Statistical data analysis for Z opacity data
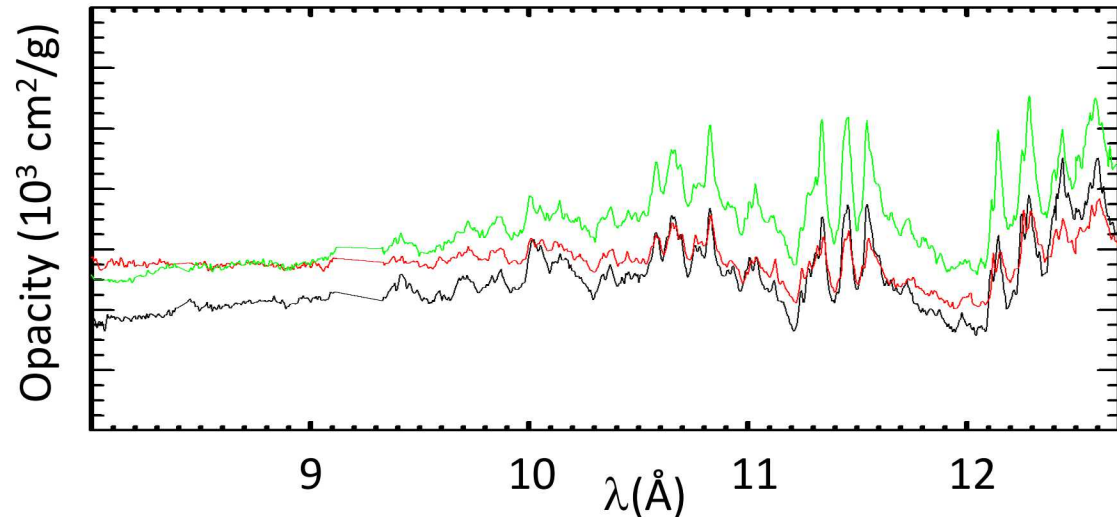
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Opacity Seminar Series, June 22, 2020

Model-data opacity disagreement and notable experiment-to-experiment variation question the accuracy of data analysis

At stellar interior conditions, calculated opacity was significantly lower than measurement.

Data at T_e=182 eV, n_e= 38e21 e/cc
Calculated opacity*
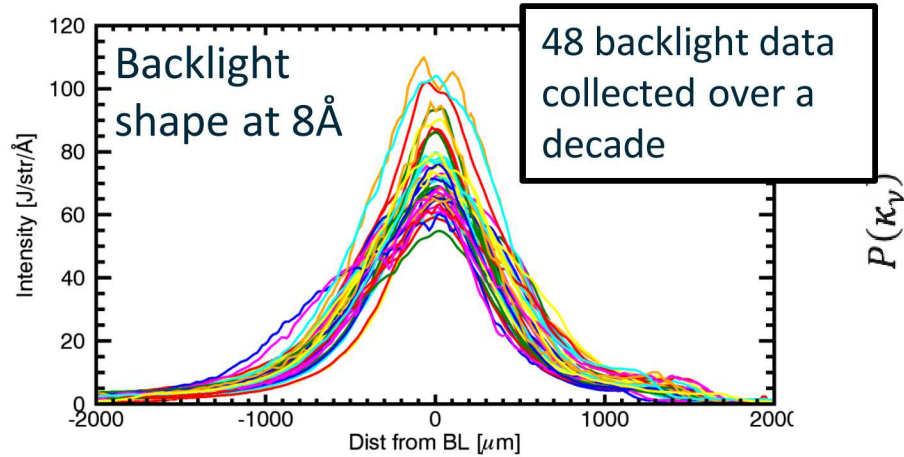
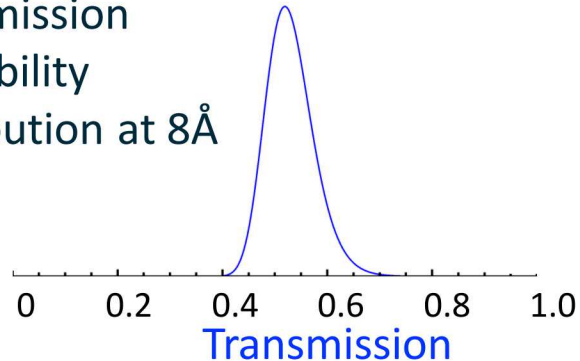Experiment-to-experiment variation is about ±20%

Data-analysis notes

- Opacity uncertainty is dominated by:
  - Transmission (20%) ← Dominant source
  - Background subtraction (3%)
  - Areal density (4%)

- How do you propagate all these uncertainties with non-linearity taken into account?

- How do you average over multiple experiments?

Analysis method was refined by using calibration-shot statistics and propagating errors by Monte-Carlo sampling
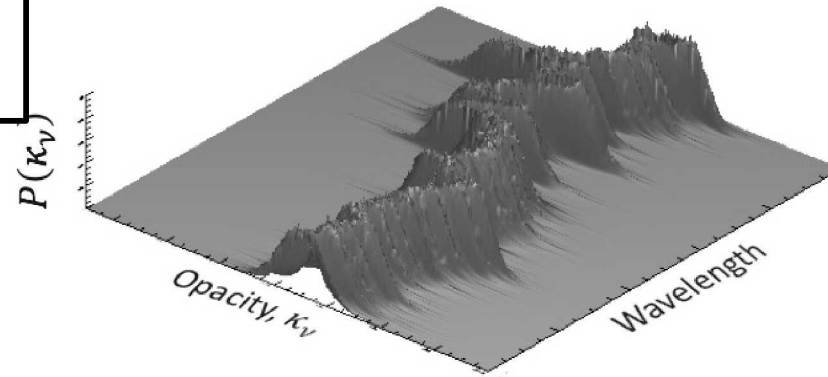
1) Transmission uncertainty was improved to ~10% by using calibration-shot statistics in shape and brightness

Backlight shape at 8Å

48 backlight data collected over a decade

Transmission probability distribution at 8Å

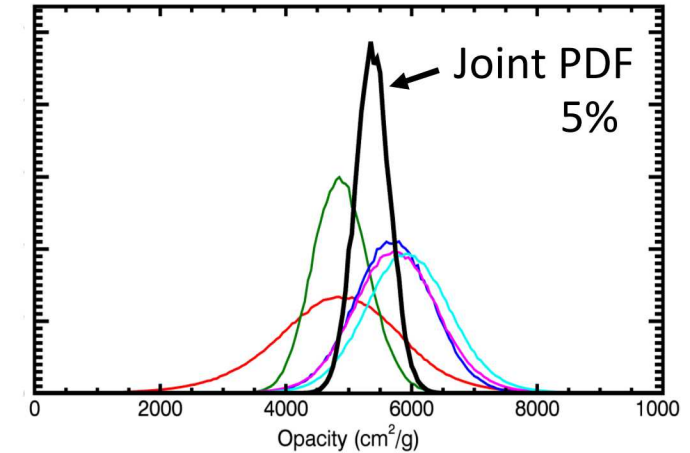2) Three sources of uncertainties were propagated using Monte-Carlo

$P(\kappa_\nu)$

Opacity, κ_ν

Wavelength

Sources of uncertainties:
- Transmission
- Background subtraction
- Areal density

3) Multiple shots were averaged by computing their product
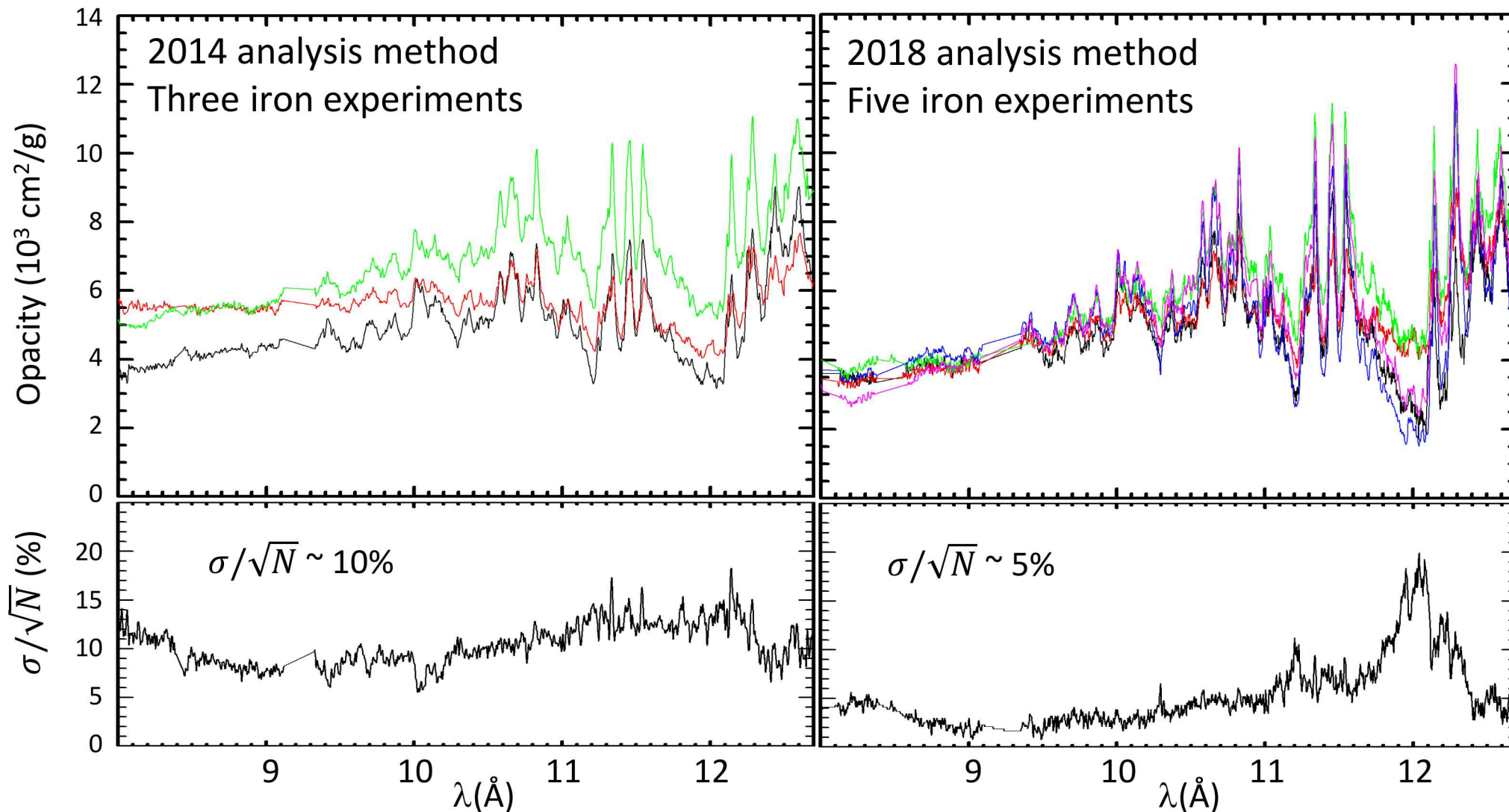
Joint PDF 5%

Less certain shots were naturally weighted less

New analysis returns asymmetric non-Gaussian opacity probability distribution as a function of wavelengths

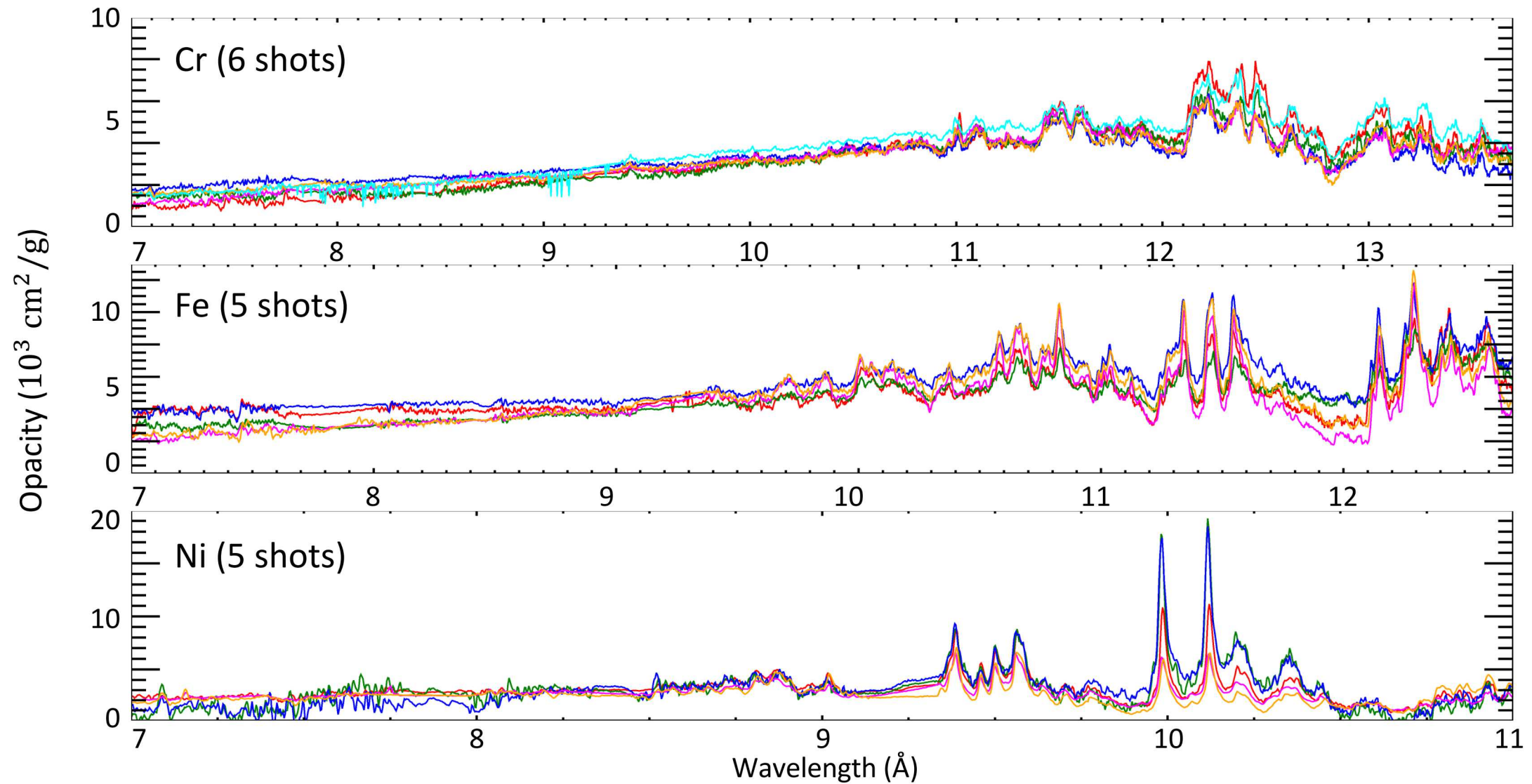# New analysis found consistent results from Cr, Fe, and Ni; Experiment reproducibility is better than originally believed

New analysis found consistent results from Cr, Fe, and Ni; Experiment reproducibility is better than originally believed

We continue consolidating our analysis method by consulting a SNL statistician

- Major data-analysis concerns were resolved
- Minor but important questions remain:

    - How many backlight data do we need?

    - How much should we trust the tail of the initial distributions?

    - What shape should we assume for the calibration-shot statistics?

    - How should we treat outlier? How should we communicate?

    - Are there any unnoticed bias?

    - What does good reproducibility mean?

    - How should we treat infrequent negative transmission in Monte Carlo sampling
    - …

We initiated a weekly discussion with a SNL statistician

Reese Davies (Statistical science)

We will refine not only result and its uncertainty, but also its interpretation and communication to maximize the credibility and impact of our results