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A LITERATURE REVIEW ON TECHNIQUES ON COLLECTING AND SAMPLING MICROMETEORITES

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ABSTRACT
Micrometeorites (MM's) are extraterrestrial particles that are dragged to the sun via P-R light drag and are captured by the earth in the process, the estimated influx of these interplanetary dust particles is estimated to be around thirty thousand tones every year. Collection of such take place in different locations, each required a different and specific methodology that can turn out to be very expensive and logistically challenging. Thus, the necessity of finding alternative methods of micrometeorites collection arises that accommodate these high costs and complicated logistics in an efficient way. The collection of MM's in urban areas is only recently becoming a popular among the scientific community and even though it presents some biases, its' easy methodology allows it to be adapted in ways that can greatly maximize the efficiency of collections made in semi-urban areas relative to others collection methods.

Keywords: Micrometeorite Collection. Sampling Techniques. Extraterrestrial Particles.

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INTRODUCTION

To study micrometeorites means an attempt to understand the origin and formation of the planets and the primitive solar system and how their parental bodies evolved. Collections with a large number of micrometeorites may contain samples of asteroids, the moon, Mars and cometary bodies, and these materials are unlikely to be found in collection of meteorites (BROWNLEE et al., 1993). The estimate of the number of extraterrestrial particles that enter Earth`s atmosphere are around 30.000 tons per year (LOVE e BROWNLEE, 1993). Meteorites are an important source of knowledge and contact with material formed from the primitive solar system, more frequently there fall of this material is in the form of microscopic dust particles (MM`s) and tones of these particles are deposited on Earth everyday (BROWNLEE, 1981). However, determining the type, proportion and quantity of this material that survived atmospheric deceleration requires a large deposit of this material, unbiased and well preserved, considering the accumulation time (TAYLOR et al., 2000). The micrometeorites can provide evidence of processes that took place previous to the formation of the Solar System (ROCHETTE, *et al* 2008).

Many modern astrophysicists are conecerned about the frequency and quantity of the impacts caused by these particles on the surface of artificial satellites, that may in the long run, cause interference or even severe damage to the operating systems onboard. Figure 1 shows the image of the rear end of the radiator of the Wide Field Planetary Camera ll (WFPC2), installed in the Hubble Telescope over a period of 15 years of exposure. Analysis of these impact marks suggest that particles smaller than a millimeter in size are able to produce holes with up to 30 [mm] in diameter (**Smithsonian National Air and Space Museum**).

FIGURE 1: Rear-end extremity of the radiator onboard Wide Field Planetary Camera ll (WFPC2), installed on the Hubble Telescope, by Eric Long, National Air and Space Museum.

Source: Smithsonian National Air and Space Museum.

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These extraterrestrial particles are formed when a small meteoroid meets the Earth`s atmosphere. The high temperatures caused by the frictional heat with the atmosphere melt the meteoroid, giving origin to a bright flash of light seen as a meteor, its` etymology of the word “metéōros” referencing “something that comes from the sky”. These particles arise from the erosion of comets and asteroids melt and chance its` shape and chemical composition, with records of collection spanning over decades in different environments (BLAKE, M., *et al*, 2018). The smaller dust particles manage to enter the atmosphere without significant heating, different from the majority of particles that melt over its` atmospheric deceleration on our planet (LOVE AND BROWNLEE, 1991). The new shapes and textures acquired by the micrometeorites are related to the velocities that can reach up to 72 [km/s], the angle of entrance and curvature of its` trajectory and may be mistaken by particles of anthropogenic origin. On the lower range of the temperatures these particles may reach, around 1350°C, the micrometeorites classified as unmelted, and with the frictional forces in play, the temperature can increase significantly forming the types Scoriaceous, Porphyritic, Barred Olivines. On the more extreme temperatures the vitreous micrometeorites are formed, around 2000°C (GENGE, 2020).

The larger meteorites have a frequency of atmospheric entry relatively low, making it difficult the studies of its` incoming flux. In this sense the micrometeorites become an ideal model to measure said flux and its` variations by the large quantity of these particles that precipitate on Earh`s surface (PARNELL, J., *et al*. 2016). According to TAYLOR *et al.,* 2000 the chances of finding micrometeorites are way more expressive than the chances of finding larger meteorites due to the difference in their number of incidences. The micrometeorites compose 95% of the flux of extraterrestrial matter on Earth(HUGHES, 1978), and are accumulated in remote places of our planet since its` formation.

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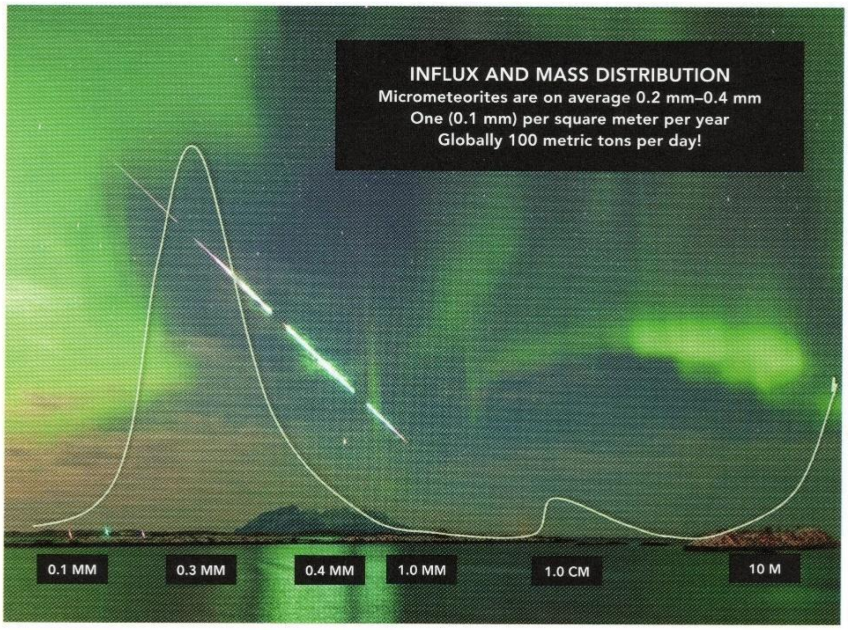
FIGURE 2. Displays the spread of earth's extraterrestrial material influx along the size of the material's bodies - (Jon Larsen. ON THE TRAIL OF STARDUST (2019), page 133)



Spherule like cosmic particles are microscopic extraterrestrial bodies that were present as dust structure in interplanetary space and did not make part of larger meteoroids GENGE et al., 2008). Traditional micrometeorites in the other hand were part of larger cosmic bodies in Space (BROWNLEE, 1985). Meanwhile the meteorites is estimated to be ~50 [tones/year] (ZOLENSKY *et al*., 2006), with estimates around ~30.000 [tones/year] the flux of micrometeorites LOVE & BROWNLEE, 1993; PEUCKER-EHRENBRINK & RAVIZZA, 2000), carrying na expressive quantity of extraterrestrial material that precipitates over the Earth is on its` microscopic form. Its speculated that micrometeorites represent samples from a larger variety of extraterrestrial matter compared to the conventional meteorites (BROWNLEE, 1985).

Frequently, only millimetric parts of meteorites that hit the Earh, due the degradations processes that take place on its` atmospheric entry, being then called micrometeorites. They usually measure less than a 1,0 [mm] and represent the primary source of extraterrestrial material accumulated on Earth (BROWNLEE, 1981; ENGRAND & MORETT, 1998; ROCHETTA, 2008; TAYLOR et al., 2000; VENENO ET AL. , 2004).

All the solid bodies in the Solar System may eject particles onto the interplanetary medium, including planets like Earth that emits materiel during impact events. However, the main sources of cosmic dust in the Solar System are asteroids and comets. Both can be thought to be part of the planetary feedstock and were preserved since its` formation formação (BROWNLEE, 1981). Individual asteroid MM`s can provide us samples of its`

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parental bodies chemical components (Genge et al. 1997a; Kurat et al. 1994), however due their microscopical size it is unlikely that its` mineralogical and chemical properties are representative of their parental bodies in larger scales, (Genge et al. 2008), becoming necessary the collection and analysis of a large number of specimens, characterizing so a difficult challenge to work in this field.

There has been made a considerable amount of modern studies with micrometeorites, mainly in terrains covered in ice and snow, with the collection of samples of these particles, yield calculations and flux estimates, such as the studies of LOVE & BROWNLEE (1993); TAYLOR *et al*. (2000) e DUPRAT *et al*. (2007). However, a very minor quantity of studies from the geological records were also found TAYLOR & BROWNLEE (1991); DAVIDSON *et al*. (2007); ONOUE *et al*. (2011); VOLDMAN *et al*. (2013). Dredge et al. (2010) e Tomkins et al. (2016) affirm that these preserved particles in sediments may provide a record of events that happened well beyond of our planet in a geological scale.

Some authors associate elevated concentrations of micrometeorites with the impact of important meteorites, such as the ones associated with the Triassic – Jurassic frontier (MIONO *et al.* 1993; CHAPMAN & LAURETTA 2004) and with the Cretaceous – Paleogenic frontier (GRACHEV *et al*. 2008).

Micrometeorites have been collected in a variety of terrestrial environments (TAYLOR & BROWNLEE, 1991), as well as in space (BROWNLEE *et al*., 1977), and vary in size from a few microns of unmelted interplanetary dust [RIETMEIJER, 1998; BROWNLEE, 1985] up to cosmic spherules up to in 2,0 [mm] in diameter [ROCHETTE *et al.,* 2008; VAN GINNEKEN *et al*., 2012].

GENGE *et al* (2017) classify meteorites in two main categories based on their chemical composition: Rocky Meteorites and Metallic Meteorites. The meteorites that assimilate rocky material are, in their majority made of inorganic crystals, while the ones that assimilate metallic material are, in their majority composed of an Fe – Ni alloy. Normally the inorganic crystal formation and the metallic bonding resist the high temperatures.

From these micrometeorites, those that are found in larger quantities, are classified as cosmic spherules: Are completely melted droplets and forged with temper texture. Because they are relatively easy to be distinguished, these particles can be seen as an

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useful study material for research of the total flux of cosmic dust (MAURETTE *et al.,* 1991).

OBJECTIVES

This study has as objective make a brief synthesis and a literature review about the knowledge related to the techniques of collection and study of micrometeorites, contributing so to the divulgation of this horizon of modern research, emphasizing the importance of such and consequently propose a methodology for new micrometeorite collection constructed around concepts and characteristics of methodology here presented.

METHODOLOGY

Generally, a method is a manner to achieve a specific objective. This is a form of cognition used to think about a study object. The method may follow two different paths, one of them is the term research, that means a general orientation (dialectical method) or even a technique of specific research (inductive-deductive method). The other path that can be followed is the method of research which is used to demonstrate the different ways in which the subject of research may interact with the case study (ABBAGNAMO, 1963, apud MOURA, 2010, apud JIMÉNEZ; JACINTO, 2017).

Considering Polak and Diniz (2011), the research object of the present study, as well as in its` nature, may be classified as applied, because it aims the immediate applicability of the produced knowledge. In respect of its` objectives, it was inserted a descriptive proposal that aims the identification and systematic cataloguing of one or more phenomenon or providing insight on a subject. Regarding the procedures, it can be characterized as bibliographic research and documental.

According to VERGARA (2011), the bibliographic research is of origin of the analysis of secondary data contained in books, articles, thesis or any other medium, this being electronic or physical, fitting to the researcher to interpret the already existing theoretical contributions.

Initially it was made a bibliographic survey that comprehends researches in portals of electronic search and posteriorly publications in the form of books and scientific articles on the topic were consulted.

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The type of study realized on this project was that of bibliographic research, that according to MORESI (2003) is a systematic study developed based on the material published in books, magazines, articles, electronic portals and in other locations accessible to the general public. Provides and instrument for any type of research. The bibliographic research presents itself as a fundamental step in the structurization of any type of scientific research, and it's what molds all the remaining project, because the research will be made according to what is exposed in the literature review (AMARAL, 2007).

METHODOLOGY OF STUDIES WITH MICROMETEORITES

According to BROWNLEE, D. E. (1985) the first researches had the marine sediments as the main reserve of these particles, but today the micrometeorites ar collected mainly from the ablation zone of the ice sheets of Greenland (MAURETTE et al., 1987) and in the Antarctic ice (MAURETTE, *et al*., 1987, TAYLOR, *et al* 1998 e HARVEY, *et al* 1991).

The collection of micrometeorites in modern times have received a lot of attention by the academic community, due the technological advances capable of making more sophisticated analysis, besides the people that are attracted in an autonomous way for these fantastic extraterrestrial particles, research made in an autonomous manner and potentially can become scientific and belong to the research groups.

The logistic costs of an expedition for the collection of micrometeorites is very high, and hence, it needs to be minutely detailed and optimized in the best way possible, in order to be assertive and manage to obtain significant samples for study. In the last years, researchers have made sampling in urban areas and/or near them, activity that initially caused some controversy in respect to the origin of these particles and the elevated number of false-positive identifications of micrometeorites.

After the collected sample and the isolated particles, are identified and grouped with respect to their morphology. And other elevated cost is the confirmation of the origin of these particles, made through the imaging of electronic microspores of retro diffusion in black and white (BSE); Secondary electronic imaging (SEI); chemical mapping through x-ray diffraction mass spectrometry displaying concentrations of Magnesium (Mg, Oxygen (O) and Silicon (Si).

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THE CLASSIFICATION OF MICROMETEORITES

The adopted system of classification in today`s research is based on the combined observations of thousands of recovered particles in the Antarctic ice in the close areas of Cap Prudhomme (MAURETTE *et al,* 1991) and from areas near the South Pole Water Well (TAYLOR *et al,* 1998). Description of the techniques used to select, prepare and analyze these materials are presented in (ENGRAND *et al,* (1998a), GENTE *et al,* (1997a), and TAYLOR *et al,* (2000)).

Different authors classify the micrometeorites under different aspects, according to Genge *et al,* (2008), the micrometeorites are mainly divided in three groups: Melted micrometeorites, partially melted micrometeorites, and unmelted micrometeorites. With the finality of a micrometeorites classification schematic with greater precision, it is necessary a division that includes optical and chemical analysis of these particles.

Table 1. A table showing the schematics for the classification of micrometeorites suggested by M. J. Genge and co-authors - The classification of Micrometeorites Genge et al. (2008)

Table 1. An outline of the classification of micrometeorites.

Groups	Class	Type	Subtype	Description
Melted MMs	Cosmic spherules (CSs)	S	CAT	Spherules with Mg/Si > 1.7 that are enriched in Ca, Ti, and Al. They have barred olivine textures.
		S	Glass	Spherules consisting almost entirely of glass.
		S	Cryptocrystalline	Spherules dominated by submicron crystallites and magnetite. Some include multiple domains.
		S	Barred olivine (BO)	Spherules dominated by parallel growth olivine within glass.
		S	Porphyritic olivine (Po)	Spherules dominated by equant and skeletal olivine within glass. Relict-bearing varieties contain unmelted minerals.
		S	Coarse-grained	These spherules contain >50% volume relict minerals.
		G		Spherules are dominated by magnetite dendrites within silicate glass.
		I		Spherules dominated by magnetite, wüstite.
Partially melted MMs	Scoriaceous MMs (ScMMs)	–	–	Vesicular particles dominated by a mesostasis of fayalitic olivine microphenocrysts within glass. ScMMs often contain relict minerals and relict matrix areas.
Unmelted MMs	Fine-grained MMs (FgMMs)	C1		Compact, chemically homogeneous FgMMs. Often contain framboidal magnetite.
		C2		Compact, chemically heterogeneous fine-grained MMs. Often contain isolated silicates and/or tochilinite.
		C3		Highly porous FgMMs. Often contain isolated silicates and framboidal magnetite.
	Coarse-grained MMs (CgMMs)	Chondritic CgMMs	Porphyritic olivine and/or pyroxene	Igneous MMs dominated by pyroxene and/or pyroxene phenocrysts within glass.
			Granular olivine and/or pyroxene	Igneous MMs dominated by pyroxene and/or olivine without significant glass.
			Barred olivine	Igneous MMs dominated by parallel growth olivine within glass.
			Radiate pyroxene	Igneous MMs dominated by radiating pyroxene dendrites within glass.
			Type I/type II	Type I CgMMs are reduced particles containing Fs and/or Fa < 10 mol%. Type II CgMMs are oxidized particles with Fs and/or Fa > 10 mol%.
		Achondritic CgMMs	–	Differentiated igneous CgMMs.
	Refractory MMs	Porous	–	Porous particles dominated by refractory minerals.
		Compact	–	Compact particles dominated by refractory minerals.
		Hydrated	–	Particles dominated by refractory minerals surrounded by Fe-rich phyllosilicates or their dehydroxylates.
	Ultracarbonaceous MMs		–	Particles dominated by carbonaceous materials with embedded

The proportion of melted micrometeorites, partially melted and unmelted is not well known, but it varies with the size of the particles (MAURETTE *et al,* 1991; TAYLOR *et al,* 2000). For sizes >100 [µm], melted MMs make up to 70-90% of the particles (Maurette et al. 1991; Taylor et al. 2000), for those MMs that size around 50-100 [µm] melted and partially melted make up around ~ 50% of the particles (Genge et al. 1997a),even though

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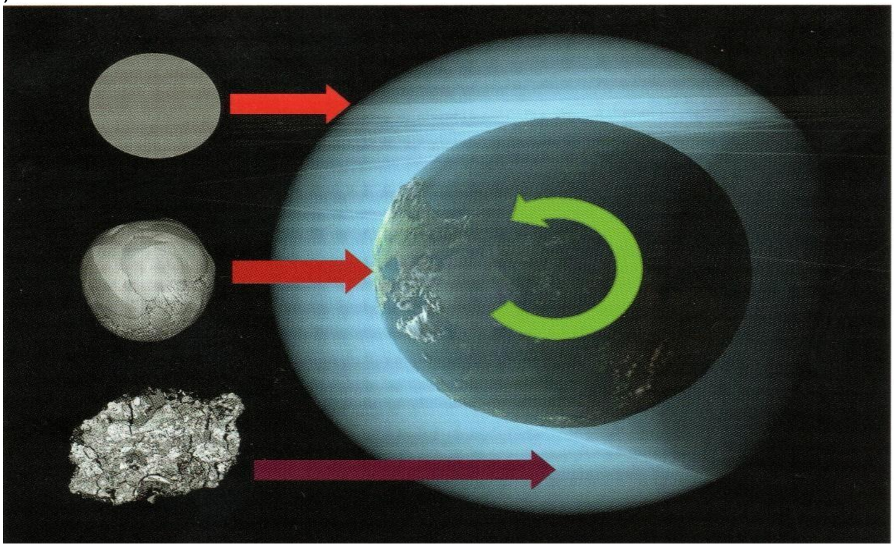
a proportion of partially melted micrometeorites to the unmelted ones is around 1 is found on this size band using a different classification (Engrand e Maurette 1998), and for those MMS sized from 25-50 [µm] melted and partially melted make up around 22% of the encountered particles (Gounelle et al. 2005b). It stands out that the chances due the atmospheric heating are in large part gradual, and hence, not always it is possible to attribute micrometeorites to a discrete group. This resulted in differences in the way how micrometeorites are classified.

ATMOSPHERIC ENTRY

The heating of the particles in their respective atmospheric entrance have a crucial role in how they fit in the proposed classification schematic.

A micrometeorite may enter the Earth`s atmosphere with very high speed, reaching velocities up to 50 times faster than a rifle bullet. Due the fact that the Earth is constantly spinning around its` own axis, depending on the angle of entrance of the micrometeorite, different amounts on frictional heating can be encountered by these particles, causing drastic differences in the peak temperatures, that consequently result in different alteration processes that taka place in the MMS, differentiating them texturally and morphologically in between them, stablishing criteria for their classification.

FIGURE 3. Displays the relative angle of the micrometeorite’s atmospheric entry relative to Earth’s rotation and the consequent alteration process in the particles. – (Jon Larsen. ON THE TRAIL OF STARDUST (2019), page 132)



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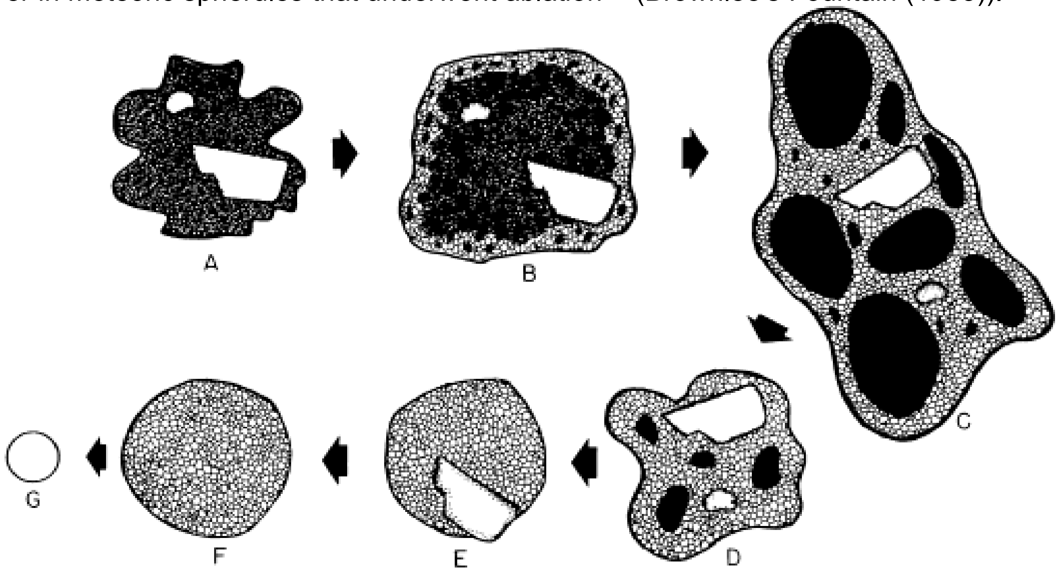
According to Brownlee (1983), cosmic spherules may exhibit a wide variety in their level of heating. This changes from particles barely heated and partially melted, up to those that were aggressively heated to the point that, having Iron and Silica as main elements in their composition, were exhausted, and evaporated by the frictional heating. The level of heating is also determined if the particle enters the atmosphere on its` own or if it`s separated from a larger meteorite during atmospheric entry. Figure 5 displays the alteration that take place in a hypothetical particle when exposed to different degrees of frictional heating.

FIGURE 4. The thermal variations of the millimetric particle is hypothetically represented in polished regions showing successive steps of heating from A to G. On stage F, all the precursor solids melted, and on stage G, the evaporation of Fe and SI. All of these stages from this figure were observer in meteoric spherules that underwent ablation – (Brownlee's Fountain (1983)).



The analysis of micrometeorites crystals identifies minerals frequently encountered in the form of crystals with larger matrices and fine grained, characterized by empty spaces. These cavities may have been caused by the evaporation of minerals during ablation. According to Feng *et al,* (2005), empty spaces may result from the rapid cooling of the melted material in the internal surface. Figure 5 shows the effects of frictional heating in the alteration process during atmospheric entry, also relating the peak temperature of the particle with today's classification of micrometeorites.

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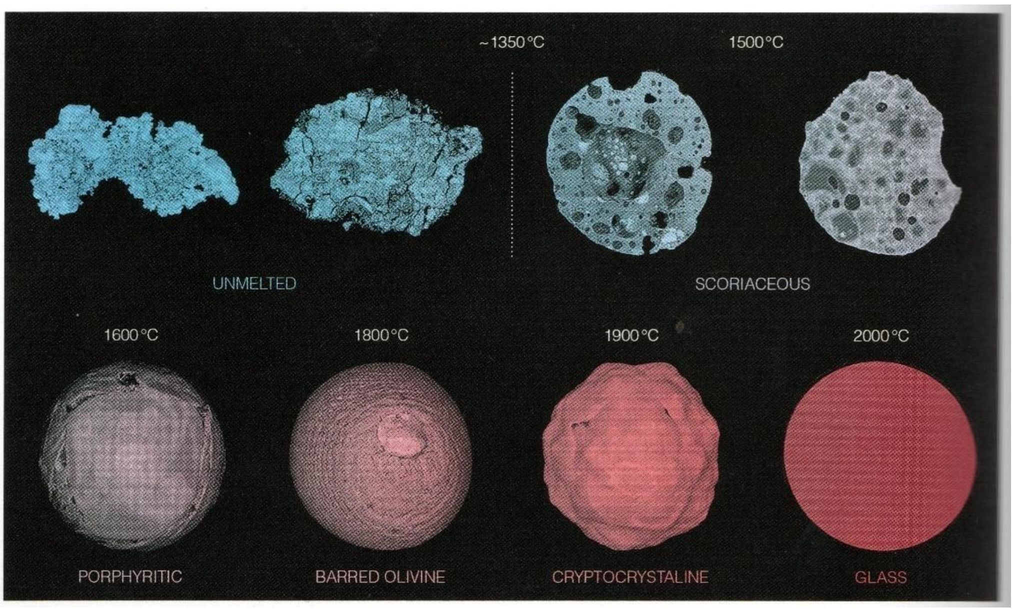
FIGURE 5. Displays the various types of micrometeorites related to its' peak temperatures on atmospheric deceleration, from unmelted to completely melted. - (Jon Larsen. ON THE TRAIL OF STARDUST (2019), page 52)



EXAMPLES OF MICROMETEORITES

Following there are some illustrative showings of some of these particles.

BARRED OLIVINE MICROMETEORITES

They are the most easily encountered and represent the melted micrometeorites. Possessing fine textures and similar patterns to a “Christmas tree” formed by magnetite crystals forged in temperatures around 1800 °C, as shown in Figure 6.

FIGURE 6. Imaging of the micrometeorite SPMM 22, collected by Scott Peterson in the location of Hamel/Minesota in December 2017. Pictures of Jan Braly Kihle/ Jon Larsen.

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CRYPTOCRYSTALLINE MICROMETEORITES

Represented by spherule particles, that can vary from the rounded to the pointed, are called “turtlebacks” because the irregular ornaments that are formed in temperature closed to the 1900 °C. Corresponding to the second most common in the samples and also belong to the melted micrometeorite groups. Figure 7 shows an imaging of the micrometeorite **SPMM 505** collected by Scott Peterson in New Hope, Minnesota, August of 2018, composed by vitreous with crystallites in small grains, is an elongated spherule with a Iron – Niquel Bead on its` extremity.

FIGURE 7. Cryptocrystalline meteorite SPMM 505 collected in July 2018. University of Augsburg, Minneapolis, Minnesota, July 2018;

VITREOUS MICROMETEORITES

Like the previous ones, these spherules also belong to fused micrometeorites. Traveling at high speed, friction raises the temperature to an extreme, fusing this particle that under the influence of rotation and angle forge its new characteristics. FIGURE 8 compares two particles: The one with a spherical shape suggests that it suffered more rotation action than the one with an elongated shape.

FIGURE 8. Glass micrometeorites. SPMM 358, University of Augsburg, Minneapolis, Minnesota, July 2018 (left) and SPMM 145, New Hope, Minnesota, May 2018. Photos by Jan Braly Kihle / Jon Larsen

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PORPHYRITIC MICROMETEORITES

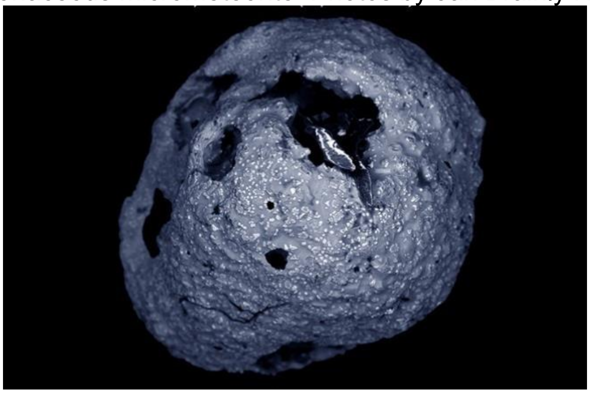
Are formed at temperatures around 1600 °C and may or may not be melted according to the temperature reached. FIGURE 9 shows micrometeorite SPMM 367, found by Scott Peterson at the University of Augsburg, Minnesota, July 2018, composed of forsterite crystals in a glassy matrix.

FIGURE 9. Porphyritic micrometeorites SPMM 367. Photos by Jan Braly Kihle / Jon Larsen

SCORIACEOUS MICROMETEORITES

In the category of partially fused micrometeorites, these spherules can be in fine form or in larger grains. The finer particles are irregular, smooth and highly vesicular. The larger particles are formed by the partial melting of CgMMs, present below among the unmelted particles (FIGURE 10).

FIGURE 10. Scoriaceous micrometeorite. Photos by Jan Brainly Kyle / Jon Larsen



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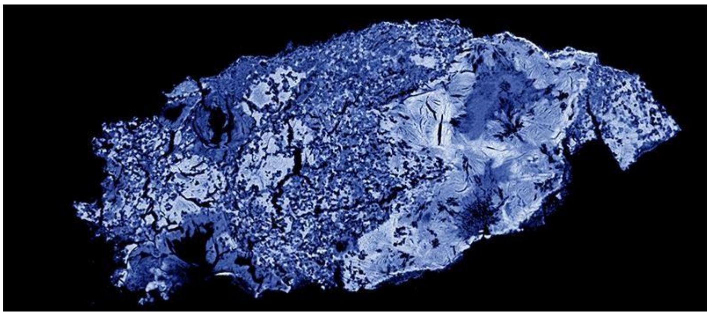
UNMELTED MICROMETEORITES

They can be represented by fine particles and some larger ones, containing CgMM and FgMM that form chondritic compositions. The larger particles contain anhydrous silicates, mainly pyroxene (FIGURE 11).

FIGURE 11. Unfused micrometeorite. Photos by Jan Braly Kihle / Jon Larsen



SAMPLING TECHNIQUES

Over the years, with the need to acquire more material for study, optimizing logistics and processing costs, different techniques have been adapted and tested, always presenting positive aspects in contrast to the negative aspects.

LIMESTONES

PARNELL, J., et al. (2016) studied the micrometeorites found in limestone rocks in the Isles of Skye, Scotland, with the objective of testing the methodology for extracting micrometeorites in 1 kg of sample, so that it is possible to carry out viable sampling programs. Also, analyze the stratification of these particles to find any patterns, and compare them with rocks in the Durness region.

Fifteen samples from the Durness Group were collected at 13 locations in the Strath and Ord regions of Skye. The material was ground to a powder using a fly press, and weighed in 1 kg portions. Magnetic separation was performed using a hand magnet over 10 g of the sample. The identification of micrometeorites was done by means of scanning microscopy (SEM).

This research concludes that a successful extraction of micrometeorites in limestone formations is possible and that these particles preferentially occur in the upper part of the succession, in the Strath Suardal formation of the Arenig age, which is consistent with previous measurements made in limestones from the Arenig area. Durness. PARNELL, J., et al. (2016) suggest a period of high micrometeorite flux in the middle Ordovician and that the similarity in stratigraphic distribution in the Skye and Durness areas is significant rather than a consequence of limited sampling.

ARCTIC ICE

The studies by ROJAS et al. (2021) proved the efficiency of glacier collection procedures, carried out through three campaigns in the vicinity of the French- Italian Concordia Station, located in the C/Antarctic Summit. They were able to identify 1280 unmelted micrometeorites and 808 cosmic spherules with diameters between 30 and 350µm, from the melting and filtering of large volumes of snow.

This study site offers unique and ideal conditions for the conservation of these micrometeorites: they are not affected by water changes and there is no risk of contamination caused by human action. The samples were collected at depths greater than 2m of snow, corresponding to years prior to 1995, referring to the beginning of human presence on the site.

The snow was thawed and the liquid filtered through sieves suitable for the size of the particles, using gravity and avoiding exerting direct pressure on these microspheres. The particles found were analyzed under scanning microscopy to confirm the origin of the material, and their studies propose the Jupiter family comets and a small part of the main asteroid belt as the origin of these micrometeorites.

Analysis of the data obtained by the CABMOD-ZoDy modeling satisfactorily reproduces the mass distribution of cosmic spheres and unmelted micrometeorites above 100µm on the Earth's surface, presenting the total mass of cosmic dust before entering our atmosphere to be about 15,000 tons / year-1. For particles smaller than 100µm, the model calculations estimate a flow of unfused micrometeorites significantly higher than that measured in the Concordia collection. This suggests the existence of highly fragile particles that are not collected through the protocol adopted in the snow samples at Dome C, in addition to the degradation resulting from friction and high temperatures in these microparticles causing the disintegration of the more fragile particles.

HIGH ALTITUDES

Micrometeorite studies are carried out by observing the marks of impacts on panels installed on artificial satellites and spacecraft, at long-term exposure sites. Dohnanyi (1972) reviewed the records of these marks on several satellites and estimated a flow of

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20,000 t/year, very close to that observed in current studies. Micrometeorites, despite their size of less than 1 millimeter, travel at an extremely high speed and their mass can cause significant damage to space equipment, posing a risk to the success of the mission. RODMANN, et al (2019) mention the fact that more and more space missions are farther and more extreme, therefore, it is necessary to guarantee the security of the mission through the smallest possible amount of defensive shields. The repetitive impact of these submicron-sized particles causes gradual degradation on spacecraft surfaces and can damage mirrors, lenses and sensors. Larger particles have the ability to pierce insulation layers and optical baffles. These micrometeorites have enough kinetic energy to pierce pressurized vessels, such as manned habitats, propulsion tanks, batteries, and space equipment cooling lines, posing a risk to mission success (RODMANN, et al, 2019).

MIRTCH, et al. 1988 proved the degradation of highly reflective metal surfaces when exposed to these simulated impacts. For this study, a shock tube was used to accelerate the microparticles to hypervelocity and perform simulations for laboratory analysis.

DEEP SEA SEDIMENTS

The collection of micrometeorites in marine sediments gave rise to the first studies and until today it is considered a good source of accumulation of these particles in a preserved environment.

PRASAD, M.S. et al, (2013) studied ten samples collected in the Indian Ocean at a depth of approximately 5,000 m, through superficial grabs in an area of 150 x 200 [km]. The sediment collection equipment covers an area of 250 $[cm]^2$ and can capture about 45 [kg] of sediment at a depth of 15 [cm]. Part of this material is sieved in a 200 [µm] mesh totaling 293 [kg]for processing. The total number of beads collected is recalculated for 45 [kg] of sediment in each of the samples for flow calculations for a given area. After drying, sieved material >200 [µm] is exposed to magnetic separation to isolate beads and other magnetic materials. By means of optical microscopy, beads are manually harvested from these magnetic fractions. The magnetic fractions are dominated by volcanogenic materials presented in different forms. The non-magnetic fractions were subjected to heavy liquid separation and were again observed under microscopy for beads with low magnetic attraction. It was possible to isolate 2166 spherules that were observed by scanning microscopy (SEM) and analyzed by means of X- rays.

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Despite being a rich environment of samples, the collection of these micrometeorites should be very well evaluated, due to the high costs of logistics and processing of the material. PRASAD, M.S. et al, (2013) mention several factors that may present certain limitations for this type of study, namely: Relatively large particle size, above 200 [μm]; destruction of the beads during the sieving process; influence of sedimentation rates; age variation of the upper 15 [cm] of the collected sediment; measurements of the diameter and density of the beads; age determination and subsampling of Australian microtektites; sedimentary density; and difference in bead yield.

PRASAD, M.S. et al, (2013) studied the flow by making estimates through the accretion rates of cosmic spherules, adopted as approximate densities for type I (iron) as 5.0 $[g/cm]^3$, and S (stony) and G (glassy) as 3.0 $[g/cm]^3$. The weight was calculated based on the measured diameters. Considering the flow where AE represents the total surface of the Earth (5.1 $.10^8$ $[km]^2$), MS is the gross weight of accumulated cosmic spherules (g), MC is the weight of sediment collected from the deep sea (g), and AS is the sediment accumulation rate in the area (g/cm2/year), respectively. The sediment accumulation rates in the area are derived from the peak abundance of microtektites belonging to the Australasian impact event. Based on spherule abundance and sediment accumulation rates, it was possible to calculate the cosmic spherule accumulation rate at ~160 ± 70 [tone/year], but the actual flow could be much higher.

The predominance of micrometeorites composed of metals, such as iron and nickel, found in the samples is related to the greater resistance of the particles against the weather, compared to the more fragile micrometeorites such as glass, which over time are degraded and not representative. in the collected samples.

RAIN WATER (URBAN AREAS)

The collection of micrometeorites through rainwater is an excellent tool, but due to their low cost, easy methodology and can be carried out in any location, they should be used with great caution. This technique uses large surfaces, such as roofs, as an apparatus for collecting particles that are carried away by rainwater and later separated by magnetic attraction. The fact that these samples come from urban centers, or nearby, has been causing discussion among researchers, suggesting that terrestrial contamination, presented in different forms, is a great impasse, significantly increasing the number of false-positive records (Genge et al. 2017) .

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Genge's (2017) surveys carried out on the roofs of Norway and Paris used 30,000 $[m]^2$ of roofing area and were able to separate 500 micrometeorite-like particles by means of optical microscopy, selected based on several factors: (1) spherical or subspherical shape; (2) color and luster (vitreous black, black to metallic gray, and translucent); and (3) presence of surface dendrites or surface metallic protrusions.

Of these, 48 particles, ranging from 300 [μm] to 400 [μm], were subjected to a process of magnetic filtering, scanning microscopy and mass spectrometry to analyze the mineralogical characteristics, and concluded that they are formed by silicates similar to those found in meteoric materials and the presence of rare earth elements. All particles are S-type cosmic spherules and have identical mineralogic properties, textures and compositions to those collected in Antarctica and deep-sea sediments, including porphyria's, barraged and cryptocrystalline and particles that retain Fe-Ni metal and sulfide beads.

Through this research they were able to conclude that the abundance of spherules recovered is consistent with estimates of the global spherule flux to Earth of ~6 [tones/day]. The relative abundance of spherule types within these modern urban spherules and about 800-1500 spherules from the South Pole Water Well locality, compared to collections of spherules accumulated over longer periods, provides the first evidence of short-term variations in flow. of cosmic dust through the Quaternary.

Several other methods are used to collect micrometeorites from rainwater, but little work has been done to evaluate the most efficient method of collecting these particles from space and then analyzing them. But it is expected that the best results are related to the collection area.

Miller (2013) used a plastic sheet mounted on the outside for one or two weeks, and through magnetic attraction it collects the particles. Hamilton (2007) used a bowl under a water trough to retain the heavier particles at the bottom and separate them through magnetic attraction.

BLAKE et al (2018) develops a research to measure the efficiency of the collector apparatus, testing four types of collectors: the first two connected the collectors to the water channel on the roof of the house, with the advantage of using the entire surface, in addition to increasing the volume of water. A collector consisted of a simple bucket placed below the trough in order to retain the micrometeorites at the bottom, by gravity, and later collected by means of magnetic attraction, while a second procedure joined a P trap to the trough with magnets fixed to the bottom of the trough. trap, waiting for the particles to be trapped by magnetism as the water flow passes through the tube. As a control, two traps were installed away from the roof water gutter.

The study by MONTEIRO (2013) carried out in the city of Planaltina/DF used the roof of some university buildings as a collection apparatus, in addition to the use of some collection containers. The methodology of Genge (2008) and Brownlee (1983) were used as a parameter to identify the micrometeorites found, separator by means of optical microscopy and use of petrographic microscope of transmitted and reflected light.

Eighty particles were separated through observations related to shape, color, brightness and transparency, suggesting that they belong to the group of molten micrometeorites and the class of cosmic spherules, due to the action of high temperatures at the time of entry into the Earth's atmosphere.

This study is important to emphasize that observations through scanning microscopy, associated with other techniques, are essential for the correct identification of extraterrestrial material. One of these particles presented in the work raise doubts about its origin and this answer could only be confirmed with high resolution methodology.

MICROMETEORITE FLUX

Studying the flow of micrometeorites means estimating the mass of this extraterrestrial matter that enters our atmosphere each year, as well as the possible incidence of these particles on the surface of artificial satellites and spacecraft, measured in [tons/year].

According to ROJAS et al. (2021), the annual flow of extraterrestrial material that enters our atmosphere is represented by particles with a size of less than 1 millimeter and the distribution of their mass and the absolute value of this flow is still uncertain due to the difficulty in controlling both the efficiency of the collection protocol and exposure parameter (product of area time in [m^2/year]).

Study of the flow of micrometeorites carried out by observations of impact marks on the surfaces of spacecraft and artificial satellites suggest an annual rate of 40,000 ± 20,000 [tons/year], as presented by DOHNANYI (1972) and LOVE & BROWNLEE (1991).

The flow studies performed by MAURETTE et al. (1987) in Greenland allowed an analysis of shorter time periods but with higher resolution, suggesting an annual inflow rate with total mass of >4000 [tons/year] during the last 2000 years.

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YADA et al. (2004) studied the micrometeorites found in the blue ice around Mount Yamato/Antarctica. Through noble gas analysis of the residue, fluxes of the order of 11,000 ± 6600 [tons/year] between 27 and 33 [kyr] B.P. and 16,000 ± 9100 [tons/year]. The results suggest that the micrometeorite accretion rate in the last glacial period was comparable to the current one.

The studies by TAYLOR et al. (2000) estimated the micrometeorites found in the water supply well of the South Pole research station. This well captures water from a depth of 90m, representing a sample of material from melting ice. The authors estimated an accretion rate of 1100 ± 200 [tons/year] for particles of size between 50-300 [μm], from 1000 to 1500 AD, however, when combined with the mass of unmelted materials, the estimates increase to 2700 ± 1100 [t/year]

About 90% of the material that enters the Earth's atmosphere is vaporized and does not reach the ground, but the iridium released by these particles precipitates to the Earth's surface. These high-resolution measurements can provide reasonably accurate estimates of this total extraterrestrial material received by Earth. Peucker-Ehrenbrink & Ravizza (2000) measured the total iridium found in the abyssal marine sediment and estimated a flux close to ~30,000 [tons/year].

DISCUSSION

Observing the collection methods, it becomes clear the need to look for alternative collection methods (such as collection in urban areas, a new methodology and only recently being popularized), due to factors such as limited exposure of the receptors used to collect the micrometeorites. observed in collections at high altitudes (stratosphere); The high costs of logistics in carrying out collections in deep sea sediments, in arctic glaciers and in high-altitude planes; and in the phenomenon of Silicone erosion observed in G-type spherules by the contact of water with the samples, observed in collections in deep sea sediments and can also be observed in samples from arctic glaciers. The importance of collection carried out in urban areas lies in the absence and/or minimization of these factors in their nature.

As with all other methods of micrometeorite collection, urban collection has positive and negative points, but taking into account all its benefits, the information that its practice is as effective as all others in a greater extent is affirmative. scale. The characteristics that make the collection of micrometeorites in urban areas through the collection of material on roofs and in gutters with the help of rainwater viable are: An easy methodology; the methodology for collecting roofs and gutters consists of simple steps that do not present much difficulty and/or threats to the collector, consisting of a simple collection of material (dust) concentrated in low points of the roof after a sweep of the same and cleaning of gutters; Abundance of roofs, in a simple way, the number of accessible roofs that present favorable conditions for the collection of these extraterrestrial particles is very expressive, resulting in a large exposure area for micrometeorites to be captured and collected, relative to other collection methods. , there is a large numerical difference in the area of direct collection of these specimens, inevitably resulting in larger collections of micrometeorites, a crucial factor in the studies of these particles; Finally, low operating costs and simple logistics is another factor that makes this collection method more affordable compared to others. Considering these points, it is easy to see the potential and effectiveness of this collection method.

However, there are also biases that need to be taken into account when it comes to this specific collection method, these being: Uncertainty in the concentration process, despite the abundant number of roofs in urban areas, it is common to face uncertainty about some aspects of the roof or gutters where the collection will be carried out, factors such as the lack of clarity on the exact age of the roof, that is, how long exactly this roof and/or gutters in question have been collecting the material to be processed, this circumstance directly affects the estimate the flow of micrometeorites from this collection; Uncertainty in the material degradation process, that is, each roof or collection zone has a unique topology, so it becomes very difficult if the process of decanting these materials with chaotic patterns, in a simple way, becomes impossible to know if during the process after decanting these particles, some specimen was stripped from the point of concentration of material, either by wind, irregular topology or even by human or animal interaction; The most important factor to consider, however, resides in the contamination of the material collected by particles of terrestrial or anthropic origin, in other words, there are particles with terrestrial origin (either by human or natural activity) that look like the rare micrometeorites and can be easily confused with these. These "imposters" have a high rate of occurrence presenting a high signal to noise ratio, and it becomes necessary to map the chemical elements of the elements identified as suspects in these collections through "mass spectrometry analysis" where the chemical spectrum is mapped and used

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for verification of extraterrestrial origin (the characteristic peaks in this are Silicone, Magnesium and Oxygen).

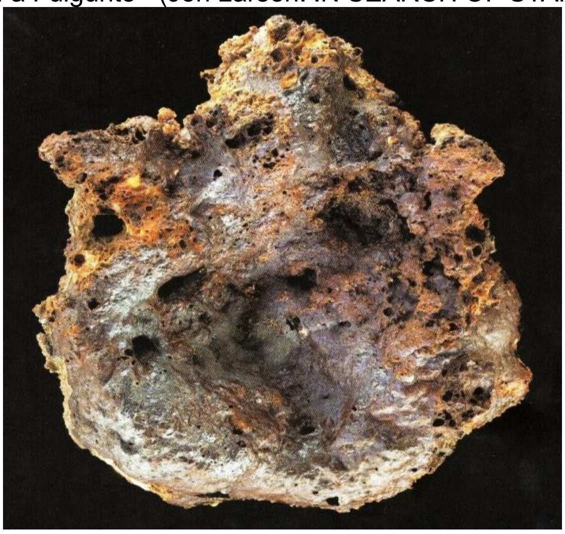
Although these biases constitute an unfavorable environment for the collection of micrometeorites in urban areas in contrast to other collection methods, the fact that the collection methodology applied in this scenario is simple, it can be optimized to minimize these deficiencies. With an appropriate choice of collection zone, it is possible to choose an environment in which essential collection parameters (collection area and time) are better controlled, thus enabling a more accurate estimation of micrometeorite flux.

Collecting and cataloging particles that contaminate the collection is a process that, if put into action, dramatically minimizes the signal-to-noise ratio, making the identification of micrometeorites more effective (both in the process of magnetic filtering and microscopic analysis), a crucial process for characterizing this collection method as efficient and feasible. This "profiling of imposters" consists of a process of identification, study and cataloging of these particles that resemble MM's, such cataloging is already being done by scientists who carry out these collections in urban areas (it is important to emphasize that this contamination process is not exclusive to urban areas, but it is also present in other collection methods, but this becomes expressive in these areas due to high human activity). The following illustrates some of the most common “impostors” found in previous collections in urban areas:

NATURALLY OCCURRING IMPOSTERS

Fulgurites

FIGURE 12. Illustration of a Fulgurite - (Jon Larsen. IN SEARCH OF STARDUST (2017), page 126)



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Fulgurites, also known as “lightning tubes”, are formed when lightning hits the desert sand and create these droplets from the molten sand, usually sized between 0.6 – 2.0 mm. There are 4 types of Fulgurites, the first as described above, but they are also created when a lightning directly hits a rock (rare occasions)(“exogenic fulgurites”), the dust plume of an erupting volcano (“exogenic volcano-fulgurites”), and the most common and not well described “exogenic phyto-fulgurites”. Even though a third of these particles are magnetic due its’ composition, in average there are 100 lightning strikes per second, and hence Fulgurites are expected to be found everywhere.

Pele’s tears

FIGURE 13. Illustration of a Volcanic Tephra (Pele’s tear) - (Jon Larsen. IN SEARCH OF STARDUST (2017), page 145)

Pele’s tear (Volcanic Tephra) are spherules created in volcanic eruptions by the quenching of magma spray usually sized between 2 – 64 mm (10 to 100 times larger than an average micrometeorite).

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Traces of Man

FIGURE 14. Illustration of a Anthropogenic Spherule - (Jon Larsen. IN SEARCH OF STARDUST (2017), page 120)

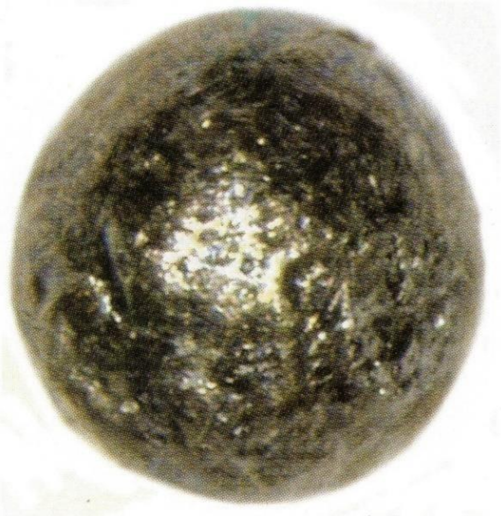
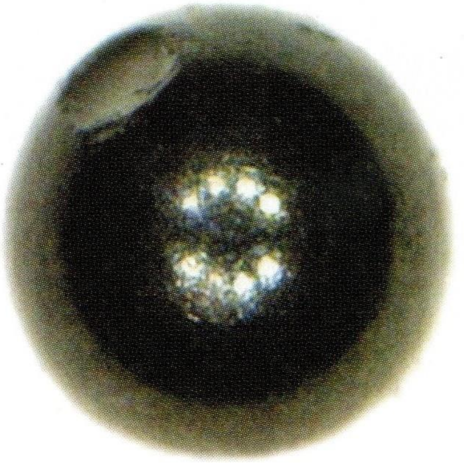


Figure 12 displays a spherule of anthropogenic origin. These types of spherules are commonly found in urban areas by human activity (from metal welding for example), and in principle can be differentiated from micrometeorites due their morphological properties (Many of these particles are created in spark fountains near ground level and are still partially melted when hitting the ground. Micrometeorites in the other hand are created in the upper atmosphere and have a different morphology).

Black Magnetic Spherules

FIGURE 15. Illustration of a BNS spherule - (Jon Larsen. IN SEARCH OF STARDUST (2017), page 107)



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Above is an illustration of a Black magnetic spherule, these particles have their sources found in asphalt concrete and glue and in roofing shingles and range in size between 3 – 125 μm. There are also referred as “fly ash” and are very common and are locally abundant, which is an indication of terrestrial origin.

FURTHER RESEARCH

As the last objective of this literature review is to propose a methodology of collecting micrometeorites in a scenario that provides conditions as to minimize the stated drawbacks and as to maximize the efficiency of the collection, both in terms of controlled parameters and in quantity of the collection. The first step is to choose a location where most of the contamination is minimized, because most of the usual contaminants have anthropogenic origin (metal spherules and BMS particles), we can expect the contamination of these spherules to decrease the further the location of the collection is, however, choosing a location too far from any urban area (a remote area) would defeat the purpose of making this methodology simple and accessible, hence a semi-urban area (or rural areas) can fit this description very nicely, because they are not remotely located but they usually are far enough from urban areas as to minimize the contaminant factor, improving significantly the signal to noise ratio of the collection.

The place suggested by this proposal is located at coordinates (19º00’53” S ; 57º56’43” W). it consists in an area of 200 $[m]$ x 3 $[km]$ located about ~30 $[km]$ from the nearest heavily populated are (Corumbá – MS, Brazil):

FIGURE 16. Satellite image of the proposed area of micrometeorites collection

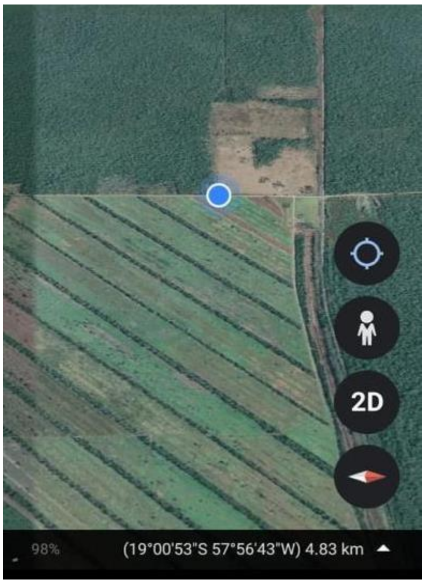

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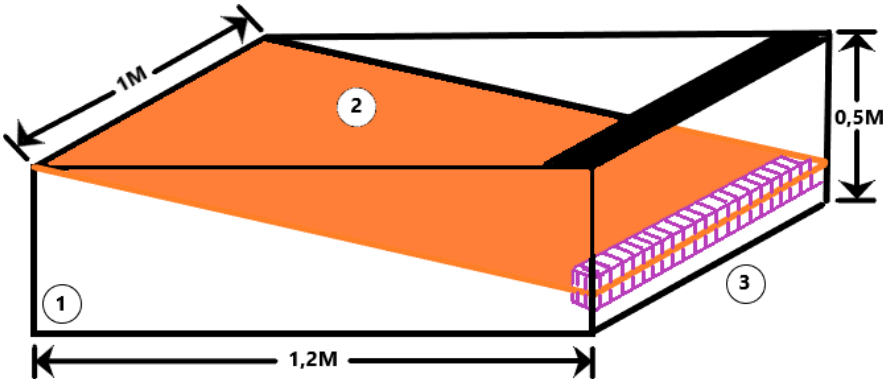
FIGURE 17. Aerial image of the proposed area of micrometeorites collection

The suggested methodology also consists of designing containers that allow the collection to have controlled parameters and control over the processes that might take place in the decantated material (Concetration and weather biasing).

FIGURE 18. An schematic on the proposed design of the micrometeorites collectors



1 – metal encasing of the designed trap (container). This choice of material was based on the fact that having this metal encasing would give weather resistance to the trap (long exposures to wind, sun and rain). The walls of the container would also not allow the micrometeorites accreted in the receptor plate to scape due weathering bias such as strong winds. The top part of the container has an aperture of 1 $[m]^2$, allowing a more accurate estimate of the micrometeorite flux.

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2 – Receptor plate made of tempered glass. The choice of using tempered glass is because is a very smooth surface and can resist long exposure to weather, this is important because if the receptor material is not smooth, some particles may get entrapped in the irregular topology of the receptor. This receptor is place inside the metal encasing in a very slight angle (exaggerated in the diagram) in order to allow the material hitting the plate to concentrate in the low point of the inclination. It is important to note that the plate would be placed at some distance below the upper most edge of the container, allowing the metallic walls of the container to not allow any accreted material to escape due weathering.

3 – Fine metallic mesh. This metallic mesh needs to be able to filter the accreted material according to size, having a granulometry of at least 100 [µm] (Most micrometeorites average around 200 [µm] - 300[µm]). This setup allows the rainwater to wash any material that has gathered along the receptor plate to be washed down to this mesh and filtering any smaller particles. It is important to note that the dimensions of the encasing are of 1 [m] x 1,2 [m], allowing a small part of the top surface of the container to be covered rather than exposed, this coverage would protect the concentration region created by the receptor plate against long exposure to the sun, preserving the longevity of this mesh.

Furthermore, some features of this designed trap would be a grid potentially covering the exposed part of the top surface of the container, this grid would impede larger bodies (such as leaves) and smaller animals to get into the container, contaminating the accreted material. Also a drainage system of the water would need to be implanted, preferably under the metallic mesh filtering the material, resembling a gutter, allowing not only the rainwater to be flowed to outside the container, but also the material made of smaller particles (that weren't captured by the mesh due its' not significant size). Some sort of weighting mechanism on the bottom of the container would also be ideal so the trap would not topple over and fall over the exposure times due to possible collisions with larger animals or very strong winds, this could be achieved by adding a layer of concrete to the bottom inner surface of the encasing.

This design along with this suggested location for the collection would allow to a more methodic collection of micrometeorites while minimizing weathering biases and contamination of the material while providing a controlled accretion process. The dimensions of this trap would allow it to be moved around in between collecting times,

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allowing this methodology not to be location exclusive, if some other potential collection sites are spotted, these traps could be moved allowing for the collection process to be repeated several times. The material choices of the container also allow the containers to have a longevity to allow multiple collections with a single trap, and in the unfortunate case of these traps being damaged, they are not difficult to be repaired, increasing its' longevity even further; It also makes the costs of producing such traps relatively low (these materials are not difficult to be obtained nor are expensive), allowing for a large number of these traps to be manufactures, covering a large area of exposure and so maximizing the efficiency of the collection.

This method allows for a controlled collection of materials: Since the expected flux of these particles are 1 micrometeorite per meter squared per year, letting the exposure area to be 1 $[m]^2$ is fitting; Due the container setup is possible to adjust the exposure time of the receptor so to no hinder the collected material (not allowing clogging of the mesh), also because these will not be placed in remoted areas (but rather just low populated zones) it is possible to have the active watch out for the outer grid protecting the receptor not to accumulate material as to block the exposed area; Due its' dimensions it is possible to use the container in several collections and in different collection sites also decreasing the logistical expenses; Because of the material chosen for this trap, it is also possible to produce several of these containers at a low cost of manufacture.

Lastly, one more procedure needs to take place using this methodology. Even though this minimizes the signal to noise ratio, there will be contamination of the collected material, this is, spherules and particles that assimilate micrometeorites but have terrestrial origin (either naturally occurring or manmade), one of the characteristics of identifying on type of impostor particles is its' locally abundance, micrometeorites fall randomly on the Earth's surface and hance it's expected to be found pretty much everywhere, but some terrestrial particles will be more common in some areas rather than others (BMS for example are more common near heavily urbanized areas). Thus it is necessary to meticulously catalog all the common contaminants of the area, a "local impostor profiling" needs to take place in order to improve the filtering process through microscopical analysis of the collected material.

All these factors allow an efficient and long-lasting methodology for collecting these extraterrestrial particles, significantly improving the signal to noise ratio and size of the micrometeorites collections that can be made from this. It becomes easy to see the

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potential of the collection using controlled parameters such as the ones described here and thus the importance of applying the concepts used to build this suggested methodology in order to have a better understanding of these mysterious particles.

CONCLUSION

The studies of micrometeorites suggest that their composition, formed by molecules and complex structures, are older than our planet and our solar system, so studying this material and understanding its physicochemical characteristics are fundamental to answer still obscure questions about the formation of the Earth. cosmos. In addition, the interest in the action of these particles in spacecraft and communication satellites are essential for the development of space research.

Because the collection of micrometeorites in urban areas is considered viable, it is necessary to develop a catalog that allows the identification of terrestrial particles that can be identified as false positives and facilitates the screening of the samples.

The implementation of an adequate methodology such as the one described in this project, which aims both to minimize uncertainties and unknowns in the collection of micrometeorites (in their decanting processes and climate bias) and to use aspects such as low cost and simple logistics to significantly amplify the reach of collections and study of extraterrestrial particles.

The field of “micrometeorites” has progressed considerably in the last two decades since the pioneering collection of particles from the deep sea (Brownlee 1985) and from Antarctic ice (Maurette et al. 1991). The characterization of many thousands of MMs by the authors of this paper and others has now allowed groups and classes of particles to be identified and placed in a genetically significant structure. In the future, as work on characterizing these materials progresses, rare types of MM will undoubtedly be recognized and will allow MMs to be used to further constrain the diversity of asteroidal and cometary bodies within our solar system.

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