S 76 E: a case of violent massive star formation in a very cold giant molecular cloud

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Introduction

S 76 is a faint optical nebula about $7'$ in diameter. It is associated with variuos signposts of massive star formation: strong water masers, powerful IR sources, etc. In recent years we performed systematic studies of this object in several molecular lines. In combination with optical, IR, radio continuum and H I data the molecular emission reveals an intriguing structure of this source which might be a prominent example of high mass star forming (HMSF) region.

The data are rather complete and indicate the presence of every basic constituent of such regions: dense core, high-velocity molecular gas, extended cold diffuse molecular cloud, atomic hydrogen, H II region, masers and IR sources mentioned above. Combining these data into a single picture might enlighten us on many important aspects of massive star formation. This task is not straightforward because the data can be interpreted in different ways. Here we present preliminary results of this study.

Observations

In 1993–1998 we observed S 76 in variuos molecular lines with the 14-m radio telescope in Metsähovi, 20-m radio telescope in Onsala and 100-m radio telescope in Effelsberg. The results of these observations have been partly published (Zinchenko et al. 1993, 1994, 1997). Here we report the remaining data. They include CO, ^{13}CO, C^{18}O, HCO$^+$, SO, SiO, N_2H^+ and HNCO observations. The source has been mapped in the CO, ^{13}CO, C^{18}O, CS, CH_3OH, HCO$^+$, N_2H^+, SiO and SO lines. The HNCO emission has been observed only at the central position.

Discussion

The basic observational facts are the following: (1) There is a very extended ($> 30'$) low brightness ($\sim$ 5 K) CO emission at $V_{\rm LSR} \approx 25 - 33$ km/s. (2) In the neighborhood of S76E there is another CO component of much higher intensity which is apparently partly shielded by the first one. The emission peak is shifted to SW from S76E. (3) In C^{18}O at least 2 distinct clumps with different $V_{\rm LSR}$ (~ 27 and ~ 33 km/s) are seen. Probably there is one more with $V_{\rm LSR} \sim 31$ km/s. (4) In CS, SO, HCO$^+$, NH_3 and N_2H^+ the emission at $V_{\rm LSR} \sim 32 - 33$ km/s dominates, though a weak component at $V_{\rm LSR} \sim 28$ km/s can be seen in SO and NH_3. The main component peaks in CS, SO and NH_3 are displaced by $\sim 10'' - 20''$ to SW or W from S76E while the emission peak of the secondary component is shifted by $\sim 1.5 - 2'$ to SW. (5) The HCN spectrum is highly distorted, apparently by foreground absorption blue-shifted by $\sim$ 5 km/s. (6) From (1,1) and (2,2) NH_3 data

the kinetic temperature peaks near S76E. (7) In the immediate vicinity of S76E the CO spectrum has an extended strong red wing. (8) Even more extended wing ($\geq$ 60 km/s) is seen in the thermal SiO emission which is rather compact and peaks near S76E. (9) The water maser emission spans a range from $\sim$ 25 to $\sim$ 35 km/s and is rather variable. Recent VLBA observations show 2 H_2O maser spots (with $V_{\rm LSR} \sim$ 28 and $\sim$ 31 km/s) separated by $\sim 12''$ approximately in the E–W direction (Slysh et al. 1999). (10) Atomic hydrogen is seen at $V_{\rm LSR} \sim$ 28 km/s. (11) The H II gas has $V_{\rm LSR} \sim$ 23 km/s. (12) The NIR source (observed with a $8''$ beam) is located rather close to the maser spots, apparently closer to the 28 km/s component.

Several unambiguous conclusions can be drawn from these facts: (1) There is a giant very cold diffuse molecular cloud in this area, accompanied by a neutral atomic hydrogen cloud at the same velocity. (2) To SW from S76E there is a local enhancement of column density and/or temperature in this cloud elongated in the SW direction. (3) Inside or behind the giant cloud there is a massive dense core moving with a radial velocity of $\sim$ 5 km/s relative to the bulk of the cloud. (4) There is a high velocity flow and a shock with a radial velocity $\geq$ 60 km/s. (5) There is an H II region with a mean velocity ~ -5 km/s relative to the giant cloud.

The most plausible model is the following. A young massive star was born near the edge of the giant cloud. Its position is marked by the IR source and H_2O emission which probably delineates the circumstellar disk. The star creates a bipolar flow but only the lobe going inside the cloud is seen in the molecular lines. The gas compressed by the flow is seen as the dense core. The H II region created by the young star is expanding due to the "champagne" effect.

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References

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