



The Toomre Sequence Revisited: HST/NICMOS Investigation of the Nuclei in Interacting and Merging Galaxies



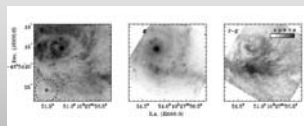
Joern Rossa (University of Florida, Gainesville, FL), Seppo Laine (Spitzer Science Center, Pasadena, CA), Roeland van der Marel (STScI, Baltimore, MD),

John Hibbard (NRAO, Charlottesville, VA), Christopher Mihos (Case Western Reserve University, Cleveland, OH),

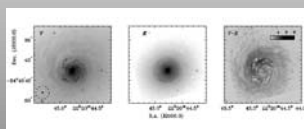
Torsten Boeker (ESTEC, Noordwijk, The Netherlands), Ann Zabludoff (Steward Observatory, University of Arizona, AZ)

Abstract

We present the NIR properties of the nuclei in the 11 merging galaxies of the Toomre Sequence (TS; Toomre 1977), based on high spatial resolution J, H, and K imaging data, gathered with NICMOS on-board HST. The observations have the advantage over our previous HST/WFPC2 investigation (Laine et al. 2003) that the results are much less affected by dust extinction. Also, the data offer significantly higher spatial resolution than existing ground-based NIR data. In most cases we confirm the position of the galaxy nucleus/nuclei reported from data in other wavebands. In NGC7764A we detect for the first time two nuclei with a separation of about 260 pc. This is consistent with the placement of NGC7764A in the middle of the merger sequence. There is a trend for the nuclei in the sequence to become less dusty and more luminous with advancing merger stage. We derive K-band surface brightness profiles for those nuclei for which the morphology allows a meaningful isophotal analysis. The results are fit with a Nuker-law for comparison with other samples of galaxies observed with HST. The majority of the nuclei have steep profiles that can be characterized as power-law type. Given the absolute luminosities of the Toomre sequence nuclei, the low number of core-type profiles is consistent with what has been found for E/S0 galaxies. However, the TS nuclei tend to have steeper profiles and higher central surface densities than E/S0s. These findings can both be explained if the TS galaxies have newly formed stars that are concentrated towards their centers. This is exactly what is expected on the basis of N-body simulations of the merger process of spiral galaxies. If left to evolve and fade for several more Gyrs, it is quite possible that the properties of the TS nuclei would look very similar to the properties of the nuclei of normal E/S0 galaxies. Our results therefore support the view that mergers of spiral galaxies lead to the formation of early-type galaxies.

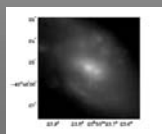


TS=9

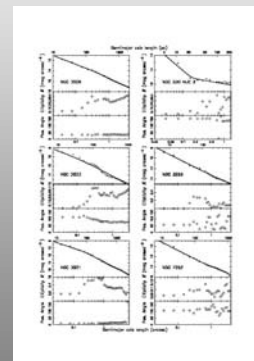
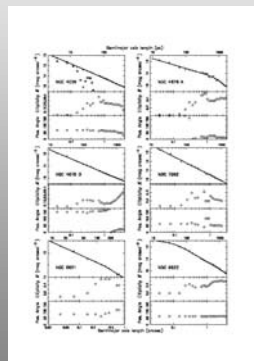


TS=11

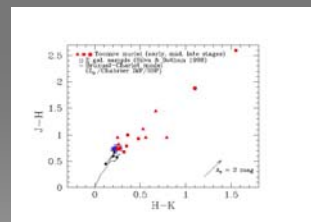
V-band (WFPC2), K-band (NIC2) and V-K image of selected mergers at various stages, indicated by the TS number (1-11)



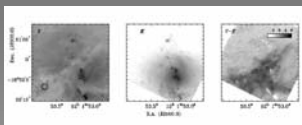
K-band image of the double nucleus in NGC7764A. FOV: 2.7 kpc x 2.7 kpc



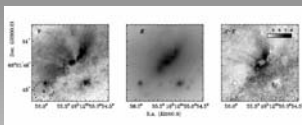
Major axis surface brightness (SB) profiles of the nuclear regions of selected TS galaxies, where a fit was possible. The sub-panels show the SB profiles overplotted with a Nuker model fit (solid line). For comparison we also plot the NICMOS PSF in the left diagram (upper left, star symbols, arbitrarily normalized).



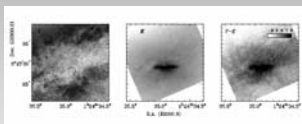
Color-color diagram of the Toomre nuclei within a 100 pc aperture (indicated by red symbols). The sample of E's studied by Silva & Bothun (1998) is also shown (blue open squares). Solid curve: Bruzual-Charlot age tracks for a Chabrier IMF, black symbols: 10E+7, ..., 10E+10 yrs.



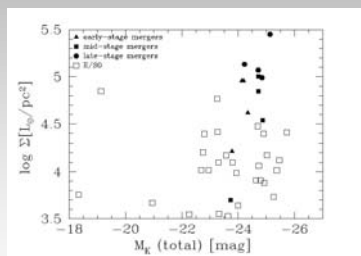
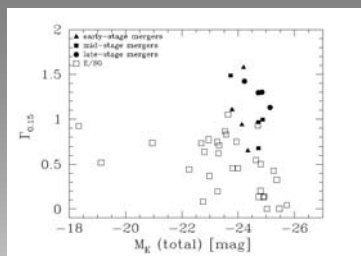
TS=1



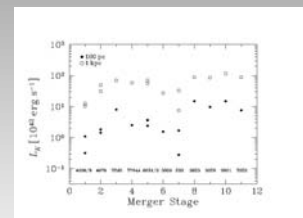
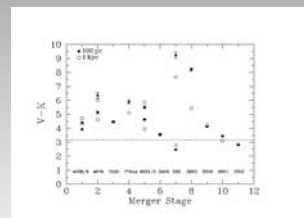
TS=5



TS=7



Relations between best-fit power-law slope at 0.15'' ($\Gamma_{0.15}$) (top panel) and surface luminosity density (bottom panel) as a function of the total K-band magnitude. The open symbols denote the data of the E/S0 galaxies studied by Ravindranath et al. (2001)



V-K color (left panel) and K-band luminosity (right panel) within apertures of 100 pc and 1 kpc as a function of merger stage.

Sample selection and Observations

Sample selection:

The Toomre sequence (Toomre 1977): 11 galaxy merger systems consisting of NGC4038/39, NGC4676A/B, NGC7592, NGC7764A, NGC6621/22, NGC3509, NGC520A/B, NGC2623, NGC3256, NGC3921, NGC7252.

Observations:

HST/NICMOS F110W, F160W, F205W, F222M (J, H, and K-band).

→ 0.075''/pixel, NIC2 aperture (19.2'' x 19.2'' fov)

References:

- Laine, S., van der Marel, R. P., Rossa, J., Hibbard, J. E., Mihos, J. C., Böker, T. & Zabludoff, A. I. 2003, AJ, 126, 2717
- Toomre, A. 1977, in: "The Evolution of Galaxies and Stellar Populations", eds. B. M. Tinsley and R. B. Larson (New Haven: Yale University), p. 401
- Ravindranath, S., Ho, L. C., Peng, C. Y., Filippenko, A. V. & Sargent, W. L. W. 2001, AJ, 122, 653
- Silva D. R., & Bothun, G. D. 1998, AJ, 116, 85