Resolving emission lines of sodiumlike Fe XVI using EBIT

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Abstract

High resolution crystal spectrometers on sounding rockets and orbiting satellites, such as the Solar Maximum Mission, show strong X-ray emission from the n= 3 to 2 transitions in neon-like Fe XVII. **Two of the strongest lines** are the 3d to 2p resonance and inter combination lines at **15.01 Å (3C) and 15.26 Å (3D)**.

Intensity ratios of these solar lines range from ~ 1.6 to 2.8. The lower ratios are a result of a line from Na-like Fe XVI inner shell satellite line **blending** with the Fe XVII inter combination line, 3D. The wavelength of the Na-like line is not known.

Here we present the results of the first attempt to measure this wavelength using **LLNL's electron beam ion trap EBIT-I** together with a vacuum crystal spectrometer. The crystal spectrometer employs a beryl crystal for dispersion.

X-rays from the Sun

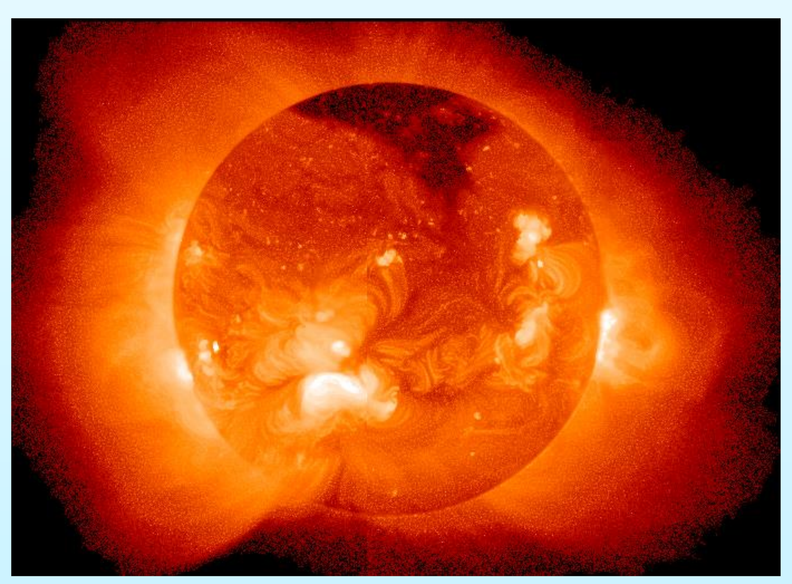

Figure 1. The Sun in the X-ray band.

- Strong X-ray emission is produced in the **corona** of the Sun.
- Fe^{16+} produces some of the **strongest X-ray emission**.

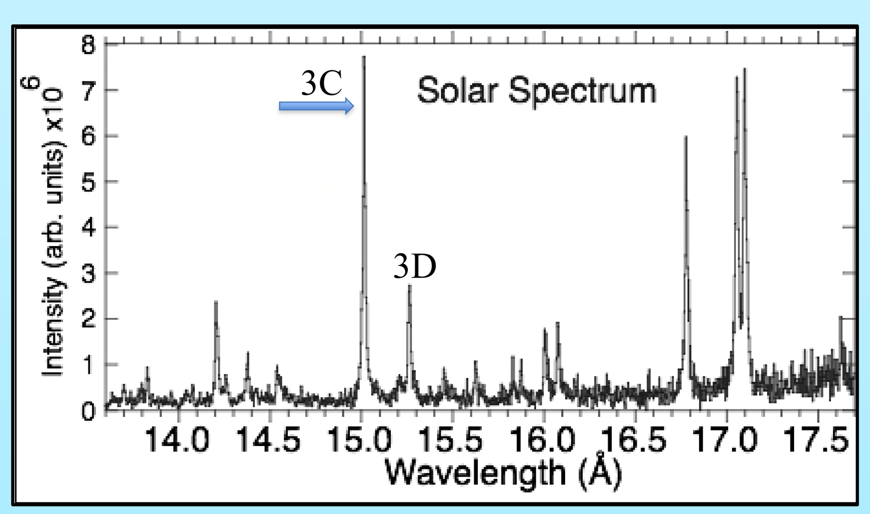

Figure 1. a high resolution spectrum, 10-18 Å wavelength band

- Figure 2 is a spectrum measured by the Solar Maximum Mission in the 1980s. Note the strong emission from Fe XVII **lines 3C and 3D**.

Components of the Experiments

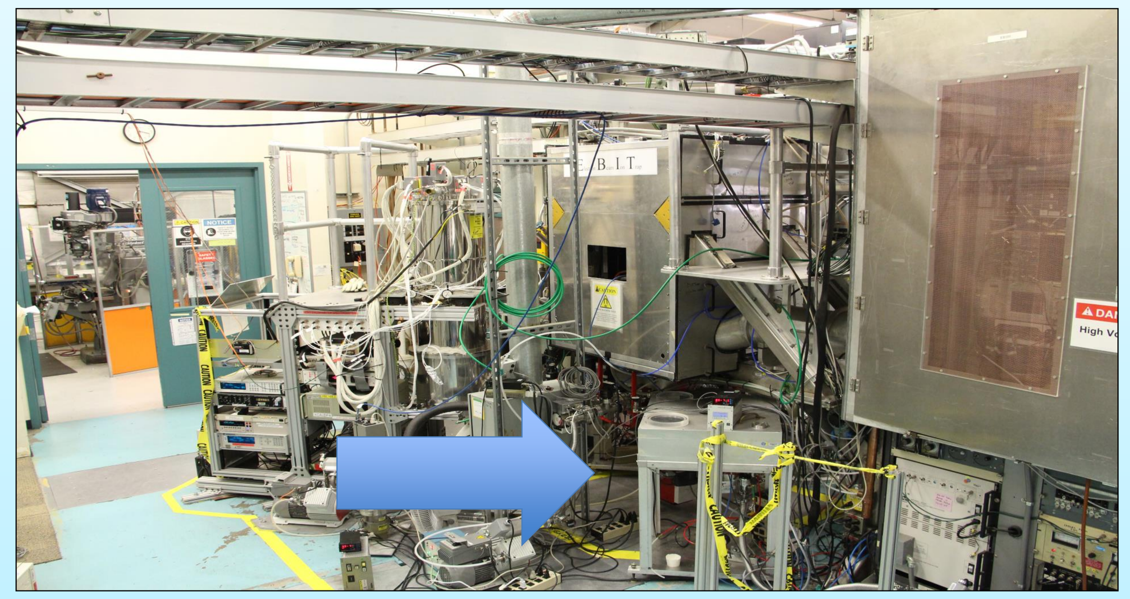

Figure 3. EBIT configuration. The arrow points to the Beryl-Crystal Bragg Spectrometer.

- As shown in Figure 3, a vacuum crystal spectrometer employing a **beryl crystal** (2d= 15.954 Å) for dispersion was used.

- X-ray emission from trapped Fe^{15+} and Fe^{16+} ions are dispersed by the beryl crystal according to **Bragg's law**, $n\lambda = 2d\sin\theta$, where n is the order of diffraction, λ is the wavelength, d is the atomic spacing of the crystal, and θ is the angle of incidence.

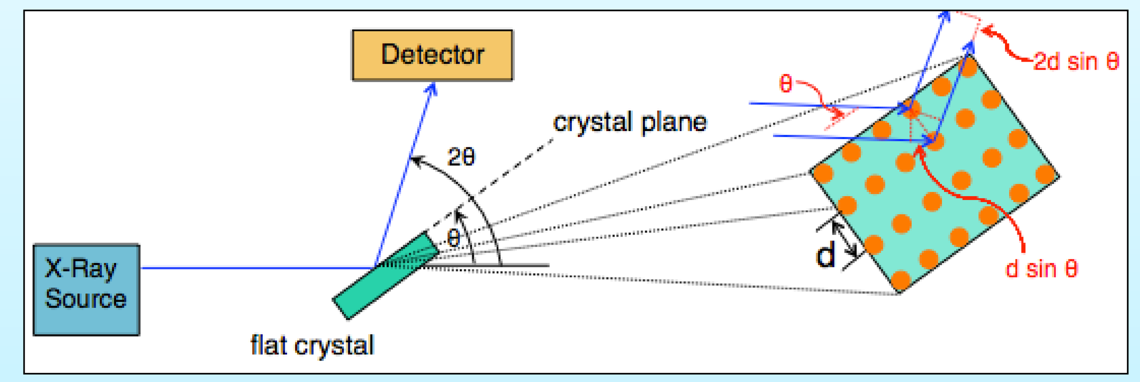

Figure 4. Cartoon of the source, crystal, and detector arrangement used in this experiment.

- Figure 4 represents the experimental setup.

- The estimated **resolving power** of the beryl crystal operating at near normal incidence is $\lambda/\Delta\lambda \sim 2500\text{-}3000$. The exact resolving power of our sample is not known.

- A gas-filled **position-sensitive proportional counter** (PSPC) was used to detect the diffracted X-rays.

Experimental Results:

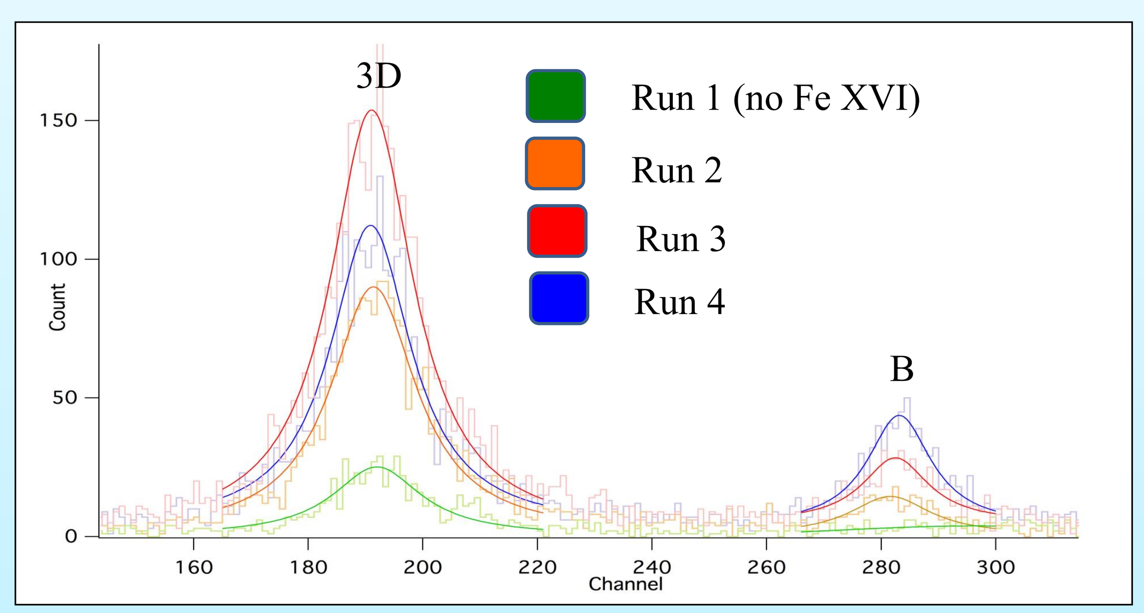

Figure 5. Shows the spectrum measured using the beryl crystal and at 4 different amount of Fe^{15+} in the trap. Run 1 has no Fe^{15+}

- As shown in Figure 5, the Fe^{15+} inner shell satellite line was **not resolved** from the Fe^{16+} line 3D.

- The **spatial width** of the lines measured by the detector is equal to it's **spatial resolution**.

- To determine if the Fe^{15+} line is not completely resolved but **still affects the centroid** of the 3D feature in this setup, we increased the amount of Fe^{15+} in the trap and looked for a shift in the centroid of line 3D relative to line B.

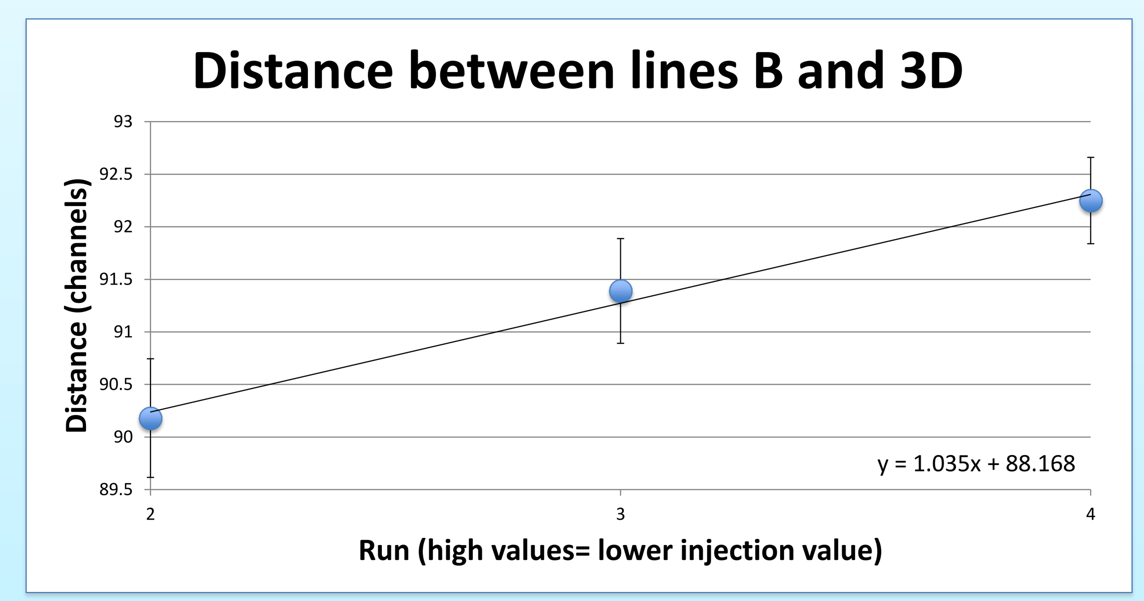

Figure 6. The distance between the B and 3D centroids. Only runs 2-4 are included.

- Figure 6 gives the distance between lines 3D and line B versus relative amount of Fe^{15+} versus Fe^{16+}.

- As more Fe^{15+} is present, the **spacing** between lines 3D and line B **increases**.

- This indicates that the Na-like Fe^{15+} line is on the high wavelength side of line 3D, i.e. its **wavelength is larger than line 3D.** This is consistent with calculations using the Flexible Atomic Code (FAC) which predicts 15.263 Å.

Conclusion:

Ultimately, the Na-like line was not resolved from the 3D line. It was discovered during the process of this experiment that the width of the spectral lines measured in this experiment equals spatial resolution of the detector so the resolution may mot be limited by the crystal. To confirm this, an **X-ray CCD is being installed** and used for detection. The CCD has a spatial resolution that is approximately 10 times better than the PSPC. Once installed, it is expected that the resolution of the instrument will only be limited by the beryl crystal.

Impact:

In celestial sources, line emission from different ions of iron and ions of other astrophysically relevant elements are often blended together. EBIT makes it possible to systematically study the line emission of a single ion. Once the spectra signature of an ion is known, emission from the ion can be identified in the spectra from celestial sources.

High resolution spectrometers are already being flown on orbiting X-ray observatories such as the Chandra and XMM-Newton. Although these instruments do not have sufficient resolving power to resolve the Fe^{15+} line from 3D, the presence and strength of the Fe^{15+} line needs to be known to properly model spectra from celestial sources.

Future missions, such as the Advanced Telescope for High Energy Astrophysics (ATHENA), will carry spectrometers with resolving powers high enough to potentially split Fe^{15+} line from the Fe^{16+} line 3D.

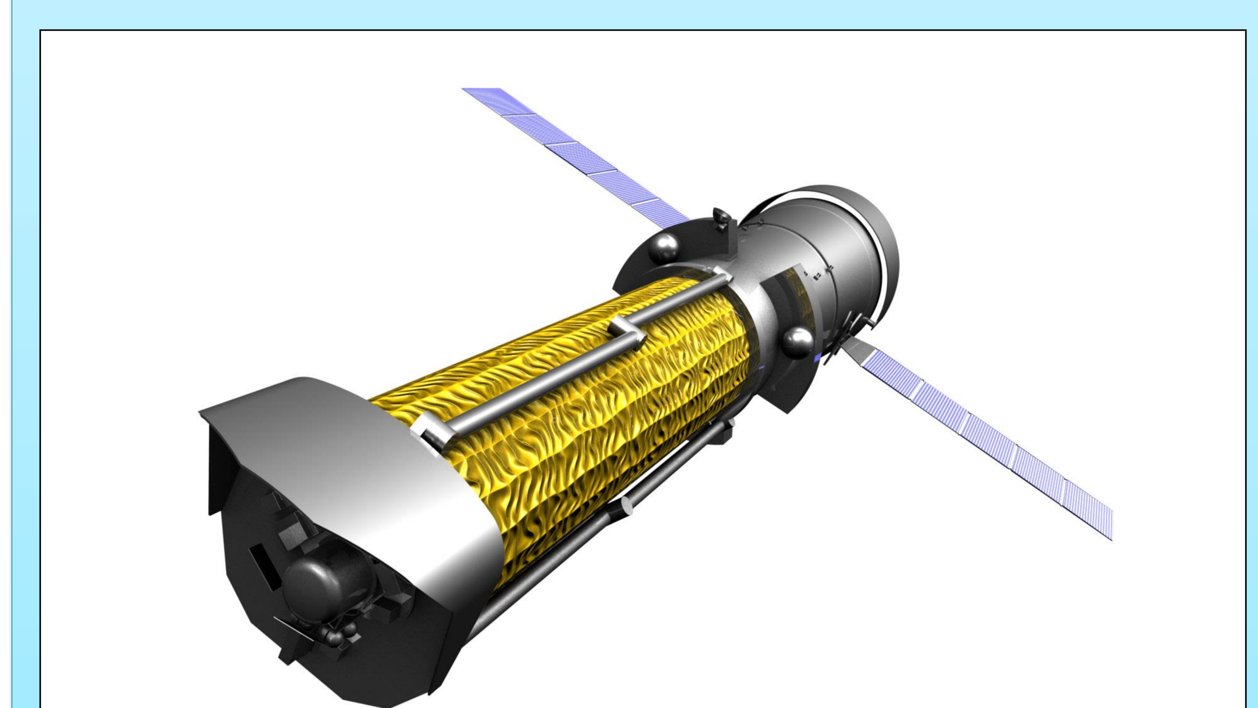

Figure 7. The ATHENA X-Ray observatory.

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