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

The self-excited tidal-wave pattern determining the orbits of the planets, asteroids, moons and rings

By Yian N. Chen, Winterthur

There are similarities between the swirling flows in the nature and in the technology. The derivation of the formation mechanism of the solar system will be based on the fluid-dynamic law applied to the vortex flow. A series of kinematic phenomena of the solar system can be unriddled by means of the vortex model developed. They include the distances of the planets from the sun, their density distribution, the generation of the asteroid belts with its numerous Kirkwood's gaps, the satellite systems of Jupiter, Saturn and Uranus, the rings of Saturn with their several divisions as well as the unusual atmosphere of Venus.

Scope

Our solar system is characterized by the orbital radii and periods of the planets (including the asteroids) as well as the spin speeds and senses about their own axes. The angular momentums can be calculated using the corresponding data. According to the conservation law, these angular momentums must be conserved from the primordial condition of our solar system up to the present stage. Since the orbits of all the planets and asteroids practically lie in the same plane through the equator of the sun, i. e. perpendicular to its rotating axis, scientists have generally accepted the concept that the primordial nebula of the solar system prior to the condensation to the planetary form must have been a disk. The recent discovery of such planetary dense gas disks in the constellations of *Cygnus* and *Cassiopeia* by the american and german astronomers has supplied strong support of this concept. The angular momentums of the present stage must therefore have been incorporated in the infant solar nebula disk.

Let's first consider the angular momentum about the sun axis: mrv_φ (m = mass, r = orbital radius, v_φ = orbital velocity). This expression is a product of mass m and circulation $\Gamma = rv_\varphi$ for the primeval gaseous disk. If we suppose that the mass of a present planet or asteroid in the gas phase was uniformly distributed within the corresponding annular belt of the primordial gaseous disk, then the distribution of the circulation in this disk would have the same pattern as the expression rv_φ in the present solar system, i. e.

$$(1) \qquad \Gamma = rv_\varphi = r^{1/2}r^{1/2}v_\varphi = \text{const}\ r^{1/2}$$

since $r^{1/2}v_\varphi$ = const according to the *Kepler law*.

In this derivation, the conservation of mass is tacitly assumed. However, this assumption is not quite fulfilled owing to the mass loss caused by the T Tauri wind during the birth of the young sun. As the mass blown away by the T Tauri wind would carry its own part of the momentum with it, the distribution of the circulation of the remaining gas particles would scarcely be affected by this mass loss.

The distribution of the circulation Γ along the radius r of the primeval solar nebula disk is a parabola of the second order according to equation (1). The corresponding curve can be divided into two ranges, one occupied by the inner planets (Mercury, Venus, earth, Mars and asteroid belts), and the other one occupied by the outer planets (Jupiter, Saturn, Uranus, Neptune and Pluto). Each range of the curve can be very well approached by a straigh line, which can be transformed into a potential vortex by a linear transformation of the velocity field. As the potential vortex is stable and inviscid, the primeval solar nebula disk would have been composed by two potential vortices, one of which was superimposed on the other.

We thus have in the primordial nebula disk two stable systems without damping, each of which could be very easy to be excited to vibrate independently of the other. As will be shown in the paper, there exists a close similarity between this potential vortex and the bathtub vortex. The excitation of the vibration would take place due to coupling of the surface winds blowing over the nebula disk with the transfer of the circulation and the wave pattern formed in the disk. This wave pattern would then disintegrate due to nonlinearity into eddies which would have represented the infant planets and asteroids. The theoretical wave pattern, which can be calculated using the *Bessel function*, corresponds very well to the present orbits of the planets and asteroids. As the asteroids are situated at the outer edge of the inner planets and thus outside the linear approach mentioned previously, a strong damping would have arisen in the primordial nebula disk in these asteroid belts. This damping would have generated a great number of strong turbulence cells there which would finally have developed into asteroids. The *Kirkwood gaps* between the asteroid belts fit therefore very well the general wave pattern of the inner planets.

The coriolis effect arising in the primordial nebula disk, which can be calculated using *Bessel's function*, corresponds very well to the angular momentum of the outer planet about its own rotating axis. In this manner we can infer that the rotation of the planet is a result of the vorticity of the primordial nebula disk.

The sun would have situated in the innermost viscous core of our inviscid potential vortex. An overshoot of the swirl velocity must have arisen between these two fields according to the theory about such a *Rankine vortex* field. From the present theory, we can develop that it is this overshoot that would have caused the special properties of Venus: Backward rotation, high temperature and pressure in the lower atmosphere (485°C and 90 bar), and high wind speed in the upper atmosphere (60 times the equator's rotating speed). The theory predicts that Venus would be still in a development stage radiating heat from its inner core just the same as Jupiter and Saturn do. The high speed wind can be compared with the expansion of exhaust gas from a gas turbine along its spirally curved impeller blades.

The very low angular momentum of the sun is, on the other hand, the result of the high viscosity of the innermost vortex core according to the theory. This phenomenon has been a central point of difficulties in most conventional theories about the formation of the solar system.

The moon systems of Jupiter, Saturn and Uranus are then miniatures of the solar system. Their patterns obey the same law as that of the solar system. The ring system on Saturn is again a result of the vibration pattern in the layer of the deposited heavy dust excited by the surface wind. The different behaviours of the A, B, C and D rings are then an expression of the difference in the turbulence levels of the surface wind. The high content of isotope of oxygen 16 in the Allende meteorite supplies strong evidence of the existence of such a heavy dust layer.

As this kind of heavy dust layer would not have been available on Jupiter due to the impact of the surface winds upon it, only the veil-like rings composed of very fine dust can be formed there in this highly turbulent environment. It is this high turbulence level which would have caused the formation of its outer moons in groups. This mechanism can be compared with a turbulent vortex disintegrated into a number of small eddies. These small eddies would have represented the infant outer moons.

Zusammenfassung

Gott schuf die Welt in nur 7 Tagen. Da er nicht viel Zeit hatte, brauchte er nur wenig Prinzipien für ihr Entstehen. Dies erleichtert den Menschen das Leben kolossal, da alle Erscheinungen immer mit diesen wenigen Grundprinzipien erklärbar sind

Gustav Eichelberg

Alle guten Sachen sind einfach

Jakob Ackeret

Die beiden hochverehrten Professoren pflegten mit diesen Zitaten uns Studierende in Zürich zu ermutigen, dass schwierige Probleme auch mit einfachen Gesetzen lösbar sind. Nur die *Kombinationen der Grundprinzipien* machen die Kompliziertheit aus. In diesem Artikel wird gezeigt, dass die Erscheinungen in der Natur, wie die Entstehung des Sonnensystems, auch durch die in der Technik gelernten Gesetze erklärt werden können.

Der französische Mathematiker *Pierre Laplace* (1749–1827) versuchte im Jahre 1776 in seiner *Nebularhypothese* eine Idee aufzugreifen, die *René Descartes* (1596–1650) bereits 1644 vorgetragen hatte. Danach sollen die Planeten aus einer rotierenden Gaswolkenscheibe entstanden sein, die beim Zusammenschrumpfen infolge der Gravitationskraft etliche Ringe abgesondert habe. Aus jedem Ring kondensiert jeweils ein Planet (Neue Enzyklopädie des Wissens, Bd. 1, S. 34–35).

Diese Nebularhypothese ist bis jetzt immer noch populär. Aber man versteht nicht, weshalb sich die Absonderung der Ringe aus der Gaswolkenscheibe ereignete. Man versteht auch nicht, wieso die Sonne die meiste Materie unseres Sonnensystems in sich sammelt, aber fast keinen Drehimpuls hat. Dieser steckt vielmehr in der Umlaufbewegung der Planetenkörper, die jedoch nur 0,13% der Materie des Sonnensystems in sich vereinigen können. Worin liegt der Grund für diesen Transport des Drehimpulses von innen nach aussen?

Carl Friedrich von Weizsäcker versuchte 1944 mit seiner *Turbulenz-Theorie* die Umteilung der Drehimpulse zu erklären. Diese Theorie wurde dann durch *Reimar Lüst, Peter Bodenheimer* und *Werner Tscharnuter* weiterentwickelt. *Rudolf Kippenhahn* führt aber 1980 in seinem Buch aus: «Leider weiss man von der turbulenten Rotation einer Gasscheibe so wenig, dass man nicht voraussagen kann, wie sich quantitativ die Trennung von Materie und Drehimpuls vollzieht. So sind wir vorläufig am Ende».

Die rotierende Gaswolkenscheibe ist eine rotierende Strömung. Eine solche Strömung tritt öfters in der Technik auf. Sie wird als *Wirbel* behandelt. Ein Beispiel ist ein *Ansaugwirbel,* der im Wasserreservoir entstehen kann, wenn eine Zentrifugalpumpe daraus Wasser absaugt und dabei nur im Teillastbereich arbeitet. Ein solcher Ansaugwirbel kann heftige Schwingungen an der Pumpe verursachen. Wie bereits in einer früheren Veröffentlichung 1979 in dieser Zeitschrift berichtet wurde, ist der erwähnte Ansaugwirbel dem *Badewannenwirbel* sehr ähnlich. Der Entstehungsmechanismus ist die *Rotation* und *Gravitation* der Erde für den Badewannenwirbel, sowie der *Vordrall* und die *Saugwirkung* des Rotors der Zentrifugalpumpe für den Ansaugwirbel. Die beiden Wirbel entstehen somit nach dem gleichen Naturgesetz. Die Messresultate an den beiden Wirbelsorten können sich einander ergänzen, woraus dann ein allgemeiner Entstehungsmechanismus abgeleitet werden kann. Auf diese Weise lassen sich die Eigenschaften der beiden Wirbelsorten eingehend kennenlernen, was zur Lösung der entsprechenden Schwingungsprobleme an der Zentrifugalpumpe einen wesentlichen Beitrag leistet. Dieses Beispiel offenbahrt eine Tatsache, dass die Technik ein Gegenstück in der Natur finden kann.

Ein weiteres Beispiel, welches zur vorliegenden Behandlung des *Sonnensystems als rotierende Strömung* geführt hatte, war die *Schwingung des Radialturbokompressors infolge der rotierenden Strömung im schaufellosen Diffusor.* Da damals vor etwa zwei Jahren über dem Erregungsmechanismus in einer solchen Strömung keine theoretische Unterlage in der technischen Strömungslehre zur Verfügung stand, suchte der Verfasser wieder ein Gegenstück dafür, also nach dem Muster des Pumpenansaugwirbels. Dabei hat er die Kenntnis erlangt, dass die scheibenförmige Nebulargaswolke des Sonnensystems ein solches Gegenstück darstellen müsste. Es muss somit gefunden werden, dass auch Schwingungen in dieser Nebulargasscheibe auftreten konnten. Sie könnten dann für die weitere Entwicklung der Scheibe zum Planetensystem eine wesentliche Rolle spielen.

Aus der Untersuchung an den Pumpenansaug- und Badewannenwirbeln hat sich ergeben, dass es sich dabei stets um *Potentialwirbel* handelt. Die radialen Strömungen an den Oberflächen dieses Potentialwirbels bewirken die Kontraktion desselben, die zum Transport der Zirkulation von aussen nach innen und damit zur Verstärkung des Wirbels führt. An den Badewannenwirbeln sind bereits Schwingungen experimentell nachgewiesen worden, die durch die radialen Strömungen an den Oberflächen erregt sind. Die Aufgabe besteht nunmehr darin, zu ermitteln, ob die rotierende Nebulargasscheibe des Sonnensystems auch Eigenschaften des Potentialwirbels hatte.

Gemäss dem Erhaltungsgesetz des Drehimpulses musste die rotierende Nebulargasscheibe den gleichen Drehimpuls (mrv_φ) aufweisen wie den in den jetzigen Planeten (m = Masse, r = Radius, v_φ = Umlaufgeschwindigkeit). Infolge der Erhaltung der Masse m, muss somit das Produkt rv_φ, d. h. die Zirkulation Γ gemäss der Strömungslehre, erhalten bleiben. Aus den Daten der Umlaufbahnen und -perioden der Planeten und Asteroiden kann man die Zirkulation Γ der Nebulargasscheibe über dem Radius r rekonstruieren. Nach dem Kepler'schen Gesetz

$$r^{1/2}v = \text{konst}$$

wird die Zirkulation

$$\Gamma = rv_\varphi = \text{konst}\ r^{1/2}.$$

Die so ermittelte Kurve Γ–r zeigt sehr klar zwei Gebiete: ein *inneres* für die inneren Planeten von *Merkur* zu *Mars* und ein *äusseres* für die äusseren Planeten von Jupiter zu Pluto, wobei jedes durch je eine Gerade sehr gut angenähert werden kann. Ein linearer Verlauf der Zirkulation mit dem Radius verleiht dem entsprechenden Gebiet des Wirbels eine Eigenschaft des Potentialwirbels, was mathematisch durch eine lineare Transformation zum Vorschein kommt. Somit ist gezeigt, dass jedes oben erwähnte Gebiet der rotierenden Nebulargasscheibe tatsächlich ein Feld des Potentialwirbels darstellte. Deshalb war das Gebiet stabil und theoretisch reibungsfrei. Diese beiden Gebiete konnten sich somit lange im Weltraum als geordnete, stabile und rotierende Strömungen um die Protosonne behaupten, die wegen ihrer übergrossen Masse zusätzlich ein Gravitationsfeld ausstrahlte.

Die rotierende Nebularscheibe der dichten Gase im Weltraum wies an den Oberflächen Grenzschichten auf, in denen die Umlaufgeschwindigkeit gebremst wurde. Diese verminderte Umlaufgeschwindigkeit an der Oberfläche der Scheibe würde im Gegensatz zur Zentralebene dann keine genügende Zentrifugalkraft mehr gegen die Gravitation der Protosonne aufbringen. Dadurch würde eine radiale Strömung entlang der Oberfläche der Scheibe nach innen induziert. Somit erzielt man eine Analogie zwischen dem Nebularwirbel des ursprünglichen Sonnensystems und dem Badewannenwirbel auf der Erde. Die Eigenschaften des Badewannenwirbels können somit auf jene des Sonnennebularwirbels übertragen werden. Dies bedeutet, dass der Nebularwirbel des Sonnensystems Schwingungen ausführen müsste. Die Schwingungsform und -periode dieser kreisförmigen, dünnen Gasscheibe lässt sich mit Hilfe der Bessel'schen Funktion berechnen. Eine so schwingende Nebulargasscheibe ist neulich von den amerikanischen Astronomen im *Sternbild Schwan* beobachtet worden. Die durch Temperaturkreislinien gekennzeichnete Schwingungsform entspricht sehr gut der Theorie.

Die für die Nebulargasscheibe des Sonnensystems theoretisch ermittelten Schwingungsknoten entsprechen auch in der Tat den Umlaufbahnen der inneren Planeten samt Asteroidengürteln (getrennt durch die Kirkwood'schen Lücken), während die berechneten Schwingungsbäuche ebenfalls die Umlaufbahnen der äusseren Planeten sehr gut wiedergeben.

Die Verschiedenheit der inneren Planeten zu den äusseren dürfte durch die Strömung bedingt sein, die durch die Protosonne aus dem Weltraum in der zenithalen Richtung erzeugt und dann entlang der Oberfläche des den inneren Planeten entsprechenden Feldes der Nebulargasscheibe nach aussen abgelenkt wird.

Somit ist die Grundtheorie, dass die rotierende Nebulargasscheibe des Sonnensystems ursprünglich Potentialwirbel darstellte und dann infolge der selbsterregten Schwingung durch die radialen Oberflächenströmungen zu kleinen Wirbeln entweder an den Schwingungsknoten (bei den inneren Planeten) oder an den Schwingungsbäuchen (bei den äusseren Planeten) zerfiel. Diese kleinen Wirbel entwickelten sich mit der Zeit zu den Planeten mit ihren Satelliten (d. h. Monden und Ringen). Wie weiter gezeigt werden kann, gehorchen die Bahnen dieser Satelliten wieder gut der Bessel'schen Funktion.

Die Asteroiden befinden sich gerade ausserhalb dem Feld des Potentialwirbels der inneren Planeten. Eine grössere Dämpfung müsste somit in der entsprechenden Zone der rotierenden Strömung der Nebulargasscheibe auftreten. Diese Dämpfung müsste die Bildung der Asteroiden zu Planeten verhindert haben. Die bisherige Hypothese gemäss der Bode'schen Reihe, dass die Asteroiden aus der Explosion eines Planeten herkamen, erwies sich somit als nicht stichhaltig. Es hat sich bereits aus der Analyse der Materie der Asteroiden herausgestellt, dass sie keine Herkunft aus einem oder einigen wenigen Planeten zeigen. Auf dieser Weise ist auch gleichzeitig bewiesen, dass die Bode'sche Reihe keine theoretische Grundlage hat.

Man kann ferner aus der Zirkulationskurve Γ–r die besonderen Eigenschaften von *Venus* erklären, weshalb sie sich rückwärts dreht und wieso ihre Atmosphäre sehr heiss (485°C) am Boden und sehr windig in der oberen Schicht (mit Windgeschwindigkeiten 60 mal grösser als die Aequatorumfangsgeschwindigkeit) ist. Die übergrosse Masse von Jupiter und die Bildung der Trojaner Asteroiden in seiner Umlaufbahn lassen sich auch durch das Wirbelmodell der Nebulargasscheibe des Sonnensystems ableiten.
Die entwickelte Theorie sieht auch vor, dass das Ringsystem von Saturn auch eine Folge der Schwingungen darstellt. Das Fehlen von Shepherd-Monden an seinen inneren Ringen, wie dies durch Voyager II festgestellt wurde, erhärtet die Zulänglichkeit der Theorie. Die Unrichtigkeit des sogenannten Resonanzeffektes von Jupiter an den Asteroiden und von Shepherd-Monden an Saturn-Ringen erhält somit eine Unterstützung durch die jetzige Theorie.
Damit ist man zur Kernfrage zurückgekehrt, wieso die Sonne nur wenig Drehimpuls aufweist trotz ihrer übermässig grossen Masse. Diese Frage ist mit der Sonderstellung der Sonne im Nebulargaswirbel zu beantworten. Die Sonne lag in der innersten Zone des Kerns dieser rotierenden Gasströmung, also weit entfernt vom inneren Rand des Potentialwirbelfeldes. Wir haben es hier somit mit einem sehr zähen Kern eines Rankine-Wirbels zu tun, der das gesamte rotierende Strömungsfeld darstellt. Die hohe Zähigkeit der innersten Zone des Wirbelkerns würde dann die Drehenergie stark vernichten, eine Erscheinung, die von den Karman'schen Wirbeln bekannt ist. Man hat neulich entdeckt, dass die Sterne, so auch unsere Sonne, mit der Alterung immer langsamer drehen.
Der Transport der Drehimpulse mrv_φ erfolgte gemäss der entwickelten Theorie durch die radialen Strömungen entlang der Oberfläche der Nebulargasscheibe, nämlich eine nach aussen gerichtete Strömung im Feld der inneren Planeten und eine nach innen gerichtete Strömung im Feld der äusseren Planeten. Diese beiden Strömungen prallen zusammen an der Stelle, wo sich jetzt *Jupiter* befindet. Deshalb wurde dort der maximale Drehimpuls aufgestockt (Sonne 156, Erde 1, Jupiter 725, Saturn 293, Uranus 64, Neptun 94 und Pluto 0,02).

History

Nearly ten years ago, I got into touch with vibrations of centrifugal pumps caused by intake vortices formed in the suction sump and forced to travel through the suction pipe to the rotating impeller. Since the theory of the formation of the intake vortex was quite incomplete at the time. I began to study the behaviours of the vortex formed in the bath tub in the hope that a close similarity will exist between both. This comprehensive study during about five years enabled me in 1979 to generate a theory about the transfer of the circulation of the vortex through its radial flow caused by the axial flow out of the vortex core. The experimental results found in the literature indicate that this outflow is confined to the surfaces of the vortex, whilst its main body remains as a potential vortex without participation of the outflow. Due to the circulation's transfer, the swirl velocity of the vortex core will be then exponentially accelerated.
For a further verification of the theory, I tried to find evidence from another vortices of the nature. This effort lead me to discover that the primordial disk-like nebula of the solar system was quite similar to the bath-tub vortex. The nebula could be reduced to two potential vortices, the smaller one situated within the larger one. This reduction was based on the distribution of the angular momentums of the present planets/asteroids along the distance from the sun. This distribution could be traced backward to represent that of the circulations of these two potential vortices of the solar nebula according the conservation laws of the masses and the angular momentums. The formation of the planets, and the asteroids, was then derived to arise from the self-excited vibrations of the inviscid potential vortices. That the positions of the present planets and asteroids correspond very well to the vibration patterns of the disk-shaped solar nebula, as predicted by means of the *Bessel function*, has encouraged me to extend the theory to the special behaviours of Venus and Jupiter, as well as to the satellites of the planets.
My friend Dr. *Peter Sulzer* was very impressed by my theory, because he found that it is based entirely on the present data of the orbits of the planets/asteroids, and on the fluid-dynamic laws without making any premature assumptions. This procedure appears to be quite similar to that for solving a technical vibration problem, using the measured data to trace backward the source governing the phenomenon. He supplied me with valuable documents and encouraged me to write down my theory. He made suggestions and discussions on many details of the paper in order to deepen the treatment. I am sincerely grateful to him for all of these.

Derivation of the primordial solar system as a potential-vortex-natured nebula disk

Since the orbits of all the planets and asteroids practically lie in the same plane through the equator of the sun, scientists have generally accepted the concept that the primordial nebula of the solar system prior to the condensation to the planetary form must have been a swirling circular disk. According to the conservation law, the angular momentums of the present planets and asteroids must be conserved from the condition of our ancient solar nebula disk up to the stage of the present solar system. In this manner, the distribution of the circulations of the swirling gas particles in the primordial nebula disk can be calculated using the present orbital data of the planets and asteroids.
This calculation leads to the discovery that the solar nebula disk would have been composed by two potential vortices, one for the inner planet field (Mercury, Venus, earth, Mars and asteroids) and the other one for the outer planet field (Jupiter, Saturn, Uranus, Neptune and Pluto). As the potential vortex possesses a stable inviscid nature, the solar nebula disk would have been able to exist as a stable system, until a kind of self-excited vibration would have disintegrated it into the vortices of the infant planets and asteroids.

Introduction

The normal galaxies in which young stars are still forming can be considered to be still in evolution. Such evoluting galaxies represent nearly always disk-shaped vortices. So did the primordial solar system during its evoluting stage, according to the present investigation. The result shows that it was the disk-like vortex of the interstellar matter which lead to the formation of the sun and the planets. The *vortex theory* is the central concept of this paper for the formation of the solar system.
The vortex model is based on the properties of the bath-tub vortices and on the instability behaviour of swirl flows in turbomachinery (e. g. formation of intake-vortices of contrifugal pumps).
It will be shown that the solar system can be reduced to two potential vortices superimposed on a simple gravitational field. This potential vortex is nothing else than a bath-tub vortex. Its gravitational field incorporates the force field generating the surface flows on the vortex, much the same as the inward flow of the bath-tub vortex out through the drain pipe.
The wave pattern arising on the bath-tub vortex corresponds very well to a stationary wave in a thin layer fluid of a cylinderical shape which can be treated using the *Bessel function*. This theory can be applied to the potential vortex of the primordial solar system. The nodal circles obtained in this way for the vibration pattern of this potential vortex corresponds very well to the positions of all the planets and the asteroids, separated by the *Kirkwood gaps*.
In this manner, the *Bode-law* for the planet distances is proved to be not correct. A general law is thus, established for all the members of the solar system. The phenomenon of the *Kirkwood gaps* is thus incorporated within the formation mechanism

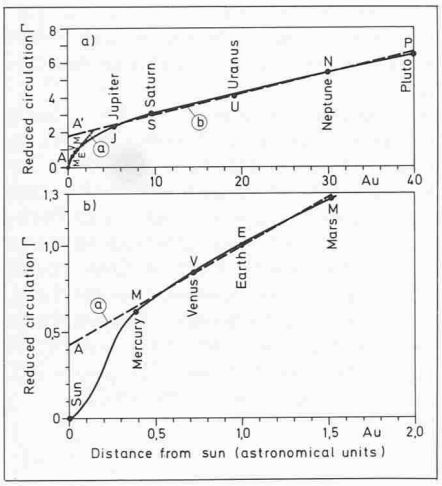


Fig. 1. Circulation Γ versus distance r from the Sun for the primordial nebula disk of the solar system
a) for the entire system
b) for the inner field

of the solar system. The conventional concept for these gaps based on a kind of resonance of Jupiter can therefore be abandoned.

The further phenomena in connection with the division of the rings of Saturn and the atmosphere of Venus will be covered in the separated parts of the paper as an extension of the theory developed.

The central point of the theory is a *self-excited vibration* arising in the primordial gaseous disk of the solar system having a potential vortex and a gravitational field. The coupling member for this self-excitation is the two radial flows generated in the boundary of the disk by the gravitation, one outward from the center and the other one inward from the outer edge of the gaseous disk. These surface winds will then induce a strong wave pattern in the gaseous disk due to a feedback effect. The strong waves generated will then be degenerated to vortices owing to the non linearity and the coriolis force. These vortices will be finally developed into planets with theire satellites and into the asteroids. The density decrease from Mercury to Saturn and its further inerease up to Pluto can be explained by the effect of these two kinds of the surface winds.

Jupiter possesses a special position in the potential vortex fields due to the frontal impact of these two surface winds according to the theoretical result. Jupiter is therefore the largest planet of the solar system and situated in a belt of strong turbulence, resulting in the formation of the two Trojan asteroid groups.

The primordial solar system at its latest development stage as two disk-shaped potential vortices

Each celestial body rotates about the axis through its center, e. g. a galaxy cluster, a galaxy, a star and a planet. The rotation must be an essential factor for their formation. The *Jeans law* predicts a mass of (0,001–0,01) times solar mass $M_\odot$ (for the temperature range T = 10 to 10^4K) which is capable of fragmentation from the surrounding gaseous clouds into a star *(J. Silk,* 1980, p. 355). The expression for M_{Jeans} is fairly insensitive to T. In fact, T is about 10 K in a cold molecular cloud as a birth place of a star. As the known stars with masses of about at least 0,01 $M_\odot$, the predicted value of 0,001 $M_\odot$ is rather low.

In addition the usual stars have still larger masses of considerably above 0,1 $M_\odot$. This means that the *Jeans law* underestimates the critical mass, because it is only based on the equilibrium between the gas pressure and the gravitational force including the balance of the heat generation and radiation, but without taking consideration of the inevitable rotation. It is this rotating movement which generates a vortex field and then opposes the transportation of matter into the central region. In this manner, an individual gas cloud of a large size can remain intact. The inward flow produced by the gravity will be limited within the boundary zone of the vortex (see the next chapter). This kind of vortex has its simple example as bath-tub vortex on the earth. Its formation is attributed to the transfer of the angular momentum (the circulation in the term of fluid dynamics) from the onter edge of the vortex inwards to the center. It will be shown in this chapter that the solar system at its formation stage as a gaseous disk represents such a kind of bath-tub vortex.

The revolution of the planet about sun is governed by the *Kepler law:*

$$(1) \qquad r^{1/2}\, v_\varphi = \text{const}$$

The angular momentum of the center of gravity of a planet about the sun will be

$$(2) \qquad \Gamma = r\, v_\varphi = r^2\omega = 2\pi r^2 f = 2\pi r^2/T$$

where r = the distance of the planet from the sun, v_φ = the orbital speed of the planet, ω = its corresponding angular velocity, f = its revolution frequency and T = its revolution period. The angular momentum of the planet about its own axis is not included in equation (2). It has no effect for the present evaluation. This will be considered in a later chapter.

The angular momentum given in equation (2) will be calculated for each planet of the solar system. The result is plotted in Fig. 1 with r as abscissa, namely in (a) for all the planets and in (b) for only the inner planets Mercury, Venus, earth and Mars in an enlarged scale of r. The value of the momentum shown in the diagramms is related to that of earth, i. e. $2\pi r^2/T = 1$ for earth.

We suppose that solar system in its primordial condition can be represented by a rotating gaseous disk, similar to that observed in the constellation of Cygnus. According to the conservation law, the planet in its original gaseous stage must possess the same angular momentum as that embodied in it after its condensation into the present form. Then the circulation $r\, v_\varphi$ of the annular cloud representing the primordial stage of the planet must have the same value of the angular momentum as given in equation (2). Thus the distribution of the circulation in the primordial rotating gas disk must retain the same value as that of the planets found at the present time, shown in Fig. 1.

As shown in the figure, the planets can be divided into two groups: an inner group consisting of Mercury, Venus, earth and Mars, and an outer group consisting of Jupiter, Saturn, Uranus, Neptune and Pluto.

The branch of the curve embodying each group can be very well approached by a straight line, namely line (a) for the inner group and line (b) for the outer group. The intersection point A of each of these two lines with the ordinate has a circulation of

$\Gamma_o = 0{,}43\, \Gamma_{earth}$ for the inner planets and
$\Gamma_o = 1{,}9\ \ \Gamma_{earth}$ for the outer planets,

$$(3) \qquad \text{where } \Gamma_{earth} = 2{,}82 \times 10^{10}\ \text{km}^2/\text{s}.$$

Γ_o is a constant for each planet group.

The circulation at the radius r will be a linear function, namely:

$$(4) \qquad \Gamma = \Gamma_o + v_{\varphi o}\, r$$

with $v_{\varphi o}$ = constant = 17 km/s for the inner planets
and $v_{\varphi o}$ = 3,4 km/s for the outer planets

From equation (4) we obtain

$$(5) \qquad r(v_\varphi - v_{\varphi o}) = \Gamma_o = \text{const}$$

for each group of the planets. Since Γ_o = constant, the flow field is thus transformed into a potential vortex field Γ_o of the revolution velocity $v_\varphi - v_{\varphi o}$ through the linear transformation from v_φ to $v_\varphi - v_{\varphi o}$, in which $v_{\varphi o}$ is a constant. This transformed potential vortex field is stable and inviscid, which indicates an ideal property of the gas system as if its viscous nature is blocked *(Chen,* 1978).

We have thus transformed the flow field of the primordial gas disk of the solar system into two potential vortex fields, one for the inner planet field A-M-V-E-M and the other for the outer planet field A'-J-S-U-N-P (see Fig. 1 b and a).

In reality, the potential vortex $v_\varphi - v_{\varphi o}$ of equation 5:

$$(6) \qquad v_\varphi = \frac{\Gamma_o}{r} + v_{\varphi o}$$

consists of two components, one of which

is a simple potential vortex $\Gamma_0 = rv_\varphi' = \text{constant}$ and the other one is a parallel velocity field for all the planets with a constant orbital velocity $v_{\varphi 0}$, as shown in Fig. 2. The simple potential vortex is a selfsustained system: it is in an equilibrium. The field of the constant velocity $v_{\varphi 0}$ requires a gravitational force of the Sun for its equilibrium, namely

$$\begin{aligned} &G\,M\,m_1 = m_1 r_1 v_{\varphi 0}^2 \\ (7)\quad &G\,M\,m_2 = m_2 r_2 v_{\varphi 0}^2 \\ &G\,M\,m_3 = m_3 r_3 v_{\varphi 0}^2 \end{aligned}$$

$$(8)\quad \text{or } G\,M\,(m_1+m_2+m_3+\ldots) = (m_1 r_1+m_2 r_2+m_3 r_3+\ldots)\,v_{\varphi 0}^2$$

$$(9)\quad \text{and } G\,M\,m = m r_s v_{\varphi 0}^2$$

$$\text{in which } m = m_1+m_2+m_3+\ldots$$

$$(10)\quad m r_s = m_1 r_1+m_2 r_2+m_3 r_3+\ldots$$

In the above equations m_1, m_2, m_3 ... indicates the mass of the planet, with the distance r_1, r_2, r_3 ... respectively from the sun; M is a mass of the sun required for the gravitational field; G is the universal gravity constant and r_s is the distance of the center of gravity S of the masses m_1, m_2, m_3, ...

The gravitational field can thus be reduced to a infinitely narrow ring of a radius r_s and a mass m, rotating with a swirl velocity $v_{\varphi 0}$ about the gravitation center with mass M. This is really a very simple system.

The primordial solar gaseous disk representing the latest stage just before its fragmentation into the sun and its planets must exhibit the same distribution of the circulation as incorporated within the potential vortex field Γ_0, and in addition the same gravitational field M as specified previously. In other words, this gaseous disk must be a potential vortex with a mass M concentrated at the center. This mass will cause a redial flow streaming inward to the center along the surface of the primordial gaseous disk.It is this surface flow which will transfer the circulation of the potential vortex inward, and thus strengthen its swirling speed. This behaviour is quite similar to that of the bath-tub vortex, as will be shown later on.

The potential-vortex field is capable to be self-excited to vibration, because it is theoretically inviscid. This vortex motion will not cause damping to the vibration. The evaluation shown in Fig. 1 reveals therefore that the inner planet field as well as the outer one in the primordial gas disk are liable to vibration due to its practically zero damping state.

The two potential vortex fields A-M-V-E-M for the inner planets and A'-J-S-U-N-P for the outer planets exceed the real regions occupied by the planets (Fig. 1). This real region has the shape of a annular ring, but not a full circular area as the potential vortex. It will be shown later on that this extension is admissible because of the favourable vibration pattern arising in the gaseous disk of the potential vortex. This vibration pattern is a transition stage of the primordial gas disk to the disintegration into the present solar system.

In addition, these two potential vortex fields are *overlapped*. The inner one A-M-V-E-M stays just within the central zone of the outer one. As will be shown in a later chapter, these two potential fields are completely discoupled concerning their vibration patterns.

The primordial gaseous disk of the solar system as a vibration system

As discussed in the previous chapter, the primordial solar system at its final development stage can be considered as a gaseous disk separated in two fields. The inner field consists of the primordial clouds of the inner planets Mercury, Venus, earth, Mars and the asteroids. The outer field consists of the primordial clouds of the outer planets Jupiter, Saturn, Uranus, Neptune and Pluto. It will be shown in the present chapter, that the generation of these planets and the asteroids arises from a vibration of this gaseous disk with one nodal diameter and a series of nodal circles. This fact can be revealed from the distribution of the planets and the asteroids from the sun.

Usually, the wave pattern of any circular gaseous disk with a nodal diameter will be described by the *Bessel function* of the first order $J_1(k\,r)$, where k is the wave number and r is the radius of the nodal circle. This function in Fig. 3 shows that the waves have ridges and furrows, separated by modal circles. The positions $(k\,r)$ of the nodal circles are compiled in column 2 of table 1.

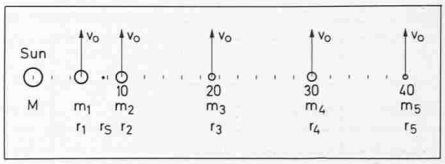


Fig. 2. Parallel-velocity field of the planets held in equilibrium by the gravity of the mass M of the Sun

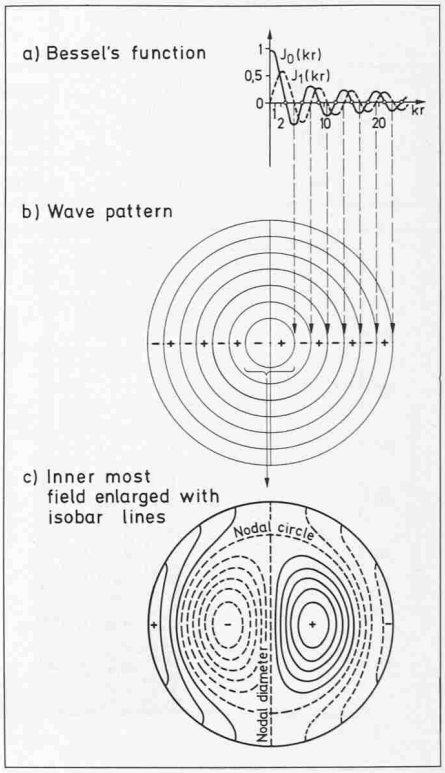


Fig. 3. Bessel's function and wave pattern for a circular gaseous disk (Lamb 1932)

Column 3 shows the relative value r/r_1, normalized by the value of the first circle. The radii r of the orbits of the planets or the asteroids for the inner planet field are also given in this table (columns 5 and 6). Their names are shown in column 4. For each group of the asteroids situated between two gaps *(Kirkwood's gaps)*, only the name

Table 1. Comparison between wave modal circle and planets/asteroids orbit

1	2	3	4	5	6	7
System	Usual gaseous disk		Inner planet field			
Circle No	for the position of modial circle		Distance of the planet/asteroid			Orbit No
m	absolute value	relative to the first circle	Planet/ asteroid	relative to the Earth	relative to mercury	m
1	3,83	1	Mercury	0,387	1	1
2	7	1,83	Venus	0,723	1,87	2
3	10,2	2,66	Earth	1 (149.67×10^6km)	2,58	3
4	13,3	3,46	Eros	1,46	3,76	4
5	16,5	4,3	Mars	1,524	3,95	5
6	19,7	5,17	Hungaria-group	1,916	4,94	6
7	22,8	5,96	Vesta	2,3	5,94	7
8	25,9	6,73	Juno	2,65	6,85	8
9	29	7,56	Kalliope	2,96	7,65	9
10	32,2	8,4	Hygiea	3,2	8,26	10
11	35,3	9,2	Cybele	3,43	8,86	11
12	38,5	10,02	Hilda-group	3,90	10,08	12

Table 2. Comparison between wave anti-modal circle and planets orbit

1	2	3	4	5	6	7
System	Usual gaseous disk		Outer planet field			
Circle No	for position ridge & furrow		Distance of the planet			Orbit No
m	absolute value	relative to the first circle	Planet	relative to Earth	relative to Jupiter	m
1	1,84	1	Jupiter	5,20	1	1
2	5,33	2,9	Saturn	9,52	1,83	2
3	8,54	4,64	Uranus	19,16	3,69	3
4	11,71	6,31	Neptune	29,99	5,76	4
5	14,7	8,00	Pluto	39,37	7,57	5

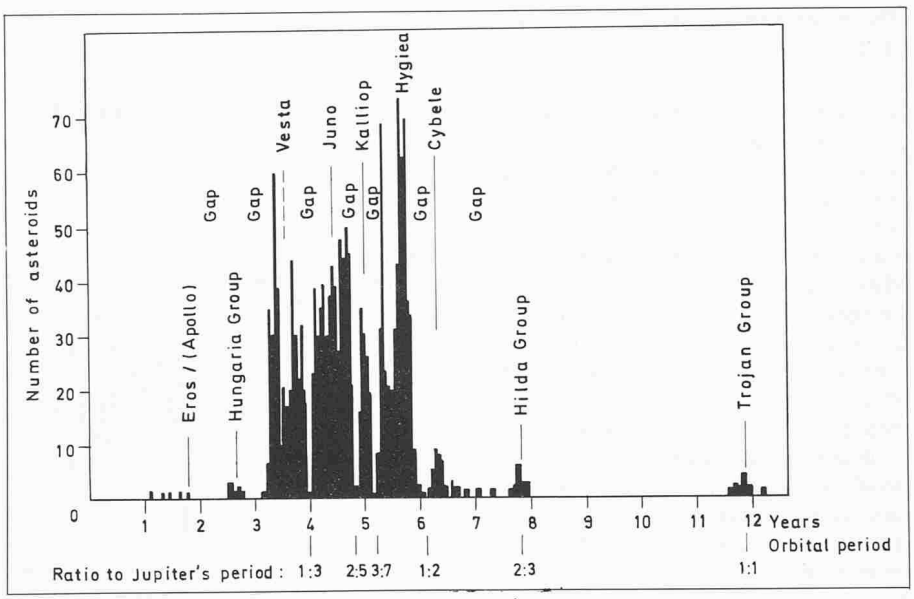


Fig. 4. Distribution density of asteroids with the several Kirkwood gaps

of a promenent representative is chosen (Fig. 4). The radius in columns 5 and 6 corresponds to that of the center of the group. The radius in column 5 is related to that of earth, and the radius in column 6 is related to that of Mercury. The values r/r_1 in column 3 and 6 are plotted in Fig. 5 as a function of the circle/orbit number, curve 1 for the wave pattern (column 3) of a usual vibrating gaseous disk and curve 2 for the distribution of the planets and asteroids of the inner planet field. The agreement between these two curves is excellent.

The position of the ridges and furrows of the wave pattern of a usual gaseous disk can be read from Fig. 3 as compiled in column 2 of table 2. Column 3 shows the corresponding values relative to that of the first circle. The names of the planets in the outer planet field are entered in column 4 with their orbital radii in column 5 (related to that of earth) and 6 (related to that of Jupiter).

A similar plot as done in Fig. 5 is carried out in Fig. 6 for the results r/r_1 established in table 2. A fairly good agreement between curves 1 and 2 can be achieved again. From the close agreement between the distribution of the planets/asteroid's belts on one hand, and the wave pattern of a usual vibrating gaseous disk on the other hand, we can infer that the formation of the planets and the asteroid's must be closely related to the vibration of the primordial gaseous disk. The distance of the orbits of two neighbouring planets/asteroids belts corresponds to the half wavelength of the vibration pattern.

A question arises, how can this vibration be excited and how can it lead to the formation of the solar system? These two problems will be investigated in the following chapters.

The investigation shown previously reveals that the orbit pattern of the planets and the asteroid's belts is closely related to the behaviour of the gas phase of the solar system. Then it is obvious that the existence of the gas component was vital for the formation of the planets and the asteroids. This result strongly opposes the hypothesis as supposed by a series of scientists that the rocky inner planets may have formed by coalescence in a swarm of small, colliding rigid bodies in elliptical orbit around the sun, without participation of any gas component. As will be shown in a further part, the unusual properties of Venus, e. g. the high temperature up to 485 degrees centigrade on the ground and the very strong wind in the upper atmosphere being 60 times faster than the rotating speed of the equator, can only be explained using the fluid-dynamic laws if this planet was formed within its gas phase which was then developed into the atmosphere with the present outstanding behaviour.

The Scientific world has long been searching for the theoretical background of the *Titius-Bode law* for the sequence of the distances of the planets/asteroid's. In addition to the fact that this law fails to predict the existence of Neptune, we have seen in the present investigation that such a simple law cannot exist at all for describing the distances of the planets/asteroids. The inner planet field obeys rather a different law from that of the outer planet field. Our new result reveals furthermore that the division of the asteroids by the serveral gaps into the different belts is not caused by the resonance of Jupiter. The formation of these belts should follow the same mechanism as that of the inner planets as will be shown in the following chapters. There is already a general doubt of the *resonance theory* because this theory can predict only some of the gaps but not all of them. This doubt is justified by the recent mesurements of *Voyager 2 in August 1981*. No shepherd moons could be detected by it in the inner rings of Saturn. According to the resonance theory, however, such shepherd moons would be present for the function of induction of the divisions between the inner rings. As will be shown in a further part, the generation of these divisions should arise from the mechanism as that of the gaps between the asteroid belts.

Evidence of generation of strong vortex by radial flow

A centrifugal pump can generate an intake vortex in the suction sump. This vortex is induced either by the preswirl of the impeller when working at a small part load or by an uneven distribution of the incident flow embodying a pre-circulation. The vortex appears at first as a small dimple on the free surface (Fig. 7a) which gradually deepens to form a cone-shaped hole (Fig. 7b & c), air bubbles break away from time to time (Fig. 7d) and are swept into the bellmouth of the pump suction pipe. Finally with strong swirl intensity, the air core lengthens to reach the suction pipe-inlet and allows continuous passage of air up the suction pipe to the pump (Fig. 7e). The formation of this intake vortex is a result of the transfer of the circulation supplied by the preswirl or the pre-circulation mentioned. This circulation transfer is made possible by the axial flow through the vortex axis caused by the suction of the pump.

The *bath-tub vortex* is generated in a similiar way. The supply of the circulation originates from the earth's rotation. The axial flow is caused by the drain action of the central tail pipe owing to the effect of gravity.

The development of the bath-tub vortex is shown in Fig. 8 *(Y. N. Chen,* 1979 a). Initially at time $t = 0$, a distribution of the swirl velocities within the bath-tub will be dictated by the angular velocity $\omega' = \omega \sin \varphi$ of the earth's rotation of the latitude φ. This distribution corresponds to a rigid-body vortex of $v_\varphi = r\omega'$. The circulation $2\pi r v_\varphi = 2\pi r^2$ increases with the radius squared. By the drain of the water through the tail pipe, a strong vortex will be gradually formed. The water drained through the tail pipe primarily comes via two ways. One of them is along the free surface of the core of the vortex, and the other one takes place along the bottom of the bath-tub due to the *Ekman boundary effect.*

This phenomenon is clearly shown in the experiment of *H. O. Anwar* 1965 (Fig. 9). The result reveals that the boundary flow (a) along the bottom floor is supplied by the downward flow (b) along the vertical wall. The rapid downward axial flow (c) along the free surface of the vortex is restricted to a thin layer. An axial air flow (g) will be generated by it due to friction. In addition, there is an inward radial flow (d) clearly observable near the region next to the cylindrical wall. This inward flow receives a downward inclination (e) in the lower level of the water when travelling towards the center *(L. L. Dagett & G. H. Keulegan* 1974).

But in the region near the upper surface of the vortex core, an upward motion (f) appears. A slight excess of the circulation accompanies this phenomenon (Fig. 9f, *H. O. Anwar).* These experimental results correspond very well to the theory of generation of an overshoot in the transition region between the outer potential vortex field and the inner vortex core (Fig. 9d, C du *P. Donaldson & R. D. Sullivan* 1971, *S. P. Govindaraju & P. G. Saffman* 1971). A profile of the radial velocity along the height near the outlet pipe is sketched in Fig. 9b. This clearly shows the concentration of the radial flow near the bottom of the bath-tub.

The radial flow over the bottom shows a maximum at a certain radius (Fig. 9c). It decreases rapidly as the drain pipe is approached. The flow in front of the entrance of this outlet pipe divides: one part flows into the pipe and the rest moves upward in a layer close to the air/water interface (*a'*), i. e. under the surface layer of the axial flow *c.* This means that the axial flow *c* meets a condition in the outlet pipe which does not match with itself (see the next chapter). Therefore, its stagnation there causes the radial flow partly to stream upward. The two flows *c* and *a'* then stay side by side and stream in opposite directions. They act as a thin toroidal ring vortex rotating with a high speed.

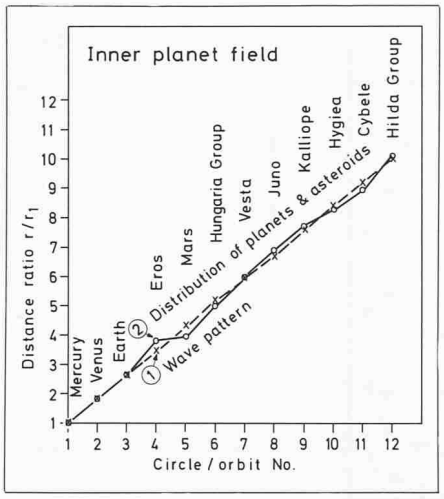


Fig. 5. Distance ratio r/r_1 versus circle/orbit No. for the inner field (r_1 = distance of the innermost circle/orbit)

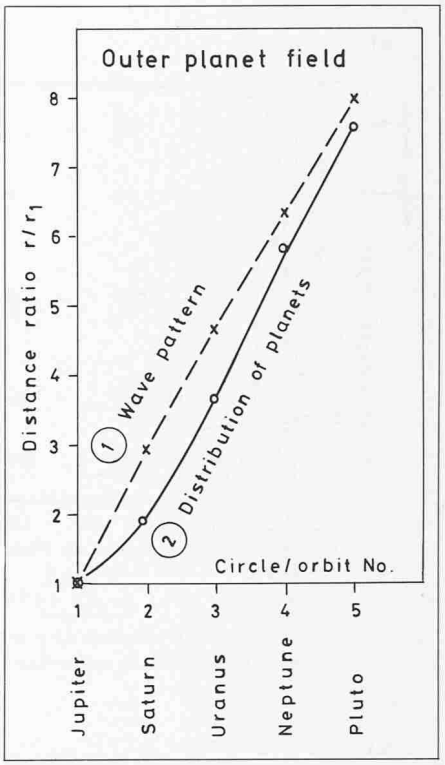


Fig. 6. Distance ratio r/r_1 versus circle/orbit No. for the outer field

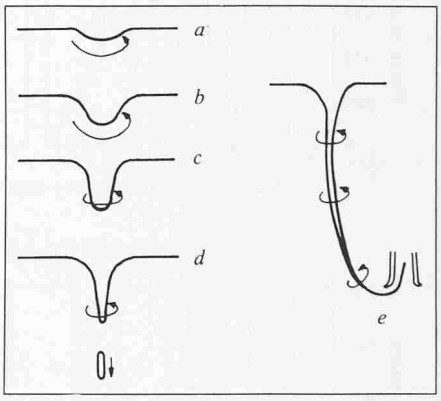


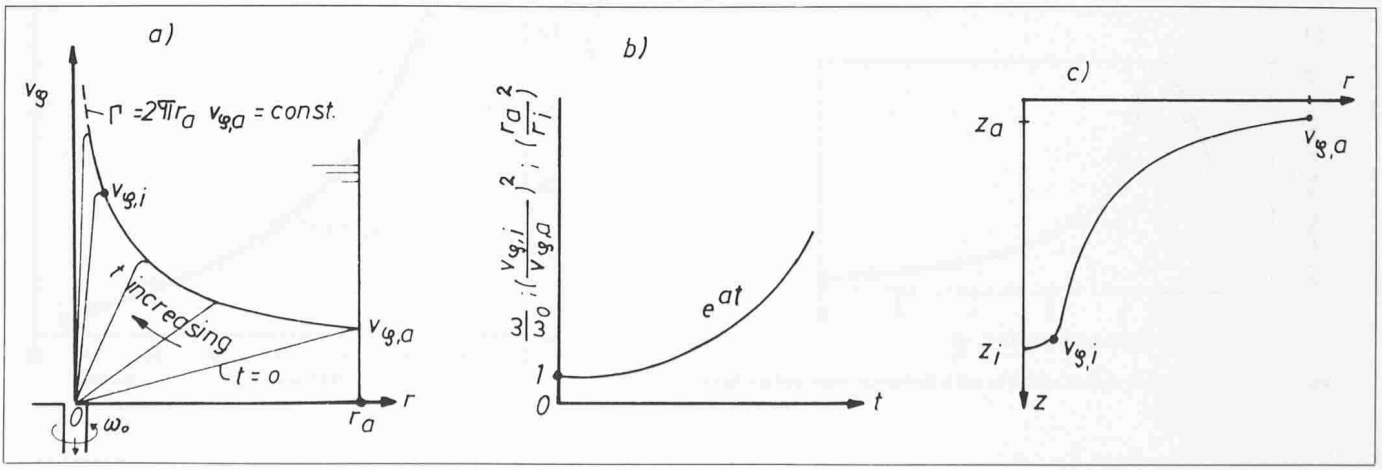
Fig. 7. Stages in development of an air-entraining vortex (Denny)

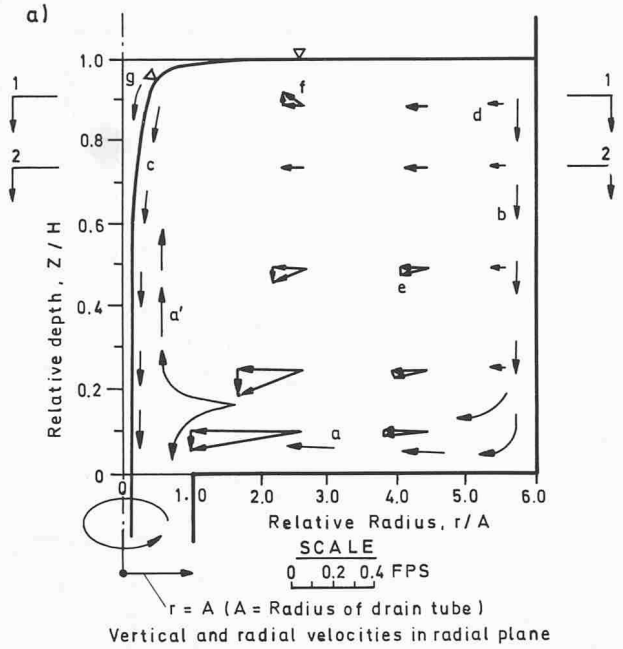
Fig. 8. Transformation from a rigid-body vortex at $t = 0$ to Rankine vortices with narrowing inner core arising from ventilation of the viscous fluid from the inner core by the axial flow

a) swirl velocity profile as a function of time

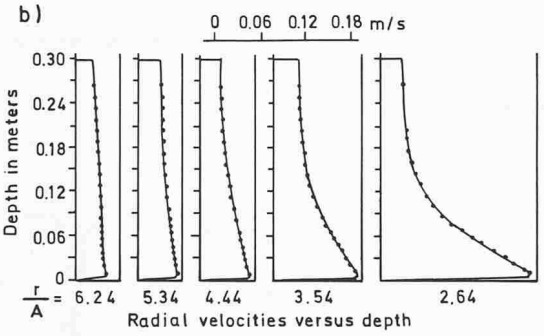
b) exponential function for the dimensionless numbers ω/ω_o, $(v_{\varphi i}/v_{\varphi a})^2$ and $(r_a/r_i)^2$

c) water surface profile for instant t

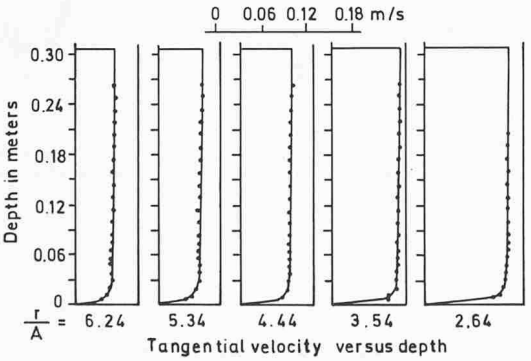




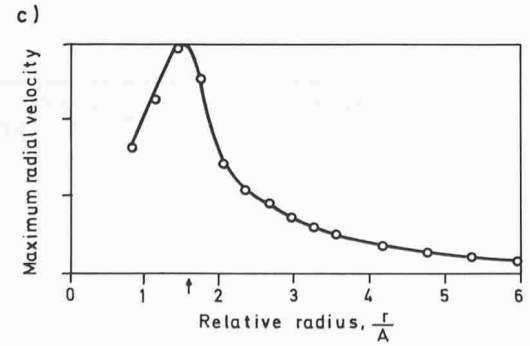
Vertical and radial velocities in radial plane



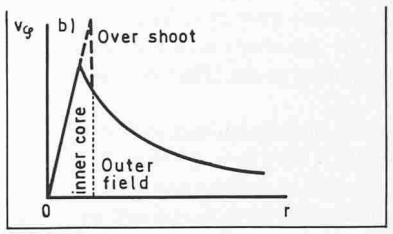
Radial velocities versus depth

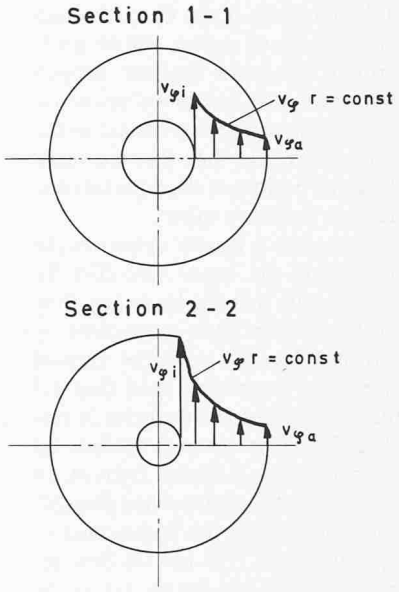


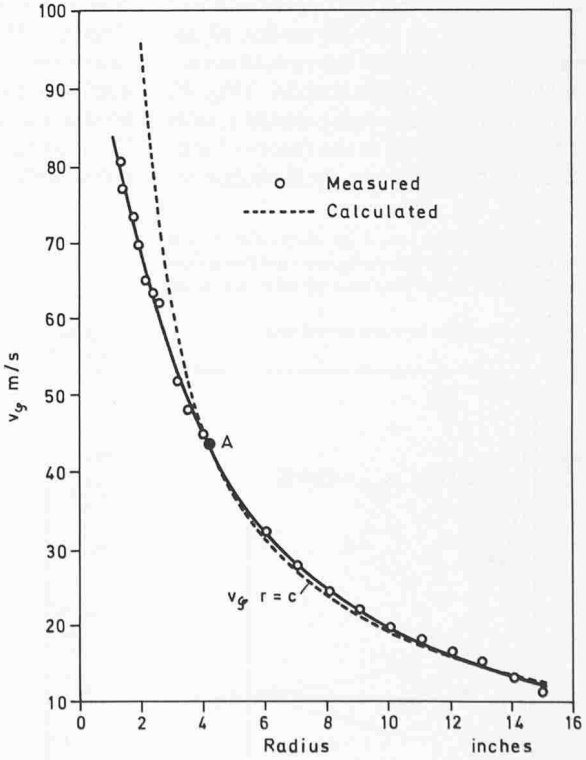
Tangential velocity versus depth



-Variation of maximum radial velocity with distance from outlet Axis







The main drain through the tail pipe appears thus mainly to originate from the axial flow c through the thin layer of the free-surface. *H. O. Anwar* found furthermore, that the main body of the vortex corresponds excellenty to a potential vortex, the swirl velocity v_φ of which is practically constant from top to bottom at any radius r (see Fig. 9e, c. f. *L. L. Daggett* and *G. H. Keulegan* 1974). This swirl velocity will only be reduced on the surface of the main vortex body, i. e. along the boundary (a) of the bottom and the free surface (c) of the air core. A shear layer of the swirl flow will be formed there. The radial flow generated in it due to the drain will be supported by the *Ekman effect*. The restriction of the surface flow on the boundary of the main vortex confirms very well the *Thomson theorem* of the vortex conservation. Thereafter, the vortex prevents a direct outflow through it and thus opposes the effect of the gravity.

The radial flow through the vortex field (Fig. 9b), whatever weak it may be, causes a contraction of the vortex. The *Stokes theorem*

$$(11) \qquad \Gamma = \Gamma' - 2\omega' F$$

can be applied, where Γ is the absolute constant circulation supplied by the earth's rotation, Γ' is the relative circulation of water to the bath-tub wall, calculated along a closed horizontal curve, within which a surface F is enclosed. ω' denotes again the local angular velocity of the earth. Since the absolute circulation is constant, we obtain the difference of the relative circulations:

$$(12) \qquad \Gamma'_1 - \Gamma'_0 = 2\omega'(F_0 - F_1)$$

between two instants 0 and 1 (Fig. 10). A contraction of the vortex from F_0 to F_1 will cause an increase of the relative circulation by $2\omega' (F_0 - F_1)$ namely

$$(13) \qquad \Gamma'_1 - \Gamma'_0 = 2\omega' (\pi r_0^2 - \pi r_1^2)$$

As a circulation of

$$(14) \qquad \Gamma_1 = 2\pi\omega' r_1^2$$

already exists at the radius r_1 due to the rigid body rotation of the water with the bath-tub, the new total circulation will be

$$(15) \qquad \Gamma_{\text{total 1}} = 2\omega'(\pi r_0^2 - \pi r_1^2) + 2\pi\omega' r_1^2 = 2\pi\omega' r_0^2 = \Gamma_0$$

This new circulation at r_1 is equal to the circulation Γ_0 at r_0. If we take r_0 as the outer radius r_a of the bath-tub, we can infer that the circulation of the water at the wall ($\Gamma_0 = 2\pi\omega' r_a^2$), acquired from the rotation of the bath-tub with the earth, will be transferred inward wiht its constant value, caused by the drain of the water. The swirl velocity at radius r_1 will then increase from its original value of $r_1\omega'$ to a value of

$$(16) \qquad v_{\varphi 1} = \Gamma_0/2\pi r_1 = 2\pi r_a v_{\varphi a}/2\pi r_1 = v_{\varphi a}\, r_a/r_1$$

r_1 will then determine the radius of the core of the bath-tub vortex. By dropping the index 1 we get a general expression

$$(17) \qquad v_\varphi = v_{\varphi a}\, r_a / r$$

from this transfer of circulation. This expression is plotted in Fig. 8 a. As shown by equations (13) and (15), the transferred circulation retains the same rotating sense as ω' of the earth. This theoretical result is borne out by the experiments carried out by *A. H. Shapiro* 1962 and *A. N. Binnie* 1964. They found a counterclockwise rotation of the bath-tub vortex in the Northern Hemisphere, thus in the same sense of the earth's rotation. Similary, *L. M. Trefethen, R. W. Bilger, R. T. Fink, R. E. Luxton* and *R. I. Tanner* obtained a clockwise rotation of the bath-tub vortex in the Southern Hemisphere, as the earth's rotation does there.

Shapiro observed furthermore for the case of a residual clockwise circulation in the Northern Hemisphere that during the first two-thirds of the draining period, the rotation was clockwise due to the initial swirl, but then changed over to a counterclockwise sense due to the earth's rotation. A continuous supply of circulation by earth is thus vital for the generation of the bath-tub vortex.

The swirl velocity v_φ will become very large when the transfer of the circulation to a very small radius (Eq. 17). The bath-tub vortex will then have a very small core rotating with a very high speed. *Shapiro* observed near the end of one experiment of this bath-tub vortex that the frequency of the revolution reaches about 0,3 Hz in a period of 15 min corresponding to an exponential increase of vorticity with time ($e^{a\,t}$) with a factor of $a = 0{,}01\ s^{-1}$ (*A. W.*

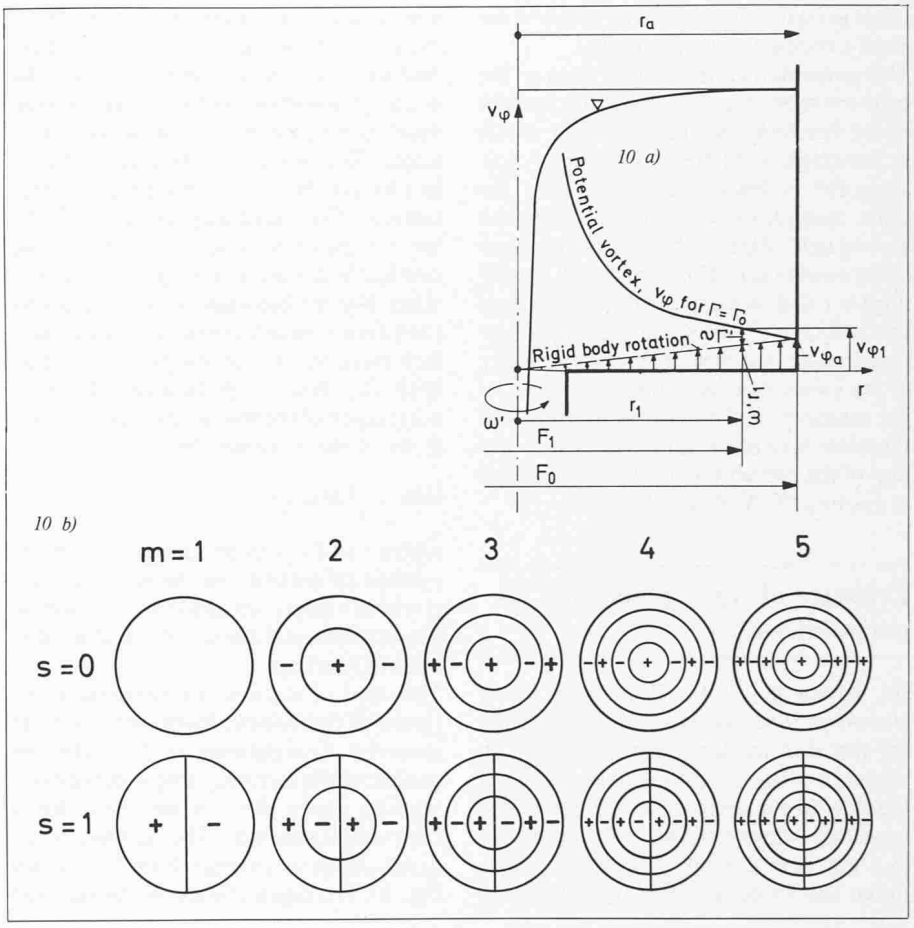


Fig. 10. Derivation of the conservation of circulation in a bath-tub vortex based on the Stokes theorem.
a) Transfer of circulation from the outer wall inward due to drain through the central outlet pipe
b) Vibration patterns without modal diameter (s = 0) and with one nodal diameter (s = 1)

Fig. 9 (left). Flow field of a bath-tub vortex (Anwar 1965, Daggett and Keulegan 1974)
a) Vertical and radial velocities in radial plane
b) Radial and tangential velocities versus depth
c) Variation of maximum radial velocity with distance from outlet axis
d) Overshoot at the boundary between the inner and outer core near the final stage of the vortex formation (Brown, Donaldson & Sullivan, Govindaraju & Saffman)
e) Swirl velocity profiles of two subsequent cross-sections
f) Comparison between theoretical and measured swirl velocities far from core

Marris 1967). This frequency is 30 000 times greater than the angular speed of the earth's rotation at that latitude.
The generation of the strong vortex in the bath-tub arises therefore from the transfer of the circulation by the radial flow which is associated with the strong radial flow along the vortex surface, induced by the drain through the outlet pipe, i. e. by the gravity field of the earth. As the shear layer of the swirl flow on this surface will also induce a radial velocity, a strengthening of this will occur. This strengthening will be the stronger, the greater the swirl velocity of the vortex core. A nonlinear increase of the intensity of the vortex with time will therefore take place, until a critical condition of the prevention of a further increase is reached *(Y. N. Chen* 1979 a).

Evidence of wave generation on potential vortex

As shown by *A. M. Binnie* and *G. A. Hoockings* 1948, the axial velocity through the throat of the inner core of a bath-tub vortex, i. e. the minimum cross section of the flow in the drain pipe, is equal to the travelling velocity of a wave, being similar to a gas flow through a nozzle at whose throat the streaming velocity is identical with the local velocity of sound. From the evaluation of the measurement results of these authors, we can infer that we are here dealing with a wave similar to the tidal wave propagating along a river whose depth is small compared with the wavelength. This wave is formed unter the effect of gravity due to existence of a free surface. The travelling velocity of the wave is equal to $(g\ h)^{1}/_{2}$, where h is the depth of water and g is the gravity acceleration. For the bath-tub vortex of a strong swirl-flow through the throat, its free surface stays in the centrifugal acceleration field, v_{φ}^2/r. With Δr as the width of the annular space of the throat, the travelling velocity of the wave will be

$$(18) \qquad (\Delta r v_{\varphi}^2/r)^{1/2}$$

where r and v_{φ} can be supposed to be the average values over the theoat. This theory yields values corresponding very well to the experimental results obtained by *Binnie* and *Hockings*.
This type of wave is not restriced to the throat of the vortex. *Binnie* and *Hockings* observed wave patterns on the entire free surface of the corresponding potential vortex with modes of s = o and 1 (number of the nodal diameters). The number of the nodal circles m extends from 0 to 4, see Fig. 10. The depth of water in the bath-tub *(h)* and the gravity acceleration *(g)* will determine the wave speed here. These wave patterns correspond very well to the theoretical prediction for the natural vibrations of water in a circular basin without drain (i. e. without vortex formation), for which the solution is given by the roots of the *Bessel function* $J_s^{\prime}(k\,r) = 0$, as already cited in a previous chapter. This means that the existence of a strong potential vortex with a strong swirling flow in the central region on one hand and with an intense air core on the other hand has little effect on the general behaviour of the tidal waves of the water. The potential vortex itself is in a stage of equilibrium. It theoretically has no damping capability to oppose the generation of the tidal waves. The water will behave itself just as if it were at a standstill without vortex motion.
The tidal waves appear to be self-excited by the interaction of the surface flow c along the water/air interface (Fig. 9) with the main body of the potential vortex. The toroidal ring vortex formed by the two flows c and a' probably acts as an additional source for this excitation due to its instability nature *(Y. N. Chen* 1979 b).

Part II: "Disintegration of the swirling solar nebula disk into vortices of the infant planets due to self-excited vibration caused winds" in the next issue of this journal (20.1.83)

Wie entsteht ein Verkehrsflugzeug?

Fluggesellschaften beeinflussen den Flugzeugbau

Von Otto Loepfe, Kloten

Waren früher die Flugzeughersteller beim Bau eines neuen Flugzeuges sozusagen alleinbestimmend, so spielen heute namhafte Fluggesellschaften bereits bei der Entwicklung eine wichtige Rolle. Der nachfolgende Beitrag soll einen Überblick über die planerischen Tätigkeiten und Entscheidungen geben, die der Einführung eines neuen Flugzeuges vorangehen.

Wie in anderen Produktionsgebieten, gaben auch in der Flugzeugindustrie vor 30 Jahren die Techniker den Ton an. Sie bauten ein Flugzeug nach besten aerodynamischen und strukturellen Erkenntnissen, stellten es vor den Hangar und beauftragten die Verkäufer, das entwickelte Produkt an den Mann zu bringen. Auf diese Art entstanden noch die DC-4 und DC-5 der Douglas Aircraft Corporation. Während die DC-4 erfolgreich war, erwies sich die DC-5 als ein Fehlschlag ersten Ranges, ganz einfach, weil sie am Markt vorbeikonstruiert worden war. So wurden von diesem Typ lediglich 12 Exemplare gebaut. Bei der Auslegung der darauffolgenden DC-6 hat die American Airlines ein gewichtiges Wort mitgesprochen und war massgeblich am Erfolg beteiligt.

Misserfolg gleich Untergang

Heute ist die Entwicklung eines Passagierflugzeuges - vor allem dann, wenn neue Techniken angewendet werden - mit derartigen Kosten verbunden, dass ein Misserfolg dem Untergang eines Unternehmens gleichkommen kann. Man spricht gegenwärtig von *Entwicklungskosten in der Grössenordnung von 1,5 Mrd. Dollar für ein neues Flugzeug.* Es braucht Verkäufe von 300 bis 400 Flugzeugen innerhalb von zehn Jahren, um die Kosten wieder hereinzubringen. Die amerikanische Lockheed Aircraft Corporation hat es nicht geschafft. Nach einem Bestellungseingang von nur 234 Tristar 1011 sieht die Firma keine Möglichkeiten mehr, im Bereich der zivilen Transportflugzeuge aus den roten Zahlen herauszukommen. Lockheed hat deshalb beschlossen, auf das Jahr 1984 die Produktion einzustellen. Opfer ist ein an sich gutes und bewährtes Verkehrsflugzeug.

Um den Risiken eines Misserfolges zu begegnen, setzt man Heerscharen von Fachleuten ein. Diese analysieren den weltweiten Markt und untersuchen den Bedarf der Fluggesellschaften bezüglich Anzahl, Grösse und Reichweite. Auch die Pläne der Konkurrenz werden aufmerksam verfolgt.

Da von den ersten Ideen bis zum Einsatz eines Zivilflugzeuges normalerweise etwa fünf Jahre verstreichen, sind solche *Marktprognosen* natürlich *mit grossen Unsicherheiten* behaftet. Trotzdem wird ein grosser Aufwand betrieben. Beispielsweise führen alle Hersteller das Swissair-Streckennetz in ihrem Computer und wollen viel besser als