Crucial Science to be Accomplished by Proposed SMEX Mission

Summary Words

The proposed SMEX mission represents a significant leap forward in our understanding of the synthesis of galaxies, stars, planets, and life. It will survey the Galaxy in the pivotal neutral and ionic species of C, N, and O that sensitively probe the structure, energy balance, chemical composition, and evolution of the Galaxy and external galaxies. Focused Galactic surveys of interstellar water, the molecule of life, will demonstrate the formation mechanisms, excitation, and critical role that water is expected to play in the sculpting of star forming regions and planet-forming disks. Such large-scale observations are not only important in their own right, and unobtainable by any other observatory, but they also dramatically complement, extend and enhance the interpretation of data from past and contemporary observatories such as SWAS, SIRTF, SOFIA and Herschel. That is, this mission makes the data from existing scientific investments substantially more meaningful and valuable.

Skeletal Outline of Points

- [CII] and [NII] Galactic plane survey: 360 degrees of Galactic longitudinal coverage, ± 2 degrees latitude.

    1. 158 μm [CII] line emission is the dominant coolant of the Galactic interstellar gas, stems from CNM, and WNM, a bit from WIM too. Up to 1% of the far-IR flux comes from this spectral line alone
    2. [NII] 205 μm is unexpectedly 10% as bright, dominated by WIM owing to 14.5 eV ionization energy of N.
    3. COBE FIRAS lacked spectral and angular resolution to clearly demonstrate the physical origins of the mapped emission lines
    4. The origin of these principal C, N, (and O) lines are necessary to interpret the structure of the Milky Way, much less the far-IR photometry and spectra of Galaxies that SIRTF & ALMA will yield
    5. Also pivotal to the interpretation of star formation at early epochs ([CII] emission shifts from SIRTF to ALMA at high-z)
    6. High angular resolution needed to disentangle multiple sources within a single beam, resolve HI structures typically of the order of 1 arcminute or smaller... COBE had a 7 degree beam (at 158 μm?)

7. High spectral resolution is needed to derive kinematical distances and yield a 3D picture of the Galactic C^+. Allows direct comparison with existing HI and CO surveys, especially since [CII] is expected to have the same complicated structure as HI shows in absorption.

- [OI] emission at 63 and 145 μm

1. Major coolant of warm (dense) gas: $n_{crit} \sim 10^5\ \mathrm{cm}^{-3}$ in collisions with H_2. Much lower with just e^-, on the order of a few $\times 10^2$.
2. Along with H_2O, [OI] probes a major repository of gas phase oxygen not bound up in CO.
3. [OI] emission largely stems from shocks and the WNM: structure of protostellar outflows, surfaces of molecular clouds
4. 63 μm emission lies 250K above ground, 145 μm lies 350K up. Measurable emission comes from even cold gas (30-50K), but gas must be at or above $n_{\rm crit}$.
5. Best strategy would be to make somewhat more targeted observations rather than a blind Galactic plane survey.

- H_2O in the Galaxy

1. Water is the molecule of life; puzzles regarding its abundance and excitation in space remain from SWAS
2. 179 μm $2_{12} - 1_{01}$ ortho-H_2O line is bright, ends in same lower state as the SWAS 557 GHz line, excitation energy is about 75K. Seen by ISO.
3. Only Herschel will be able to observe it; no new surveys planned
4. High angular and spectral resolution needed to disentangle self-absorption from a bright 179 μm continuum in some regions
5. Major repository of oxygen in the molecular ISM
6. Interstellar abundance is low; formed and processed on grains in the condensations of protostars. Released into ISM in great abundance when reprocessed.
7. Major gas coolant in protostellar disks and envelopes, plays a role in sculpting their structure
8. Intricate connection of star forming environments to Solar System comets
9. Survey of carbon stars may elucidate the fraction of water-carrying cometary systems around other stellar systems

- Other lines of interest

1. Many other water lines of interest between 1.4-2.0 THz
2. Ground state of CH, H_3O^+; low lying states of OH, CH^+
3. Coarse measurement of continuum

- Connection to other Observatories

1. SIRTF: MIPS 160 μm detector expected to be saturated in the Galactic plane. Last useful array is the 70 μm array. SMEX continuum measurements in the 150-200 μm range will add a vital SED point before ground-based submillimeter bolometer arrays kick in at 350 μm, and more like 870 μm...
2. SIRTF: How does [CII] and [NII] relate to the infrared continuum flux and temperature? How about warm H_2 seen by SIRTF/IRS?
3. AST/RO: Connection of [CII] to existing CO and [CI] surveys
4. SIRTF($z<1$), ALMA ($z>1$): Measurement of [CII] in other galaxies; star formation rates as function of redshift, ISM pressure, galaxy physical and chemical evolution, etc...
5. SWAS: Extend SWAS maps to cover more of the Galactic plane. What is the excitation of o-H_2O? Better estimate of abundances and spatial substructure in the water lines, comparison to CO, [CI]...
6. SOFIA and ALMA: Continuum measurements, [CII] survey, H_2O survey are needed "finder charts" for pointed observations by ALMA and SOFIA
7. etc...