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PREPARATIONS FOR THE MEASUREMENTS OF GAS-HYDRATE CRYSTAL CLOUDS IN THE OUTER SOLAR SYSTEM

by

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Előkészületek gázhidrát kristály felhők mérésére a külső naprendszerben.

A tanulmányban a szerző 1. a naprendszer kémiájára, 2. a gázhidrát összetevők kristályformáira és 3. a jégkristály felhőkön mutatkozó légköri „haló" jelenségekre alapozott kísérlet elvégzését ajánlja a külső naprendszer típusú kristályfelhők (KN-t-KF) megfigyelésére. Tekintettel a Pluto-Charon kettős bolygó-rendszer igen tömör jellegére (kis méretek), az ilyen KN-t-KF jelenléte a rendszer L4 és L5 Lagrange pont-jai közelében várható. Ezért e kettős bolygórendszer Lagrange KN-t-KF-jének a Pluto Fast Flyby Mission alkalmával való megfigyelésére egy kísérlet tervezésének és összeállításának intenciója lett eljuttatva a NASA NRA 93-OSSA 5 részlegéhez. Ehhez a kísérlethez az előkészületek elvégezhetők az Antarktiszon (amint az felvázoltatott az Antarktiszi Metoriokról tartott 18. Szimpoziumon [Tokyo, 1993]), hasonlóképpen ajánlottak az előkészületek Föld körüli pályán az ürrepülőgéppel és más, külső bolygókhoz (mint például a Cassini) tartó űrobjektumok révén is.

On the basis of. 1. Solar System chemistry, 2. crystal forms of gas-hydrate compounds, and 3. the atmospheric „halo" phenomenon in ice crystal clouds, an experiment to observe Outer Solar System type Crystal Clouds (OSS-t-CC) has been proposed in this paper by the autor. Considering the very compact (small-scale) nature of the Pluto-Charon double-planet system such OSS-t-CC may be expected in the vicinity of the Lagrangian points L4 and L5 of this system. Therefore an intention to plan and construct such an experiment for observation of the Lagrangian-point OSS-t-CC in this double-planet system by the Pluto Fast Flyby Mission has been sent to the NASA call of NRA 93-OSSA 5. Preparations to this experiment can be carried out in Antartica (as summarized on the 18th Symposium on Antaractic Meteorites, Tokyo, 1993.), on Earth orbit by Space Shuttle and other space probe missions to the outer planets, (i.e. Cassini) have also proposed.

INTRODUCTION

There are different, indepent pictures about the Solar System. They were developed by using disciplinary „filters" of concepts. Such disciplinary filters sometimes may be characterized by cardinal concepts. For the Solar System we mention three of them.

The first was: the *mass-point*. Considering the celestial bodies to be mass-points, and using the law of motion and law of gravitation by Newton to describe their movements, the mechanical view of the Solar System has been formed (in the 17th century). Another cardinal concept is the *chemical composition of materials*. By this concept a material map with different mineral belts around the Sun in gradually increasing distance could has been sketched (in the middle of our century). The third concept is the *size-frequency of the mineral-rock-planetary-body sequence* (or with other words: the crystal-rock cloud) in the Solar System. In this picture the number of bodies are summed up in every size-intervals (size-regions) to give the size-frequency-distribution, and this distribution is the function of time. This function also describes changes and evolutionary processes in the Solar System, because it appears on the cratered surfaces of planetary bodies as a result of their collisions by with this crystal-rock cloud. These three independet overviews of the Solar System are summarized in **Table I.**

Table I

The „parameter distinguished" column show those regions where reductions over the „regardless of" column were carried out in model-building.

Three kinds of multiple-particle system-approaches in the Solar System Evolution Models

Authors	Multised considered	Parameter distinguished	Regardless of	Phenomena which preserved the events
Kepler Newton	orbiting mass-points	orbital elements	a. chemic. comps. b. size-frequency	remnant orbits of celestial bodies in the Solar System
Larimer Levis-Barshay Grossman	orbiting minerals	chemical composition	a. orbital element b. size-frequency	composition of minerals in smaller and larger bodies of the Solar System
Hartmann Wilhelms Wood Chapman	orbiting bodies and „particles"	spectrum of size-frequency of „particles"	a. orbital element b. chemic. compos.	crater statistics of surface layers of different age from planetary bodies

OUTER SOLAR SYSTEM TYPE CRYSTAL CLOUDS

In the 60ies and the 70ies a more and more detailed model was published by different experts about the chemical structure of the Solar System. (*Barshay* and *Lewis*, 1975, *Grossman*, 1972, etc.) On the basis of these models one can see what kind of minerals may be expected (because of its equilibrium with the surrounding solar-system conditions during its origin) in different distances from the Sun. The equilibrium and the implicated chemical composition at a given solar distance were calculated in these models from the estimated temperature, pressure at that place and from solar element abundances. A more crude chemically changing belt „map" departing from the Sun has also been suspected from the average density of planets changing with solar distances. According to the chemical equilibrium models the minerals of crystal clouds in the Outer Solar System may have been mainly H_2O, NH_3, CH_4 and their gas-hydrate compounds. They are the candidates for OSS-t-CC.

A „SCATTERING" PHENOMENON IN CRYSTAL CLOUDS

The bright halo (or ring) surrounding Sun or Moon is a well know atmospheric phenomenon, although it occurs only occasionally. This halo is produced by the refraction of the light of a „central" light source in tiny (10—100 mikrometer sized) water-ice crystal particles floating in the atmosphere. From the multitude of floating particles those sum up the bright halo which are well oriented in order to refract the light of the source into the eyes of the observer. We may show the rising up of the phenomenon from the refraction geometry of crystal particles (local picture) and from the arrangement and orientation of particles — randomly dispersed — in the crystal cloud (global picture). The origin of the phenomenon is essentially similar to that of the rainbow, but at rainbow there is backscattering (inner reflection backwards) of the light in rain drops, so the light source is in backward when we observe the rainbow's arc. *(Fig. 1.c.)*

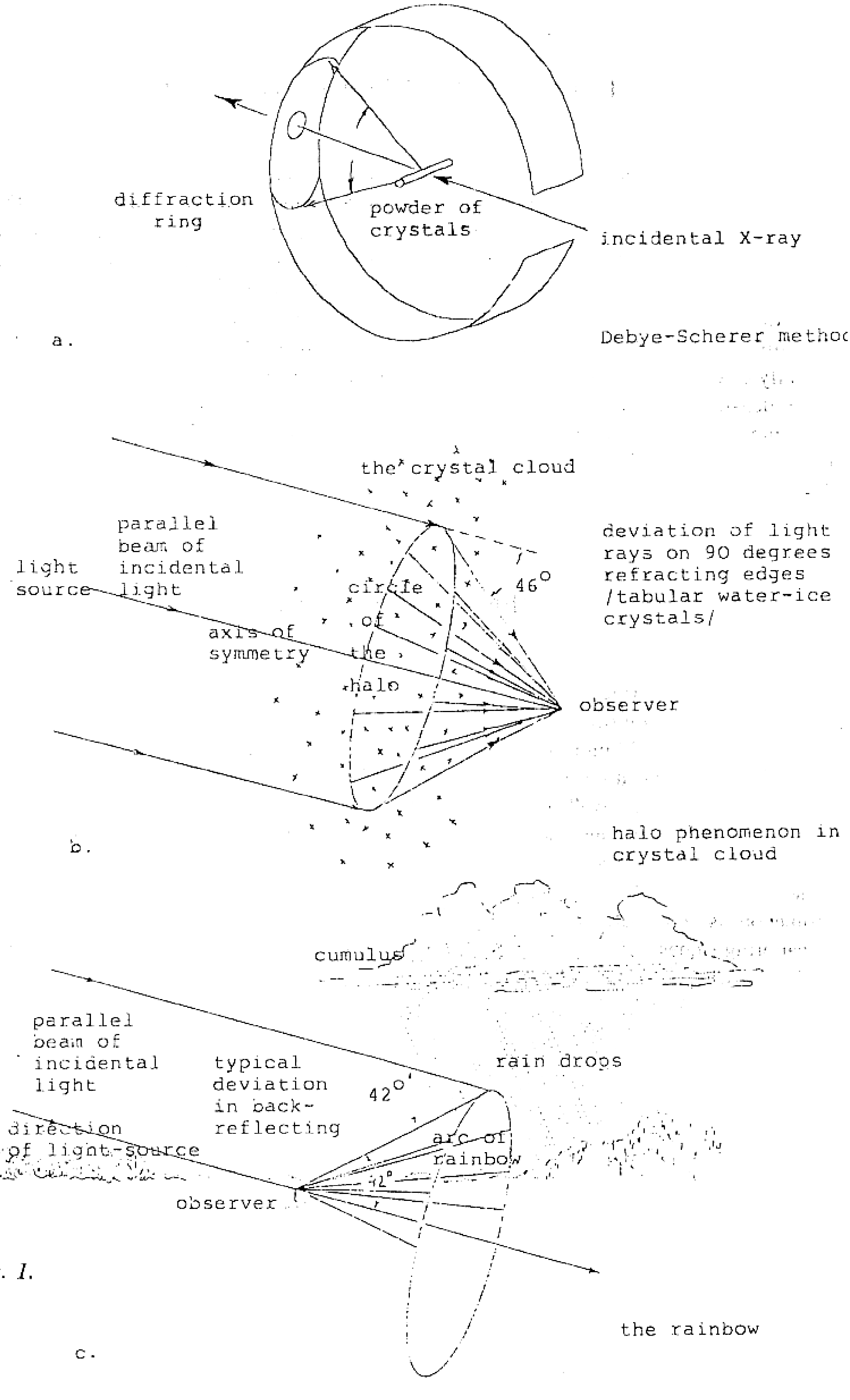
diffraction ring
powder of crystals
incidental X-ray
a.
Debye-Scherer method
the crystal cloud
parallel beam of incidental light
light source
circle of the halo
axis of symmetry
deviation of light rays on 90 degrees refracting edges /tabular water-ice crystals/
46°
observer
b.
halo phenomenon in crystal cloud
cumulus
parallel beam of incidental light
typical deviation in back-reflecting
rain drops
42°
direction of light-source
arc of rainbow
42°
observer
the rainbow
c.

Fig. 1.

THE LOCAL AND THE GLOBAL PICTURE

The local picture: Here we show typical paths of the light when it refracts during crossing through water-ice crystals. In this respect there are two characteristical and frequently occurring forms of such crystals: the needle (or pencil) like and the tabular prismatic ones. *(Fig. 2.)* The typical path of refracting light during the passing through these crystal forms depends on the refracting angle at the prismatic edge of the crystal (and also depends on the refraction coefficient of water-ice). The refracting phenomenon can be characterized by the deviation angle, which is the angle between the direction of entrancing light and the direction of departing light stepping out from the crystal. Because of its molecular structure, the characteristical crystal form of water-ice is the hexagonal prims. This form may have been developed into two different prismatic edge/hexagonal diameter ratio. If this ratio is large, the form of hexagonal prisms is pencil like, elongated. If this ratio is small, the form of the hexagonal prisms is plate-like, tabular (*Grennler,* 1980).

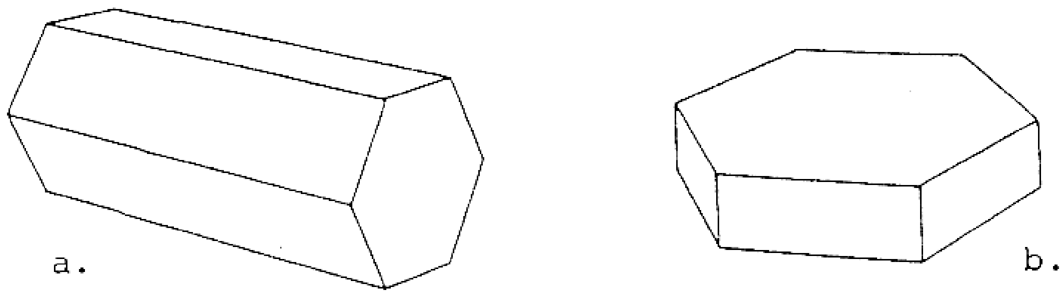

Fig. 2. The two most frequently occurring water-ice crystal-form:
a. elongated, pencil-like hexagonal prims, b. tabular prism.

The two different hexagonal forms has different dominating refracting angle. For the pencil-like, elongated form the prismatic edge is 60 degrees; this can be seen when we complete its hexagonal cross-section to a regular triangle *(Fig. 2.a.)* For the tabular crystal form the dominating refracting angle can be found at the closing faces (pedions) of the prims. This angle between the pedion and any of the prismatic faces is 90 degrees.

The deviation of the passing and so rafracting light through a pencil-like water-ice crystal (with 60° refracting angle) is min. 22 degrees. This deviation for the tabular case, (when refracting angle is 90°) is min. 46 degrees. The deviation angles are more if the incidental direction is not perpendicular to the prismatic edges (or their parallel lines cut through the incidental point of the light ray) (*Greenler,* 1980).

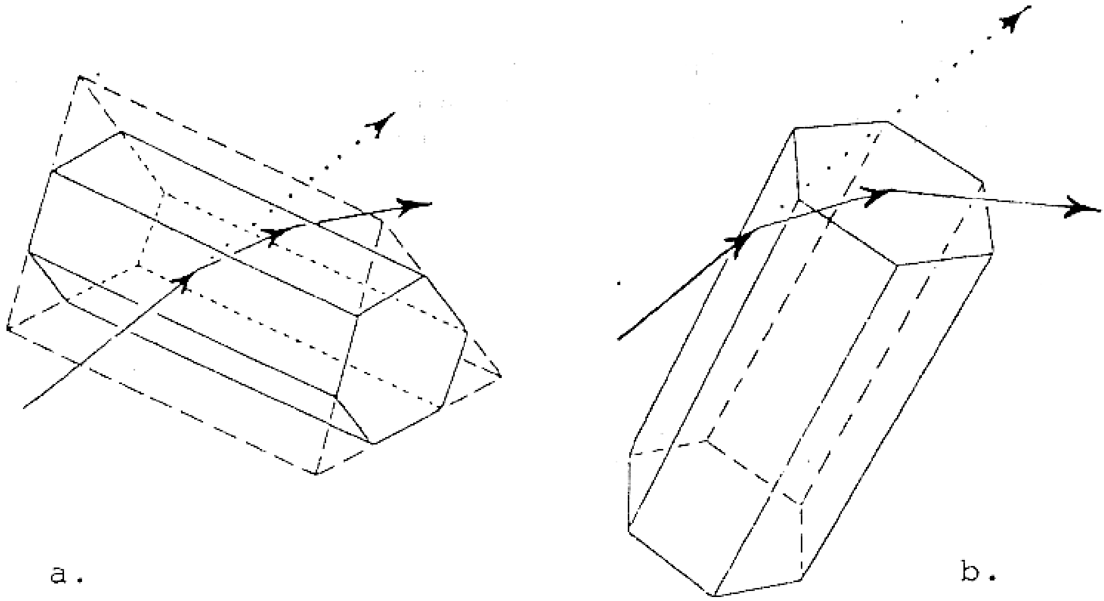

Fig. 3. Deviation of the refracted light-ray passing through
a. the elongated hexagonal prism, givin 22 deviation, and,
b. the tabular hexagonal case at pedion-prismface refraction, giving 46° deviation.

The probability of the dominating deviation of the refracting ray on a randomly oriented crystal depends on the form of the crystal. For an elongated crystal there are larger surfaces on the crystal to meet with light rays on the prismatic faces. Therefore the dominating light ray passing is through the pencil, almost perpendicularly to the 60° refracting edges. For tabular crystals there are larger surfaces on the crystal to meet with light rays on their pedions. Those rays which suffer refraction step out from the crystal at the prismatic faces. Therefore the dominating light ray passing, which produces refraction in tabular crystals, is that with 90° refracting edge. *(Fig. 2.b.)*

In summary we may conclude, that for crystal clouds consisting of mainly elongated, pencil-like water-ice crystals, the most probable deviation for its crystal components is the 22 degrees one. Similarly, for crystal clouds consisting of mainly platelike, tabular water-ice crystals, the most probable deviation for its crystal components is the 46 degrees one. The global picture will show how sum up local deviations (local refractions) to give the halo phenomenon.

Global picture: Let us imagine, that the crystal cloud consists of homogeneously dispersed ice crystals with similar measure and characteristical form (as earlier discussed) in the atmosphere. In the global picture the light source-observer axis is the main selector for the phenomenon to produce. Of the light rays running parallel with this axis the suitable orientation (in space) and the suitable position (in the cloud) of some crystals select those rays which have refracted (and so deviated) path advancing into the ocular of the observer. On the other hand, of the randomly oriented crystal particles the source-observer axis, the parallel beam of light rays and the (local) refraction rules (shown earlier) select those ones which can contribute to form the halo phenomenon. Therefore the selection is a mutual and simultaneous coincidence of both the local and the global rules and effects of refraction and observational geometric arrangement. Although the actors, i.e. the particles, which produce the effect, change from instance to instance, (because of the rotation) the global phenomenon remains. *(Fig. 1.b.)* In this respect the phenomenon is very similar to the X-ray diffraction method of Debye-Scherer for crystal-powder materials. There, such mutuality between X-rays with a given wavelength and well oriented (of the randomly dispersed) crystals produce interference rings (according to the rules of interference of waves on a lettice, given for example as Bragg-conditions). *(Fig. 1.c.)*

THE „GIGANTIC LENS IN FRAGMENTS" MODEL FOR HALO

All the geometric arrangement of the global picture preserves the cylindrical symmetry of the source-observer axis. For observer halo forming light rays arrives along a mantle of a cone. The vertex of this cone is at the observer. The basic circle (a large circular refracting ring region) is the halo itself, in the cloud. In this region well oriented crystals (form instance to instance) refract the parallel light of the source along the mantle of the cone into the direction of the observer. We may summarize this mutual working of suitable crystals so, that they work as if they were a „gigantic lens in fragments" in the cloud. Because of local rotation the components of this gigantic lens always change. But the particles are similar and they have great number enough to sum up the phenomenon continuously.

The contributing particles form only the edge region of the lens. But the cloud may serve as a „set of opportunity" for not only one type of halo formation. If the form of the ice crystals is not dominated by neither the pencil-like nor the tabular shapes, then both of the two most probable halos can appear. In this double-halo formation light rays and refracting rules select the instantaneous representatives for both halos from the same crystal cloud.

OUTER SOLAR SYSTEM TYPE CRYSTAL CLOUDS

The chemical crystallization (and local chemical equilibrium) models (*Barshay, Lewis*, 1975, *Grossman*, 1972) deduced the composition of minerals in the Outer Solar System. There the principal components of crystalline material - which can form clouds - are ices. These ices are the crystalline precipitates of highly volatile (mainly atmospheric) compounds in terrestrial and Inner Solar System conditions: CH_4, HN_3 and H_2O. In chemistry they are called gas-hydrates. These minerals have a common crystal-form characteristic: they all have crystal structure in the regular (cubic) system. (*Berecz, Balla-Achs*, 1980) Therefore investigators may expect such cubic crystals as the main components of OSS-t-CC. Because of the dominating refracting angle for cubic crystals is the 90°, in the estimation and experiment planning we can use up the experiences shown earlier in the case of tabular water-ice crystals (*Bérczi*, 1993).

On the basis of the refracting rules for cubic crystals (now regardless of refraction coefficients) the two different type of refracting paths in such crystals don't give different deviations. *(Fig. 4.)* Therefore both ray paths contribute in forming a 46 degrees type halo (as first estimation) for OSS-t-CC.

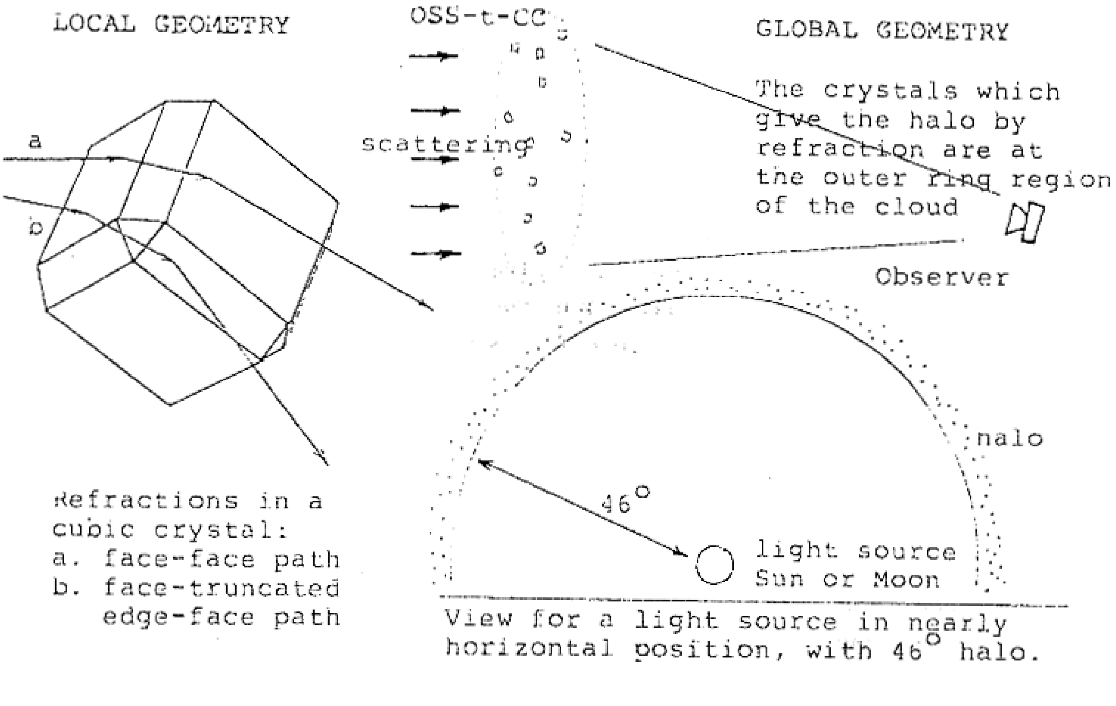

Fig. 4. Local and global geometry of the halo formation in an OSS-t-CC. Cubic cristal refractions show the two main types of path which contribute to the 46° halo formation.

PROPOSED MEASUREMENTS FOR THE PLUTO FAST FLYBY MISSION, NASA

NASA plans to launch a space probe towards the Pluto at the beginning of the next millenium. The name of this mission is Pluto Fast Flyby. On the basis of the given estimations the author has proposed the following experiment for this mission. (*Bérczi,* 1993a)

The Pluto (c.a. 4000 km in diameter) and its moon, the Charon (c.a. 2000 km in diameter) forms a close double planet system. (Pluto-Charon-System= PCS.) From the celestial three body problem it is known that in the vicinity of two larger, almost circularly rotating bodies there are semistable regions, where a third mass system may exist for a longer time. These points are the Lagrangian Points. In our case especially the L_4 and L_5 points are interesting in focus, because in such points many satellites are known. Most of them are in the case of Sun-Jupiter system, where the Troian asteroids can be found, but the *Kordilewsky* moons of the Earth-Moon system are also detected by Apollo astronauts (photographed), and Voyagers also found such type of satellites in the vicinity of Saturn, of the Saturn-Titan system.

My hypothesis was that tiny crystals of gas-hydrates may have been accumulated in the vicinity of the L_4 and L_5 points of the Pluto-Charon-System (PCS). We call these clouds Lagrangian Point Crystal Clouds (LPCC). In the proposed experiment the Pluto-Charon-LPCC system is the object for observations, because Pluto or Charon may be the light source behind the LPCC.

Orbit planning may make it possible for the Pluto Fast Flyby probe *to see through the LPCC* in the direction of both Pluto and Charon. On the basis of the earlier given estimations the width (the Diameter) of the suspected halo around the light source (Pluto or Charon) should be a 46 degrees type one. But other components may also be important to study. If the LPCC is dense enough to produce halo during seeing through it, than from the position of halo rings the nature and composition of LPCC in the Pluto-Charon System can be determined. The method later, if successful, can be used for other double-planet system, too, although it has less probability, because of the extraordinary compactness of the PCS, which may be an important condition in the experiment of the Pluto Fast Flyby Mission on LPCC. *(Fig. 5.)*

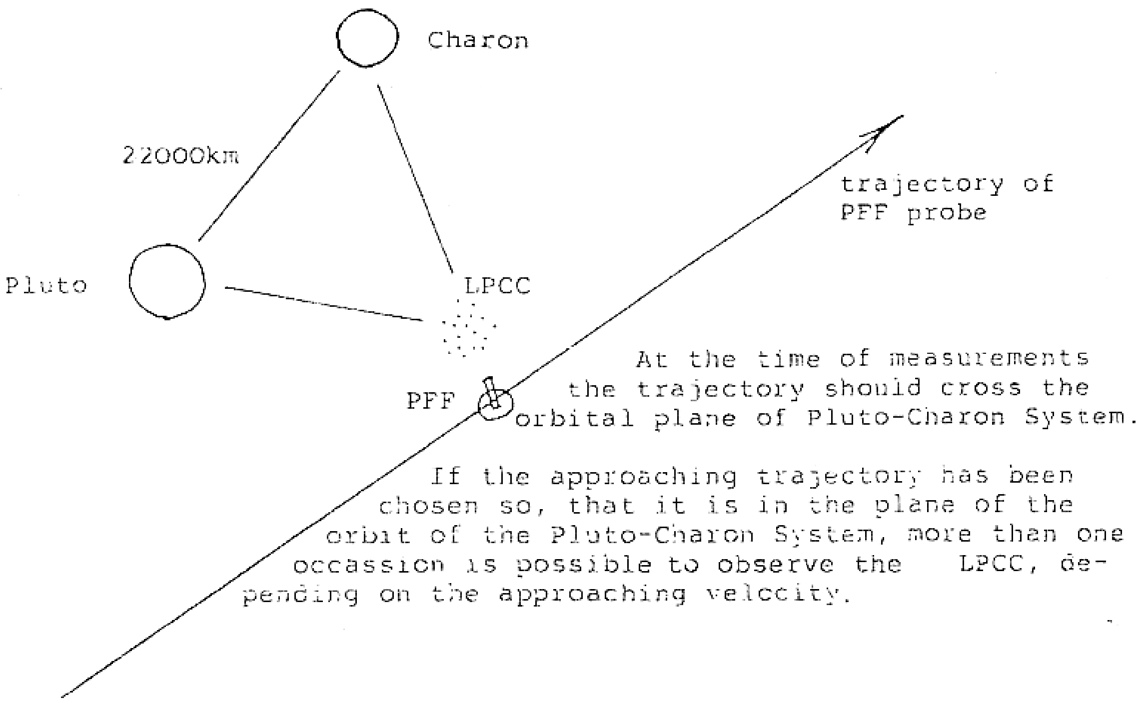

Fig. 5. A simple sketch about the spatial arrangement and real distance rations for the observation of Lagrangian Point Crystal Cloud in the Pluto-Charon System (the proposal). The sketch shows the LPCC in the triangular Lagrangian Point and the experimental arrangement of trajectory and orientation of the Pluto Fast Flyby probe to Charon.

PREPARATIONS...

There are three different places where preparations to such halo-type measurements can be carried out. The first one is a desert-like region, where different transparent „salts" may be the refracting minerals. This experiment can be accomplished in Hungary, too. The other place is Antartctica, where in the colt atmospheric conditions low temperature ices may be the refracting minerals. (*Bérczi,* 1993b) The thired place is the Space Shuttle where space-cold real ice candidate crystals may be the actors. For all these experiments the most suitable light source is our Moon.

SUMMARY

An Outher Solar System type Crystal Cloud (OSS-t-CC) measuring experiment and its conceptional background has been discussed. In this experiment knowledge from different disciplines was built together. The most important basis came from climatology: the phenomenon of halo around a light source in terrestrial atmosphere. Outer Solar System type components were taken from solar system chemistry models: a characteristical refracting rule was shown on the basis of regular system crystal structure and form of gas-hydrates. Finally the idea, where to look for this OSS-t-CC was triggered by the NRA 93-OSSA-5 call for experiments by NASA which turned my attention to the close binary-planet system of Pluto and Charon. For Pluto-Charon system the close binarity suggested that in Lagrangian Points Crystal Clouds may be dense enough to exhibit the proposed halo phenomenon. Although the principles and concepts abouth the experiment has been built together, further discussoins are necessary to reveal the probability of measurability of the OSS-t-CC in the Pluto Charon System. But proposals for more simple experimental preparations in terrestrial conditions were also given, which may confirm or reject the type of experiment which should be a new method in identification of OSS-t-CC in other places.

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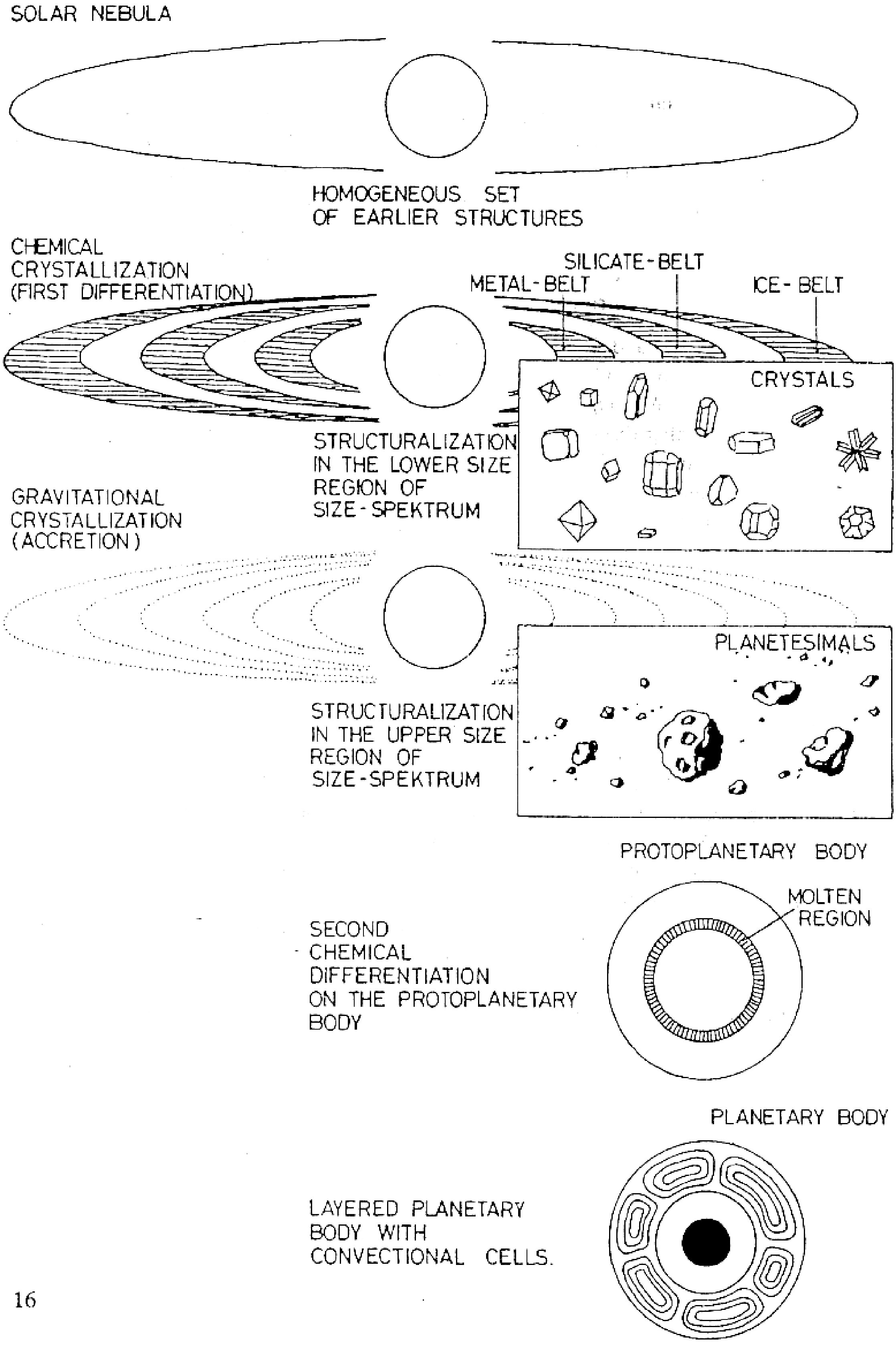

SOLAR NEBULA
HOMOGENEOUS SET
OF EARLIER STRUCTURES
CHEMICAL
CRYSTALLIZATION
(FIRST DIFFERENTIATION)
SILICATE-BELT
METAL-BELT
ICE-BELT
CRYSTALS
STRUCTURALIZATION
IN THE LOWER SIZE
REGION OF
SIZE-SPEKTRUM
GRAVITATIONAL
CRYSTALLIZATION
(ACCRETION)
PLANETESIMALS
STRUCTURALIZATION
IN THE UPPER SIZE
REGION OF
SIZE-SPEKTRUM
PROTOPLANETARY BODY
MOLTEN
REGION
SECOND
CHEMICAL
DIFFERENTIATION
ON THE PROTOPLANETARY
BODY
PLANETARY BODY
LAYERED PLANETARY
BODY WITH
CONVECTIONAL CELLS.