



The Dusty Young Universe: Photometry and Spectroscopy of Quasars at $z > 2$

This is a Herschel-PACS GTO Key Project of 165 hours coordinated by Klaus Meisenheimer (MPIA), being a collaboration between MPIA, U Liege and MPE. The Team Members are:

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Abstract:

The detection of a significant fraction of the highest redshift quasars ($z > 5$) in the (sub-)mm wavelength range indicates that a substantial amount of dust has been synthesized already during the first billion year since the Big Bang. Recent 24 μm observations with Spitzer have shown that very hot dust is present close to the QSO core in most $z > 5$ quasars. However, both the (sub-)mm and MIR observations can only catch tails of the dust emission spectrum, at $rest > 200 \mu\text{m}$, and at $rest < 5 \mu\text{m}$, respectively. Measuring the peak of the dust emission, expected to reach 10...30 mJy around $rest \sim 50 \mu\text{m}$ ($120 < obs < 700 \mu\text{m}$), has been beyond the capabilities of FIR satellites or ground-based sub-mm telescopes. Thus, critical properties, such as FIR luminosity, dust temperatures and mass, remain unconstrained.

To improve on this situation, we propose a Herschel Guaranteed Time Key Programme (GT KP) to collect far-infrared and sub-millimeter photometry of more than 100 high redshift quasars using the PACS and SPIRE instruments. We plan to determine the SEDs of three samples of QSOs: (i) all $z > 5$ quasars known to date, (ii) a dozen radio loud quasars and galaxies at the highest redshifts, and (iii) 29 Broad Absorption Line (BAL) quasars together with a comparison sample of 17 non-BAL QSOs at matching redshifts. In addition, we plan to obtain PACS spectroscopy of four very dust-rich and lensed high-redshift QSOs and galaxies for spectral line diagnostics, which will help to disentangle the contributions of AGN- and starburst-heated dust and thus complement the SED-based study.

We will spend in total 165 hours of PACS GT in this key programme, 115 hours for the photometry with PACS and SPIRE, and 50 hours for the FIR spectroscopy.

Projects and Science Objectives:

I. Far-IR – submm photometry of very high redshift QSOs: 95 hours

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- SEDs at $\lambda = 100, 160, 250, 350, 490 \mu\text{m}$ of the highest redshift quasars ($z > 5$) including all known quasars at $z > 6$
- sample includes 16 QSOs with $z > 6$; 61 QSOs at $6 > z > 5$; 17 radio-loud QSOs with $z > 3.5$
- dust masses and temperature, FIR luminosities of host galaxies 1 Gyr after big bang; history and frequency of dust production
- comparison: radio-loud / radio-quiet by including RGs and QSRs
- search for close companions/overdensities on mini-maps
- Spitzer proposal got awarded 70.0 hours to collect for all sources IRAC/MIPS photometry

II. Far-IR – submm photometry of BAL QSOs around $z = 2.5$: 20 hours

D. Hutsemekers (Co-PI), J.F. Claeskens, T. Nakos

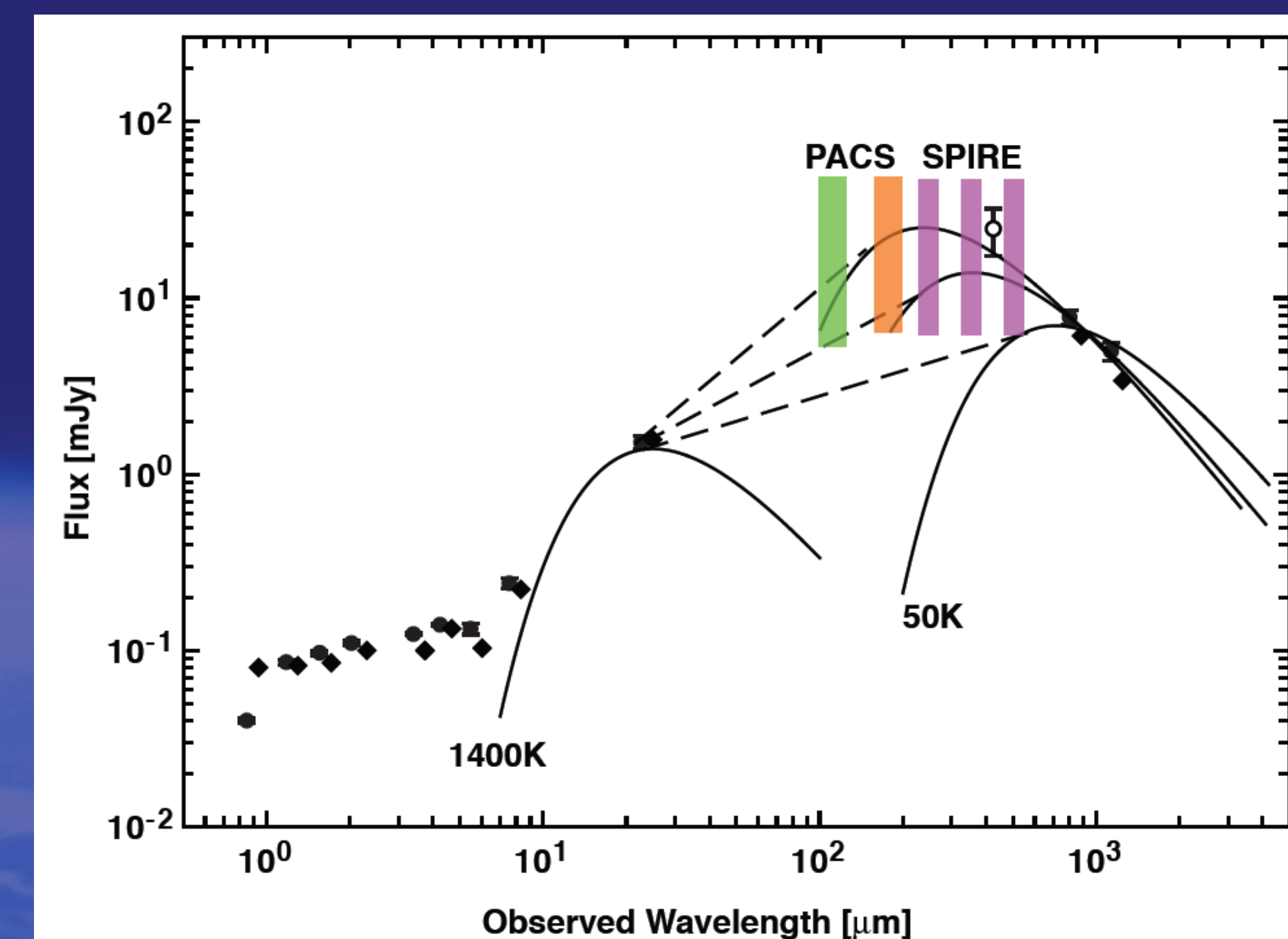
- SEDs at $\lambda = 70, 160, 250, 350, 490 \mu\text{m}$ of Broad Absorption Line (BAL) quasars ($2.0 < z < 2.9$) and comparison sample of non-BALs ($2.0 < z < 2.5$)
- sample includes 29 BALs and 17 non-BALs
- dust masses and temperatures in BAL systems
- establish differences between the FIR properties of BAL and non-BAL QSOs
- correlation between BAL clouds and dust ?
- evolutionary sequence BALs \rightarrow normal QSOs ?

III. PACS spectroscopy of lensed high-z QSOs & galaxies ($2.3 < z < 3.9$): 50 hours

L. Tacconi (Co-PI), A. Contursi, R. Genzel, D. Lutz, A. Poglitsch, E. Sturm

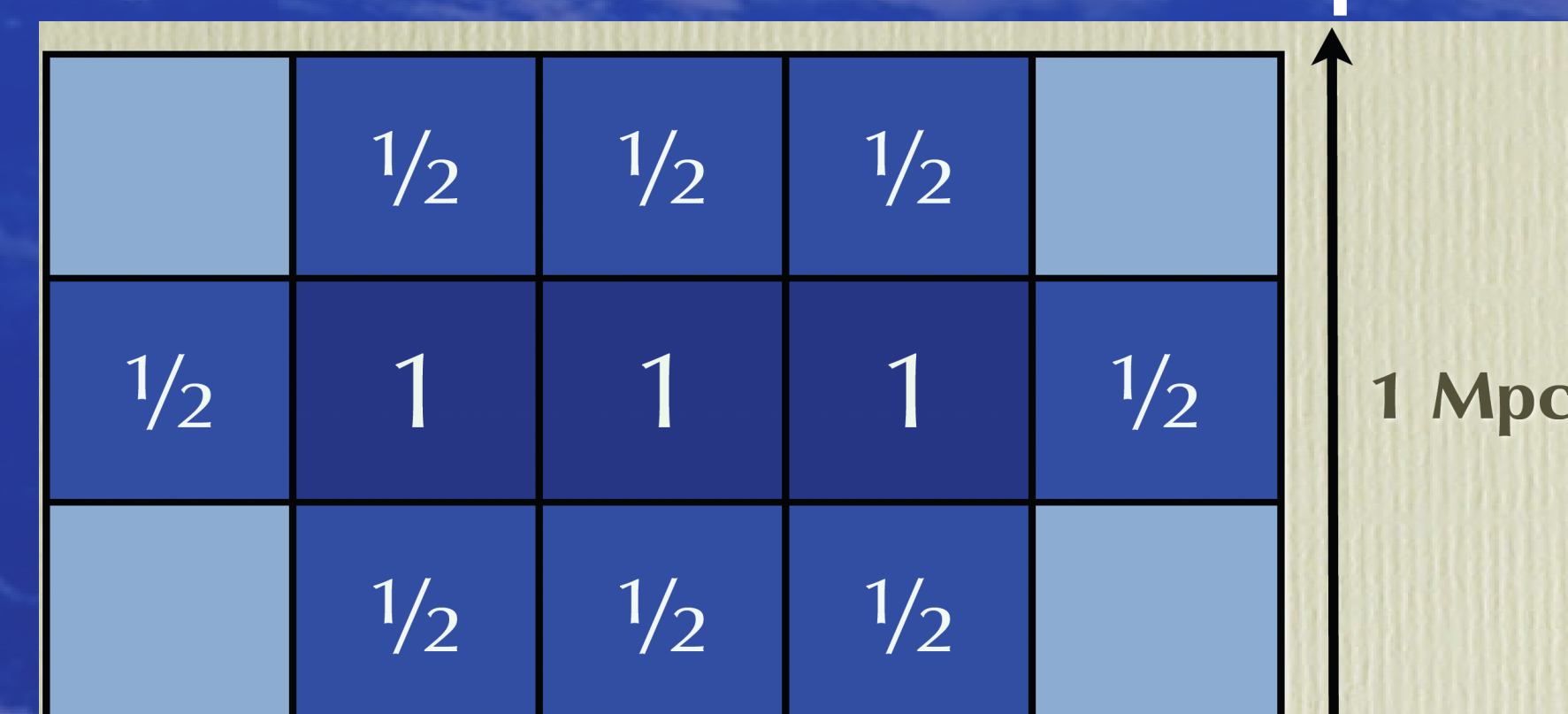
- spectroscopic signatures for AGN activity and starbursts ([SIII], [OIV])
- sample includes four lensed QSOs/galaxies at $2.3 < z < 3.9$
- quantify the contribution of star formation and AGN activity in these objects
- study their obscuration and physical conditions
- 1st time: place high-z QSOs and obscured star forming galaxies on excitation diagram

Observations of high-z QSOs with Herschel



Typical SED of a dust-rich QSO at redshift $z = 6$ (combined measurements of SDSS J1148+5251 ($z = 6.41$, dots) and SDSS J1044-0125 (BAL at $z = 5.71$, diamonds), shifted to $z = 6$). The far-infrared to sub-mm wavelengths are essential for determining the dust temperature. The 5σ limits to be reached by PACS (100/160) and SPIRE (250/350/490) are shown as the lower edge of vertical bars.

PACS observations: mini maps



Our PACS photometric observations will be executed in point source mode and will produce mini maps. This figure shows the footprint of the point-source AOT on the sky for the PACS blue array (2x4 matrices). This AOT consists of two chop and two nod positions. The central dark blue regions (50"x150"; i.e. 2.1 sq.arcmin) will receive the full integration time. Another 6.9 sq.arcmin will receive half of the central integration time.