White Paper for *Frontiers of Plasma Science Panel*

Date of Submission:	***June 15, 2015***

Indicate the primary area this white paper addresses by placing "P" in right column.
Indicate secondary area or areas by placing "S" in right column

	"P", "S"
• Plasma Atomic physics and the interface with chemistry and biology	P
• Turbulence and transport	S
• Interactions of plasmas and waves	S
• Plasma self-organization	
• Statistical mechanics of plasmas	

Indicate type of presentation desired at Town Hall Meeting.

	"X"
Oral	X
Poster	
Either Oral or Poster	
Will not attend	

Title:	**Transport of ionizing radiation**
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- ***Describe the research frontier*** **and importance of the scientific challenge.**

Research Frontier: Develop a comprehensive understanding of the transport of ionizing radiation through plasmas.

There is a great deal of atomic physics involved in the transport of ionizing radiation through plasmas. In addition to inverse bremsstrahlung, absorption can occur by photoionization or by atomic excitation. Excitation followed by decay can be considered to be an elastic scattering process. Photoionization followed by recombination and radiative decay can be considered to be an inelastic scattering process. Yet this may be too simplistic. In cases of laboratory interest photoionization occurs by the photoelectric effect, so that all energy beyond the ionization energy goes to a single electron. For realistic parameters, this can be a large multiple of the ionization energy. The resulting population of energetic electrons can alter the plasma state and energy transport. In addition to these effects, Doppler shifts can cause lines emitted from one transition to be absorbed by a different one. This is a dominant effect for radiation transport in many astrophysical plasmas. All of these absorption, scattering, and emission processes cause an evolution of the photon spectrum with time and distance.

To my knowledge, no code intended to model the dynamics of laboratory plasmas treats the energy produced by photoionization correctly. Figure 1 shows how the average energy for photoionization of a specific ion in carbon as source temperature varies. Note that the energy distribution produced is not at all Maxwellian. In addition, all standard radiation hydrodynamic models treat the opacity as though there is

zero scattering, an approximation that becomes less accurate as densities decrease below solid density. If one is to understand the transport of ionizing radiation through plasmas, one needs much better models and one needs a lot of atomic physics, along with experiments to test this knowledge.

- ***Describe the approach to advancing the frontier and indicate if new research tools or capabilities are required.***

Continuing advances in theory and computations are clearly needed, and need to be supported. In particular, the development of practical models that account for one or more of the effects mentioned above is an important area to advance.

It will be challenging to obtain experimental evidence. It is far from trivial to produce an experimental system that is many photon mean-free-paths in extent, but in which processes related to radiation transport are dominant over the competing collisional processes. This seems likely to require experiments that can deliver substantial energy yet also can work with large volumes of gas or plasma. While some work can likely be done on large-scale facilities such as Omega, Z, and NIF, an intermediate scale laser facility that included a very large experimental chamber would be an optimum place to make progress on this area of research.

- ***Describe the impact of this research on plasma science and related disciplines and any potential for societal benefit***.

Progress in understanding the transport of ionizing radiation in plasmas will improve our predictive understanding of plasma behavior. This fundamental advance will impact a wide range of plasma research and applications. The applications include x-ray sources, laboratory astrophysics, and novel designs for particle sources.

References (Maximum 1 page)

Figures (maximum 1 page)

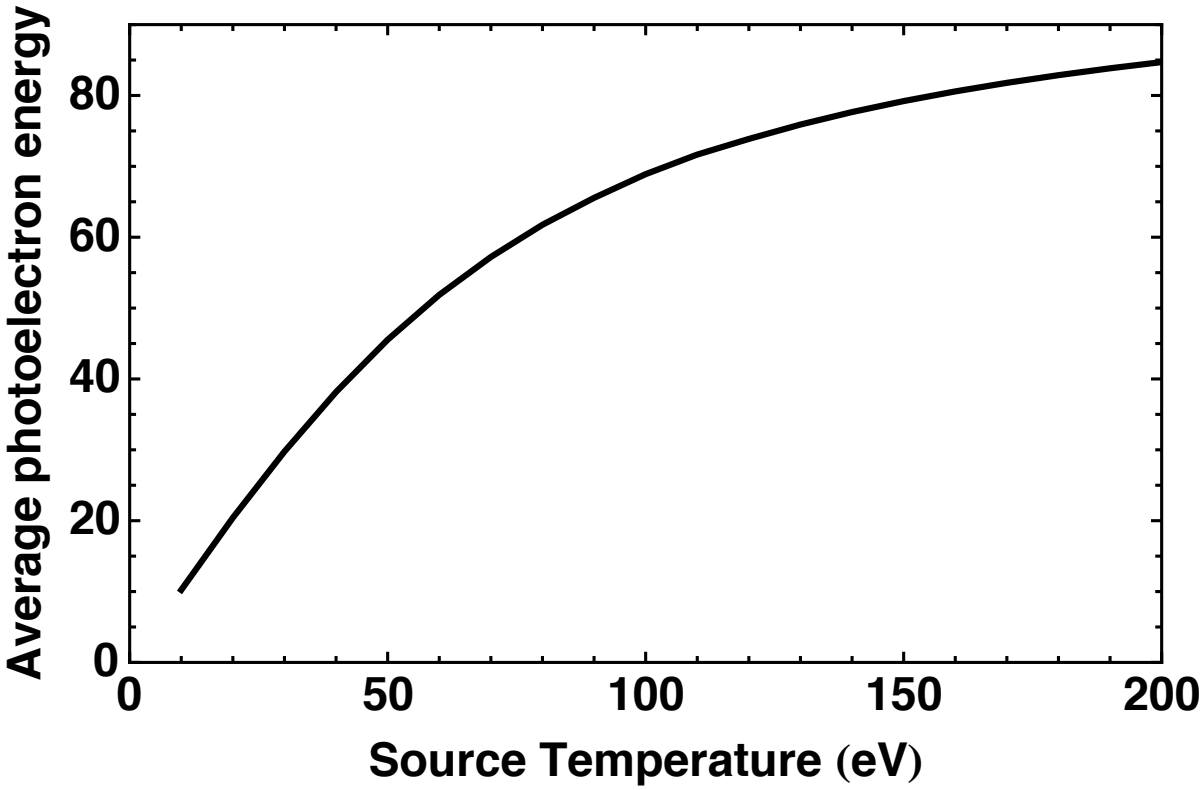

Figure 1. The average photoelectron energy produced by photoionization of the ground state of carbon 3+, as a function of the temperature of a Planckian radiation source that impinges upon it.