ASTRONOMY:

Orion Sheds New Light on Star and Planet Formation

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Even casual observers of the night sky in winter will easily spot Orion the Hunter with its striking alignment of three bright, bluish-white belt stars. More experienced sky gazers who have trained their small telescopes on Orion know that the middle "star" in the Hunter's Sword hanging off the belt is in fact a young star cluster shrouded in glowing nebulosity. This cluster, the Trapezium, is a set of massive, hot stars born within the last million years or so. The surrounding gas and dust that they illuminate are the raw materials from which they and many hundreds of lower-mass Trapezium cluster stars have formed. Astronomers have long hypothesized that such star-formation activity is accompanied by the generation of planets.

Imaging studies have shown that the entire Orion nebula region is a hotbed of star-formation activity (see the figure). On page 93 of this issue (1), Briceño *et al.* report a detailed survey of a region of Orion not searched previously for young, sunlike stars. Their results support earlier suggestions that a few million years after a parent star is formed, the stage already is set for planet formation. Furthermore, this work is one of several recent studies pointing to variability as a distinguishing characteristic of stellar youth.

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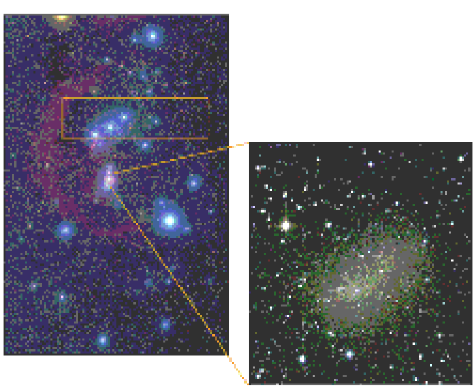

A well-known star nursery. One of the most intensely studied star-formation regions, the Orion Nebula (**right**), is found in Orion's Sword. Briceño *et al.* have focused on stellar variability in less active regions to gain insights into the early stages of star formation believed to be associated with the generation of planets.

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To understand how interstellar gas clouds might produce solar systems like ours, astronomers have looked almost exclusively to regions that, much like the Orion Nebula, contain newly formed stars embedded in massive clouds of gas and dust. Particular attention has been paid to young stars that show evidence of ongoing planet formation in the form of circumstellar disks that are the presumed sites of protoplanets. The presence of such disks has long been inferred spectroscopically (2). More recently, many direct images of protoplanetary disks have been obtained by the Hubble Space Telescope and large ground-based telescopes (3). The direct detection of these candidate protoplanetary disks, combined with the growing number of known extrasolar planets (4), suggests that the formation of planets may be a common occurrence. But essential aspects of this process, such as the characteristic time scales for the different stages of planet formation, have remained controversial. Observations of a few dozen nearby, young, sunlike stars suggest that, after about 10 million years, circumstellar gas and dust disks are either cleared out by planets, incorporated into planetesimals, or otherwise dispersed (5, 6). But these conclusions rest on a few spectral properties measured for a relatively small number of stars.

To develop a more statistically significant sample of young stars, Briceño *et al.* used a wide-field optical imaging system to survey a large (roughly 2° by 10°) area north of the Orion Nebula, along Orion's belt. Much of this region is devoid of the raw materials necessary for ongoing star formation. The investigators used stellar variability rather than spectral indicators of the presence of a circumstellar disk (such as strong hydrogen Balmer emission lines or strong infrared emission) to identify young stars for subsequent study by spectroscopy. Because they are far from the active star-forming Orion molecular clouds, these young stars must have formed in episodes of star formation that well predate the current swarm of activity in the Orion nebula.

Using this approach, Briceño *et al.* have isolated a population of over 150 young (<10-million-year-old) stars in the vicinity of, but displaced from, the well-studied stellar nurseries in Orion (7). This allows them to place much firmer constraints on the time scale for accretion from a circumstellar disk onto a young star. They observe substantial differences between the spectroscopic properties of a stellar sample with a characteristic age of about 1 million years and those of a sample with a typical age of about 10 million years. A far smaller percentage of stars in the latter sample shows evidence of accretion from circumstellar gas and dust. This suggests that, if planets are to form around these slightly older stars, then planetesimals (or perhaps even protoplanets) should be present already because the raw materials necessary for protoplanetary coagulation have been severely depleted by this time. Alternatively, most circumstellar disks may become so stable within about 10 million years of their formation that alternative spectral tracers [such as infrared emission from molecular hydrogen (8)] may be required to detect any residual material.

Other recent imaging studies of the Orion region have also made use of, or were concerned with, stellar variability. Infrared imaging data collected as part of the Two Micron All-Sky Survey (2MASS) (9) demonstrated that about 40% of the roughly 2700 stars in the Trapezium's vicinity are variable, including the well-studied, infrared-luminous Becklin-Neugebauer object (10, 11). The spatial distribution of these infrared variable stars closely follows that of the dense molecular cloud, emphasizing the close relation between intrinsic stellar variability and stellar youth. But the infrared variables detected by 2MASS display a wide variety of temporal behavior, ranging from periodic to random. This suggests that a wide variety of physical mechanisms are responsible for variability in young stars. Potential explanations include rapid rotation of spotty surfaces, short-lived accretion events, and temporary obscuration of stars by orbiting or infalling dust clouds.

Chandra X-ray Observatory high-resolution imaging observations of Orion (12, 13) have established beyond doubt that almost all young stars are prolific sources of x-ray emission. This high-energy emission appears to occur often in the form of relatively short but very strong bursts of hard x-rays. The most volatile x-ray sources appear to be the very youngest, most highly obscured protostars, but almost all sunlike stars in Orion display variable x-ray output (13).

The Briceño *et al.* wide-field optical search for variable stars in Orion will continue to cover new ground, and we can expect this work to identify many hundreds of additional young stars. Statistical analyses of these new populations should offer further specifics concerning the time scale for planet formation. Meanwhile, the wealth of imaging data recently collected for Orion suggests that over a remarkably wide range of the electromagnetic spectrum, the one constant of stellar youth is variability.

References and Notes

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