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The Redshift Evolution of Bulges and Disks of Spiral Galaxies in COSMOS

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Abstract. We present a preliminary analysis of the bulge and disk properties for a sample of over 4000 L^* spiral galaxies at $z < 0.84$ from the COSMOS 2 square degree survey. We find that for early Hubble type spiral galaxies (Sa–Sb), the bulge-to-disk ratio is roughly constant over the last 7 Gyr of lookback time. This suggests that bulges of early type spirals were in place early on, consistent with other downsizing signatures. There is a monotonic increase in the bulge-to-disk ratios of late type spirals but that likely reflects the well-known decline in the star formation rate from $z \sim 1$ to the present. For this sample of L^* spirals, we also find that the median exponential scale length of disks remains unchanged at 3.1 kpc from $z = 0.0$ to $z = 0.84$.

1. Introduction

The redshift evolution of galaxy properties provides important constraints on the evolutionary history of the Hubble sequence. In this contribution, we present a preliminary analysis from the COSMOS 2 square degree survey of the disk size and bulge prominence in a sample of L^* spiral galaxies. With this same sample, we have found in a parallel study a dramatic evolution in the bar fraction from $z \sim 0.8$ to the present, but the majority of the evolution occurs in low mass, low luminosity spiral galaxies. The high luminosity, high mass and red spiral galaxies seem to have matured early, not only in their star formation rate, but also dynamically in developing galactic structures such as bars (Sheth et al. 2007). We explore how the evolution in the bar fraction relates to the evolution of bulges and disk sizes.

2. Sample Selection

An overview of COSMOS is given in Scoville et al. (2007a) and details of the *HST* observations are described in Scoville et al. (2007b). The photometric catalog and redshift measurements used for this study are in Mobasher et al. (2007) and Capak et al. (2007). We choose all spiral (Sa–Sd) galaxies (spectral type $T_{\rm phot} > 2$, details on $T_{\rm phot}$ in Mobasher et al. 2007) at $z < 0.84$ that are L^* and brighter (we assume one magnitude of evolution: $M_V^* = -20.7$ at $z = 0$ to -21.7 at $z = 0.9$, Capak et al. 2003). The redshift limit restricts the analysis to rest-frame g-band observations (see detailed discussion in Sheth et al. 2007). With these criteria we are left with a sample of 4409 L^* spirals which are then fitted with GALFIT (Peng et al. 2002).

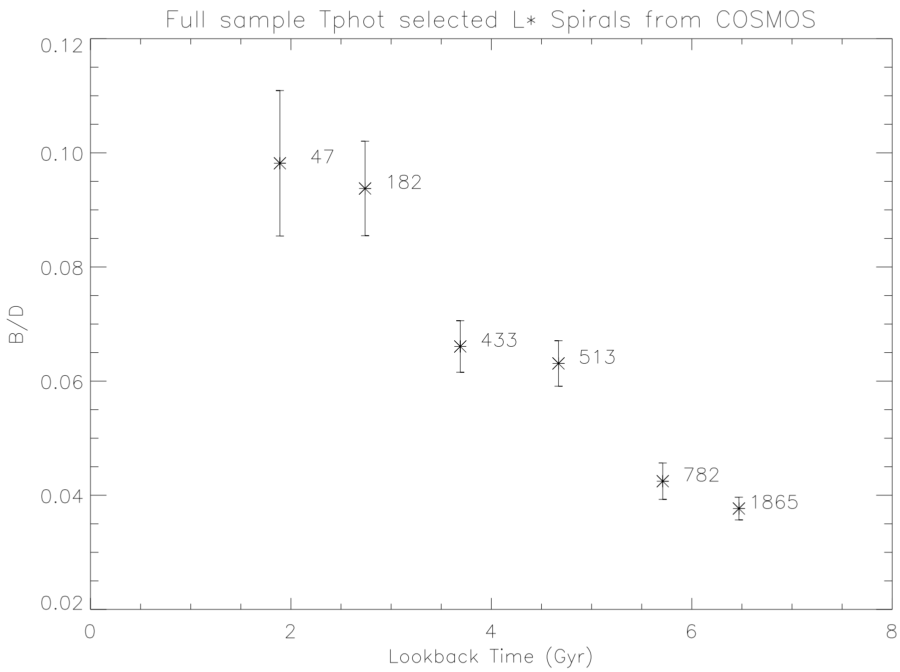

Figure 1. The median bulge-to-disk ratio for the entire COSMOS sample as a function of lookback time. The error in the median is computed by Monte Carlo simulations, taking observed values for B/D and superposing random errors with a dispersion equal to the estimated errors in measurement of the luminosities. The numbers next to the data points reflect the galaxies in each bin. We see a monotonic increase in B/D from $z = 0.84$ to the present.

We fitted each galaxy iteratively with a two-component (Sersic + exponential) model until the residuals were minimized. Each galaxy and residuals were individually examined by eye for robustness. We were able to obtain good results for 3822 galaxies where we measured a slew of parameters such as the luminosity of the disk and bulge, the Sersic index, the exponential disk scale length (R_e), etc. The bulge-to-disk (B/D) ratio is calculated by dividing the measured luminosity for the Sersic component by that of the exponential component. We did not try to deconvolve the contribution from the bars or AGN in these measurements because we assume that the median value is representative of the bulk properties of the sample.

3. Evolution of the Bulge-to-Disk Ratio

The median bulge-to-disk ratio for all the spirals in our sample is shown in Figure 1. There is a monotonic increase in the B/D ratio over the last 7 Gyr.[1] However, the known fading of disks relative to the bulge can also mimic this trend. Since star formation is known to decrease dramatically from $z \sim 1$ to the present, this result should be interpreted with caution.

[1]We assume a Λ-dominated cosmology ($H_0 = 70\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$, $\Omega_\mathrm{M} = 0.3$, $\Omega_\Lambda = 0.7$).

However, the result is completely different for early Hubble type galaxies (Sa–Sb). For these systems the median B/D is roughly constant, and even decreases slightly from $z \sim 0.84$ to the present! Note that our selection of early types is based on the SED (color) of the system and not on its structural properties such as bulge properties, etc. The result in Fig. 2 implies that in the red, early Hubble type systems, the bulge prominence stays constant or decreases to the present day. The expected selection effect of k-correction would have been smaller B/D ratios at higher redshifts because we observe increasingly bluer rest-frame light, which probes the star-forming disk;[2] but the observed trend is exactly the opposite. Figure 2 is thus a robust result which indicates that the bulges of early Hubble type systems were already in place at $z = 0.84$, consistent with other downsizing signatures. This does *not* mean that all early type bulges were present by $z = 0.84$, it simply means that a bulge in an early type galaxy, once formed, does not change significantly over time.

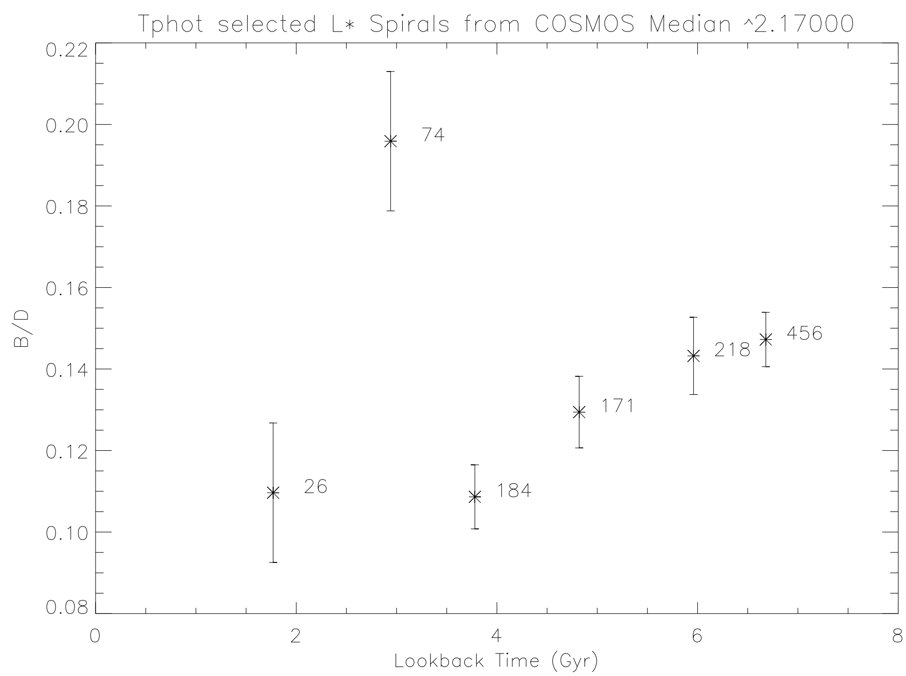

Figure 2. The same B/D redshift evolution as in Fig. 1 but for early Hubble-type spirals only ($2 < T_{\rm phot} < 3$). The B/D is roughly constant. This implies that bulges of early Hubble-type spirals were already in place at a lookback time of 7 Gyr, consistent with other signatures of downsizing. The figure should *not* be misinterpreted as showing that all early type bulges were in place at that time. All this figure shows is that the relative prominence of bulges in early Hubble-type spirals does not change significantly over time.

In the late type systems we see the same monotonic increase in the B/D ratio as we move from high to low redshifts, but this cannot be disentangled from the

[2]The COSMOS field was observed only in the F814W band with the ACS.

effects of k-correction. If real, it suggests that the bulges in late type systems are growing with time.

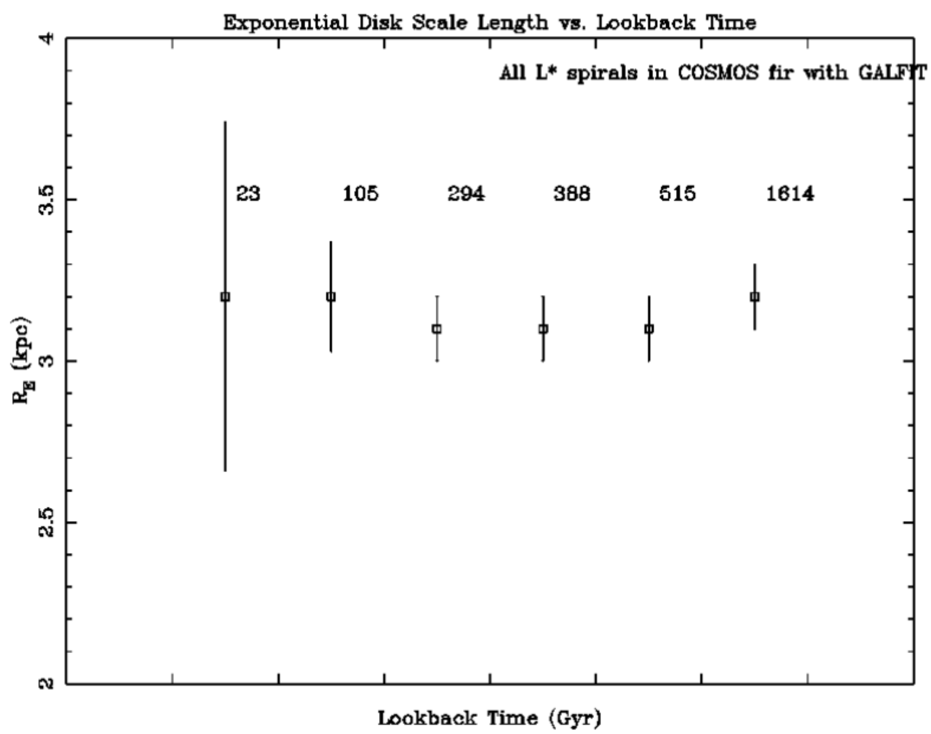

Figure 3. The median exponential scale length of spirals is shown as a function of redshift. We find no change in the disk scale length for this L^* sample, consistent with previous studies.

4. Evolution of the Disk Scale Length

Finally, we studied the redshift evolution of the exponential disk scale length of the sample. As shown in Fig. 3, we see no evolution in the median exponential scale length of the disk. Since we specifically choose to explore the same part of the luminosity function by allowing L^* to vary, the constant scale length suggests a size–magnitude relationship like the one seen in the local Universe.

5. Conclusions

• Analysis of L^* spirals in COSMOS shows that the median bulge-to-disk ratio in early Hubble-type spirals (Sa–Sb) is roughly constant from $z = 0.84$ to the present. Bulges of early type spirals were in place at a look back time of 7 Gyr and bulges in these systems show little evolution.
• There is a monotonic increase in B/D ratio for late type systems but the change is hard to disentangle from k-correction effects and may simply reflect a fading of the stellar disk rather than an increase in the bulge luminosity.

• The median exponential scale length of spirals remains constant at 3.1 kpc over the last 7 Gyr of lookback time.

References

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Discussion

Trujillo: You say that at given morphological type B/D has not evolved since $z \sim 0.8$. Since morphological types are based on visual classification where the prominence of the bulge over the disk is one of the keys to specifying the type, I wonder whether the lack of evolution is not just a definition issue?

Sheth: The morphological type here is *not* determined from a visual classification. It is based on galaxy colors (SEDs matched to spectral templates for different spirals). So the B/D measurement is an independent measure from type. The robustness of the B/D invariance at redshift for early types (spectral) means that bulges in these galaxies were in place as early as 7 Gyr ago. The change of B/D in late types could be evolution of the bulge but could also be the fading of the disk.

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