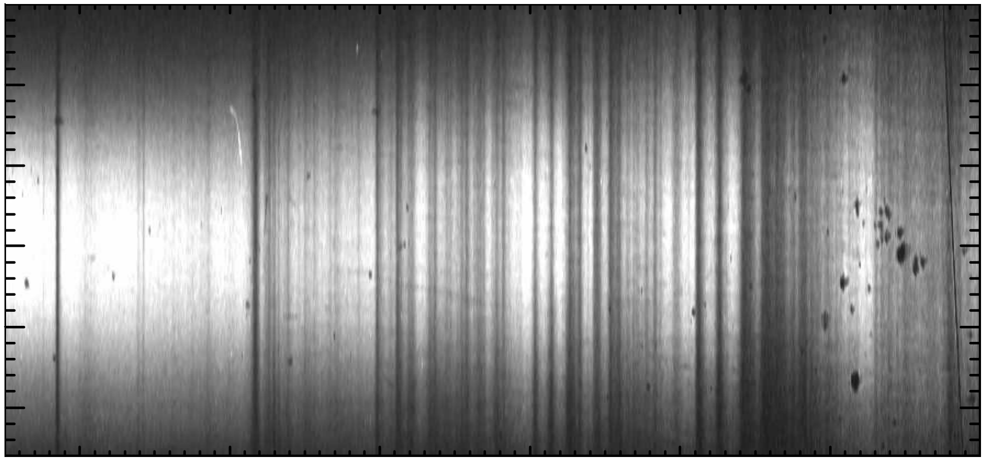
SAND2006-7343C

High energy density plasma spectroscopy at the Z facility

20 Years of Spectroscopy with EBIT

Berkeley, California

November 14, 2006



L shell Fe absorption

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
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NNSA National Nuclear Security Administration

Sandia National Laboratories

Many people contribute to this work

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M. Bump, O. Garcia, L.B. Nielsen-Weber, and T.C. Moore {K-Tech Corp., Albuquerque, New Mexico}

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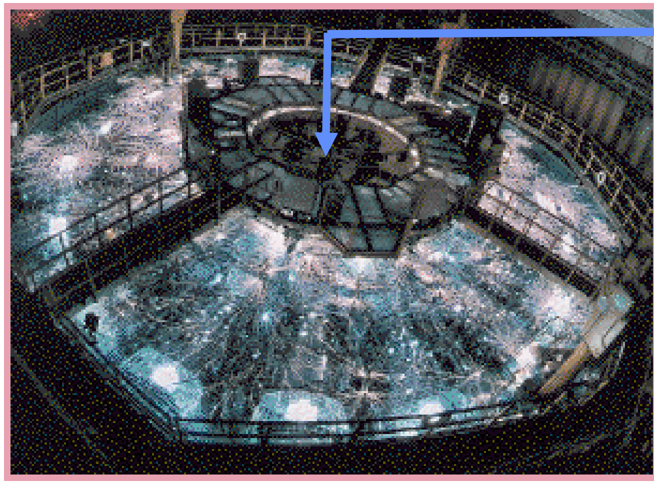
Z experiments probed a broad variety of plasmas with emission or absorption spectroscopy

- Z-pinch
- Dynamic hohlraum
- Capsule implosions
- Opacity measurements

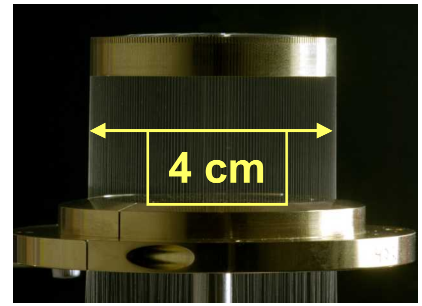
EBIT measurements have supported this work by line identification and wavelength measurements. Exploitation of transition probability and polarization effects should strengthen future research.

Z experiments implode plasmas with 20 million Amp current

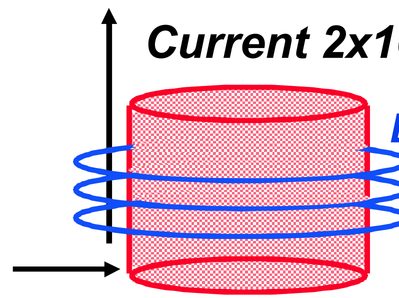
Z accelerator



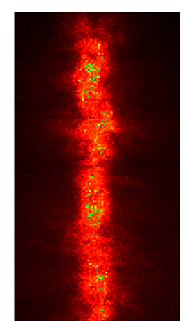
40 m



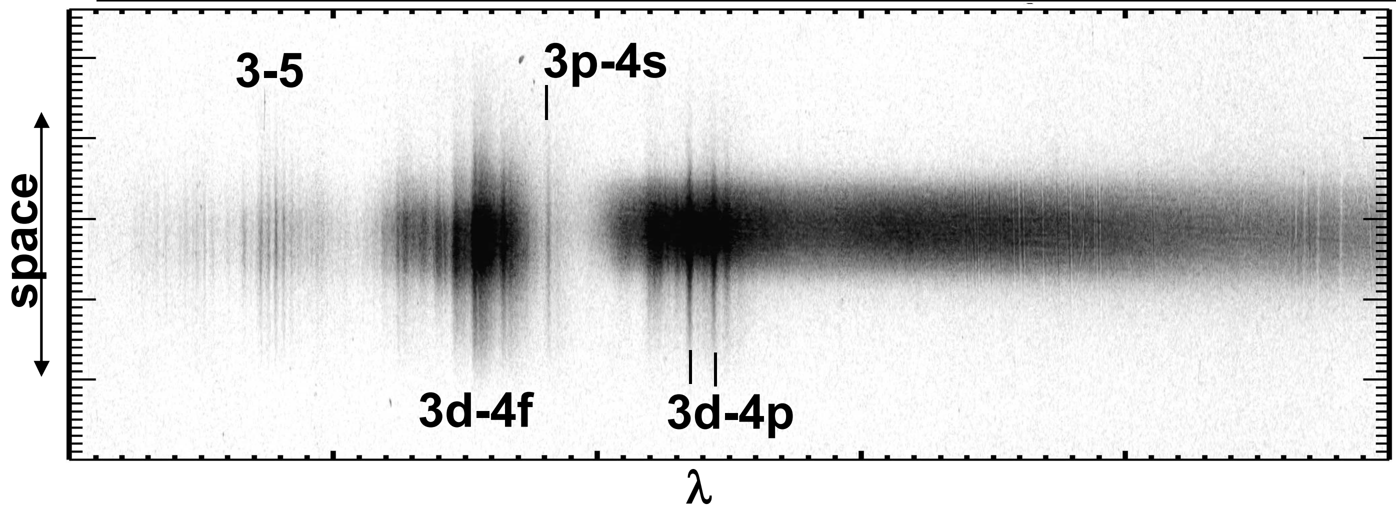
tungsten wire array



X-ray image



Tungsten plasmas emit > 200 TW of x-rays, but radiation processes are not completely understood

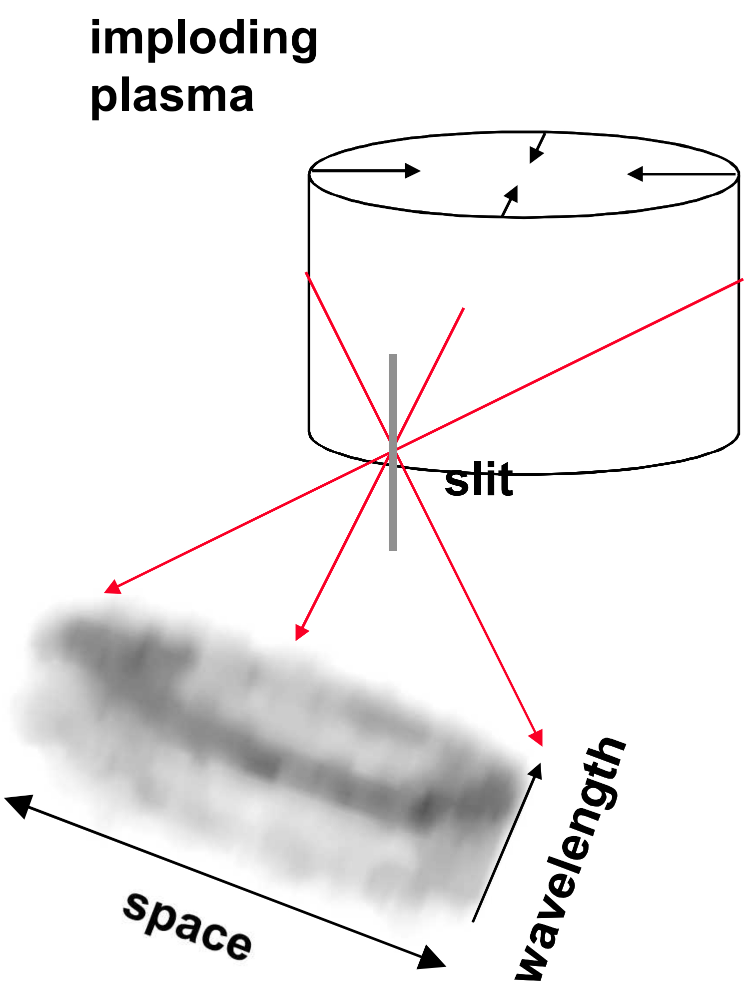


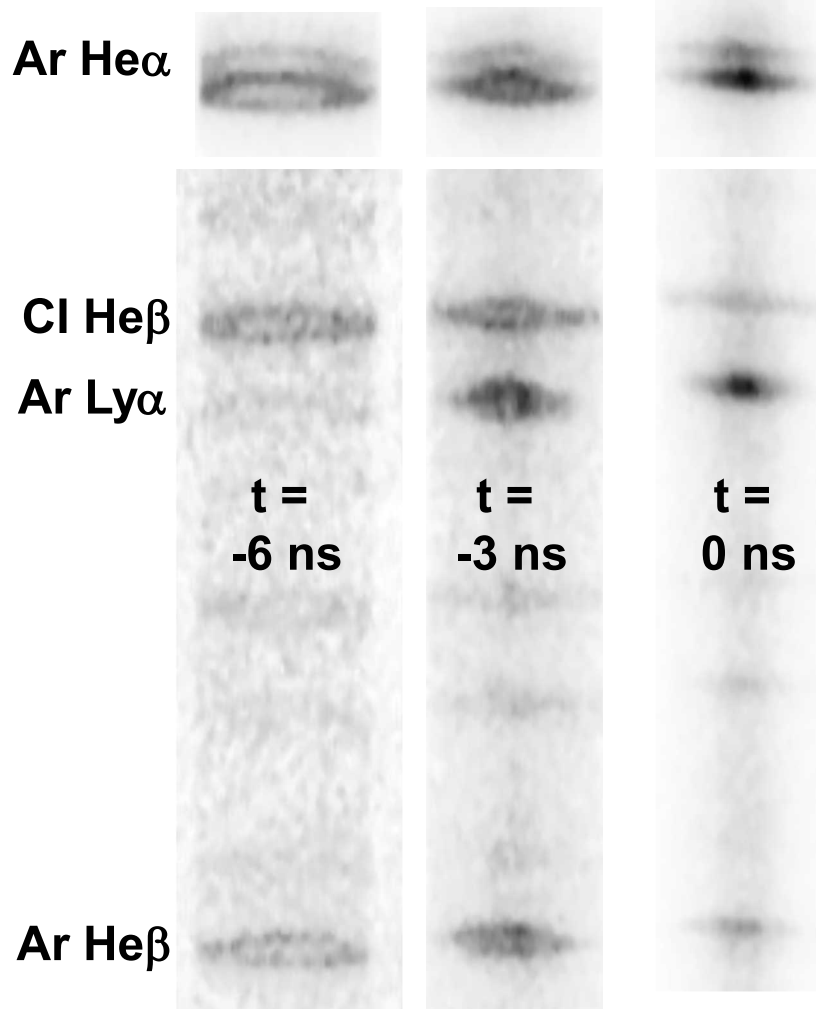
space-resolved time-integrated spectrum

- **One outstanding puzzle is that x-ray energy exceeds pinch kinetic energy.**
- **Spectroscopy can help solve this problem**
- **First we must identify the lines!**

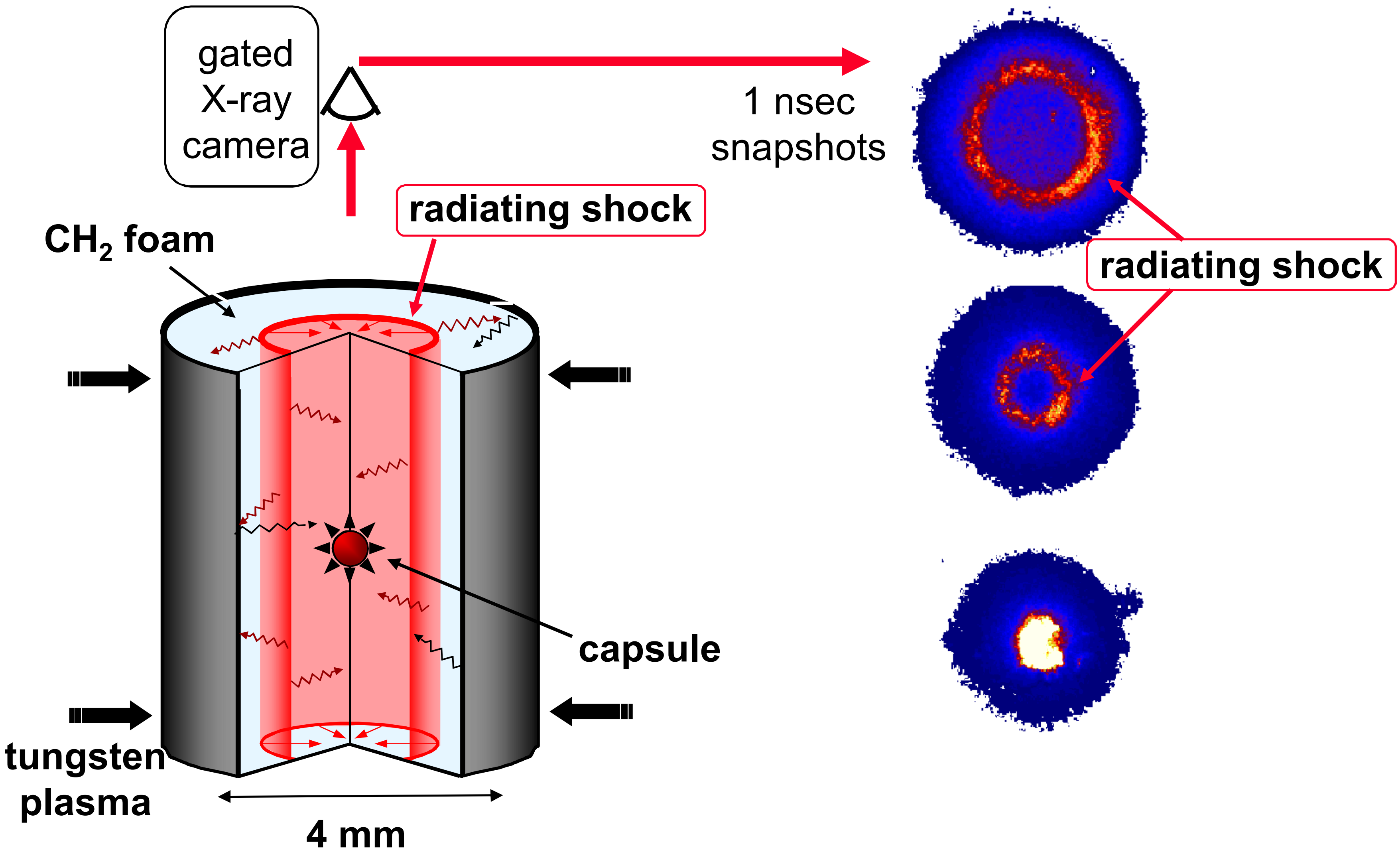
<u>Then apply:</u>
Tomographic spectroscopy
Polarization spectroscopy

Doppler-shifted line emission may help understanding of kinetic energy thermalization

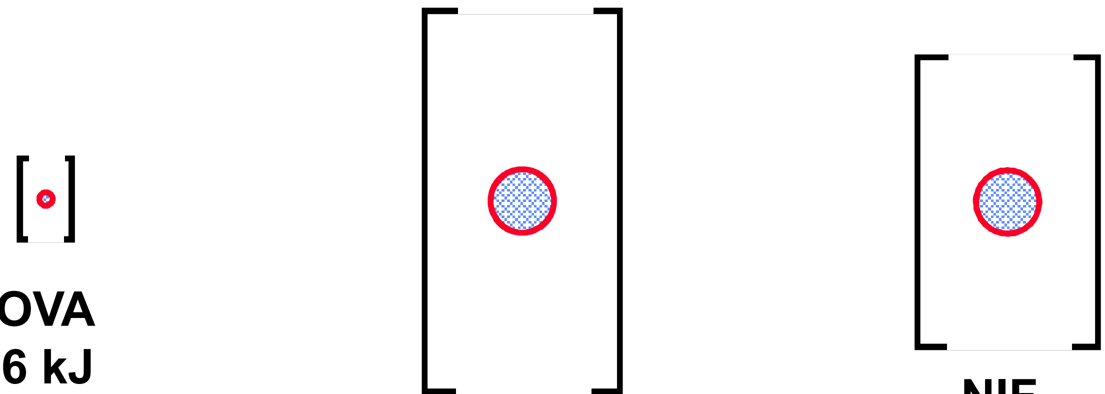




Dynamic hohlraum radiation source is created by accelerating a tungsten plasma onto a low Z foam



Dynamic hohlraums are interesting because they couple large x-ray energy to implode capsules



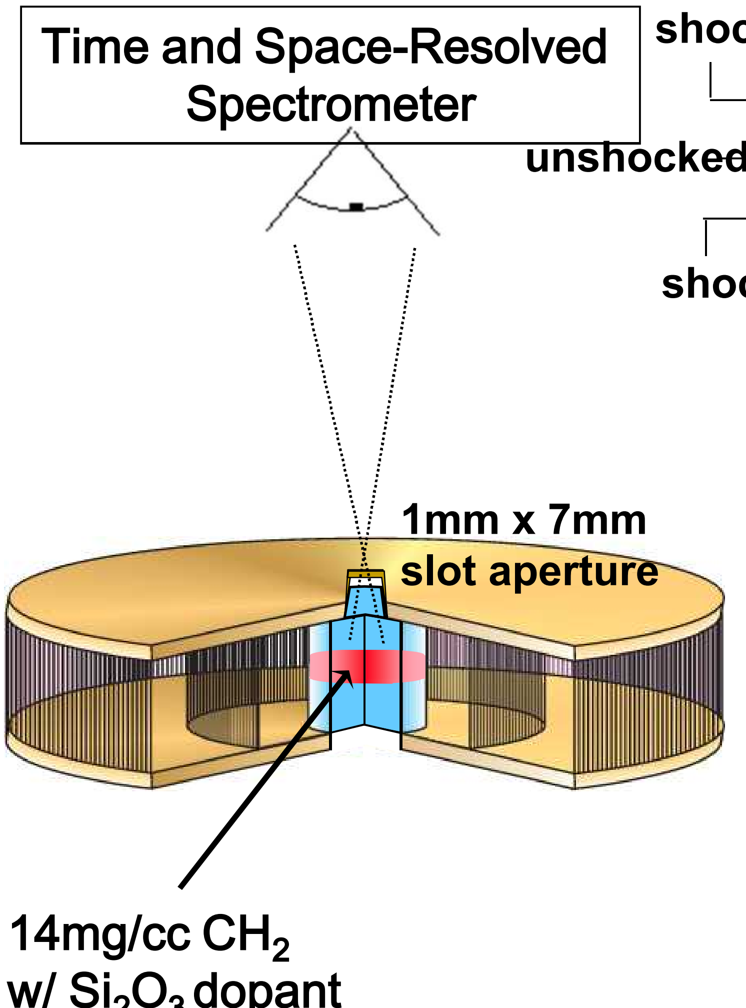
NOVA
1.6 kJ
0.44 mm

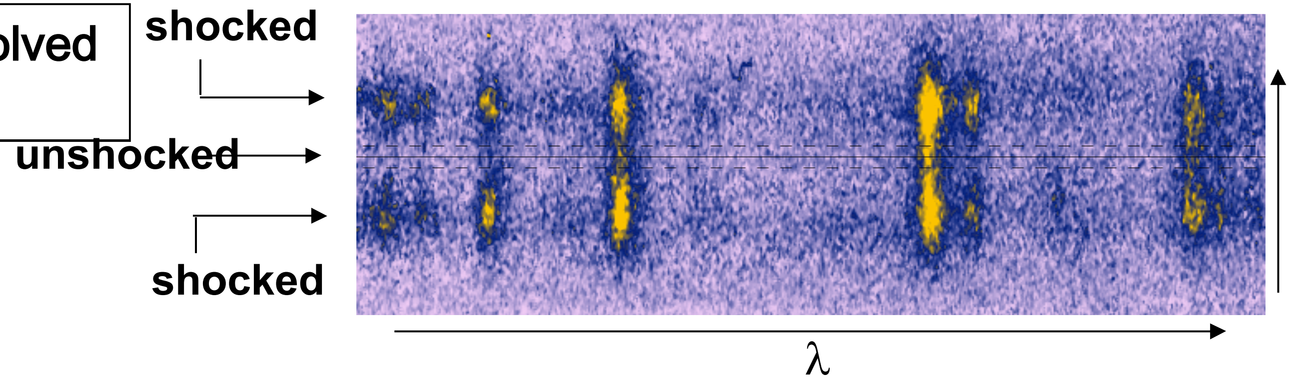
Z
DH
40 kJ
2 mm

NIF
150 kJ
2 mm

- **Z DH provides an intermediate step between NOVA and NIF**
- **Exploiting this potential requires accurate interior diagnostics of the *drive temperature* and the *symmetry***

Si tracer spectroscopy probes local dynamic hohlraum interior conditions.





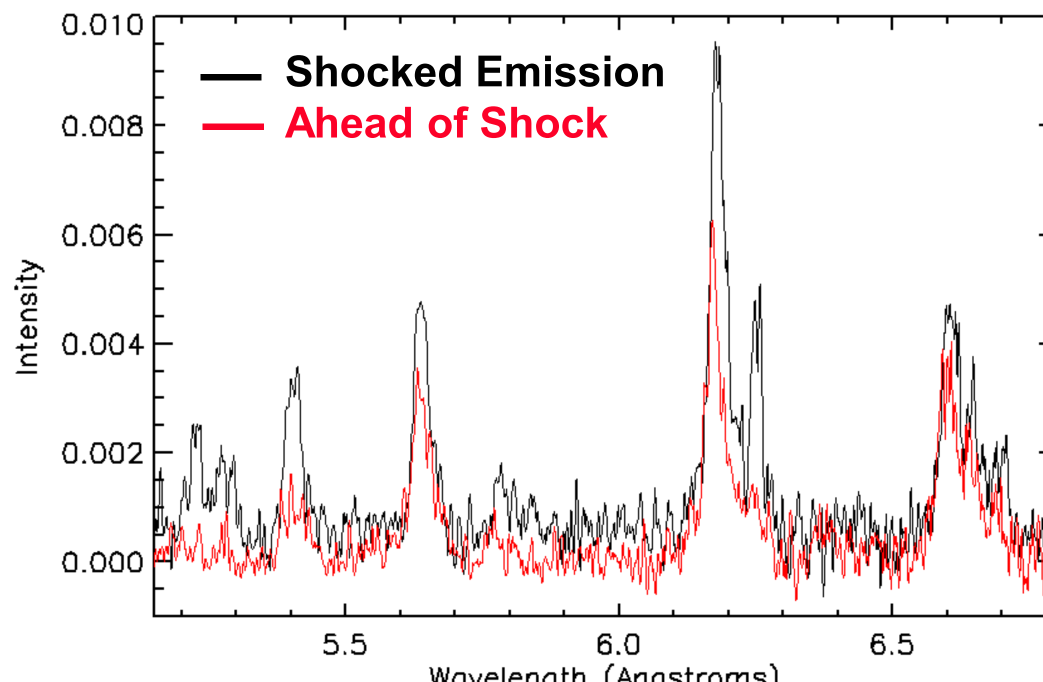
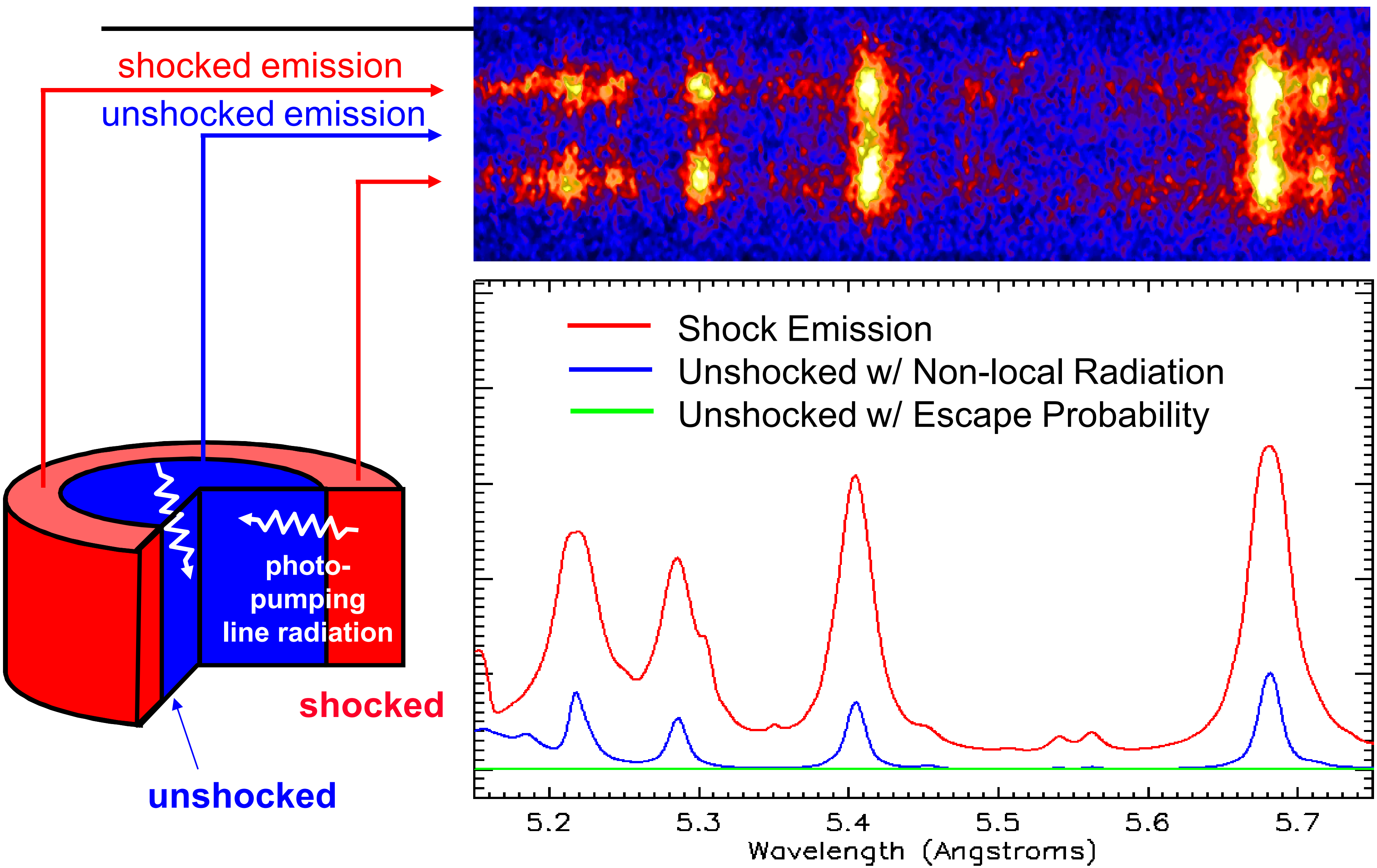
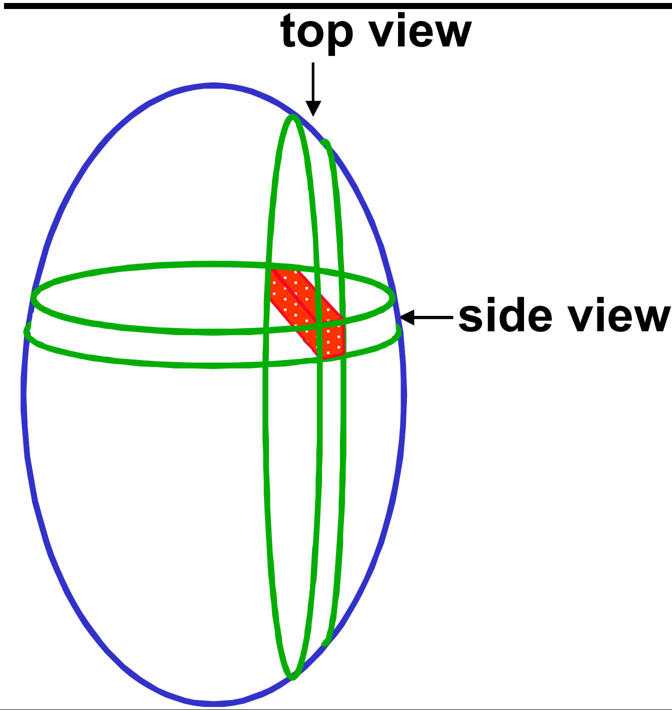
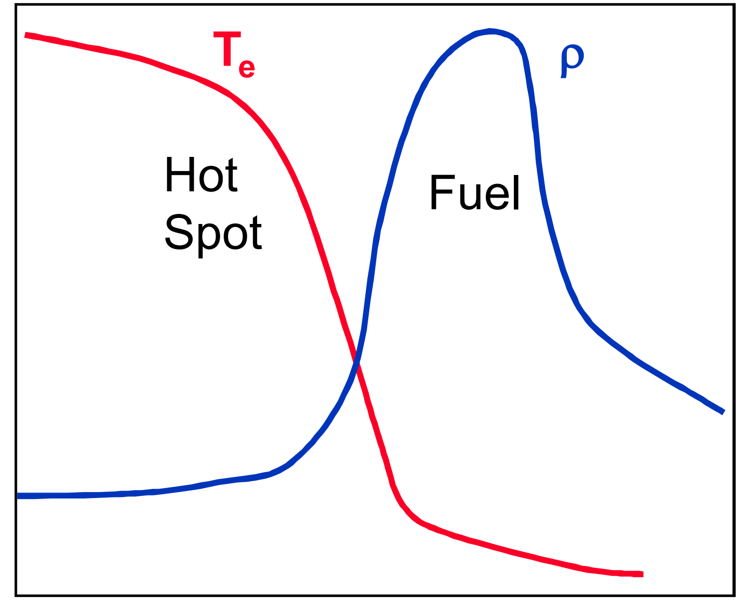


Photo-pumped line emission can be used to determine conditions ahead of the main shock.



Tomographic reconstruction of the 2D T_e and n_e spatial profiles could test capsule and hohlraum understanding



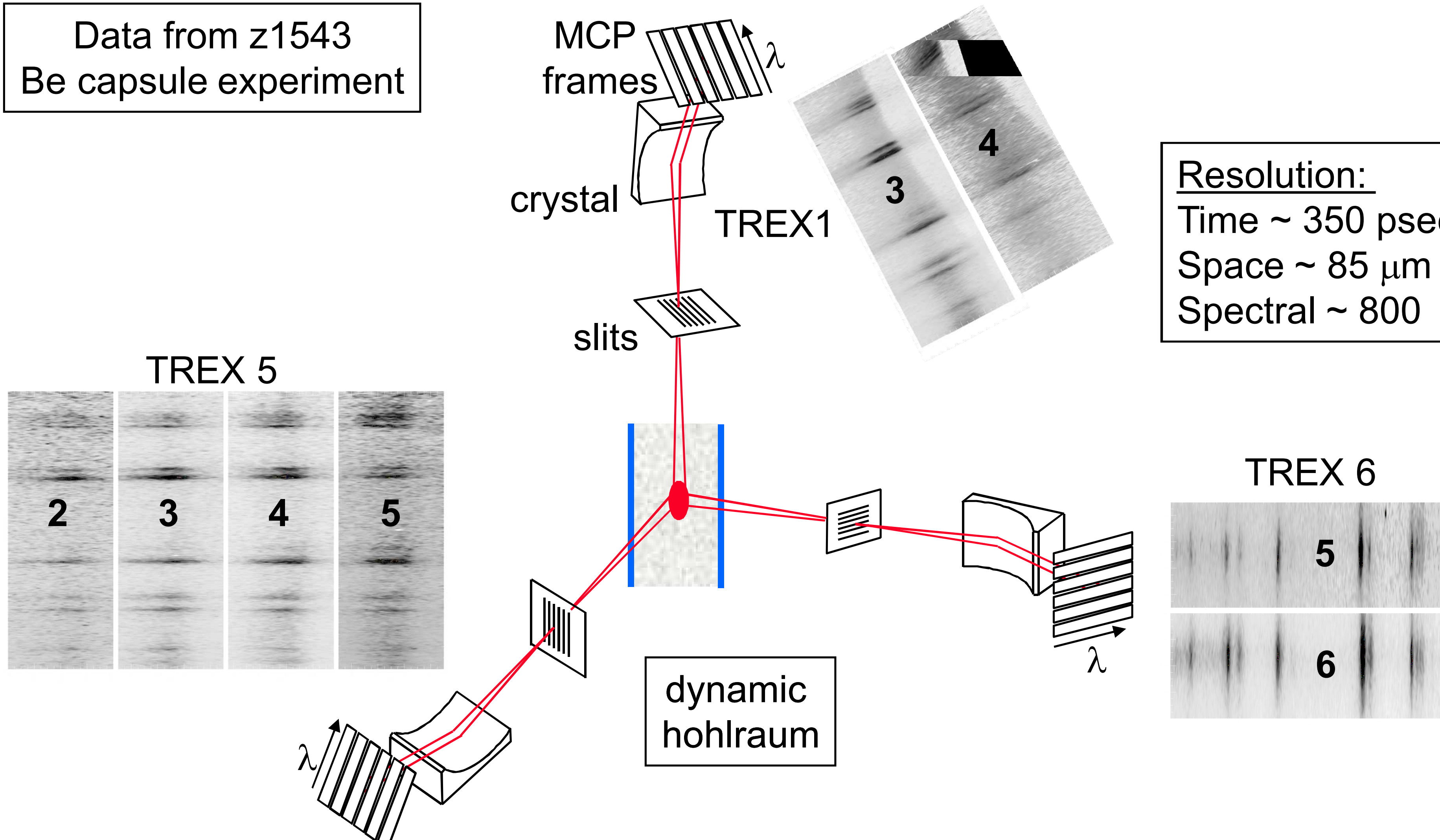


Each space-resolved lineout represents a slice through the plasma
Each photon energy depends on spatial emissivity and opacity properties
The combination is a powerful constraint on T_e (r,θ) $n_e(r,\theta)$

Diagnosing hot spot Te and ne profiles is a key ICF capability

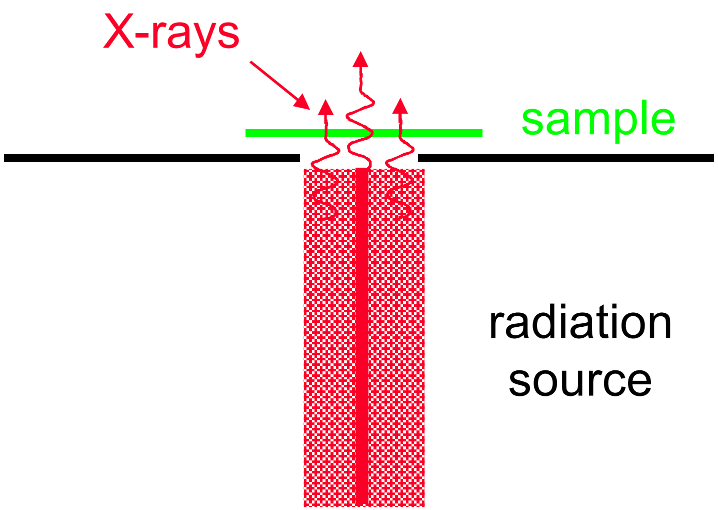
We are meeting the biggest challenge for tomographic spectroscopy: acquiring the data

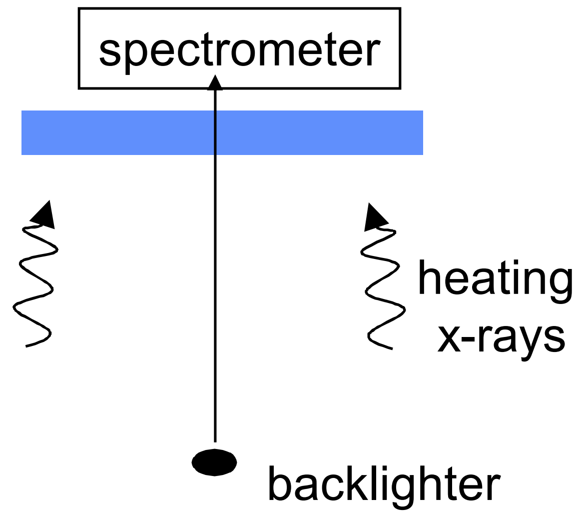
Data from z1543
Be capsule experiment

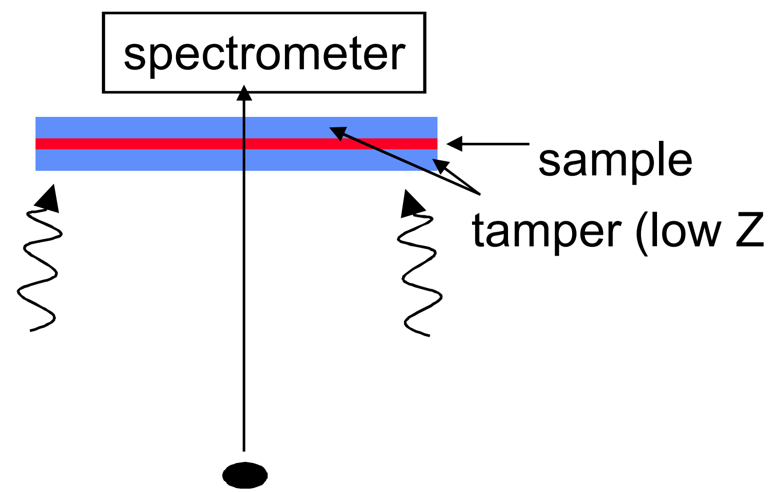


<u>Resolution:</u>
Time ~ 350 psec
Space ~ 85 μm
Spectral ~ 800

The dynamic hohlraum radiation source is useful for opacity measurements

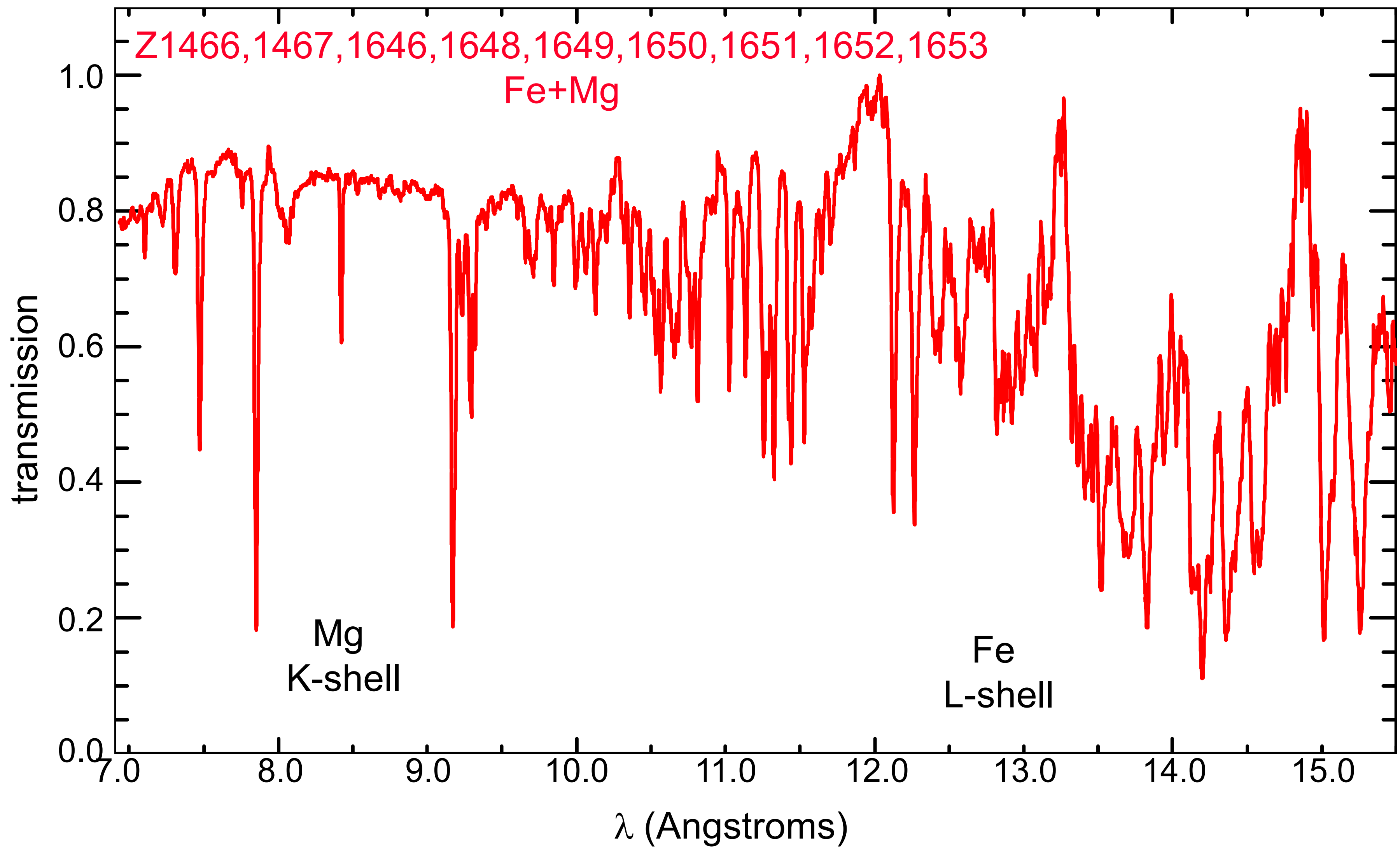




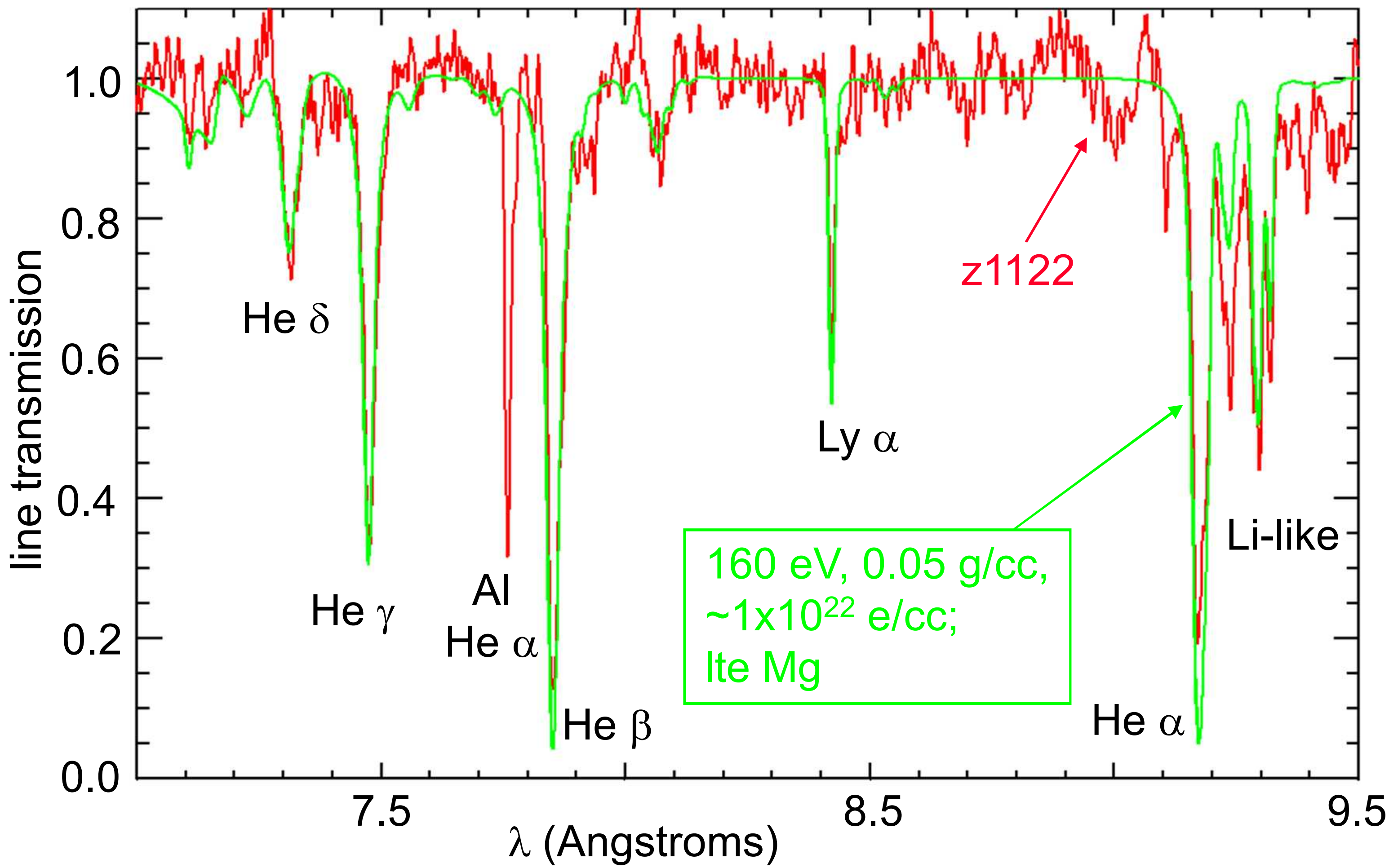


- The source both heats and backlights the sample
- Experiments with and without sample determine the opacity

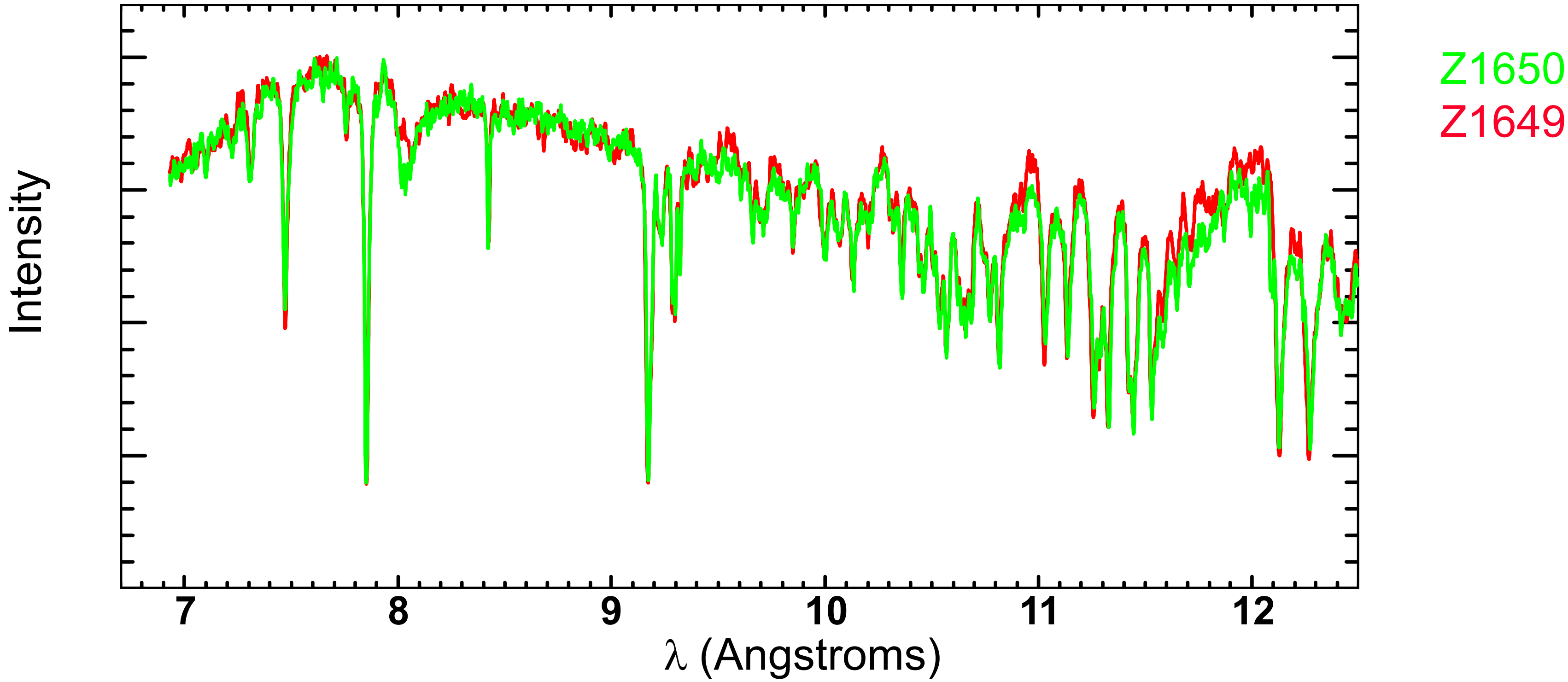
The dynamic hohlraum backlighter measures transmission over a very broad λ range



The sample conditions are diagnosed from Mg absorption spectra



The shot to shot reproducibility is good, if conditions are carefully controlled

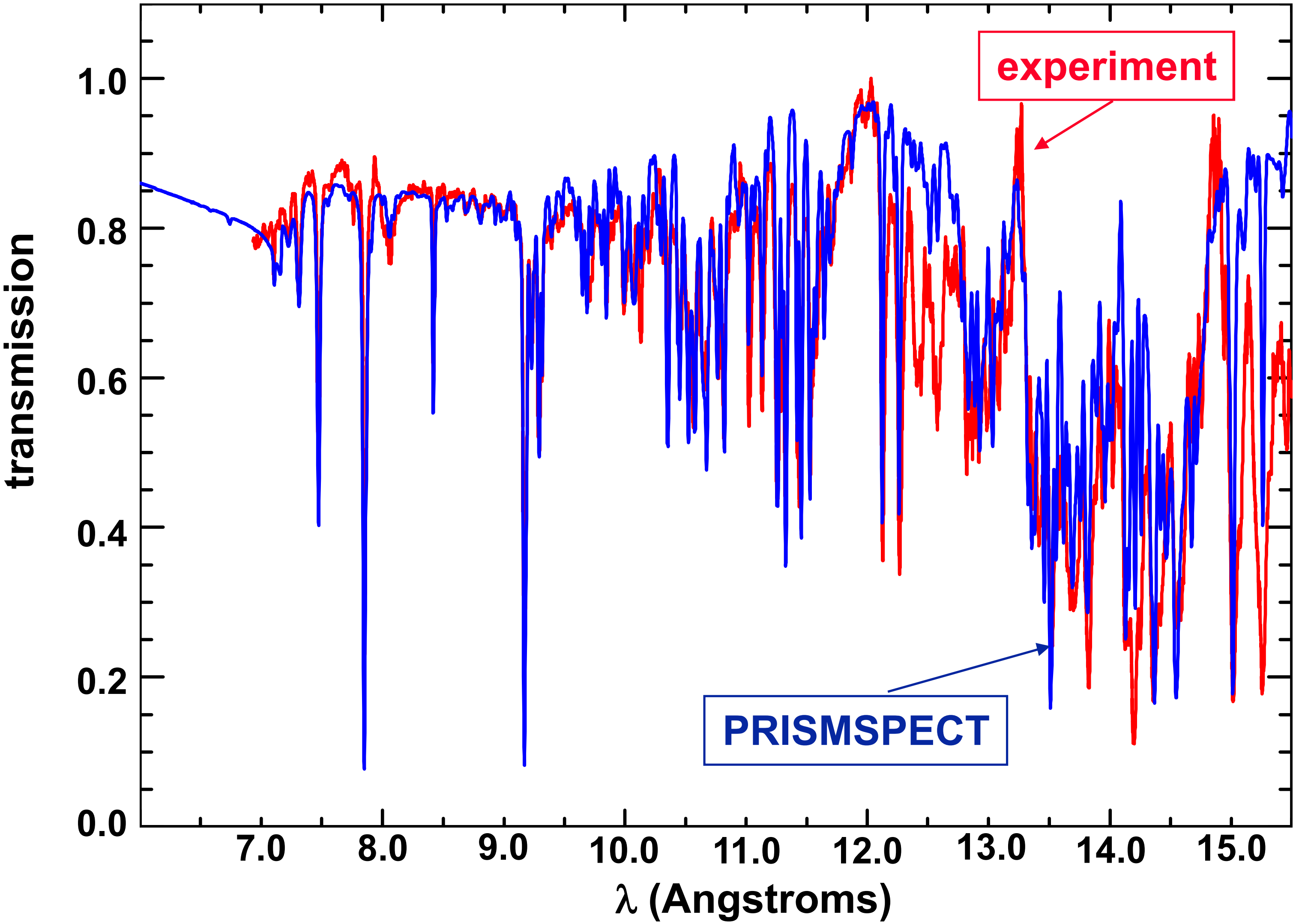


• Both experiments used 10 μm CH | 0.3 μm Mg + 0.1 μm Fe | 10 μm CH sample

• No scaling was applied for this comparison

• Reproducibility is not always this extraordinary, but variations are less than approximately ±10%

Comparisons with PRISMSPECT exhibit remarkable agreement, if we adjust the sample areal density



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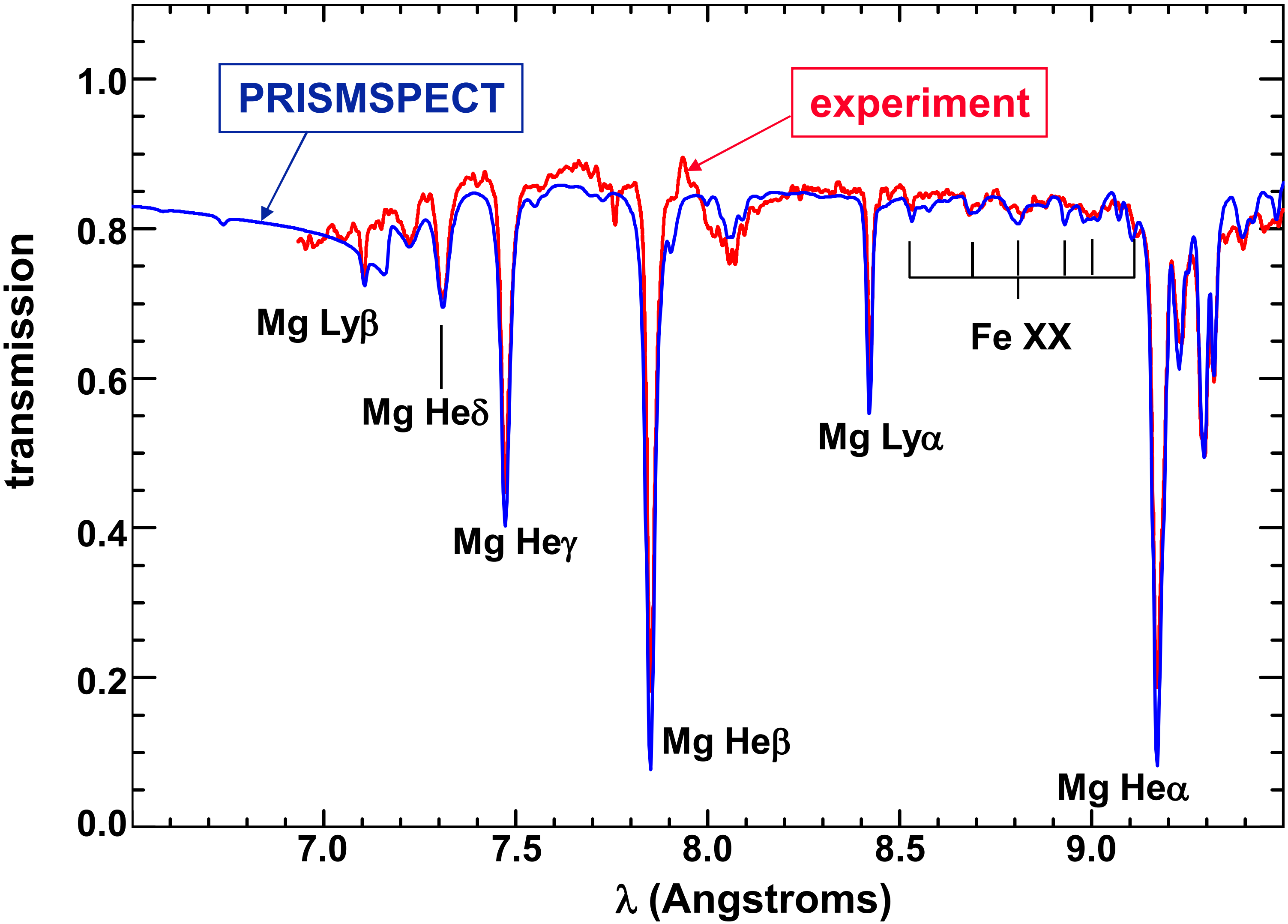

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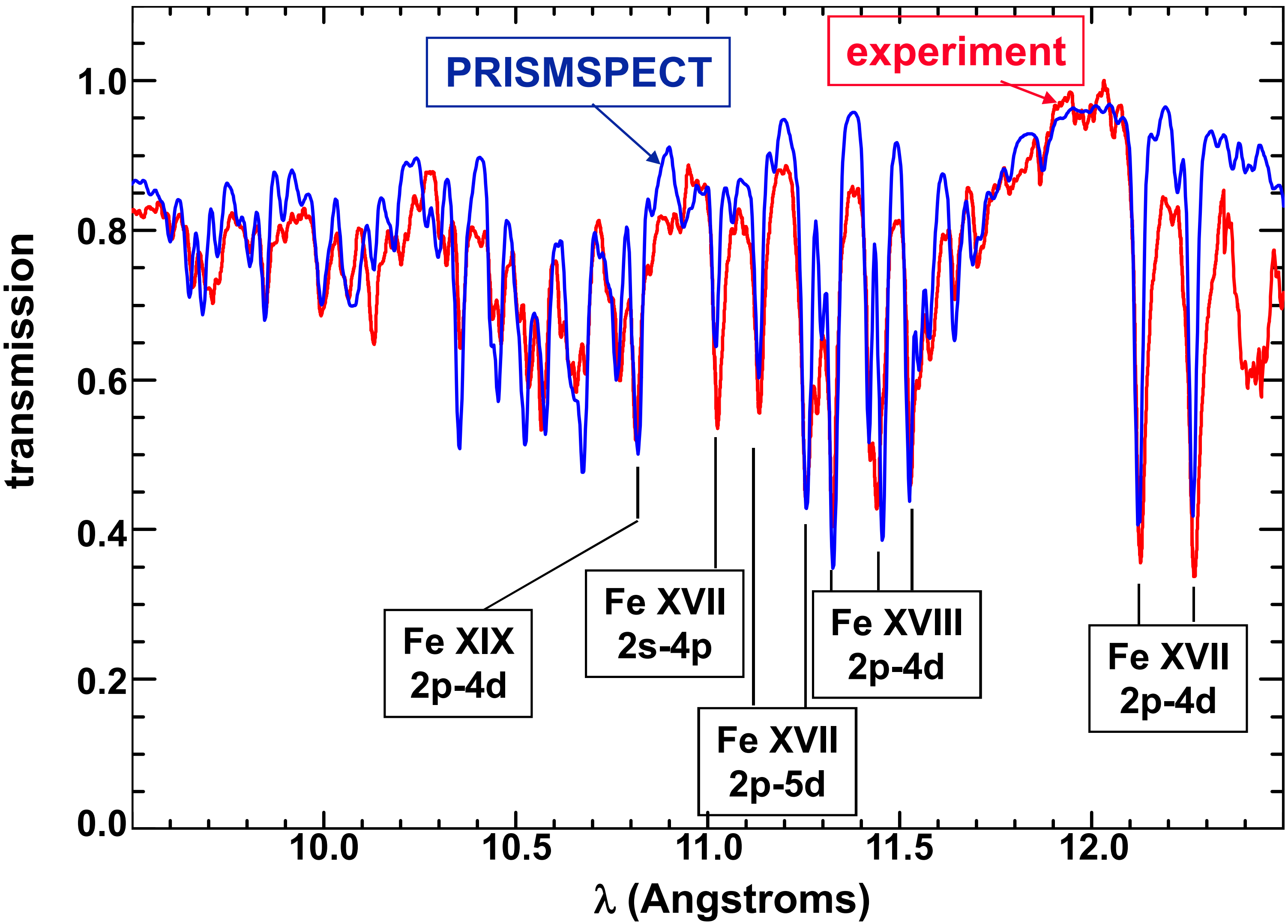

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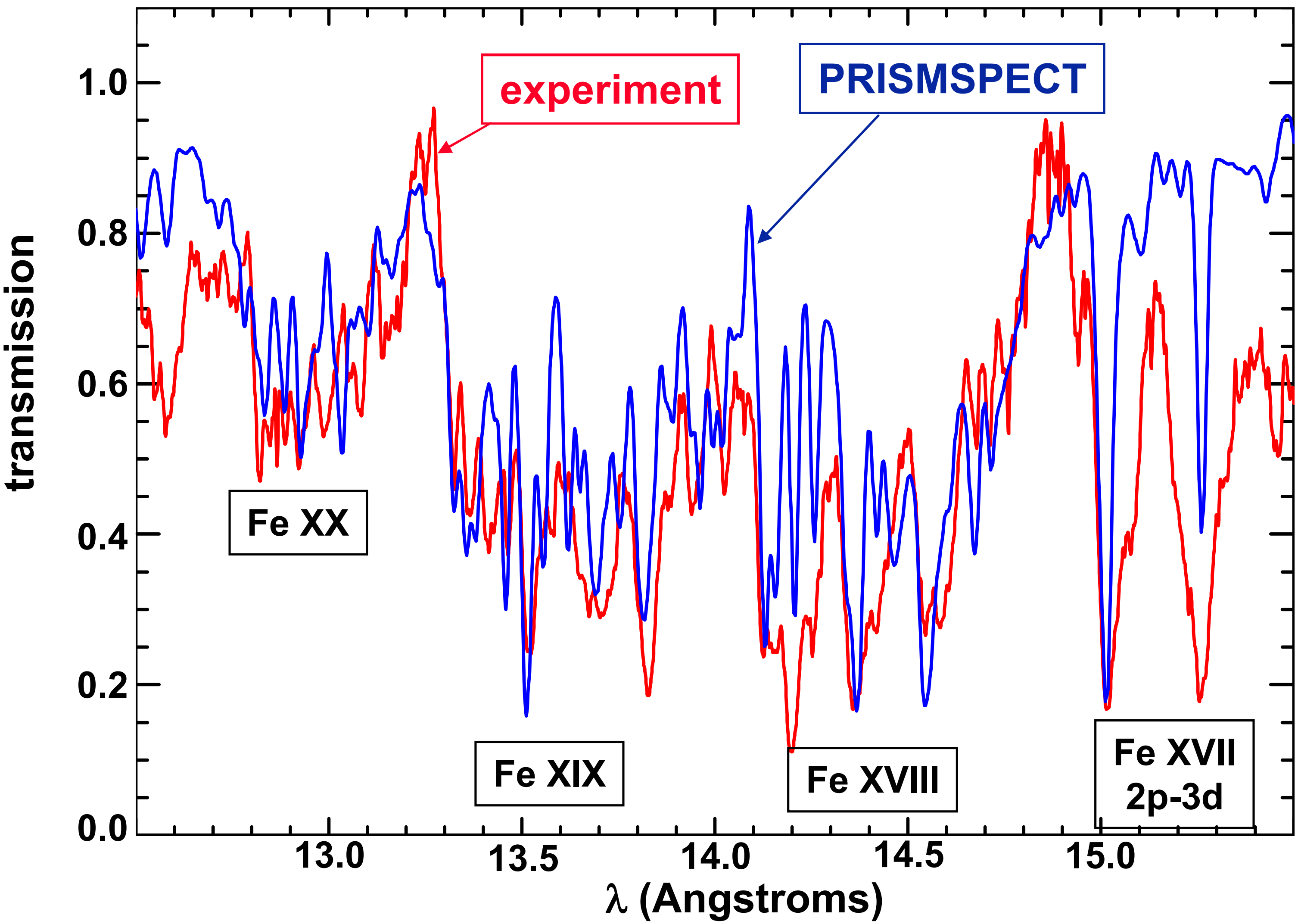
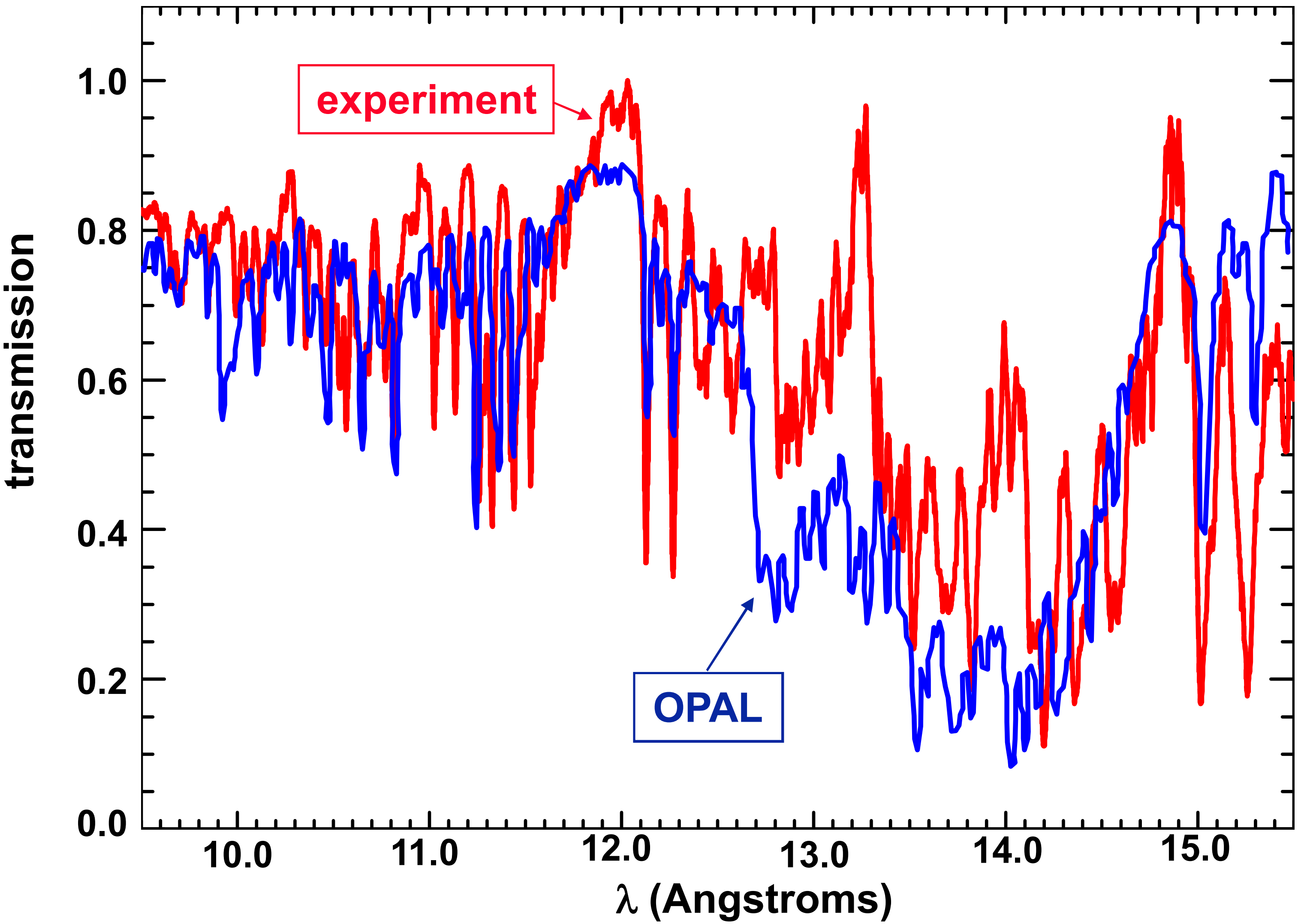
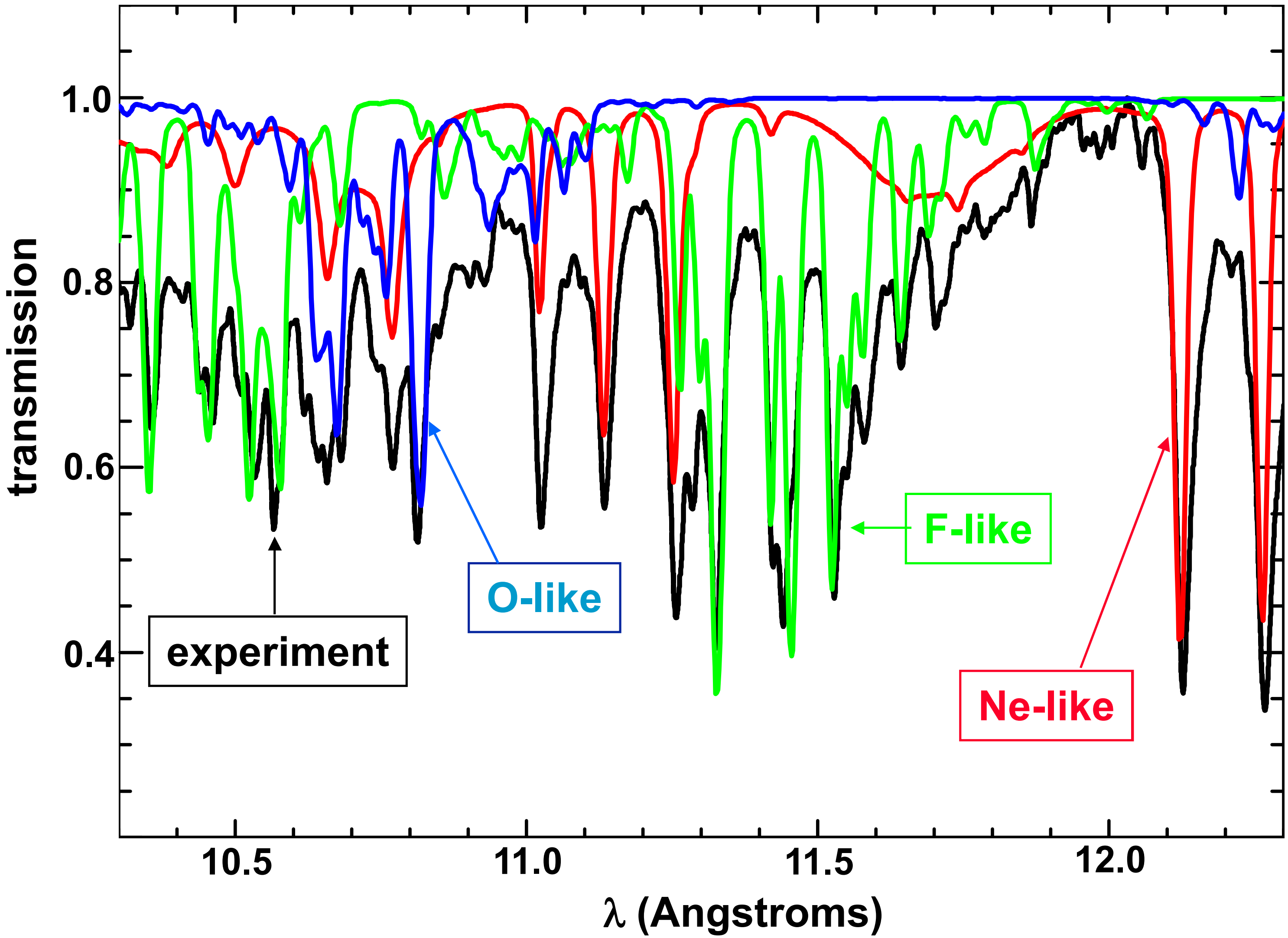


Initial comparisons with OPAL exhibit reasonable agreement



The data enables tests of the calculated charge state distribution



Conclusions of present work

- **The excellent agreement between PRISMSPECT calculations and the measurements demonstrates a promising degree of understanding for both modeling and experiments**
- **This agreement depends on assumption that the sample areal thickness was not as specified. Therefore it should be regarded as a relative opacity measurement at present.**
- **Comparisons with MUTA and OPAL are also promising, but refinements may be needed**

This data provides the ability to test model calculations of:

- **Charge state distribution**
- **Relative line intensities and wavelengths**
- **Level of detail required for different classes of transitions**

Improved experiments may be needed to test model calculations of continuum absorption

goals for future work

- Determine experiment uncertainties
- Evaluate possibility of self emission, non-LTE effects, photopumping, gradients
- Refined model comparisons
- Optimize tamping and sample design with benchmarked rad-hydro simulations
- Extend to higher densities and temperatures:
- ZR planned for 2007 completion

ZR & use of dedicated experiments should extend measurements to ~ 180-220 eV regime