiplicity affects the planets around those stars. For example, in the Chamaeleon cloud studied by SPHERE, disks were sparse within binary systems where the higher-mass primary star was accompanied by a close-orbiting, lower-mass secondary star, which implies that some aspect of that stellar configuration suppresses the formation of planet-birthing disks.

Individual stars and disks are wonderful for learning about specific physical circumstances, but we need broader observations to get a better overview of how planets come into being—in a sense, we can understand the fine details only by seeing how they fit into the bigger picture. Comparing and contrasting the characteristics of these planetary nurseries, including their density, age and chemical structure, is what will lead to that gestalt.

The study of planetary birth is at an inflection point. In the past, these objects were found only rarely, but now observations are sweeping them up wholesale. As I like to say about new fields of science, this is when it goes from stamp collecting to zoology—from "We found another of these weird objects!" to "We have enough that we're starting to note trends and see the underlying mechanisms that create them."

There are still many questions about how our own solar system came to be and evolved over the eons into its current configuration. A critical step toward answering them is to make observations that let us find the deeper connections between other planetary systems and ours.

You might think astronomy is the study of everything over your head, but in fact it includes what's under your feet, too. ●



ESO/A. Garufi et al.; R. Dong et al.; ALMA (ESO/NAOJ/NRAO) (CC BY 4.0)

The MWC 758 planet-forming disk is about 500 light-years away.