RPHDM2024
PARIS

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Radiative Properties

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BOOK OF ABSTRACTS

The RPHDM bi-annual meeting series started in 1984 and since 2000 it has been held alternating European and US locations. The last three editions took place in Santa Barbara, USA (2016), Hamburg, Germany (2018) and Santa Fe, USA (2022).

The purpose of the meeting is to bring together an international group of researchers studying radiation-dense matter interactions and related topics such as plasma spectroscopy, non-LTE population kinetics, opacity studies, spectral line shapes...

Covered topics

Previous meetings have covered hot-plasma absorption and emission spectroscopy, radiation heating, opacities, spectral line shapes, dense plasma effects and their role in the breakdown of the isolated atom model, non-equilibrium atomic kinetics and radiation transfer.

Experiments using high-intensity short-pulse lasers and z-pinch type discharges to generate and diagnose hot dense matter are central. XUV, VUV and X-FEL sources, warm dense matter studies, and high-energy laser-related experiments, are particularly timely.

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TOPICS

- X-RAY SOURCES: XRS
- PLASMA SPECTROSCOPY
- WARM DENSE MATTER: WDM
- ASTROPHYSICAL PLASMAS: ASTRO
- MAGNETIC CONFINMENT FUSION: MCF
- SPECTRA LINE SHAPES: SLS
- INERTIAL CONFINMENT FUSION: ICF
- FREE ELECTRON LASERS: XFEL

The scientific program of the 2024 workshop consists of oral and poster contributions.

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ATOMIC DATA AND PROCESSES. I

NLTE-12, Benford's Law for Atomic Databases and All That

Yuri Ralchenko*

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This talk will cover two topics. First, an overview of the 12th non-LTE Code Comparison Workshop that was held in Valladolid, Spain (Oct 2023) will be presented. This meeting was attended by more than 20 researchers who submitted case calculations with 14 different collisional-radiative (CR) codes. The proposed cases included (i) CR and photoionization kinetics and the L-shell emission of Fe for typical astrophysical conditions, (ii) CR kinetics and K-shell emission of Kr in dense plasmas of NIF imploded capsule experiments, and (iii) ionization balance and spectra of Au in hot laser-produced plasmas. We will present comparisons of the submitted data, main conclusions of the meeting, and future plans.

The second part of the talk (in collaboration with J.-C. Pain) will address applications of Benford's law to atomic spectra and opacity databases [1]. This intriguing, and yet not fully understood, law of anomalous numbers states that the significant digits of data follow a logarithmic distribution favoring the smallest values. We will discuss the compliance with this law of the atomic databases focusing on (i) line energies, oscillator strengths, and Einstein coefficients from the NIST Atomic Spectra Database [2] and (ii) radiative opacities from the NIST-LANL Lanthanide Actinide Opacity Database [3].

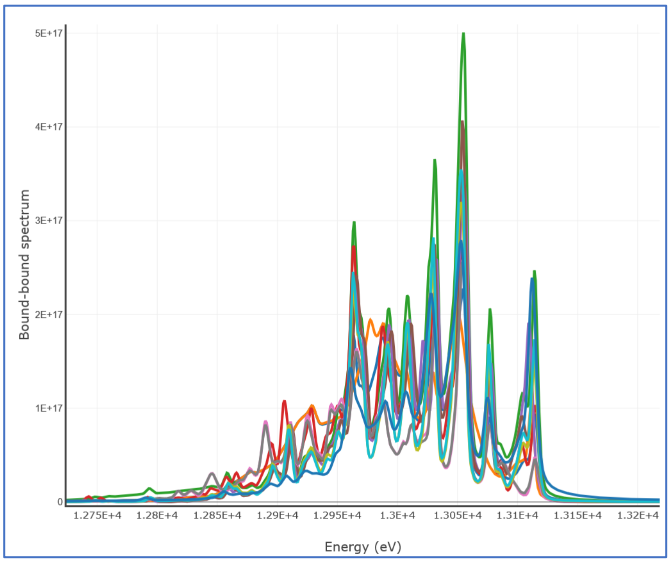

Figure 1. NLTE-12: Comparison of the bound-bound Kr spectra at 2000 eV and 3×10^{24} cm^{-3}.

References

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[3] URL https://nlte.nist.gov/OPAC/.

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Time-resolved spectroscopy for Z stellar opacity research

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Time-resolved spectroscopy using a novel hCMOS Ultra-fast X-ray Imager (UXI) is transforming stellar interior opacity measurements at the Sandia Z facility. Calculated opacities disagree with measured opacities [Bailey et al. Nature (2015), Nagayama et al. PRL (2019)], which questions the accuracy of calculated opacities used for the solar interior. The novel time-resolved data help to resolve this dilemma in three unprecedented ways. First, time-resolved measurements of the backlighter history, sample evolution, together with calculated opacities at each time step allows us to assess how temporal integration have affected the published, film-based results. These tests show that the temporal integration cannot explain the reported discrepancy. Second, measurements of the sample temperature and density evolution refine our understanding of the Z opacity platform and enable improved experimental design. Third, Sandia's UXI technology enables measurements of iron opacities at multiple conditions from a single experiment. This not only increases the number of opacity measurements per experiment but also allows to study how opacity changes with conditions from a single experiment. In this presentation, I will summarize the results on sample evolution in Fe experiments as well as progress towards the first extraction of absolute *time-resolved* opacity and remaining challenges to obtain that goal.

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Tungsten VUV spectroscopy in WEST tokamak 1-4 keV plasmas

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Since Tungsten (W) was chosen as the plasma-facing material in the future tokamak ITER, several magnetic fusion devices have been equipped partly (JET) or entirely (ASDEX-Upgrade) with W components. Among them, the WEST tokamak has a prominent place because of its capability to sustain 2-5 keV plasma discharges for minutes in a complete W environment.

WEST is equipped with two extreme UV spectrometers, one of which provides a wide variety of measurements thanks to its versatility. It covers the range 5-340 Å with two mobile detectors, each viewing a narrow interval (~20 Å at 15 Å, 60 Å at 310 Å) and a spectral resolution of ~0.2 Å. Its single line of sight can scan the lower half of the plasma with a minimum period of 4 s.

Spectra measured with this spectrometer are very complex due to the large number of spectral structures emitted by W. We have undertaken an extensive work of spectral line assignment using the HULLAC code and the NIST atomic database [1]. W^{25+} to W^{45+} ionisation stages have been identified. From four spectral lines from the higher stages we estimate the W density profile in the core plasma provided the electron temperature is high enough [2].

The strong and broad quasicontinuum (QC) at 45-65 Å has been extensively observed in magnetic fusion devices [3]. It has been attributed to W^{28+}-W^{45+} with additional lines from various ionisation stages. Up to now collisional-radiative modelling has not allowed to reproduce it in a satisfactory way, which suggests that the atomic structure of W or the radiative transitions and their probabilities are not well understood. A semi-statistical approach used in dense plasmas [4] has been applied with encouraging results, concerning both the ionisation degree of W and the quasicontinuum itself.

Given the complexity of this spectral feature, in parallel we have recently started to use artificial intelligence (AI) tools to investigate the relation between the spectral shape of the QC and the thermodynamic profiles of the plasma, in particular the electron temperature. The first step is to establish a relation between the spectrum and the maximum temperature along the line of sight. We have found that the temperature can be predicted with a very satisfactory accuracy (± 50 eV) in a boad range (300-3500 eV) if the AI algorithm is trained with plasma discharges performed on the same day. Plasma discharges performed several days from each other do not provide good results, possibly due to the changing vessel status. The next step is to investigate the possibility of extracting the whole temperature distribution from the QC analysis.

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High resolution, sub-picosecond x-ray spectroscopy of buried layers heated with high intensity, short pulse lasers*+

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Short pulse, laser (SPL) heated matter has opened an avenue to studying matter at conditions previously unobtainable. While SPLs can generate matter at extreme densities and temperatures, characterization of the heated matter can be extremely challenging. The conditions are extremely dynamic in nature, requirement a careful monitoring of the plasma evolution.

High temporal and spectral resolution spectroscopy can play an important role in understanding the heating dynamics of buried layers. At the onset of heating, the laser deposits energy into non-thermal electrons at the laser-target interaction plane. Some fraction of the non-thermals escapes the target, producing a charge imbalance and a return current. The spectral features during this heating phase result from thermal and non-thermal electron distributions. Temporally resolving the Li-like satellites along with the He_α complex provides an avenue for studying the plasma temperature as it transitions from a relatively low temperature to a high temperature. We look at the impact of the non-thermal electrons on the sulfur He_α and Li-like dielectronic complex using the LLNL sub-picosecond, high resolution-STreaked Orion High REsolution treX (STOHREX). The targets were 50 µm diameter "dots", made from 160nm of FeS and 60 nm KCl, tamped by 3 µm of parylene. The experiments were performed at the Orion laser facility using ~700 fs, 532 nm, 150 J focused to a 100 µm spot. The impact of non-thermal electrons on the inferred temperature rise is studied using recent adaptations to the Cretin code to account for non-Maxwellian electron distributions on spectral features. The preliminary results will be presented along with spectroscopic modeling.

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