Gravitational lensing reveals extreme dust-obscured star formation in quasar host galaxies

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ABSTRACT

We have derived dust temperatures, dust masses, star formation rates and far-infrared luminosities for 104 gravitationally-lensed quasars at z∼1–4 observed with *Herschel*/SPIRE, the largest such sample ever studied. By targeting gravitational lenses we probe intrinsic luminosities more typical of the population than the extremely luminous sources otherwise accessible. We detect 87 (84 percent) of the sample with SPIRE: 82 (79 percent) quasars have spectra characteristic of dust emission, and we find evidence for dust-obscured star formation in at least 72 (69 percent). We find a median magnification-corrected SFR of 220^{+840}_{-130} $M_{\odot}yr^{-1}$ and L_{FIR} of $6.7^{+25.5}_{-4.1} \times 10^{11}$ $L_{\odot}$. The results are in line with current models of quasar evolution, but suggest that *most* quasars exist in a transitional phase between a dusty star-forming galaxy and an AGN dominated system. This further indicates that AGN feedback does not quickly quench star formation in these sources. Additionally, we find no significant difference in dust luminosities between radio-loud and radio-quiet quasars, implying that radio mode feedback has no significant effect on host galaxy properties.

Key words: gravitational lensing – quasars: general – galaxies: evolution – galaxies: star formation – submillimeter: galaxies – infrared: galaxies

- Проблема AGN- SF : quenching or inducing?

Принимаемая модель (Sanders et al)

- Merging-- dusty SF galaxies – dust-obscured FIR QSO (several Myr) - UV QSO.

According to the current paradigm of galaxy evolution, some fraction of the quasar population is expected to be transitional sources from DSFGs to UV-luminous quasars. These transition sources will be FIR-luminous, with clear evidence of ongoing star-formation.

- До сих пор исследования относились только к квазарам и галактикам SDSF очень высокой светимости.
- Вывод: использовать грав-линзированные изображения квазаров с целью выяснить связь между DSFG и квазарами.

- Выборка: все известные линзированные квазары, наблюдавшиеся Hershel observatory:
- At the time of proposal, these included all currently known optical/radio selected quasars lensed by foreground galaxies. In total, there are 104 lensed quasars.
- Типичное усиление яркости ~10
- Измерялись: T и масса пыли, SFR.

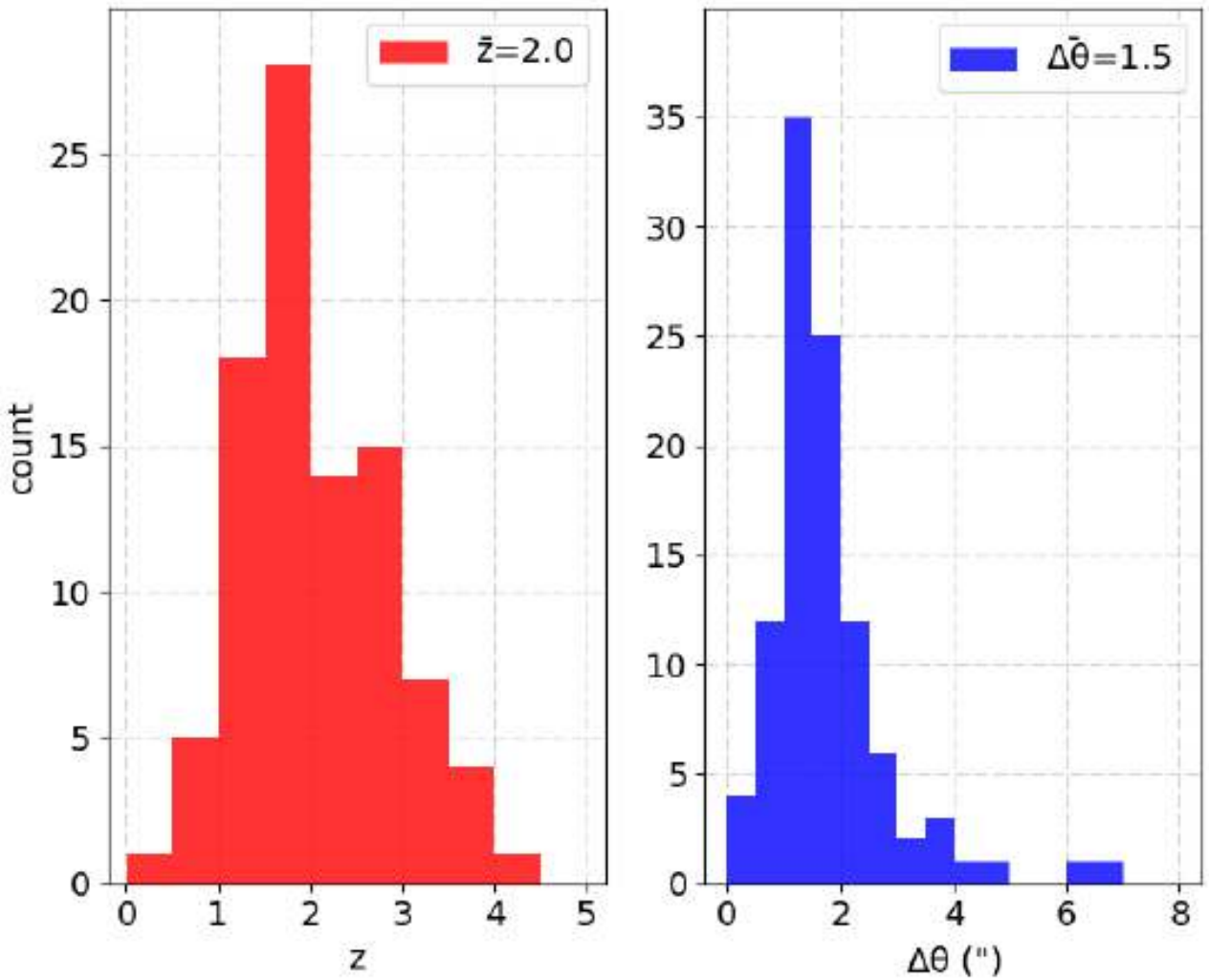


Figure 1. (left) The redshift distribution of the sample, which has a median redshift of 2. (right) The image separation distribution of the sample (excluding SDSS J1029+2623 with a maximum separation of 22.5 arcsec).

ИЗМЕРЕНИЯ

$$S_\nu \propto \nu^\alpha, \quad (1)$$

to describe the flux-density (S_ν) as a function of frequency (ν) in the case of synchrotron emission, and a characteristic modified black body,

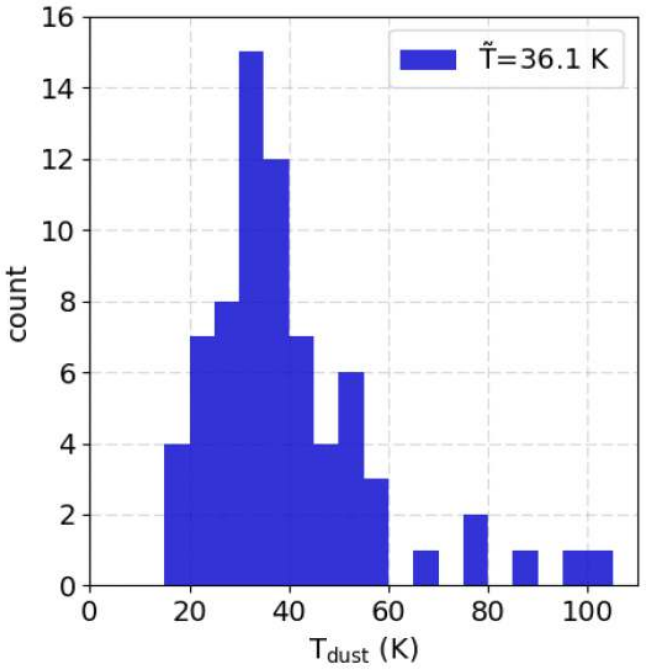
$$S_\nu \propto \frac{\nu^{3+\beta}}{e^{h\nu/kT_d} - 1}, \quad (2)$$

to describe the heated dust component, where h is the Planck constant, k is the Boltzmann constant, T_d is dust temperature,

$$L_{FIR} = \frac{4\pi D_L^2}{(1+z)} \int_{40\ \mu m}^{120\ \mu m} S_{\nu,rest}\, d\nu,$$

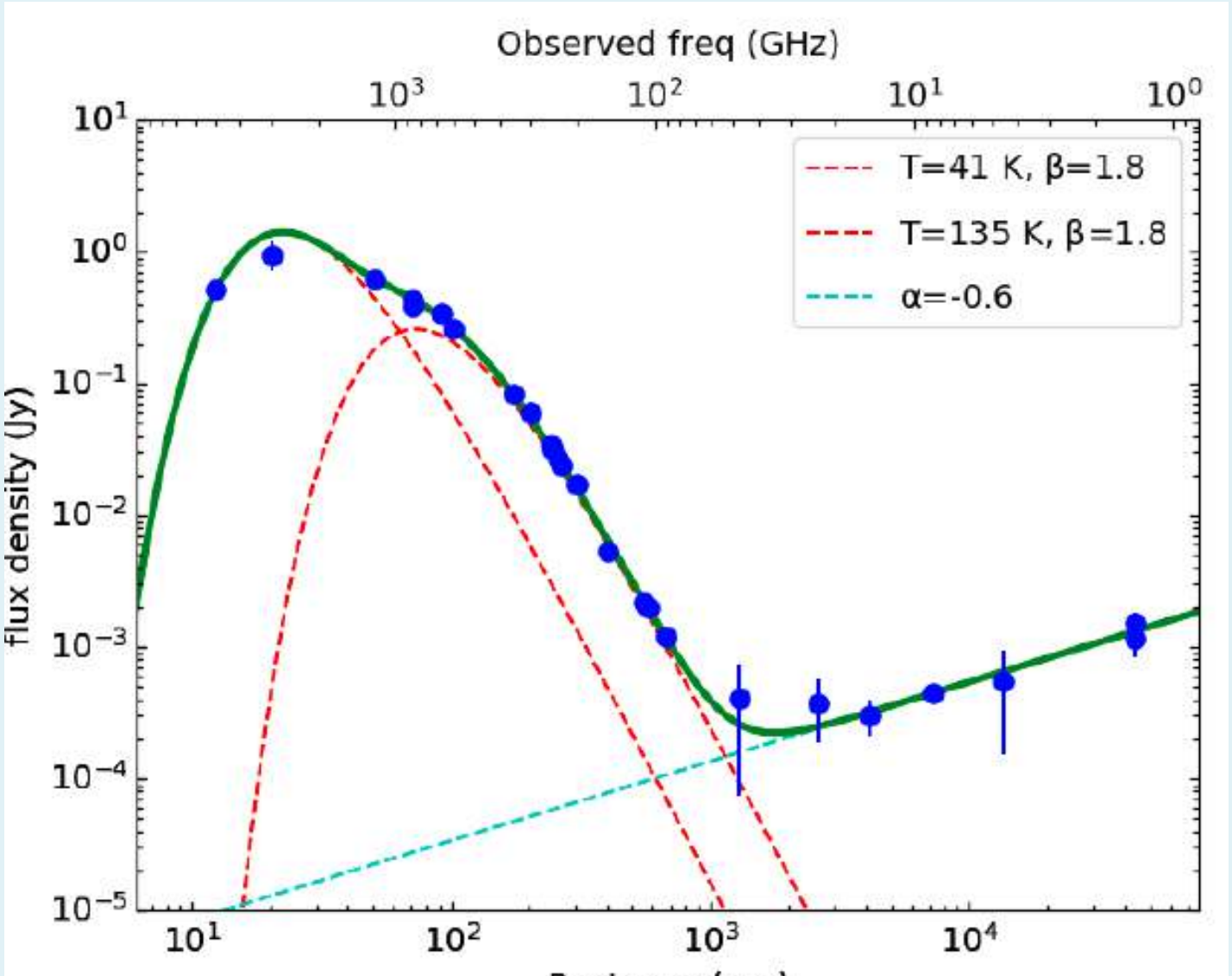
$$SFR\,(M_\odot\ yr^{-1}) = \frac{L_{IR}}{5.8 \times 10^9},$$

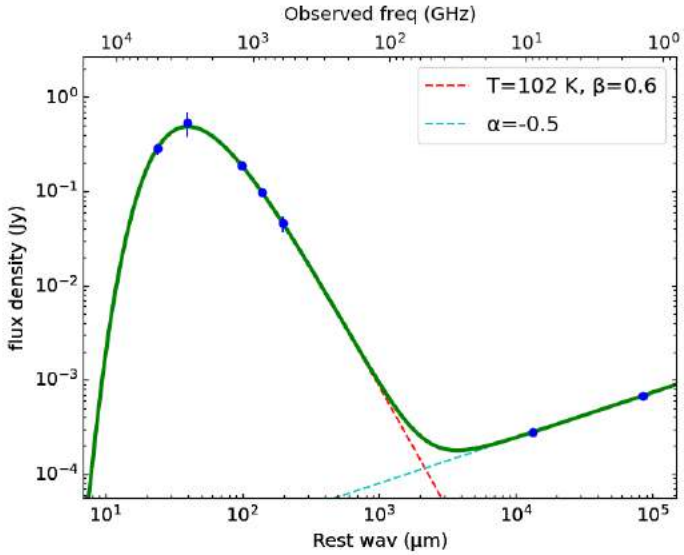
$$M_{dust} = \frac{S_{\nu,obs}\, D_L^2}{(1+z)\, B_{\nu,rest}\, \kappa_\nu},$$



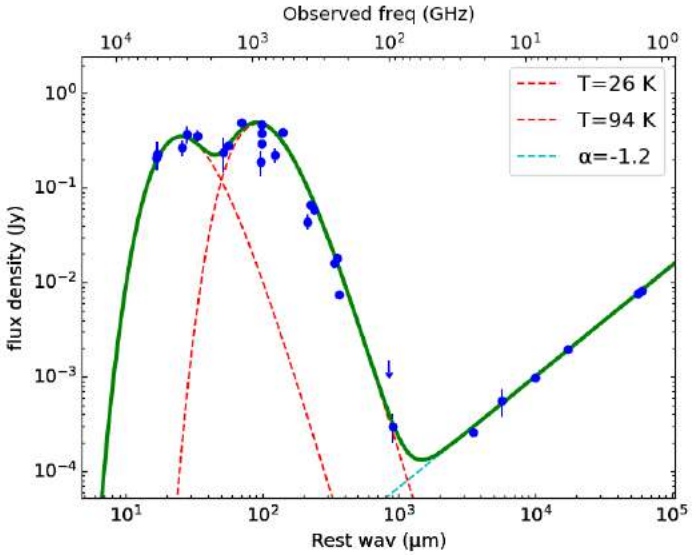
Значения SFR = 100 – 1000 Мс/год.

Пример: двух-температурная пыль + синхротрон





(a) HS 0810+2554, $z = 1.51$



(c) H1413+117, $z = 2.55$

- Сравнение с «un-lensed DSFGs» – по Magnelli etal 2012 :
- “A HERSHEL VIEW OF THE FIR PROPERTIES OF SUBMILLIMETRE GALAXIES”

  (61 объект).

Получено:

сходное значение Tdust, но в несколько раз более низкая средняя светимость FIR (220Ms/yr vs 800 Ms/yr).

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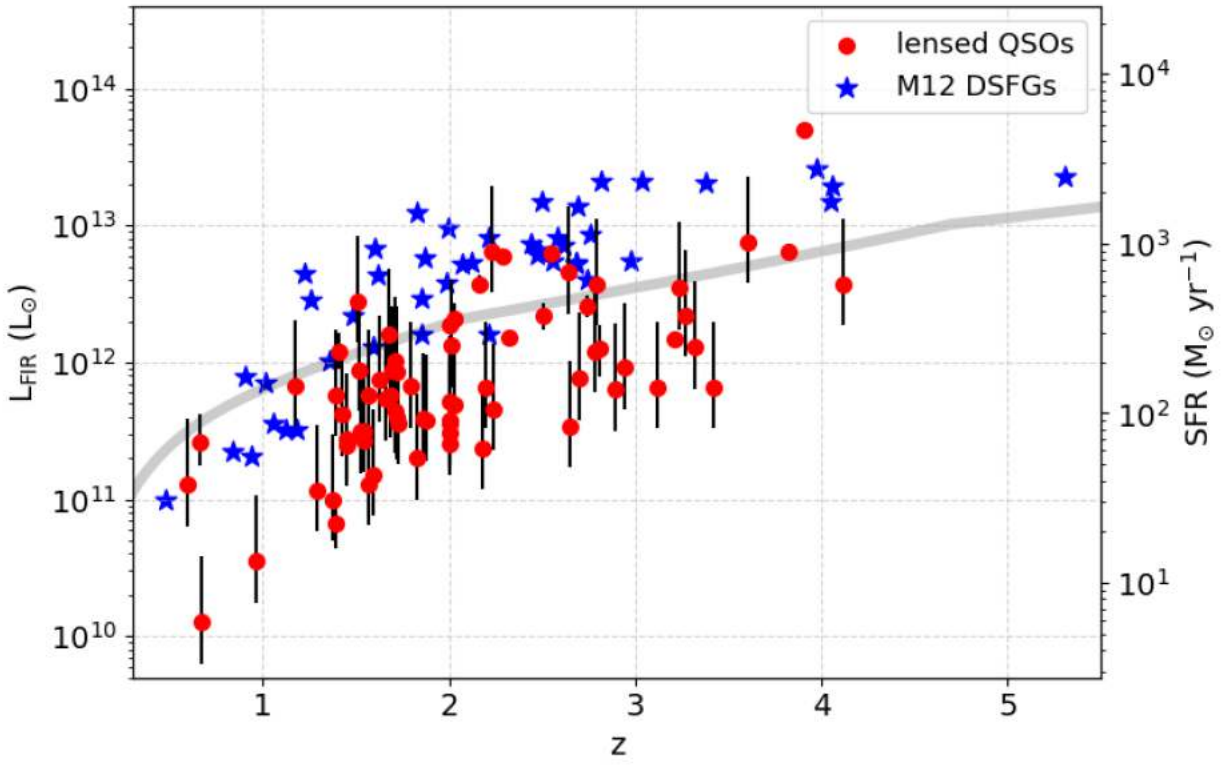


Figure 12. FIR luminosity (40–120 μm) and equivalent SFR against redshift for the lensed quasars in this sample and for the M12 DSFGs. The quasar luminosities are magnification-corrected. Where the dust magnifications are unknown, the value is assumed to be 10 with a factor of 2 error. The grey lines show the luminosity detection limit for a source with T_d = 36 K and β=1.5, assuming a fixed 3σ detection limit (as in Fig. 8).

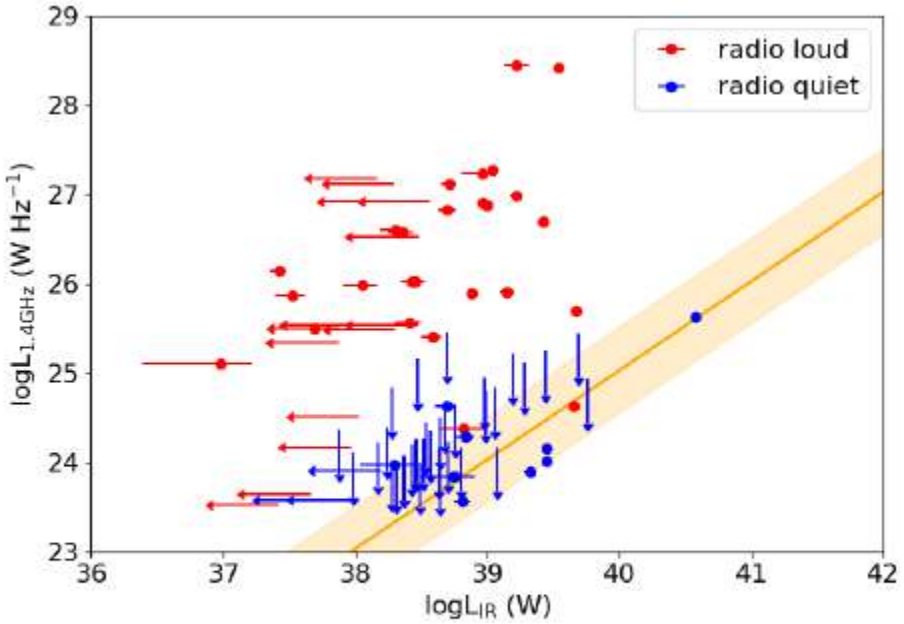
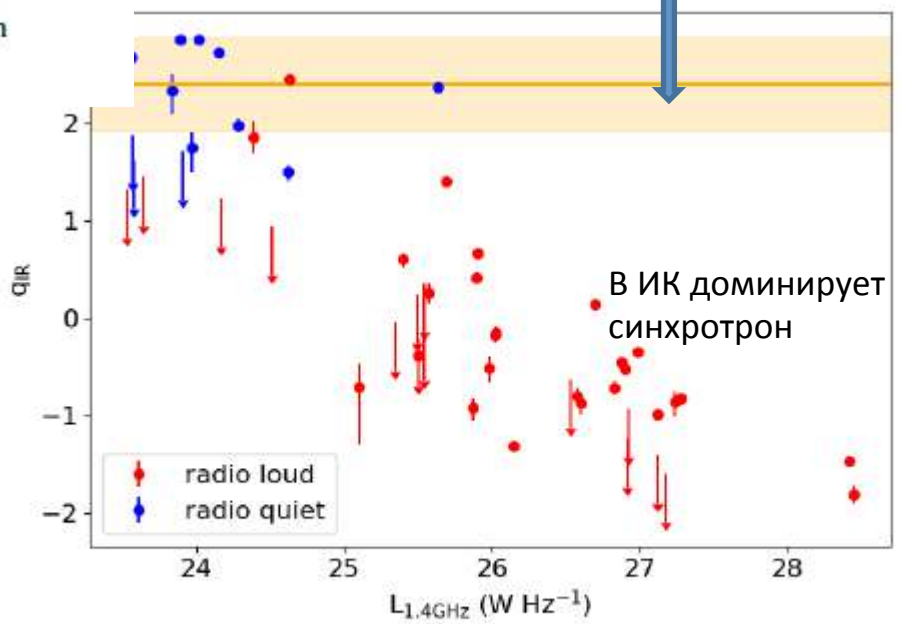


Figure 14. The radio-infrared correlation for the quasar sample. The median q_{IR} from Ivison et al. is shown in yellow; the shaded region is $2\sigma_q$.

$$q_{\rm IR} = \log_{10}\left(\frac{L_{\rm IR}}{3.75\times10^{12}\,L_{1.4}}\right)$$

Галактики без активных ядер



В ИК доминирует синхротрон

Figure 15. Radio-infrared factor, q_{IR}, for quasars in the sample with radio detections. The median q_{IR} from Ivison et al. in yellow, as before.

- 80% квазаров выявляют присутствие heated dust (признак активного SF).
- Сравнение с выборкой DSFR-галактик (без видимых квазаров) по Hershel на тех же z показывает аналогичную Tdust но на порядок более низкую SFR.
- Общее согласие с моделью Sanders et al, 1988: FIR- квазары – это промежуточное звено между DSFGs and UV-bright quasars, where feedback from the quasar has not yet fully quenched star-formation within the host galaxy.
- The high detection rate implies most quasars in the redshift range z 1–4 are FIR-luminous transitional sources. This result suggests a transition time of the order of the lifetime of the quasar (i.e. . 100 Myr), but not as short as 1 Myr, as has been suggested.
- Фазы FIR-luminous quasar и un-obscure quasar не различаются по SFR, так что radio-loud фаза не отражается на SF.