Planets in the Early Universe

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Abstract

We argue that planets can form in the very early Universe following immediately the very first episodes of metals production by Population III stars. We show such old "primordial" planets can form in both metal-rich and metal-poor environments. The condititons for the formation of metal-rich planets can be met in multiple isolated pockets of enriched and weakly-mixed gas close to the sources — massive Population III stars. Observations of distant quasars at redshifs $z \sim 5$ and, particularly, gamma-ray bursts at redshifs $z \sim 6$ show a very wide spread of metals in absorptions: from [Z]$\simeq -3$ to [Z]$\simeq -0.5$. Both observations and numerical simulations predict such metal-rich pockets to be more numerous than those with lower metallicity. Physical conditions in such metal-abundant clumps can be similar to the ones where protoplanets form now.

Clumps with low metallicity accrete under self-gravity to higher densities due of low opacity. In such cases the circumstellar accretion disks are expected to rotate faster compared to their high-metal analogues. This can result, in turn, in the radial drift of dust particles to the disk periphery where they coagulate and start forming planetisemals. Discoveries of planets with low-metallicity hosts (e.g. a pulsar planet in globular cluster M4 with [Fe/H]=-1.5, a planet around a halo star IP13044 in the Helmi stream with very low metallicity of [Fe/H]=-2 and a most recent 2 planets around an F dwarf HIP11952 with [Fe/H]=-1.9) demonstrate that planets can indeed be formed in metal-underabundant conditions. Though disk instability appears to be a strong candidate for forming planets in metal-poor systems, other mechanisms are also possible (for ex., Nayakshin 2011) and discussed.