ORIGIN OF THE SOLAR SYSTEM: PROBLEMS AND PERSPECTIVES

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THE MANY ORIGINS OF ONE SOLAR SYSTEM:

The problem of the origin of the solar system (hereinafter called OSS) has continued to attract the attention of scientists and thinkers since the middle of the eighteenth century at the latest. The ideas that have been put forward in attempts to reconstruct the evolutionary history of the solar system are many and varied—starting from being of a somewhat philosophical nature in the early days to the incorporation of the rigours of modern science. Apart from the cosmic fascination of the problem, its attraction lies equally well in the fact that it provides a gigantic scientific puzzle with many clues. The task of the puzzle-solver is to decide on the proper relevance of these clues, and then try to apply his knowledge of scientific laws to solve the puzzle. As decades and centuries have gone by, the number of clues known to us have increased due to our expanding knowledge of space, and so has our knowledge of scientific laws. As a result the problem has become much more complex today than it was thought to be in the early days of investigation. The purpose of this paper is to outline some of the salient features of the problem. This paper is by no means a review of the theories of OSS, and hence no attempt has been made to present an exhaustive list of the theories in this field. The interested reader may find surveys of the various theories of OSS in articles by ter Haar and Cameron (1963), ter Haar (1967) and Huang (1973), and in a monograph by Kopal (1972).

In the following we shall briefly describe the historical background of the subject and the nature of the observational data or clues for the problem that are known to us today. We shall then discuss some of the major controversies and interpretive differences that characterize the problem of OSS today.

HISTORICAL DEVELOPMENT—THE DIFFERENT APPROACHES:

Historically, there have been two different approaches to the problem. The first one proposes a theory known as the *cataclysmic theory*, which suggests that the protoplanetary material was torn out of the Sun during a close encounter or a collision of the sun with one or more stars. The earliest known proponent of this theory is Buffon (1745). This theory is now generally considered obsolete for a number of reasons—most importantly, the improbability of such close stellar encounters and the unlikelihood of production of almost circular planetary orbits by this process (see e.g. Nölke 1930 ; Russell 1935). Some of the later works belonging essentially to this approach are those of Chamberlin (1901), Moulton (1905), Jaffreys (1929), Jeans (1931) and Woolfson (1964).

The second approach—whose following are now the most ubiquitous in the literature—proposes the *nebular theory*. This was introduced as a semi-philosophical idea by Kant (1755), and later put on a more detailed scientific basis by Laplace (1796). This approach in essence proposes that a rotating gas cloud that gathered out of the tenuous interstellar medium evolved by gravitational contraction into a flattened lenticular form. During its further gravitational shrinkage, the cloud left behind a series of concentric rings which were to act as the protoplanetary clouds that would collapse to form the planets. The central part of the cloud evolved to form the Sun. Laplace proposed that the satellite systems formed around the planets by an identical series of processes in the protoplanetary gas clouds. It has later been generally recognized that, unlike the massive stars, small planets cannot form by the collapse of gaseous clouds. Even the largest planet Jupiter could not form by such a process (see e.g. Kumar 1972). Most theories today assume the disperse protoplanetary medium to consist of gas and particulate matter (dust)—with the accumulation of the particulate matter being responsible for the formation of the planets or the planetary embryos. The particulate matter could either be the interstellar dust that already existed in the original cloud, or it could be the result of condensation in the gas cloud, or a combination of both. Once the particular matter has agglomerated to form the planets or the planetary embryos, some of the remaining volatile gases could condense on these objects.

Perhaps the most notable among the modern versions of the nebular theory are those of von Weizsäcker (1944), Berlage (1962), Safronov (1969), Cameron, (1973) and Kuiper (1974). These works contain references to earlier works by these authors. In particular, Cameron has developed a popular theory of OSS—a theory which, in an attempt to keep up with our expanding knowledge of the physics of space, has undergone a number of transformations. But even in its latest version (op. cit.) Cameron's theory is essentially a legacy of Kant and Laplace, with some new considerations thrown in. Some theories such as Kuiper's suggest that the solar nebula resulted from an "unsuccessful" binary star, of which the secondary component became a nebula.

McCrea (1960, 1963) has suggested a theory of OSS which does not belong to any of the above approaches. In his theory, a large original cloud breaks up into a number of "floccules", some of which later coalesce to form the Sun and others form the planets.

Of special interest is a theory proposed by Schmidt (1944), and later developed by B. J. Levin, E. Ruskol and V. Safronov (see Safronov 1969 and references therein). This theory—known as the *planetesimal theory*—starts by assumi ıg that the Sun captured swarms of solid particles from the interstellar medium into circumsolar orbits. These particles gradually accreted to form increasingly larger solid objects ("planetesimals")—eventually to form the planets. The panetesimals, as intermediate steps towards the formation of planets and satellites, are now a feature of most theories of OSS. The idea of planetesimals can be traced back to Moulton and Chamberlin.

An approach which is radically different from all the above approaches, and one which is based on our knowledge of modern space physics, was introduced by Alfvén (1942-45, 1954). This approach has later been developed by Alfvén and Arrhenius (1970a, 1970b, 1973, 1974, 1975). These authors have called their approach the *actualistic approach*. They have questioned the validity of the assumption, even in many modern theories, of a primitive solar nebula—a concept which Laplace introduced on the basis of the eighteenth-century knowledge of science. Alfvén and Arrhenius have instead started by carefully analyzing the nature and relevance of the observational evidences bearing on the problem. They have followed the *actualistic approach* (or the archaeologist's approach)—which is to look at the present state of the solar system and to try to extrapolate this state back into more and more remote past. This is in contrast to all the other theories, which start from the other end of the time sequence by *hypothesizing* a primitive state of the solar system (e.g. a solar nebula).

In many respects, a distinct partition can be made among the theories of OSS today, with the Alfvén-Arrhenius theory on one side and all other theories on the other. The present author feels that this partition is important to stress—as shall be done in the following discussion.

THE NATURE OF OBSERVATIONAL DATA:

Any realistic theory of OSS must of course be developed in close contact with the pertinent observational data. These data are many, and opinions differ among the authors on the relative pertinence of the various data. In the following we shall try to outline the nature of these observations vis-a-vis their places in the theories.

(a) **Regularity of the Planetary Orbits**:—Perhaps the most striking feature of the solar system is that the planets all have "direct" orbits (moving counterclockwise as seen from the North pole of the ecliptic, in the same sense as the spin of the Sun) with very small eccentricities and inclinations (with respect to the ecliptic plane). This was the feature that prompted Kant and Laplace to formulate their theories which envisioned the protoplanetary disperse matter in the form of a flattened rotating disc.

The spacing between two consecutive planets increases as one moves outward from the Sun. Early attempts to fit an analytical expression to this trend led to the well known Titius-Bode law, which is

$$a_n = 0.4 + 0.3 \times 2^n$$

where a_n is the orbital distance in astronomical units of the n-th planet from the Sun, counting Venus as the zeroeth planet and including the asteroids at $n=3$ (an exploded planet!). For Mercury, one has to assume $n=-\infty$. This is undoubtedly a convenient way to memorize the planetary distances, but whether or not any deeper significance of this law exists is a matter of great controversy. Attitudes in this respect range from rigorous attempts to 'derive' this law as a consequence of the formative processes of the solar system to outright dismissal as a "number magic". For extensive discussion of the Titius-Bode law, see Nieto (1972).

(b) **Similarity between the Planetary and the Satellite Systems**:—Satellite systems of the planets bear a similarity to the planetary system in that, with a few exceptions, the former also consist of objects moving in direct orbits around the central planets with very small eccentricities and inclinations (with respect to the orbital plane of the respective planets). One striking exception in respect of inclination is the Uranian satellite system where the orbital plane of the satellites (in very nearly circular coplanar orbits) makes an angle of 98° with the orbital plane of the planet. The capability of a theory of OSS to explain this fact provides an important testing ground for the theory.

A further point of similarity is in the so-called *groupings* in the planetary and the satellite systems. With regard to their relative orbital spacings the planets tend to crowd together in two groups—the terrestrial planets (Mercury to Mars) and the giant planets (Jupiter and beyond*). The groups also differ with respect to the size and the mass of the planets. Similar groupings are also present in the satellite systems of Jupiter, Saturn and Urnaus (see e.g. Alfvén and Arrhenius, 1970a). The Titius-Bode law, however, does not apply to the satellite systems unless one postualtes a number of "missing" satellites.

Most theories of OSS have relegated the problem of formation of satellite systems to a corollary to the theory of formation of the planetary system. However, Alfvèn and Arrhenius have suggested that because of the similarity between the planetary and the satellite systems, these systems are most likely to have had indentical genetic history, and hence one should aim at developing a general theory of the origin of orbiting *secondary bodies* around a gravitating *central body*, rather than that of planets around the Sun. Furthermore, since there are three well-developed satellite systems (those of Jupiter, Saturn and Uranus) but only one planetary system, the emphasis in developing such a theory should be laid on the satellite systems. These authors point out that this approach has a great advantage in that it puts severe constraints on any theoretical model.

(c) **Irregular Satellites**:—The satellites which do not satisfy the similarity aspect are known as irregular satellites. Of these, the Jovian satellites Jupiter 8, 9, 11 and 12, the Saturnian satellite Phoebe and the Neptunian satellite Triton have an additional irregularity in that they orbit in the retrograde direction (opposite to the planetary spin). This fact suggests that the above satellites are not natural satellites (i.e. satellites formed as a consequence of a series of formative processes in an environment gravitationally controlled by the planet). It has frequently been suggested that these are objects

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* With the exception of Pluto, whose mass is more similar to that of the terrestrial planets.

originally in circumsolar orbits that have been gravitationally captured by the respective planets and have been brought into their present orbits by tidal evolution of the post-capture orbits. The retrograde orbits may result from such captures.

The satellite-to-planet mass ratio for Triton is disparately large compared to that for the other satellites (excepting the Moon). This fact has led to the suggestion that Triton may originally have been a planet. This ratio is large also for the Moon (which, however, has a prograde orbit). This has led to the suggestion that the Moon may have been an original planet that has been captured by the Earth. For discussions of the problem of caputure in the solar system see Bailey (1971) and Alfvèn and Arrhenius (1972) and references therein.

The planet Mars has two tiny satellites Phobos and Deimos in nearly circular prograde orbits. Cameron (1973) has suggested that they are captured bodies, but they may well be regular satellites (Burns 1972). The Jovian satellites Jupitor 6, 7 and 10 which have the character of a group of regular satellites because of their proximity, are irregular in the sense that they have high eccentricities and inclinations. They are sometimes suggested as being captured bodies (Bailey 1971).

A reverse of the capture mechanism is assumed in Kuiper's suggestion (Kuiper 1974) that Pluto may have originated as a satellite of Neptune and was later transferred to a circumsolar orbit.

(d) **Angular Momentum**:—The total angular momentum in the solar system resides in the orbital angular momenta of the planets and the satellites, and in the spin angular momenta of the Sun, the planets and the satellites. Strictly this list should also include the angular momentum in asteroids and comets. The spins of the Sun and the planets, except Venus and Uranus, are prograde. An interesting fact is that the planets, while containing less than 1 percent of the total mass in the solar system, contain 99 percent of the total angular momentum in their orbital motion (assuming that there is no "hidden" angular momentum inside the Sun—i.e. the interior of the Sun rotates at the same angular velocity as the surface layers). The question then arises as to how a protoplanetary disperse medium around the Sun is supplied with sufficient angular momentum in order to put it into orbital motion so as to eventually give rise to the present observed state. Obviously, in absence of such angular momentum, the disperse medium would fall into the Sun. Laplacean-type theories resolve this question by having the requisite amount of angular momentum already present in the primitive solar nebula, while some other theories suggest that the Sun in the past contained an additional spin angular momentum which was transferred to the protoplanetary medium, setting the latter into orbital motion. This process inevitably points at hydromagnetic phenomena, since the only known mechanism by which angular momentum can be transferred from a rotating celestial body to a surrounding disperse medium is via magnetohydrodynamic processes. The first suggestion of magnetohydrodynamic, angular momentum transfer from the Sun was made by Alfvèn (1942-45). Later many authors have discussed this problem, either in connection with the problem of OSS or in connection with the problem of star formation (for references, see Huang 1973).

(e) **The Asteroidal Belt and the Saturnian Rings**:—The asteroidal belt, consisting of some 5,000 asteroids, is located between the orbits of Mars and Jupiter, with a few asteroids inside the orbit of Mars and a few beyond the orbit of Jupiter. These are relatively small solid objects, the largest of them having a diameter of about 1,000 km. The early view of the asteroids as an exploded planet is now being replaced by that of a number of planetesimals that were unable to accrete further to form a planet—probably because there simply were not enough of them to permit such an accretion (which requires frequent collisions among the planetesimals).

The observations of asteroids have not been utilized in any significant way in the theories of OSS except in the Alfvén-Arrhenius theory. These authors have identified certain signatures (features in the spatial distribution) in the asteroidal belt that are predicted from their theory of OSS. These features—unlike the so-called Kirkwood gaps—cannot be explained as a result of resonance with Jupiter following the formation of the asteroids, and hence are quite likely to be the result of the formative processes. Furthermore, Alfvén and Arrhenius have shown that the asteroidal *families* (a family being characterized by asteroids with nearly the same values of the semi-major axis, eccentricity and inclination) also conform to and confirm the processes which, according to them, lead to the formation of the solar system.

The Saturnian ring system (consisting of swarms of solid grains orbiting Saturn in four distinct rings—the A, B, C and D rings) may provide another important testing ground for the theories. But opinions differ regarding whether or not the structure of the Saturnian ring system is a direct result of the formative processes, or whether this structure resulted from post-formative processes such as collision between orbiting grains and resonance with one or more of the satellites. The former view is held by Alfvén and Arrhenius who show that a number of spatial features in the ring system can be predicted as a result of formative processes suggested in their theory. For a general discussion of observations and theories of the Saturnian ring system see Franklin et al. (1971).

(f) **Comets, Meteors and Meteorites**:—Comets must also be considered as members of the solar system, and hence must find their place in any scheme of OSS. They may either have originated inside the solar system and have then been ejected by planetary perturbation into their present orbits with very large semi-major axes. Alternatively, they may have originated outside the solar system and have then been perturbed into orbits that bring them to the inner regions of the solar system. Both views are currently being suggested, and the subject of origin of the comets continues to be vigorously discussed. The reader is referred to a recent review by Marsden (1974).

It is now well established that the meteors originate from the comets. The meteorites are variously suggested to originate from the comets or from the asteroidal belt (see e.g. Wasson 1974).

(g) **Solar, Planetary and Primeval Magnetic Fields** :—The Sun today has a general surface magnetic field of the order of 1 gauss, corresponding to a dipole of moment 10^{33} gauss cm^3 located at the centre of the Sun. The planets Mercury, Earth and Jupiter have dipole moments of the order of 10^{23}, 10^{26} and 10^{30} gauss cm^3, respectively, with their dipole axes roughly aligned with the spin axes. Mars does not seem to have any appreciable magnetic field. Nothing is known about the magnetization of the other planets. The magnetization of the Sun and the planets has not found any place in most theories of OSS. We shall return to this question in the next section.

A related matter is the recent finding that certain components of meteoritic material (believed to be original solar system condensates; see below) show a magnetization which can be interpreted as the result of the material having condensed from a vapor phase in an environment permeated by magnetic fields as high as 0.1-1 gauss (Brecher 1972). This seems to indicate the existence of a primeval magnetic field in the circumsolar environment.

(h) **Cosmochemistry** :—A new dimension to the problem of OSS has evolved over the last three decades or so—and has come to be known as cosmochemistry. An entire discipline in itself, it deals primarily with the chemistry of extraterrestrial solar system materials—meteorites and lunar matter. It also includes theoretical studies of the chemistry of various astrophysical objects and disperse media both inside and outside the solar system. Of primary mportance are the meteorites which represent tangible samples of cosmic matter which, unlike the Earth or the Moon, have not been morphologically altered since their formation by processes such as geological evolution or melting and attendant phase separation. The meteoritic matter is often believed to be the product of condensation from a vapor phase in the circumsolar environment in which the protoplanetary material is also supposed to have condensed. By studying and properly interpreting the meteoritic data, one can derive the physical conditions, within certain limits, in the environment in which this material condensed and agglomerated. Furthermore, application of age determination techniques to the meteoritic material helps us to determine some relevant time-scales. Thus, studies of meteoritic material yields information potentially useful for the problem of OSS. A comprehensive text on the subject of meteorites in general has been written by Wasson (1974), while the relevance of meteoritic science to the problem of OSS has been discussed by Anders (1971). The latter should, however, be read in conjunction with Arrhenius and Alfvén (1971) for completeness. For literature on cosmochemistry in general, the reader is referred to Urey (1952, 1966) and Suess (1965).

(i) **Pertinent Astrophysical Observations** :—Astrophysical observations, by which we shall here refer to observations of objects and systems outside the solar system, are of relevance to the problem of OSS for two reasons : (*i*) It is reasonable to believe that the solar system is not the unique planetary system in the universe, and that elsewhere in the universe there are similar systems at some stages of their respective evolutionary processes. (*ii*) There are stars similar to the Sun elsewhere in the universe at some stages of their life cycles. Some authors believe that the processes of the formation of the planets may be closely linked to the processes of formation and evolution of the Sun itself. For their theories, it is important to learn about the properties of young stars that will evolve into stars similar to the Sun. In the former context, the observations of interest are those of planetary nebulae and the interstellar dust clouds—both of which have been variously suggested as the precursors for planetary systems. In the latter context, observations of the so-called " young stars " in general may be of interest. Much mention is made in the literature of a class of such stars known as T Tauri stars whose special property is that they eject mass at a rate of about 10^{-7} solar mass per year (Kuhi 1966)—i.e., they emit a wind similar to the present-day solar wind but with much greater intensity. Many believe the Sun to have passed through this stage in the past, and try to incorporate this T Tauri phase in the scheme of OSS. Thus, Cameron chooses the mass of his initial solar nebula in such a way that, after the formation of the planets, the remaining mass can be blown away by the T Tauri wind.

SOME CURRENT PROBLEMS AND INTERPRETIVE ASPECTS :

There are numerous questions and controversies in the problem of OSS which are far from being resolved. It is out of the scope of this paper even to try to enumerate these. We shall instead briefly describe certain problems and interpretive aspects which to this author appear to deserve most attention at this time.

(a) **The Actualistic Approach vs. Other Approaches** :—The observational data of the problem of OSS are of course subject to various interpretations. It is impossible to evolve a scheme of OSS from these data without introducing certain amount of scientific speculation. Ideally, one wants to choose that particular interpretation which reduces the speculative element to a minimum. This is the essence of the actualistic approach. In this approach one begins by examining the present state of the solar system (the least speculative state and traces back to the states in more and more remote past (i.e. to increasingly more speculative states), using observational data and the laws of physics as guidelines. This is an approach which was successfully used by Hutton in reconstructing the past history of the Earth. All the other approaches to the problem of OSS start by postulating a primitive state such as a solar nebula and try to form the present solar system out of this. Such postulated states are significantly different from the primitive state that Alfvén and Arrhenius deduce on the basis of the actualistic approach, and hence a need has clearly developed for judging the merits of the various approaches.

(b) **Plasma vs. Neutral Gas Origin of the Solar System** :—Another question—and a very fundamental one—is whether the disperse medium from which the solar system formed was a hot tenuous plasma as suggested by Alfvèn and Arrhenius, or a relatively cold dense neutral (nonionized) gas as suggested by all other authors. Alfvén and Arrhenius have strongly emphasized the importance of plasma and magnetohydrodynamic effects in the formative processes of the solar system. There have been no satisfactory arguments against these authors reasoning in favour of a plasma origin. In fact this reasoning has generally been ignored and theories have continued to develop on the basis of a neutral gas origin. It is interesting to note, however, that in the most recent version of his theory of OSS, Cameron has pieced together a number of speculative and disjointed ideas in an effort to tailor-make a primitive solar nebula in which ionization and magnetic field strength would be reduced to such low values that processes in this nebula could be treated without the application of magnetohydrodynamics and plasma physics. Eventually, however, Cameron is forced to invoke magnetohydrodynamic effects in order to explain the tilt of the orbital plane of th Uranian satellites (Cameron 1975). Since Cameron's theory is the most well-developed version of the neutral gas theories, one already begins to notice the inevitability in the theories starting from the neutral gas assumption of invoking magnetohydrodynamics.

The inference of the plasma origin is a consequence of the following two basic assumptions in the Alfvén and Arrhenius theroy: (*i*) all central bodies have spin; (*ii*) all central bodies have magnetic dipole moments exceeding a certain value, with the dipole axis being roughly aligned with the spin axis. The first of these assumptions is definitely valid. The second assumption is reasonable in view of the present-day observations of the solar and planetary magnetic fields. The subsequent development of the theory is based on modern space physics pertaining to the behavior of particles and fields in space—a subject which has had no impact on the other theories of OSS. The existence of a primeval magnetic field, as mentioned earlier, also support the suggestion of plasma origin.

(c) **Advantage of the Assumption of Identical Genesis of Planetary and Satellite Systems** :—As mentioned earlier, the satellite systems have been relegated to a postscript in most theories of OSS, although many (starting with Laplace) have suggested the identical genesis of the planetary and the regular satellite systems. If, however, one treats the satellite systems on an equal basis with the planetary system and tries to develop a general theory of formation of secondary bodies around a central body, certain advantages immediately emerge. For instance, one notes that the planets (central bodies of satellite systms) could never have set forth a T Tauri type wind. Hence, even if the Sun (central body of the planetary system) did have this property, it could not have had any significant influence on the process of planet formation. Furthermore, the planets were never nearly as hot as the Sun, and hence the temperature of the central body is not likely to have had a dominating influence on the process of formation of secondary bodies. In short, the assumption of identical genesis permits one t formulate a theory without inquiring about the early states of the Sun, about the theories of star formation and the associated long chain of speculation.

(d) **The Physics of Condensation** :—A very lively controversy exists today regarding the physical conditions under which the protoplanetary—and particularly the protometeoritic—solids condensed from the circumsolar gaseous medium. It has long been believed that such condensation takes place much in the same way as the condensation process in the laboratory, with the vapour phase and the condensing solids having the same temperature (Anders 1971; Lewis 1972). It has recently been pointed out, following the original suggestion by Lindblad (1935), that this is an unrealistic assumption and that a careful analysis of the problem indicates that the condensation would take place with the vapour phase having a much higher temperature (high enough to be a plasma) than the condensing solids (Lehnert 1970; Arrhenius and Alfvén 1971; Arrhenius and De 1973). It has further been shown that this situation helps us to understand a number of observations in meteorites which seem puzzling on the basis of a process of condensation under the condition of temperature equilibrium.

(e) **The Original Matter** :—It is, however, by no means established that all the solar system solids condensed in the circumsolar environment. For instance, the original disperse medium (derived from the interstellar medium) may have, and very probably would have contained dust particles. Some of this material may have been heated to high enough temperatures during its emplacement around the Sun so as to create a vapour phase which would later condense. Another portion may have survived as solids and later accreted to form the planetesimals. In fact, the entire amount of the solar system solids may be of one or the other kind. This problem is still far from being clarified.

(f) **Orbital evolution of a grain population** :—A topic of current interest is the mode of accretion of swarms of orbiting grains into larger bodies (planetesimals) and eventually to the final secondary body. Studies of this problem has given rise to the concept of *jet streams*, i.e., narrow streams of orbiting particles with very similar values of semi-major axis, eccentricity and inclination (see e.g. Alfvén and Arrhenius 1970a and references therein). Contrary to the common belief, it has been shown that inelastic collisions between orbiting grains result not in scattering of the grains, but in a progressive equalization of the grain orbits, thus giving rise to the narrow streams of orbiting grains. Within these streams accretion can proceed efficiently giving rise to a number of planetesimals, until the largest of these planetesimals becomes massive enough and sweeps up all the matter in the jet stream by gravitational capture. The end result is a secondary body. Asteroidal families may represent jet streams that have been preserved to date.

For a discussion of a number on current problems in the theories of OSS covering a wide spectrum of topics, the reader is referred to Reeves (1972).

REMARKS :

We have attempted, within the scope of this brief paper, to provide a glimpse of the problem of OSS in many of its aspects. We have tried to outline some of the current problems and controversies in this field in the hope of attracting fresh views on these questions. It is unlikely that observations will help us to decide between the theories in the near future. It is also unlikely that any particular theory of OSS is entirely correct or that any particular theory is entirely wrong. Further progress in his field at the present time can perhaps be made only through a much wider participation on the part of the astrophysical community in this effort. Fresh views are particularly needed in order to counteract the Laplacean inertia which has circumscribed our vision for too long a time.

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ANNOUNCEMENT

The Computer Society of India is holding its annual convention at Hyderabad during January 20-23, 1976 with "Computer and Social Change" as the theme of the meeting. Those who are interested in presenting papers should send in the abstract to D. V. R. Vithal, Program Chairman, CSI 76, Computer Group, T.I.F.R., Bombay 400 005, so as to reach him before October 1, 1975.

ERRATUM

In the paper entitled " Some results of a recent study of the Supernova Remnant 3C 400.2 at 49 cm " by W. M. Goss, S. G. Siddesh and U. J. Schwarz (*Bull. Astr. Soc. India,* **3,** 36, 1975), all the numbers in seconds of arc should have been in *minutes of arc.*