MNRAS **000**, 1–2 (2017) Preprint 27 December 2020 Compiled using MNRAS LATEX style file v3.0

A hyperluminous obscured quasar at a redshift of $z \approx 4.3$

Andreas Efstathiou[1]★, Katarzyna Małek[2,3], Denis Burgarella[3], Peter Hurley[4], Seb Oliver[4], Veronique Buat[3], Raphael Shirley[4,5,6], Steven Duivenvoorden[4], Vicky Papadopoulou Lesta[1], Duncan Farrah[7,8], Kenneth J. Duncan[9,10], María del Carmen Campos Varillas[4]

[1] *School of Sciences, European University Cyprus, Diogenes street, Engomi, 1516 Nicosia, Cyprus*
[2] *National Centre for Nuclear Research, ul. Pasteura 7, 02-093 Warszawa, Poland*
[3] *Aix Marseille Univ, CNRS, CNES, LAM Marseille, France*
[4] *Astronomy Centre, Department of Physics and Astronomy, University of Sussex, Brighton, BN1 9QH, UK*
[5] *Instituto de Astrofísica de Canarias, E-38205 La Laguna, Tenerife, Spain*
[6] *Universidad de La Laguna, Dpto. Astrofísica, E-38206 La Laguna, Tenerife, Spain*
[7] *Department of Physics and Astronomy, University of Hawaii, 2505 Correa Road, Honolulu, HI 96822, USA*
[8] *Institute for Astronomy, 2680 Woodlawn Drive, University of Hawaii, Honolulu, HI 96822, USA*
[9] *Royal Observatory Edinburgh, University of Edinburgh, Blackford Hill, Edinburgh EH9 3HJ, UK*
[10] *Sterrewacht Leiden, Universiteit Leiden, Leiden, Netherlands*

Accepted XXX. Received YYY; in original form ZZZ

Key words: galaxies: active – galaxies: high-redshift – galaxies: formation – infrared: galaxies – submillimetre: galaxies

★ E-mail: a.efstathiou@euc.ac.cy

SUPPLEMENTARY MATERIAL

APPENDIX A

In Figure 4 we present a fit to the SED of HELP_J100156.75+022344.7 with CIGALE. Despite the differences in the methods used (e.g. CIGALE uses the torus model of Fritz et al. 2006 whereas CYGNUS uses the tapered disc model of Efstathiou & Rowan-Robinson 1995) the fit is very similar to the one with CYGNUS shown in Figure 2 of the main Letter. It shows in particular that the luminosity of HELP_J100156.75+022344.7 is dominated by the AGN. As in Figure 2 in the main Letter, there are discrepancies in the SUPRIME N921 and IRAC4 bands. In addition there is a discrepancy at 100μm which may be due to the limited AGN templates used. In order to make a quantitative comparison of the fits with CYGNUS and CIGALE, we compute *a posteriori* the χ^2 statistic which we define as

$$\chi^2 = \sum \frac{(S_\nu - S_\nu^{model})^2}{\sigma^2 + (f_c \times S_\nu)^2 + (f_m \times S_\nu^{model})^2}$$

where S_ν is the observed flux given in Table 1 and S_ν^{model} is the corresponding model flux. In the denominator we add in quadrature the error in the observed flux σ given in Table 1, a calibration error for the flux given by $f_c \times S_\nu$ and an assumed error for the model fluxes $f_m \times S_\nu^{model}$. The reason for introducing the calibration error is that the point source photometry may be in error by up to 10% (see IRAC Instrument Handbook). The model errors may include uncertainties in the model flux due to the interpolation of elements in the model libraries (see also Lanz et al 2014).

The fits with CYGNUS and CIGALE have 6 degrees of freedom. Assuming f_c and f_m are equal to 0.15 or 15%, the resulting reduced χ^2 are 4.3 and 4.8 respectively. If we assume more conservatively $f_c = 0.1$ and $f_m = 0.1$ then the corresponding values of reduced χ^2 are 6.6 and 7.5 respectively. We therefore conclude that the two fits are of similar quality.

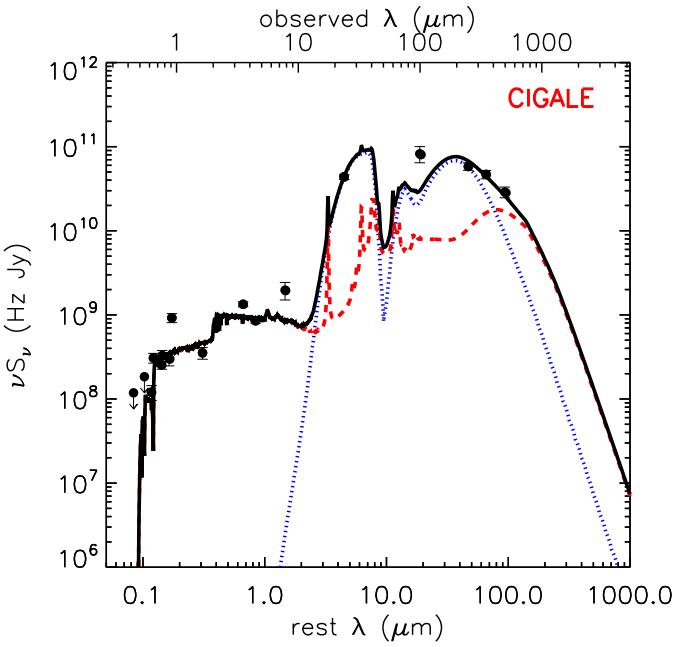

Figure 1. Best fit to the SED of HELP_J100156.75+022344.7 with CIGALE. The emission from the host galaxy is indicated by the red dashed line, the AGN torus emission by the blue dotted line and the total emission by the black solid line.

APPENDIX B

This paper has been typeset from a TEX/LATEX file prepared by the author.

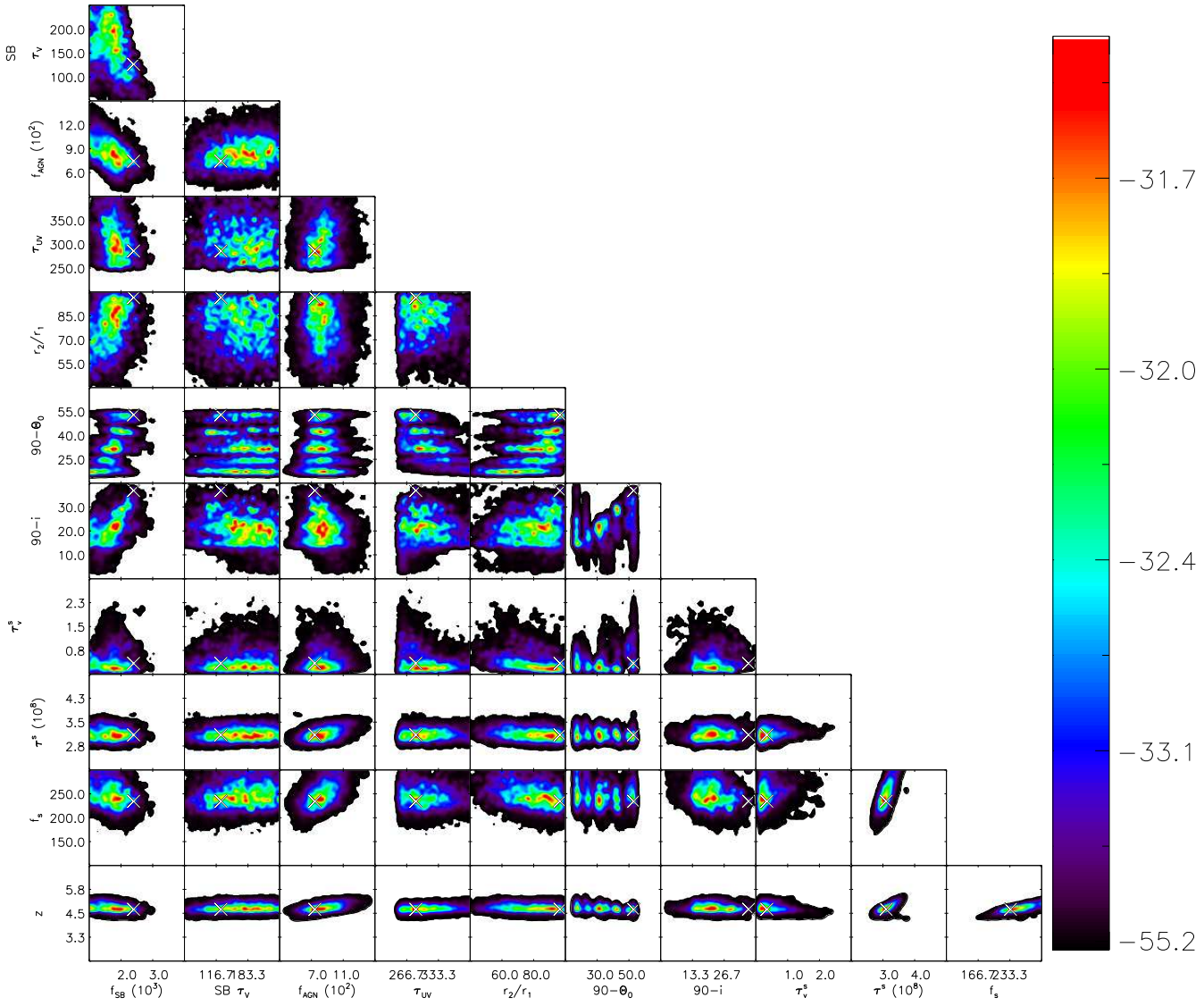

Figure 2. Plot showing the covariances between the parameters of the SED fit of HELP_J100156.75+022344.7 with the CYGNUS models and using the photo-z option of SATMC. The X symbols mark the best fit. Also shown in color is the variation of the log-likelihood from its maximum of -32 according to the color scheme on the right.

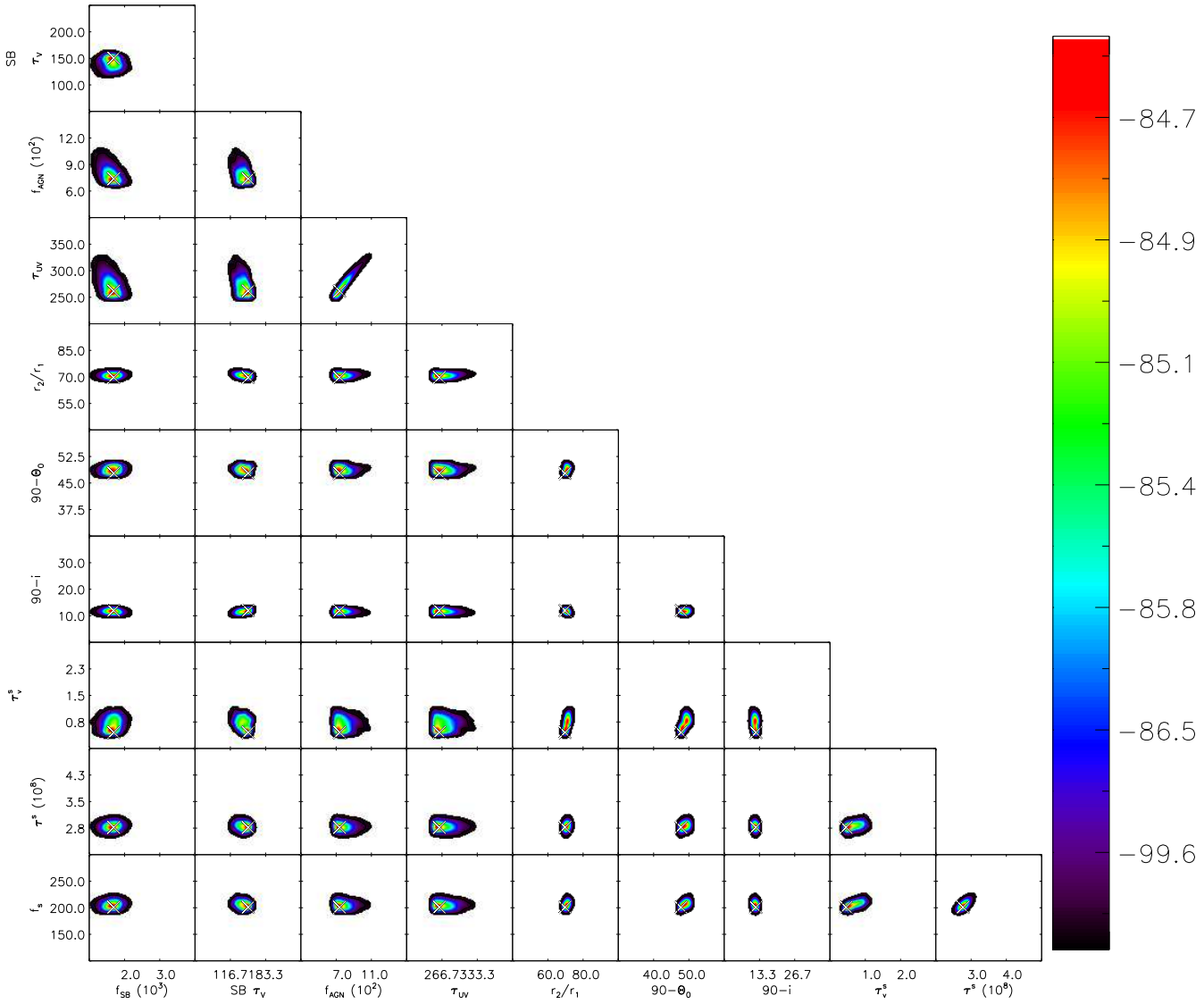

Figure 3. Same plot as Figure 2 showing the covariances between the parameters of the SED fit of HELP_J100156.75+022344.7 with the CYGNUS models and z fixed at 4.33

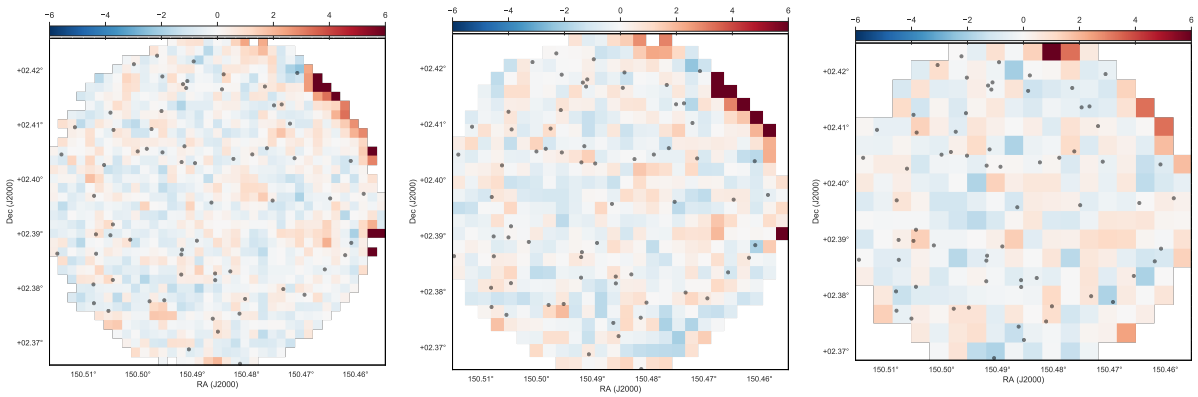

Figure 4. Plot showing the p-value maps at 250, 350 and 500μm (from left to right). The p-value maps are a form of Bayesian residual map. Each pixel in the p-value map is the effective sigma value of the true pixel flux in the distribution of model pixel fluxes from the posterior. Each pixel p-value is therefore a measure of how well the model accounts for the true pixel flux. The fact that all pixels have a p-value between -1 and 1σ gives us confidence that the prior list used by XID+ (Hurley et al 2017) is accounting sufficiently for the map and important priors are not missed. The dots denote all the priors used by XID+.