SUPERNOVAE AND METEORITES: A RETROSPECTIVE OF SCIENTIFIC VIEWS

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In 1834, J. Berselius analyzed the composition of the Krasnojarsk meteorite (the Pallas Iron) and discovered that its metal was largely composed of the three elements Fe (88 mass %), Ni (11%) and Co (0.5%). Later it was shown that these three elements are present in the metal of all meteorites [1]. In 1869, as D.I. Mendeleev formulated his "Periodic System Of The Chemical Elements," he noted Group VIII, which began with Fe, Ni and Co. In 1919, P.N. Chirvinsky specifying the guesses of Theodore von Grothgus (1820) about the existence in space of a "triple union" of elements (Fe, Ni, S), replaced S by Co. However, the nature of the close relationship of Fe, Ni, and Co in meteorites has long remained unclear.

An explanation for this phenomenon was obtained in the late 20th Century after the first investigations of supernova SN1987A, which had exploded 168,000 years ago in the Large Magellanic Cloud, a satellite dwarf galaxy of the Milky Way found in the constellation Dorado. SN1987A was discovered on 2/23/1987 at the Mount Wilson Observatory in Chile. It has been studied for 30 years and continues to provide new information on the composition and evolution of material in interstellar space.

This supernova explosion triggered nuclear chain reactions (e.g. H→He and others), one product of which was a heavy isotope of Ni. Observations of SN1987A's changing spectrum showed a gradual progression of spectral lines from Ni to Co to Fe. This aspect of the spectrum can be explained by radioactive decay of isotopes in the expanding supernova cloud from ^{56}Ni →^{56}Co →^{56}Fe. The last isotope is stable. Further, SN1987A's brightness curve from 130-260 days corresponds to the ^{56}Co – ^{56}Fe radioactive decay law [2]. The ultimate stability of the complex of Fe, Ni, and Co is explained in nuclear physics in that the internal binding energy in their nuclei has the maximum value.

In May 1994, the Hubble Space Telescope (HST) obtained new spectral data for SN1987A's gas and dust envelope. Elements and compounds characteristic of stony meteorite material were detected, including notably SiO_2. Observations with the ALMA radiotelescope complex in Chile beginning in 2012 confirmed that the cold dust cloud of SN1987A, expanding at rates of several thousands km/c, contains particles which could serve as building material for new protoplanets [3; 4].

Summary. The composition and structure of meteorites have preserved evidence of the prehistory and early history of the Solar System [5]. Chondrites may be considered as analogues of protoplanetary material which have frequently retained their primordial heterogeneity. A key part of these meteorites are their inclusions of nickel-cobalt iron. Studies of supernova SN1987A have shown that the characteristic composition of meteoritic metal (Fe-Ni-Co) can be linked to the products of stellar evolution, including supernova explosions. The assumption of the existence of a genetic connection between stars and meteorite materail, expressed by the author in the 1990s [1], is confirmed by the latest astronomical observations [6].

References:

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