Spectral simulations of a H-C-O-Si plasma

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For the Plasma Dynamics Laboratory, University of Washington

We present here some simple, preliminary spectral simulations using the *PrismSPECT* non-LTE modeling code (see http://www.prism-cs.com/Software/PrismSpect/PrismSPECT.htm) and the *ATBASE ab initio* atomic models (see http://www.prism-cs.com/Software/AtomicData/AtomicData.htm)

The assumptions for these calculations are:

Time-independent, non-LTE ("collisional radiative equilibrium") ionization and level population calculation, with optically thin radiation transport

Predominantly hydrogen plasma, but with the following impurities, % atomic:

C: 0.25% O: 0.50% Si: 0.10% $n_{\rm ion} = 3 \times 10^{15} \text{ cm}^{-3}$ $T_{\rm e} = T_{\rm i} = 15, 50 \text{ eV}$ (two separate calculations)

Atomic Model ATBASE v. 5.1

Detailed Configuration Accounting (L-S coupling):

- H: 12 levels
- C: 641 levels
- 0: 1304 levels
- Si: 1678 levels

For C, O, and Si, we use all non-autoinizing levels of each ion stage (for Si, only up through Si⁺⁷, above which we use only ground states)

The following five slides show the *PrismSPECT* GUI for setting up the calculations.

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Low temperature (15 eV) results

Ionization balance – mean charge states:

Z_H:1 (2.3 X 10⁻⁶ H^o)

Z_C:3.99 (~1% C⁺³)

*Z*₀:4.19 (62% O⁺⁴, 26% O⁺⁵, 10% O⁺³, 1% O⁺⁶)

Z_{Si}:4.01 (>99% Si⁺⁴)

PrismSPECT ionization and excitation output

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The GUI for the *PrismSPECT* spectrum viewer



PrismSPECT simulated spectrum, with strong lines labeled...note: every line is from oxygen

T=15 eV



Same simulated spectrum as previous slide, but with a logarithmic y-axis: note domination of lines over continuum, and also note that the continuum is dominated by recombination, rather than free-free emission.



Again, the same simulated spectrum, but here it is degraded down to a very low resolution. This should enable us to better estimate what signal would be expected in a broad-band EUV/soft-x-ray detector.



The only difference between these two figures are the y-axes – linear (left) vs. log (right).

We next did a second calculation, identical in every way, except that the plasma temperature was increased to 50eV. High temperature (50 eV) results

Ionization balance – mean charge states: $Z_{\rm H}$:1 (3.3 X 10⁻⁷ H°) $Z_{\rm C}$:4.23 (77% C⁺⁴, 23% C⁺⁵) $Z_{\rm O}$:5.99 (1% O⁺⁵, 99% O⁺⁶) $Z_{\rm Si}$:5.92 (1% Si⁺⁴, 23% Si⁺⁵, 59% Si⁺⁶, 16% Si⁺⁷)

Note: increase by >1 charge state, compared to 15 eV calculation

PrismSPECT ionization and excitation output



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The GUI for the *PrismSPECT* spectrum viewer

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PrismSPECT simulated spectrum. Note the different wavelength coverage. Also, only the three strongest lines are identified (and they are all from silicon).



This is what the 50 eV spectrum looks like in the same photon energy range we showed for the 15 eV spectrum.



Spectrum plotted with logarithmic y-axis. Note the even weaker continuum than in the 15 eV spectrum, as well as the damping wings of





And the 50 eV spectrum degraded to low resolution (note linear y-axis)



Logarithmic representation of the low-resolution spectrum, compared to the 15 low-resolution spectrum.



Conclusions

•The spectrum is line dominated (and seems that it would be for significantly lower impurity levels)

•A small number of strong lines dominate

•In a given spectrum (at a specific temperature) a single element can completely dominate the emission

•At low resolution, the spectrum is moderately peaked, at $h\nu{\sim}kT$

•Over this range – a few 10s of eV – the emissivity is of order 10^{18} ergs/s/cm³/ster/eV

Future Work

•More of the strong lines should be identified in the 50 eV case

•Lower (or different) impurity levels could be explored

•Given a time-history of temperature and density, we could perform a time-dependent calculation – there's a very good chance that the plasma is far from equilibrium