IS THERE A COMPACT CENTRAL MASS CONCENTRATION IN OUR GALAXY?

CHARLES H. TOWNES
University of California at Berkeley
Berkeley, CA 94720

1. Introduction

Since the center of our own galaxy is the closest region of this type, it should provide a proving ground for our understanding of such regions. And fortunately, recent developments in radio, infrared, and x-ray astronomy allow us to look at the center of our galaxy in considerable detail—a privilege not possible in the visible region because of the rather dense dust clouds surrounding it. We find there many complex and interesting phenomena, including evidence for a compact central mass of a few million solar masses from the dynamics of stars and gases. However, its existence has been doubted because the radiant energy coming from the very center is much less than normal theoretical expectations for a black hole of such a mass. This discrepancy has led to speculation whether the velocity measurements could be misleading, whether the concentrated mass is in some form other than the expected black hole, whether the radiation might be taking place in an exotic form, being directed away from us or happening to be low at the moment, or whether our theories of such radiation are as yet incomplete. The general characteristics of the very central region of our galaxy will be reviewed along with the dynamic evidence for a large concentrated mass and comparison of the radiation it emits with that of various theoretical models.

2. The Central Region of our Galaxy and Sgr A*

Radiation from the center of our galaxy was first seen in the radio region in 1932 by Jansky (1932), but it was only in the recent few decades that the growing fields of radio interferometry and infrared astronomy have allowed...
us to see details of composition and structure in this region. Plate 1 provides high resolution radio maps of the region made with the VLA, showing four panels of different intensity levels. The blue color is used to indicate synchrotron type radiation and red color for thermal radiation from ionized gas. At the lowest exposure, the intense point source known as Sagittarius A* shows up very prominently. This point source is a strong candidate for a black hole, and is possibly the heavy black hole indicated by dynamical measurements. However, its radiated intensity is orders of magnitude weaker than first expectations for such an object.

Surrounding the ionized region of Plate 1 is relatively warm molecular gas, of temperature about 200-300K. Figure 1 shows a map by Güsten et al. (1987) of the HCN 0 → 1 transition in this warm, dense, and clumpy gas. Large variations in density are indicated on the map. The dark central region in its center contains very few molecules, but is occupied by the ionized gas shown in Plate 1 along with some atomic material. At increasing radii from the center of the galaxy, the HCN radiation fades out. This does not mean that no HCN is present, but rather that the temperature and densities are too low for this particular transition of HCN to be strongly excited. In fact, clumpy clouds and somewhat turbulent motion continue for some distance from the center, as shown by observations of CO and other molecules.

The hole in the center of the molecular cloud immediately raises the question as to how it was formed. The energy required to form it has been estimated to be as large as about $10^{53}$ ergs. While the clouds containing HCN are in general circulating around the center, they do not all move at the same speed, and hence should collide with each other and make a more uniform motion and distribution after a period of time of about 100K years. Hence, some very energetic phenomenon must have occurred within the last 100K years, quite possibly the same one which produced the central hole. While this may immediately suggest infall of material into a black hole and a subsequent explosion, it might instead be due to a series of supernovae, or an intense starburst.

Sagittarius A* is unique in our galaxy in terms of its intensity and radio characteristics, and has been intensively examined since its discovery. Rogers et al. (1994) have found it’s size to be about $1.4 \times 10^{13}$ cm at 3 mm wavelength. Position measurements over a period of about 10 years shows that is velocity across the field of view is smaller than about 15km s$^{-1}$ (Backer, 1994). This rather low velocity, compared to the velocity of the many stars nearby of about 150 km s$^{-1}$ or more, indicates that it must be substantially heavier than the average such star. The probability of its having such a low cross-field velocity is less than about 1% if its mass is equal that of the average nearby star, but about 25% if its mass if 40 time