INFRARED EMISSION FROM THE GALACTIC CENTER

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Most of what we know about the Center of our Galaxy is derived from infrared observations made during the last few years. There are two reasons for this. First, there are about 30 magnitudes of visual extinction towards the Galactic Center (Becklin et al. 1978b) making observations shortward of 1 µm almost impossible. Second, most of the luminosity from the region is emitted at infrared wavelengths, peaking at around 50 µm - 100 µm.

The spatial distribution of the central few parsecs of the Galaxy has been recently mapped at 30 µm, 50 µm, and 100 µm by Becklin, Gatley and Werner (1981). Using the full 30" resolution of the Kuiper Airborne Observatory, they have shown that there is a significant color temperature gradient in this region, with the central 30" (1.5 pc at an assumed distance of 10 kpc) having a somewhat higher temperature (~ 100°K) than its surroundings. The dust density, however, peaks in a ring lying in the Galactic plane with a diameter of about 4 pc. The region interior to this ring appears to be optically thin to ultraviolet radiation, so that the dust in the ring is warmed by direct heating from energy sources within the central 1.5 pc region. Becklin et al. (1981) conclude that the bolometric luminosity of these energy sources is in the range 1-3 x 10^7 L☉. Ground-based infrared continuum observations with higher spatial resolution (e.g. Becklin et al. 1978a at 10 µm; Gatley, Becklin and Telesco 1981 at 30 µm) show that the hot dust within the central 30" exists in a number of clumps, each of which is of the order 0.2 pc in diameter. The clumps lie on an arc which is displaced by about 0.3 pc from the VLBI radio source, the presumed nucleus of the Galaxy.

The VLBI radio source coincides, within errors, with the compact 2.2 µm object named IRS16 by Becklin and Neugebauer (1975). It is surrounded by a 2 pc diameter cluster of 2 µm sources at least some of which are late-type giant stars (Neugebauer et al. 1976). IRS16 itself, however, shows no recognizable stellar features in its 2 µm spectrum (Wollman et al. 1981).

The unique properties of the Galactic Center VLBI source have been recently summarized by Lo et al. (1981). It has a flat radio spectrum between 1.4 and 22 GHz, with a flux density of about 1 Jy, corresponding to a radio luminosity of 1 L☉ (about 10^4 times less than that of the M81 VLBI source). Its measured diameter is a few x 10^-2 arcsec (10^14 - 10^15 cm), but the apparent size is probably exaggerated by interstellar scattering. The source is mildly variable. So far, no satisfactory model for the Galactic Center VLBI source exists. Its high luminosity and flat radio spectrum make it unlikely to be a pulsar with smeared-out pulses. In its lack of X-ray emission of radio flaring activity it differs from binary-star radio sources such as
Cygnus X-3. The radio source may well have its origin in some kind of accreting collapsed object, but the physical means by which radio emission is generated in such a system is not understood.

The ionized gas in the central few parsecs of the Galaxy has been mapped at radio wavelengths with the VLA (Brown, Johnston and Lo 1981) and by means of the 12.8 μm [NeII] line (Lacy et al. 1980) and hydrogen Brackett lines (Neugebauer et al. 1978; Nadeau et al. 1981). The gas has a clumpy distribution similar to that of the hot dust. Depending on whether the clumps are each internally ionized or all ionized by a central single object, the rate of ionization is between $2 \times 10^{50}$ and $10^{51}$ s$^{-1}$. Such an ionization rate would be enough to produce the infrared luminosity, and corresponds to that of a few 04 stars. In the Galactic Center, however, the effective temperature of the ionizing radiation must be less than 35,000 K (i.e., of spectral type later than 08) in order to fit the observations of various ions such as those of neon, argon and sulfur (Lacy et al. 1980).

The kinematics of the gas in the clumps has been studied by Lacy et al. (1980) using a Fabry-Perot etalon at the 12.8 μm line of [NeII]. They find that the velocities of the gas clumps, which range from −260 to +260 km s$^{-1}$, can be explained as orbital motions in a potential well produced by a point source of $3 \times 10^6$ M$_\odot$ and a distributed mass of $3 \times 10^6$ M$_\odot$ within 1 pc of the center. An alternative model, consisting only of a distributed mass of $10^7$ M$_\odot$, however, produces almost as good a fit to the data. The high internal velocities of the clumps, about 100 km s$^{-1}$ means that they are short-lived; one new clump of about 1 M$_\odot$ of gas must be formed each 500 years, and an equivalent mass of gas must be removed from the region.

The nature of the ionization (and luminosity) source in the Galactic Center has been considered by Lacy, Hollenbach and Townes (1981). They consider the possibility that the $3 \times 10^6$ M$_\odot$ point source suggested by the neon data is a black hole, and showed that if the black hole is accreting matter at a rate of $5 \times 10^{-5}$ M$_\odot$ yr$^{-1}$ the accretion disk will have a luminosity and effective temperature which would provide a good match with the observed degree and rate of ionization. The authors show that there are at least two problems with the black hole model, however. First, the predicted 2.2 μm brightness of the accretion disk is about 100 times greater than is observed at IRS 16 (a problem which arises in almost any model relying on a single ionization source). Second, the black hole would cause tidal disruption of stars in the central cluster at such a rate that accretion of the resultant gas onto the black hole would liberate far more energy than is observed at infrared wavelengths. In other words, if there is a black hole at the Galactic Center it must have a much lower mass and accretion rate than is suggested by the neon data in order not to produce effects contrary to observation. Lacy et al. (1981) therefore favor an alternative model for the Galactic Center in which the ionization is provided by a cluster of OB stars which, either because of an unusual initial mass function or because of the cluster has an age of $> 4 \times 10^6$ yr, excludes stars with effective temperatures above 35,000 K. They suggest that the gas clumps are produced by mass loss from red giant stars, either as a result of tidal disruptions or planetary nebula formation. This gas is subsequently removed from the center by star formation.
In his talk yesterday, van der Heuvel pointed out that there is no evidence for black holes in any X-ray binary star except for Cygnus X-1. With the absence of evidence for the existence of an exotic object in the Galactic Center, we are forced to conclude that black holes are going out of fashion, in our Galaxy at least.

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REFERENCES

DISCUSSION

S. Inagaki : You said that \(3 \times 10^6 M_\odot\) black hole model is favorable from velocity. What kind of velocity field is observed?

Answer : The velocities are largest close to the VLBI source, and decrease away from it.