Cosmic Formation and the Evolution of Galaxies and Massive Black Holes

Richard Genzel

2003 Balzan Prize for Infrared Astronomy

Balzan GPC Adviser: Per Olof Lindblad
Main Researchers: Avishai Dekel, Christopher McKee, Eliot Quataert, Amiel Sternberg
Graduate Students: Natascha Förster-Schreiber, Kristen Shapiro
Affiliated Institutions: Max-Planck-Institut für extraterrestrische Physik (MPE); University of California, Berkeley
Period: 2003-2010

Richard Genzel is Director of the Max-Planck-Institut für extraterrestrische Physik in Garching, Germany. Genzel's projects supported by Balzan funds aimed to explore how the connection between the evolution of central black holes and galaxies came about, what physical processes were involved and when the local black hole/galaxy mass relationship was established. They also investigated how massive galaxies like the Milky Way were formed and what the role of galaxy collisions and mergers in the assembly of galaxies was, including the mechanisms leading to the fuelling of the most luminous quasars. This was done by using instruments his team had developed for ground-based, airborne and space telescopes. In particular, the second part of the Balzan Prize was used to strengthen the interaction between the experimental/observational group at the Max-Planck-Institut für extraterrestrische Physik (MPE) and several theoretical and interpretative research groups, in particular, the University of California, Berkeley (USA) and the University of Tel Aviv (Israel), by supporting scientific exchange and providing short-term support for collaborative research, specifically carried out by young scientists.

One highlight of the research supported in part by Balzan funds was a new major effort using the MPE-developed SINFONI near-infrared integral field spectrometer (at the ESO-VLT) for the first-ever survey of the kinematics of massive star forming

galaxies at redshift ~2, approximately 3 billion years after the Big Bang. This groundbreaking survey, called SINS, was highly successful and provided key insights into the evolution of stars forming galaxies at that epoch. It become clear that large disks comparable in mass to the modern Milky Way already existed at that time, but with substantially different physical properties. These observations, in conjunction with theoretical work by other groups in Israel and California, led to a significant shift in thought on how massive galaxies formed and evolved during this epoch. The SINFONI observations suggest that, rather than major mergers, rapid and continuous accretion of gas from the dark matter halos (the so-called 'cold flows') may have dominated the mass assembly of massive galaxies. This very ambitious, unique survey led to the publication of a number of papers, including a milestone article in *Nature* in 2006.

The Balzan funds helped to provide seed funding for the support of young researchers at MPE, and to stimulate international collaboration. Dr. Natascha Förster-Schreiber, hired at MPE (in part by Balzan funds), became the leading scientist of the SINS survey, and her outstanding work led to the prestigious Minerva MPG Fellowship (an independent research position funding a small research group for five years) in 2007. In Tel Aviv, a research group led by Professor Amiel Sternberg also carried out active work on this project. The seed funding by the Balzan Foundation led to the award of prestigious Deutsch-Israelische Projektkooperation (DIP) funding by the Deutsche Forschungsgemeinschaft (DFG). The DIP funding allowed MPE-Israel collaboration to include the theoretical group of Professor Avishai Dekel at Hebrew University, Jerusalem. Balzan funding also supported scientific research and international exchange in galaxy formation/evolution at the University of California, Berkeley, mainly with Professors Christopher McKee and Eliot Quataert, while also including graduate student Kristen Shapiro, who spent part of her time at Berkeley and part at MPE.

Publications

Bouché N et al. 2010. The Impact of cold gas accretion above a mass floor on galaxy scaling relations. The Astrophysical Journal. 718: 1001-1018.

Bouché N et al. 2007. Dynamical properties of z ~ 2 star-forming galaxies and a universal star formation relation. The Astrophysical Journal. 671: 303-309.

Cresci G. 2009. The SINS Survey: Modeling the Dynamics of z ~ 2 Galaxies and the High-z Tully Fisher Relation. The Astrophysical Journal. 697: 115-132.

Förster-Schreiber NM et al. 2006. SINFONI integral field spectroscopy of z ~ 2 UV selected galaxies: rotation curves and dynamical evolution. The Astrophysical Journal. 645: 1062-1075.
Förster-Schreiber NM et al. 2009. The SINS Survey: SINFONI integral field spectroscopy of z ~ 2 star-forming galaxies. The Astrophysical Journal. 706: 1364-1428.
Genzel R et al. 2006. The rapid formation of a large rotating disk galaxy three billion years after the Big Bang. Nature. 442: 786-789.
Genzel R et al. 2008. From rings to bulges: Evidence for rapid secular galaxy evolution at z ~ 2 from integral field spectroscopy in the SINS Survey. The Astrophysical Journal.
Genzel R. 2009. Astrophysics: Galaxies in from the cold. Nature. 457: 388-389.
Nesvadba NPH et al. 2006. Lyman break galaxies under a microscope: the small-scale dynamics and mass of an arc in the Cluster 1E 0657-56. The Astrophysical Journal. 650: 661-668.