STUDY OF THE GALACTIC CENTER WITH A HIGH RESOLUTION GAMMA RAY TELESCOPE

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It is generally accepted that massive black holes are the most likely source for the energy radiated from active galactic nuclei, and may explain the enormous amount of energy emitted by quasars, radio galaxies, Seyfert galaxies, and BL Lacertid objects[(1)]. Although the detailed mechanisms of the black hole formation in galactic nuclei are not clear at present, it seems to be quite possible that the formation of massive black holes is a general outcome of the evolution of galactic nuclei[(2)].

In 1971, Lynden-Bell and Rees[(3)] reviewed the infrared luminosity and other observations on the center of our galaxy, and proposed that the energy source in the center is a black hole. They assumed a Kerr form of black hole, and obtained from the different previous observations masses ranging from 10^2 to 10^8 solar masses.

More recent studies in the far infrared, radio and gamma regions have set two different, and mutually exclusive mass limits on a possible massive black hole in the galactic center. Allen and Sanders[(4)] using the $\lambda = 2.2\ \mu m$ range have set the size of the black hole in the center $\leqslant 100$ solar masses. R. Genzel[(5)] set a lower limit of 10^6 solar masses based on velocity observations of the interstellar dust and molecular gases in the central region obtained in the IRAS and HEAO missions.

Recently, 0.511 MeV annihilation photons have also been observed in the direction of the galactic center[(6,7)], showing a 6-month variation[(8)], and indicating the existence of either a single compact source at the center, or a group of sources with a centroid at or near the Galactic Center[(9,10)].

None of these previous observations give, however, conclusive evidence for the existence of a massive black hole in the Center of our Galaxy, or a relatively accurate estimate for its mass.

We suggest that a detailed study of gamma rays in the energy range of 1 MeV - 1 GeV, emitted from the direction of the galactic center, carried out with a high angular and energy resolution gamma ray telescope would contribute most significantly to the solution of this problem.

The High Resolution Gamma Ray Telescope (HRGT) under construction at The University of Texas at Dallas and The University of California, Los Angeles[(11)] seems to be a unique detector specifically applicable to this purpose. The new concept in the design of this telescope is the combination of liquid and gas drift chambers with scintillation detectors for imaging and tracking the secondary particles generated by the gammas with a very high angular and energy resolution. The telescope consists of a Liquid Argon Converter, an Argon-Methane Gas Drift Chamber, and a Liquid Argon (Xenon) Calorimeter, and has an event-by-event processing and decision making feature (Fig. 1). The telescope

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will be operated as a (a) Compton (or Compton-Pair) Telescope in the energy range 1-50 MeV, and as a (b) Pair Conversion-Shower Telescope in the energy range 50 MeV - 20 GeV, with two different cryogenic liquid fillings (Argon and Xenon) of the calorimeter. The entire telescope will be surrounded with plastic scintillator plates to reject charged particles. The Liquid Argon Converter and Liquid Argon (Xenon) Calorimeter will operate also as scintillation detectors for triggering the telescope, and for time-of-flight discrimination to suppress the background photons.

The angular resolution of the HRGT varies between 13 and 1 mrad for gammas at 1 and 10 MeV energy, respectively, and is smaller than 1 mrad for gammas of $\geqslant$ 10 MeV. The latter angular resolution can be improved by observing a large number of gammas, 10^4, using statistical methods, to $\sim 10\ \mu$rad. The energy resolution of the HRGT is $\leqslant$ 5% for gamma energies 1 - 10 MeV, decreases slowly with increasing energy, and becomes $\sim$ 2% at 1 GeV.

The first prototype HRGT (Fig. 2) will be completed in the first half of 1989. The development and construction of the HRGT was supported by the Strategic Defense Initiative Organization, Office of Innovative Science and Technology. We intend to continue the improvement of this prototype and apply the new telescope for astrophysical studies first in balloons, and later in other space vehicles.

We started to model the Gamma Ray Emission from the Galactic Center in order to

(1) Distinguish a black hole from other possible structures of the Galactic Center
(2) Optimize the new High Resolution Gamma Ray Telescope that is being built at our institutions
(3) Plan a balloon flight and subsequent space flights to study the gamma rays from the Galactic Center with our High Resolution Gamma Ray Telescope
(4) Carry out similar analysis for the potential use of other gamma ray detectors for distinguishing a massive black hole in the Galactic Center
(5) Develop the conceptual design of a High Resolution Gamma Ray Telescope for studying the Galactic Center in the Space Station, or other permanent space platforms.

The first major objectives of our study are:

(a) to simulate and model the possible black hole in the Center of our Galaxy
(b) to simulate the expected few MeV gamma ray spectrum and its angular distribution from this black hole
(c) to simulate the detection of these gamma rays in the High Resolution Gamma Ray Telescope
(d) to simulate the requirements of the balloon flight and the subsequent space flights, and the adaptation of the prototype High Resolution Gamma Ray Telescope.

We plan to model four types of black holes combined with various types of accretion models. The four black hole models to be used are the Schwarzschild, Kerr, Reissner-Nordstrom, and Kerr-Newman models[12]. We shall very the mass, charge and angular momentum (if applicable) in these models. With respect to the different accretion models, we shall use the four most important ones with spherical accretion, thin and thick isotropic disks, and

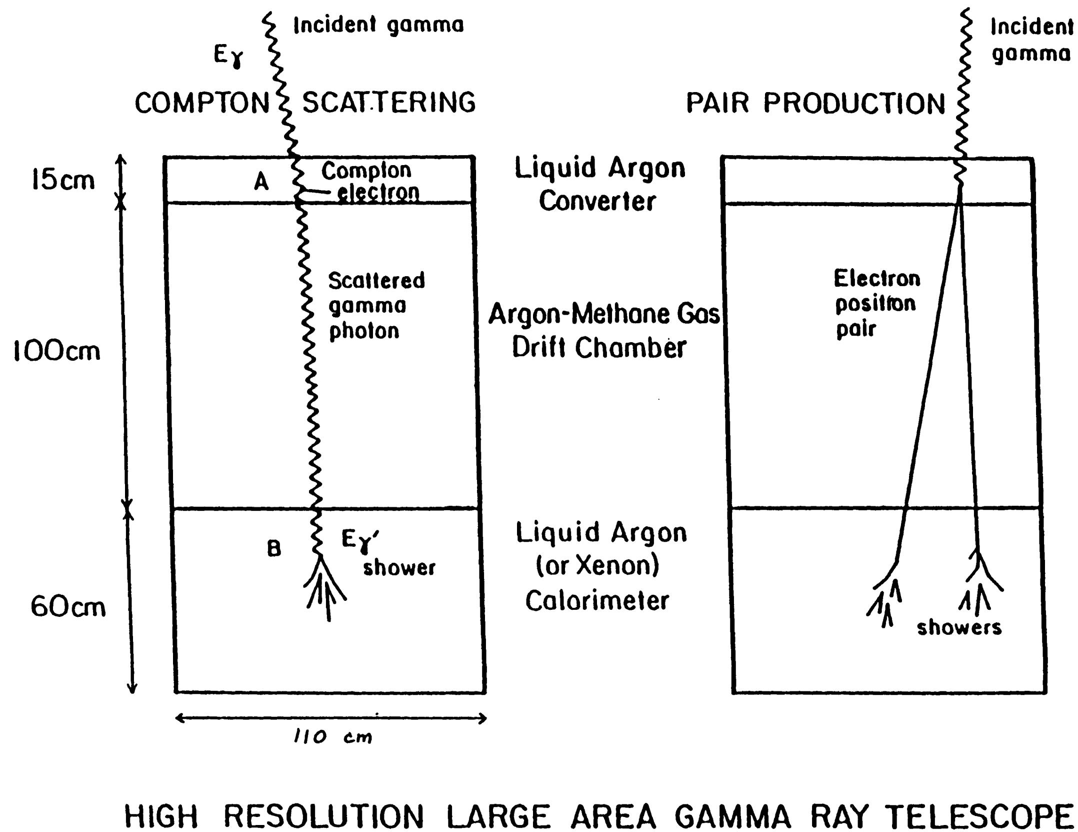

Fig. 1
The schematic sketch of the HRGT

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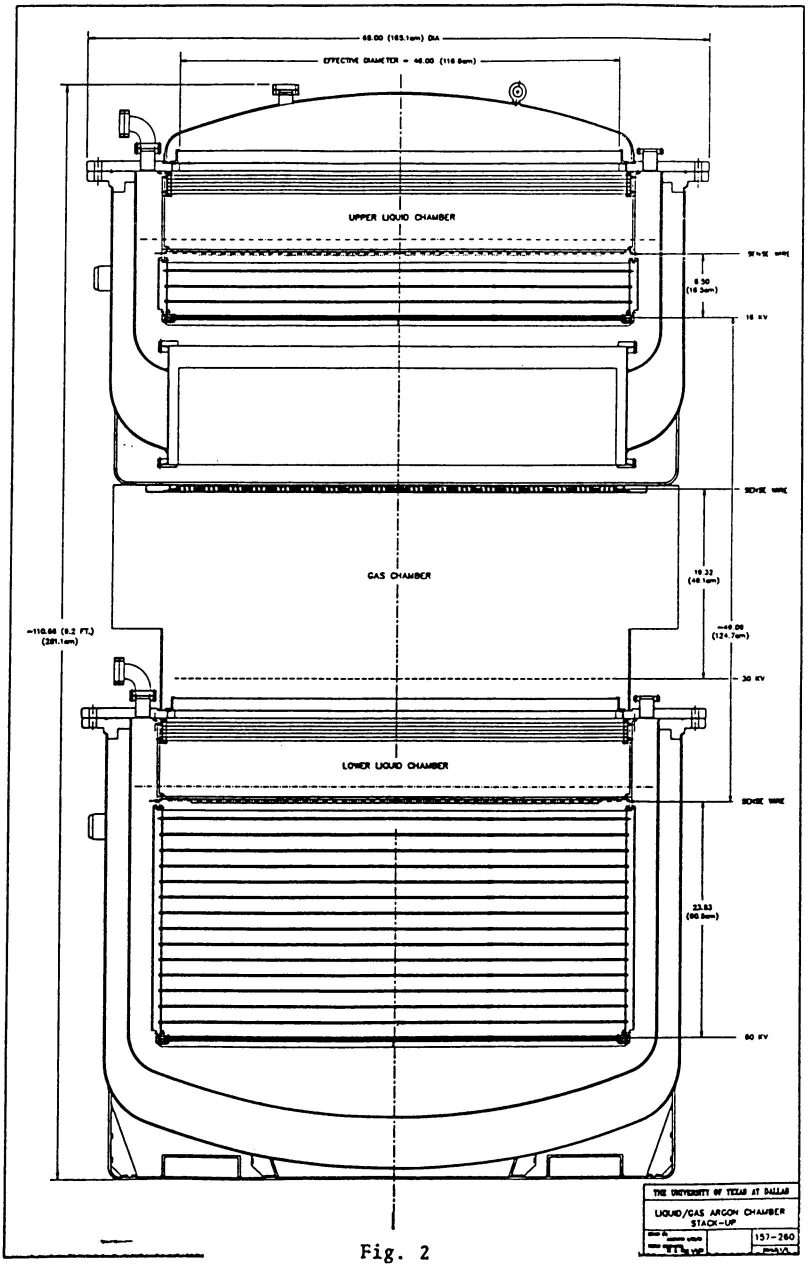

Fig. 2

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with clumpy non-isotropic disk[13]. We will start with spherical accretion, and proceed to disks of various degrees of thickness and isotropy.

Considering all possible combinations of the black hole and accretion models, we shall calculate the energy spectrum in the vicinity of the source. Then we shall apply a series of models of the interstellar medium, ranging from an isotropic and homogeneous mixture of dust and gas to a complex structure of dust and gas clouds, and large-scale filaments of matter[14].

The energy spectrum observed at the telescope location will be calculated for different combinations of the above models, and for different masses of the hypothetical black hole. All simulations and calculations will be carried out on the Cray X-MP/24 supercomputer of the University of Texas. The simulation of the HRGT and its operation with a variable number of point like gamma ray sources ($\lesssim$ 100 sources) has already been carried out, resulting in the expected angular resolution of the telescope. The simulation of the first few combinations of black hole and accretion models are already in progress.

Based on the results obtained for the HRGT a similar study will be carried out modeling all other gamma ray detectors, particularly those of GRO, which could contribute to studying the possible existence of a Massive Black Hole in the Center of our Galaxy. This study will finally lead to a the most proper design of a large High Resolution Gamma Ray Telescope for future Black Hole experiments carried out in the Space Station, or other permanent space platforms.

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