Borderline type-1 QSOs: Probing AGN/host galaxy evolutionary aspects

J. Zuther[1], A. Alonso-Herrero[2], T. Bertram[3], A. Eckart[1,4], S. Fischer[1], M. García-Marin[1], J. W. Kim[5], S. Komossa[6], S. König[1], M. Krips[7], G. Lemson[8], J.-U. Pott[3], S. Ridgway[9], J. Scharwächter[10], J. Staguhn[11], C. Straubmeier[1], E. Tremou[1], L. Wisotzki[12], W. Yuan[13], H. Zhou[14]

[1]I. Physikalisches Institut, Universität zu Köln, Zülpicher Str. 77, 50937 Cologne (Germany), [2]CSIC, Madrid (Spain), [3]MPIA, Heidelberg (Germany), [4]MPIfR, Bonn (Germany), [5]ARI, Heidelberg (Germany), [6]MPE, Garching (Germany), [7]IRAM, Grenoble (France), [8]MPA, Garching (Germany), [9]NOAO, Tucson (USA), [10]ANU (AUS), [11]NASA GSFC (USA), [12]AIP, Potsdam (Germany), [13]NAO/Yunnan Observatory (China), [14]The University of Sciences and Technology of China (China)

Motivation

Luminous quasi-stellar objects (QSOs) are believed to originate, at least in part, in the violent gravitational interaction of massive spiral galaxies in major mergers, or in gravitational instabilities induced by small companion galaxies in minor mergers. This places QSOs in an evolutionary context, in which QSO activity is a transient phenomenon. The matter accreted onto the central supermassive black hole (SMBH) originates from the hosts of the progenitor galaxies and is driven towards the central region of the QSO in the course of the merger. At the same time, the inflow of matter triggers intensive star formation throughout the host, which culminates for ultraluminous infrared galaxies (ULIGs). In the transition phase, nuclear outflows and the hard ionizing radiation sweep the circumnuclear region free of gas, subsequently quenching the star formation in that region.

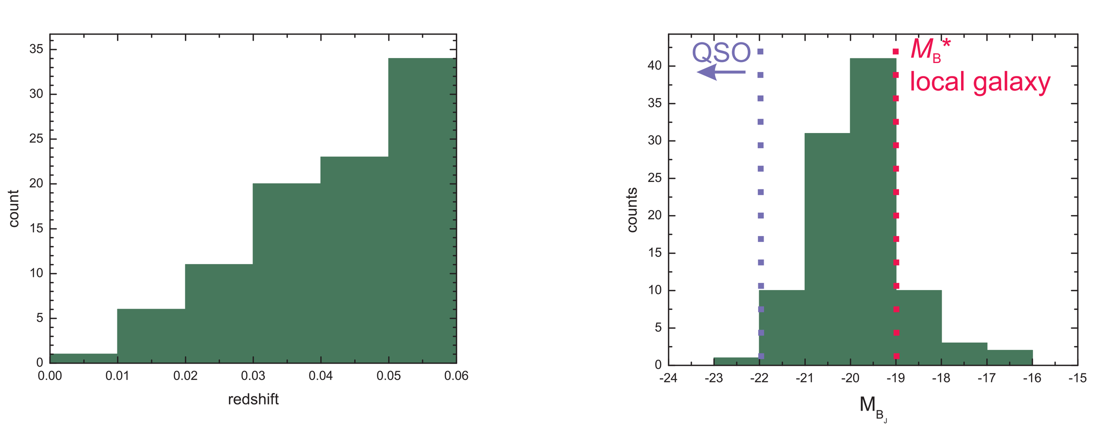
Key questions are:

What are the relevant/dominating physical processes regulating the extreme star formation and the fueling of the SMBH?

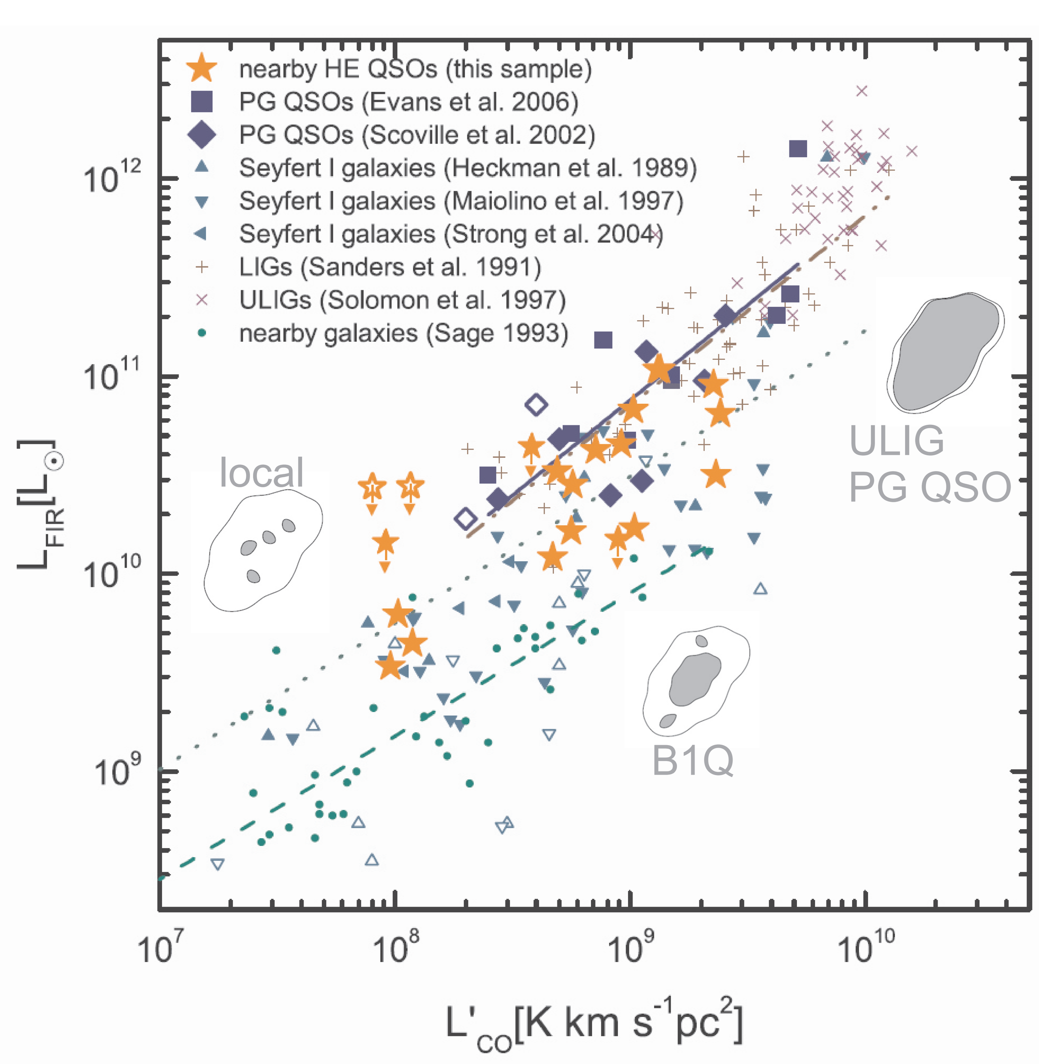
What are the time scales for the chain of events in a typical merger (on which matter is redistributed throughout the host)?

The sample

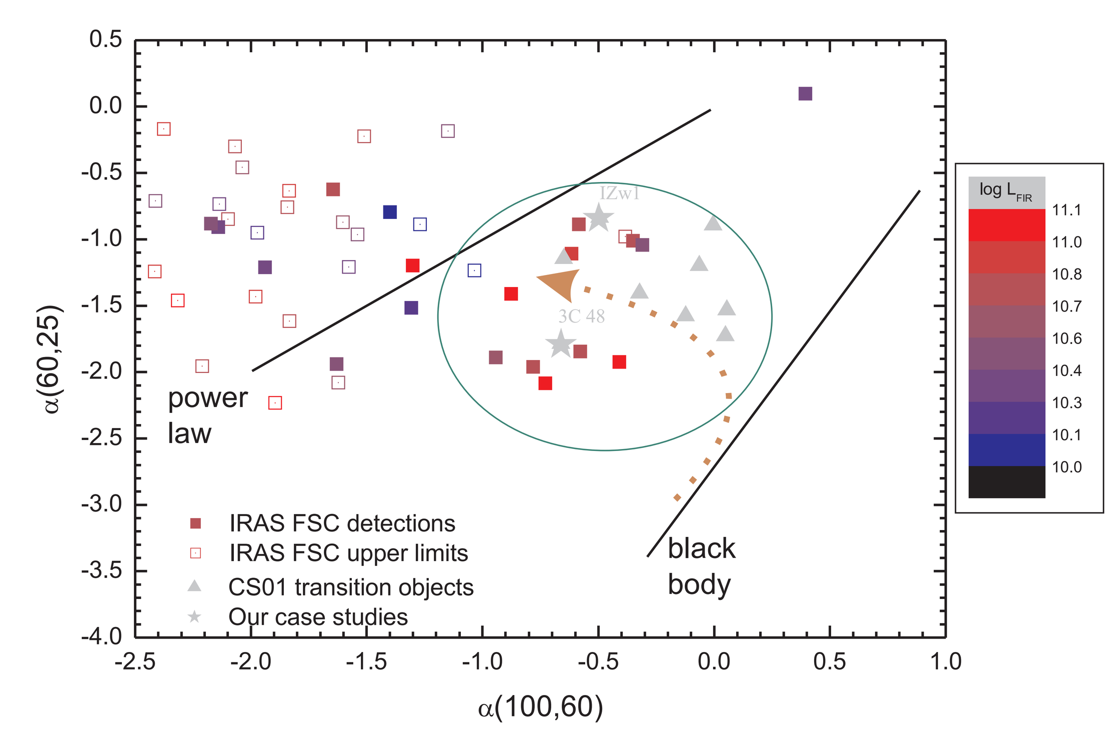
- 99 targets selected from the Hamburg/ESO type-1 QSO survey (Wisotzki et al. 2000, A&A, 358, 77)
- Flux limited with $B_J \lesssim 17.3^{mag}$
- Redshift cut $z \lesssim 0.06$
- **Borderline type-1 QSOs (B1Qs):** Absolute blue magnitudes scatter around the classical demarcation between Seyfert galaxies and QSOs ($M_B \sim -22^{mag}$; Schmidt & Green 1983)
- B1Qs are numerous as compared to low-z luminous QSOs/ULIGs
- 48% IRAS far-infrared detected. Luminosities typical of LIGs up to ULIGs
- 82% X-ray detected with ROSAT (23% with XMM)
- 16% radio detected with FIRST and NVSS.
- 80% have optical spectroscopy by Wisotzki et al. (priv. comm.)
- 60% have 6dF spectra
- *These data enable for a thorough classification of sample members before further detailed follow-up*
- 39% observed at mm wavelengths (69% detection rate) with molecular gas mass range $M_{CO} = (0.4\text{-}9.7)*10^9\ M_{sun}$ (Bertram et al. 2007, A&A, 470, 571)
- Star-formation efficiency intermediate between local galaxy populations (inactive and Seyfert) and higher-z PG QSOs and ULIGs
- 45% of the CO detected B1Qs are also detected in HI (21cm) with average $M_{HI} = (1.1\text{-}38)*10^9\ M_{sun}$ (König et al. 2010, A&A, 507, 757)
- Use IRAS 2-color diagram as a basis for studying the evolutionary scenario with respect to B1Qs.
- ***11 transition objects*** as best candidates to show merger together with type-1 AGN signatures



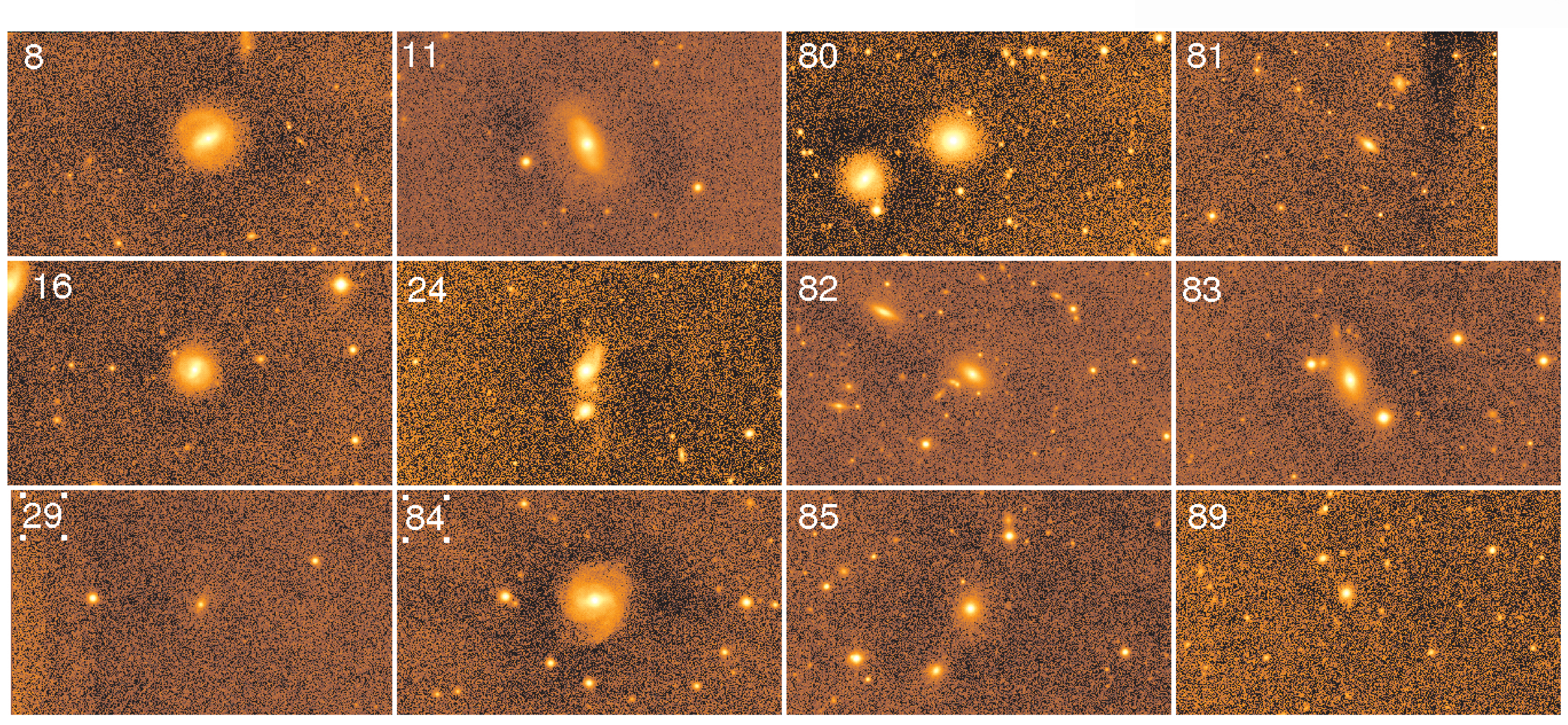
Above: *Redshift distribution and absolute brightness distribution of the B1Qs. Indicated is the classical QSO/Seyfert demarcation at $M_B = -22^{mag}$ and the brightness of an L* local normal galaxy.*



Right: *FIR luminosity as a function of CO luminosity for the B1Q sample and various other Seyfert 1, PG QSO host, luminous infrared galaxies and normal galaxies. The lines represent power law fits to the individual samples. Also shown are examples of molecular gas distributions with different fractions of molecular gas taking part in active star formation (dark areas). Adopted from Bertram et al. (2007).*



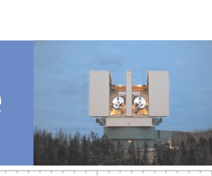
Right: *IRAS two-color diagram of B1Qs. Color coding according to infrared luminosity. Closed symbols correspond to detection in all bands, whereas open symbols correspond to upper limits. In the evolutionary scenario, the IRAS colors evolve from the black body regime across the diagram to left part o f the diagram where the FIR emission is driven by a power-law.*



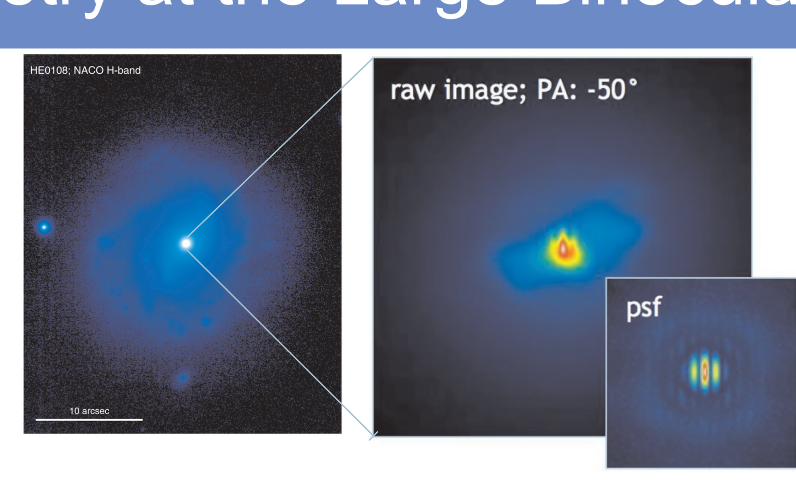
Left: *NIR study with SOFI at the ESO NTT of 6 transition objects (first 2 times 3 panels) and 8 B1Qs chosen randomly from rest of the sample. JHK imaging (4' FOV) and H+K longslit spectroscopy (R~600). Note that the transitions objects appear to be dominated by barred spiral hosts, whereas the other hosts appear like early types. The environments of the latter objects appear to be denser than those of the transition objects. Therefore, in the class of LIGs, secular evolution seems to be an important factor. These preliminary results await further detailed investigation of our NIR data set, especially of the NIR spectra.*

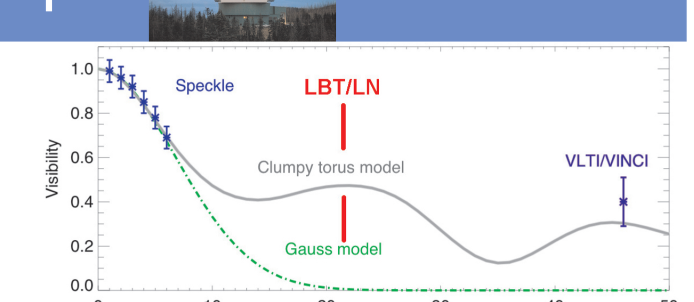
Furthermore, there appears to be a high incidence of narrow line Seyfert 1 (NLS1) galaxies. This is based on a study of the visible wavelength spectra and might provide clues to the proposed youth of such NLS1s when compared with the (U)LIG-to-QSO evolutionary scheme.

Future prospects with NIR interferometry at the Large Binocular Telescope



The B1Qs presented here are the NGC1068s for future major observational facilities, in terms of angular resolution, and will help to improve significantly the statistics of the nuclear environment of AGN (Eckart et al. 2004, SPIE, 5491, 106). The NIR interferometric beam combiner imaging camera LINC-NIRVANA will soon provide 9mas (at 1.2µm) angular resolution, which will resolve nuclear structures on 7pc scales (at z=0.04). This is essential for assessing the dusty nuclear environment, and finding clues about the fueling processes of the central black hole of B1Qs and AGN in general.





Left: *Example observation of the nucleus of one B1Q. The LBT PSF is indicated. The Fizeau type setup provides a large FOV and therefore direct imaging capabilities.* ***Right:*** *LBT interferometry fills the short spacing gap between speckle and long baseline interferometry, allowing for discrimination of different AGN torus models (Hofmann et al. LN-MPFIR-TN-SCI-001).*

Contact: zuther@ph1.uni-koeln.de