PrismSPECT: Vi	ewing results from run <baseline_te5tr150ni15dl100_v1></baseline_te5tr150ni15dl100_v1>
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Setup: Plasma Elements Simulation Type	At. #       Element       # fraction       Atomic Model       Add         1       H       0.999       C:/files/physics_projects/photoionized_plasmas/simulations/F       Add         6       C       0.001       C:/files/physics_projects/photoionized_plasmas/simulations/F       Delete
Plasma Properties	
Spectral Grid	Number fractions will be normalized to 1. Element Properties
Output	Element: C (Z = 6) Modify Name: Carbon
Run Simulation	Number Eraction: 0.001 At. Weight: 12.0112
View Results: Spectra	Atomic Model Model type: C Detailed configuration accounting (DCA) C Tabular Data C Default Model: Emission K-Shell Spectroscopy View
Ionization Line Intensities	Custom         File:       sct/carbon_v1/Z06_C_emis_kshell_spectra.atm       Browse       Edit         Help       Next >

## D. Cohen 29 Feb 2008

Some simple PrismSpect tests of recombination spectra in photoionized plasmas

H: 99.9% at. C: 0.1% at.

 $n_i = 10^{15} \text{ cm}^{-3}$  $T_e = 5 \text{ eV}$ 

T\_r = 150 eV T\_spec = 500 eV

I used the canned K-shell emission atm files

I wanted a cold, highly ionized plasma of relatively low density to focus on the spectral signatures of recombination

Here's some of the set-up screens for the baseline PrismSpect simulation:

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Setup:	Steady-state Independent \	/ariables		
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Atomic Processes				
Spectral Grid	- Plasma Parameters			
Output	Plasma Temperature:	5	Table	eV 🔻
	Ion Density:	1e+15	Table	ions/cm^3 💌
Run Simulation	Number Fraction:		Table	
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	Help		< Back	Next >

lonization / Populations Viewer [baseline_Te5Tr150ni15DL100_v1]				
File Edit View Axes Text Graph Layers Help				
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Ionization / Level Populations Data	-	-Graph Selected I	lons / Levels	
		X-axis quantity:	Units:	
Ion / Level Fraction				
Electron Density 1.004e+15				
Mean Charge 1.004 Cooling Bate 2.023e+08				
E-Hydrogen Mean Charge 1				
tie-HI 1.446e-05		l <sup>1</sup>		
E-HII 1				
<u>Caldor Mean Chalge</u> <u>0</u> <u>0</u> <u>1.047e-11</u>				
⊕-CV 0.0003865				
⊕-CVI 0.9996	I ⇒ 1	5		
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Note the carbon is nearly all H-like, but essentially none of it is bare.

Spectra Viewer [baseline_Te5Tr150ni15DL10	0_v1]		
File Edit View Axes Text Graph Layers Help			
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Spectra Units Plot: Intensity	1e+9 [		
Selected Plot Resolution: 0 Apply to all Spectral components	le+5 le+3	30 Wavelength (	40 A)
Ion Upper Configuration Term Lo	ower Configuration	Term Photon Energy Wavelength	f (BB) / xsec (BF)
CVI 5p(1) 2P 1s	(1)	2S [1/2] 470.398 26.3564	0.01394
CVI 4p(1) 2P 1s CV 3p(1)3d(1) av 1s	(1)3~(1)	25 [172] 459.375 26.9888 15 436.724 28.9886	0.0227
CVI 3p(1)3d(1) 2P 1s	(1)35(1)	2S [1/2] 435.558 28.4646	0.079
CV 3s(1)3d(1) av 1s	(1)3p(1)	1P 434.385 28.5415	0.0253
CV 3p(1)3d(1) av 1s	(1)3s(1)	35 433.288 28.6138	0.01297
CV 3p(1)3d(1) av 1s	(1)3d(1) (1)2-(1)	1D 431.808 28.7118	0.06589
CV 30(2) av 1s CV 30(1)3d(1) av 1«	(1)3P(1) (1)3d(1)	IF 430.310 28.8115 3D 429.785 28.847	0.06943
CV 3s(1)3p(1) av 1s	(1)3s(1)	1S 429.658 28.8555	0.0396
CV 3s(1)3p(1) av 1s	(1)3s(1)	3S 429.623 28.8579	0.05907 🗸
-Filter Transition Table Data-	(1)0 (I) 	<u> </u>	
Filter Elements: All▼ Ions: All	Transitions: B-B 🕶	☐ Hide satellites ☑ Hide le	vels not Min. osc. strength: 0.01
Help			Close

Note: The C VI K-edge is at 25.3 Angstroms; the edge that's visible here, near 32 Angstroms, is the C V edge/RRC. This reflects the fact that for a pure recombination spectrum, the strong features are from the i-1 ionization state.

The lines at 40+ A are the resonance and intercombination lines of C V. Presumably the forbidden line is absent because of the relatively high density, but I'm surprised that the intercombination line isn't stronger, as G > 1 for photoionized plasmas.

Turning up the radiation field (Tr=250) – still no bare C:



Spectra Viewer [baseline_Te5Tr250ni15DL100_v1]	
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Spectra units Plot: Intensity • erg/cm2/ster/s/eV • Add • Delete All Resolution Selected Plot Resolution: 0 Apply to all Spectral components	36
Ion       Upper Configuration       Term       Lower Configuration       Term       Photon Energy       W         C ∨I       5p(1)       2P       1s(1)       2S [1/2]       470.398       2E         Image: C ∨I       5p(1)       2P       1s(1)       2S [1/2]       470.398       2E         Image: C ∨I       5p(1)       2P       1s(1)       2S [1/2]       470.398       2E         Image: C ∨I       5p(1)       2P       1s(1)       2S [1/2]       470.398       2E         Image: C ∨I       5p(1)       2P       1s(1)       2S [1/2]       470.398       2E         Image: C ∨I       5p(1)       2P       1s(1)       2S [1/2]       470.398       2E         Image: C ∨I       5p(1)       2P       1s(1)       2S [1/2]       470.398       2E         Image: C ∨I       5p(1)       2P       1s(1)       2S [1/2]       470.398       2E         Image: C ∨I       5p(1)       1s(1)       Transitions: B-B ▼       Hide satellites       Image: C ∨I       Hide sat	/avelength 3564 mgth: 0.01 Close

Maybe the electron temperature is just too low. Try Te=15eV. But still Tr=250. ni=1e15.

lonization / Populations Viewer [baseline_Te15Tr250ni15DL100_v1]					
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Ionization / Level Populations Data		Graph Selected Ions / Levels			
		X-axis quantity: 🗾 Units:	-		
Ion / Level Fraction					
Electron Density 1.005e+15     Mean Charge 1.005					
- Hydrogen Mean Charge 1		1			
⊕-HI         1.793e-06           ⊕-HII         1           ⊡-Carbon Mean Charge         6					
B-CIII 8.301e-24 B-CIV 1.442e-17					
⊕-CVI 24106-11 ⊕-CVI 1.156e-05 ⊕-CVII 1	•	Fraction			
		•			
		0 1			
Show lons Show Levels					

OK, this made a huge difference; now bare C is dominant.

Though I'm somewhat surprised that it went from nothing to completely dominant going from just  $T_e=5eV$  to 15eV.

Here's the synthetic spectrum from this simulation:

Spectra Viewer [baseline_Te15Tr250ni15DL11	00_v1]	
File Edit View Axes Text Graph Layers Help		
Spectra Plot: Intensity ▼ erg/cm2/ster/s/eV ▼	1e+9	
vs: Wavelength Angstroms Add Add Delete Delete All Resolution 0 Selected Plot Resolution: 0 Apply to all Spectral components	(A) 1e+8 1e+7 1e+7 1e+6 1e+6 25 Wavelength (A)	
Ion     Upper Configuration     Term     Lo       C VI     5p(1)     2P     1s(       ◀     Image: state of the st	wer Configuration Term Photon Energy Waveler 1) 2S [1/2] 470.398 26.3564 B-B ▼ □ Hide satellites ▼ Hide levels not in atomic model Min. osc. strength:	ngth

The RRC (at 25.3 A) is still very weak compared to Ly-alpha (near 33 A).

Let's convolve down to R=800

Spectra Viewer [baseline_Te15Tr250ni15DL100_v	1] 📃 🗖 🔀
File Edit View Axes Text Graph Layers Help	
<u>   א</u>	
units Plot: Intensity  erg/cm2/ster/s/eV vs: Wavelength  Angstroms Add  Delete Delete All Resolution 800 Selected Plot Resolution: 800 Apply to all Spectral components	le+9 le+8 le+7 le+6 le+5 le+4 25 30 Wavelength (A)
Ion     Upper Configuration     Term     Lower Configuration       C ∨I     5p(1)     2P     1s(1)       ✓	onfiguration Term Photon Energy Wavelength ▲ 2S [1/2] 470.398 26.3564 ▼ F Hide satellites ▼ Hide levels not in atomic model Min. osc. strength: 0.01 Close

Doesn't make much difference

But, when I integrate the power in a band around Ly-alpha and then around the RRC, I get just a factor of 4 ratio in integrated power:

Line Intensity Viewer [baseline_Te15Tr250ni1]	5DL100_v1]	
File Edit View Axes Text Graph Layers Help		
<u> </u>		
Select line/band type:	- Graph Selected Line Intensities / Ratios	
Freq-Integrated Power in Band	X-axis quantity:	-
Select plot quantity:		
Intensity rig/ster/cm 2/s		
Line Intensity Data	1.0	
Lines / Bands		
Line ID Line Value	0.5-	
Intensity_2 7.731e+06		
	-n	
Add Edit Delete	-0.5-	
Batios		
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	-1.0 -0.5 0.0 0.5 1.	0
	Chevu in Constal Viewer	
Add Edit Delete	Line/Band ranges Fitted lines Background cor	ntinuum fit
Help		Close
		0.036

Hmmm... so there's significant integrated power in the RRC... but it's not highly peaked (though in linear space, it looks plausibly to have a width of  $\sim$ kT.

See what difference it makes to lower T to 10eV:

Ionization / Populations Viewer [baseline_Te10Tr250ni15DL100_v1]				
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Ionization / Level Populations Data	-	Graph Selected Ions / Levels		
		X-axis quantity: Units:	-	
Ion / Level Fraction			_	
Electron Density				
- ∰-CV 1.21e-05 - ∰-CVI 1 - ∰-CVI 1e-30	•	Fraction		
		0 1		
Show lons Show Levels				

Wow, Ionization completely different - back down to no bare C at all.

Now	trv	ni=1e13	and	Te=10eV
11011	u y	111-1010	ana	10-1001



same thing – still no bare C at all.

5 March 2008 – looking at lowering the density (not so much for the RRC, but for the f-i-r complex  $n_i = 1e8$ , Te=15eV



Ionization is very high

Spectra Viewer [baseline_Te15Tr250ni8DL10]	0_v1]	
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Spectra		
units	1e-05	
Plot: Intensity r   erg/cm2/ster/s/eV r	00102	
vs: Wavelength 💌 Angstroms 💌	S <sup>1e-06</sup> ₹	
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	1e-10 25 30 35	
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CVI 5p(1) 2P 1s(	(1) 2S [1/2] 470.398 26.3564	<u></u>
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Filter Transition Table Data		
Filter         Elements: All         Ions: All         Transitions:	B·B▼ ☐ Hide satellites ▼ Hide levels not in atomic model Min. osc. strength:	0.01
Help		Close

Spectrum is very, very similar to the higher density, highly ionized case (here in the Lyman series)

There are no helium-like features b/cs of the very high ionization

Let's go down to 5 eV now



The ionization is significantly lower (again), despite the much lower density

Spectra Viewer [baseline_Te5Tr250ni8DL100_v1]	
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le-06 8e+02	
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Resolution: 800 Apply to all	
Spectral components 30 40 Wavelength (A)	
Ion Upper Configuration Term Lower Configuration Term Photon Energy Waveler	nath
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	•
Filter Transition Table Data	
Filter     Elements: All     Ions: All     Transitions: B-B     Hide satellites     Hide levels not in atomic model	0.01
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This doesn't look much different than the higher density models: RRC is narrow, but still weak, and G << 1.