THE PLANETOID-IMPACT HYPOTHESIS OF CP F, A, AND B STAR FORMATION: POSSIBILITIES AND PERSPECTIVES

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ABSTRACT. A possibility is analyzed of explaining the chemical anomalies of chemically peculiar (CP) F-A-B stars basing on the assumption of the formation of a large number of moonlike planetoids both in the course of separation of the components and in late stages of close binary evolution.

Primitive igneous differentiation of such planetoids results in their crust becoming deficient in Mg, Ca, Sc and enriched in Fe, Sr, Ba, and the Rare Earths. Infall of such planetoids or crust fragments ejected in their collisions with one another onto an A star makes it Am-type. The deficiency of some elements relative to normal abundance can be accounted for if one assumes that these elements present in the matter streaming from one binary component to another condense with subsequent rain-out into a component or formation of the planetoids.

The more diverse and complex anomalies (including the separation of isotopes) can be explained in the same context of the close binary evolution by invoking the ideas of magnetic cosmochemistry which considers the consequences of extremely nonequilibrium processes associated with the flow of magnetic-field generated electrical currents through a rarefied matter in space.

There have been many attempts to explain the CP phenomenon on F, A, and B stars within various versions of the accretion hypothesis. These usually involve the accretion of remnants of the protostellar cloud including the possibility of elemental separation in condensation, the formation of planetesimals, and even nuclear processes (Searle and Sargent 1967; Tomley et al. 1970; Dolginov 1975), as well as the effect of magnetic field on gas and dust accretion (Havnes and Conti 1971; Havnes 1975). Cowley (1977) has recognized broad possibilities inherent in the planetesimal-impact hypotheses, particularly if combined with other processes. However he pointed out

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difficulties which can hardly be overcome within these hypotheses, namely: (1) it is unclear how infall of condensate onto a normal star could produce deficiency of some elements, and (2) it is unclear how to account for the strong isotopic shifts of Hg, Pt, He.

Our version of the accretion hypothesis for the CP phenomenon (Drobyshevski 1975a) provides a possibility to overcome these difficulties. It is predicated on the assumption of planetary systems being a by-product and/or limiting case of the evolution of binaries (Drobyshevski 1974a). In this context, numerous (up to 10^4) moonlike planets can form as matter flows from one component to another both in the course of their formation and separation as a result of rotational-exchange breakup of the rotating protostar (Drobyshevski 1974b) and in late stages of the close binaries evolution, when the primary becoming a red giant overflows the Roche lobe. There are grounds to believe that moonlike bodies can form not only in accretion disks (Drobyshevski 1975a) but within the primary itself as well, the conditions for fast condensation of planetoids being generally more favorable here than in classical protoplanetary disks (Drobyshevski 1975b). the most probable place for the formation of planetoids within the primary is the vicinity of the inner Lagrangian point, indeed, one can assume that conditions ensuring gas-dynamic suspension of growing planetoids can obtain here in the stream of outflowing matter. Part of the condensate can also rain-out into the primary thus forming a rocky core (Drobyshevski 1975a; Slattery 1978). Therefore the material streaming to the secondary should be depleted in refractory condensate (Sc_2O_3, ZrO_2, Al_2O_3, $CaTiO_3$, etc.) which can account not only for the deficiency of some elements but also for the frequently observed abundance differences between binary components which may be even equal mass and luminosity.

As a result of primitive igneous differentiation of material in initially molten moonlike bodies, the last-to-solidify melt forming their anorthosite crust becomes usually depleted in Mg, Al, Ca, and Sc while concentrating such elements with a large ionic radius as Sr, Y, Zr, Ba, and Rare Earth Elements, primarily Eu. A comparison of the composition of lunar highland rocks as measured in the Apollo and Luna 20 experiments with that of Am stars shows them to be practically identical (Fig.1) (Drobyshevski 1975b). A certain exclusion to this is the anomalies of iron and the geochemically related anomalies of Al and Ca which are due to the Moon s being generally deficient in iron. In more "normal" moonlike bodies the composition of the crust should agree closely with that of Am stars.

All Am stars are believed to be components of either young or evolved close binaries (Abt 1983; Drobyshevski

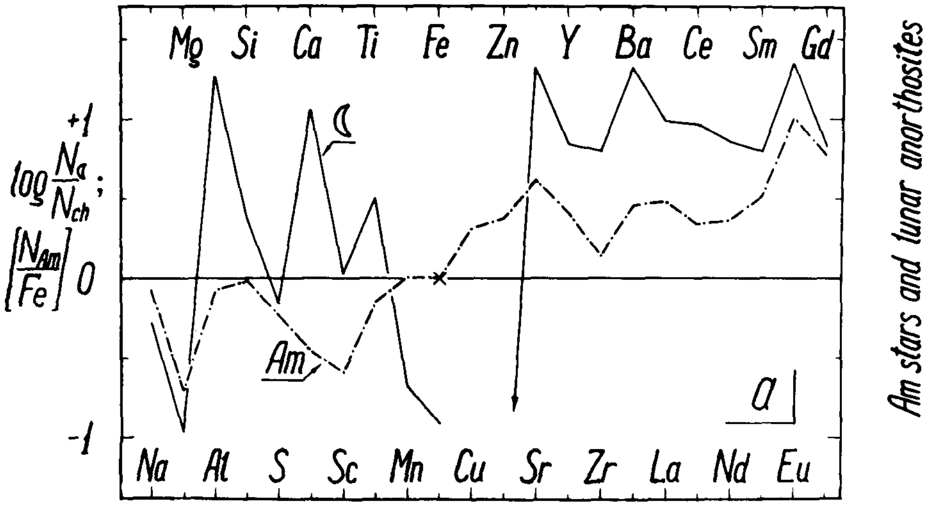

Fig.1. A comparison of the chemical composition anomalies of Am stars (normalized to "normal" stars and iron (Smith 1971)) with the chemical composition of the Moon's anorthosite crust (normalized to that of C1 chondrites).

1973b), so that in the context of the above ideas the presence in them of numerous moonlike planetoids would appear to be only natural. In rare collisions with one another the planetoids shed off fragments of their anorthosite crust. Infall of these fragments (and of the planetoids proper) onto the stellar components of the A class (with convective envelope masses of $\sim 10^{-10}-10^{-8} M_{\odot}$) makes them Am stars. The reasons for differences in the anomalies between even similar components and for correlations of some anomalies with star temperature are obvious. Thus the problem of the Am phenomenon may be considered solved.

The properties of Ap stars are more complex and more diverse. One may suggest that early Ap ("helium" and "silicon") stars possess primordial magnetic fields and are single. As for late Ap stars, their properties and the presence of a rather disordered magnetic fields on them can be readily accounted for by assuming them to be evolved binaries with a white dwarf-type companion (van den Heuvel 1968). Actually, they are second generation magnetic stars (first generation magnetic stars, where a weak field generated by outer convection builds up under the convective envelope due to the accretion of matter from the outside, are Am stars) (Drobyshevski 1973a). It is only natural to attribute the diversity of the properties of Ap stars to the presence of magnetic fields and their effect on the differentiation of matter and condensation of planetoids. (In particular, it is the effect of magnetic field which is usually held responsible for the maintenance of patchiness in the surface chemical composition.)

The transport of magnetic field by weakly ionized rarefied gas generates in the latter electric currents producing extremely nonequilibrium conditions (enhanced electronic temperatures, particle beaming, lasing effects, etc.) which are accompanied by exotic chemical reactions. This gives us grounds to define a new branch of science, namely, magnetic cosmochemistry. As evidenced by laboratory experiments (Basov et al. 1974; Thiemens and Heidenreich 1983; Letokhov 1983) under such conditions, in particular, efficient isotope separation can occur. The success of the planetoid-impact hypothesis in the interpretation of the Am phenomenon gives us grounds to believe that this as yet undeveloped science may offer promise for the explanation of some "nonstandard" anomalies on Ap stars. This approach is linked in more than one way with Alfvén's (1981) ideas on the role of electric currents in space.

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