Kinematic Imprint of Clumpy Disk Formation on Halo Objects

INOUE, Shigeki
(Mullard Space Science Laboratory/NAOJ)

Clumpy disk galaxies in the distant universe, at redshift of $z \gtrsim 1$, have been observed to host several giant clumps in their disks [1]. They are thought to correspond to early formative stages of disk galaxies [2]. On the other hand, halo objects, such as old globular clusters and halo stars, are likely to consist of the oldest stars in a galaxy (age $\gtrsim 10$ Gyr), clumpy disk formation can thus be presumed to take place in a pre-existing halo system.

Giant clumps orbit in the same direction in a premature disk and are so massive that they may be expected to interact gravitationally with halo objects and exercise influence on the kinematic state of the halo. Accordingly, I scrutinize the possibility that the clumps leave a kinematic imprint of the clumpy disk formation on a halo system.

I perform a restricted *N*-body calculation with a toy model to study the kinematic influence on halo objects by orbital motions of clumps and the dependence of the results on masses (mass loss), number, and orbital radii of the clumps. My result shows that halo objects can be rotated by clump motions and acquire disky rotation in a dynamical friction time scale of the clumps, ~0.5 Gyr (the top panel of Figure 1). The influence of clumps is limited within a region around the disk, while the halo system shows vertical gradients of net rotation velocity and orbital eccentricity (the bottom panel of Figure 1). The signicance of the kinematic influence strongly depends on the clump masses; the lower limit of postulated clump mass would be $\sim 5 \times 10^8 M_\odot$. The result also depends on whether the clumps are subjected to rapid mass loss or not, which is an open question under debate in recent studies. The existence of such massive clumps is not unrealistic. I therefore suggest that the imprints of past clumpy disk formation could remain in current galactic halos. This result has already been published in a refereed journal [3].

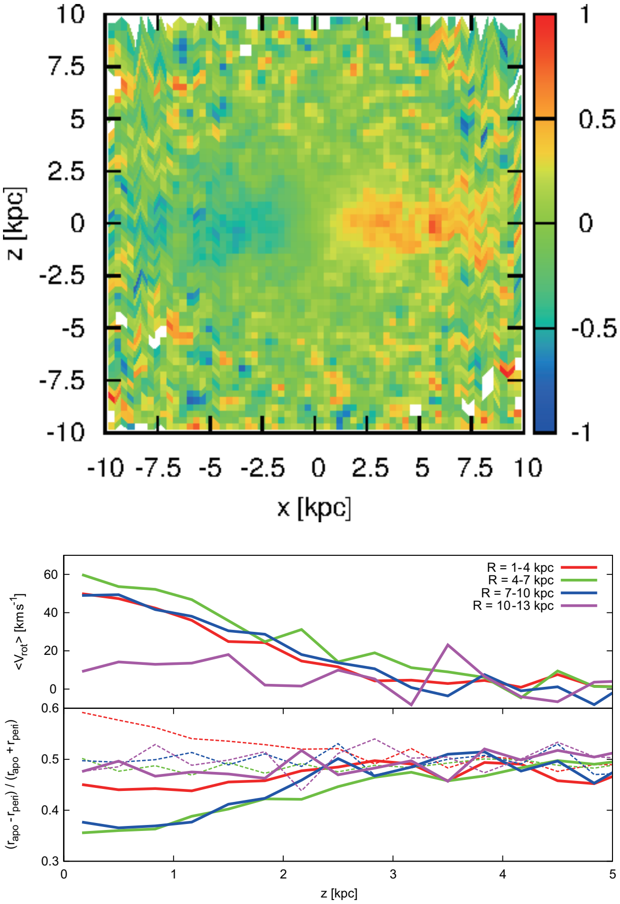

Figure 1: Map of mean line-of-sight velocity from the edge-on view (top). The values are normalized by the line-of-sight velocity dispersion inside $r_0 = 4$ kpc, which is 106 km s^{-1}. The mean azimuthal velocity and orbital eccentricity, $e \equiv (r_{\rm apo} - r_{\rm peri})/(r_{\rm apo} + r_{\rm peri})$, of the halo objects as functions of distance from the clump orbital plane (bottom), where $r_{\rm apo}$ and $r_{\rm peri}$ are apo- and pericenter distances, respectively. Each line indicates a radial range in cylindrical coordinate, R. In the bottom panel, the halo objects rotating prograde and retrograde are separately plotted; the thick and thin lines correspond to prograde and retrograde ones, respectively.

References

[1] Elmegreen, D. M., Elmegreen, B. G., Marcus, M. T., Shahinyan, K., Yau, A., Petersen, M.: 2009, *ApJ*, **701**, 306.
[2] Noguchi, M.: 1998, *Nature*, **392**, 253.
[3] Inoue, S.: 2013, *A&A*, **550**, A11.