Simulated Disk Galaxies at z=2 in OWLS

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ABSTRACT

We study the properties of galactic disks at redshift z=2 selected from the Nbody/gasdynamical OverWhelmingly Large Simulations (OWLS). Our emphasis is on the understanding of the correlations that exist between the disk parameters and the properties of the dark matter halos they inhabit. Our main results suggest a complex relation between the specific angular momentum of the baryons in the galaxy and that of the dark matter: extended, fast rotating disks can reside in very low spin dark matter halos contrary to expectations from previous semi-analytical models. Furthemore, the orientation of the disk and the dark matter angular momentum correlate only weakly, with a mean alignment of 50º. The scaling relations of our galaxies are compared with the recent observations of high redshift objects reported from SINFONI data.

The OWLS project

The **O**ver**W**helmingly **L**arge **S**imulation project (OWLS) consists of a series (~70) of cosmological N-body and hydrodynamical simulations aimed at following the evolution of a large volume (25-100 h^{-1} Mpc) representative of the universe from z~127 up to z~2 or 0.

The sample

Our sample consists of ~150 halos in the mass range $M_{vir} = 1\times10^{11}$-5×10^{12} h^{-1} M_{sun} selected from a 25 h^{-1} Mpc box simulated with 512^3 particles. Our galaxies contain typically between ~[3×10^4-4×10^5] baryonic and ~[2×10^4-6×10^5] dark matter particles within the virial radius, allowing us to study the sizes, rotational speeds and orientations of the galaxies in the sample.

Angular momentum: baryons vs. dark matter in simulated galaxies

j_{bar} vs j_{drk}

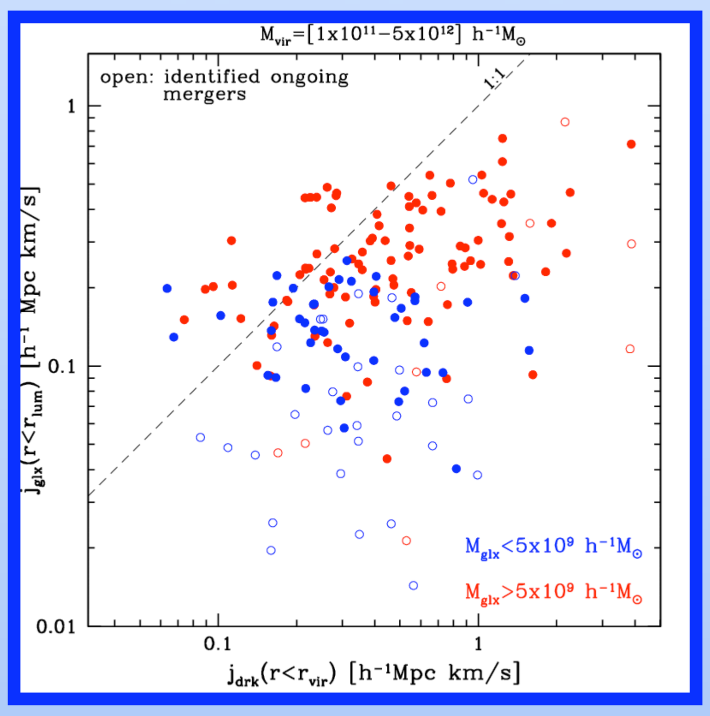


Figure 1 The correlation between j_{drk} (specific angular momentum of the DM halo) and j_{bar} (baryons within the central galaxy) deviates strongly from the 1:1 relation commonly assumed in the semi-analytical models (dashed line). Interestingly, there exist a population of "fast rotating galaxies" that shows $j_{bar}>j_{drk}$. They tend to populate dark matter halos with spins that are typically small for their mass.

Disk sizes

Mo, Mao and White (1998) proposed a relation between the typical size of the disk, R_d, and parameters of the dark matter halo:

$$R_d = \frac{1}{\sqrt{2}}\left(\frac{j_d}{m_d}\right)\lambda r_{200} f_c^{-1/2} f_R(\lambda, c, m_d, j_d)$$

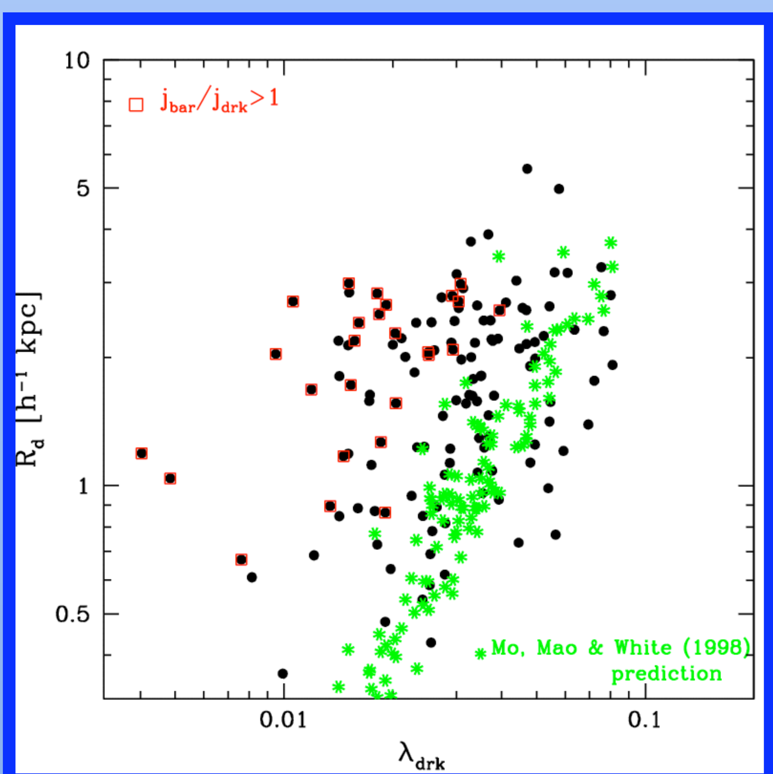


Figure 2 Shows the derived disk sizes of our galaxies based on the above equation assuming $j_d/m_d=1$ (green asterisks) compared to the direct measurements in our simulations (black dots). Red squares highlight the position of galaxies with $j_{bar}>j_{drk}$ in Fig 1.

Alignments

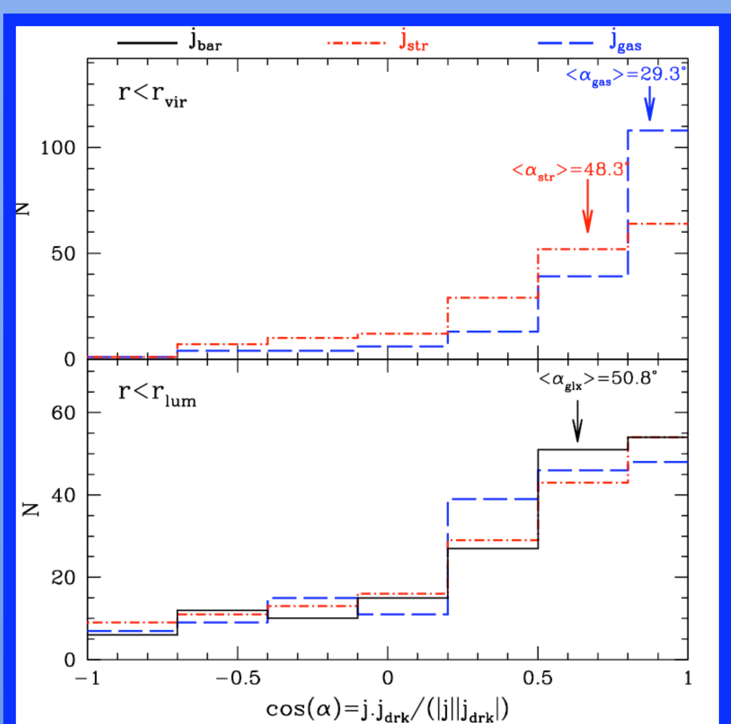


Figure 3 The distribution of the relative alignment between the orientations of j_{drk} ($r<r_{vir}$) and the baryons in the galaxy ($r<r_{lum}$, bottom panel) shows a median of ~50º both for stars and the gas. When all baryons within r_{vir} are considered (upper panel), the alignment with j_{drk} improves in the case of the gas (median ~29º), but does not appreciably change for the stellar component.

The size-velocity plane and SINFONI observations

Cold gas vs stars

Recent Hα observations of galaxies at high redshifts (z~1.5-2.5) performed with SINFONI/VLT have revealed extended emission in disk-like structures that seem to follow the distribution of z=0 galaxies in the size-velocity (SV) plane (Förster Schreiber et al. 2006, Bouché et al. 2007).

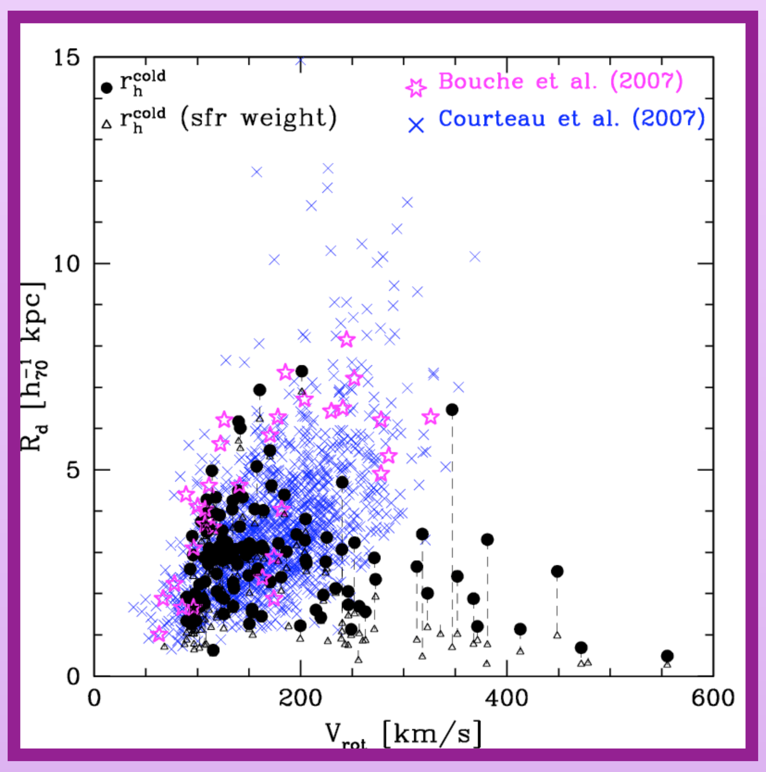
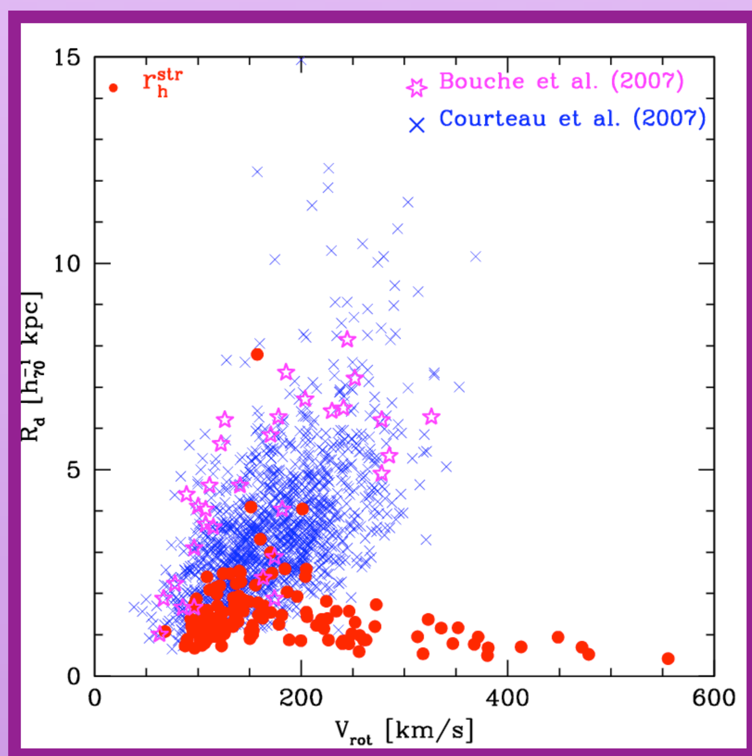


Figure 4 Shows the (*cold-dense gas*) SV plane for our galaxies (solid circles), Hα SINFONI (magenta) and z=0 galaxies from Courteau et al. 2007 (blue). In our sample we do find objects (R_d>5 kpc) comparable to those observed by SINFONI but not predicted by previous models.

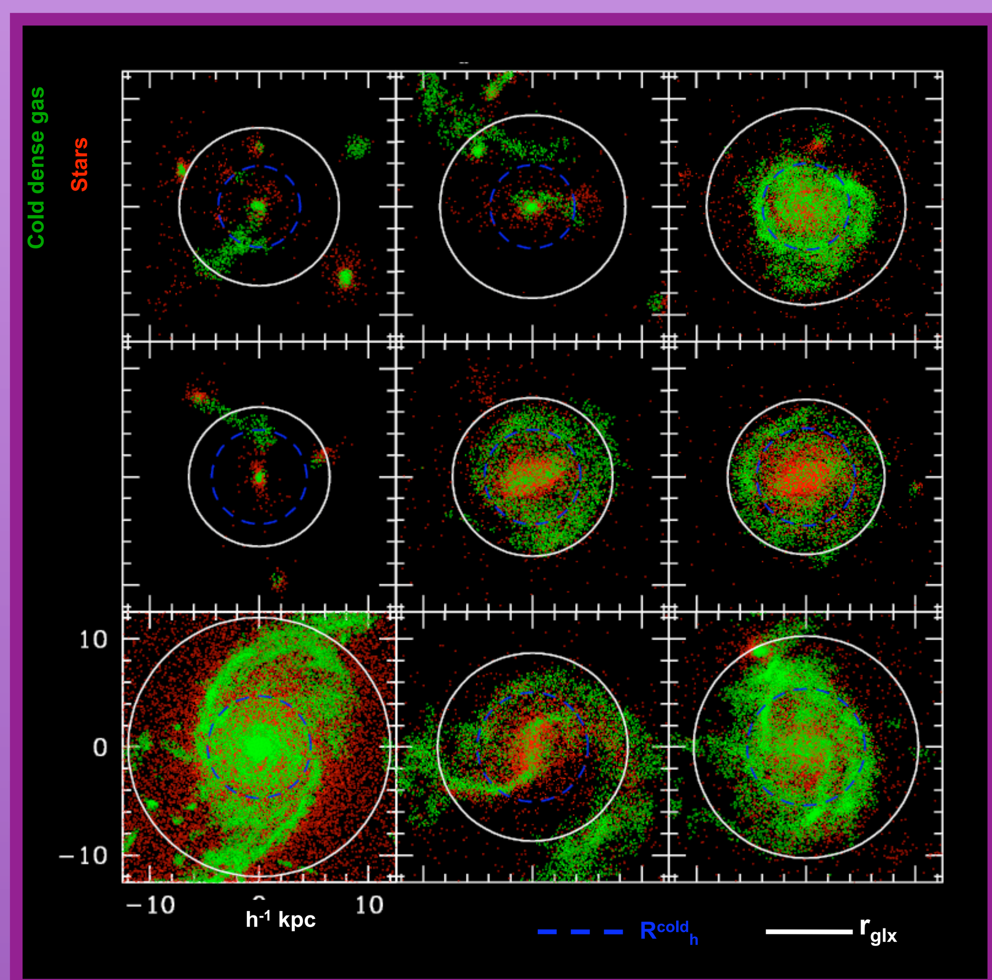


The half mass radius of the stars in the simulations (red points right panel) become significantly smaller than the cold gas disks, and therefore, smaller than the present day galaxies.

Morphologies of extended 'disks'

Figure 5 Face-on view of the 9 most (cold gas) extended objects in our sample. Our systems show an irregular, clumpy and not always centrally concentrated distribution of cold gas, in good agreement with Hα observations.

We find that the fraction of clumps ongoing mergers is not large in these extended systems. About **78%** of the galaxies with r_h>3h^{-1}kpc are real rotating disks.



References:
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