INVESTIGATING ULTRAVIOLET EXCITATION PROCESSES IN 67P/CHURYUMOV-GERASIMENKO. Eric R. Schindhelm¹, Michael F. A’Hearn², Jean-Loup Bertaux³, Lori M. Feaga², Paul D. Feldman⁴, Joel Wm. Parker⁵, Andrew J. Steffl⁵, S. Alan Stern¹, Harold A. Weaver¹, ¹Southwest Research Institute, Department of Space Studies, Boulder, CO, ²Department of Astronomy, University of Maryland, College Park, MD, ³University of Versailles Saint-Quentin en Yvelines, Versailles, France, ⁴Johns Hopkins University, Department of Physics and Astronomy, Baltimore, MD, ⁵Johns Hopkins University Applied Physics Laboratory, Laurel, MD

Introduction: We report analysis of far-ultraviolet (FUV) spectra of the coma of 67P/Churyumov-Gerasimenko taken by the Alice imaging spectrograph onboard the Rosetta spacecraft. Alice is comprised of an off-axis paraboloid telescope followed by a Rowland mount spectrograph feeding a double delay line microchannel plate detector [1]. Its large field of view and moderate spectral resolution are ideal for sensitive detection of FUV atomic and molecular emission from the coma. The slit is 5.5° in length with a 0.1° wide top and bottom and 0.05° narrow center. Unlike typical cometary FUV spectra, the emissions observed from 67P appear so far (heliocentric distances >2.5 AU) to be dominated by electron impact excitation from photoelectrons produced by the photoionization of H₂O. We present the evidence for this conclusion and compare the relative strengths of the collisional excitation mechanism to the traditionally observed resonant scattering.

Observations: In November 2014 through January 2015 Alice performed a series of observation campaigns from near-terminator orbits. The radial distances to the comet in these orbits varied between approximately 10 km and 30 km. The pointing profiles were stares above the sub-solar limb, scans across the sub-solar limb, and nadir stares. These observations generally sampled full rotations of the comet (~12.4 hours), allowing us to characterize the variation of the coma from all points around the surface. During the nadir-stares it was possible to measure emission from the sunlit species above the nucleus, free of contamination from the interplanetary medium.

Discussion: The coma spectra mostly consist of H I and O I emission lines, species resulting mainly from the dissociation of H₂O, CO, and CO₂. An example spectrum and pointing is shown in Figure 1. In this spectrum the sunlit nucleus is apparent in the bottom of the slit by reflected solar C II 1335 Angstrom emission and rising flux at long wavelengths, while coma gas emission appears throughout the slit. The gas emission shows diurnal variation that can fluctuate by up to an order of magnitude, peaking when the high activity areas are in view.

![Figure 1:](image)

There is significant OI emission at λλ1152 and 1356 Angstroms, which cannot result from the OI resonant scattering of solar far-ultraviolet photons. The forbidden O I λ1356 multiplet is indicative of excitation due to electron impact by electrons produced by
the photoionization of H$_2$O [2]. The relative intensities are roughly consistent with 200 eV laboratory electron impact spectra [3]. These emissions are unlikely to result from photo-dissociation of H$_2$O into excited atomic states, based on solar rate [4] and H$_2$O absorption selection rules that favor the formation of O I in singlet states rather than triplets (1304 Å) or quintets (1356 Å) [5].

Additional support of the H$_2$O photoelectron excitation mechanism comes from nadir observations, where HI emission above the night side of the nucleus can be observed without contamination of interplanetary HI emission. In these spectra, the ratio of Lyman-α to Lyman-β is also consistent with photoelectron impact of H$_2$O, but not resonant scattering of the solar FUV lines.

FUV spectra of cometary coma previously measured from Earth are typically dominated by resonant scattering. It is likely that the differences with the Rosetta Alice spectra are related to the very different spatial scales sampled: the Alice spectra sample the innermost coma (heavily weighting points within 30 km of the nucleus) whereas most Earth based observations are primarily sampling the coma at thousands to tens of thousands of kilometers from the nucleus. Since the photoelectron density is highest near the nucleus, collisional excitation should be relatively more important for the Rosetta observations.

C I $\lambda\lambda$1561 and 1657 and C II $\lambda$1335 emission also appear in these spectra, and their relative strength implies electron impact excitation of either CO$_2$ or CO. The relative intensities of 1657:1561:1335 are approximately 2:1:1, which more likely results from CO$_2$ dissociation [6, 7, 8]. Combined with cross sections of 100 eV electrons, the ratio of C I $\lambda$1657 to Lyman-β can be used as a proxy for the CO$_2$/H$_2$O ratio. The R-Alice data suggest this ratio varies from a few percent to ~10 percent, consistent with direct measurements of the CO$_2$/H$_2$O ratio made at infrared wavelengths by the VIRTIS imaging spectrograph [9] onboard Rosetta.

We will present additional results of the coma evolution, CO$_2$/H$_2$O ratio, and spatial distribution as the comet continues towards the sun and other regions of the nucleus become illuminated.

References: