Origin of the solar system

24.1.47

Address to Geological Society

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(1) Preliminary remarks.

(2) Regularities in solar system – Bode's law.

(3) Dynamical agencies – Tidal action, condensation, rotation.

(4) Laplace's nebular hypothesis

(5) Chamberlin & Moulton's theory

(6) Jeans & Jeffreys' theory.

(7) Russell & Lyttleton – Lyttleton's modification.

(8) Hoyle's theory

~~(9) Alfvén's theory~~

(9) Weiszacker's theory.

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(1) Mr President & Gentlemen,

Carefully chosen the subject – Geologists interested but only remotely – danger of dealing with common subjects – Exc. of cosmic time-scale – Remarks of Hawkins "Doubtless their arithmetic is beyond cavil, but premises incomplete & inaccurate. The hoary imposture of the accuracy of the 'exact' sciences still deludes mankind, through the wholly illogical belief that a rigidly logical argument must reach a correct result whatever errors may have existed in the premises". – "Wegener is not clear regarding the earth forces causing mighty mass movement. Jeffreys is of opinion that known forces are 10^{14} times too small! But Geologists have Huxley's Mathematical mill too much in mind to pay much heed to ~~opinion~~ of physico-math opinion on a geo. problem. If adequate geological proof of continental drift be forthcoming it will be believed in spite of etc." i.e. right of opinion denied – modern trends of increased cooperation. Let it grow. – [illegible].

(2) isolated system, ten planets, special stress on Bode's law
← (1) sense of revl^n (2) nearly circular (3) nearly – near eccentric (3) coplanar – farthest most oblique

(4) Sun's rotation (5) big ones less dense (6) Satellites big ones more regular (7) satellites – how & when

– when is 2×10^9 years.

(3) Three agencies – tidal friction – gravitational instability, Condensation, less dense bigger condensation.

rotation – A.M. – gases & liquids (Jeans results)
(invariable)

(4) Laplace's theory – rotating nebula like a ~~rigid body~~ threw off rings – rings became planets.

Objections (i) 90% A.M in planets (50% in Jupiter), 10% in ☉'s rotation – Internal

adjustments so that 90% in 1/100 mass distribution impossible

(ii) Spiral nebula would be formed & then stars & not planets.

(5) Chamberlin & Moulton } – collision theory
& Jeffreys & Jeans } 'planetesimal & tidal' – accretion from nuclei & dust & forall –

general description – cigar form of filament – A.M. explained & explain of other regularities.

satellites by collision of sun & planets.

Differences: Planets solid from the beginning vs Planets pass thro' a liquid stage

Likes by geologists vs mathematicians

Compression due to accretion builds mountains vs Thermal contraction sufficient for building mountains.

Retention of atmosphere only if solid vs horrible even if fluid

Primitive crust must be geologically recognisable if originally fluid & then solid but they are not } same must be true of planetesimals

(6) Binary theory of Russell & Lyttleton – Even on tidal theory A.M is not enough. If intruding star at tidal acha must be at least = 0.03 A.U. at least for effective collision. If its mass = $M_\odot$ its A.M per unit mass = 0.25. Average A.M per unit mass for planets = 2.5 ie ten times too small in most favourable case – Binary hypothesis (M_0 & M_1) binary M_0 sun – M_2 intruder. M_2 draws filament from M_1 which M_0 catches – Later M_1 leaves M_0 & M_1, M_2 separate from each other. enticement theory – Mathematically possible to frame the theory – A.M. difficulty is met – Satellites by interaction of planets themselves – other processes as in tidal theory.

objections - Luyten & Hill's analysis shows that it is more probable that M_1, M_2 go away with the filament also - Spitzer Jeffrey's says formation of satellites impossible, planets cannot come near enough till they condense & then no tidal action - Spitzer's contention that temperature of the filament won't give thermal velocities to the particles not controllable by gravitation & filament left to itself would dissipate in about an hour at most.

(7) Lyttleton's modification - makes binary theory slightly less catastrophic - M_0 (Sun) is distant companion of a close binary (M_1, M_2). M_1 & M_2 first merge into a single body & due to rotational instability breaks up into a pair. The filament produced during fission is captured by M_0. Thus M_0 is companion of a triple star & triples & multiples are frequent. Solar systems more common.

Cataclysmic theories make solar system a rare entity. Probability $1 : 10^{60}$ of encounter - aim is to make collision theory & capture theory more frequent ~~in Lyttleton & (ii) Hoyle~~ - Discovery of stars of planetary dimensions makes forces this way - (i) Lyt (ii) Hoyle.

(8) Hoyle's theory - M_0 has a companion which is a supernova. When this bursts, M_0 can capture part of diffuse material thrown out - only a small part required - A.M. can be adjusted. Estimate of one supernova occurring in galaxy every 500 years ie in 10^9 years 10^6 planetary systems are formed.

(9) Return to nebular as opposed to "collision" theories - Weizsäcker's theory - Sun formed out of a primeval nebula - 10^9 years ago mean densities in interstellar space must have been higher than now. Material in nebula was in turbulent motion with eddy velocities of ~ 25 km/sec. Out of this Sun was formed by condensation with gaseous envelope round it. This is unstable because of viscous forces due to Kepler velocities of particles & result of viscous forces would be dissipation of outer parts into space & inner parts falling into the sun. Gaseous envelope does not however disappear till matter from interstellar space falls into sun. The stage when further accn of mass ceases is the stage of formation of planets. Here the A.M. difficulty is the reverse ie gaseous envelope has too much A.M. This is got rid of by dissipation. In fact after formation of planets 99% of envelope will have

dissipated. At the stage where accretion ceases formation of planets is possible if we can construct motions where viscous stresses ~~are least~~ would operate least ie if quasi-stable states are possible so as not to lead to complete dissipation. The main point of W's theory is to have shown possibility of such states. Such states are characterised by closed orbital paths of particles rel to observers in circular paths. For observer in path of radius r_{n-1} particles have vortex cell motions (retrograde) such that for greatest stability an integral number exists between r_{n-1} & r_n. Size of each cell (distance $r_n - r_{n-1}$) is determined by max. eccentricity of rel. orbit. With $e = .3$, $r_n = r_0(1.894)^n$ (5 cells in each ring) giving Bode's law. For this motion dissipation is least and takes place along circles r_n + along these are greatest possibilities exist for planet formation. Planet formation follows on planetesimal lines Direct capture & then gravitational capture & time for planet formation $\simeq 10^8$ years. mean life of gaseous envelope $\simeq 10^7$ years ie before planets form envelope has completely dissipated. That is why planets are poor in lighter elements. - Satellites formed from planets by clouds in rotation round them. "Secondary or subsidiary eddies having direct rotation & eddies coming together to form planets accretion theory of Hoyle & Lyttleton.

This theory has features of Laplace's theory, not catastrophic, also of Chamberlin & Moulton's theory, looks more terrestrial in appeal with turbulence, viscosity & eddies & seems & more likely to appeal to Geologists. Mathematically most complicated.
