Radiative Losses of the Solar Corona

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A comprehensive set of calculations of the radiative losses of solar coronal plasmas has recently been made [1]. The radiative losses of the solar corona are an important quantity in evaluating the plasma energy balance of the Sun, which provides an understanding of the corresponding energy source. The LANL suite of atomic structure and collision codes [2] was used to generate a comprehensive set of collisional data for 15 coronal elements. These data were then used in the plasma kinetics code, ATOMIC [3], to generate the radiative losses as a function of the electron temperature. The calculations were made using a new capability of ATOMIC to consider all elements under the influence of one global electron density. The coronal equilibrium model was used in all calculations and the validity of this approach was checked by also solving the full set of collisional-radiative equations for selected temperatures.

The radiative losses computed by ATOMIC are shown in Fig. 1. We compare this calculation, labeled ATOMIC (DW ground), with previous work [4]. The agreement between the sets of calculations is fair in that the broad structure of the radiative losses as a function of temperature is qualitatively the same in both calculations. However, in some regions there are large differences in the magnitude of the radiative losses. In particular, the peak in the ATOMIC calculations of the radiative loss around a temperature of 10^7K is not seen in the calculations of [4]. Also, below 10^6K, our ATOMIC calculations are larger by around a factor of two than the calculations of [4]. The continuum contribution also appears to be different between the two sets of calculations, since we see a difference in the magnitude of the radiative loss at the highest temperatures considered. We also show a comparison with a calculation made using the most recent version of the CHIANTI software [5] (labeled CHIANTI6). This version contains significantly higher quality atomic data than the much older 1999 version, especially for heavier elements, and so appears to produce a more accurate radiative loss than the older calculations of [4]. For example, the CHIANTI6 calculations find a peak in the radiative loss at a temperature of around 10^7K, also found in our ATOMIC calculations. However, the CHIANTI6 calculations are still significantly lower than the ATOMIC calculations between 3×10^4K and 10^6K.

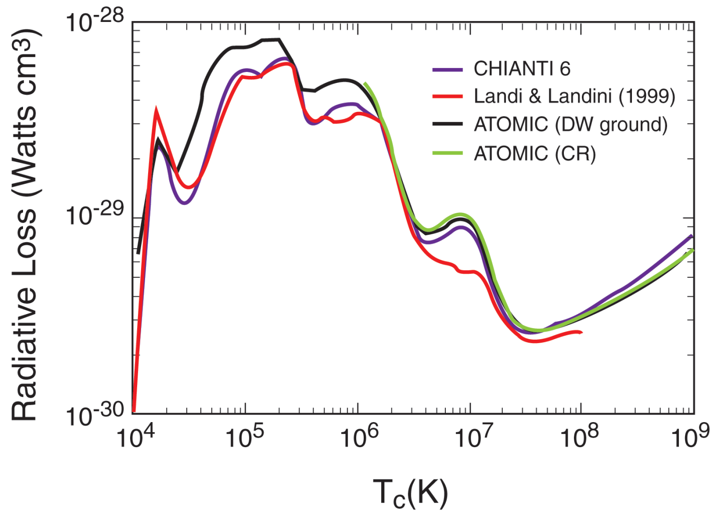

Fig. 1. Radiative losses from a coronal plasma containing 15 elements. ATOMIC calculations (solid black line) are compared with those of [4] (dashed red line) and a calculation made using the most recent version of CHIANTI [5] (dot-dashed magenta line). Also shown is an ATOMIC calculation obtained by solving the full set of collisional-radiative equations, labeled ATOMIC (CR) (green line).

Figure 2 shows the contributions to the radiative losses from the 15 individual elements in the study. For a given temperature, several elements contribute to the total radiative loss, with the most prominent contributions coming from C, O, Si, and Fe. A study was also made of the variation in the radiative losses as a function of changes in the elemental abundances of the corona. This study considered the various compositions that are thought to exist in the solar upper atmosphere (SUA) that can have different abundances of elements, which have a low first ionization potential (FIP) compared with the photosphere. The radiative losses show a marked dependency on the relative abundance of these low-FIP elements, even at high temperatures, due in part to the strong contribution from Fe to the total radiative loss.

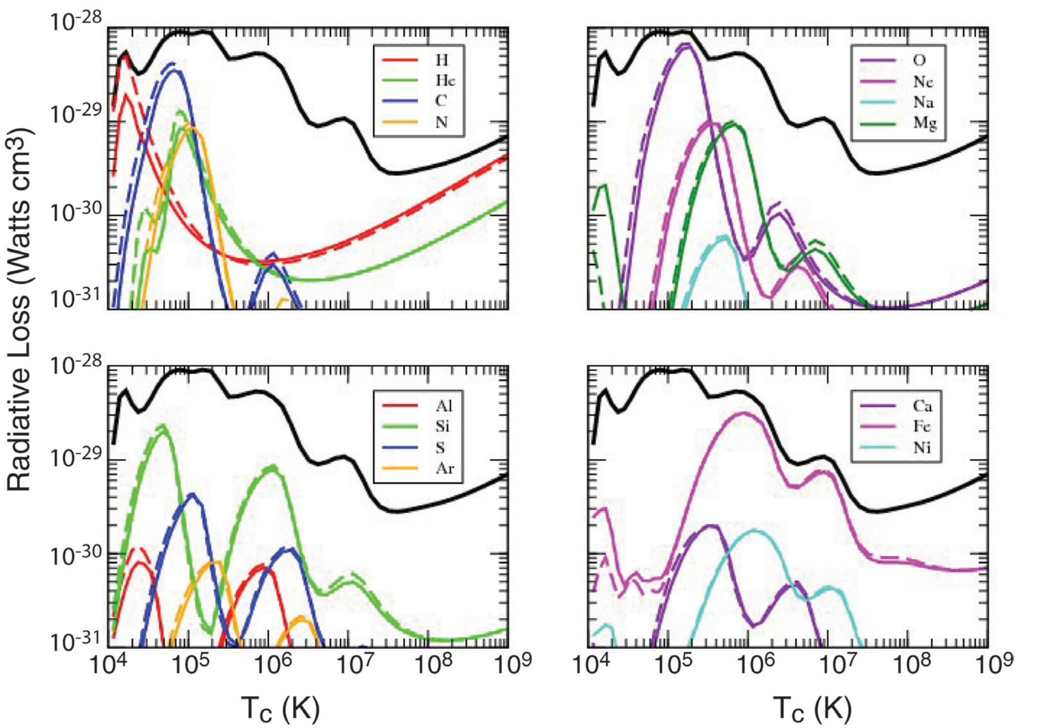

Fig. 2. Radiative losses from individual elements as labeled. The solid lines from each element indicate calculations made using distorted-wave collisional data from the ground configuration, and the dashed lines for each element indicate calculations made using plane-wave Born and scaled-hydrogenic data from the ground configuration. The thick solid line in each panel represents the total radiative losses summed over all 15 elements.

This study suggests that an independent determination of the solar coronal radiative loss could provide an alternative method of determining solar abundances, a topic of some controversy in recent years [6].

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