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A FINAL TECHNICAL REPORT ON NASA GRANT NAG5-1626
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This grant covered the major part of the work of the Principal Investigator and his collaborators as a Guaranteed Time Observer on the Hubble Space Telescope. The work done naturally divided itself into two portions the first being study of nebular objects and the second investigation of the interstellar medium between stars. The latter investigation was pursued through a contract with Princeton University, with Professor Lyman Spitzer as the supervising astronomer, assisted by Dr. Ed Fitzpatrick. Following the abrupt death of Professor Spitzer, his responsibilities were shifted to Dr. Fitzpatrick. When Dr. Fitzpatrick relocated to Villanova University the concluding work on that portion of this grant was concluded under a direct service arrangement.

This program has been highly successful and the resulting publications in scientific journals are listed below. To the scientist, this is the bottom line, so that I shall simply try to describe the general nature of what was accomplished.

There were three nebular programs conducted, one on the Orion Nebula, the second on the Helix Nebula, and the third on NGC 6822. The largest program was that on the Orion Nebula. This involved both HST observations and supporting groundbased observations obtained with a variety of instruments, including the Coude Feed Telescope at the Kitt Peak National Observatory in Arizona, the Cerro Tololo Observatory in Chile, and the Keck Observatory on Mauna Kea, Hawaii. Moreover, considerable theoretical modeling was done and all of the data analysis was performed at the Rice University in Houston, except for the PI's period of sabbatical leave (6-96 through 7-97) when he was based at the Max Planck Institute for Astronomy in Heidelberg, Germany.

The Orion Nebula program was the most productive part, resulting in numerous papers, but more important in the discovery of a new class of objects, for which we coined the name "proplyds". The proplyds are protoplanetary disks surrounding very young stars still in the process of creation. The Orion Nebula is the residual material from a burst of star formation that occurred about 300,000 years ago. Each of these new stars has a surrounding disk of protoplanetary material. The same physics that renders the Nebula so highly visible means that the protoplanetary disks are also quite visible. With the wisdom of hindsight, we now see that this was to be expected and that we should have been searching specifically for this type of object. The discovery of these objects and their subsequent detailed investigation has lead to an accurate assessment of the frequency of protoplanetary disks in young stars and determination of the likelihood of survival of these disks into an era where planets actually form.

The Helix Nebula program was a study of the so called "Cometary Knots" in this closest explosive remnant of a nearby collapsed star. These Cometary Knots are clouds of dust and gas have masses about that of our Earth and sizes about that of our solar system. We established that they are far more numerous than thought and actually contain a significant fraction of all the material ejected from the parent star as it collapsed. The subject of later General Observer programs is a determination of the detailed properties of these features and whether or not they will survive and become rogue planets randomly moving about the Milky Way Galaxy, unbound to any one star.

NGC 6822 is one of the closest galaxies to our own. Since we cannot study large star formation complexes in our own Galaxy because of nearby interstellar extinction, the best thing is to look at similar regions in nearby galaxies. We determined that the star formation complexes in that galaxy closely resemble those to those in our own. Moreover, we established on a firm quantitative footing that one can use the total luminosity in the primary optical emission line as a measure of the rate of star formation, thus providing a fundamental tool for studying the star formation process in other galaxies.

The program carried out by Spitzer and Fitzpatrick had one main focus, i.e., to study the properties of individual clouds of gas and dust in the Milky Way's interstellar medium (ISM). Interstellar space is full of such clouds and the absorption lines observed in the directions of most stars generally arise from the superposition of absorptions arising in many such physically distinct regions. The high spectral resolution data available with the Goddard High Resolution Spectrograph, combined with a detailed "component model" analysis, allowed the complex spectra to be disentangled and the abundances of a wide range of atomic species to be measured individually for each of the clouds present along a line of sight. The program included two distinct classes of targets: a set of nearby stars located in the Galactic disk and a small set of more distant objects located in the Galactic halo. The analyses of these stars has provided basic observational input --- including measurements of gas temperature, electron density, and dust composition --- for theories attempting to explain the physical processes operating in the ISM, including the gas-phase ionization mechanisms and the growth/destruction mechanisms for dust grains.

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