

## **New and Complete Methods to constrain the Evolution of Massive Galaxies and their central Black Holes**

### *Final report*

In this second year of work we have completed several of the steps detailed in our application. Details on the scientific achievement are detailed in the following list:

1. Francesco Shankar has refined the semi-empirical model for galaxy evolution (SHAM) built on top of numerical dark matter merger trees. Details of the code have been provided in the Application and in the mid-term report, but for convenience are briefly reviewed here. Along the main branch the central galaxy is initialized via empirical correlations, and morphologically progressively transformed from disc to bulge/spheroid via minor and major mergers, as well as disc instabilities. Similarly, all infalling satellites on the main branch are initialized via empirical correlations and assigned a dynamical friction timescale. One paper has been submitted on results obtained with this model: Shankar, Mei et al., submitted. This paper shows for the first time how environment can efficiently break degeneracies among different galaxy evolution models.

2. The SHAM model has been used to study on one side environmental dependence, and on the other side the role of progenitor bias in determining the global size evolution of early-type galaxies. A separate paper is in preparation.

3. A Halo Occupation Distribution (HOD) model that assigns central and satellite galaxies to dark matter haloes in a given simulation has been developed. The HOD technique is extremely useful and complementary to full galaxy models, as it empirically probes the spatial location of galaxies inside and outside dark matter haloes. A technical paper led by the Fellow is in preparation. The latter work will serve as a base to create the mock catalogs for the preparation phase of the European mission EUCLID.

4. Regarding the other important goal of the Marie Curie project, i.e., the co-evolution of BHs and galaxies, the Fellow has further refined the continuity equation codes started before the beginning of the Marie Curie, to insert predictions of small and large scale structure of active galaxies at all redshifts and luminosities. A paper on this project is underway, and will be submitted by the end of 2013-

beginning of 2014. Other achievements in this respect have been a clear advance in the determination of the local BH mass function, an invited review for Classical and Quantum Gravity (submitted), and a refinement of the QSO merger model. All these papers are included in the lists below.

5. A variety of additional projects have been started by the Fellow during this second year with different collaborators, and all focused on the project of the Marie Curie grant. These projects will still serve as a base for future publications in the years 2014-2015.

The support of the European grant will anyway be acknowledged in all the publications where the support of the Marie Curie grant has been relevant.

The main projects are (not given in any publication list below):

- study of the bolometric luminosity function of active galaxies;
- obscured fraction of active galaxies;
- study of the colour and velocity functions of massive, early-type galaxies coupled to their size evolution;
- general predictions of alternative models for the size evolution of early-type galaxies using expansion and shut-down models.

It is relevant to point out that thanks to the visibility offered by the Marie Curie grant, the Fellow was able to step in a number of shortlists for faculty jobs in Europe. In June 2013, he has been offered a permanent Lectureship at the University of Southampton, UK.

PUBLICATIONS (First Author):

3-F. Shankar, S. Mei, et al. 2013, The dependence of the mass-size relation of early-type galaxies on environment in the local Universe, MNRAS, submitted.

2-F. Shankar, et al. 2013, The coupled Size, Number Density, and Environmental evolution of massive Spheroids in hierarchical models of galaxy formation, MNRAS, to be submitted.

1-F. Shankar 2013, Black Hole Demography: from scaling relations to models, Classical and Quantum Gravity, submitted.

OTHER PUBLICATIONS contributed by the fellow during the Marie Curie fellowship and submitted in 2013:

8-S. Kavirai et al. 2013, The role of major mergers in the size growth of spheroids, MNRAS, submitted.

7-M. Bernardi et al. 2013, The massive end of the luminosity and stellar mass functions: Dependence on the fit to the light profile, MNRAS, submitted.

6-M. Bernardi et al. 2013, Sersic index and B/T ratio in SDSS galaxies: Evidence for the two-component Sersic-Exponential model, MNRAS, re-submitted.

5-L. Delaye et al. 2013, Mass-size relation of red sequence early-type galaxies in high redshift clusters, MNRAS, submitted.

4-R. Laesker et al. 2013, Supermassive Black Holes and Their Host Galaxies II. The correlation with near-infrared luminosity revisited, MNRAS, resubmitted after first referee report.

3-V. Allevato et al. 2013, Clustering of X-ray selected AGNs at  $z=3$ , to be submitted.

2-F. Fiore, F. Shankar et al. 2013, Connection between galactic outflows and Black Hole accretion, to be submitted.

1-M. Stringer, G. Novak, F. Shankar et al. 2013, Galaxy Size evolution as a consequence of cosmology and feedback, to be submitted.

OTHER PAPERS (First Author) to be submitted within end 2013-beginning 2014, linked with the Marie Curie project

(semi-drafts on the following papers are possibly available upon request):

5-F. Shankar, et al. 2014, Testing Halo Occupation Distribution models against the DEUSS simulations, MNRAS, to be submitted.

4-F. Shankar, et al. 2014, The Bulge-Halo Conspiracy from the Size Evolution of massive Spheroids, MNRAS, to be submitted.

3-F. Shankar, et al. 2014, Constraining black hole evolution from their Clustering, MNRAS, to be submitted.

2-F. Shankar, et al. 2013, Revisiting local scaling relations and Demography of super-massive Black Holes, MNRAS, to be submitted.

1-F. Shankar, et al. 2013, Merger-induced quasars, light curves and their host halos, MNRAS, to be submitted.

Conferences in 2013:

4-Conference, contributed talk: Physical Processes of Galaxy Formation 21-28 July 2013 <http://mrs2013.pytheas.univ-amu.fr/>

3-Turku, EWASS Symposia 7-12 July 2013 (<http://www.astro.utu.fi/EWASS2013/programme.php>)

2-IAP Galaxy Conference: contributed talk. <http://www.iap.fr/col2013/>

1-LEIDEN EUCLID MISSION CONFERENCE: Participation as an Euclid member. Euclid is the next generation European space mission. <http://euclid.strw.leidenuniv.nl/home.html>