Reinhard Genzel

2003 Balzan Prize for Infrared Astronomy

Professor Reinhard Genzel has made fundamental contributions to Infrared Astronomy. He has developed instrumentation which enabled him and colleagues to make outstanding discoveries, including evidence for a massive black hole in the centre of our galaxy.

Cosmic Formation, Evolution of Galaxies and Massive Black Holes

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The detailed study of stars' motion by Genzel's group shows that the Milky Way, our galactic centre, contains a central black hole which is a few million times as massive as the Sun. This is arguably the best evidence for the existence of black holes. It has also recently become clear that most massive black holes have formed early in the evolution of the universe, and that their evolution was intimately related to that of the galaxies in which they are embedded. Genzel's project supported by Balzan funds was in fact aimed at exploring how this connection came about, what physical processes were involved, when the black hole/galaxy mass relationship was established.

The main highlight of the research supported in part by the Balzan funds has been a new major effort, using the MPE-developed SINFONI near-infrared integral field spectrometer at the ESO-VLT (Very Large Telescope of the European Southern Observatory in Chile) 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 (Spectroscopic Imaging survey in the Near-infrared with SINFONI), has been highly successful and has given key insights into the evolution of star-forming galaxies at that epoch. It has become clear that large and massive disks comparable in mass to the modern Milky Way already existed at that time, but with substantially different physical properties. These recent observations, in conjunction with theoretical work of collaborators in Israel and California, have 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.

The Balzan funds have been helpful in providing seed funding for the support of young researchers at MPE, and for stimulating international collaboration. A young scientist, Dr. Natascha Förster Schreiber, was hired at MPE (in part by Balzan funds), and has become the leading scientist of the SINS survey. Her outstanding work has attracted world-wide attention. She won a 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 Prof. Amiel Sternberg has also started active work on this project. The seed funding by Balzan led to the award of prestigious DIP funding (German-Israeli Project) by the German Science Foundation. The DIP funding allows MPE-Israel collaboration to include the theoretical group of Prof. Avishai Dekel at Hebrew University (Jerusalem). Balzan funding also supports 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 spends part of her time at Berkeley, and part at MPE.

Publications:

- Bouché, N. , et al., *The Impact of cold gas accretion above a mass floor on galaxy scaling relations,* "The Astrophysical Journal" (submitted).
- Bouché, N. , et al., *Dynamical properties of z ~ 2 star-forming galaxies and a universal star formation relation, "*The Astrophysical Journal", 671, 303-309, 2007.
- Cresci, G., *The SINS Survey: Modeling the Dynamics of* z *~ 2 Galaxies and the High-*z *Tully-Fisher Relation,* "The Astrophysical Journal", 697, 115-132, 2009.
- Förster Schreiber, N.M., et al., *SINFONI integral field spectroscopy of z ~ 2 UV-selected galaxies: rotation curves and dynamical evolution*, "The Astrophysical Journal", 645, 1062-1075, 2006.
- Förster Schreiber, N.M., et al., *The SINS Survey: SINFONI integral field spectroscopy of* z *~ 2 star-forming galaxies,* "The Astrophysical Journal", 706, 1364-1428, 2009.
- Genzel, R., et al., *The rapid formation of a large rotating disk galaxy three billion years after the Big Bang,* "Nature", 442, 786-789, 2006.
- Genzel, R., et al., *From rings to bulges: Evidence for rapid secular galaxy evolution at z ~ 2 from integral field spectroscopy in the SINS Survey*, "The Astrophysical Journal", 2008.
- Genzel, R., *Astrophysics: Galaxies in from the cold*, "Nature", 457, 388-389, 2009.
- Nesvadba, N.P.H., et al., *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, 2006.

- Shapiro, K.L., et al., *Kinemetry of SINS high-redshift star-forming galaxies: Distinguishing rotating disks from major mergers*, "The Astrophysical Journal", 682, 231-, 2008.
- Shapiro, K.L, et al., *The SINS Survey: Broad emission lines in high-redshift star-forming galaxies*, "The Astrophysical Journal", 701, 955-963, 2009.

Statements by the Prizewinner and by Natascha Förster Schreiber:
The future thus appears bright. I hope that my colleagues and I can continue to play an active role in this adventure. The support of the Balzan Prize will be an important foundation and stimulus for our work. Reinhard Genzel (Berne, 07.11.2003)

We have been able, for the first time, to obtain well resolved, two dimensional images of the gas motions in distant star-forming galaxies, whose light has travelled more than 11 billion years to the Earth. Reinhard Genzel (2006)

This very ambitious and unique survey has led to the publication of about a dozen papers, including a milestone paper published in Nature in 2006 (Förster Schreiber, et al., 2006, 2009; Genzel, et al., 2006, 2008, 2009; Nesvadba, et al., 2006; Shapiro, et al., 2008, 2009; Cresci , et al., 2009; Bouché et al., 2007, 2009). Reinhard Genzel (2009)

Our results showed convincingly for the first time that very large and massive rotating disk galaxies like the Milky Way did exist as early as 3 billion years after the Big Bang. The key implication is that these galaxies must have formed very rapidly and mostly through fairly smooth accretion mechanisms. This was an unexpected discovery and represented a major breakthrough in the field of galaxy evolution. Natascha Förster Schreiber (2009)