PLANETARY SYSTEMS OF THE GALAXY

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ABSTRACT. Definition of planets, relative contents of planetary systems in Galaxy, and main results of searching for them are adduced. It is supposed to distinguish four types of planets accordingly their inner substance composition: hydrogenous-helium (H_2, He, Ne), ice (H_2O, CH_4, NH_3 and their cluster tree, also N_2 and Ar), silicate, or metallic (alligations of Fe with Ni, Co, Cr) ones. Hydrogenous-helium compositions of planets are the most possible. But existence of two metallic (or metallic and silicate) and one ice planet in pulsar systems are suspected.

Key words: planetary system, types of planets.

1. Definitions

Planets are generated in circumstellar disks with a residual of angular momentum, where exist conditions for forming space bodies with mass of about some Jupiter masses (Ruzmaykina, 1981, Dole, 1970).

Evolution of planets is bond with gravitational differentiation that defines the lowest values of planetary masses of about $10^{-10} m_\odot$ with a diameter of about 500 km) (Alexandrov and Zakhozhaj, 1980).

Depending on medium elemental composition values of planet masses and can deflect from the mentioned above (mass at a tenth, and size at 100 less).

Space bodies with masses less then stellar, which are possible to be formed, as well as stars, by means of autogravitation, are defined as substars (Alexandrov and Zakhozhaj V.A., 1980), or brown dwarfs (Tarter, 1975). As the highest possible mass of planet is accepted the least mass of substar.

So, in accordance to Rees (1976), if temperature of the coldest interstellar clouds is about 10 K, then the highest valuation of planet mass makes up $(0.003 - 0.007) m_\odot$.

In the article under 'planetary system' we understand a space bodies system, in which at least one planet is present (Alexandrov and Zakhozhaj, 1983ab, 1986). Other components of the system can be planets, substars, stars, or their remnants (white dwarfs or pulsars).

2. Desired relative composition of planetary system

Hohlfeld and Terzian (1977), using results of Heppenheimer (1974) about influence of secondary components on protoplanetary nebula evolution, and using mass function of secondary components, inputed by Abt and Lavy (1970), proposed method for estimation of relative composition in double stellar systems. Alexandrov and Zakhozhaj (1983a) have generalized the results on different multiplicity stars with taking into account Branch's (1976) remarks about propriety of reduced power dependency of mass function for secondary components after Abt and Lavy (1970). Using mainly statistic characteristics of the nearest stars, they have determined value of relative contents of planetary systems in Galaxy as $0.2 \div 0.3$. Another authors appraisals are about 0.1 (Problema CETI, 1975, Problema Poiska vnezemnich Tzivilizatziy, 1981, Problema Poiska Zhizni vo Vselennoy, 1986).

3. Results of searching for planetary systems

The most effective methods of searching for planetary systems are the astrometrical one, radial velocities, direct images of protoplanetary formations, coverings, analyses of pulsars emission (Alexandrov and Zakhozhaj, 1983b, 1986, Gold, 1975, Zakhozhaj and Aleksandrov, 1981, Zakhozhaj and Ruzmaykina, 1986, Moroz V.I., 1981, Black, 1980, Greenstein, 1977). It is known already, that masses of invisible (obscure) satellites of Proxima (Niedzielski, 2001), Barnard's star (till three planets) (van de Kamp, 1974, 1975), and Laland 21185 (Gatewood, 1996) correspond to planets. It is suspected existence of planets or substars in systems of ε Eridanus (Lippincott, 1974, van de Kamp, 1974, 1975b) and $DM + 59°1915$ (Shaht, 1984), and double star 61 of Cygnus (two satellites near A component and one - near B) (Deych, 1978, 1977, Niedzielski A., 2001). Till April, 2001, 53 solitary obscured satellites and three components near υ And were detected by means of radial velocities' variations measures (Burrows, Hubbard, Lunine, Liebert, 2001). For the objects $m \cdot \sin i < 38 m_J$, where m_J -Jupiter mass, i - declination of planet orbit to viewing plane. For 37 satellites among mentioned ones $m \cdot \sin i = 0.15 \div 3m_J$. As the method gives masses of satellites with accuracy up to $\sin i$, it is too early to assert, that all the objects are planets. And only for system HD 209458, that is fond as shadowing variable (Charbonneau et al., 2000), it succeeded determine angle i. Mass of component as it was shown was planetary one $m \approx 0.69m_J$.

Measurements of pulsar emission frequency variations allowed to detect two and suspect one planetary systems. Till four planets are disclosed near pulsar PSR B1257+12 (Wolszcan and Frail, 1992, Wolszcan, 1994, 1997). One planet is fond near pulsar PSR B0329+54 (Demianski and Proszynski, 1979). A planet, or substar is revealed near double pulsar PSR B1620-26, which is located in spherical cluster N1 (Arzoumanian et al., 1996).

The orbital telescope IRAS has permitted to reveal protoplanetary formations near Vega and β Pic. (Robinson, 1984, Smith and Terrile, 1984). Later it has succeeded to receive protoplanetary disk image β Pic (Fizika za Rubezhom, 1986) with using of special eclipse coronograph. In the inner vicinity of the disk (to 30 A.U.) area without gas and dust was detected. It can't be excluded presence there some formed planets. In nearstellar disk of HD 141569 (radius of the disk - 400 A.U.) there is a slit at 250 A.U. from the central star, where a planet with mass $m \approx 1.3m_J$ is prospected (Perryman, 2000, Weinberger et.al., 1999). Now altogether about a hundred of protoplanetary disks are revealed around young stars of the main sequence with ages $10^6 \div 10^7$ years, including T Tauri stars (Kalas, 1998). Typical disk size is about 10^3 A.U. (Beckwith and Sargent, 1996, Perryman, 2000).

4. The main types of hypothetical planets

Depending on physical conditions (temperatures and pressures) in planets formation zones of protoplanetary clouds, and if chemical elements prevalence there likes to the solar one, so it is proposed to separate planet composition substances in four groups (Flirenskiy et al., 1981, Cameron and Pine, 1973). To *group I* actually volatile elements (H_2, He and Ne,), which can't be condensed under temperatures higher then 10 K, are related. Substances, that can be condensed into ices under temperatures $10\ K \leq T \leq 200\ K$ (H_2O, CH_4, NH_3 and their clutrat tree, also N_2 and Ar). *Group III* consists of silicates (can be condensed under temperatures less 1700 K and pressure about 0.1 bar). Alligations of Fe with Ni, Co, Cr are included to *group IV*. Under pressure less 10^{-5} bar and temperatures less $1350K$ iron can be condensed after wide spread silicates of enstatite and forsterite. Under the higher pressures condensation of iron surpasses silicates condensation. Under pressure $0.1bar$ iron condensation temperature ($T \approx 1700$ K) is higher by 80 K than forsterite. condensation temperature. With increasing of pressure the tendency keeps. If temperature is below 700 K, then begins FeS, which stands apart in the cores of planets jointly with iron alloies.

H_2 and He, as gases, can be captured by enough massive planets (masses more 10^{29} g) under temperatures below 200 K (Zharkov, 1980). Such planets are hydrogenous-helium ones. In less massive planets of low-temperature vicinity will predominate ices (ice planets). In middle-temperature zone of protoplanetary disk ($T > 200$ K) ices can't be condensed. They disappear like hydrogen and helium. Under temperatures $T < 350$ K will be appeared hydrated silicates, which under heating educe water and can form hydrosphere, or cryolitesphere. In range of temperatures less $1500 \div 1700$ K (depending on pressure) are to be formed *silicate planets*. Higher by 200 K is a zone, where silicate substance is lost but exist conditions for forming of *metallic planets*.

Zone of metallic planets has too narrow temperature interval ($T = 1700 \div 1900$ K) under pressure $P = 1$ bar and $T = 1600 \div 1700$ K under $P = 0.1$ bar. In Solar system this vicinity spreads from $0.1A.U.$ till $0.4A.U.$ Correspondingly, silicate planets zone has upper temperature limit about 200 K and spreads up approximately to 3 A.U.

Increasing of protoplanetary disk density by k times causes the same growth of optical thickness at arbitrary distance r. To restore optical thickness to previous meaning it is necessary decrease the distance r by k times. But, as result, right away it causes insolation increasing and upgrowth of temperature by $\sqrt{k}$ times. So, dimensions of temperature zones are to decrease by $\sqrt{k}$ times correspondingly. If star like Sun has a protoplanetary disk 10-ly denser, than Sun's one, so dimensions of metallic and silicate planets zones are to be less 3, i.e. $0.03 \div 0.1A.U.$ and $0.1 \div 1A.U.$

Extension of temperature zone boundaries is possible as result of star luminosity (L) increasing, because dust particles temperature in nonabsorbing interstellar medium $\propto L^{1/4}/r^{1/2}$. When increasing of star luminosity is 10 arm (A5V spectrum), boundaries dimensions rise by 3 times, i.e. reach $0,3 \div 1$ A.U. for metallic planets and $1 \div 10$ A.U. for silicate ones. In model of protoplanetary cluster after Cameron and Pine (1973) masses of silicate planets reach $20m_\oplus$ and faintly depend on density of cluster substance. For metallic planets zone mass of planet is limited by $0.2m_\oplus$, that corresponds to Earth core. Thus the largest radius of metallic planets is finite by 3000 km, and upper limit for silicate planets masses is, probably, equal some tens of $m_\oplus$.

For low-luminosity stars ($M0V$ spectrum) and for density of near-Sun protoplanetary disk situation becomes reverse - magnitudes of temperature zones decrease by 3 times $0.03 \div 0.1$ A.U. for metallic planets and $0.1 \div 1$ A.U. for silicate planets). Masses of the planets decrease by order too. Hydrogen-helium planets could be formed at orbits like orbit of the Earth.

5. Desired physical properties of extrasolar planets

Masses of invisible (obscure) satellites of main sequence stars correspond to hydrogen-helium giant planets. Their parameters (0.38 g/cm^{-3} - medium density of planet in system HD 209458, mentioned before) are in good coincidence with models of hydrogen-helium planets, located near stars.

Masses of planets near pulsar PSR B1257+12 equal to $2.8m_\oplus$ and $3.1m_\oplus$, their big orbit semi-axes amount to 0.17 A.U. and 0.36 A.U. Most probably, the planets are silicate or metallic. The third desired planet with period 25.34 days is metallic. The fourth planet with period 170 years is hydrogen-helium one.

There is a planet with mass more than $2m_\oplus$ and big orbit semi-axis $a = 7.3$ A.U. near pulsar PSRB 0329+54. Most probably the planet is icy or hydrogen-helium.

Temperatures of hydrogen-helium planets in range $200 \div 1500$ K increase thickness of their atmospheres and can't provide dissipation of atmosphere hydrogen. As result, there is a wide variety in optical properties of their atmospheres.

Sudarsky et. al. (2000) have proposed to segregate giant planets into four types, or classes. 'Jupiter' class ($T_{eff} \sim 150$K) planets have ammoniac clouds, for 'water' class ($T_{eff} \sim 250$ K) is specify predominance of condensed water. For planets 'without clouds' $T_{eff} \geq 350$ K. In fourth, 'high temperature' class ($T_{eff} \geq 900$ K) predominance of absorption by alkaline metals and by iron is specify.

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