Chemical Abundances in the Universe:
Connecting First Stars to Planets
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On the origin of giant planets and their hosts

Misha Haywood

GEPI, Observatoire de Paris, CNRS, Université Paris Diderot; 92190 Meudon,France
email: Misha.Haywood@obspm.fr

Abstract. The correlation between stellar metallicity and giant planets has been tentatively explained by the possible increase of planet formation probability in stellar disks with enhanced amount of metals. There are two caveats to this explanation. First, giant stars with planets do not show a metallicity distribution skewed towards metal-rich objects, as found for dwarfs. Second, the correlation with metallicity is not valid at intermediate metallicities, for which it can be shown that giant planets are preferentially found orbiting thick disk stars.

None of these two peculiarities is explained by the proposed scenarios of giant planet formation. We contend that they are galactic in nature, and probably not linked to the formation process of giant planets. It is suggested that the same dynamical effect, namely the migration of stars in the galactic disk, is at the origin of both features, with the important consequence that most metal-rich stars hosting giant planets originate from the inner disk. A planet-metallicity correlation similar to the observed one is easily obtained if stars from the inner disk have a higher percentage of giant planets than stars born at the solar radius, with no specific dependence on metallicity. We propose that the density of H_2 in the inner galactic disk (the molecular ring) could play a role in setting the high percentage of giant planets that originate from this region.

Keywords. Galaxy: disk, stars: abundances, stars: kinematics, (stars:) planetary systems

1. The galactic origin of stars with giant planets

Metal-rich stars ([Fe/H]>+0.20 dex) found in the solar neighborhood, including giant planet hosts, have migrated from the inner disk by the effect of radial mixing (Haywood 2009 ApJL698, L1). Fig. 1a shows the (apocenter, pericenter) distribution of stars with giant planets (SWGP), and illustrates that the bias towards high metallicity has an orbital signature: SWGP will small mean orbital radius are significantly more metal-rich than SWGP with a mean orbital radius greater than 8 kpc. This is interpreted as an indication of the inner and outer origins of the metal-rich and metal-poor thin disk objects. It implies that most SWGP are more metal-rich than the solar vicinity because they are born in a region where most stars are significantly enriched in metals.

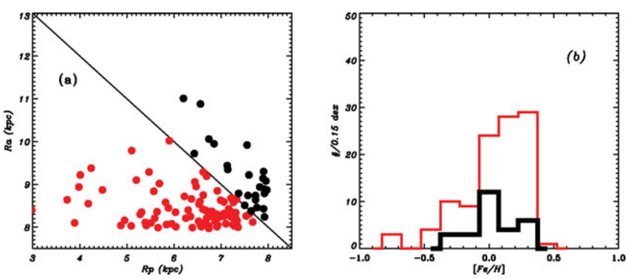

Figure 1. (a) The (apocenter,pericenter) distribution of SWGP. The line is for (Ra+Rp)/2=8 kpc. (b) The histograms are for SWGP with (Ra+Rp)/2<8kpc (thin line) and (Ra+Rp)/2>8 kpc (thick line)

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2. Two caveats

The planet-metallicity correlation fails at low metallicities (-0.7<[Fe/H]<-0.3 dex) and when the host stars are giants. Giant stars hosts are known to have a metallicity not skewed towards high metallicity. This last point is easy to interpret: since most giants are young objects, the radial migration effect cannot be significant in their case. Migration is a process which time scale is the gigayear. Hence, we don't expect young populations to contain objects more metal-rich than the solar vicinity.

The second case where the correlation breaks down is at -0.7<[Fe/H]<-0.3 dex, where stellar populations in the solar vicinity can be divided into two groups: the thin and the thick disks, which differentiate both by their α-elements content and their asymmetric drift. It has been shown in Haywood (2008, A&A 482, 673) that in this metallicity interval, giant planets are found preferentially on thick disk stars, in a proportion of 10 objects being either thick disk or transition objects (between the thin and the thick disks) and 2 objects (one dwarf, HD 171028, and one giant, HD 170693) compatible with belonging to the metal-poor thin disk. There is a hint here that distance to the galactic center may play a role by noting that metal-poor thin disk stars have a probable origin in the outer disk.

3. Another origin for giant planets ?

It is shown in Haywood (2009) that given these arguments, and some other known properties of the metallicity in the galactic disk (its radial gradient), the planet-metallicity correlation can be easily reproduced (Fig. 2), if the rate of planets varies with the distance to the galactic center. Although this is not evidence that the relation between the metallicity of stellar disks and the rate of giant planet formation does not exist, there is no need to invoke such relation to reproduce the known correlation between metallicity and planets.

Given these different results, what galactic property with a dependence to the galactic center may influence the rate of giant planets ? It is tentatively suggested that the incidence of giant planet formation could be higher in regions of the Galaxy where the density of molecular hydrogen, the prime constituent of these objects, is higher. It appears that the galactic radius of origin of the metal-rich stars, at 3-5 kpc from the galactic center, is precisely the location of the molecular ring in the Galaxy.

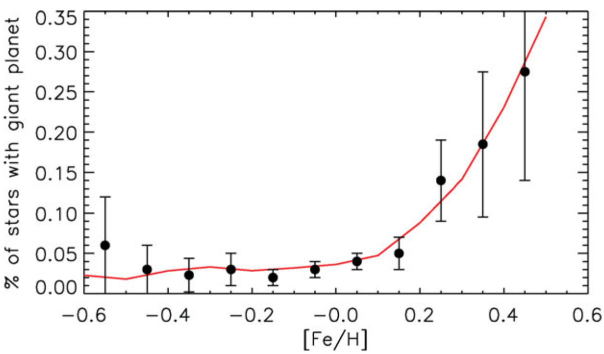

Figure 2. The planet-metallicity correlation is well reproduced assuming that stars originating in the inner galactic disk have a higher percentage of giant planets, with no need to assume a relation between the metallicity of stellar disks and the rate of giant planet formation.

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