World of Knowledge

Probing the Formation Mystery of Sunlike Stars

Chin-Fei Lee
Assistant Research Fellow
Institute of Astronomy and Astrophysics

It is now known that stars are formed inside clouds of gas and dust by means of gravitational collapse. Dense condensations called protostars will first form in the beginning and then grow into stars as gas and dust continue to fall onto them. The details of the process, however, are complicated by the presence of magnetic field and angular momentum. In particular, gas and dust are also found to be ejected from around the protostars, forming supersonic protostellar jets interacting with the surrounding material.

The jets are now believed to be launched from accretion disks around the protostars, allowing us to probe the accretion process, which remains heretofore unresolved, as it requires us to directly observe the inner parts at the AU scale. As a result, the jets become the key to unlock the mystery of star formation. In spite of numerous studies, their physical properties (e.g., speed, episodic nature, collimation, and angular momentum) are still not well understood. The Submillimeter Array (SMA) atop Mauna Kea in Hawaii, with the capability of probing warm and dense molecular gas at high angular resolution, is thus used to study the physical properties of the jets in details.

Hergib-Haro (HH) 211 is a well-defined bipolar (two-sided) jet located at only 1000 light-year away in the constellation Perseus and is thus one of the best candidates for our study. Sitting at the center of the jet is a protostar deeply embedded in the cloud. It is only about 20,000 years old with a mass of only 6 percent of the mass of our Sun. It will eventually grow into a star like our Sun in tens of million years.

With the SMA, we have zoomed in to the jet and retrieved critical information from it. Two tentative yet critical pieces of information have been retrieved from the jet. Firstly, the mass-loss rate (the amount of material ejected per unit time) in the jet is found to vary with time with a period of about 30 years. This periodic variation of the mass-loss rate may be due to a solar-type magnetic cycle. The polarity of the magnetic field of our Sun is known to change over time with a period of about 22 years, resulting in the periodicity of the Sun's activity. Similar magnetic cycle may have started in the protostar long before the star is born, resulting in a periodic mass-loss rate in the jet. Alternatively, the periodic variation may be due to a periodic disturbance of an unseen stellar companion orbiting the protostar at about 4 AU away with a period of 30 years. Secondly, the jet is found for the first time to carry away excess angular momentum from the protostar. The angular momentum per unit mass is very small, less than 50 AU km/s, strongly suggesting that the jet is launched from an accretion disk very close to the protostar, and much closer than the distance of Mercury from our Sun. This finding is consistent with the prediction in the theoretical model of star formation, the “X-Wind” model, developed by former Tsinghua University President and Academician Frank Shu (Frank Hsia-Seng Shu) and his colleagues. Further observations have been proposed to confirm our results.

The SMA is a joint venture of the Smithsonian Astrophysical Observatory (SAO) in U.S. and the

Academia Sinica Institute of Astronomy and Astrophysics (ASIAA) in Taiwan. It is a radio interferometer with eight 6-meter antennas operating in submillimeter wavelengths, allowing us to see the jets in great detail. A much more powerful radio interferometer, Atacama Large Millimeter/Submillimeter Array (ALMA), is now under construction in northern Chile, as a much more powerful version of the SMA. It will allow us to zoom in all the way to the centers of star-forming regions with much finer details and unlock the mystery of star formation directly. The ALMA project is the largest ground-based astronomical project ever carried out. ASIAA has joined the project since 2005.

The work described here was published in the 1 December 2007 issue of the Astrophysical Journal (Chin-Fei Lee, Paul T. P. Ho, Aina Palau, Naomi Hirano, Tyler L. Bourke, Hsien Shang, and Qizhou Zhang, 2007, ApJ, 670, 1188-1197).

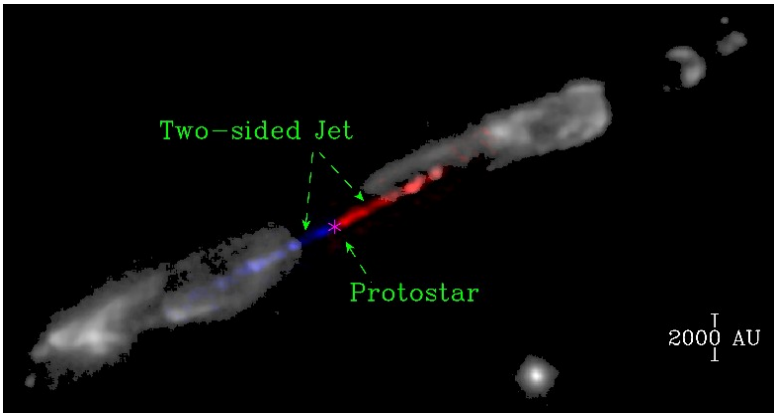

Figure 1. The two-sided (red for receding and blue for approaching sides) jet HH 211 observed with the SMA (Lee et al. 2007). Gray image shows the shock emission produced by the jet (Hirano et al. 2006).

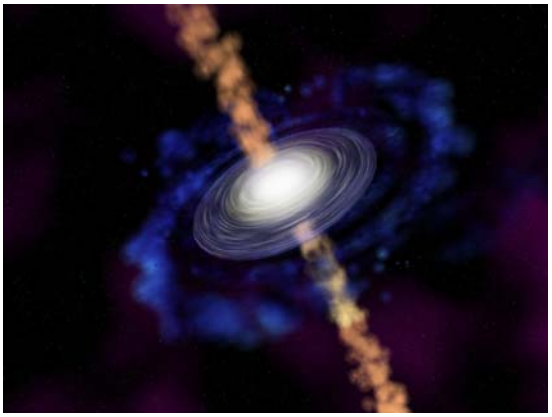

Figure 2. An artist's conception showing a supersonic jet ejected from a disk around a protostar (Picture Credit: Change Tsai).