Unraveling the sequence of events that results in the birth of stars, and in many cases planetary systems, is not just important for astronomy, but also for giving humanity a sense of its place in the cosmos. Fortunately, there is no shortage of interesting nearby examples to study, and the thermal-infrared optimization of Gemini’s telescopes makes them uniquely suited to excel in this area of astronomical research.

The mysterious early stages of stellar birth are often shrouded and obscured by dense clouds of optically thick gas and dust. However, infrared observations have penetrated many of these murky and chaotic realms to reveal young bodies with accretion disks and jet-like outflows, (see the article on the birth of a very massive star by Ben Davies starting on page 74 of this issue). Occasionally, these objects display short-lived transient flare-ups, such as in 2003 when American amateur astronomer Jay McNeil noticed a newly glowing cloud in the constellation of Orion. Named after its discoverer, the McNeil Nebula is home to a pre-natal star that suddenly shone forth like a lighthouse beam through a temporary breach in the dense clouds surrounding its stellar nursery. Rapid follow-up observations at Gemini allowed University of Hawai’i astronomers Colin Aspin and Bo Reipurth to study the event and watch it unfold over several months (see Figure 1). The quick turn-around of the observations was made possible in large part by the flexibility of the queue-scheduling scheme which Gemini was just initiating at the time of this event.

Fortunately, detecting the formation of possible planetary systems around other stars is less time-critical than an event like the sudden illumination of McNeil’s Nebula. In the more advanced stages of planet formation, young stars have flattened disks of dust and gas around them. These particles are the likely building blocks of planets. Observations of these circumstellar disks in the thermal infrared are key to understanding their diverse characteristics.

Gemini’s foray into the study of proto-planetary circumstellar disks began in late 2001 – during what might, in retrospect, be considered the commissioning of the Gemini South telescope system – and involved the early use of the mid-infrared instrument OSCIR on the Gemini South telescope. These first observations focused on the infrared excess around the bright star Beta Pictoris (originally discovered in 1983 by the Infrared Astronomy Satellite, or IRAS) and hinted at an intriguing edge-on disk full of potentially interesting structure.
Figure 2: Artist's rendering of what the environment around HD 23514 might look like as two Earth-sized bodies collide.

Artwork by Lynette Cook for Gemini Observatory.
However, because of signal-to-noise issues, the observations required follow-up confirmation that finally came with the use of T-ReCS on Gemini South in 2003-4. The new data (see Figures 3 - 5), verified some of what OSCIR had detected in 2001 and was published in the journal *Nature* (C. Telesco et al.). The result was also presented at a press conference during the January 2005 meeting of the American Astronomical Society in San Diego, California.

Like other circumstellar disk results to follow, this early evidence led to the conclusion that very recent catastrophic collisions of bodies within Beta Pictoris’ rocky, dusty disk created a debris cloud of small dust particles that gave the disk a lopsided appearance at specific mid-infrared wavelengths (see Figure 4). Models predict that the wind from the central star clears away such small particles (about the size of cigarette smoke particles) relatively quickly, if they are not being continually replaced by ongoing, frequent collisions.

A similar conclusion was announced later in 2005, when another *Nature* paper spotlighted the work of Inseok Song and his collaborators. The star, BD +20 307, was another IRAS infrared excess target, but this time the team (with both Gemini and Keck data) used spectroscopy to determine the temperature and particle size of the infrared-emitting dust as well as pinpoint the distance of the dust-producing collisions from the star. From this evidence, the team concluded that collisions between asteroids (or even Earth-sized planets) created the dust. Even more exciting, the collisions were occurring frequently at a distance from the Sun-like star comparable to the Earth-Sun distance in our solar system. For the first time, a solar-system analog existed that could be showing what our own solar system was doing during its formation (or during the era of heavy bombardment) some 4.5 billion years ago (see Figure 2).

In accord with the BD +20 307 result, a team led by Joseph Rhee (University of California, Los Angeles) et al. (that also included I. Song) found another dusty disk around a sun-like star (HD 23514) in the well-known Pleiades star cluster. In this case, the warm dust is also at a similar Earth-Sun distance, but the primary flux density peaks at a non-standard wavelength of ~ 9 microns (see Figure 7). The presence of so much small warm dust at this distance from the star is not easy to account for, unless a large amount of material is converted to very fine dust due to collisions in the first hundred million years of this sun-like star’s life. The team concludes that the existence of dust near BD +20 307 and HD 23514 make it likely that such terrestrial planet formation is common.

Another compelling finding surrounds the star Zeta Leporis and Gemini South T-ReCS observations made by a team led by Margaret Moerchen (while a Ph.D. student at the University of Florida). Like BD +20 307 and HD 23514, Zeta Leporis is surrounded by dust of recent origin. However, the most intriguing part of this work is the detection and first-ever full-spatial resolution of what is likely an analog to the asteroid belt in our own solar system. At about the
same distance as the asteroid belt in our planetary system, Moerchen detected a maximum mid-infrared flux around Zeta Leporis and accurately measured its separation from the star. This infrared flux is indicative of many collisions between multiple small bodies in orbit around the star, just like one would expect in the formation of the asteroid belt.

Finally, at the other end of the stellar life cycle, a team led by UCLA astronomer Eric Becklin offers up a unique view of the dusty fate of old planetary systems and what our solar system might have in store for us in another 4-5 billion years. This time, using the MICHELLE mid-infrared spectrograph, Becklin’s team looked at an ancient stellar ember, a white dwarf named GD 362 and found an unexpected preponderance of photospheric metals. According to Becklin, “This is not an easy one to explain. Our best guess is that something similar to an asteroid, or possibly even a planet around this long-dead star, is being ground up and pulverized to feed the star with dust. By studying the composition of the dust, we can actually determine the material in a far off planetary system.”

Piecing together a coherent picture of the formation (and demise) of planetary systems from proto-planetary circumstellar debris disks is still a young field that will keep astronomers and theorists busy for the foreseeable future. Gemini’s mid-infrared sensitivity, spatial resolution, and instrument suite are well-positioned to continue the momentum of the past 10 years in this important area of study. Ultimately, our findings will allow us to assemble an understanding of our origins, just as clouds of gas and dust coalesced some five billion years ago to assemble the fortunate circumstances in which we can even ponder such profound questions.

References: