Key Science Programs for the SPEAR Mission

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Abstract

At the broadest level, the goal of the SPEAR mission is to understand the role energetic plasmas in the Galactic ISM. This goal can be subdivided into key projects. Those projects primarily derived from sky survey observations include: 1) Global modeling of the ISM: Is the FUV background consistant with any existing global model of the ISM? 2) Superbubbles: How do they evolve and interact with their surroundings? 3) Molecular Hydrogen in the Galaxy and Halo: What is the nature, distribution and life cycle of Molecular Clouds and Diffuse H_2 in the Galaxy? 4) Interstellar Dust: How is it distributed, and how does it affect the energy balance and chemical abundances in the ISM? 5) Supernova Remnants: What is the distribution and morphology of old Galactic and Halo SNR? Projects suited to pointed observations include: 1) Studies of the structure of shocks in the ISM. 2) What are the properties of interfaces between hot and cold gas?

Global Models of the ISM

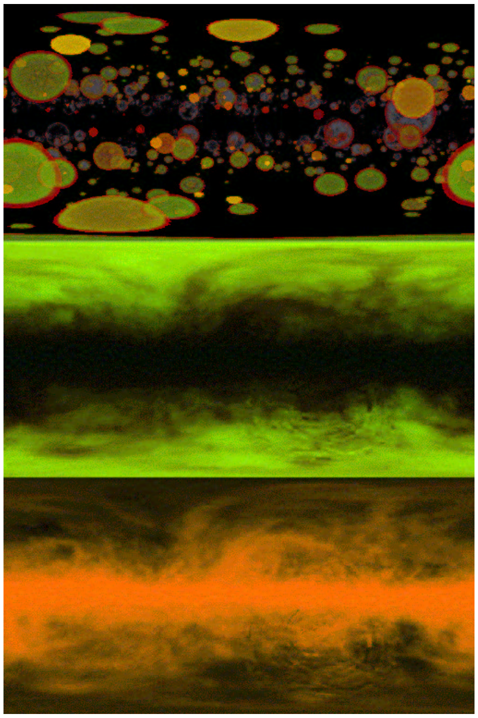

Figure 1. Simulated FUV sky brightness for three models of the state of interstellar gas. Green represents O VI $\lambda\lambda$ 1032,1038 emission. Red represents C IV $\lambda\lambda$ 1550 emission. (Korpela 1997)

Figure 1 shows three models of the state of interstellar gas. The upper model, derrived from Slavin and Cox (1992,1993) shows hot gas concentrated in isolated supernova remnants, with FUV emission arising in the interface regions between the hot gas and the neutral ISM.. The middle model show the distribution of emission that would be expected in a Galactic fountain model. (Shull & Slavin 1994) Emission in these models, which is primarily concentrated toward the Galactic poles, tends to be brighter in O VI $\lambda\lambda$ 1032,1038 emission than in C IV $\lambda\lambda$ 1550 emission. In contrast, a McKee Ostriker type model (McKee & Ostriker 1977, bottom) including a pervasive hot (10^6) K ISM results in emission primarily at hot/cold interfaces. This results in a low contrast sky that is brighter in C IV emission than in O VI . Of course, none of these models is likely to be an accurate representation of the real FUV sky. MHD simulations of interstellar matter indicate that reality is likely to be more complex that any of these models could indicate. Reality is likely a combination of all three models with active processes leading to strong variations over the sky. The all-sky maps arising from the SPEAR mission will result in a significant increase in our understanding of the global state of interstellar gas.

Interstellar Dust

Dust grains affect energy exchange in the ISM, obscure extragalactic radiation, and catalyze H_2 formation. Dust grains starlight and re-emit the energy at IR wavelengths. However, the majority of FUV photons are scattered. The scattered FUV photons can penetrate deeper into clouds where they have a profound effect on interstellar chemistry (Duley & Williams 1984, Hollenbach 1990). One of the long standing problems in the ISM is the determination of the scattering properties of interstellar dust. Previous measurements have resulted in widely varying estimates of the albedo and scattering phase function. One of the task of SPEAR will be to use measurements of diffuse (scattered) Galactic light to determine these properties. By measuring optically thick lines of site, and performing a full radiative transfer calculation, it should be possible to resolve much of the ambiguity resulting from earlier measurements.

Properties of Superbubbles

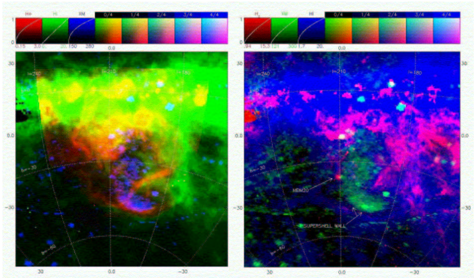

Figure 2. Multiband images of the Eridanus-Orion superbubble. (Heiles, Haffner & Reynolds 1999)

Figure 2 shows images of the Eridanus-Orion superbubble taken at several wavelengths. In the left image, red represents ionized hydrogen at a temperature of $\sim 10,000$ K, green represents neutral hydrogen at temperatures from 100 to several thousand K, and blue represents soft X-ray emission from million degree gas. In the right image, red represents H_2 at a temerature of 10 to 100 K. Taken together, these images show the state of gas from 10K to $10^{6.5}$K, with a gap between $10^{4.3}$K and $10^{5.8}$ K. Much of the interesting physics involving the interaction of the shell with its surroundings involves gas passing through this intermediate temeperature range. The SPEAR bandpass includes multiple emission lines from O III, O VI , O V, O VI , C II, C III, and C IV, spanning the missing temperature range.

Molecular Hydrogen in the Galaxy and Halo

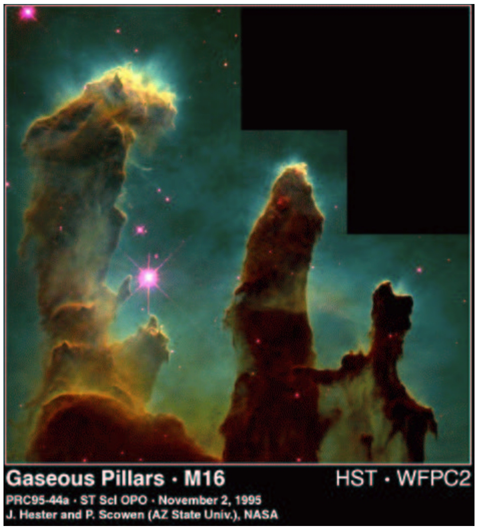

Figure 3. HST image of an H_2 photodissociation region.

Molecular gas, consisting primarily of H_2, plays an important role in flow of matter and energy through the ISM. When concentrated in molecular clouds, H_2 plays a critical role in cooling protostellar regions and gas shocked in cloud collisions, H II regions, and SNRs. A less well understood component of molecular gas is diffuse H_2. FUV absorption measurements from FUSE (Shull *et al.* 2000) have shown that diffuse $H_2$is ubiquitous in the Galaxy. Many questions remain about the life cycle of this diffuse gas and its role in the cycle of energy flow through the ISM. SPEAR will observe fluorescence of H_2excited by the interstellar radiation field. SPEAR's sensitivity to this molecular gas will be unprecedented. For typical values of the FUV radiation field, SPEAR will be able to see quantities of $H_2$with column densities as low as a few times 10^{15} cm^{-2}. The possibility also exists that SPEAR will detect fluorescence of other molecular species such as CO, N_2 , or OH.

Supernova Remnants

There are more than 200 known supernova remnants in the Galaxy (Green 1996). Identification of these SNR has generally been made by radio surveys of the Galactic plane. Any statistical study of the nature of these remnants is therefore limited to those near enough to the galactic plane, and young enough to have sufficient surface brightness to be detected via radio continuum emission. Slavin and Cox (1992, 1993) suggest that there may be a population of old FUV emitting SNR. (See Figure 1, Top). Identifying such remants would be important in understanding the late stage evolution of isolated SNR and their interaction with the ISM. In addition, little is known about the distribution of SNR in the galactic halo. Because of the low ambient density, these SNR should be larger than galactic SNR and persist for longer times. (Shelton 1996) SPEAR spectral imaging will have the sensitivity to identify such remnants.

Shocks in the ISM

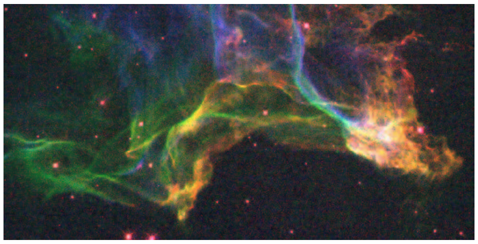

Figure 4. A 3 color HST image of a shock region in the Cygnus Loop. Green represents Hα emission, blue represents [O III] emission, and red represents S IIemission. Each line samples a slightly different temperature region.

Radiative shocks propogating through the ISM the emit FUV emission lines whose intensity depends upon the shock velocity, the density and ionization state of the preshocked gas, and the thermal structure of the post-shock cooling region. (Cox & Raymond 1985, Shull & Draine 1987) The emission lines C IV $\lambda\lambda$ 1550, He II λ 1640, and O VI $\lambda\lambda$ 1035, among others, sample gas temperatures from 50,000 to 500,000 K. This temperature range corresponds to shock velocities between those found in optical filaments ($\sim$100 km/s) and those blast waves that produce X-rays ($>$300 km/s). Study of these emission lines can identify the peak post-shock temperature, and therefore the velocity of the shock responsible for the emission.

Nonradiative shocks are fast ($\sim$200 km/s) shocks that have not developed a complete line cooling layer. Their emission lines, which are created in a thin ionization zone where atoms are energized by impact, are much fainter than thoose in a radiative shock. Since these lines are emitted just behind the shock front, they may provide diagnostics of microphyical processes in the shock region.

Interfaces Between Hot and Cold Gas

Many assumptions are made when modeling the interfaces between hot and cold gas in the galaxy. The interfaces could be regions of energy transport by conduction, or they could be regions of turbulent mixing of hot and cold gas. Does the interstellar magnetic field play an inportant role in determining the properties of an interface? How do non-equilibrium processes change the structure of interface regions? Each of these assumption leads to a prediction of FUV emission line intensities in the boundary regions. SPEAR observations will allow these assumptions to be tested.

REFERENCES

Cox, D., & Raymond, J. 1985 *ApJ*, **298**, 651

Duley, W. & Williams, D. 1984 *Interstellar Chemistry*, (Academic Press:London)

Green, D. 1996 *IAU Conf.*, **145**, 419

Heiles, C., Haffner, L., & Reynolds, R. 1997 *ASP Conf. Ser.*, **168**, 211

Hollenbach, J. 1990, in *Evolution of the Interstellar Medium*, ed: Blitz, (ASP:San Francisco), 167

Korpela, E. 1997 *Ph.D. Thesis*, University of California

McKee, C. & Ostriker, J. 1977 *ApJ*, **218**, 148

Slavin J., & Cox D. 1992 *ApJ*, **392**, 131

Slavin J., & Cox D. 1993 *ApJ*, **417**, 187

Shelton, R. 1996 *Ph.D. Thesis*, University of Wisconsin

Shull, J. M., & Draine, B. 1987 in *Interstellar Processes*, eds: Hollenbach & Thronson, (Reidel Publishing:Dordrecht), 283

Shull, J. M., & Slavin J. 1993 *ApJ*, **427**, 784

Shull, J. M., *et al.* 2000 *ApJ*, **538**, L73

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