ORIGIN, EVOLUTION AND PRESENT STRUCTURE OF THE ASTEROID REGION

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ABSTRACT

Space research has demonstrated that it is necessary to revise many generally accepted theories of diffuse media in astrophysics. A consequence is that the evolutionary history of the solar system must be rewritten. From in situ measurements in the magnetospheres, including the solar wind, it now becomes possible to extrapolate to the state at cosmogonic times. The scenario can now be based on reliable measurement. Moreover mathematically erroneous formulae must be revised.

The conclusion is that the asteroids do not derive from an "exploded planet". Similar to the Saturnian ring they represent a planetesimal state in the cosmogonic evolution. In both cases the bulk structure is essentially given by the cosmogonic shadow effect. The contraction ratio 2:3 is found with an accuracy of a few percent.

A. SPACE RESEARCH AND THE THEORY OF DISPERSED MEDIA

Space research is now precipitating a thorough revision of astrophysics, including views on the origin, evolution, and present structure of the solar system (Alfvén 1981a, 1983a)

1. One of the reasons is that in the pre-space age, observations were confined to the visual octave and a few short-wave radio octaves. Now the whole electromagnetic spectrum is observable. Essential for our field of research is that the opening of the infrared and ultra-short radio bands containing the molecular spectra, is now available, which means increased ability to explore interstellar clouds similar to that one from which the solar system has originated.

2. Still more important is that in situ measurements of cosmic plasma - from the ionosphere out to the region of the giant planets - have given us a new view of their properties. The Chapman-Cowling views on the properties of "ionized gases" is no longer sacrosanct.

3. Further, in the laboratory, thermonuclear research has given a spin-off which is valuable for cosmic plasma physics. Still more important is the large number of laboratory experiments which have been designed specifically for clarifying cosmic situations.

4. The theory how to "translate" results from one parameter region to another has made important progress.

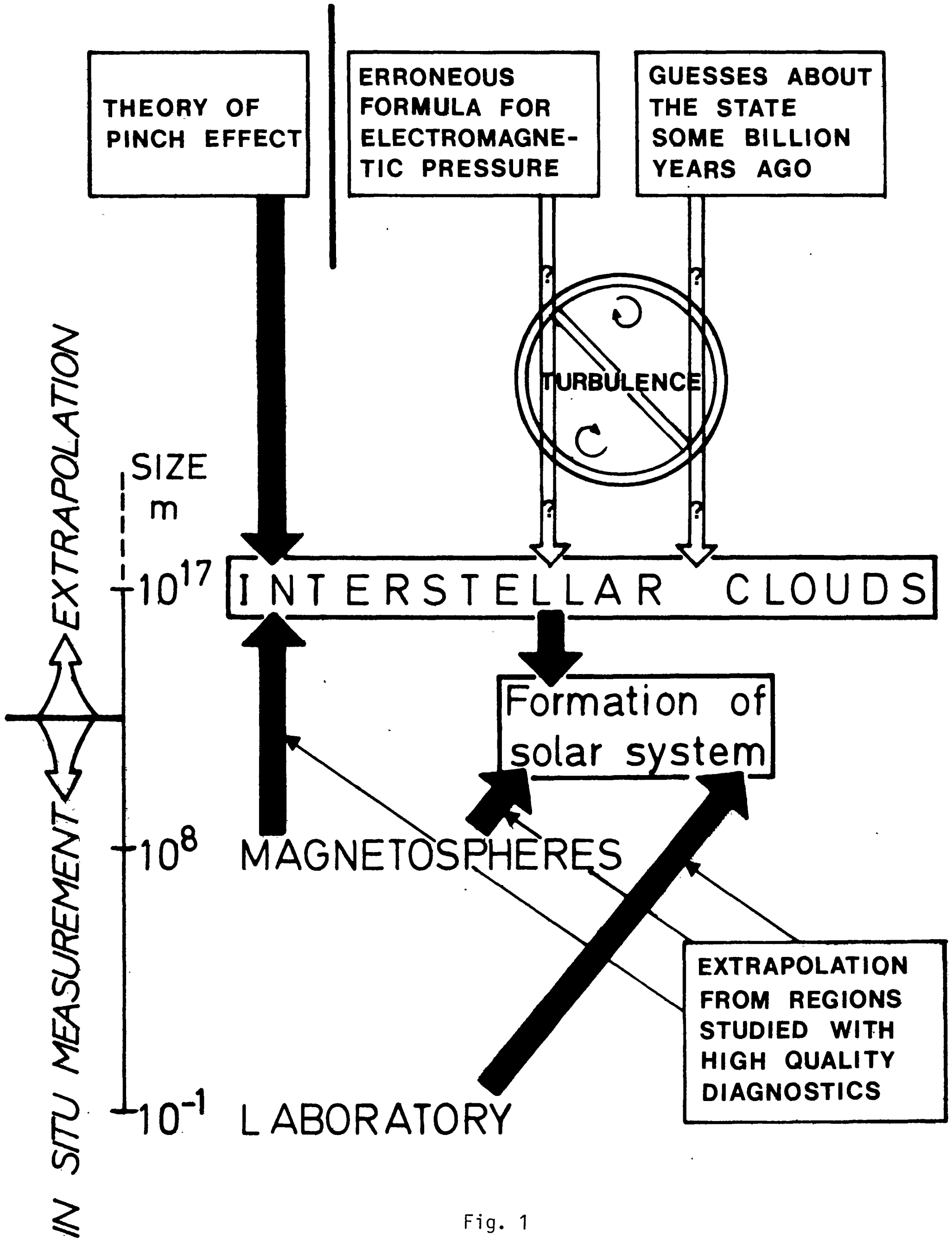
THEORY OF PINCH EFFECT
ERRONEOUS FORMULA FOR ELECTROMAGNETIC PRESSURE
GUESSES ABOUT THE STATE SOME BILLION YEARS AGO
TURBULENCE
SIZE m
10^{17}
INTERSTELLAR CLOUDS
Formation of solar system
10^{8}
MAGNETOSPHERES
10^{-1}
LABORATORY
EXTRAPOLATION FROM REGIONS STUDIED WITH HIGH QUALITY DIAGNOSTICS
IN SITU MEASUREMENT
EXTRAPOLATION

Fig. 1

Fig. 1 Flow of information for clarifying evolution of Solar System

White arrows: Approaches based on guesses and on erroneous formulae, e.g. neglect of (B∇)B term in pressure equation.

There are no decisive arguments for the view that large scale turbulence was of major importance.

Black arrows: Approaches based on in situ measurements in the magnetospheres, extrapolated laboratory results, and the use of correct formulae.

This survey of plasma physics regions illustrates that in the laboratory and in the magnetospheres (including solar wind region) out to 10^{12} m, high quality diagnostics is possible. This means that it is possible to acchieve scientific results of permanent value.

Outside the reach of spacecrafts astrophysical theories are necessarily more speculative. Studies of these regions should to a large extent be based on extrapolations from the accessible regions.

Theories of the origin of the solar system have so far largely been based on guesses about the state some billion years ago. Hundred different theories have originated from hundred different guesses.

The progress of space research makes it now possible to treat the cosmogonic problems through extrapolations from phenomena studied with high quality diagnostics. This will transfer cosmogony from a play ground of wild ideas into a respectable science.

5. Observations and theory have clarified that electric current are decisive for the properties of cosmic plasmas. Energy transfer from one region to another cannot be fully understood without knowledge of the circuit in which the currents flow.

6. Because electric currents often flow in filaments and sheets, cosmic plasmas are often highly inhomogeneous. Homogeneous models are often misleading.

7. Because many interstellar clouds, including clouds of the type our solar system is likely to derive from, are observed to consist of dusty plasmas the theory of such plasmas are decisive for cosmogony. The usual treatment of the evolution of clouds must be substituted by plasma theory. The new field of science called gravito-electromagnetism (Mendis et al. 1982, 1983) is often of decisive importance.

B. OBSERVABLE PARAMETER RANGES

In situ measurements of cosmic plasmas have already been made over very wide parameter ranges. Densities vary between the relatively high values in the lower ionosphere down to the 12 orders of magnitude lower densities in interplanetary space. Magnetic fields have been measured between several milliteslas in some magnetospheres down to picoteslas in the solar wind. Concerning temperatures, it should be observed that the electron temperature may differ by orders of magnitude from the gas temperature in the same region, and the radiation temperature may differ drastically from both.

C. SPACE AGE APPROACH TO COSMOGONY

1. Because of our increased knowledge of the properties of dispersed media, the theory of origin and evolution of the solar system can now be based on extrapolations of the properties of dispersed media which are studied by in situ measurements (cf. Fig.1, see also Alfvén 1981a, Ch. IV,V).

This changes the status of cosmogony, which is now being transferred from a play ground of more or less wild hypotheses to a serious science.

Of course we are still only in the beginning of this transfer process. However, there are clear indications how the work should be planned: the new physics of dispersed media which comes out of space research should be transferred into the parameter regions which is relevant in cosmogony.

This approach leads to the following.

2. It is impossible to neglect plasma effects in cosmogony. Arguments for this view have been summarised in Alfvén and Arrhenius (1975, 1976). They are still valid but our present knowledge makes it possible to state them in a much more cathegorical way (Alfvén 1981a, 1983a).

3. Theories based on large scale turbulence should be regarded with considerable scepticism. There are no decisive observational support for the view that real turbulence is of mayor importance in the physics of dispersed cosmic media (Alfvén 1981a, Ch. IV.4).

4. In conventional theories of the formation, evolution, and collapse of interstellar clouds the second term in the pressure equation

$$\nabla(p + B^2/2\mu_o) - (B\nabla)\, B/\mu_o = 0$$

is usually neglected. A mathematically correct treatment leads to a drastic revision of the whole field (Alfvén 1981a, Ch. IV.8).

5. The planetary system and the satellite systems were formed by basically the same process ("hetegonic approach"). The differences between the systems are produced essentially by differences in two parameters (Alfvén and Arrhenius 1976, Ch. XXIII).
a. mass of the central body;
b. spin of the central body.

Total mass falling in towards a "central body" and its chemical composition are also relevant. Further, the magnetic field of the central body must be large enough to dominate the behaviour of the falling down matter.

D. FROM INTERSTELLAR CLOUDS TO PLANETS, SATELLITES (AND ASTEROIDS)

All this leads to the following sequence of cosmogonic processes. (See Alfvén and Carlqvist 1978, Alfvén 1981a, Ch. V).

1. Cloud phase
Formation and evolution of interstellar clouds (Alfvén 1981a, Ch. IV:8 and V). The theory must be based on the properties of dusty plasmas.

Electromagnetic forces do not necessarily counteract the contraction, but may assist it and trigger it off. These processes lead to the formation of stars (Alfvén 1981a, Ch. IV:8)

2. Plasma phase
Remnants of the cloud fall in towards the star (sun). Critical velocity phenomena are essential, producing the band structure of solar system (Alfvén and Arrhenius 1975 and 1976, Ch. XXI and XXVII, Alfvén 1981a, Ch. IV:6, Giuli 1968b).

The fact that none of the cosmically abundant elements has critical velocities between 13-14 km sec^{-1} (for Ne, N, C and O) and 34 km sec^{-1} (for He) explains why there is a semi-void region between Mars and Jupiter. Indeed, the smeared out density in this region is less than 10^{-6} of that in the adjacent regions. (See Table 21.5.1 in Alfvén and Arrhenius 1976). This gives a simple and straight-forward explanation of the location of the asteroid region.

3. Planetesimal phase
Condensation in the dusty plasma leads to formation of planetesimals. They accrete to planets and satellites. When in most regions the planetesimals accrete to large bodies information about the plasma-planetesimal transition is obliterated. Exceptions are
(a) the Saturnian ring system (SR) because it is located inside the Roche limit (Alfvén and Arrhenius 1975 p. 160-167 and Alfvén and Arrhenius 1976, Ch. XVIII).
(b) the asteroidal region (AR) where, because of the low density, the evolution to big bodies proceeds with a time constant larger than the

age of the solar system (Alfvén and Arrhenius 1975, p. 167 and Alfvén and Arrhenius 1976, Ch. XVIII:8).

These two regions give us the most valuable information about the plasma phase and plasma-planetesimal transition.

4. Planet and satellite phase
This is the end result of normal planetesimal accretion.

E. TRANSITION FROM PLASMA TO PLANETESIMAL STATE

1. Our studies aim primarily on understanding the (smeared out) mass distributions in the planetary and satellite systems.

Neither in the SR nor in the AR has it yet been possible to measure the mass distribution directly. In the SR it is derived by Holberg from optical and radio measurements. In the AR Burkenroad has derived it from photometric data by assuming that all asteroids have the same albedo and density (See Alfvén and Arrhenius 1975.) Although we know that this is not the case, the error introduced by this assumption could not be more than perhaps a factor 10. Because the masses of visible asteroids vary by a factor of 10^6, such a correction is not very important.

2. This transition is associated with a contraction by a factor Γ = 2:3. For the theory of this contraction see Alfvén and Arrhenius (1975) and (1976, Ch. VI). The factor Γ = 2:3 is found in four different cases in the Saturnian rings (Alfvén 1981b, Alfvén and Mendis 1983, Alfvén 1983b). The observed values differ from the theoretical value by less than a few percent.

This demonstrates that it is possible to reconstruct certain aspects of the plasma-planetesimal transition with an accuracy of a few percent.

F. STRUCTURE OF THE SR AND AR

Pioneer and Voyager results show that the Saturnian rings consist of four superimposed structures: (1) Transients, (2) The bulk structure, (3) Fine structure, and (4) The hyperfine structure (See Alfvén 1983b). Of these, essential parts of (3) are due to resonances, whereas (2) is essentially produced at the plasma-planetesimal transition.

Comparing these SR result with earlier AR results (see Alfvén and Arrhenius 1975 and 1976) we find that there are important similarities between the dynamical structure of SR and AR (Alfvén 1981b, Alfvén and Mendis 1983).

1. However, the structure of asteroid region (AR) differs from that of the Saturnian ring (SR) in two respects.

Gravitational resonances are orders of magnitude larger in the AR. This is due to the fact that the Jupiter/Sun mass ratio is 10^{-3}, whereas the Mimas/Saturn ratio is only 10^{-7}. This makes the Kirkwood gaps very conspicuous in contrast to the resonance phenomena in the SR. Holberg's analysis of the Voyager data show small but clearly identifyable maxima at the resonance points (Fig. 2). These are orders of magnitude smaller than the Kirkwood gaps which - moreover - have the opposite signs. Of

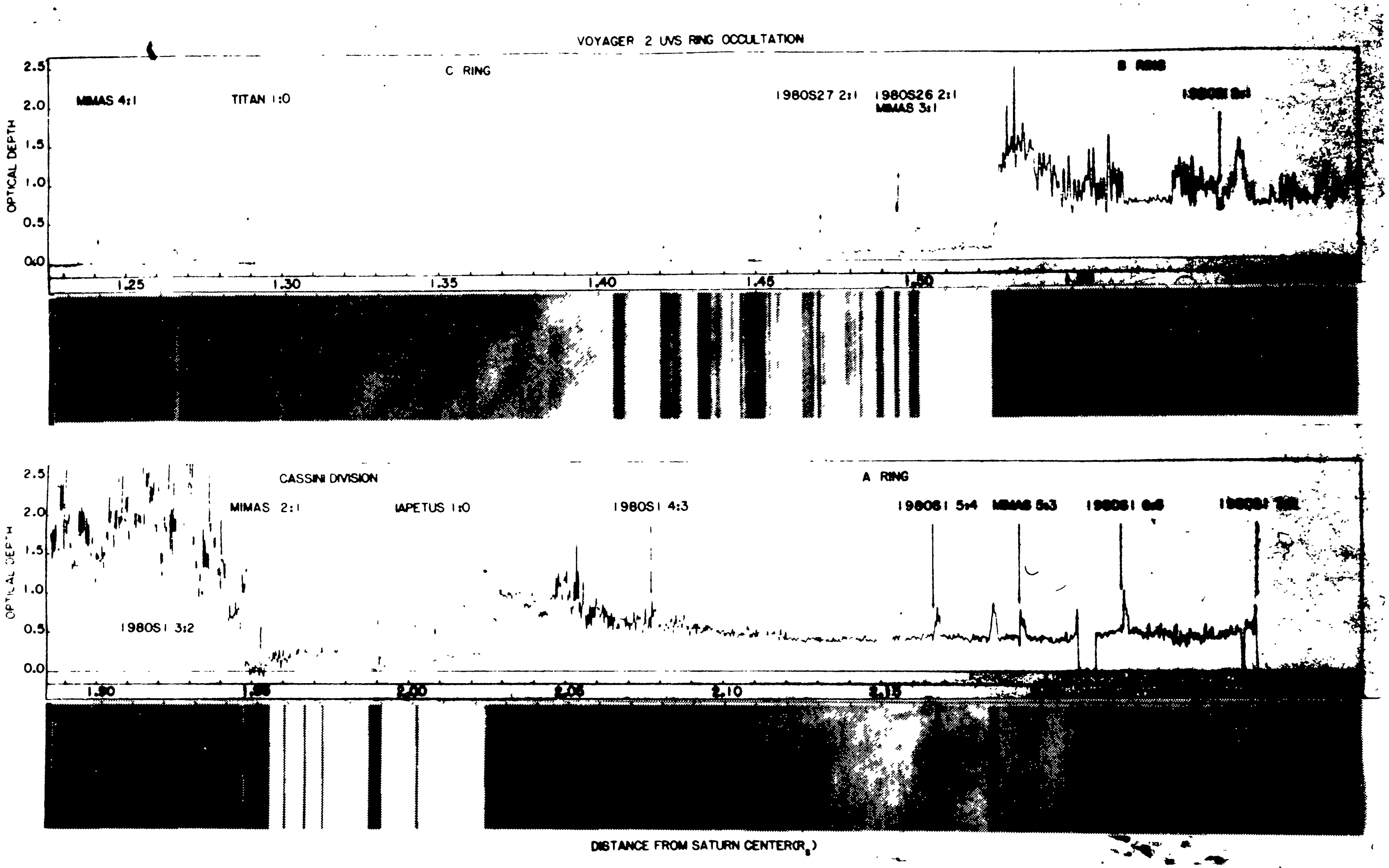

Fig. 2
The normal optical depth of the rings from Voyager 2 UVS ring occultation data. Below is the brightness of the rings in transparent light (For detailed analysis see Alfvén 1983b).

special interest is the Mimas 2:1 resonance at 1.945. It is a rather small peak at the left side of the about two orders larger Cassinis division.

Holberg's curves clearly demonstrate that the Cassini division cannot be produced by resonance phenomena as claimed by celestial mechanics scientists. It is depressing to remember that they have made this claim for decades in such a fanatical way that they not even have mentioned the objections which have been made repeatedly. From Holberg's curves it is clear that these objections were correct. By their refusal to obey the rules which are essential for all scientific discussion, the mentioned group of scientists has delayed the progress of cosmogonical science by decades.

2. In the SR there is a correction of the contraction ratio due to the cosmogonic shadow produced by the visible planetesimals. This correction brings down the theoretical value from $\Gamma = 2:3 = 0.667$ by a few percent to about 0.63 - 0.65. This is probably not applicable in the AR for the following reason.

In the AR the visible asteroids are only the biggest representatives of a numerous population of planetesimals, most of which are too small to be observed with our present instruments. We do not know the mass function but in general a population of celestial bodies is such as to make the biggest bodies contain most of the mass, and the smallest to exhibit the largest total area. Statistics of the visible asteroids support this conclusion.

As the correction of Γ is produced by the direct absorption of plasma, it should be proportional to the total area. Hence the shadow effect should be produced essentially by the smallest members of the asterid population. The result is that the observable asteroids should not necessarily exhibit any change in the theoretical value $\Gamma = 0.667$. As there are few collisions between the largest bodies, these often get their initial eccentricity e = 1:3 reduced only a little. On the other hand, the smallest (subvisual) asteroids collide so frequently that their e-values have decreased to close to zero. Hence the shadow effects are likely to be produced essentially by low-eccentricity bodies.

3. Allowing for these differences, there are decisive similarities between SR and AR. Both are produced by the same type of plasma-planetesimal transition. This is shown by Table 1 and 2 which demonstrate that the contraction ratio Γ is exhibited also in the AR. Indeed the deviations from the theoretical value are less than a few percent - like in the SR. For a more detailed discussion see Alfvén and Arrhenius (1975, 1976), Alfvén (1981b), Alfvén and Mendis (1983), Alfvén (1983b).

Adding the four identifications in SR and the three identifications in the AR we obtain no less than seven cases where the theoretical Γ value is confirmed.

Hence the bulk structure of the mass function in the asteroidal belt is derivable from the same law for plasma-planetesimal transition as is so clearly shown in Holberg's curves for the SR. This confirms the interpretation of the AB as an intermediate state in planetary

TABLE 1

Contraction ratio Γ in the Saturnian rings

(Identifications from Holberg's data)

			Γ
Mimas	3.075		
Janus	2.510		
Shepherds	2.349	2.330	0.646
	2.310		
Cassini Center	1.984		
Outer B	1.945		0.63
Holberg min	1.58		0.655 (0.650 - 0.660)
Inner B	1.525		0.635
Inner C	1.235		

Theoretical value 0.63 - 0.65

TABLE 2

Contraction ratio Γ in the asteroidal belt

	a	Γ
Jupiter	5.18	
Main belt outer limit	3.50	0.676
High density outer limit	3.22	0.674
High density inner limit	2.36	0.683
Main belt inner limit	2.20	

Theoretical value 0.667

formation.

The conclusion is that scientists studying asteroids should play an important role in the development of cosmogonic science. However this requires that we concentrate our interest on those problems which are most relevant in this respect.

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