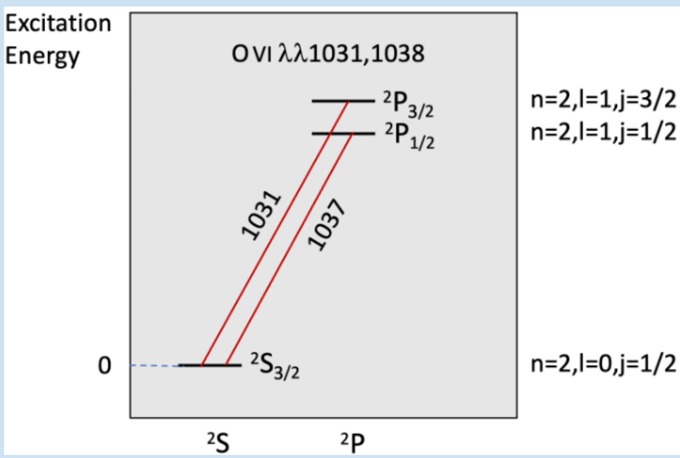
1a(i)	**2**	OVI is oxygen with **5 electrons stripped off** (ionized). The ion is **O^{+5}**
1a(ii)	**3**	Oxygen has 8 electrons. OVI has 3 electrons. Two are in the 1s subshell, and one is in the 2s subshell. **The electron configuration is "1s^2 2s"**
1a(iii)	**3**	**OVI has the same electron configuration as neutral lithium.** As such, OVI has an energy structure like that of lithium and thus **OVI has a spectrum like that of lithium** (though the transition energies are different)
1b(i)	**2**	A **fine-structure doublet is a pair of absorption lines** that (In most of the case) there is a single ground state energy for which the first excited energy state is split into two levels by a relatively small energy difference.
1b(ii)	**2**	The atomic physics that splits the upper energy state is the **interaction between the orbital angular momentum of the electron and the electron spin**.
1c	**8**	
Prob 1	**20**	

2a	**4**	As stated in the paper, the **ionization energy of OVI is 10.2 Ryd**. The ionization for HI is 1 Ryd. Thus, the ratio of the wavelengths is lambda(OVI) = (1/10.2)*lambda(HI) = 912/10.2 = 89.4 angstroms. Photons with energy higher than this can also ionize OVI, so the range is **lambda(OVI) < 89.4 angstroms**.
2b	**2**	**Photoionization. Collisional Ionization.**
2c	**4**	**Photoionization of OVI occurs when a photon of energy >113.9eV is absorbed by the ion and the electron is ejected.** Thus, for photoionization to dominate, the density of UV photons with E >113.9eV must be above a critical threshold. Models show that the ratio of the density of ionizing photons to the density of hydrogen needs to be > 0.1 (that ratio is called the ionization parameter). This can occur near active galactic nuclei and gamma-ray bursts. In the ISM of galaxies, the ionizing radiation field has a sharp break at 54 eV caused by the HeII edge in hot-star spectra and so photoionization less likely. In the CGM and IGM, photoionization of OVI by the extragalactic background radiation can occur as well.
2d	**4**	**Collisional ionization of OVI occurs in hot environments where the average kinetic energy (KE) of free electrons is >113.9 eV. As an electron passes by an OVI ion can give up some of its KE to the most loosely bound electron and eject it.** Collisional ionization of OVI requires “coronal” plasma temperatures of 10^5–10^6 K. At 300,000 K the ionization fraction of OVI is a maximum (about 0.2). However, non-equilibrium conditions are common because hot plasmas are thermally unstable (they cool). Astrophysically, collisional ionization can happen in the ISM, CGM, ICM, and the WHIM (IGM).

Prob 2	**14**		

3a	**6**		**L = N(OVI)/(f_OVI * alpha_O * n_H)**
3b(i)	**3**		log(L) = 13 - (-1 - 4 - 1) = 13 + 6 = 19; L = **10^{19} cm**; converting to kpc, there are 10^{21.5} cm/kpc; L = 10^{19-21.5} = 10^{-2.5} = **0.0033 kpc**
3b(ii)	**2**		R_gal = 50,000 lyr = 15 kpc. L/R_gal = 0.0033/15 = 0.00022 = 2e-4.
3c(i)	**2**		The Galactic OVI column densities are plotted on Figure 1. Only the Local ISM data have column densities of 10^13 on average, all others Galactic components have column densities of 10^14. So, this example corresponds to **local ISM (LISM) absorption in this context**.
3c(ii)	**2**		A typical ISM cloud is about 10 pc, or 0.01 kpc in diameter. **So, our cloud is about 1/3 the average size of an ISM cloud. Still, it is reasonable.** If it was a little more or a little less ionized, or the hydrogen density was slightly higher it would be very average.
Prob 3	**15**		

4a(i)	**4**		These two figures (3&4) are showing how OVI column density evolves with redshift. Per the psper, two interesting conclusions can be drawn. (**1) the mean column density of intergalactic OVI components evolves "only weakly" over cosmic time. (2) both low and high redshifts, there is no difference in the mean OVI component column density between the intervening and proximate samples.**
4a(ii)	**4**		If OVI is photoionized, then the absorbing gas must evolve such that the high-z absorbers must have smaller sizes, lower metallicities, or lower OVI ionization fractions (or some combination of these three) than their low-z counterparts. On the other hand, if both galactic and intergalactic OVI absorbers are formed in radiatively cooling regions of initially hot shock-heated plasma passing through the coronal regime provides a unified explanation for the no-evolution of OVI column densities without any need for tunable parameters or for photoionization.
4b(i)	**4**		This figure (5) is showing how the Doppler b parameter evolves with redshift. **IGM OVI components are, on average, almost twice as broad at low-z than at high-z**. This difference is not due to resolution, since the instrumental line widths of each sample are much smaller than the mean OVI line widths:
4b(ii)	**4**		The key advantage of the radiative cooling model is that it naturally explains the non-evolving column density insensitive to metallicity. **The author confesses that is less clear how it could explain the evolution in IGM b-values**. If gas were cooling with time, one would expect the b-parameters to get smaller from high-z to low-z, and the opposite is measured. Something is increasing the line broadening with cosmic time- but is remains a mystery.
Prob 4	**16**		

5a	**3**		This paper presents a meta-study of pre-published OVI absorbers across a wide range of astrophysical environments and across a cosmic time with a focus on learning which models of the gas structures are best suited to describing OVI absorbers and how they evolve with redshift.
5b	**3**		For a decade (preceding this paper) OVI absorption observation grew such that there is now a large database of high-resolution data. Several models have been proposed to understand the astrophysics of OVI absorbers, given that OVI seems to arise in so many astrophysical environments and across most of cosmic time. The large amount of data in the literature provides

			a unique opportunity to undertake global meta-study to better understand competing models of OVI absorbers and nature of diffuse universe.
5c	**3**		The paper draws data from the literature. These data are measured quantities, such as the absorber redshifts, component column densities, Doppler b parameters, and instrumental parameters. These quantities are sufficient for the study, as they are observed with instruments of similar resolutions, have been analyzed using the same methods, cover a wide range of astrophysical environments, and cover a wide range of redshifts.
5d	**3**		Quite simply, the author created subsamples by astrophysical environment (Galactic, IGM, associated, etc.) and by redshift. They then examined how the column densities compared across environment and across redshift, and then how b-parameter compared across redshift. They used the findings from these comparisons to consider, compare, and discuss competing models of the origin of OVI absorbers across all these environments and across cosmic time.
5e	**3**		All astrophysical environments appear to have the same average OVI column density, and this average does not appear to evolve over cosmic time. This suggest a model that naturally explains this behavior and that favored model is shock-heated radiatively cooling gas.