Zeitschrift: Schweizer Ingenieur und Architekt

Herausgeber: Verlags-AG der akademischen technischen Vereine

Band: 101 (1983)

Heft: 8

Artikel: Formation of the solar system from a potential-vortex-natured nebula disk. Part IV: The satellite systems of the outer planets

Autor: Chen, Yian N.

DOI: https://doi.org/10.5169/seals-75087

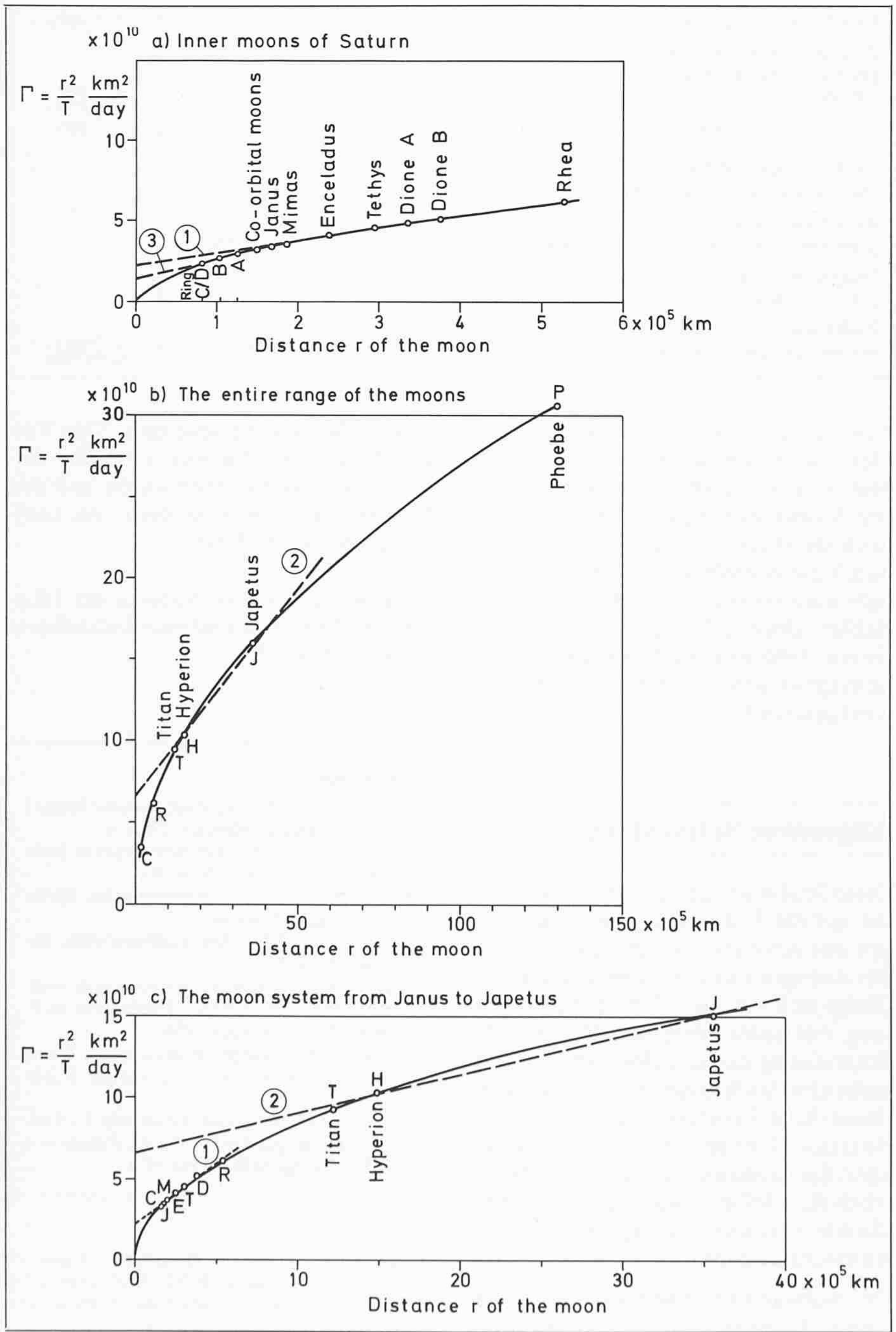
Formation of the Solar System from a potential-vortex-natured Nebula Disk

Part IV: The Satellite Systems of the outer Planets

By Yian N. Chen, Winterthur

The satellites of the planets Jupiter, Saturn and Uranus show a great variety of properties. Whilst the moons of Saturn have a distribution quite similar to that of the planets of the sun, those of Jupiter and Uranus show a rather different pattern. It can be shown that the moon system of Saturn should have been formed by both the outward and the inward surface wind according to the same mechanism as the planet system of the sun, but those of Jupiter and Uranus would only be generated by one surface wind, namely an inward surface wind for Jupiter and an outward one for Uranus.

Because of the difference in directions of the surface winds among these three planets, their ring system also show quite different behaviours. A ring system with heavy particles exists for each of Saturn and Uranus, but only veil-like rings of very tiny dust are attached to Jupiter. Due to the same mechanism, an atmosphere is available for the moon Titan of Saturn, but none can be detected for the moon Ganymede of Jupiter despite the fact that the gravity of Ganymede is by 37% stronger than that of Titan.



The moon system of Saturn

The satellite system of Saturn will be considered using the theory developed for the solar system. Saturn possesses outside of its rings a comprehensive moon system, which can be considered as a small-sized solar system. Now, we leave the small innermost moons such as the A ring shepherd, and the F ring shepherd as a close association with the ring system, so that we will only consider the circulations of the further satellites from co-orbital moons to Phoebe.

The circulations of the inner moons from co-orbital moons to Rhea are plotted in Fig. 42a, and with a further extension to include Titan, Hyperion and Japetus in Fig. 42c, in which the distance r of the satellite from Saturn is used as the abscissa. Fig. 42b extends the plot up to the farest satellite Phoebe. As is shown in Fig. 42a and c, the curve in the range from co-orbital moons to Rhea can be approached by a straight line (No. 1). Similary, the curve in the range from Titan and Hyperion to Japetus can be again approached by another straight line, No. 2 (see Fig. 42b and c). We can therefore separate the moons into two groups, the inner one from co-orbital moons to Rhea and the outer one from Titan to Japetus. Since Phoebe cannot be included into the outer group, it appears that Phoebe does not originally belong to the system. As is suspected, it has been captured by Saturn from outside, because it orbits Saturn backwards and in the ecliptic plane (i.e. not in the plane of Saturn's equator). The transition zone between the inner satellites and the outer ones is here characterized by the existence of a very large satellite (i.e. Titan), quite along the same line as Jupiter in the transition zone between the inner planets and the outer ones of the solar system. We can thus conclude that Saturn with its satellites must originate from a primordial gas disk similar to that of the solar system. Only the size is much smaller.

In the following we will examine the behaviour of the satellite system of Saturn using the theory developed for the solar system. Fig. 43 shows a plot of the distance r of the satellite from Saturn with the satellite number (i.e. the orbit number) as the abscissa, namely curve 1 for the inner moons normalized by the distance of the co-orbital moons, and curve 2 for the outer moons normalized by the distance of Titan. As a comparison, the theoretical curve for the inner

Fig. 42. Circulation of the moons of Saturn
a) Inner moons b) Entire moons
c) Moons without Phoebe

planets and the asteroids is given as curve 3 from Fig. 5, and that for the outer planets is plotted as curve 4 from Fig. 6.

As curve 1 is lower than curve 3, we can infer that the travelling velocities of the tidal waves are not constant in the entire gas disk. The ratio of the heights of the two curves indicates the ratio of the local wave velocity to that of the co-orbital moons. This is shown in curve 5. As this curve descends rapidly from orbit No. 1 to No. 3, and then remains practically horizontal at higher orbit numbers, we can derive that the primordial gas disk in the region of co-orbital moons to Mimas is still under the influence of the great radius of Saturn. Its thickness decreases with the increase of the distance r up to Mimas, beyound which it remains practically constant up to the outer edge, i.e. the position of Rhea. This is shown in Fig. 44a in which the distances of the inner moons are plotted in multiples of the Saturn's radius. A similar plot for the inner planets of the solar system is carried out in Fig. 44b. The thickness of the gas disk in the region of the planets Mercury and Venus is already outside the influence zone of the radius of the sun. The dimensionless distance r/r_{sun} is much larger than that r/r_{Saturn} of the Saturn's system. The planets Mercury and Venus are situated at the distances of 41.6 and 77.7, compared to 2.52 and 3.08 for co-orbital moons and Mimas.

The outer moons Titan and Hyperion are supposed to be a twin because of their small distance and the small size of the latter (Titan: 5140 km diameter, Hyperion:350 km diameter). They are ascribed to belong to the same orbit No. 1 in curve 2. Japetus has then No. 2. Curve 2 coincides very well with the theoretical curve 4 for the outer planets of the sun.

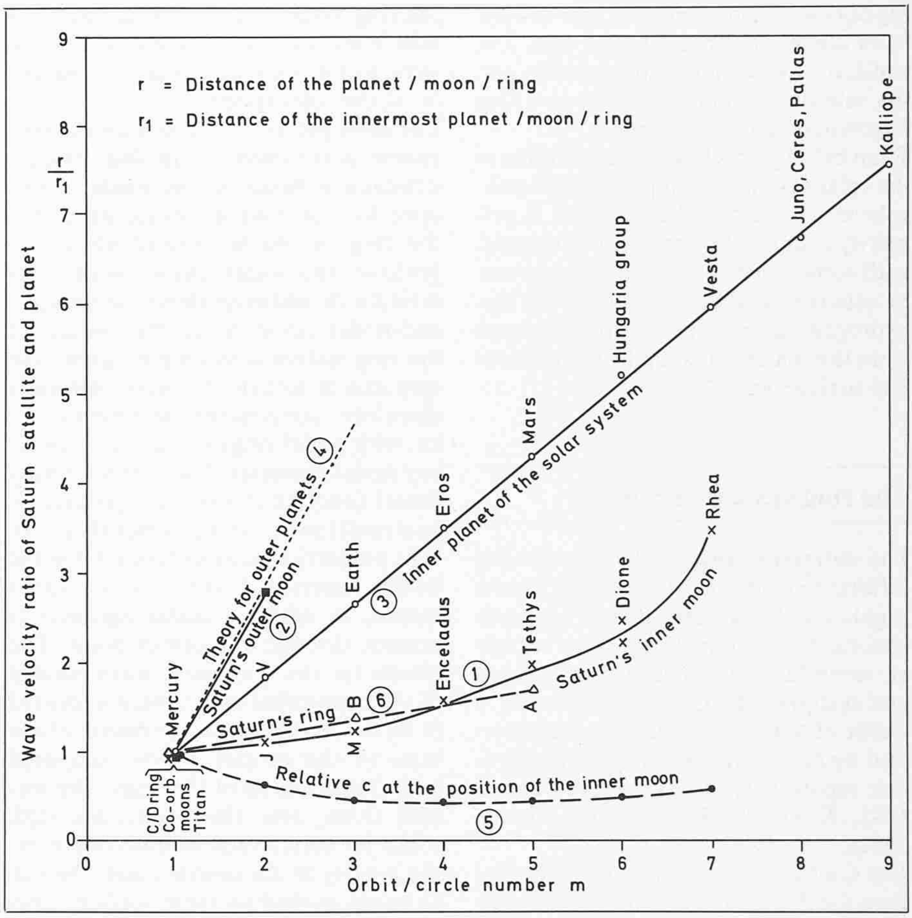
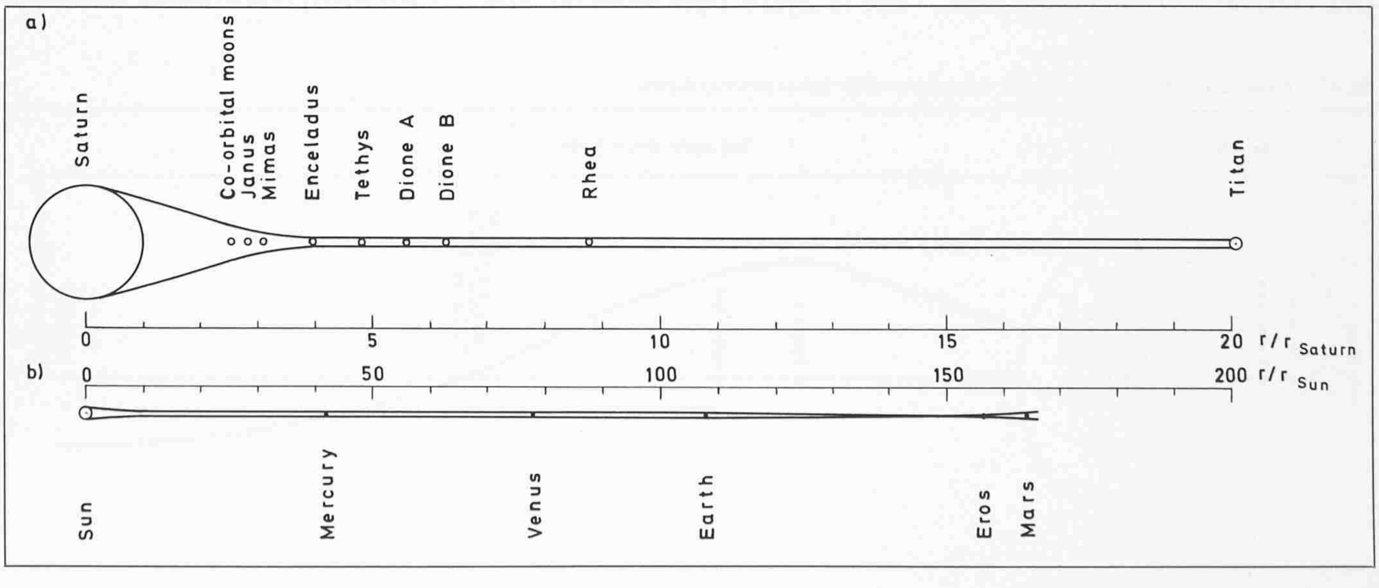


Fig. 43. Wave pattern of the infant vortex disk of Saturn compared with that of the primordial solar system 1. Saturn's inner moons 2. Saturn's outer moons 3. Inner planets of the solar system 4. Theory for the outer planets of the solar system 5. Relative wave travelling velocity c of the infant vortex disk (relative to that for the position of Co-orbital moons) 6. Saturn's rings A, B and C/D

From Fig. 43 we can infer that the moon system of Saturn appears to be formed by the same mechanism as that of the solar system. It is initiated by the vortex generated in the primordial gas disk of the solar system. This vortex will then take the form of a small gas disk, in which a tidal wave pattern will be induced by the surface winds of the vortex itself, i.e. in the same manner as in the solar system. This miniature gas disk will then dissolve into Saturn and its satellites, see Fig. 45.

According to Fig. 45, we have again an outer field of a large scale and an inner field of a small scale, much the same as in the solar system. The two fields are discoupled owing to the great difference in their wavelengths and their natural frequencies. This is again reflected in the great mass of Titan produced by the impact of the two surface winds blow-

Fig. 44. Comparison between the solar nebula disk and the Saturn's infant vortex

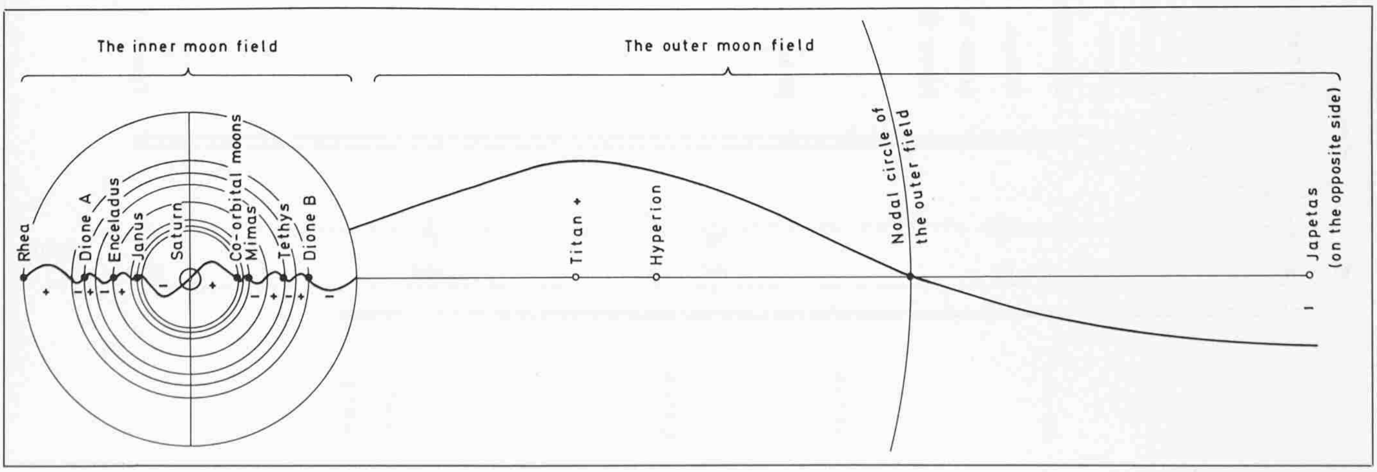


ing outward from the center and inward from the outer edge of the gas disk. The similarity between the solar system and the satellite system of Saturn can thus be considered to be complete.
Titan belongs to a few of the satellites in the solar system which possess an atmosphere. This atmosphere, which is primarily composed by molecular nitrogen with some trace of methane, is overcast by extensive hydrogen clouds. Does this hydrogen component still originate from the matter piled up by the primordial surface winds?

The ring system of Saturn

The different rings of Saturn exhibit different structures. The A ring shows highly regular pattern. The B ring turns chaotic. Some ringlets are close together, some far apart. The B ring is dense and opaque. The Cassini division of a width of 4800 km, which is characterized by considerably low particle densities, separates the two rings (*F. Renner*, 1981, *R. Gore*, 1981, and *J.A. Burns*, 1981).
The C ring contains much less material than the B ring. There is the french division situated in between. The D ring is rather more tenuous. Therefore, it was not detected by the Pioneer-Saturn mission. These two rings seem to belong to each other, because there is a very narrow division, the Guerin division of a width of about 1200 km, staying between them. The F ring, separated by the Pioneer division from the A ring and bounded by shepherd moons, has irregular pattern. The F, E and G rings will not be covered in the present consideration, since their structures have not been yet definitely investigated.
The circulation of the ring based on the distance r of its center from Saturn is also entered in Fig. 42a. A straight line (No. 3) can be drawn through it. Thus, the ring system can be treated as a gas disk in its primordial condition, just the same as for the moon system of Saturn or for the solar system.
The wave pattern of the primordial ring system is sketched in Fig. 46a. Its construction is based on the model developed for the inward surface wind that the ring should be formed about the positive anti-nodal circle, whilst the division should arise about the negative anti-nodal circle. Since the pattern of the ring system is symmetric about the spin axis of Saturn, the wave pattern is therefore constructed symmetrically, i.e. with nodal rings alone, but without any nodal diameter. The corresponding Bessel function $J_o\ (kr)$ will possess an anti-nodal point in the center (Fig. 3a). This property is quite different from the Bessel function $J_1\ (kr)$ for the inner moons, in which a nodal diameter is present through the center point. The reason for the symmetric wave pattern of the primordial ring system appeared to lie in the very large dimension of the mass in the central region compared with the extention of the rings. The surface flows over the primordial disk could be maintained symmetrically by the gravity of the central mass. The tidal waves excited by these surface flows would have thus arisen with a symmetric pattern. The dimensionless distance r/r_1 normalized by the distance of the C/D Ring is plotted as curve 6 in Fig. 43.
The circulation curve in Fig. 42a reveals that the primeval gas disk of the ring system touched that of the inner moons. If the wave motions of this two disks would take place simultaneously, they would be closely coupled. Since their mode patterns exhibit clear independency from each other, the wave motion of the disk of the ring system must be supposed to have arisen, after the wave motions in the primeval gas disk of the moon systems had degenerated to vortices representing the infant moons. Then the central region of the primeval gas disk became independent, and only after then could the process of the formation of the ring system be initiated. The theory developed for the formation of the moon systems of planets and the planet system of the sun can be applied to this process, as is sketched in Fig. 46 for six periods a to f of the development.
Picture a shows the vortex model for Saturn just after the separation from its moon system. A lens-shaped deposition of heavy dust, which would be produced by the inflow as sketched in Fig. 11, would be embedded within the lens-shaped gas disk of this primeval vortex. A tidal wave as shown in this picture would be gradually self-induced by the surface flow which were generated by the gravity according to the theory developed previously.
The slender form of the gas disk in its outer edge would make the inward surface flow rather parallel. The thin layer of deposited heavy dust would act as a massive wall for this surface flow. An enlargement of the edge region is given in picture a′ with its velocity proviles v_r (surface flow) and v_φ (swirl flow).
The wave pattern could therefore drive the dust to pile up toward the positive anti-nodal circles as shown in picture a, according to the model developed for the outer field of the solar system. The negative anti-nodal circles would be finally developed into gaps, separating the wave pattern into the three wavelengths A, B and C/D of the annular shape.
A boundary layer would be formed between the surface wind and the heavy dust layer acting as a massive wall. *Strong turbulence* would arise in this boundary layer. Its intensity would depend on the local profile of the surface wind. As this profile would change from circle to circle, the turbulence intensity would change accordingly. Each circle would thus exhibit a *unified tur-*

Fig. 45. Formation of the satellites from the wave pattern of the infant vortex of Saturn



bulence level, different from that of its neighbouring circle. The surface wind would carry the gas inward continuously, and the gas layer over the dust wall would get thinner and thinner. In the same manner, the velocity profile of the boundary layer would become steeper and steeper with the result, that the turbulence intensity would increase rapidly in the course of time. This development would lead to the disintegration of the dust layer by the eddies of the turbulence. The dust would be then rolled up by the eddy cells, which were more or less uniformly distributed along the circle. These *dust eddy cells* would arrange themselves into a ringlet along the circle, orbiting around the center of the vortex. These dust eddy cells would be finally condensed to solid particles. As the turbulence intensity differs from circle to circle, the eddy cells would be orderly separated by the circles. This would lead to the orderly separation of the ringlets from each other.

Fig. 46b shows a period of the development, in which the gas layers of the outermost wavelength A have become so thin that the dust disk embedded in them has completely disintegrated into the system of ringlets of condensed solid particles mentioned. In the following periods corresponding to pictures c and d, the gas layer within the wavelength B has also become thin, so that the further ringlet systems B has been generated.

In the meanwhile, the lens-like vortex would have become thicker and thicker. The surface winds over the wave pattern would have become steeper and steeper. The angle α of the surface wind against the central plane of the disk during the period d would be very large (see Fig. 46d).

Picture e displays the final period that the complete system of the three rings A, B and C/D would have been developed. As the gravity along the central plane of the lens-like dust disk is the largest due to the congregation of its mass, this dust disk would be finally pulled by it inward into a sphere (see picture f). This sphere would then be developed into the core of the planet.

It is well known in the *fluid dynamics* that an approaching flow of a bluff body, such like a circular cylinder, will become more turbulent, the nearer it comes to the surface of the cylinder, as already mentioned in the previous chapter about "Jupiter with its Trojan asteroid groups and moon clusters". The stagnation of the flow results in the deceleration of it and thus in the production of turbulence to 2.5 to 70 times as high as that in the original flow.

For our case, the degree of the stagnation of the surface wind on the main vortex body is expressed by its angle α against the central plane of the gas disk. The turbulence level over the different wavelengths A, B and C/D is sketched in Fig. 46 g. It is especially strong over the innermost wavelength C/D. It could be expected that the dust layer there would be exposed to a very strong disturbance of the turbulence. This dust layer could be stirred up to mix with the surface wind. It could be conceivable that only a layer of very tenuous dust would be left behind after the surface wind had carried all the gases into the main vortex body. This mechanism may explain the property of the C/D ring embodying only tenuous particles.

In the same manner we could explain the phenomenon that the B ring is rather chaotic compared with the regular A ring. This difference appears to be caused by the different levels of turbulence being higher in the B region but lower in the A region.

The recent evaluation of the *Voyager 2 measurement* reveals that the size of the typical particles of the ring first increases from 8 meters in the A ring to kilometer in the B ring, but then decreases to 2 meters in the C ring, and to very small in the D ring (*R. Berry,* 1981). This result corresponds well to our flow model developed. Since the thickness of the primeval gaseous disk would have increased from the A ring to the B ring, the size of the particles should thus increase accordingly. The rapid increase of the turbulence intensity from the B ring to the C and D rings, however, would have prevented the formation of any large moonlets in the latter. The G and E rings would have originated from the very thin outer edge of the primeval gaseous disk. They became therefore the faintest among the rings of Saturn.

The *formation of the ring system of Saturn* is closely connected with the *dust layer along the central plane of the primordial vortex* according to the theory developed. As this central dust layer is a product of the inflow in our flow model as sketched in Fig. 11b, a similar ring system occurs therefore also on Uranus. As, in addition, no such inflow exists in the primordial vortex of Jupiter, such a ring system can therefore not be generated here. Instead, Jupiter has rings of only very tenuous dust which should be left behind by the inward surface flows from a disk of rather mixed gas and dust due to high turbulence level. These tenuous rings have therefore a very low surface mass density of 10^{-9}–10^{-10} g/cm³, compared with that of 10^{2}–10^{4} g/cm³ for the Saturn's rings (from the data compiled by *J.A. Burns,* 1981). The thickness of the Jovian rings, however, is with a value of up to 30 km much larger than that of the Saturn's rings (less

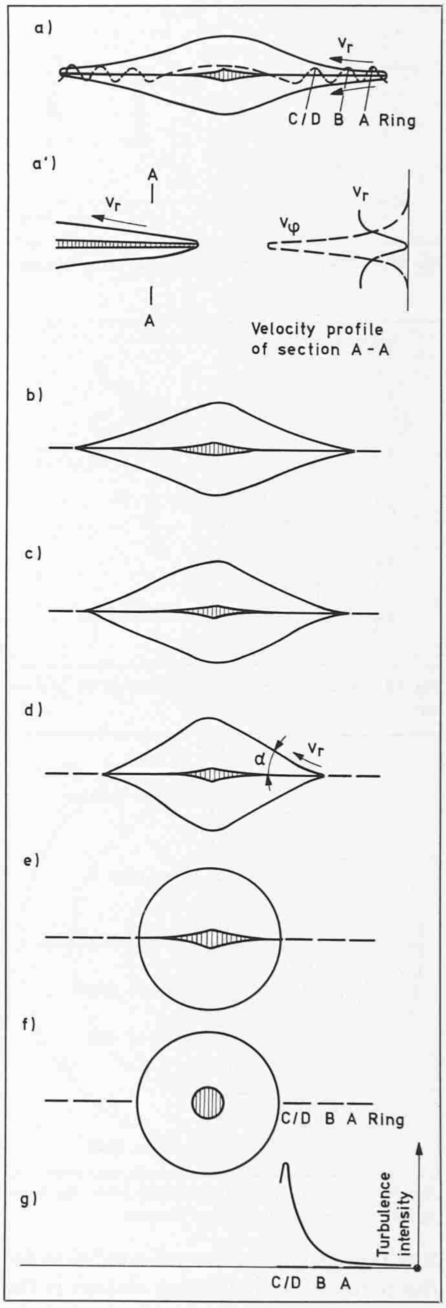
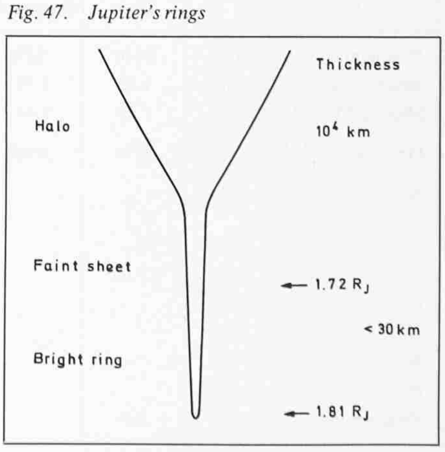


Fig. 46. Development of the ring system of Saturn

than 2 km). The still much thicker halo (10^4 km) inside the rings of Jupiter with very low densities demonstrates together with the rings their origin from a highly turbulent primordial gas disk (see Fig. 47). From the theory we can

Fig. 47. Jupiter's rings



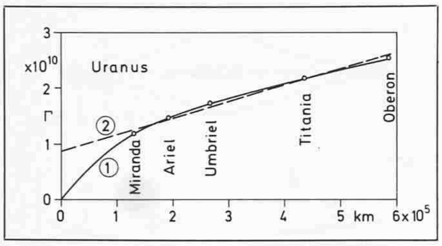


Fig. 48. Circulation of the infant vortex of Uranus

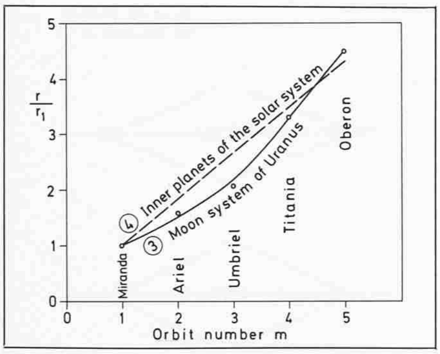


Fig. 49. Wave pattern of the infant vortex of Uranus

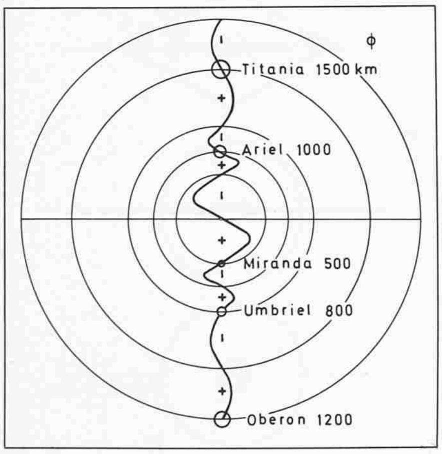


Fig. 50. Formation of the moons from the wave pattern of the infant vortex of Uranus

further derive that the pre-condition for the formation of the ring system is the slender from of the outer edge of the primeval lens-like gas disk of the primordial vortex. This pre-condition can only be fulfilled by a primordial vortex having a very large gas component compared to its dust content. This is only the case for the outer planets such as Jupiter, Saturn, Uranus and perhaps Neptune. The gas components of the inner planets such as Venus, earth and Mars were too small to fulfill this condition. Therefore, no rings can be formed on these inner planets.

The moon system of Uranus

A similar evaluation as done for Saturn is carried out for the moons of Uranus. The results are given in Fig. 48 for the circulation as curve 1 with its approaching straight line 2 and in Fig. 49 for the mode pattern as curve 3 including the theoretical curve (as curve 4) for the inner planets of the solar system. It is thus seen that curves 3 and 4 are quite similar. From these we can infer that the primordial gaseous disk of the moon system appears to have only an outward surface wind, but no inward surface wind from its outer edge. This is quite different from the system of Saturn. The reason for this difference may lie in the different sizes of the systems.

The *radius ratio* of the *outermost moon to its center planet* is

$r_{Oberon}:r_{Uranus} = 586{,}000:25{,}900 = 22{,}6$ for Uranus and

$r_{Japetus}:r_{Saturn} = 3{,}558{,}400:60{,}000 = 59.3$ for Saturn

The ratio for Uranus is only 38% as that for Saturn. Thus the moon system of Uranus would rather stay entirely under the influence of the inflow as shown by 3 in Fig. 11b applied to the solar system. This inflow in the form of a jet impinging on the plane of the gas disk (c.f. Fig. 11c) would cause the surface wind streaming outward down to the outer edge of the gas disk. Only a single wave pattern would thus be induced on the gas disk by this surface wind (see Fig. 50). The sizes of the moons are quite uniform (see the diameters given in Fig. 50). An extreme large moon, which is required as a border satellite in the interaction zone of two fields in a system, such as in the solar system or in the Saturn system, can thus not be present in the Uranus System.

The inflow cited above will produce a ring system on Uranus according to the same mechanism as shown in Fig. 46 for Saturn. This ring system has been discovered by Voyager 1 (*J. A. Burns*, 1981). But it is still lacking in details from it. Let's hope that this gap will be bridged by the further Voyager missions.

The moon system of Jupiter

Jupiter possesses a special position in the solar system. It is the greatest planet and shows some uncommon behaviours. The circulations of the moons of Jupiter are shown in Fig. 51b for the entire system (curve 1) and Fig. 51a for the inner moons from 1971 J1 to Kallisto (curve 2). Whilst the curve branch for the inner moons can be approached by the straight line 3, the outer moons from Leda to Sinope can be approached by the straight line 4. The mode patterns of the two fields are shown in Fig. 52 by curve 1 for the inner moons and by curve 2 for the outer moons.

It is seen from the curves that the two innermost moons 1971 J1 and Amalthea form a group 5. The second moon group 6 is formed by Leda, Mimalia, Lara, and Lysithea whilst the third group 7 is formed by Ananke, Carme, Pasiphae, and Sinope. Each of these groups will be considered as a unit for the calculation of the mode pattern. The result ist shown in Fig. 52 as curve 1 for the inner moons, and as curve 2 for the outer moons. The mode pattern for the outer planets of the solar system is given as curve 3 from Fig. 6. Both the curves 1 and 2 have a similar course as curve 3. From this similarity we can conclude that all the inner and outer moons of Jupiter are formed by means of the same mechanism as the outer planets of the solar system. This mechanism would arise from the inward blowing surface wind interacting with the tidal waves of the primordial gas disk according to the theory. No surface wind blowing from the center outward would be present for the case of Jupiter. This phenomenon appears to be in a close connection with the special position of Jupiter in the solar system, possessing only surface winds blowing towards it as a center, as already covered previously. Referring to the corresponding investigated result, the two moon groups 6 and 7 in Fig. 51 would originate from two individual turbulent vortices of the primordial Juvian gas

Table 3. Comparison between Titan and Ganymede (J. A. Burns and J. B. Bollack 1981) as well as between Mars, Venus and Earth

Moon / Planet	Titan	Ganymede	Mars	Venus	Earth	
Diameter d [km]	5120	5276	6794	12104	12757	
Mean density [g/cm³]	1,92	1,93	4,0	5,1	5,5	
Mass in M 10^{-23} [kg]	1,35	1,47	6,63	48,7	59,74	
Gravity $= \frac{4GM}{d^2}$	9870	10200	27200			
Atmosphere					Primeval estimated	Present
N_2 [%]	99		2,7	4	2,85	78,1
CO_2 [%]	0,03		95,32	96	97,15	0,03
CH_4 [%]	1					
O_2 [%]			0,13	30 ppm		20,9
Ar [%]						0,93
He [%]						0,0005
Pressure bar	1,6		0,01	90	41,1	1

disk. Each of these vortices would finally be disintegrated into a group of moons.

However, the moon group 7 revolves in a retrograde sense around Jupiter. Was this group in the form of an eddy cell (a proto-comet?) captured by Jupiter rather accidently and then locked in the maximum pressure field of the vibration pattern of the gaseous disk of it?

The innermost moon group 1 (Fig. 51) appears again to reflect a strong turbulence there. The ratio of the distance radius of these moons to the Jupiter radius: (129,000–182,000) : 71,500 = 1.8–2.54 is small. In this transition zone from the gas disk to the sphere of the future planet, the flow could be especially turbulent due to discontinuity.

Since the primordial gas disk of Jupiter was lacking in the jet-like inflow as argued previously, there would scarcely be a lens of heavy particles formed along the inner region of the center plane, thus contradictory to the properties of Saturn and Uranus (see Fig. 46). It is therefore no wonder that only veil-like rings with a halo of fine dust can be observed on Jupiter.

An athmosphere for Titan but none for Ganymede despite its larger gravity – Reason seen in the formation process

In the solar system, Titan of Saturn is the only moon known to possess a substantial atmosphere. The more massive moon Ganymede of Jupiter, however, does not possess any atmosphere at all despite its greater mass and gravity. The gravity is characterized by the product of ϱd (ϱ = density, d = diameter) as shown in *Table 3* (ϱd = 9,870 for Titan and 10,200 for Ganymede). This fact stays in contradiction to the conventional theory that the gravity determines the existence of the atmosphere. This discrepancy could indicate that the

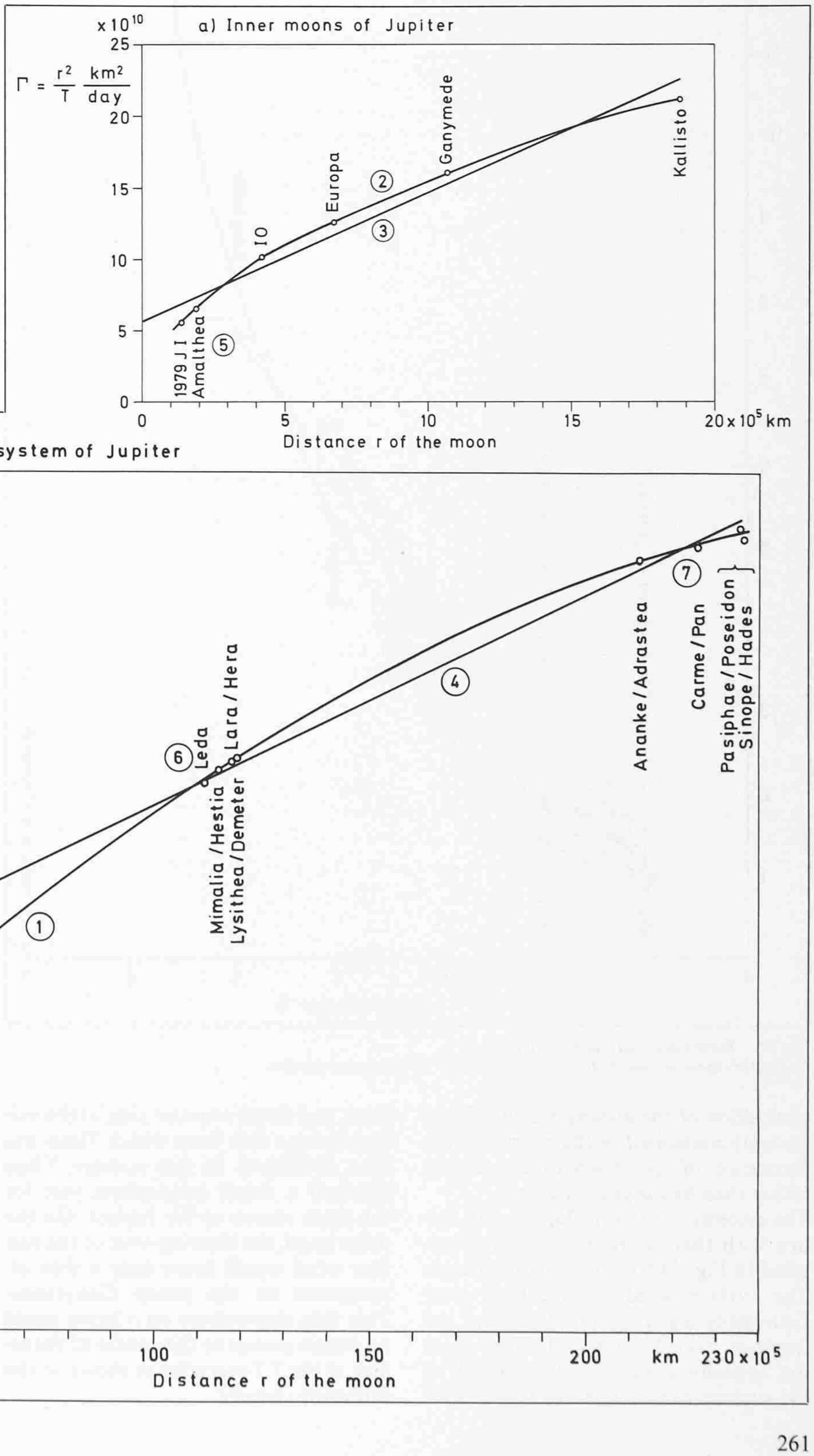


Fig. 51. Circulation of the infant vortex of Jupiter
a) Region of inner moons
b) Region of entire moons

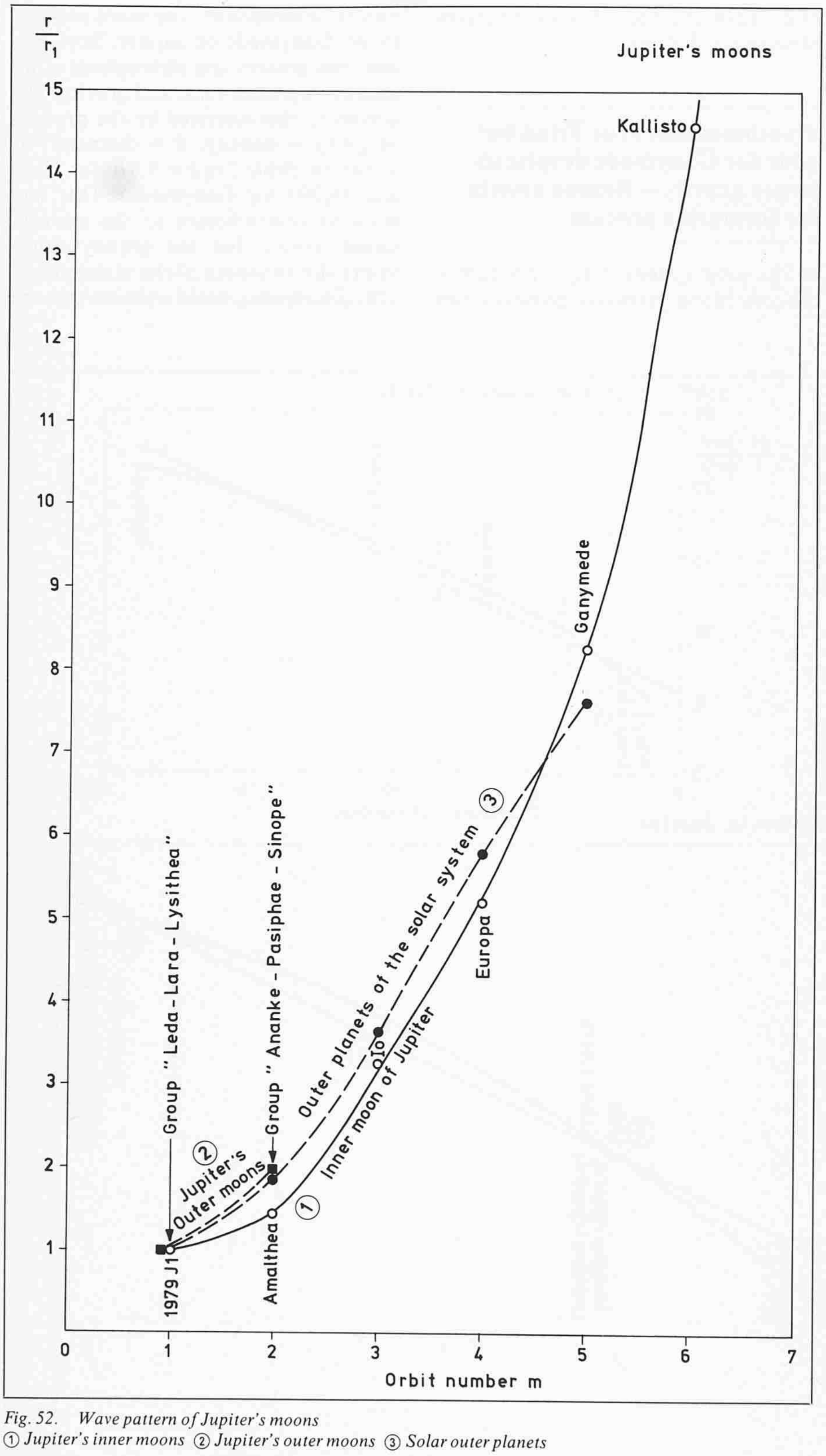


Fig. 52. Wave pattern of Jupiter's moons
① Jupiter's inner moons ② Jupiter's outer moons ③ Solar outer planets

generation of the atmosphere would be strongly controlled by the process of the formation of the moon or the planet, rather than by the gravity alone.

The systems of the sun, Jupiter and Saturn with their surface winds are compiled in Fig. 53 for a close comparison. The surface winds would blow over Ganymede away in one direction, but impinge over Jupiter and Titan from the apposite directions. The impact of the surface winds appeared to pile up a thick and dense annular ring in the primordial gas disk from which Titan was then developed. In this manner, Titan received a dense atmosphere just for the same reason as for Jupiter. On the other hand, the blowing-over of the surface wind would leave only a thin atmosphere on the moon Ganymede. This thin atmosphere on a moon could no longer persist in the course of the attack of the T Tauri wind as shown in the following chapter.

Sources of the constituents of the atmospheres

The constituents of the interstellar medium in the protogalaxy were hydrogen of 76% and helium of 24% (*P.M. Metzger,* 1980). The present condition of the interstellar gas in the environment of the sun incorporates a somewhat less hydrogen of only 70%, but a more helium of 28% owing to the generation of heavier elements by the star's explosions. This hydrogen is mostly in the molecular form in the region from the sun's orbit inward to a distance of 4000 persecs (12,000 light years) from the nucleus of the galaxy (Physics Today, 1980). The hydrogen molecules have been discovered by means of the existence of carbon monoxide, whose molecules stay in a proportion of 1:10,000 to the hydrogen molecules (*M.A. Gordon* and *W.B. Burton,* 1979). A great number of further molecules are also present in the Galaxy, as shown in *Table 4.* Their representation is made in this table in the sequence of the frequency of their occurences (*B.E. Turner,* 1973). Table 4 reveals that most of the molecules are composed of hydrogen, carbon, nitrogen, and oxygen.

The main component of carbon dioxide in the atmospheres of Venus and Mars is not detected in the interstellar gas from which the solar system was born. This carbon dioxide appeared to be formed during the development of these planets owing to the collision of the corresponding molecules according to the following equation

$$2CO + H_2 \rightleftharpoons CH_4 + CO_2$$

The rates of the combination and the dissociation of the molecules are a function of the density and the temperature of the gases. The dependence of the equilibrium of the components of the above equation on the temperature under a pressure of about 1 bar is given in Fig. 54. This shows a tendency which can also be applied to another pressures, prevailing in the region of Mercury to Mars under the influence of the inflow (Fig. 53). We can thus infer that during the very warm period of the planets, certain amounts of CO_2 and CH_4 could be formed. Their proportion to CO and H_2 would increase during the cooling-down of the planets. This yielded a high content of CO_2 in the infant atmospheres of Venus, earth and Mars. During the further development stages of earth, however, the CO_2-component had been absorbed and regenerated to oxygen by biological processes so that a high percentage of nitrogen is left in the atmosphere. Scientists argue that, if no such a possess were present

Table 4. Interstellar molecules (after B. E. Turner 1973)

Molecule		*Occurrence frequency*
Hxdroxyl radical	OH	~ 600
Formaldelyde	H_2CO	~ 150
Methylidyne (ionized)	CH^+	88
Methylidyne	CH	60
Carbon monoxide	CO	60
Water	H_2O	35
Carbon monosulfide	CS	20
Cyanogen radical	CN	14
Ammonia	NH_3	12
Hydrogen cyanede	HCN	10
Hydrogen sulfide	H_2S	7

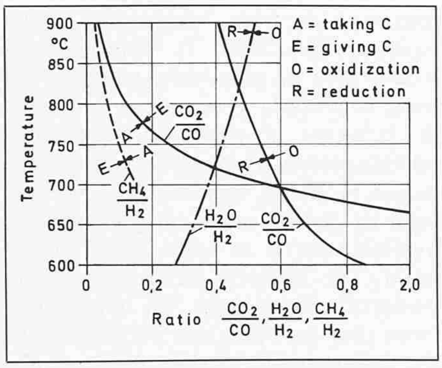


Fig. 54. Equilibrium under technical condition at a pressure of 1 bar for the gas components CO; H_2, CH_4 and CO_2 (D. Dioszeghy and M.V.R. Ungarn, 1970)

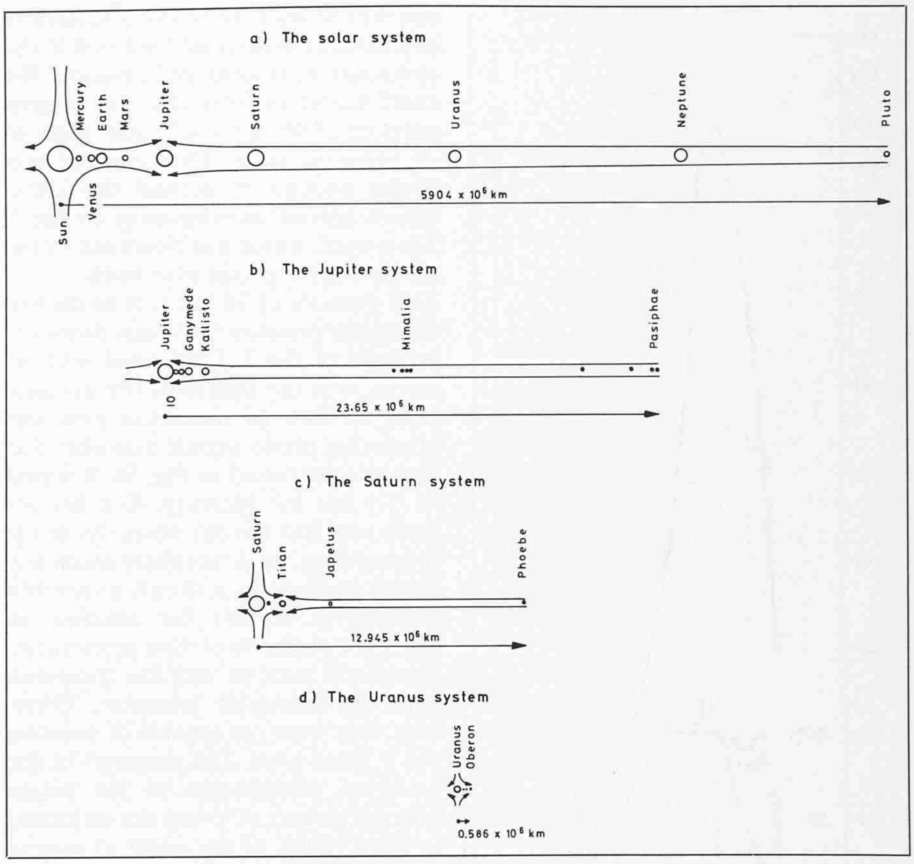


Fig. 53. Comparison between the surface winds in the primordial systems

on the earth, the CO_2-component would remain at about the same level as on Venus and Mars (*Table 5*).

As discussed in the chapter about "Overshoot" of the circulation curve as cause of the high temperature and the strong wind of Venus, the atmosphere of Venus should originate from the primordial vortex with very large outer swirl velocities due to the overshoot of the circulation. Its pressure is therefore as high as 90 bar from this favourable generation condition. The atmospheres of its neighbouring planets would not be able to possess such a high primeval pressure (see the estimated values given in Fig. 55 with the explanation shown in the following section).

As we have also shown that the high swirl velocity of the atmosphere around Venus is an expression of the strong primordial circulation, the state of its infant vortex would be still conserved in the present stage of the atmosphere. It

Table 5. Constituents of the atmosphere (in %)

Component	*Molecular weight*	*Interstellar gas*	*Sun*	*Mercury*	*Venus*	*Earth*	*Mars*	*Jupiter*	*Saturn*	*Pluto*	*Titan*
H_2	2	90	89	98				90	94		0,2
He	4	9	11	2		0,0005		10	6		
CH_3	15							0,02	0,02		
CH_4	16		0,06					0,07	0,05	primary	7
NH_3	17		0,015						0,02		
H_2O	18		0,1			0,0033		$1 \cdot 10^{-4}$			
Ne	20		0,0077		0,0005	0,0018	0,00025			secondary	
HF	20				$1 \cdot 10^{-6}$						
HCN	27								trace		$2 \cdot 10^{-5}$
CO	28										
N_2	28				4	78,1	2,7				82–(94)
C_2H_6	30								trace		$2 \cdot 10^{-4}$
O_2	32					20,94	0,13				
H_2S	34		0,0025					trace			
Hcl	36,5				$4 \cdot 10^{-5}$						
Ar	40	0,09 N_2	0,00058		0,007	0,93	1,6			secondary	12
CO_2	44				96	0,034	95,32				0,03
NO_2	46					$1 \cdot 10^{-7}$					
O_3	48					$4 \cdot 10^{-5}$	$1 \cdot 10^{-5}$				
SO_2	64				0,015	$2 \cdot 10^{-8}$					
Pressure [bar]				10^{-12}	90	1	0,007			10^{-3}–10^{-4}	1,6
Temperature				700 day 90 night	730	288	218	130 cloud's top	50–60 cloud's top	55	93

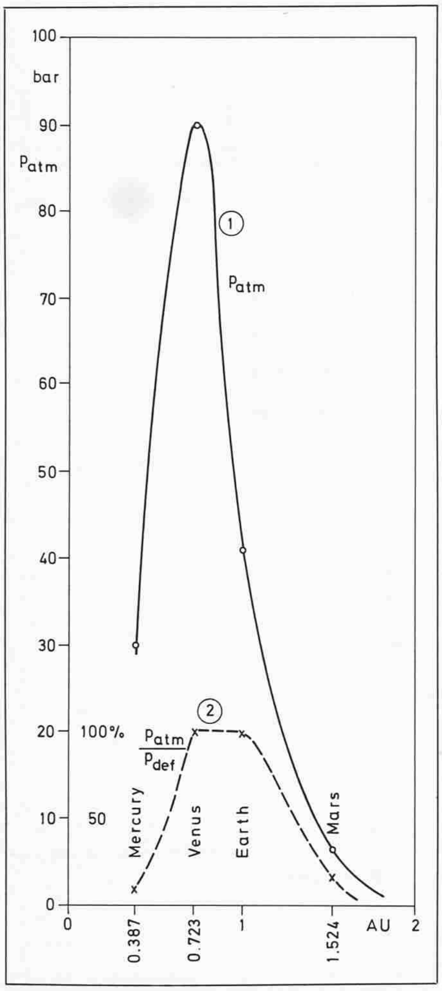
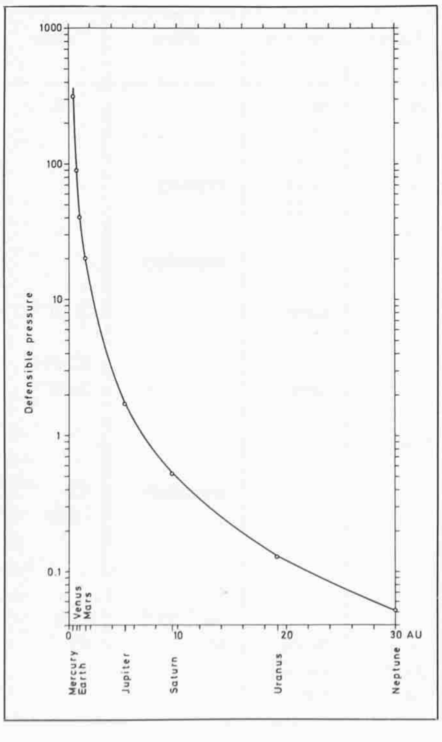


Fig. 55. Derivation of the pressures of the lower layers in the infant atmospheres of Mercury, Earth and Mars from that of Venus
① *Absolute pressure P_{atm}* ② *Relative value to defensible pressure P_{def}*

Fig. 56. Defensible pressure P_{def} versus distance r from the Sun



can thus be argued that this atmosphere still sustains its original condition of the composition, velocity and pressure. We could therefore infer that the present pressure of 90 bar would also apply to its primeval stage. This pressure was strong enough to defend the atmosphere against carrying-away by the T Tauri wind, which was blown out by the sun during the period of its birth.

This pressure of 90 bar will be termed defensible pressure for Venus. Since the pressure of the T Tauri wind will decrease with the square of the distance from the sun, the defensible pressures of another planet should also obey this law, as constructed in Fig. 56. It would be 315 bar for Mercury, 41.1 bar for earth and 20.2 bar for Mars. As at the present time, no atmosphere exists any longer on Mercury, and only a very thin atmosphere of 0.01 bar remains on Mars, the pressures of their primeval atmospheres must be very low compared with the defensible pressures. Therefore, they were not capable of resisting the T Tauri wind. The pressures of the primeval atmospheres of the neighbouring planets of Venus are estimated to have values of the order of magnitude as shown by curve 1 in Fig. 55. Curve 2 gives the ratio of this pressure to the defensible pressure. This ratio is shown to be 0.09 for Mercury, 1.0 for the earth and 0.16 for Mars according to this estimation. The very small value for Mercury accounts for the completely blowing-away of its primeval atmosphere, and the higher value for Mars accounts for the tiny survival of its primeval atmosphere after the attack of the T Tauri wind. The supposed pressure of 41.1 bar for the earthly primeval atmosphere would be reduced to the present condition of 1 bar with the present composition, if this primeval atmosphere were composed of carbon dioxide of 97.15% and nitrogen of 2.85% (see Table 3). Since these values correspond well to those of Venus and Mars (*see Table 5*), the estimation given in Fig. 55 seems to be reasonable.

The solar wind is a degenerated form of the ancient T Tauri wind. From its mean speed of 600 km/s and a mean density of 30 hydrogen atoms per cm^3 blowing over the earth (*J.A. Eddy*, 1981), its dynamic pressure can be calculated to be 9×10^{-14} bar. If we suppose that the corresponding pressure of the T Tauri wind was in the order of magnitude of 41.1 bar as the defensible pressure, then the strength of the present solar wind has been reduced to 1.5×10^{-15} times that of the T Tauri wind.

The atmospheres of Jupiter and Saturn were able to resist the T Tauri wind because their pressures of about 1000 bars were much higher than the corresponding defensible pressure of 1.74 and 0.52 bar, respectively (Fig. 56).

The defensible pressure of Titan can be taken from that applied to Saturn, i.e. 0.52 bar (Fig. 56). This value is much less than the pressure of 1.6 bar of the present atmosphere on Titan. This is the reason, why its atmosphere can exist.

If the primeval atmosphere of Ganymede were composed of the same gases as that of Titan, a pressure of

$$1.6\ \frac{10'200}{9\,870} = 1.65\ \text{bar}$$

could be generated on it, if the gravity ratio between the two moons is taken into consideration within the above equation (see Table 3). This pressure would then be practically equal to the local defensible pressure of 1.74 bar. As, however, no atmosphere is present on Ganymede, its primeval atmosphere would be either very thin or/and very light so that no sufficient pressure was available on it to resist the T Tauri wind. The different behaviour of the primeval atmosphere on Ganymede from that on Titan can be ascribed to the different sort of the surface winds, as shown in the previous section (Fig. 53). A thick atmosphere is only possible for Titan owing to the impact of the surface winds blowing from the opposite directions, whilst no such a favorable condition was present for Ganymede.

There is still a further point which needs to be stressed. The components of hydrogen and helium in the atmosphere of Jupiter are 90 and 10%, respectively, whereas in the atmosphere of Saturn, hydrogen is overrepresented than helium (94%:6%). On the earth, helium shares only 0.0005% and hydrogen can be nearly only found in the ionosphere. This fact gives an additional confirmation that there has been existing a mechanism (i.e. the opposite surface winds) carrying the light molecules from both the inner and outer primordial planets to the infant vortices of Jupiter and Saturn. The content of helium is the lowest on Saturn due to the very low temperature in the atmosphere.

The temperature near the top of the cloud is about 125° K on Jupiter and about 95° K on Saturn. The atmosphere of Saturn is therefore much cooler than that of Jupiter. According to the theories, helium on Saturn should have condensed and sunk to the core about $2.5\cdot10^9$ years ago, as the planet cooled to this very low temperature. In Jupiter, however, the rain of helium should have not yet occured owing to the hotter condition (*R. Berry*, 1981). This reason should account for the fact that the content of helium on Saturn is much lower than that on Jupiter.

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Composition of the Allende meteorite as evidence for the theory

The model of the separation of the heavy dust from the interstellar gas by the jet-like inflow as shown in Figs. 11b and 46 can thus explain not only the density distribution of the planets (Fig. 12), but also the origin of the rings of Saturn, Uranus and Jupiter. This cold model for the primordial nebula disk excludes the vaporization of the dust particles and thus the mixture of their vapour with the gas components prior to the generation of the infant vortices of the sun and planets.

This theory finds strong confirmation, as the composition of the Allende meteorites is carefully analysed. As shown by *J.A. Wood* (1981) a conglomeration of small objects, mostly about a millimeter in size, from spherical to highly irregular in shape, is embedded in a matrix of very-fine-gained, dark gray, earthly-looking matter. He states that each of these small inclusions is an integral mineral system that had formed more or less independently of the material now surrounding it. It seems that the inclusions were dispersed in space when they formed, and subsequently accreted together with fine-gained matter into the meteorite. The minerals have high concentration of calcium, aluminium and titanium. If the meteorite were heated to progressively higher temperatures in a gas of solar composition, these minerals would be the last major elements to vaporize; if the hot vapour were cooled, they would condense first.

These calcium- and aluminium-rich inclusions (CAl's) have a special property concerning the content of the isotopes of oxygen 16, if compared with those of the terrestrial and lunar samples. Wood explains that oxygen is the only element that would have been abundant in both the gas (as water and carbon monoxide molecules) and the dust of the solar nebula. All the other elements were concentrated in one component or the other: H, He, C, N etc. in the gas; Si, Mg, Fe, S, Al and so on in the dust. Apparently, the gas contained oxygen was close to terrestrial oxygen in the isotopic make up and the heavy dust was enriched in the isotopes of oxygen 16 that are present in the CAl's. *Wood* suggests that the high-energy events in the nebula would then have transformed the heavy dust into CAl's.

The fact that the said special isotopes of very rich oxygen 16 are not detected in the terrestrial and lunar samples would indicate no deposition of the heavy dust mentioned on the surfaces of the earth and the moon. This heavy dust must be hidden deeply inside of these. This corresponds very well to our model that the heavy dust would have concentrated itself first along the central plane of the primordial nebula disk and then within the inner core of the planet/moon, and within the rings of the outer planets.

Closing Remarks

Since the present paper was submitted in November 1981 to this Journal, a series of *new measurements* from the American and Russian spacecrafts as well as from astronomers all over the world have become available. They can be used to examine the theory developed in the paper. In the meantime I had the opportunity to deliver two lectures about the theory mentioned, one at the Federal Institute of Technology, Zurich, in July 1982, and the other one at the common conference of the Swiss Society of Science and the Swiss Society of Engineers, Winterthur, in November 1982. Very lively discussions arose from the audience during the meetings and from private communications afterwards about many details which are not quite specified in the paper. My answers could serve to deepen the theory—for example the origin of the solar nebula, the birthplace of comets, the bipolar outflow of the infant sun and others—.

Venus as an under-developed planet

The two Soviet spacecrafts, *Venera 13* and *Venera 14,* which landed on Venus in March 1982, sent back the first color photographs of the planet and the chemical analysis of its soil. According to these findings, the planet's soil is made of *fresh basaltic rock* at the both landing sides (*Nigel Henbest,* 1982, *Sam S. Mims,* 1982 and *Bruce M. Cordell,* 1982). This material supplies an evidence that Venus has active volcanoes, thus still alive quite similar to the earth ("The year in science", Discover 1983, January, p. 64). The *radar map* performed by the *American orbitor* for the *region of Venus* at 30-kilometer resolution (*Michael J.S. Belton* and *Eugene H. Levy,* 1982) shows that the Maxwell Montes of a height of 11 km appears to be a great volcanic construct. Then this highland could not be formed by the head-on collision of two continental plates, which is applied to the formation of Himalayas on the earth. At this kind of the head-on collision no mechanism for the formation of volcanoes can be involved. The volcano in the Maxwell Montes must therefore arise from the hot-spot dynamics from the deep interior.

Referring to *Robert D. Reasonberg,* 1982, Venus has about the same radioactive heat generation content as the earth, according to the result obtained by the Russian spacecrafts. These two planets ought to be about the same as regards their behaviour as thermal engines, because both their energy supplies come out of the interior.

The means by which Earth expels its internal heat shapes its surface. Sea-floor spreading drives terrestrial plate tectonics. On Venus, however, no such sea-floor spreading appears to be currently active, because no subduction can occur owing to the high buoyancy of the lithosphere, which arises from its very high temperature. Sea-floor spreading would be here a very inefficient way for heat to escape, again because of the high surface temperature. The *hot-spot dynamics* may be rather the main mechanism for the heat escape. Hot spots are places where long, deep, *convective upwellings from the deep mantle reach the base of the lithosphere* and expel their heat. Radar mapping suggests that fresh rock originating from hot spots is really being created in the Beta and Sorpion Tail area of Aphrodite. These anomalies could then be supported by the strength of the upwellings of the mantle. As further revealed by Fred Scarf, active lightning takes place over these regions implying volcanic activity of today.

The statement of *R.D. Reasonberg* verifies our theory that Venus is still very hot in its interior. It remains an under-developed condition compared with the earth. No terrestrial plate tectonics did occur, even for the Ishtar highland. We can therefore conclude that it is the heat from the interior which causes the very high temperature in the lower atmosphere as proposed by the present theory. The greenhouse effect due to trapping of the radiation of the sun does not appear to be the main cause.

The rare gases neon (molecular weight 20) and argon (40) in the atmospheres of the three inner planets Venus, earth and Mars stay in a ratio of $72 \cdot 10^{-3}/0.2 \cdot 10^{-3}/0.016 \cdot 10^{-3}$ (i.e. neon is much less than argon) contrary to the ratio of the aboundance of 13 in the sun. Here neon is much richer than argon (see table 5).

The present theory predicts that most of the lighter gas, neon (much lighter than CO_2, N_2 and Ar), was carried away by the outward surface flow (7 in Fig. 11) from the corresponding primordial solar nebula belt, whilst the heavier argon had remained. Therefore, we have an overproportional abundance of argon in the present atmosphere of these inner planets.

As a matter of fact, the runaway *greenhouse effect* needs a starting point. At the very start, the planet's surface must be cold (*John T. Houghton,* 1977). Its surface temperature was then essentially determined by equilibrium between absorbed solar radiation and emitted long-wave radiation. As water vapour accumulated in the atmosphere, the surface temperature would rise owing to the proposed greenhouse effect. This high surface temperature would in turn increase the evaporation from the surface, until either the atmosphere became saturated with water vapour or until all the available water had evaporated. As for Venus the surface temperature would always be above the boiling point of water at the surface pressure, all liquid water would have been evaporated. A greenhouse condition would be generated according to this process.

The supposition of the existence of the *cooling period on Venus* is based on the model that our sun was about 30% cooler than it is now when the solar system was young. The lower solar luminosity may have allowed earth-like conditions for a time on Venus. Earth-like plate tectonics began building continents, possibly Ishtar and lowland basins. Oceans may have filled those basins. As, however, the plate tectonics does not appear to be responsible for the formation of the highland Maxwell Montes as reasoned previously, such a cooling period may not exist at all. Then a starting point for the initiation of the runaway greenhouse effect could be considered to be not present.

Ring or rings for Neptune

The present theory has predicted the existence of rings for all the gas-planets. This prediction has become true for the fourth gas-planet Neptune. At a meeting of the *American Astronomical Society* held in July 1982, the Villanova University astronomer *Edward Guinan* made known his respective discovery. He believes that the ring is small. Its inner edge is 2700 miles above the cloudtops. He and his associates evaluated from the measurement carried out during the 1968 eclipse that a minute and a half after the star reappeared from behind Neptune its light had briefly dimmed. *Guinan* implies that a ring or rings around Neptune causes the dimming ("The year in science", Discover 1983, January, p. 66).

Rapidly rotating core of the Sun as its prime driver

A. Claverie et al., 1981, disclosed in their measurement of the solar-surface oscillations with the 5-minutes period that the splitting of the corresponding discrete lines indicates a rapid internal rotation of the sun. The core of the sun rotates with its angular velocity 3–9 times as rapidly as the observed surface rotation, if a core of 0.5 and 0.15 solar radii, respectively, is assumed. Even the rotation rates of the surface at the equator and the pole are not equal. The equator rotates much faster than the pole. The former rotates once in 25 days, compared with 34 days for the latter. It is these differential rotation rates which alter the magnetic field of the sun with the result in producing the sunspot cycle. As these differential rotation rates consume immense energy due to viscosity effect, astronomers are anxious about the aging of the sun that its rotation rate may be rapidly—of course in a cosmic scale—slowed down due to this energy loss.

The investigation of *G.E. Williams*, 1981, on the mud layers deposited on the bed of a *South Australian lake* (in the *Flunders Ranges*) 700 million years ago—i.e. in the Precambrian epoch—reveals however that the sunspot cycle kept the same period during this epoch as that at the present time. *Williams* finds a pattering of thick and thin layers of the lake's sediments with a cycle of 11/22 years corresponding to the known sunspot cycle. Then the sun cycles must be a driving force of climatic changes 700 million years ago. A lake that was ice-covered for part of the year, but open water in summer, produced seasonal bands of sedimentary layering, similar to the annual growth of rings of a tree. The thickness of a layer indicated the temperature in the year. The warmer the summer the more sediment was washed down into the lake by meltwater.

The changes in the temperature of the atmosphere appeared to be produced by charged particles from the sun (chiefly protons). Since the effect was strong at the time, the eart's shielding magnetic field must be as weak as only about 10% of the today's value at the very end of Precambrian. The earth's magnetic field appeared to be just changing its polarity to run through a minimum strength.

This investigation shows that for 700 million years, i.e. over a period of 15% of the lifetime of our sun, the pattern of the solar cycles and thus the solar differential rotations have remained unchanged. There must be a mechanism supplying energy to these differential rotations. The rapid rotation of the solar core could represent the prime driver of this mechanism, much the same as the rapidly rotating core in the role of the maintenance of the bathtub vortex.

As the sun is burning its hydrogen to helium in the core, this central region will become denser and denser. The contraction of the sun to feed this dense core will produce a radial inflow of hydrogen, similar to the radial inflow of the bathtub vortex caused by the draining of water through the central outlet pipe. Therefore, a similar transfer of the angular momentum from the solar outer surface inward will produce a rapidly rotating core, which in turn maintains the surface rotation rates. This feedback effect seems to be efficient because of the rather small surface rotating velocity of about 2 km/s. A slight radial inflow would already suffice to establish the necessary coupling mechanism.

Near outer region beyond Pluto's orbit as comet's birthplace

According to the conventional theory, the comets are dwelling in a spheric shell, the *Oort cloud*, with an inner radius of some 20,000 AU with the sun as the center. A passing star would leave a wake along its path in the cloud and disturb the comets encountered by it. The gravitational tug of the sun is then able to pull the corresponding comets into its planetary region as a comet-shower.

The comets are thus held in the shell very far from the sun. Their distribution, inclinations and directions are quite random just like the molecules in an ideal gas according to the theory. The Oort cloud should be terminated at about 200,000 AU where the gravitational perturbations of the neighboring stars begin to be effective.

The astronomers are of the opinion that the origin of the comets came from the solar system itself. They were somehow ejected from the system and pumped into the Oort cloud. However, the mechanism of this ejection is not yet clear. All the conventional hypotheses have certain weak points in their formulations, which are summarized in the review paper given by *Frank Reddy* recently ("Astronomy", August 1982, pp. 8–17).

Whilst all the conventional theories created the Oort cloud in one way or another, none of them could clarify the birth place of the comets, from which they were ejected into the Oort cloud.

The vortex theory developed in the present paper reveals that the formation of the asteroids in the inner planet field arose from the eddies generated in the outer zone outside the corresponding primordial inner potential vortex owing to instability of the swirl flow. The radius of the outermost asteroid-subbelt is 2.5 times as large as that of the stable swirl flow region, i.e. the radius of the Mars orbit.

It can thus be expected that the primordial outer potential vortex should also be associated with such an unstable swirl flow zone outside the orbit of Pluto. The outermost radius of this zone could similarly reach 2.5 times the radius of the Pluto orbit, i.e. 100 AU or perhaps still further beyond that. Then the eddies made of icy-rocky core surrounded by swirling gas layers were able to form in this outer zone according to the same mechanism as the asteroids did in the inner planet field. These eddies with icy-rocky core are then the primeval elementary celles of the comets. In this manner, the elementary pro-to-comets were generated owing to instability of the swirl flow extending from the Pluto belt outwards up to 100 AU or further beyond that. This result agrees very well with the value as imagined by Cameron in his revised model. A sound foundation for the birth place of the comets can thus be established by the present theory. These elementary proto-comets were then carried by the surface wind of the primordial solar disk inwards into the planetary field and afterwards ejected by the large protoplanets into the Oort cloud.

But it is conceivable that the surface wind mentioned was only able to carry the rather small icy-rocky cells into the planetary system, but left the larger ones still at their birthplace outside the Pluto orbit. Then we might expect that many members among the remainder may be quite mighty and capable of disturbing the movement of the outermost planets like Uranus and Neptune irregularly owing to their irregular distribution within their belt. We must of course wait until the spacecrafts Voyager 1 and Voyager 2 travel into this belt, and see whether this theory can be varified by their measurements. If it is a positive result, then there will be no need any longer to search for the tenth planet or a dark star such like a brown dwarf outside the reach of our present solar family (*Wolfgang Engelhardt*, 1982, and *J. Allen Hynek*, 1982).

The comets are generally considered to be composed of icy hydrates or water molecular cages, in which gases such as ammonia, methane, nitrogen and others, may be trapped (*John C. Brandt* and *Robert D. Chapman*, 1981). These clathrates are formed at extremely low tem-

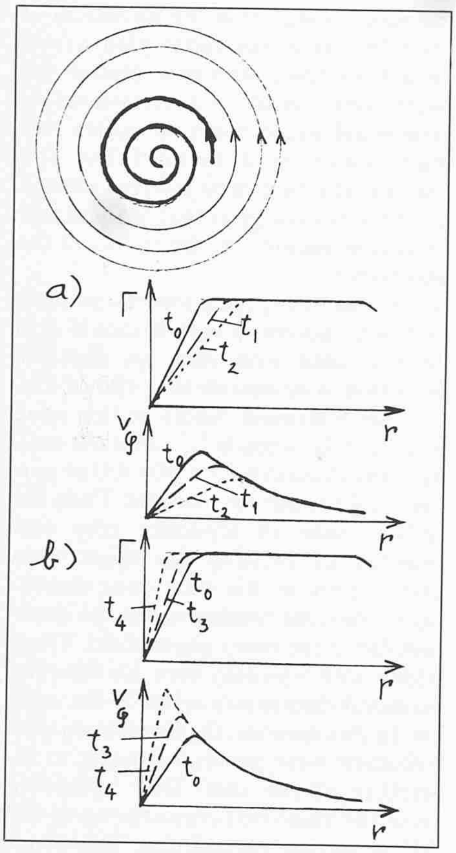
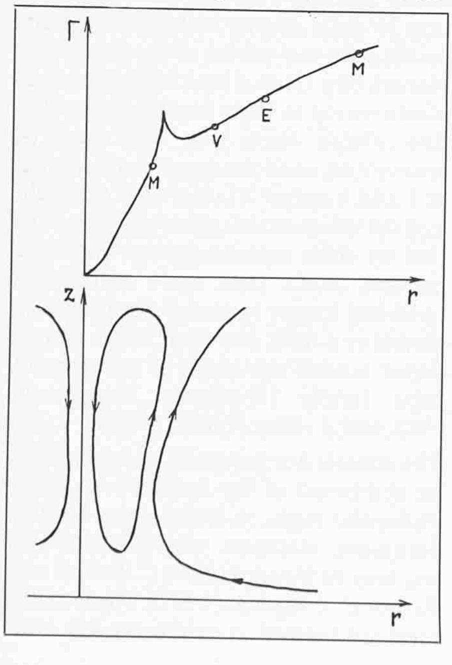


Fig. 57. Development of the vortex with an inner core (whose circulation increases with radius r) and an outer potential field (with constant circulation over the radius).
a) For a usual vortex in the earthly fluid, the core spreads into the outer potential field with the advance of time from t_0 over t_1 to t_2 due to viscosity effect, whilst the swirl velocity v_φ of its edge diminishes accordingly.
b) For a cosmic vortex in the universe, however, the core contracts in the course of time from t_0 over t_3 to t_4 due to gravity of the mass piled up within the core, whilst the swirl velocity v_φ of its edge is getting higher and higher in accordance with the propagation of the potential field inwards

Fig. 58. A cosmic hurricane blowing over the central region of the primordial nebula disk (i.e. within the belt of Mercury) generated by the supersonic swirl flow of the overshoot and the radial supersonic flow of the contraction of the inner potential vortex



peratures. Volatile gases combined with less volatile water to form ice. Ammonia forms a water hydrate and molecular methane, nitrogen and argon from water-ice clathrates (according to *Tobias Owen* of the State university of New York at Stony Brook, see *Richard A. Kerr,* 1982). In the latter ice, voids formed in networks of loosely bound water molecules are filled by any of a variety of atoms or molecules that happens to fit into the available space.
The atmosphere of Pluto (10^{-3} to 10^{-4} bar) is composed mainly of methane with traces of argon and neon (*D. Mulholland* [1982]; "Exotische Chemie der Planeten", Neue Zürcher Zeitung, 21 June 1982). Pluto is like a snow ball with a composition of 74% water ice and 5% methane ice as mantle and the rest as rocky core. Pluto must be developed from the conglomeration of clathrates similar to Titan. As the primeval comet cells as icy-rocky asteroids were dwelling outside the orbit of Pluto, their composition must be quite similar to that of Pluto. The spectra of comets being rich in OH, H, C_2, C_3, CH, H_2O^+, and OH^+ can be considered to be conformable to the theory.

Contraction of the primordial nebula disk

The potential vortex is self-sustained between its centrifugal force and pressure field, as known from the classical aerodynamics. Only the superimposed parallel flow had to be balanced by the gravity of the infant sun. The necessary solar mass for this balance can be calculated to be $M = 0.3\ M_\odot$ for the inner planet field and $M = 0.1\ M_\odot$ for the outer planet field, if the mass of the present planet system is used. Here $M_\odot$ represents the mass of the present sun. As the mass loss during the development of our solar system (caused by T Tauri Wind at the birth of the sun, bipolar outflow as jets from the poles of the infant sun and escape of gases from the planets and their satellites) was distributed on both the sun and the planets, the above equations may be also valid for both the masses at the late primordial condition (i.e. the condition at which the primordial nebula disk was just about to disintegrate from its vibration pattern into the subvortices of the protoplanets).
The necessary mass of the infant sun to keep the parallel flow in equilibrium was thus much less than its available mass. This condition was only possible because of the favourable pressure field of the superimposed potential vortex, having a deep underpressure in the central region and a high pressure in the outer zone. This pressure field balanced the major centrifugal force of the swirl flow and thus enburdened the gravity capacity of the infant sun. The excess of the solar mass: $M_{ex} = 0.7\ M_\odot$ for the inner planet field and $M_{ex} = 0.9\ M_\odot$ for the outer planet field was thus available to pull the potential vortices inwards and thus made them contract.
The corresponding acceleration of the contraction was continuously compressing the core of the inner potential vortex, in the innermost central region of which the infant sun was also continuously compressed. But this contraction ceased at once, as soon as the primordial nebula disk disintegrated into subvortices. Then the potential vortices lost their existence and with them the favourable pressure field.

Origin of the solar potential vortices

Our solar primordial potential vortices should be developed along the same line as the bathtub vortex does, as shown previously. As we have already known the condition of the solar potential vortices just before their disintegration, we can trace back their original states using the conservation law of the circulation. However, the solar primordial potential vortex was much more involved than the bathtub vortex. The circulations within itself, and at its inner and outer edges were not the same. Each of these circulations should be kept conserved for its own.
According to the example of the bathtub vortex, the original solar nebula disk should incorporate only one potential vortex with a large core. The supply of the rotating energy by the Galaxy to this cosmic vortex was, however, restricted to the very beginning of its life. No further energy supply was available during the whole procedure of its development, this in contradiction to the bathtub vortex.
The evidence for this can be found in the two following phenomena. The ecliptic plane of our solar system is inclined by an angle of about 40° against the rotating gaseous disk of the Milky Way. The rotation sense of our solar system is backward, i.e. against the rotation sense of the Milky Way. An abstraction of the rotating energy of our solar system from the Milky Way in the manner, in which a protoplanet with its infant satellites had abstracted its rotating energy from the rotating solar nebula disk, or in which the bathtub-vortex abstracts its rotating energy from the rotating earth, was thus unlikely.
We thus come to a conclusion that the potential vortex in the primordial nebula had to be formed as an isolated event happening but once. This event can be compared with the sporadic formation of individual vortices in a fluid due to flow separation caused by an unspeci-

fied mechanism. If we take a *Karman vortex,* whose swirl velocities are very well measured, as an example for such a flow separation, we find a close similarity between its original circulation distribution and that of a cosmic vortex in the primordial nebula disk at its early stage.

Normally, the core of the Karman vortex will spread out to larger size with decreasing swirl velocity. The vortex will thus decay and finally die out. For a vortex in the cosmos with a very large dimension and a huge amount of mass, however, its gravity field will come into action pulling the swirling flow of the vortex inwards against the outward spreading of the core, and strengthen the vortex. This strengthening of the cosmic vortex by the gravitational pull can be compared with that of the bathtub vortex by the inward draining of water toward the tailpipe (Fig. 57).

In this manner, we can trace back the origin of the cosmic vortex in the solar nebula disk to be a usual vortex in a separated flow as a swirling cell, whose energy is abstracted from the mean velocity of the flow at its separation. Because of no further energy supply, the swirling cell in the earthly flow will decay due to viscosity, whilst the one in the cosmic space will sustain itself due to its own gravity field.

The arms of the spiral galaxies, in which the new stars are forming, are not smooth at all. They show rather a flow pattern of a separated free-shear layer rolling up into a family of individual large-sized vortices. Each of this vortices appears to incorporate again a series of smaller vortices arranged in a random fashion. Therefore, the derived result of the present theory that the primordial solar nebula was originary a vortex being similar to that formed from a separated flow corresponds well to the vortex-like appearance of the spiral arms of the galaxies, for example the Whirlpool Galaxy M51 in the constellation Canes Venatici and galaxy M81 in the constellation Ursa Major.

Bipolar outflow of the proto-sun as a hurricane within Mercury's belt?

It will be shown in this section that the contracting movement of the inner potential vortex will lead to a jet-like outflow from the poles of the infant Sun. Could this outflow represent the bipolar outflow observed on a great number of young stars?

When the vibrating solar nebula disk had reached its latest stable stage and was about approaching the threshold of disintegrating into individual subvortices (representing the infant condition of the present planets with their satellites), the wave pattern of the nebula disk corresponded to the orbits of the present planets as shown in the theory developed. The contraction of the inner potential vortex, caused by the excess of the gravity of the sun at this latest stable stage, can then be calculated from the said excess of 0.7 $M_\odot$.

We obtain the acceleration of the center of gravity of the inner field:

$$b_s = 0.7\, v_{\varphi o}^2 / r_s$$
$$= 0.7 \cdot 17^2 \cdot 10^6/0.9 \cdot 149.67 \cdot 10^9$$
$$= 1.52 \cdot 10^{-3}\,[\mathrm{m/s^2}]$$

The acceleration of the inner edge of the inner field (i.e. the Mercury belt) will be:

$$b_M = (0.387/0.9) \cdot 1.52 \cdot 10^{-3}$$
$$= 0.65 \cdot 10^{-3}[\mathrm{m/s^2}]$$

We therefore had a radial flow with an acceleration of $0.65 \cdot 10^{-3}[\mathrm{m/s^2}]$ from the belt of Mercury toward the sun, as a result of the contraction of the nebula disk. This inward flow was continuously supplying matter to the outer edge of the sun.

Within one-quarter of a year ($7.88 \cdot 10^6$ s), a very short time in the cosmic scale indeed, this acceleration would produce the following increase in the radial velocity of the Mercury belt:

$$v_r = 0.65 \cdot 10^{-3} \cdot 7.88 \cdot 10^6$$
$$= 5{,}120\,[\mathrm{m/s}].$$

It is thus to be expected that the radial velocity of the swirling flow in this belt was highly supersonic. Since an "overshoot" of the swirling velocity was formed in the transition zone from this inner edge of the inner potential vortex to the core region, the maximum swirl velocity of the overshoot could exceed one-tenth of the swirling velocity. With the revolution velocity of the present Mercury of 48 km/s we have the excess of the swirling velocity in the overshoot:

$$v_\varphi = 48/10 = 5\,[\mathrm{km/s}].$$

This overshoot representated a very heavy hurricane with a supersonic swirl flow blowing in the belt of Mercury, just before the primordial nebula disk was disintegrated into subvortices of the protoplanets. The supersonic radial flow was then deflected by the strong swirling flow to rise from the disk surface in the directions to the north- and the south-pole of the infant sun, according to the same mechanism as applied to the formation of the hurricane (Fig. 58). The belt of this overshoot can be compared with the *eye wall of the hurricane.* As the contour of this swirling wall was quite similar to a *Venturi-nozzle,* the deflected radial supersonic flow remained supersonic in the axial flow up to a very high altitude above the two poles. This bipolar outflow would first weaken the infall of matter from the space above and below the primordial nebula disk, then stop it, and finally get the upper hand, before this disk was disintegrated into the subvortices.

It is well known for the hurricane that a high pressure zone is formed along its vertical axis. But this zone is very narrow. For the *cosmic hurricane* mentioned such a high pressure zone could no longer represent any major infall of the matter from the space. Such bipolar jets have already been observed on a dozen infant stars in their late formation stage, as reported by *Charles J. Lada* recently ("Scientific American", July 1982, pp. 74–83). Their axial velocities reach as high as slightly above 100 km/s. It is the first time for a theory capable of explaining the phenomenon of the bipolar outflow. This theory is entirely based on the fluid dynamics derived for the flow properties of the primordial solar nebula disk. No assumption has been made in any principal stage of the derivation of the theory.

The star MWC 349 in the constellation Cygnus has been discovered to have a disk (*E. Erickson* and *F. Witteborn* of Kniper Airborn Observatory; *R. Thompson, P. Strittmatter* and

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D. W. Strecker of Steward Observatory of the University of Arizona). Data for further two infrared sources, AFGL 490 and AFGL 961, having bipolar jets, suggest also the presence of a disk. It seems that the presence of the bipolar jets stays really in a close relationship with the development of the nebula disk accompanying the infant star. The bipolar jets were detected as *molecular clouds* using the emission spectrum of CO at 0.78 mm wavelength, when CO molecules decay from their third excited rotational state to their second excited rotational state.

The mass flows in these bipolar jets were calculated to be extremely high using the conventional method, in which the normal composition of the cosmic gas consisting primarily of H_2 and He with only a small trace of CO was assumed. As the abundance ratio is 10,000 : 1 between H_2 and CO, a mass of gas in the flow of the bipolar jets for the infant star AFGL 490 was calculated to be 30 times the mass of the sun, although the mass of AFGL 490 itself is suggested no more than 15 times the mass of the sun. The proportion of 2 : 1 between the mass in the bipolar jets and the mass in the infant star itself is quite surprising.

The present theory reveals, however, that the bipolar jets originate from the inward flow of the inner potential vortex due to its contraction. As the primary component of this inner potential vortex, representing the inner planet field, is CO_2 owing to the combination of CO with H_2O or H_2 according to the theory, the abundance of CO in the gas could be by a factor of some hundreds higher. Thus the mass flow carried by the bipolar jets would be by a factor of some tens lower than the value found in the conventional calculation. Then the mass loss of the infant star AFGL 490 due to the formation of the bipolar jets would only be about a solar mass. This result gives a reasonable feature for such a star at its late developing stage.

No evidence of magnetic field for planet's formation

The vortex theory for the formation of the solar system as presented in the paper is entirely based on the fluid-induced vibrations initiated at very low temperature of the primordial nebula disk. No magnetic field would play any essential role.

Hannes Alfvén suggested, however, a theory that the magnetic field is as important as gravity in forming the planets. Alfvén believes that the early Sun turned very quickly and generated a whirling, strong magnetic field. This field then picked up the inflowing gas to enable it to form the planets.

J. M. Moran et al. (1978, Ap. J. Lett. vol. 224, L67) recently mapped the magnetic field of a forming star in the W3 region and found intensities of 2 to 9 mG across the field. But no field reversals were present. This indicates that the star itself does not yet generate its own magnetic field. The measured magnetic field has apparently originated from the general interstellar field of the Galaxy. It has been only compressed by the forming star (*M. J. Reid* and *J. M. Moran* 1981, Masers, Ann. Rev. Astron. Astrophys. vol. 19, pp. 231–276). The neglect of the magnetic field in the present theory is thus justified by the result of this measurement.

The authors' address: Dr. *Y. N. Chen*, dipl. Ing. ETH, Gebr. Sulzer, Aktiengesellschaft, CH-8401 Winterthur.

Umschau

Langer Weg zur gesteuerten Kernfusion

Neuer amerikanischer Testreaktor in Betrieb genommen

(AD). Im kürzlich fertiggestellten *«Tokamak Fusion Test Reactor»* (TFTR) des *Instituts für Plasmaphysik* der *Universität Princeton* (US-Staat New Jersey) wurde Ende Dezember 1982 erstmals Wasserstoffgas so weit aufgeheizt, dass sich die elektrisch negativen Elektronen von den elektrisch positiven Atomkernen trennten und ein *«Testplasma»* bildeten. Das als Plasma bezeichnete *ionisierte Gas* konnte für die Dauer von *fünf Hundertstelsekunden* stabil gehalten werden. Die aufgrund der Bewegungsenergie der Partikel errechnete Temperatur im «Torus», der ringförmigen Plasmakammer, entsprach etwa 100 000 Grad Celsius. Die Temperaturwerte sollen nun gesteigert werden.

Tausendmal mehr, d.h. eine Temperatur von 100 Mio. Grad, ist erforderlich, um auf der Erde Energie mittels jener Prozesse zu erzeugen, die sich *im Innern unserer Sonne* und anderer Fixsterne abspielen - dort allerdings bei Temperaturen von «nur» 12 bis 15 Mio. Grad. Infolge der Verschmelzung (Fusion) leichter Atomkerne zu Kernen schwererer Elemente wird nukleare Energie frei. Sie kompensiert zu einem grossen Teil Energieverluste, die z.B. durch die Abstrahlung von Licht und Wärme entstehen.

Seit etwa drei Jahrzehnten bemühen sich Wissenschaftler in internationalen Forschungsstätten darum, das Prinzip dieser thermonuklearen Fusion für die Gewinnung von Energie nutzbar zu machen. Würden sich selbsttätig erhaltende, kontrollierte Verschmelzungsreaktionen verwirklichen und in wirtschaftlicher Weise nutzen lassen, wäre die Energieversorgung der Welt gesichert. Denn der Rohstoff - *Wasserstoff* sowie seine Isotope *Deuterium* und *Tritium* - ist praktisch unbegrenzt vorhanden und mit relativ geringen Kosten aufzubereiten. Im Vergleich zu anderen Energieträgern würde er nur in äusserst geringen Mengen verbraucht. Und im Gegensatz zur Energiegewinnung mittels Kernspaltung von Uran und anderen dafür geeigneten schweren Atomkernen oder zur Erbrütung von Spaltmaterial wäre das Risiko, Gefahren durch radioaktive Materialien und Abfallprodukte heraufzubeschwören, unvergleichlich *geringer,* wenn auch nicht völlig ausgeschaltet. Immerhin ist *Tritium ein radioaktives Wasserstoffisotop,* allerdings mit der kurzen Halbwertszeit von 12 Jahren. Das nichtradioaktive Deuterium allein kommt im gegenwärtigen Stadium der Technik noch kaum als Fusionsbrennstoff in Frage, weil es eine wesentlich niedrigere Reaktionsrate besitzt.

Von der «Zähmung der Wasserstoffbombe» ist im Zusammenhang mit der kontrollierten thermonuklearen Fusion die Rede, weil die - in einzelnen Experimenten für sehr kurze Zeit und in geringem Umfang auch schon erzielten - Verschmelzungsreaktionen nicht explosionsartig ablaufen. Sie kommen zustande, wenn die Abstossungsenergie von Atomkernen mit gleicher elektrischer Ladung durch die bei extrem hohen Temperaturen gegebene grosse Bewegungsenergie überwunden wird. So können Deuterium- und Tritiumkerne verschmelzen und Kerne des schweren Elements Helium bilden, wobei überaus *energiereiche Kernneutronen* frei werden. Diese würden gezwungen, ihre Energie zur Erzeugung von Wärme als Zwischenstufe für die Stromproduktion abzugeben.

Voraussetzungen dafür sind u.a. *ausreichend hohe Plasmatemperaturen* und ein *stabiles*