THE INFRARED SPECTRA OF QUASARS AS SEEN BY ISO: PROSPECTS FOR FIRST

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Abstract

ISOPHOT observations supplemented by mm photometry with IRAM gained new insights on dust and synchrotron emission in quasars and radio galaxies. They confirmed former hypotheses, but also raised new suggestions as well: While evidence is growing for the dustiness of quasars, the AGN-starburst connection and the unificaton between radio galaxies and steep stectrum radio-loud quasars, new trends like the redshift dependence of the mid-to-far-IR (AGN-to-starburst) luminosity contribution and the IR-to-radio power ratio are puzzling. Larger data bases from the ISO archive and from the upcoming IR satellites SIRTF and ASCA during the next years will support the findings from the first samples with ISO. However, for most of the new suggestions – in particular those related to cosmic evolution – a clarification will have to wait until the next generation of larger IR telescopes like FIRST.

Key words: Galaxies: photometry – Quasars: general – Infrared: galaxies

1. Introduction

ISOPHOT (Lemke et al. 1996) the photometer on board ISO provided mid- and far-IR observations of unprecedented sensitivity. These data were supplemented by mm photometry with the IRAM 30-m-telescope. Within the *ISO European Central Quasar Programme* various samples of quasars and related objects were observed. The main emphasis was on clarifying the nature of the IR emission – dust versus synchrotron – and the unified schemes (see Fig. 1). More details can be found in Haas et al. (1998), Chini et al. (1999), Haas et al. (2000) and Meisenheimer et al. (2001). Here we summarize the results for two samples with regards to the prospects for FIRST.

2. PG quasars

17 optically bright quasars randomly selected from the Palomar-Green (PG) catalog were observed in order to probe the existence and properties of dust in these sources and the link to ultraluminous IR galaxies (ULIRGs):

The SEDs of the PG-quasars are shown in Fig. 2. The new observations increase the fraction of optically bright quasars detected in the mid- and far-IR from about 30% to 70% (12 out of 17), providing evidence that most – if not all – quasars are surrounded by considerable amounts of dust similar to normal spiral galaxies. For non-PG-quasars the dust content may be even higher, since the Palomar-Green sample is biased against bright host galaxies because of the restriction to stellar appearance on images. Nevertheless, if the evolutionary chain *merger of two dust rich galaxies – quasar – "naked" elliptical galaxy* is correct, then the dust has to disappear at some stage between the quasar and the elliptical galaxy period. Here FIRST could reveal the "dust-disappearing-stage".

Also, of cosmological interest is the possible trend that the coldest dust component appears warmer in quasars at high redshift. This issue is related to the SED maximum in the FIR and the shape of the Rayleigh–Jeans tail in the sub-mm range, therefore it can ideally be investigated with FIRST.

From the shape of the SEDs the hypothesis can be confirmed, that the AGN powers mainly the MIR emission and that bursts of starformation are required in order to explain the FIR and sub-mm output.

For the study of the AGN-starburst connection both the MIR and the FIR ranges are necessary. Therefore FIRST should extend its wavelength coverage as far as possible into the MIR range, otherwise a direct study of the AGN-starburst connection via the SEDs would be restricted to high redshifts.

As a new alternative, at low redshifts the steepness of the Rayleigh–Jeans tail (measured by the dust emissivity exponent β) could provide clues to discriminate between mergers in an early status and more evolved AGN: As a trend from ISOPHOT observations, ULIRGs seem to have a lower β than quasars (Klaas et al. 2001). Furthermore, the PAH 7.7μm strength seems to be better correlated with the sub-mm than with the FIR emission (Haas et al. 2001). Thus, the shape of the Rayleigh–Jeans tail could reveal essential AGN-starburst informations – a challenge for FIRST.

3. 3CR radio galaxies and quasars

20 radio galaxies and radio-loud quasars from the 3CR catalog with powerful FR II lobes were observed in order

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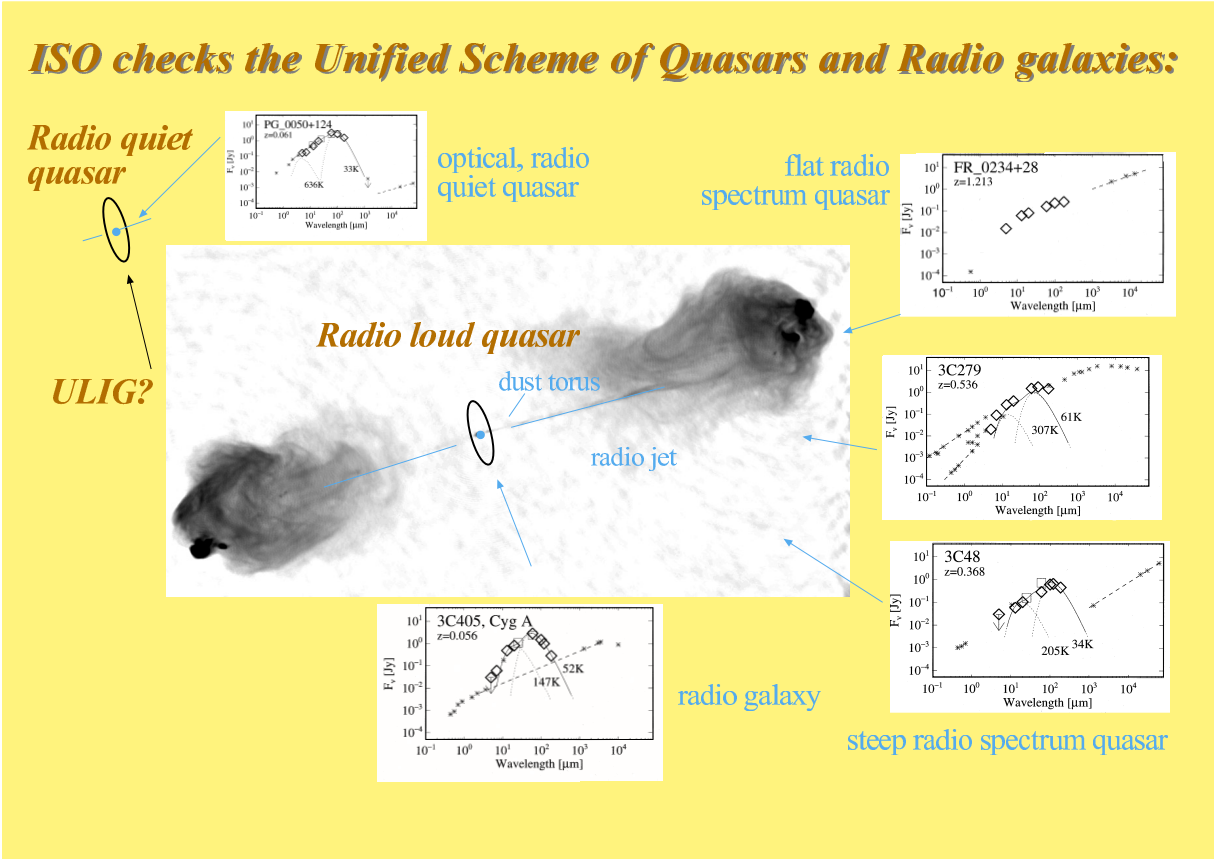

Figure 1. Illustration of the pure aspect-angle unified schemes between ULIRGs, radio-quiet (PG) quasars, flat and steep spectrum radio-loud quasars and radio galaxies. The dashed arrows indicate the directions (pole-on, intermediate and edge-on aspect-angles) from which the observer looks at the system, resulting in SEDs with different relative dust and synchrotron contributions.

to discriminate between dust emission and synchrotron radiation, and to check the unification of radio galaxies and quasars.

The SEDs of the 3CR radio galaxies and quasars are shown in Fig. 3. For the first time a sufficient number of radio galaxies (6 out of 10) and radio-loud quasars (7 out of 10) could be detected individually in the mid- and/or far-IR to allow for a statistically meaningful trend. 12 sources exhibit a clear thermal bump rising above the smooth synchrotron spectrum, and in the remaining sources the upper limits are still compatible with the presence of luminous dust emission. Considering pairs of quasars and galaxies which match in redshift and isotropic 178 MHz radio power of the FR II lobes, both samples show the same mid- and far-IR detection statistics – in agreement with the predictions of the unified scheme.

In addition to the purely geometric unification, also a trend with cosmic evolution can be seen: While at high redshift ($z > 0.8$) both the radio galaxies and the quasars show a similar IR-to-radio 178 MHz luminosity ratio in accordance with pure unification, at low redshift ($z<0.8$) some of the radio galaxies exhibit relatively fainter IR fluxes than the quasars. This difference seems to be mainly a function of redshift and not one of lobe radio power (Meisenheimer et al. 2001). FIRST's long wavelengths coverage and sensitivity – also for the faint high redshift sources – could confirm these trends of cosmic evolution, and find clues to its reason.

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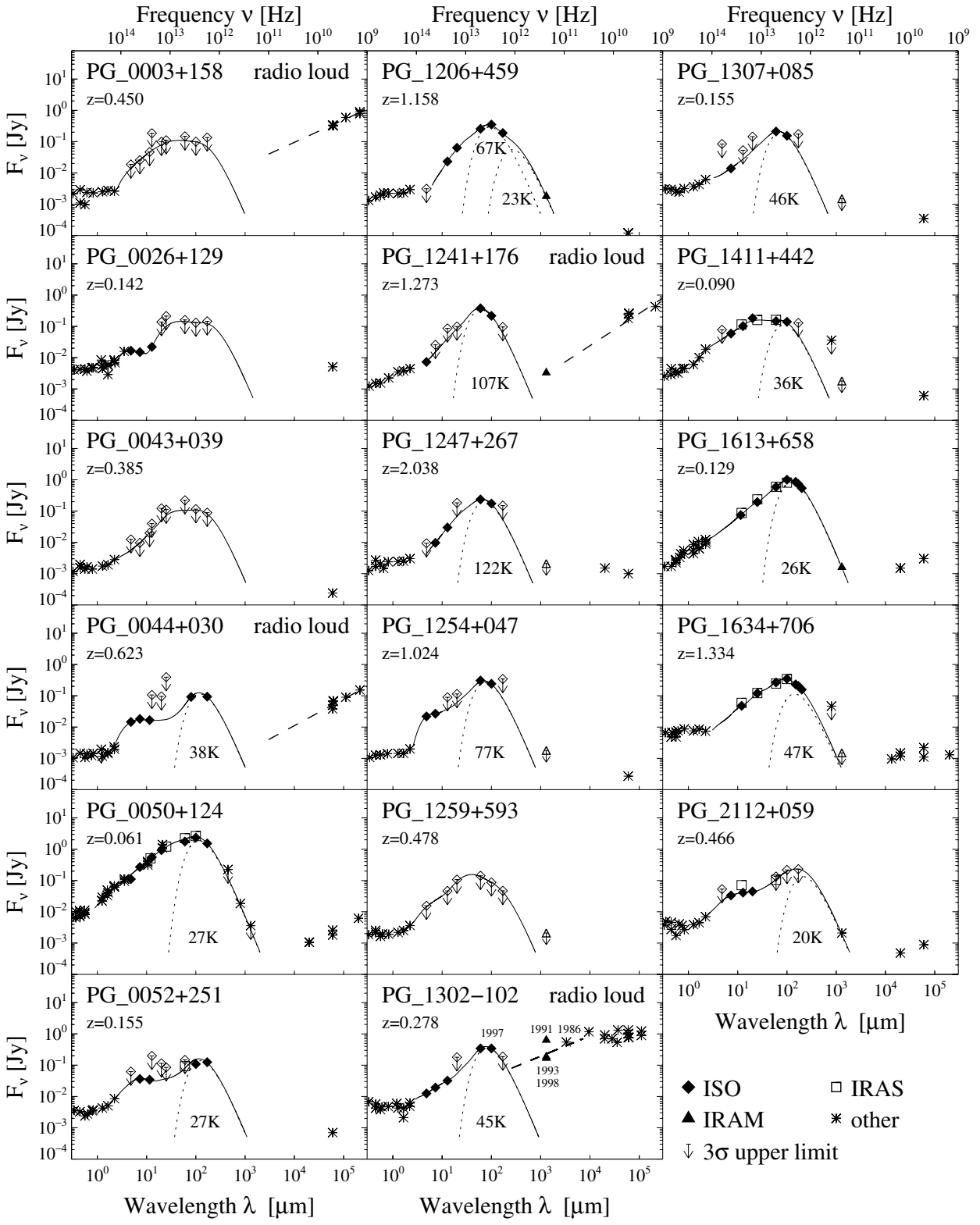

Figure 2. SEDs of 17 PG quasars from the ISO European Central Quasar Programme. The wavelength and frequency ranges are as observed and not corrected to the rest frame of the objects. Several modified blackbodies with emissivity proportional to λ^{-2} are eyeball fitted to the data (solid lines) and only the coolest components are plotted individually (dotted lines). The temperatures listed are corrected for redshift. The long–dashed lines indicate extrapolated synchrotron spectra. For the variable radio source PG 1302–102 different epochs of the data groups are indicated by the year. Reference: Haas et al. (2000).

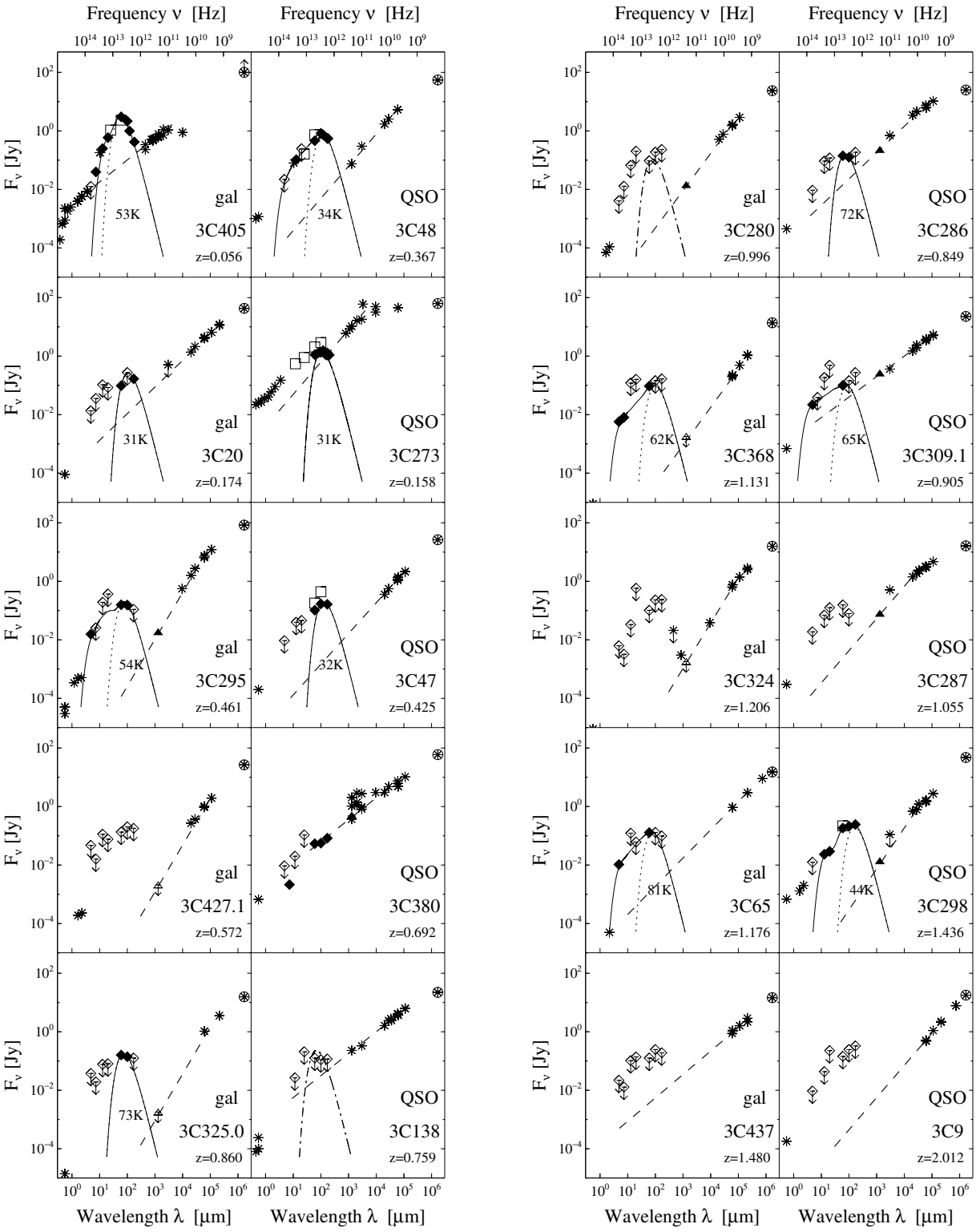

Figure 3. Observed spectral energy distributions of the pairs of 3C radio galaxies and quasars ordered according to the redshift of the galaxy. Symbols abd lines as in Fig. 2, the encircled stars represent the total flux at 178 MHz from the 3CR catalogue. In cases of non–detection of one member of a pair, the dashed–dotted line illustrates, how the blackbody of the partner would show up at corresponding redshift and that it would not exceed the upper limits. Reference: Meisenheimer et al. (2001).