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Atomic Data Needs for X-ray Astronomy

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Abstract. With the launches of the Chandra X-ray Observatory and XMM-Newton, high resolution X-ray spectra of cosmic sources are broadening our understanding of the physical conditions, such as temperature, density, ionization state, and elemental abundances. X-ray emitting astrophysical plasmas can be generally classified by their dominant ionization mechanism, either collisional ionization or X-ray photoionization. The atomic data needs are significantly different for these two cases; however, for both cases it is important that we identify robust and accurate diagnostics and that we verify completeness of the broadband models. We discuss the status of the atomic data currently used in atomic databases for X-ray astronomy, in view of theoretical and experimental atomic physics considerations.

1. X-ray Spectral Modeling

The new generation of X-ray satellites are producing images and spectra of unprecedented resolution, bandpass and effective area. With the new opportunities to study high energy plasma processes under a wide range of physical conditions comes the challenge to develop appropriate models.

Many high energy sources emit a very strong continuum from one or more processes, including synchroton radiation, Compton scattering, and bremsstrahlung. Additionally, line emission may arise in both collisionally ionized and X-ray photoionized plasma, while intrinsic and interstellar absorption may produce lines as well as spectral edge features. Lines are produced in collisionally ionized plasma predominantly by the process of electron impact excitation from ground state and low-lying metastable levels, while X-ray photoionization may produce lines via the recombination cascade.

Most spectral models of high energy sources invoke numerous simplifying assumptions which may or may not prove valid when confronted with more detailed observational data. For example, time-dependent effects on the spectra are generally ignored, even though many astrophysical plasmas are known or suspected to be far from ionization equilibrium. Furthermore, plasmas are generally treated as optically thin, an assumption which may not hold for some of the brightest spectral lines. The breakdown of the simplifying assumptions is not necessarily bad news: time-dependent and optical depth effects can provide diagnostic information on heating, cooling, dynamics, scale sizes, magnetic confinement, and other physical processes of great interest. The key to exploiting this rich complexity lies in accurate atomic data in a comprehensive database.

1.1. Line Ratio Diagnostics: Fe XVII

Ne-like Fe XVII emission, formed over a broad range of temperatures, includes the strongest emission line in the solar X-ray spectrum. This ion provides a potential wealth of diagnostic information on the temperature, density, and scale sizes of the plasma (e.g. Schmelz et al. 1997), yet line ratios calculated by various methods can vary by 50%, leading to large errors in the quantities to be determined. Recent laboratory measurements disagree with most theoretical values, suggesting problems in our understanding of the atomic processes of this system (Brown et al. 1998; Laming et al. 2000).

1.2. Global Models: Abundances in Elliptical Galaxies

Broadband models of optically thin plasma in collisional ionization equilibrium are fit to moderate resolution ($\Delta E/E \sim 10$) X-ray spectra to determine the temperature and composition of the hot gas. Abundances determined for elliptical galaxies seem at odds with our understanding of galactic evolution (e.g. Arimoto et al. 1997), leading to the suggestion that the models for the Fe L-shell emission were in need of revision. Brickhouse et al. (2000) found from an examination of these models for the bright X-ray binary Capella, that the models were indeed inadequate, lacking emission lines from high-lying Rydberg levels ($n > 5$) and leading to a low determination of the line-to-continuum ratio.

2. Conclusions

While some outstanding issues in spectral modeling are being resolved by laboratory experiments and comparisons with well understood astrophysical plasmas, the models remain largely untested. Analysis of new data from Chandra and XMM-Newton will require experimental confirmation of such data as photoabsorption edge energies, dielectronic recombination rate coefficients, and electron impact collision strengths, as well as better models of key atomic processes.

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