How to Build A Big Star

September 6 2005

The most massive stars in our galaxy weigh as much as 100 small stars like the Sun. How do such monsters form? Do they grow rapidly by swallowing smaller protostars within crowded star-forming regions?

Some astronomers thought so, but a new discovery suggests instead that massive stars develop through the gravitational collapse of a dense core in an interstellar gas cloud via processes similar to the formation of low mass stars.

"In the past, theorists have had trouble modeling the formation of high-mass stars and there has been an ongoing debate between the merger versus the accretion scenarios." said astronomer Nimesh Patel of the Harvard-Smithsonian Center for Astrophysics (CfA).

"We've found a clear example of an accretion disk around a high-mass protostar, which supports the latter while providing important observational constraints to the theoretical models."

Patel and his colleagues studied a young protostar 15 times more massive than the Sun, located more than 2,000 light-years away in the constellation Cepheus. They discovered a flattened disk of material orbiting the protostar. The disk contains 1 to 8 times as much gas as the Sun and extends outward for more than 30 billion miles - eight times farther than Pluto's orbit.

The existence of this disk provides clear evidence of gravitational collapse, the same gradual process that built the Sun. A disk forms when a spinning gas cloud contracts, growing denser and more compact. The angular momentum of the spinning material forces it into a disk shape. The planets in our solar system formed from such a disk 4.5 billion years ago.

Evidence in favor of high-mass accretion has been elusive since massive stars are rare and evolve quickly, making them tough to find. Patel and his colleagues solved this problem using the Submillimeter Array (SMA) telescope in Hawaii, which offers much sharper and highly sensitive imaging capabilities compared to single-dish submillimeter telescopes.

SMA is currently a unique instrument that makes such studies possible by allowing astronomers to directly image the dust emission at submillimeter wavelengths and also to detect emission from highly excited molecular gas.

The team detected both molecular gas and dust in a flattened structure surrounding the massive protostar HW2 within the Cepheus A star formation region. SMA data also showed a velocity shift due to rotation, supporting the interpretation that the structure is a gravitationally bound disk.

Combined with radio observations showing a bipolar jet of ionized gas, a type of outflow often observed in association with low-mass protostars, these results support theoretical models of high-mass star formation via disk accretion rather than by the merging of several low-mass protostars.

"Merging low-mass protostars wouldn't form a circumstellar disk and a bipolar jet," said co-author Salvador Curiel of the National Autonomous University of Mexico (UNAM), who is on sabbatical leave at CfA. "Even if they had circumstellar disks and outflows before the merger, those features would be destroyed during the merger."

The team plans more detailed observations using the SMA and the National Radio Astronomy Observatory's Very Large Array, which initially detected the bipolar jet.

The researchers, in addition to Patel, Ho, and Curiel, are: P. T. Ho, T. K. Sridharan, Q. Zhang, T. R. Hunter and J. M. Moran, of CfA; Jose M. Torrelles, Institute for Space Studies of Catalonia (IEEC)-Spanish Research Council (CSIC), Spain; and J. F. Gomez and G. Anglada, Instituto de Astrofisica de Andalucia (CSIC), Spain.

This research is being reported in the September 1, 2005, issue of Nature.

The SMA is a joint project between the Smithsonian Astrophysical Observatory and the Academia Sinica Institute of Astronomy and Astrophysics in Taiwan and is funded by the Smithsonian Institution and the Academia Sinica.

The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities.