The Spectrum of Comet Austin

J. C. Green *et al.* (*1*) present the ultraviolet spectrum of comet Austin (1988) in the region from 910 to 1180 Å, which shows features at 1025, 1041, and 1128 Å. They state that these are neutral oxygen (OI) lines, produced as a result of oxygen atom pumping by solar Lyman β neutral hydrogen (HI) radiation at 1025 Å. Their scenario is given in their figure 3, reproduced here as Fig. 1 in a slightly modified form.

Green *et al.* note that the 1128 Å transition is optically forbidden because it occurs between two even parity oxygen atom states, whereas the selection rules permit transitions between odd and even parity only (*2*). However, they do not say that the 79176 Å (7.92 μm) transition is equally forbidden, as both relevant states are odd (*3*). It is also forbidden because of the restriction (for one photon) of $^3D \rightarrow {}^3S$ transitions, further amplified by the long transition wavelength. Thus, the 7.92-μm line will be extremely weak compared to the allowed transition at 11286 Å (1.13 μm), thereby suppressing the cascade 1041 Å emission. The comment by the authors that 1041 Å radiation "is not unexpected" is therefore unexpected. An example of a doubly forbidden transition that has similar restrictions to the 7.92-μm line is the $^1S \rightarrow {}^1D$ 557.7-nm OI green line, with a radiative lifetime of 0.8 s, whereas a transition having the same lower level, the 115.2 nm $^1D^0 \rightarrow {}^1D$ line, has a 2.2-ns lifetime (*4*). Scaling the green line radiative rate to the longer wavelength of the 7.92-μm line should result in a transition rate on the order of 5×10^{-3} s^{-1}, which is almost ten orders of magnitude smaller than that for the competing 1.13-μm radiation (*4*). As a general rule in atomic spectroscopy, a closed loop of allowed transitions must have an even number of steps. Thus, in Fig. 1 three of the loops are forbidden and one is allowed.

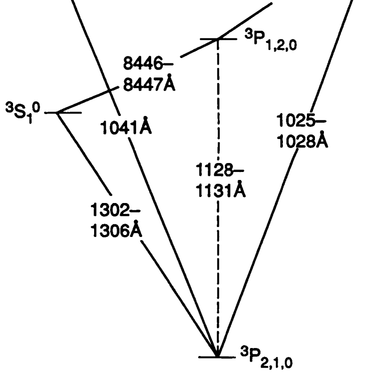

Fig. 1. A partial energy level diagram for OI from Green *et al.* (*1*). The 79176 Å and 1128–1131 Å pathways are optically forbidden.

Green *et al.* deal with the forbidden nature of the 1128 Å line by arguing that the cometary system is optically thick in 8446 Å emission. They say that this density is many orders of magnitude higher than what is expected, considering that the modeled typical maximum value is 10^6 cm^{-3} at a distance of 10 km from the comet (*5*). The same reasoning must hold for the 1041 Å identification. Only if the system is extremely optically thick at 1.13 μm is it possible for 7.92-μm radiation to lead to 1041 Å emission. Meier *et al.* (*6*) discuss the 1.13-μm line for the terrestrial atmosphere in terms of the Lyman β pumping model, and conclude that it should be optically thin. Thus, the enormous optical depth required for *all* the atomic lines shown in Fig. 1, except for those at 1128 Å and 7.92 μm, appears to be untenable.

Given the 0.6 Å width of the Lyman β line (7), O atom excitation ought to be as effective in Earth's atmosphere as in cometary atmospheres (that is, heliocentric velocity should be irrelevant). Such being the case, the mechanism proposed by Green *et al.* should lead to observation of 1041 Å radiation in the terrestrial dayglow. A search of the dayglow spectrum at 140 to 260 km presented by Gentieu *et al.* (*8*) shows no evidence for a feature at this wavelength, but in a spectrum taken at 600 km (*9*) there is a hint of a feature which might be OI 1041, although neutral nitrogen (NI) lines are another possible identification.

The supposition that there should be strong resonance trapping in each fully allowed transition of the A→B→C→D emission sequence of Fig. 1 is unprecedented. It is doubtful that the initial excitation source for the 1041 and 1128 Å spectral features is the Lyman β line because excitation of the upper state of the 1025 Å OI transition should not lead to these two lines. We conclude that either the features are not caused by oxygen, or if they are, they are generated in a different manner from what Green *et al.* propose.

An alternative possibility is that the two lines are produced by direct resonance excitation from solar lines that are in close coincidence with them. As Green *et al.* suggest, the 1128 Å feature could well be a neutral carbon (CI) line. In fact, there are strong nearby solar doubly ionized iron (FeIII) lines and triply ionized silicon (SiIV) lines, as well as many CI lines, their widths being dependent on the region of the sun from which they originate. Because of the blue shift caused by the heliocentric velocity, true resonance excitation probably does not take place, but cometary CI transitions could be pumped by solar lines lying 0.1 to 0.2 Å toward the red. Although there are numerous elementary ionized lines in the 1041 Å region (*10*), the solar spectrum is devoid of features from 1039 to 1062 Å (*11*). Thus, if photoexcitation is the source of the 1041 Å radiation, the mechanism is not evident.

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Response: We did not state unequivocally that the coma was optically thick, but rather that we had no complete explanation for the origin of the observed emission. We presented the optically thick scenario as one that could explain, within the context of this single observation, the lines observed and their intensity ratios.

We disagree with Slanger's comparison of the coma with atmospheric observations. Heliocentric velocity *is* relevant in determin-

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