



Radiation-Hard Sulfides as Mercury Hollow Bright Material

Noah Jäggi¹, Océane Barraud², and Catherine A. Dukes¹

¹Laboratory for Astrophysics and Surface Physics, University of Virginia, 395 McCormick Road, Charlottesville, VA 22904, US (noah.jaeggi@bluewin.ch)

²Institute for Planetary Research, German Aerospace Center (DLR), Rutherfordstraße 2, 12489 Berlin, Germany

The formation of hollows on Mercury—small, irregular, depressions often surrounded by brighter halos—has been thought to be driven by the preferential loss of volatile components due to intense solar radiation, micrometeoroid bombardment, and thermal cycling, leaving behind a refractory, spectrally distinct layer. One such process is the decomposition of regolith sulfides under solar wind ion irradiation.

Previous ion irradiation experimental studies on sulfides such as NiS, CuS, CoS, FeS, and MoS have demonstrated the formation of metallic surface layers through cation chemical segregation and preferential sulfur loss [1-5]. Laboratory observations of Fe surface-enhancement with subsequent visual darkening for ion and laser irradiated troilite (FeS) and recently, pentlandite [(Fe,Ni)₉S₈], thereby informed the hypothesis that similar process could occur with Mercury-relevant sulfides [e.g., 6, 7]. Instead of FeS, however, Mercury appears depleted in Fe at the surface, and sulfides are expected to contain mostly Mn, Ti, Cr, Mg, and Ca, based on the correlation with sulfur on the planet's surface as inferred from MESSENGER's X-Ray Spectrometer (XRS) and Gamma-Ray Spectrometer (GRS) data [8-10].

To test if sulfides relevant to Mercury darken under ion irradiation, we focus on MgS and CaS, two sulfides that also were proposed as likely hollow-forming material based on visible-to-near-infrared spectral analysis [11]. Unlike their transition-metal counterparts, these sulfides exhibit irradiation-hardening behavior, resisting the formation of a metallic top layer when exposed to solar wind-speed protons and helium ions [12]. This suggests that their response to space weathering differs fundamentally from that of previously studied sulfides, which also impacts how global exospheric models incorporate sputtered sulfur. Notably, our data reveal that MgS and CaS undergo significant brightening under irradiation in not only the visible-to-near-infrared (VNIR), but also the thermal infrared (TIR) spectral range. This optical alteration for stoichiometrically sputtered sulfide species aligns with the observed reflectance properties of hollows' bright halos on Mercury.

We therefore propose that irradiation-hard sulfides, such as MgS and CaS, could be responsible for the bright spectral signatures surrounding hollows. However, rather than forming metal-rich coatings, these compounds develop radiation-resistant, chemically stable surfaces that enhance reflectance while maintaining their compositional and structural integrity under Mercury's extreme solar radiation conditions. This mechanism offers a new perspective on hollow bright material formation, emphasizing the role of non-transition-metal sulfides in shaping the planet's surface evolution.

[1] Feng and Chen (1974), *J. Phys. C*, **7**(5), L75

[2] Coyle et al. (1980), *J. Electron Spectrosc. Relat. Phenom.*, **20**(2), 169–182

[3] Loeffler et al. (2008), *Icarus*, **195**(2), 622–629

- [4] Christoph et al. (2022), *J. Geophys. Res. Planets*, **127**(5)
- [5] Chaves et al. (2025), *Meteorit. Planet. Sci.*, in process
- [6] Blewett et al. (2011), *Science*, **333**(6051), 1856–1859
- [7] Blewett et al. (2013), *J. Geophys. Res. Planets*, **118**(5), 1013–1032
- [8] Nittler et al. (2011), *Science*, **333**(6051), 1847–1850
- [9] Weider et al. (2012), *J. Geophys. Res. Planets*, **117**(10), 1–15
- [10] Weider et al. (2015), *Earth Planet. Sci. Lett.*, **416**, 109–120
- [11] Barraud, Besse and Doressoundiram (2023), *Sci. Adv.*, **9**(12)
- [12] Jäggi et al. (2024), *55 Lunar Planet. Sci. Conf.*, Abstract #1306