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The discovery of Fe and Ni free atoms in comets atmospheres even far from the Sun

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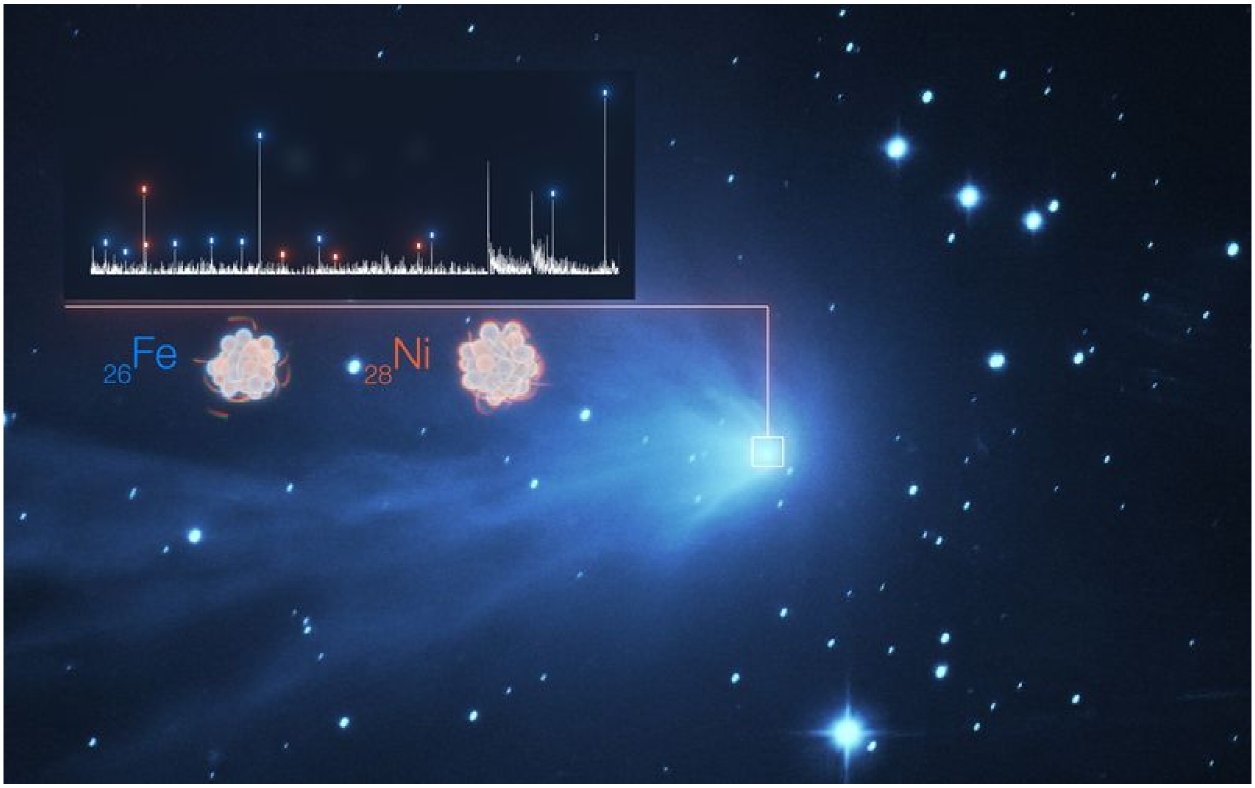
In this talk I will present the unexpected discovery of iron and nickel free atoms in the coma of comets, even far from the Sun. We have identified dozens of FeI and NiI lines in the high resolution optical spectra of most of the comets observed by our team in the last 20 years using UVES at the VLT [1]. These lines are ubiquitous in cometary comae, we found them also in the interstellar comet 2I/Borisov [2,3] and they were recently identified in archival spectra of the Great comet Hyakutake [3,4]. If various metallic lines were already detected in the sungrazer comet C/1965 Ikeya-Seki [5], that approached the Sun so close that dust grains vaporized, it was a surprise to find them in comets as far as 3.25 au, where the equilibrium temperature is far too low to allow sublimation of silicates (Tsub ≥ 1200K) and sulfides (Tsub ≥ 600K). The spatial extension of the lines is very short indicating that the FeI and NiI atoms originate from the inner coma, close to the nucleus. We developed a fluorescence model that allowed to compute their production rates. The NiI/FeI abundance ratios cluster around NiI/FeI~1 and does not depend on the heliocentric distance or the comet dynamical type [1], but there is a correlation with the level of carbon-chain depletion (C_2/CN) [3]. This Ni/Fe ratio is about 10x higher than what is measured in the Sun and the meteorites, as well as in the coma of Ikeya-Seki and the dust of 1P/Halley [6] indicating an other orgins. We made the hypothesis that these atoms could be released from organometallic complexes, yet undetected in the cometary material, such as carbonyls that have much lower sublimation temperatures. In particular $Fe(CO)_5$ and $Ni(CO)_4$ are expected to sublimate at Tsub~ 100K, intermediate between the sublimation temperature of H_2O and CO_2. The higher sublimation rate of $Ni(CO)_4$ with respect to $Fe(CO)_5$ would naturally explain the overabundance of nickel. In the present contribution, we summarize this discovery and the challenges it raises. **References:** [1] Manfroid, J., Hutsemékers, D., Jehin, E.: Nature 593, 372 (2021) [2] Opitom, C., Jehin, E., Hutsemékers, D., et al.: A&A, accepted (2021) [3] Hutsemékers, D., Manfroid, J., Jehin, E. et al.: A&A, accepted (2021) [4] Bromley, S., Ne, B., Loch, S., et al. 2021, arXiv e-prints, arXiv:2106.04701 [5] Preston, G.W.: ApJ 147, 718 (1967).
Illustration: *Detection of heavy metals in the atmosphere of comet C/2016 R2.* Credit: ESO/L. Calçada, SPECULOOS Team/E. Jehin, Manfroid et al.


26Fe
28Ni