Radiation Darkening of Europa's Cryoplume Fallouts. U. Raut[1,2,3], B. D. Teolis[1,2,3], B. D. Mamo[3,1,2], O. J. Tucker[4], T. M. Becker[2,3], P. M. Molyneux[2], K. D. Retherford[1,2,3], T. K. Greathouse[2], G. R. Gladstone[2,3]. [1]Center for Laboratory Astrophysics and Space Science Experiments (CLASSE), Southwest Research Institute, San Antonio, Texas, 78238 (uraut@swri.edu); [2]Space Science and Engineering, Southwest Research Institute, San Antonio, Texas, 78238; [3]Department of Physics and Astronomy, University of Texas at San Antonio, San Antonio, Texas, 78249, [4]NASA Goddard Flight Center, Greenbelt, MD, 20771.

Introduction: Europa's plumes appear to be episodic in nature [1-3], in contrast to Enceladus' constant venting. However, the scale and frequency of cryovolcanic eruptions at Europa are not well-known, and indeed remain to be confirmed. In the absence of direct plume observations during Europa reconnaissance by the Clipper mission, deposits emplaced on the surface may be the best evidence of recent geological activity [4, 5]. Mass outflow rates, ejection speeds and grain size primarily control the radial extent and thickness of the plume fallouts, and recent studies show collisional dynamics closer to the vents influence the surface fallout distribution [6]. Figure 1 shows an example estimate of the distribution of the fallout flux onto Europa's surface from a 500 kg/s plume source ejected at 1km/s speed [7].

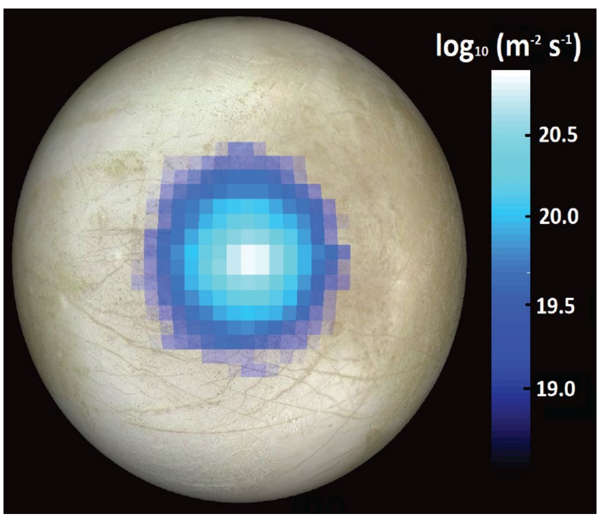

Figure 1: Estimated H_2O fallout flux distribution onto Europa's surface from a 500 kg/s water vapor plume with a 1km/s ejection speed [6]. We model the radial extent and thickness of plume deposits as a function of mass ejection rates and speeds and other relevant parameters. Relatively recent plume deposits, enriched in water ice, may appear UV-bright, contrasting against Europa's low ultraviolet albedo. Energetic processing by magnetosphere ions and electrons darkens the cryoplume fallout. Lab measurements of UV darkening rate together with precipitation flux of magnetospheric charged particles provide brightness and longevity estimates of cryoplume fallouts.

While visible and infrared imagery through Clipper's Europa Imaging System (EIS) and Mapping Imaging Spectrometer for Europa (MISE) has been discussed as indirect plume detection methods [4], ultraviolet (UV) surface spectroscopy observations by Europa-UVS present a unique approach to identifying and characterizing cryoplume fallouts. Europa is surprisingly dark in the far-ultraviolet with albedos < 2% [8-11]. Plume fallouts, consisting of spectrally bright H_2O recondensed vapor and ice grains, will contrast drastically against Europa's dark UV surface, especially at wavelengths longward of 165 nm. Water ice appears brighter above this threshold (see Mamo et al. ibid companion abstract # 2240) since the longer wavelength photons cannot induce the $X\ ^1A_1 \rightarrow A\ ^1B_1$ electronic transition. Observing localized spots of spectral brightening due to spewed/recondensed water ice may constitute a novel and highly effective plume fallout detection approach with Europa-UVS.

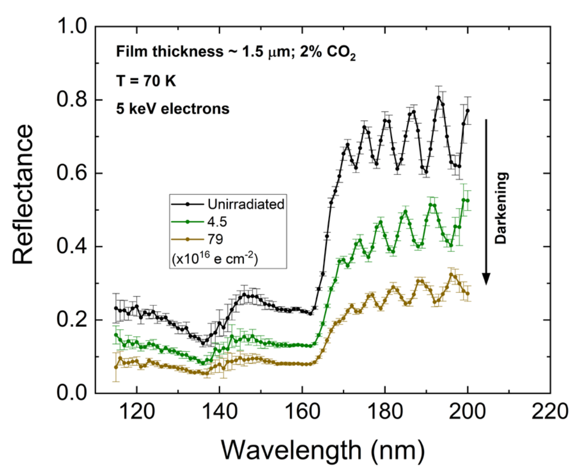

Figure 2: Preliminary data showing far-UV darkening of water ice films with trace amounts of CO_2 under 5 keV electron irradiation. Next steps are to estimate darkening cross section and its dependence on stopping power, which will be combined with precipitation flux of energetic charged particles to predict the age of cryoplume fallouts since emplacement.

But how long will the cryoclastic fallouts from episodic/inactive plumes remain UV-bright under continual radiolytic processing by the impinging magnetospheric charged particles? Radiation darkening, as postulated for the Saturnian icy moons [12], motivates new experiments to quantify darkening rates of water ice films under electron irradiation in the lab and at Europa. Far-ultraviolet brightness of pure water ice films deposited at 80 K remained unaffected during 5 keV electron irradiation. However, the films darkened significantly when trace amounts of CO_2 (<5%) were added as shown in Figure 2. Europa's plumes may also spew other species such as H_2, CO_2, CH_4, NH_3, organics, salts and silicates in trace concentrations, similar to Enceladus [13, 14]. These species could be entrained with recondensing water ice grains and vapor to be trapped within the plume deposit and subject to energetic processing.

We will measure the dependence of darkening rates on (1) CO_2 abundance, (2) energy/stopping power of the incident charged particles and (3) combine these findings with the energetic particle precipitation flux [15-17] to estimate the age of a cryoplume deposit based on its observed brightness. Future studies will also explore other species such as SO_2, salts and simple organics.

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