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Characterizing charge state distributions in Si and Fe photoionized plasmas to test high density effects in astrophysical code XSTAR

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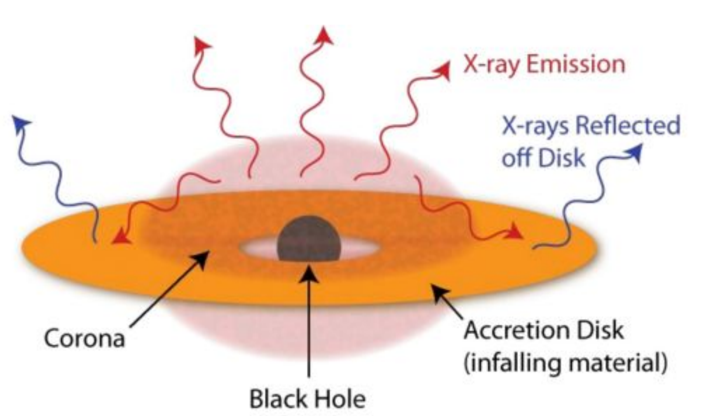
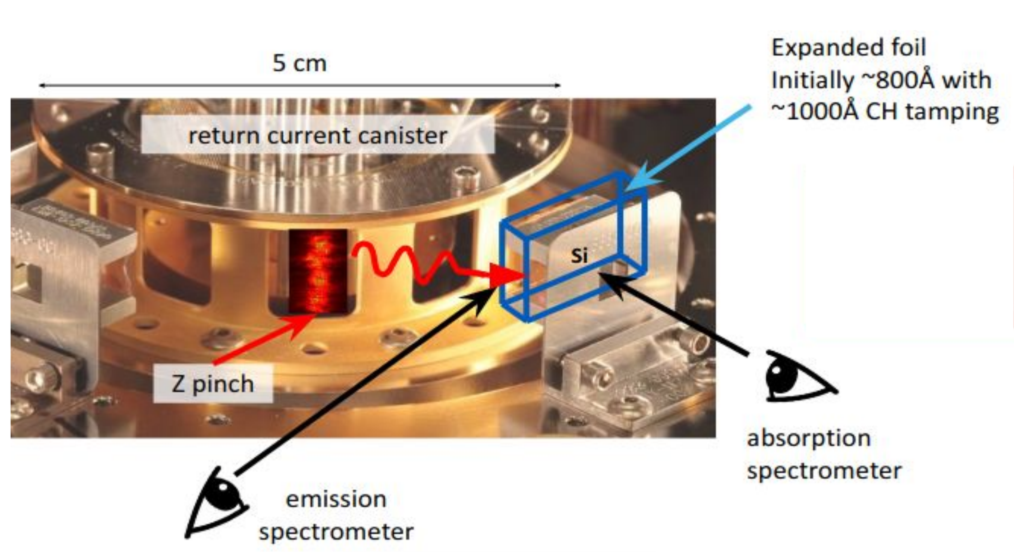
The Supersolar Fe Abundance Problem

- Black hole accretion disks reflect radiation emitted by the corona.
- Fits to the reflection spectra observed in AGN's and x-ray binaries predict very high Fe abundances, often inconsistent with results from stellar evolutionary theory.

Pictorial representation of how reflection spectra are created.



- The astrophysical codes used to fit these spectra reference atomic data that has not been fully benchmarked against laboratory results.
- **The photoionized plasmas experiment at Z provides a platform to observe plasmas in regimes (n_e, T, ξ) relevant to these astrohpysical conditions.**



Experimental setup for the photoionized plasmas experiment.

Validating XSTAR's High-Density Effects

- The supersolar Fe abundance predicted by the models may stem from upper limits on n_e.
- New high-density physics has been incorporated into the astrophysical code XSTAR.
- Photoionization routines from XSTAR are used to set the thermal and ionization balance within XILLVER

Fitting PrismSPECT ATBASE Opacities to a Transmission Spectrum

$$\frac{\kappa_\nu}{\rho} = \frac{\pi e^2}{mc}\frac{N_A}{M} f_l f_{l\to u}\phi_\nu \to X_\nu \equiv \frac{M}{N_A f_l}\left(\frac{\kappa_\nu}{\rho}\right) = \frac{\pi e^2}{mc} f_{l\to u}\phi_\nu$$

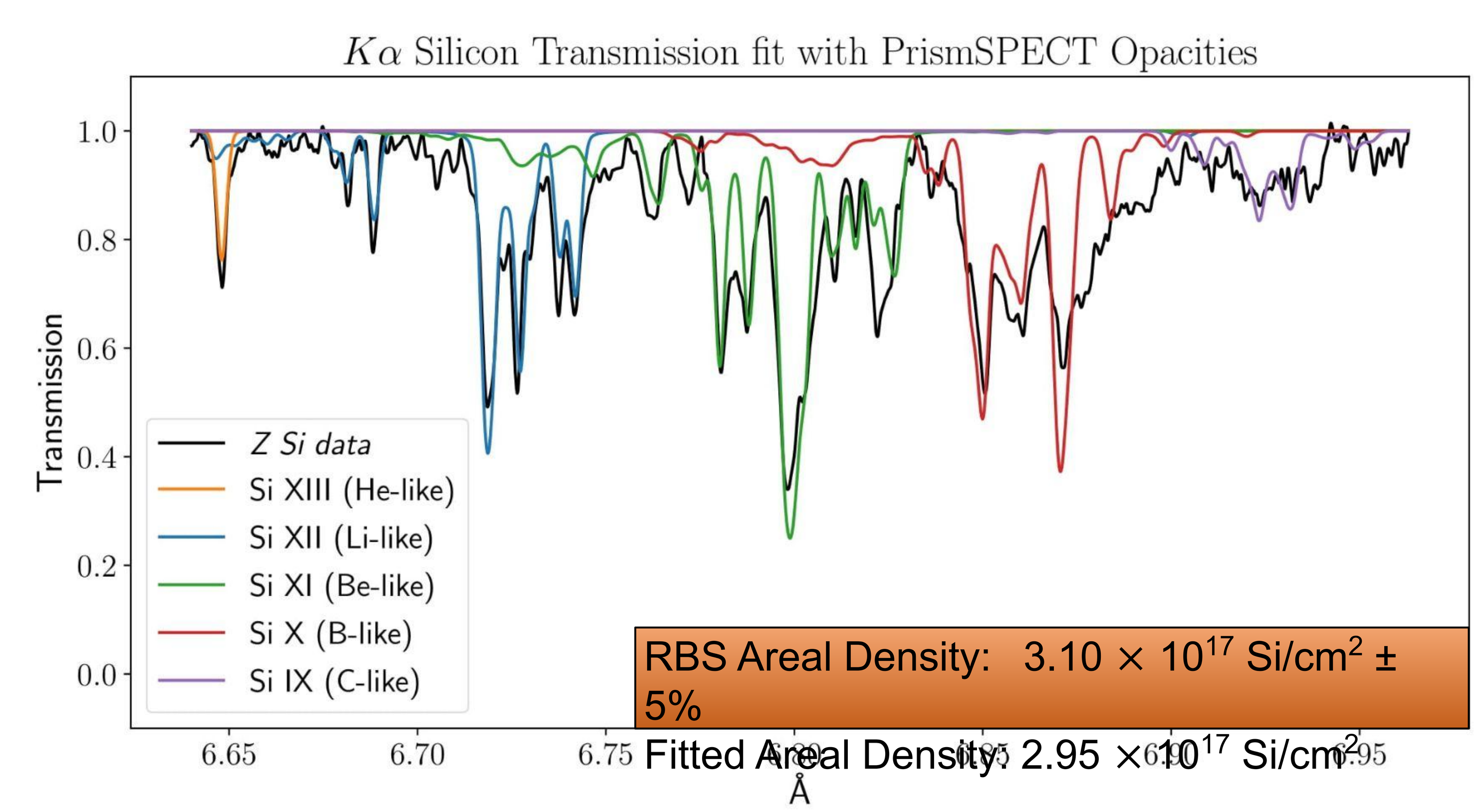
$$T_\nu = \exp\left[-\sum_i X^{\text{prism}}_{\nu,i} \times nl_i\right] \qquad \frac{\lambda}{\delta\lambda} \sim 2400$$

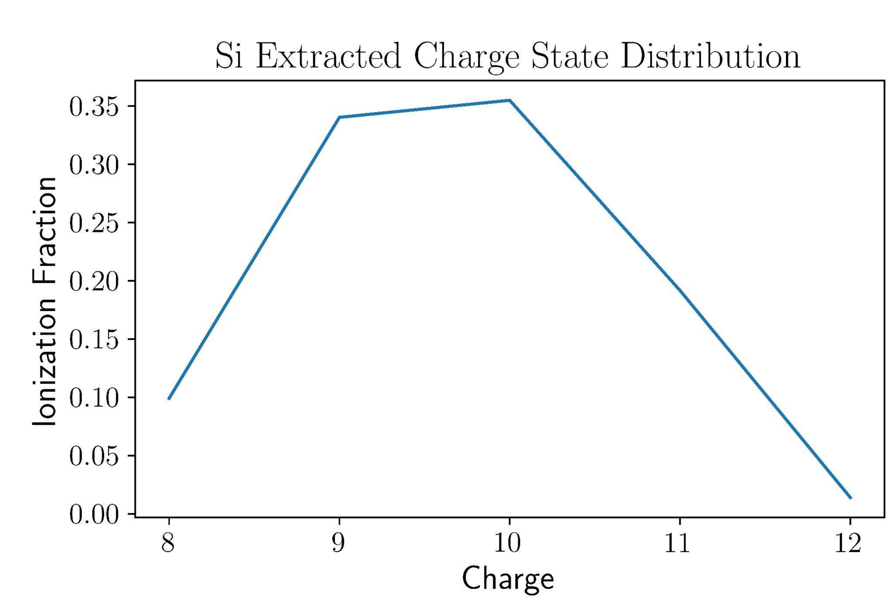
Fit parameters

- X_ν [cm^2] is an opacity "cross-section": it is independent of plasma parameters *except* for the line shape term ϕ_ν.
- Using the X_ν quantities obtained from PrismSPECT for each ion of interest, we calculate the transmission T_ν.
- We use a broadening profile consistent with the resolution of the spectrometer.
- We perform a χ^2 minimization fit to find the areal densities for each ion.

Preliminary Fit to Silicon Transmission Data

- The Si transmission spectrum was obtained by averaging data across several shots.
- The manufacturer of the Si foil provides an areal density measured with Rutherford Backscattering (RBS).
- **The total areal density returned by the fit shows good agreement with the RBS value.**

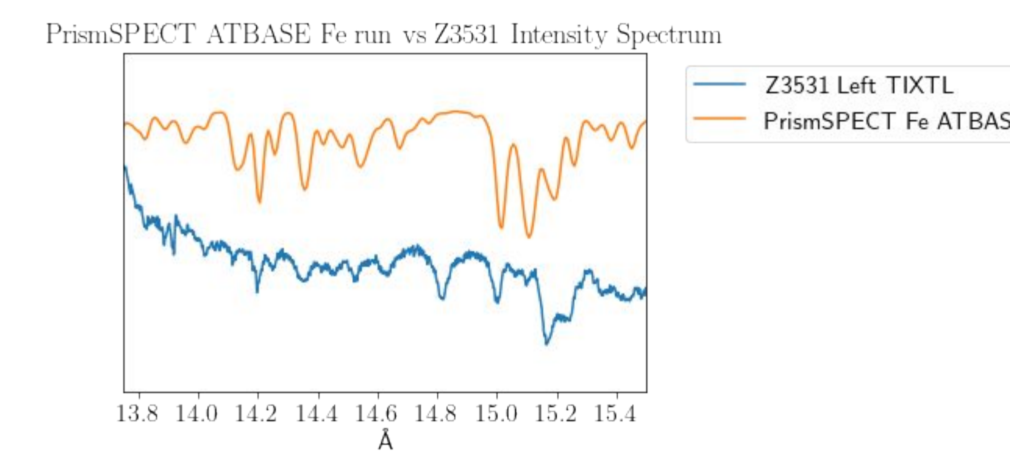




- **Average Z ~ 9.7.**
- This is a lower average Z than previous calculations from XSTAR without high-density effects
- A less ionized charge state distribution would suggest recombination is a dominant process.

Fitting to Fe Transmission and Comparing to XSTAR

- Fe absorption data contain many more features in the spectrum and are mixed in with O lines.
- The backlighter spectra can be difficult to process: there are few features with which to perform the wavelength dispersion accurately.
- An initial attempt to fit charge state spectra to the Fe absorption data yields a similar areal density to the RBS value.



Acknowledgements

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