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Introduction: Recent astronomical observations and theoretical modeling led to a consensus regarding the global scenario of the formation of young stellar objects (YSO) from a cold molecular cloud of interstellar dust (organics and minerals) and gas that, in some cases, leads to the formation of a planetary system. In the case of our Solar System, which has already evolved for ~4567 Ma, the quest is to access, through the investigation of planets, moons, cometary and asteroidal bodies, meteorites, micrometeorites, and interplanetary dust particles, the primitive material that contains the key information about the early Solar System processes and its evolution. However, laboratory analyses of extraterrestrial samples, astronomical observations and dynamical models of the Solar System evolution have not brought yet any conclusive evidence on the nature and location of primitive matter in the Solar System, preventing a clear understanding of its early stages.

As a statement of the obvious, the primitive matter in the Solar System being still unknown, it is difficult to define its signature, to identify where it is preserved in the Solar System, and what it is made of. Furthermore, the primitive matter is not defined in a unique way and there is currently no real convergence in the definition of primitive Solar System materials in closely related scientific fields of astronomy, astrochemistry, cosmochemistry, planetary science, and possibly astrobiology. These disciplines use different approaches: astronomy focuses on both observations and modeling of celestial objects, astrochemistry exploits radio observations of complex organics molecules in molecular clouds, cosmochemistry relies on meteorite and asteroid/comet sample analysis, planetary science investigates the evolution and properties of small bodies and planets, while astrobiology addresses more generally the question of whether life exists beyond Earth. Primitiveness is therefore a wide-ranging concept whose definition and scaling vary from one community to another with different tools and, therefore, different criteria.

Planetary scientists qualify as primitive the asteroids of taxonomic types D, P, T and of the taxonomic C-complex (Ch-, Cb-, C-, G-, B-, Cgh-types) because their reflectance spectra and their low albedo values are consistent with those of carbonaceous chondrites, although the generally featureless spectra of these objects permit alternative interpretations. Collisional studies and analyses of astronomical observations indicate that some of these asteroids may be rubble piles that endured collisions and re-accumulation. Thus, these bodies, which possibly mixed and endured major structural changes, cannot be considered primitive by themselves. However, although these small bodies have been repeatedly destroyed and reformed, the intensity of the chemical, thermal, and physical processes they underwent may still be weak and/or localized enough to preserve some primitive matter within them.

Results: We propose that the evolution the Solar System should be instead described based on the physical processes in action through time and at the different spatial scales rather than using (supervised) classification techniques. By analogy with stellar and galactic physics in which automated parameterizations are considered for stars, we define primitive matter in our Solar System through a parameterization scheme based on the amount and intensity of processes the matter underwent since its delivery to or its formation in the Solar System instead of defining it on the basis of its age only. Of course at some point, the time of formation comes into play, but first, the matter considered the most primitive in terms of a specific process should show little evidence for subsequent modification by other processes. The selected parameters are those involved in a canonical view of YSO formation and evolution towards planetary systems based on the current understanding of processes and transformations of solids and gases in the early Solar System . These include *(i)* irradiation from the young Sun, *(ii)* evaporation and gas-solid condensation, *(iii)* dust agglomeration, *(iv)* melting of dust agglomerates during transient heating events (e.g., shock waves, current sheets, etc.), *(v)* accretion of thermally processed and unprocessed solids and ices into pebble- and planetesimal-sized bodies, *(vi)* core-mantle differentiation, *(vii)* thermal metamorphism and aqueous alteration, and to some extent *(viii)* regolith formation and space weathering. In this order, these processes and transformations define different levels of primitiveness with respect to the primordial (thermally unprocessed in the Solar System) protosolar molecular cloud matter. The fact that a given process may have occurred once or several times and in different environments (e.g., hot/cold, dry/wet, low/high energy) does not count for our purpose. Other processes like extrasolar irradiation, extrasolar grain implantations, low and moderate energy impacts and, to a certain extent, regolith formation and space weathering are not considered here as discriminating criteria as they could occur along the entire lifetime of our Solar System, and are not expected to modify the material properties in a way that may alter its primitiveness. This approach allows us to define in a new way the level of primitiveness intrinsic to our Solar System (Table 1). The most primitive is not necessarily the oldest, as usually considered, but the least affected in the number or kind of processes it underwent inside the limit of our Solar System. Accordingly, some old objects/matter may be primitive, but some other old objects/matter may not be, on this basis. Conversely, some younger objects/matter may still be primitive, on this same basis. For instance, the second largest asteroid (4) Vesta is the likely source of howardites-eucrites-diogenites (HEDs) meteorites, and has thus experienced melting and differentiation processes that drastically altered the composition of its original components. Although (4) Vesta accreted very early in the Solar System history, its matter cannot be considered primitive as a whole, while other smaller carbonaceous and/or undifferentiated asteroids may be more primitive despite being accreted later (Table 1).

Discussion: Though perfectible, this new parameterization scheme of primitiveness in our Solar System already presents several advantages. i) It is a relative scale that takes into consideration the wide-ranging concept of primitiveness, and that can be used by various communities involved in this quest about the origins of our Solar System. ii) It allows us to rank the primitiveness of any celestial objects and of the matter they are made of on a same scale. iii) It establishes new criteria for studying the evolution of the primitive object or matter, which may or may not be related to its age. iv) It permits avoiding some contradictions, such as the fact that carbonaceous chondrites or C-type asteroids are commonly called "primitive", in the usual definition, and yet most of them are probably not primitive as a whole, even if some of their material is primitive, justifying that they are good candidates to sample primitive material. v) It avoids the investigation of the early evolution of the Solar System to be limited by the analytical precision related to radiometric ages, and by isotope heterogeneity at a specific time in the Solar System.

Conclusion: We show that neither the age of an object, nor its mineralogy is discriminant enough for revealing its primitiveness, and propose a new parameterization scheme based on the processes the matter underwent since its delivery to the Solar System [1]. By ranking celestial objects and their constituents, two antagonistic sources of primitive materials in the protoplanetary disk emerge, one close to the Sun resulting from evaporation, condensation and melting of the protosolar molecular cloud dust followed by accretion into asteroidal bodies, and the other at large heliocentric distances resulting from agglomeration of the protosolar and solar dust into cometary bodies, the latter reservoir remaining poorly sampled so far.

Reference: [1] Libourel et al. (2017) *Icarus, 282,* 375-379.

Processes → / **Example ↓**	Irradiation from the young Sun	Condensation	Dust agglomeration	Transient heating	Accretion	Differentiation	Thermal Metamorphism Aqueous alteration	Regolith formation, Space weathering	**Age after CAI (in Ma)**
Presolar grains Organics & minerals	(✔)								Presolar
GEMS	✔	(✔)							?
Fine-grained spinel-rich CAIs	✔	✔	✔						0
Compact Type A CAIs	(✔)	✔	✔	✔					0–0.3
Chondrules		(✔)	✔	✔					0–5
Comets		✔	✔	(✔)	✔		✔	✔	?
Chondritic porous IDPs		✔	✔	(✔)	✔		✔	✔	?
Chondrites			✔	✔	✔	✔	✔	✔	2-4
Magmatic iron meteorites					✔	✔	✔		0.2-0.3
Eucrites, 4 Vesta						✔	✔	✔	< 1
Earth crust						✔	✔	✔	300-900
Prebiotic chemistry								?	300-900

Table 1: Example of chronological sequence of processes experienced by selected extraterrestrial objects ranked according to their inferred primitiveness. G.L., P.M. and M.D. acknowldegde support from the French Space Agency CNES.