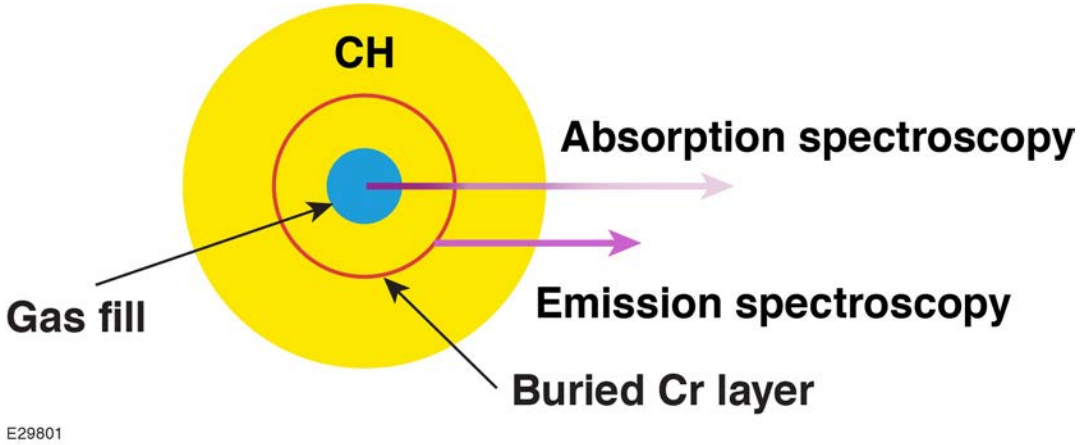
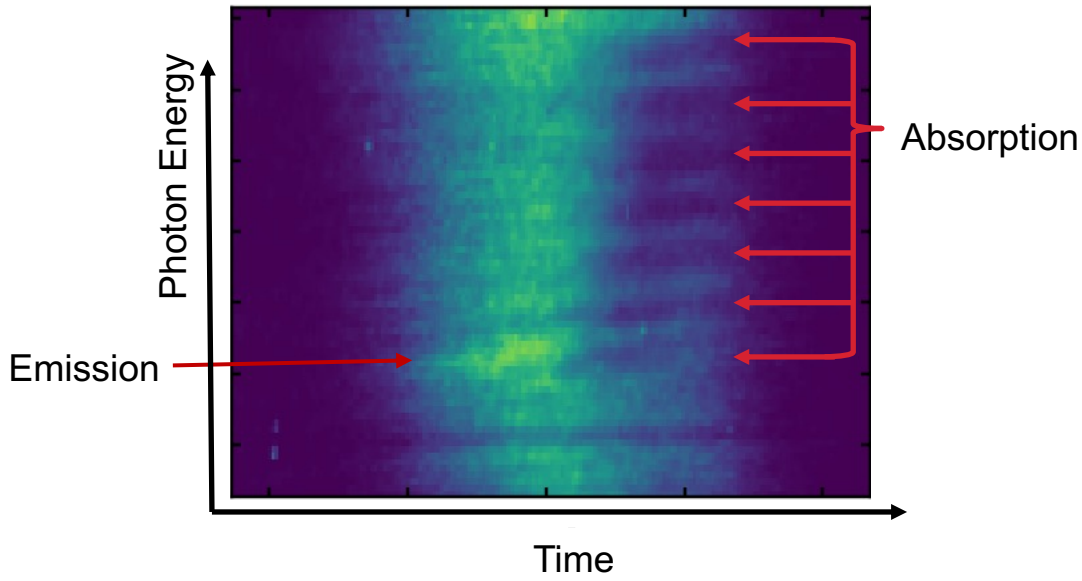
Utilizing implosions to constrain atomic physics of Gbar materials

Laser-driven spherical Implosion



Time-resolved Cr spectrum during x-ray flash



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Summary

Spherical implosions both compress matter to Gbar pressures and provide an internal x-ray source to probe that matter.

- **Spherical implosions offer superlative diagnostic access and ”self-backlighting” x-ray emission to probe the atomic physics of a localized tracer layer.**
- **Transition of Cr from emitting to absorbing is ascribed to a shock wave transiting, ionizing the buried layer.**
- **Constraints from additional measurements provide a robust platform for atomic physics studies at Gbar pressures.**

Collaborators

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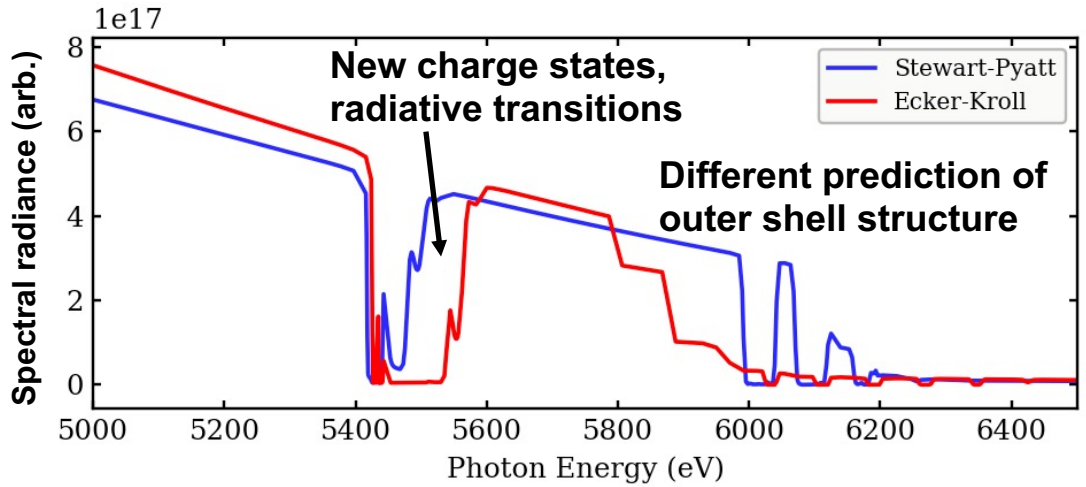
Motivation

Understanding behavior of matter at Gbar pressures is important to astrophysics and inertial confinement fusion (ICF).

- **Material properties depend on atomic physics.**
- **Atomic physics fundamentally changes at extreme conditions.**
- **Modified $|\Psi\rangle$ manifest as spectroscopic signatures[1, 2]**

Two continuum lowering models yield observable differences in predicted spectra[3] (200 eV, 40 g/cc, 3 Gbar)

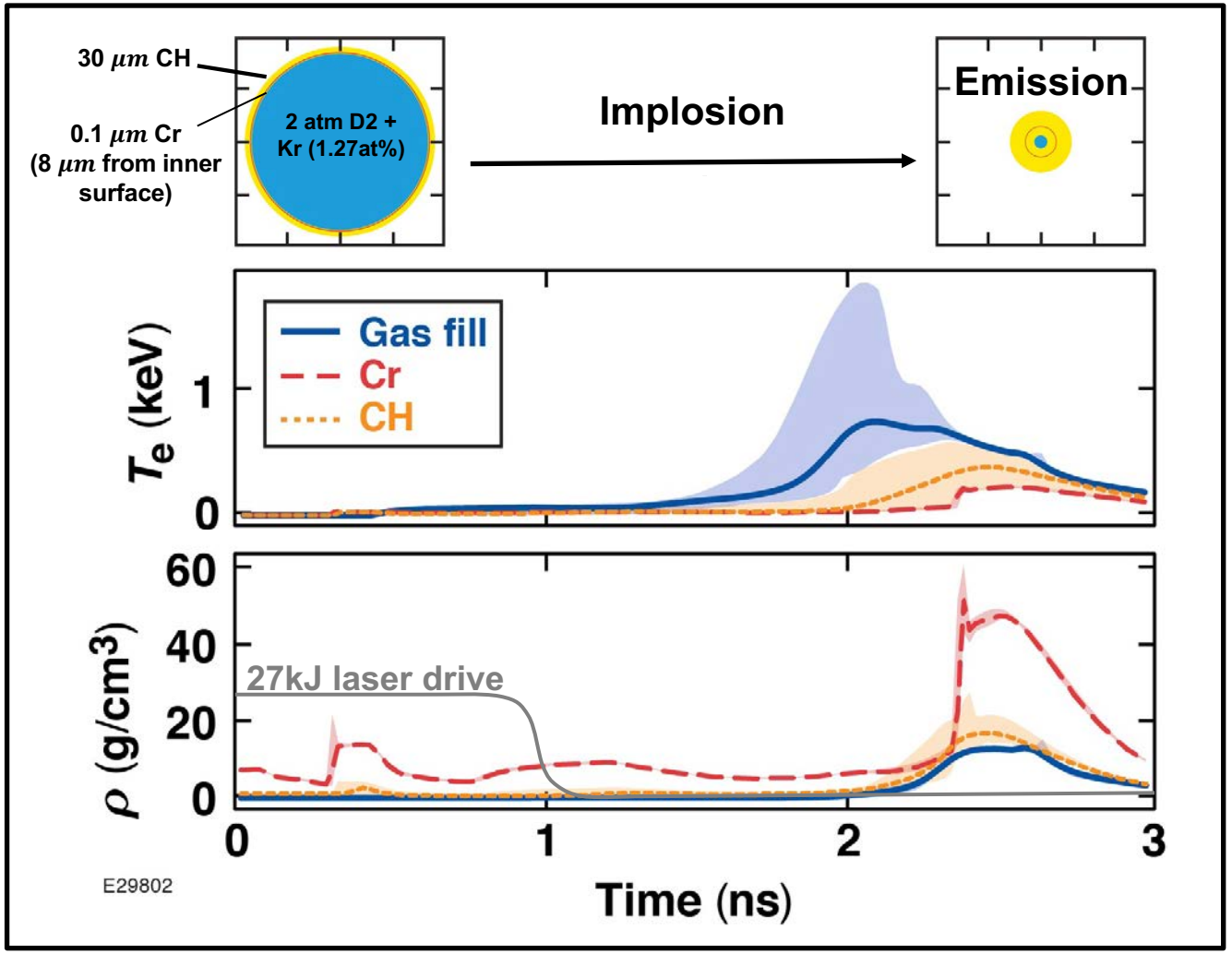


X-ray spectroscopy offers a ”window” into the atomic physics of Gbar systems

1. S.J. Rose, D.L. Foulis, and P. Gauthier, J. Phys. B At. Mol. Opt. Phys. 31, (1998).
2. S.X. Hu, V. V. Karasiev, V. Recoules, P.M. Nilson, N. Brouwer, and M. Torrent, Nat. Commun. 11, 1 (2020).
3. J.J. MacFarlane, I.E. Golovkin, P.R. Woodruff, D.R. Welch, B. V. Oliver, T.A. Mehlhorn, and R.B. Campbell, Inert. Fusion Sci. Appl. 2003 457 (2004).

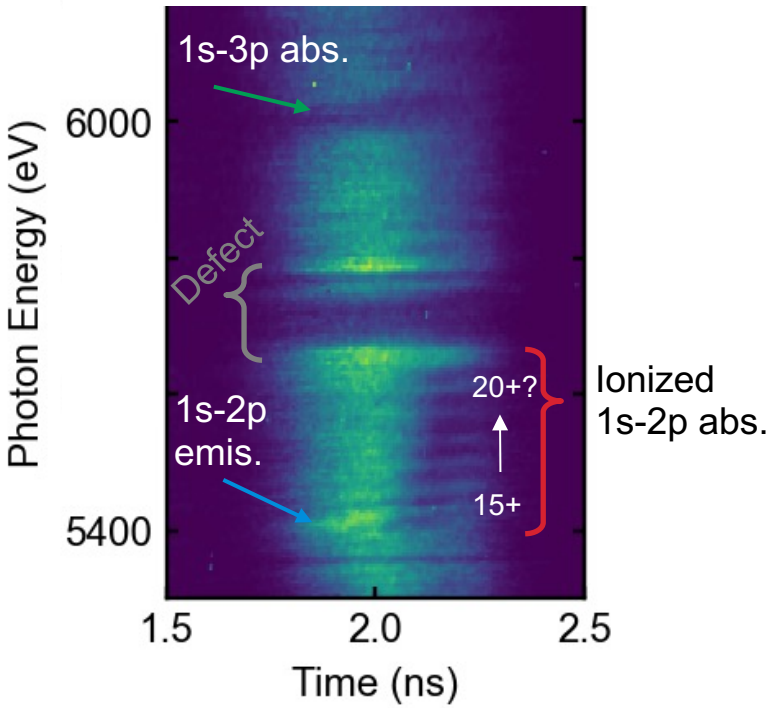
Spherical implosions offer an unrivaled ability to assemble and probe atomic physics of dense plasmas.

- **Uniquely capable of assembling material at extreme conditions**
  - Hot, emitting core probes the surrounding dense shell
  - Conditions sufficient to perturb atomic wavefunctions
- **Advanced target fabrication techniques allow deposition of sub-micron layers in the shell**
  - Localized spectroscopic tracer minimizes gradients
- **We are designing implosions to optimize atomic physics measurements of dense plasmas**

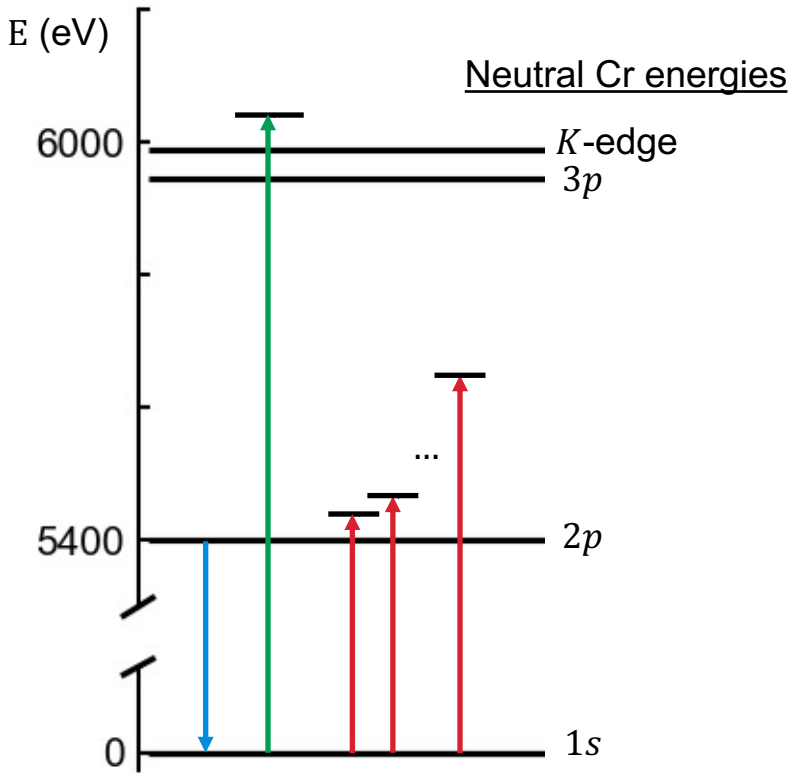


Cr ionizes during the ~400ps core flash, indicating rapid change in thermodynamic state.

Time-resolved Cr spectrum during core flash

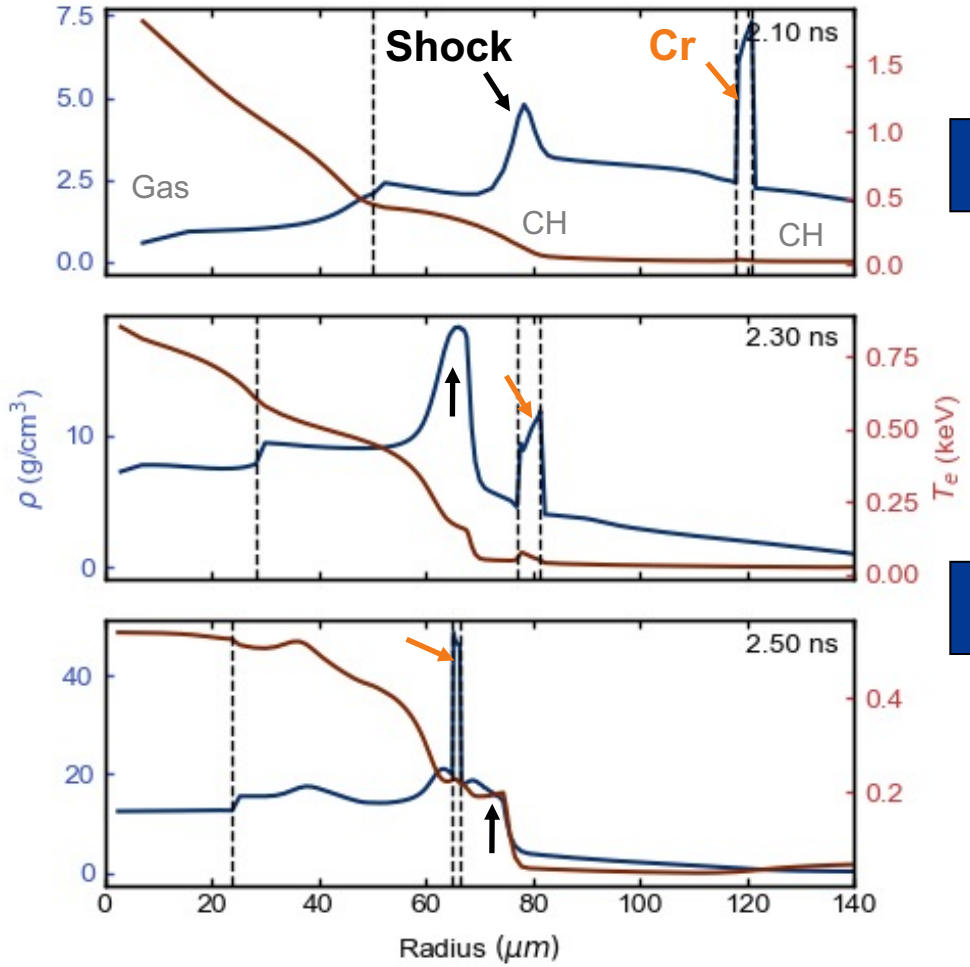


Shifted features indicate ionization



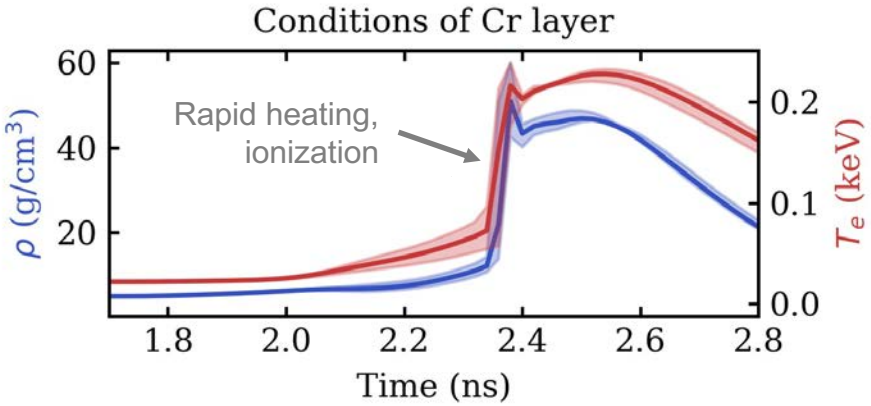
Hydrodynamic simulations indicate that Cr is heated to ≈ 200 eV by a shock racing out from the imploded core during the x-ray flash.

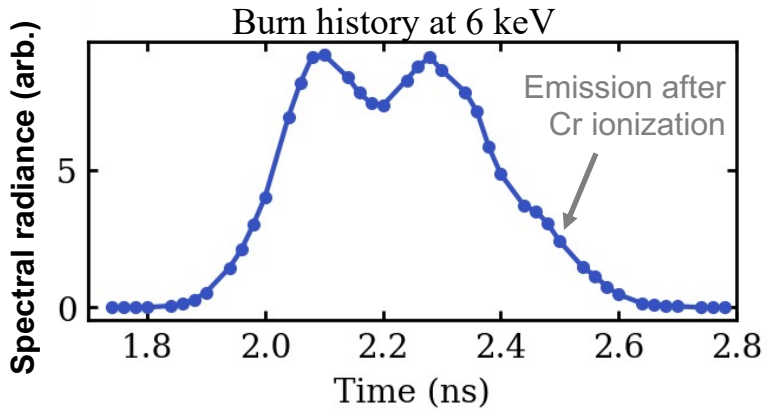
1-D *LILAC*[1] simulations



Spatial average

Radiative transfer

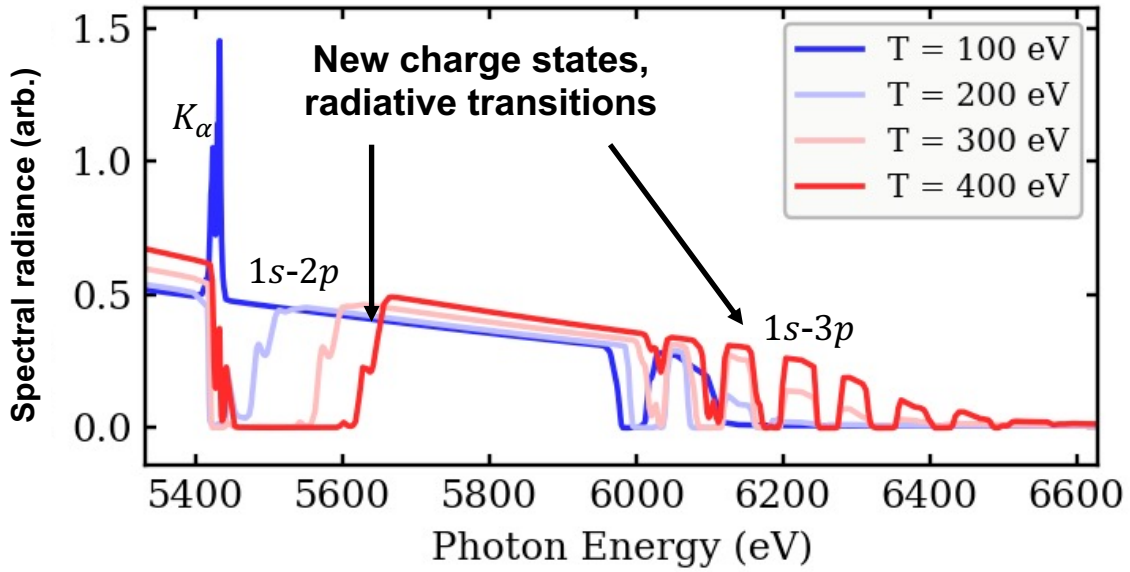




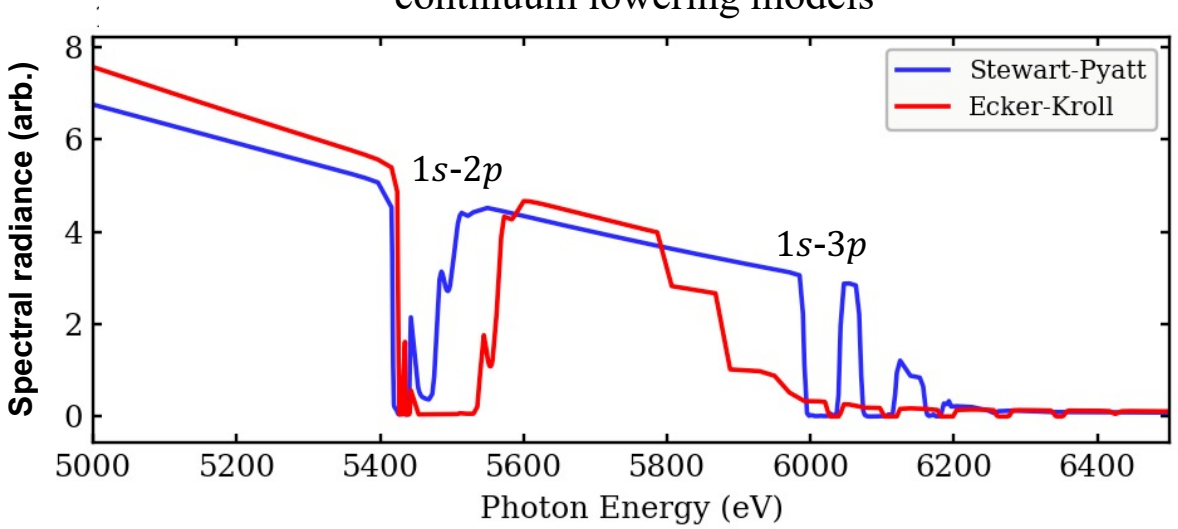
1. J. Delettrez, R. Epstein, M. C. Richardson, P. A. Jaanimagi, and B. L. Henke, Phys. Rev. A 36, 3926 (1987).

An opportunity exists to extend atomic physics to Gbar pressures: 1s-2p absorption depends on ionization through temperature and atomic model.

Synthetic Cr spectra[1]



Synthetic Cr spectra[1] at 200 eV, 40 g/cm^3 with two continuum lowering models



- **Additional constraints on T, ρ are provided by other diagnostics**
  - Neutron yield, time-resolved imaging, time-integrated spectrometers, etc.

Observed spectra constrained by additional diagnostics provide a rich understanding of atomic physics of Gbar Cr

1. J.J. MacFarlane, I.E. Golovkin, P.R. Woodruff, D.R. Welch, B. V. Oliver, T.A. Mehlhorn, and R.B. Campbell, Inert. Fusion Sci. Appl. 2003 457 (2004).

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