Oral Abstracts:

**Experimental Studies in Laboratory Astrophysics from High z to High Z**
Daniel Savin (9:45-10:15 am)

Our understanding of the cosmos rests on knowledge of the underlying atomic and molecular physics that has shaped the evolution of the universe. Here I will review a selection of experimental studies by my group related to first star formation, AGN winds, the origins of organic chemistry, and more.

**High resolution X-ray spectra and the EBIT**
Eric Silver (10:15-10:35 am)

The X-ray telescopes and spectrometers flown on Chandra and XMM-Newton are returning exciting new data from a wide variety of cosmic sources such as stellar coronae, supernova remnants, galaxies, clusters of galaxies, active galactic nuclei and X-ray binaries. To achieve the best scientific interpretation of the data from these and future spectroscopic missions and related ground-based observations, theoretical calculations and plasma models must be verified or modified by the results obtained from measurements in the laboratory. Such measurements are the focus of several laboratory astrophysics programs that use an electron beam ion trap (EBIT) to simulate astrophysical plasma conditions. Here we describe our recent spectroscopic measurements on the NIST and CfA EBITs.

**Condensed Matter Astrophysics: Determining the Quantity and Composition of Dust in Astrophysical Environments, with X-rays**
Julia Lee (10:35-10:55 am)

High spectral resolution X-ray instruments on powerful X-ray satellites (e.g. Chandra, XMM-Newton) pointed through dust and gas at bright black holes and neutron stars can be used to study dust and intervening material in unique ways. With the new subfield of Condensed Matter Astrophysics as its goal, I will discuss my group's efforts to combine techniques and knowledge from physics disciplines (astrophysics, atomic physics, and experimental condensed matter/solid state physics), geology, and chemistry, to determine the quantity and composition of interstellar gas and dust in the ISM and ionized environments in a way that has not been fully embraced before. Through a combined experimental program at synchrotron beam-lines and space-based X-ray (Chandra and XMM) observations of compact objects, we present initial results based on X-ray absorption studies, and compare with Spitzer IRS studies along the same lines-of-sight to show that these two wavebands are sensitive to different populations of grains. Efforts to provide a database of absolutely calibrated X-ray standards (including stardust samples), and progress, will also be discussed.

**Pressure broadening of alkali-metal resonance lines in the presence of helium or molecular hydrogen**
Jim Babb (10:55-11:10 am)

Calculations and measurements of pressure broadening for the resonance lines of sodium and of potassium in the presence of helium or of molecular hydrogen are summarized. The data are useful for modeling the atmospheres of substellar mass objects.
Evolution of the early solids in the solar nebula: Meteoritic evidence
Michail Petaev (11:10-11:25 am)

The primitive unequilibrated chondritic meteorites consist mainly of materials formed in the first few million years after the birth of the Solar System or in the previous generations of stars. Laboratory studies of these materials provide direct information on their physical and chemical properties and, combined with proper computer modeling, allow physicochemical conditions in their source regions to be evaluated. After a brief review of nebular and presolar materials, I will discuss several examples of my own studies relevant to the evolution of early solids in the solar nebula.

Extended magnetohydrodynamic simulations of laboratory magnetic reconnection
Nick Murphy (11:25-11:45 am)

Magnetic reconnection is responsible for energy release and magnetic topology changes in solar flares, coronal mass ejections, accretion disks, the ISM, the Earth's magnetosphere, and laboratory plasma experiments. Remote sensing investigations of astrophysical reconnection are difficult because very short length scale processes play key roles in energy release. In situ measurements are possible in near-Earth space plasmas but only at the locations of a small number of satellites. Laboratory experiments, however, are capable of investigating both local and global dynamics in a controlled setting. I present extended magnetohydrodynamic (MHD) simulations of the Magnetic Reconnection Experiment (MRX) located at the Princeton Plasma Physics Laboratory. We find that geometric effects control the reconnection rate more than the inclusion of collisionless (two-fluid) effects. Communication between small and large scales contributes to asymmetry in either the inflow or outflow direction, depending on the geometric mode of operation. I conclude with a discussion of the NIMROD extended MHD code which was developed to simulate long time-scale nonlinear behavior in laboratory plasmas but is continuing to be applied to astrophysical situations.

***Lunch Break and Poster Session in the Rotunda***
11:45 am-12:45 pm

Extraterrestrial organic chemistry
Michael McCarthy (12:45-1:05 pm)

The interstellar medium, which less than four decades ago was thought hostile to the chemical bond, is now known to be an astonishingly rich source of both familiar and exotic molecules. A long-term goal of our research effort is to understand the diversity and complexity which arises in this unique chemical laboratory, and the synthetic processes at work there. This talk will describe laboratory efforts now underway in close coordination with radio astronomy to search and discover new astronomical species, and highlight how these new species can be used to improve our understanding of the chemical and physical environments related to stellar evolution. Looking forward, it is clear that new approaches to laboratory astrophysics will be needed as next-generation radio observatories come on-line in the next few years. I will highlight one approach that we and others are developing to tackle this challenging problem.

Laboratory simulations of ice evolution during star formation
Karin Oberg (1:05-1:20 pm)

Complex organic molecules (>6 atoms) have been detected toward low- and high-mass protostars, galactic center clouds, protostellar outflows and comets, demonstrating the existence of efficient astrophysical pathways to prebiotic complexity. The detected molecules all reside in the gas. Yet many probably form on interstellar grains, in ices that evolve with their environment and finally
evaporate as the grains are heated by new-born stars or by shocks. We have explored this ice evolution with laboratory simulations of UV induced ice photochemistry at low temperatures (20-100 K) under ultra-high vacuum. The experiments show that UV irradiation of protostellar ices is efficient enough to explain the complex molecule observations. Moreover, the experiments predict that before the onset of thermal evaporation close to the protostar, small fractions of the complex ice will continuously evaporate non-thermally due to photodesorption, resulting in gas-phase fingerprints of the ice composition as it evolves; a prediction which can be directly tested with current facilities.

**AtomDB v2.0: Updated Atomic Data for X-ray Astronomy**
Adam Foster (1:20-1:40 pm)

Successful analysis of spectra from X-ray observations relies on both on successfully modeling the plasmas involved, and a large integrated database of atomic data underlying these models. We introduce here the first major update to the AtomDB database (www.atomdb.org) since 2001. This database is targeted at optically thin, collisionally ionized hot plasmas. Data for all hydrogen and helium like ions has been expanded to include n shells up to n = 10, allowing for the inclusion of more lines than were previously present. In addition, the data for many of the hydrogen-like and all of the helium like ions of astrophysical interest have been upgraded to R-Matrix calculations for transitions with n ≤ 5. Ionization and recombination data, both dielectronic (DR) and radiative (RR) have been taken from Bryans et al (2006, 2009) to reflect more modern data collections. For recombination to helium and lithium like systems, state-selective DR and RR rates have been used to accurately populate the excited levels of the recombined ions. For many of the less ionized ions, data has been included from CHIANTI 6.0.1 (Dere 2009), replacing the CHIANTI 2.0 data which was in the previous AtomDB release. We outline here not only the changes, but detail the effects of these changes on the calculated spectra, with particular attention to diagnostic line ratios and radiated power, to demonstrate the effect that this will have on observation analysis.

**Atomic collisions in astrophysical plasmas and gases**
Vasili Kharchenko (1:40-1:55 pm)

Collisions between ions, atoms and molecules in the astrophysical environment are considered. Non-equilibrium processes in atmospheres of the terrestrial and extrasolar planets are discussed with focusing on the non-thermal escape and atmospheric evolution. Database on the charge-exchange collisions of solar wind ions with neutral gas and nano-size dust particles and production of the energetic neutral atoms (ENA), X-ray and EUV emissions are briefly reviewed.

**Dielectronic recombination rate coefficients and stability of warm gas in AGN**
Susmita Chakravorty (1:55-2:10 pm)

In this talk I want to illustrate a case where having the 'right' data from the laboratory experiments shows its effects on the results for Quasar astrophysics. Understanding the thermal equilibrium (stability) curve may offer insights into the nature of the warm absorbers often found in active galactic nuclei. Its shape is determined by factors like the spectrum of the ionizing continuum and the chemical composition of the gas. We find that the stability curves obtained under the same set of conditions, but using recently derived dielectronic recombination rates, give significantly different results, especially in the regions corresponding to warm absorbers, leading to different physical predictions. Using the current rates we find a larger probability of having thermally stable warm absorber at 10^5 K than previous predictions and also a greater possibility for its multiphase nature. The results obtained with the current dielectronic recombination rate coefficients are more reliable because the warm absorber models along the stability curve have computed coefficient values, whereas previous calculations relied on guessed averages for the same due to lack of available data.
The HITRAN Database
Larry Rothman (2:10-2:30 pm)

The molecular spectroscopic database, known as HITRAN (HIgh resolution TRANsmission), has been in existence for almost four decades. I will briefly review the history of the development of this spectroscopic archive as it evolved from one that was primarily driven by the need to have a catalog of the main infrared absorbers in the terrestrial atmosphere to the present and future archive that covers many applications including those in astrophysics. HITRAN is the international standard for high-resolution spectral simulations from the microwave through UV, and it involves a program of combining and evaluating both experimental and theoretical determination of spectral parameters of absorption transitions.

Identifying and using advantages and limitations of laboratory and theoretical spectroscopy: H2O and CO2 line lists for HITRAN and HITEMP
Iouli E. Gordon (2:30-2:45 pm)

The HITRAN database is a compilation of spectroscopic line parameters that are being used in a variety of applications including astrophysics. The HITEMP database is a similar database but suitable for temperatures exceeding those in the Earth atmosphere. Both databases are carefully selected amalgamations of theoretically and experimentally determined spectral parameters. In this talk examples of assembling the water-vapor line list for the HITEMP database and carbon dioxide line list for the HITRAN database will be discussed. The pros and cons of theoretical and experimental data and how these data are being combined into high-accuracy reference line lists will be explained.

***Coffee Break and Poster Session in the Rotunda***
2:45-3:00 pm

Laboratory astrophysics needs high-resolution spectroscopy (of metal-poor stars)
Anna Frebel (3:00-3:20 pm)

In order to carry out spectroscopic chemical abundance analyses of stars, atomic data is required for each absorption line to be measured in the spectrum. Only then abundances can be calculated. I will give a brief overview of what is required in terms of atomic data, what is available and where, and how recent improvements have made a significant difference in what we know about the neutron-capture nucleosynthetic history of the Galaxy.

SMA spectral line survey of IRC+10216 in the 345 GHz band
Nimesh Patel (3:20-3:35 pm)

We report a spectral-line survey of the extreme carbon star IRC+10216 carried out between 293.9 and 354.8 GHz with the Submillimeter Array. A total of 440 lines were detected, more than 200 for the first time; 213 are unassigned. Maps at an angular resolution of ~3'' were obtained for each line. A substantial new population of narrow lines with an expansion velocity of ~4 km/s (i.e. ≈30% of the terminal velocity) was detected. Most of these are attributed to rotational transitions within vibrationally excited states, emitted from energy levels above the v=0, J=0 ground state with excitation energy of 1000-3000 K. Emission from these lines appears to be centered on the star with an angular extent of <1''. We use multiple transitions detected in several molecules to derive physical conditions in this inner envelope of IRC+10216.
Primordial atomic recombination and other related calculations
Hossein Sadeghpour (3:35-3:55 pm)

The cosmological ionization history is affected by how hydrogen and helium atoms recombine. The level of precision from the CMB temperature and polarization anisotropies has reached below the 1% level, requiring similar level of accuracy in the calculations of recombination. Atomic recombination processes which lead to the formation of neutral H and He are discussed. Highly-excited Rydberg recombination, also in collisions with electrons and protons, will need to be included. I will also touch upon additional atomic processes which are currently under investigation at ITAMP.

Discussion
Nancy Brickhouse (4:15-5:00 pm)

Poster Presentations (in the rotunda from 11:45 am-12:45 pm and 2:45-3:00 pm):

The Spectrum of the 1/4 keV Band Diffuse Soft X-Ray Background
Richard J. Edgar (SAO), Wilton T. Sanders (NASA/HQ), Jeffrey P. Morgenthaler (Planetary Institute), and Randall K. Smith (SAO)

The spectrum in the 145-284 eV (42-85 Angstrom) band of a portion of the diffuse x-ray sky was obtained in 1993 by the Diffuse X-ray Spectrometer. We compare these data to a model including a computation of the spectra of a few ions due to solar wind charge exchange in the heliosphere, obtaining solar wind parameter ranges by studying the in situ observations at a similar phase in the solar cycle, i.e. in 2003. The one spectral feature which is consistent with an unblended, isolated line is coincident with the hydrogenic oxygen Balmer gamma (n=5 to 2) transition, which should be strongly pumped by charge exchange.

Measurements of Electron Impact Excitation Cross Sections Using Inclined Beams at the Harvard-Smithsonian Center for Astrophysics
Richard E. Rosati, Larry D. Gardner, Nigel Atkins, and John L. Kohl

The analysis of absolute spectral line intensities and intensity ratios with spectroscopic diagnostic techniques provides empirical determinations of chemical abundances, electron densities, temperatures and outflow velocities in astronomical objects. Since spectral line intensities and their ratios are often controlled by the excitation rate coefficients for the electron temperature of the observed astronomical structure, it is imperative that one have accurate values for the relevant rate coefficients. Here at the Harvard-Smithsonian Center for Astrophysics, we have been carrying out measurements of electron impact excitation (EIE) for more than 30 years. We will illustrate our experimental approach in the context of EIE in C^{2+} (2s^2 \ ^1S_0 \rightarrow 2s2p \ ^1P_o) for which we have confirmed a signal and have just begun to collect data. The technique employed utilizes a modulated beam of a single ion species which is crossed at 45 degrees with a similarly modulated electron beam. Photons from the decay of ions excited by collisions with the electrons are collected synchronously with the beams' modulation pattern by an absolutely calibrated optical system. Since the wavelength of 977 \ Å decay photons is below the cutoff of commonly available transmitting materials, our new detection system utilizes a windowless microchannel plate detector together with a spherical mirror coated with Al/MgF_{2}/B_{4}C layers. The new microchannel plate detector and new mirror have been thoroughly calibrated at the wavelength relevant to this experiment and at wavelengths relevant to forthcoming measurements. Suitable filters are inserted into the photon detector system to limit the optical bandpass, when necessary, to reject unwanted wavelengths. An improved ion beam disposal scheme has been implemented to greatly reduce elevated background levels, attributed to high energy neutral atoms, that are detectable with the windowless detector.
ProtoEXIST: Advanced CZT Detector Development for Wide-field Hard X-ray Imaging
Branden Allen, J. Hong, J. Grindlay, CfA, S. Barthelmy, R. Bakeer, GSFC

The ProtoEXIST program is dedicated to the development of a scalable, redundant and robust architecture for a large (2-4 m²) CdZnTe (CZT) detector plane for use in astrophysical imaging with wide-field (>80 x 80deg) coded aperture imaging of GRBs, AGN, and other high energy phenomena over the band ~5-600 keV. Redundancy and scalability are achieved through use of individual 2 cm x 2 cm x 0.5 cm CZT crystals each bonded directly to an ASIC to comprise a single detector crystal unit (DCU), which are close-tiled (~0.5 mm gaps) into a single imaging detector plane. On Oct. 9, 2009, the first phase of ProtoEXIST utilizing a 8 x 8 array of DCUs with the RadNet ASIC, each with 8 x 8 pixels, culminated in a successful balloon flight with a single 256 cm² detector plane which imaged the galactic black hole binary Cyg X-1 (see Hong et al). Detector development continues with the introduction of the NuSTAR ASIC enabling a finer 32 x 32 pixel array on each individual DCU for ProtoEXIST2. I discuss the system architecture as well as ongoing studies of the ProtoEXIST1 detector plane and individual DCUs. I then introduce the ProtoEXIST2 detector and current innovations for its future development.

First high altitude balloon flight of Wide-field Hard X-ray Telescope ProtoEXIST1 with advanced CZT imaging detectors
Jaesub Hong, B. Allen, J. Grindlay, (CfA), T. Garson, H. Krawczynski (Wash. Univ.), S. Barthelmy, N. Gehrel (GSFC)

We carried out the first (and successful) high altitude balloon flight (~131,000 ft) demonstration of the wide-field hard X-ray telescope ProtoEXIST1, launched from the NASA balloon launch facility at Ft Sumner, New Mexico on October 9, 2009. ProtoEXIST1 is the initial phase in a series of experiments designed to develop a large array of advanced CZT imaging detectors needed for the next generation wide-field hard X-ray imaging survey telescopes (e.g. EXIST, as proposed to Astro2010, which is still urgent as a future MIDEX or Probe class mission). ProtoEXIST1 consists of a close-tiled 16 x 16 cm (256 cm²) imaging array of CZT detectors (2.5 mm pixel) which read out a 1024 cm² Tungsten mask, with passive side shields and a rear Active shield. The detector plane is at least a factor of four larger than any previous fine pixel contiguous CZT detector system. Although the balloon flight lasted only about 7 hr due to strong winds at the 3mb float altitude, the imaging hard X-ray (30-600 keV) detector and 20 x 20 deg coded aperture telescope performed flawlessly during the flight. We detected Cyg X-1 during a ~1 hour observation of the source (of which only the final 10min were stable inertial pointing). In this talk, we will review the telescope design, detector development, and the overall flight performance and unique imaging data (e.g. charged particle rejection) recorded.

Weak equivalence principle test on a sounding rocket, SR-POEM

The weak equivalence principle (WEP) is an essential postulate of general relativity and is assumed implicitly in cosmology and astrophysics. Thus, it is critical to our understanding of such diverse phenomena as black holes, quasars, the events of the early universe, the expansion of the universe, and gravitational radiation. SR-POEM, our WEP measurement on a sounding rocket, will compare the free fall rate of two substances yielding an uncertainty of 10⁻¹⁶ to 10⁻¹⁷ in eta, the estimate of fractional gravitational acceleration. During the past two years, the design concept has matured and we have been working on the required technology, including a laser gauge that is self aligning and able to reach 0.1 pm / rt Hz for periods shorter than 40 s. I will describe the status and plans for this project.