Tadpole Galaxies in the Hubble Ultra Deep Field

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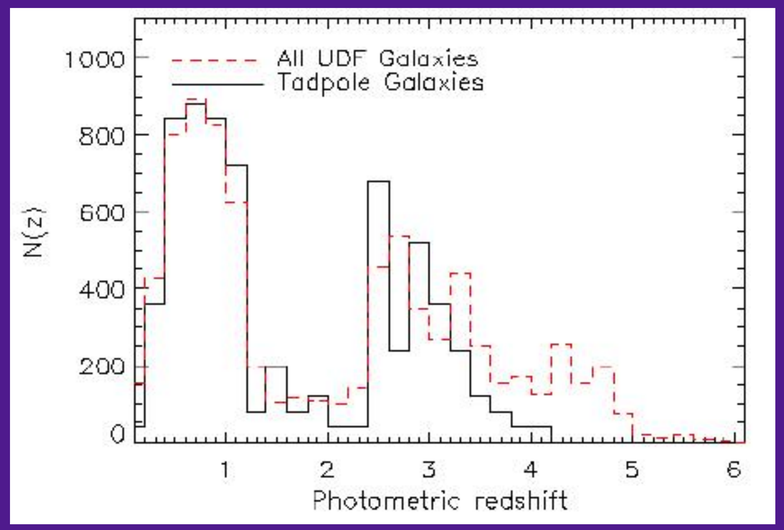
Research objectives:

- **Systematically select elongated, asymmetric "tadpole galaxies" from the UDF**
- **Investigate properties of the tadpole galaxies to i_AB=28.0 mag**
- **Determine their redshift distribution, and the connection between these dynamically unrelaxed galaxies and variable objects in the UDF (Cohen et al. 2005).**



Photometric redshift distribution of galaxies in the UDF. Tadpole galaxies are multiplied by a factor of 16 for comparison. Tadpole galaxies in general follow the distribution of the field galaxies in the UDF.

Procedures:

Galaxies with the characteristic tadpole shape (a "knot" plus a "tail") were systematically selected from the UDF F775W-band data in the following manner. Source extraction was performed using the SExtractor (SE) package (Bertin & Arnouts 1996). The crucial SE parameter that was adjusted to give the desired catalogs of knots and tails was the one that controlled the deblending algorithm, which tells SE how many nearby pointlike objects are to be counted as one source. With the deblending parameter set to a high value, SE will separate the nearby pointlike objects into separate sources. By contrast, when the deblending is set to a low value, the program will count the nearby objects largely as one source. Both of these are used to generate two different source catalogs: the high deblending SE output catalog contains many pointlike sources, including the knots of the tadpole galaxies; the low deblending output catalog contains extended sources, including the galaxies' tails. The SE catalogs contain many more sources than the desired ones; the correctly shaped objects must be selected from these two initial catalogs. The desired tadpole galaxies have a knot or concentration with an extended tail, so these types of sources must be selected from the initial catalog and related spatially such that they represent real objects. Both input SE catalogs contain the following information about the selected sources: x and y pixel locations, size of the semi-major axis (a), size of the semi-minor axis (b), and the position angle (PA) of the semi-major axis from north through east. First, the knots of the tadpoles were selected by setting an ellipticity limit. SE computes the values of the semi-major and semi-minor axes of each source, so a "knot" was defined to be a source from the high-deblending catalog with an axis ratio greater than some critical value (in our case, b/a > 0.70). In the same way, the "tails" needed to be highly elongated objects, so a similar procedure was performed on the objects from the low-deblending catalog, but with the criterion that their b/a < 0.43. The two new lists of correctly shaped objects had to be related spatially on the image, and hence a new set of objects was defined where a knot was within a certain distance from a tail, scaled to the size of the semi-major axis, which was taken to be < 4a units. We also required that the knot be at least >0.1 semi-major axis units from the center of the tail, in order to reduce the number of galaxies with central brighter nuclei only (edge-on, mid- to late-type disk galaxies), since we are after asymmetric objects here. The objects also must have a knot *at one end* of the tail, and this was accomplished by selecting only those tails that had a knot within a certain PA difference from the semi-major axis of the tail. This step prevented including knots and tails that were close together on the image, but not spatially part of the same galaxy. The results from this analysis are summarized below and in the figures.

What we found:

- **A clear abundance of elongated, asymmetric ("tadpole") galaxies in the UDF**
- **Tadpole galaxies' redshifts follow the redshift distribution of all field galaxies in the UDF**
- **Roughly 6% of galaxies are tadpoles at any given redshift to i_AB=28.0 mag**
- **If indeed tadpole galaxies are dynamically young, then galaxy assembly kept up with the reservoir of available field galaxies as a function of cosmic epoch**
- **Tadpole galaxy sample has little overlap with the sample of variable galaxies in the UDF**
- ***The tadpole galaxies' morphologies combined with the lack of overlap between the present sample and the sample of galaxies found to be variable support the idea that these galaxies are in the process of a merger event, i.e. at a stage that precedes the "turn-on" of their AGN and onset of variability***

References:
Bertin, E. & Arnouts, S. 1996, A&AS, 117, 363B
Conselice, C. et al. 2003, ApJL, 600, 139-142
Elmegreen, D.M, et al. 2004, ApJL, 604, 21-24
Elmegreen, D.M. et al. 2004, ApJ, 603, 74-81
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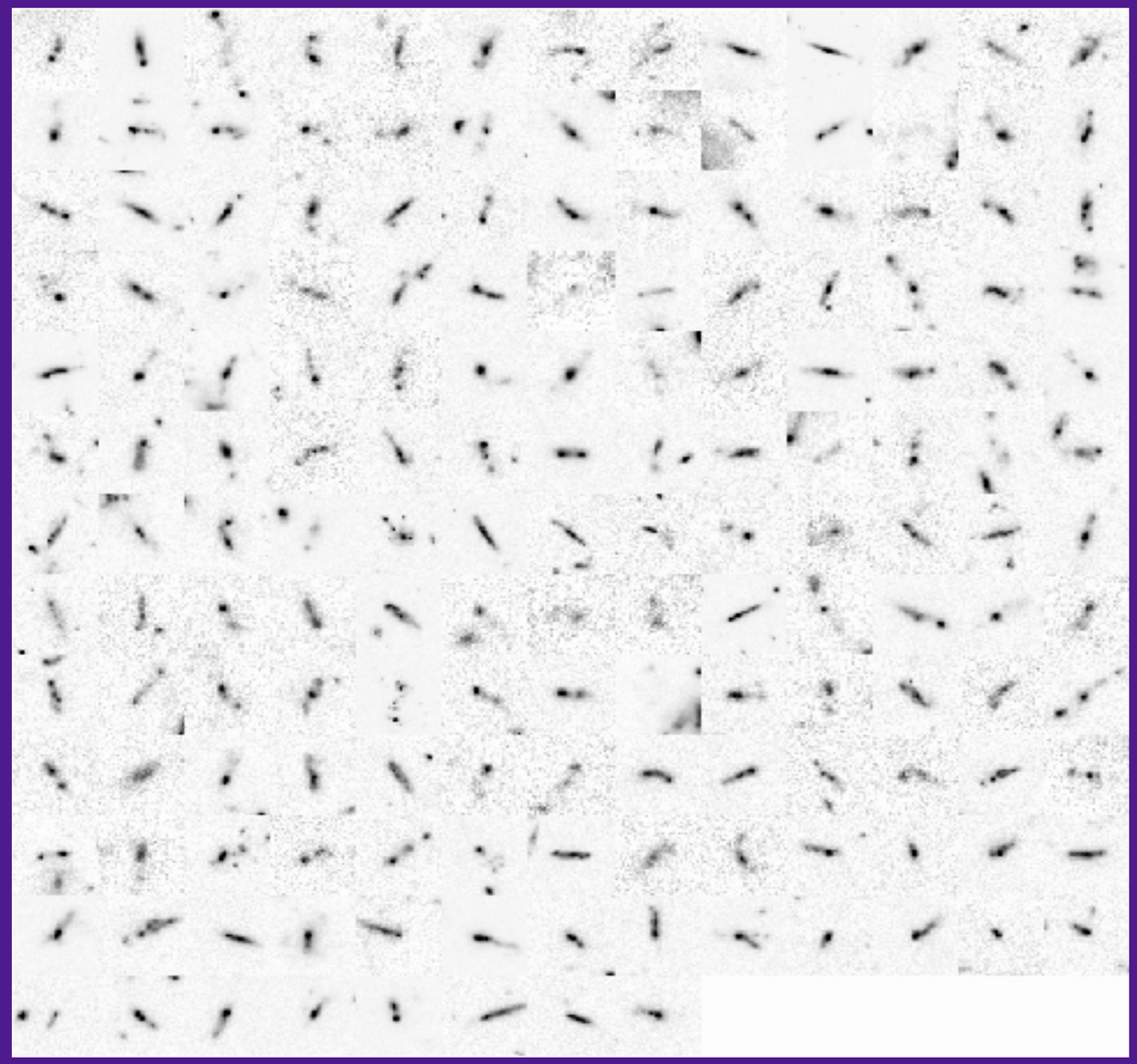
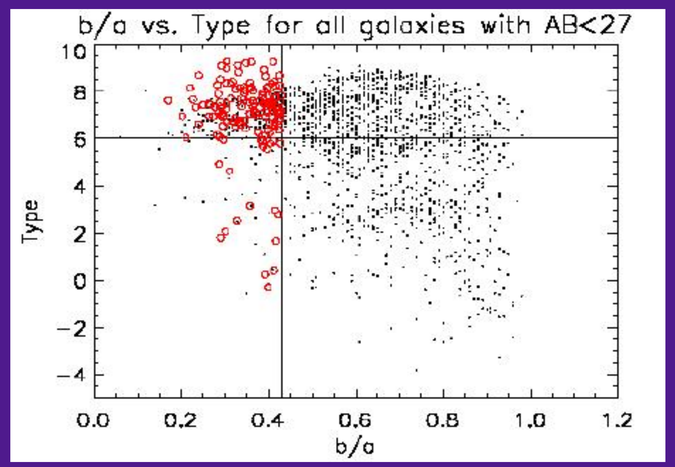
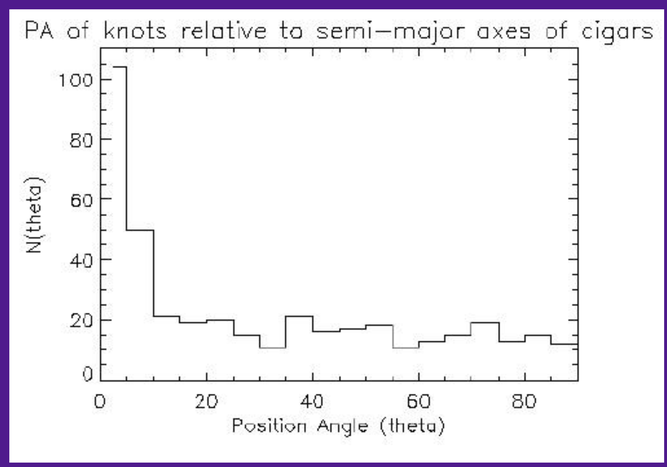


Final set of tadpole galaxies selected from the UDF.



Axis ratios are plotted here as a function of Type as computed by LMORPHO (Odewahn et. al. 1996). Field galaxies are solid black dots; tadpole galaxies are open red circles. The b/a cut imposed by the tadpole-selector program is shown by the vertical line at b/a=0.43. There is a definite clustering of the tadpole galaxies above Type 6 (Sd), which is shown by the horizontal line at this value. The overabundance of Tadpoles at high Type-values is further evidence that these objects are in excess to the number of edge-on galaxies expected for the field. In particular, the fraction of tadpole galaxies to field galaxies of Types>6 comprise 14.7% of the sample; for Types<6, the fraction of tadpoles to all galaxies drops significantly to 4.8%.



This plot shows the distribution of the position angle of each knot relative to the center of the semi-major axis of the nearest tail. Tadpole galaxies have a clear excess of small Δ(theta), suggesting that they are indeed dynamically a separate class, with at least one concentration well away from the geometric center in the major axis direction; tadpole galaxies are in general *not* edge-on mid- to late-type disks, and more likely dynamically unrelaxed.

Dr. Gerald A. Soffen Memorial

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