The Archival Study of Extragalactic Tidal Tails in NGST Observations

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Tidal tails of interacting and merging galaxies, if present with the same frequency and characteristics as in the local universe, should be readily visible out to reasonably high redshifts in many NGST images, even with relatively short exposure times, and especially so in those of moderate and longer exposure times. Although many may be detected from the ground, the detection of these features in greater numbers, at fainter levels, and at higher resolution will provide data with which to attack several important astrophysical problems which can best be done with NGST. Rather than from targeted surveys of galaxies with tidal tails, the main results may mostly be determined from generic “blank” survey fields and from fields targeted for other reasons than observations of tidal tails. The easy detectability of these features would be, although serendipitous, an extra bonus and an important component of the ultimate value of the NGST Data Archive.

1 Introduction: Scientific Motivation and Objectives

Tidal tails of galaxies are the tell-tale signatures of galaxy interactions and mergers and offer us clues to a better understanding of the dynamics of such interactions by providing us with a greater number of examples for use in modeling of these systems. NGST can provide us with a larger number and variety of specific cases, which in turn provides clues to the time-scales and ages of the interactions, and ultimately to bigger questions such as the evolution of the galaxy merger rate and the luminosity function for galaxy interactions and mergers with respect to redshift. For example, were there more mergers and interactions between gas-rich galaxies at higher redshift, and were the masses of gas involved appreciably larger or smaller than what we see locally? The class of objects known as ULIRGs (Ultraluminous Infrared Galaxies) includes some of the best examples of galaxy-galaxy interactions and mergers, especially between gas-rich spirals. But this class of galaxies by no means accounts for all or even a very large fraction of the total population of interacting or merging galaxies. ULIRGs are, by definition, the most luminous galaxies in the infrared, but are relatively scarce in the local universe. Only one, Arp 220 at z=0.018, exists within a redshift volume
of $z=0.033$. But many more interacting and merging galaxies have tidal tails, and ULIRGs only account for about 5% of interactions or mergers within $z=0.05$ or so. Moreover, although NGST is expected to have detectors tuned to the IR, if samples were to be only IR-selected and based more on the nuclear properties, there would be more selection effects to consider. Obscuration by dust does not play nearly as strong a role in tidal tails as it does in the nuclei of some of these galaxies. So the detection of tidal tails is a good way, and in fact one of the best ways, to identify populations of interacting and merging galaxies. As part of a better understanding of the evolution of the galaxy interaction and merger rate with redshift and the associated luminosity function of such objects with redshift, we may also gain a better understanding of the galaxy populations in such specific fields as the Hubble Deep Field. However, the effects of k-corrections will have to be considered above redshifts of 2.5 or so. (See the HDF STScI May 1997 Workshop poster of Borne, Bushouse, Colina, and Lucas for more on this.) We have chosen mainly to concentrate on the range $0 < z < 1.5$ in this paper, as it is known to be a region of great interest with regards to star formation, and starbursts triggered by interactions and mergers may be a very significant contributor to the global star formation rate over this redshift range.

2 Simulated Observations

2.1 Rationale and Methods

As an example of what will be possible with NGST, we have simulated NGST observations of an interacting system with tidal tails. The simulation is based on an HST WFPC2 I-band (F814W) image of the galaxy IR 23128-5919, taken from our HST snapshot survey of ULIRGs. The galaxy IR 23128-5919, at a redshift of $z=0.05$, is a fairly typical example of the ULIRG systems. Based on photometry of this galaxy’s tidal tails and on the typical characteristics of tidal tails in general from Schombert et al. (1990), we assume that tidal tails are typically 21-23 mag arcsec$^{-2}$ in the I-band, and that their $V-I$ colors are roughly 1.0 for areas with older, redder stars, and about 0.1 for areas where there are bluer ”hot spots” or massive young star clusters. Our I-band WFPC2 exposures consisted of two 400 second exposures (the paired exposures being used for cosmic-ray rejection). We have approached the problem of simulating what will be detectable with NGST in two different ways. First, following the methods employed by Giavalisco et al. (1996), we used available information about NGST and its planned detectors to simulate images of IR 23128-5919 at redshifts of $z=0.5$, 1.0, and 1.5 (see Bushouse, Colina, Lucas, and Borne 1998). These redshift values place the rest-frame I-band in the near-IR J, H, and K bands. Simulated NGST JHK images were constructed by manipulating the WFPC2 I-band image to include the effects of cosmological changes in angular size and the resulting amount of signal falling onto individual pixels in the NGST detectors. K-corrections were not included as they are not large enough to be critical over the $0 < z < 1.5$ range because we are still within the regime of I-band shifted to K-band at $z=1.5$.

Our other approach was to use the on-line NGST exposure time calculator (ETC) to compute the expected signal-to-noise ratio of tidal features at different redshifts and
exposure times, as well as the exposure time necessary to obtain a given S/N on these features.

2.2 Results

Our results may be viewed in several ways. First, for a visual comparison, the original WFPC2 I-band image of the galaxy at \( z=0.05 \) (Figure 1) may be compared to the images of the galaxy when redshifted out to \( z=0.5 \), 1.0, and 1.5 respectively, as is shown in Figure 2. In this case, all exposure times were taken to be the same as our original WFPC2 I-band exposures (400 seconds). The three images shown in Figure 2 represent what NGST would see in the J-band for a galaxy at \( z=0.5 \), in the H-band for a galaxy at \( z=1.0 \), and in the K-band for a galaxy at \( z=1.5 \). (See Bushouse, Colina, Lucas, and Borne, 1998, in “Science With NGST” for more details on the creation of our simulated images.)

Second, from our use of the on-line NGST exposure time calculator, our results may be represented numerically in terms of a standardized exposure time on our “typical” galaxy, IR 23128-5919, in order to see what level of S/N is reached, or they may alternatively be considered in terms of a standardized S/N in order to determine what exposure time is required to reach that level of S/N. For our estimates based on a standardized exposure time of 400 seconds, our best case estimate was for tidal tail features with \( I=22 \) mag arcsec\(^{-2}\) at \( z=0.5 \), which yields S/N=196 in the J band. Our worst case estimate was for \( I=24 \) mag arcsec\(^{-2}\) at \( z=1.5 \), which yields S/N=62 in the K band. Looking at it another way, if we assumed a desired S/N=20, our best case was for \( I=22 \) at \( z=0.5 \), for which a 4-second exposure in J was required, and our worst case was for \( I=24 \) at \( z=1.5 \), for which a 40-second exposure in K was required. Therefore features such as these should be easily detectable in NGST images of only moderate exposure times.

3 Conclusions: Benefits of NGST and Value of the Archive

Unlike many specifically targeted surveys of various classes of objects, but perhaps much more like the HST Medium Deep Survey and other similar projects, the detailed, in-depth study of tidal tails out to higher redshift should be an added serendipitous benefit of observations of many fields with NGST. If indeed as frequent at higher redshifts as we would expect \textit{a priori}, our simulations and calculations show that they should be very easily seen even in reasonably short exposures with the detectors proposed for NGST. The greater resolution and fainter detection limit of tidal tails should enable us to more thoroughly study the nature of such galaxy interactions at higher redshift, and to better estimate any evolution in the galaxy merger rate with time, as well as to better determine any evolution in the luminosity function of such galaxy mergers over time. It will also enable us to study the tidal tails detected in greater detail, perhaps revealing such features as massive star clusters and dwarf galaxies embedded in the tidal tails at significantly higher redshift than has ever been
possible before, and thereby also enabling us to better understand any evolutionary
effects in those kinds of features, and the roles which they may play in the evolution
of galaxies as a whole. We have chosen here to describe our results in terms of
observations of a kind which should be relatively easy for NGST, especially if the
objects are typically within some range of brightness of our example, IR 23128-5919,
as we would expect many to be (although this object in particular may be more
toward the brighter side of a typical distribution than some). At any rate, we do this
mostly to point out the great value which such observations may have in helping us
better understand the dynamics and types of interactions more common at higher
redshifts by providing more detailed resolution and better morphological information
about progenitors in galaxy interactions and mergers at higher redshifts, as well as the
general points mentioned above about any evolution in the merger rate and luminosity
function of interactions and mergers. This relatively easy detectability of tidal tails
would be an additional valuable asset of the eventual NGST Data Archive as well.

References

Borne,K.D., Bushouse,H., Colina,L., and Lucas,R.A. “STScI HDF May Workshop
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Sanders,D. and Mirabel,F. ARAA 1996, 34, 749

Figure 1: The original WFPC2 I-band image of the z=0.05 ULIRG IR 23128-5919 from Bushouse, Colina, Lucas, & Borne (1998).
Figure 2: The redshifted images of IR 23128-5919 at $z=0.5$, $z=1.0$, and $z=1.5$, respectively, from Bushouse, Colina, Lucas, & Borne (1998). These images represent I-band shifted to J, H, & K respectively.