Onsala Proposal

Ramakrishnan 0108.F-9324

Resolving systematics in the Planck sub-millimetre spectra of radio-loud AGNs

Semester: may2021 **Science Cat.: External galaxies**

Abstract

We found possible dust contamination as denoted by the sub-millimetre excess in the radio spectra of bright AGNs observed during the Planck campaign. The origin of the dust in most cases seems to be intrinsic as they are unaffected by the Galactic dust. A majority of sources in the sample showing this trait are blazars, which as per the definition are old ellipticals with no significant traces of dust. The SEDs of these sources seem to be unlike the starburst galaxies that are known to have higher gas/dust temperatures. We propose continuum observations of the dust emission in 16 AGNs. Our goal is to characterise the nature and origin of the sub-mm flux in terms of the particle acceleration in addition to the dust in these objects and re-visit the evolutionary stage of AGNs in elliptical galaxies.

Applicants

Name	Affiliation	Email	Country		Potential observer
Venkatessh Ramakrishnan	Universidad de Concepcion (Astronomy)	vramakrishnan@udec.cl	Chile	Pi	Yes
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Is this a long term proposal: No

No overall scheduling requirements

Observing runs

run	telescope	instrument	time request (minimal)	frequency (GHz)	weather (pwv)	LST range	comments/constraints
A	APEX	SEPIA180 (159-211 GHz)	1h (1h)	167	any		
B	APEX	SEPIA345 (277-371 GHz)	1h (1h)	285	any		
C	APEX	SEPIA660 (581-727 GHz)	4h (4h)	679	any		

Targets

Source	RA	Dec	Epoch	Vlsr (km/s)	Duration (min)	Runs	Comments
1741-038	17:43:58.86	-03:50:04.6	J2000	315998.0	2	B	
0528+134	05:30:56.42	+13:31:55.1	J2000	617558.0	12	C	
0446+112	04:49:07.67	+11:21:28.6	J2000	361835.0	1	A	
0827+243	08:25:50.34	+03:09:24.5	J2000	282216.0	12	C	
0458-020	05:01:12.81	-01:59:14.3	J2000	685309.0	2	B	
0048-097	00:50:41.32	-09:29:05.2	J2000	190363.0	12	C	
0430+052	04:33:11.10	+05:21:15.6	J2000	9881.0	1	A	
1606+106	16:08:46.20	+10:29:07.8	J2000	367562.0	12	C	
0202+149	02:04:50.41	+15:14:11.0	J2000	121410.0	1	A	
1502+106	15:04:24.98	+10:29:39.2	J2000	551124.0	2	B	
2134+004	21:36:38.00	+00:41:54.0	J2000	582988.0	12	C	
0823+033	08:25:50.34	+03:09:24.5	J2000	151682.0	1	A	
0735+178	07:38:07.39	+17:42:19.0	J2000	127100.0	1	A	
0202+149	02:04:50.41	+15:14:11.0	J2000	121410.0	12	C	
0823+033	08:25:50.34	+03:09:24.5	J2000	151682.0	12	C	
1741-038	17:43:58.86	-03:50:04.6	J2000	315998.0	1	A	
0823+033	08:25:50.34	+03:09:24.5	J2000	151682.0	2	B	
0458-020	05:01:12.81	-01:59:14.3	J2000	685309.0	12	C	
0238-084	02:41:04.80	-08:15:20.8	J2000	1498.0	1	A	
0202+149	02:04:50.41	+15:14:11.0	J2000	121410.0	2	B	
0458-020	05:01:12.81	-01:59:14.3	J2000	685309.0	1	A	
0827+243	08:25:50.34	+03:09:24.5	J2000	282216.0	2	B	
0446+112	04:49:07.67	+11:21:28.6	J2000	361835.0	2	B	
1606+106	16:08:46.20	+10:29:07.8	J2000	367562.0	2	B	
1741-038	17:43:58.86	-03:50:04.6	J2000	315998.0	12	C	

Targets are continued on the last page

Scientific Rationale

Motivation

Traditionally, blazars have been defined as sources dominated by synchrotron and inverse-Compton emission across the whole electromagnetic range. In the standard framework, blazars are active galaxies in old, settled ellipticals with no appreciable amounts of dust. The new, extremely surprising Planck results (Planck Collaboration et al., 2016) now show that this "text-book" picture is not correct for a large fraction of blazars.

For at least 16 of the 104 blazars in the complete, flux-limited Northern *Planck* sample, we find clear evidence for a sub-millimetre spectral upturn (basically, at the three highest Planck frequencies – 353, 545 and 857 GHz). For the best sources, this excess follows the form $F_\nu \propto \nu^2$. Additionally, no variability was detected in the four Planck scans. This indicates that the excess is caused by a thermal component that starts to dominate over the synchrotron around $2 - 4 \times 10^{11}$ Hz.

Background

The first discovery of the high frequency excess in the radio continuum spectra of Seyferts and radio-quiet quasars were reported by Antonucci & Barvainis (1988) and Barvainis et al. (1996). These signatures are characterised by a steep spectrum at low-frequencies and flatter or inverted spectrum at higher frequencies ($>$ 10 GHz). The physical origin of the high-frequency component is still unclear. On the shorter wavelength, Behar et al. (2015) reported a millimetre excesses in several radio-quiet AGNs. They attribute this excess to the accretion disk coronal emissions. The synchrotron luminosity detectable in the submillimetre regime could be from non-thermal electrons in addition to the thermal ones originating from the magnetised disk in nearby Seyfert galaxies (Inoue & Doi, 2014).

Emission mechanisms

Despite the possible signature of the upturn in selected sources, most observations at frequencies above 300 GHz by Planck turned out to be non-detections (Planck Collaboration et al., 2016). The spectral turnover at a higher frequency cannot be ruled out on the basis of the present study. With the APEX sensitivity it is possible to explore the broadband spectral profile, which leads to characterising the origin of the sub-millimetre flux and as well as in distinguishing the physical origins of the high-frequency upturn. Some of the most potential emission-related processes connected to the radiation at sub-millimetre wavelengths are: (i) *dust emission*; (ii) *Free-free emission/absorption*; (iii) *synchrotron self-absorption*; (iv) *synchrotron from accretion flow:*; (v) *synchrotron from disk corona.*

Objectives

With the proposed APEX programme, we aim to address the following questions through careful modelling of the broadband spectral energy distribution by taking into account the above emission mechanisms.

(i) What is the highest possible T_B for compact jets in the mm-regime? Is the maximum brightness temperature limited by inverse Compton radiation to 10^{12} K as suggested by Kellermann & Pauliny-Toth (1969), or is it closer to the 10^{11} K equilibrium value as claimed by Readhead (1994).

(ii) Is the jet magnetically dominant near the launching base? At mm-wavelengths the effect of synchrotron self-absorption becomes negligible, and we are able to reach to a region closer to the jet launching base, a region in which modern GRMHD theory predicts magnetic dominance. Comparison to the equipartition brightness temperature, will immediately tell if the jet is particle energy ($T_{int} > T_{eq}$) or magnetic energy ($T_{int} < T_{eq}$) dominated.

(iii) What is the physical process responsible for the dominance of particle energy over magnetic energy if observed? Is the inferred excess of particle energy over magnetic energy really

a problem, or is it consistent with the observation of shock or bulk motion with velocities near the speed of light?

We hope to be able to answer at least some of the above questions with the proposed observations, which when complemented with the existing *Planck* observations can place stringent constraints on most of the above-mentioned variables. A more-thorough analysis on the spectral energy distribution of some of the sources with a better detection rate at the highest Planck band is ongoing. We will extend our multi-zone modelling approach that is employed currently to all the sources observed through this proposal.

Sample selection

We shortlisted a sample of 16 galaxies with non-detections at sub-millimetre bands and as well as displaying an upturn from the Planck Collaboration et al. (2016) study. The sub-millimetre data from the *Planck* observations of some of these galaxies show large uncertainties, therefore, making the judgement on the acceleration processes and gas/dust contamination impossible. However, for a few small-z sources, in particular 0430+052 (Figure 1), archival IRAS and other infrared data allows us to delineate the whole spectrum of this IR component. It can be roughly fitted with a single-temperature heated dust component, with temperature about 15 K (corresponding to $\nu_{\rm peak}$ around 10^{12} Hz).

The SEDs of the dusty blazars in our sample appear to be quite unlike those of ULIRGs, starbursts and other galaxies which typically have much broader thermal-dominated SEDs with higher gas temperatures. While the known types of galaxies have a range of dust temperatures, our newly detected blazars seem to be totally dominated by just the cool 15 K dust. The nature of this dust component is unclear.

The fact that a considerable fraction of blazars are found in dusty ellipticals forces both a redefinition of "blazar" and a re-evaluation of the merger-starburst-AGN evolutionary scenario which will be addressed by this proposal.

Facilities Requested

We request APEX observations using the SEPIA receivers 180, 345 and 660 to address the systematics at the sub-millimetre bands of *Planck* observations as discussed above.

Observing Requirements

We have used the ON-OFF observing time calculator at APEX V7.3 to estimate the total time needed to achieve our goal. We request a tuning frequency of 161 at LSB, 291 and 685 GHz at USB for the three SEPIA receivers. The sensitivity and resolution of APEX at respective frequencies is sufficient to constrain the continuum emission to be nuclear in these active galaxies. We require modest SNR observations that allows us to robustly constrain the accretion/jet physics using our models. We use typical (default) time calculator values and request a rms of 10 mK over $\sim$ 20 km s^{-1} channels (sufficient to resolve the nuclear emission and provide a continuum sensitivty). We request 1, 2 and 12-minutes of observing time per source using SEPIA180, SEPIA345 and SEPIA660, respectively, including the telescope and calibration overheads. Thus, in total it amounts to 4 hours for the entire sample with 16 sources. We add another 30-minutes per frequency for technical setup extending the total time request to 5 hours and 30 minutes.

Scheduling Requirements

Since switching frequencies takes up a bulk of the overheads, we request observations at a given frequency for all source before switching to another band. Although not mandatory, we prefer to schedule a given source at all frequencies during the same week.

References: [1] Antonucci, R., Barvainis, R. 1988, ApJ **332**, L13. [2] Barvainis, R., et al. 1996, AJ **111**, 1431. [3] Behar, E., et al. 2015, MNRAS **451**, 517. [4] Inoue, Y., Doi, A. 2014, PASJ **66**, L8. [5] Kellermann, K. I., Pauliny-Toth, I. I. K. 1969, ApJ **155**, L71. [6] Planck Collaboration, et al. 2016, A&A **594**, A13. [7] Readhead, A. C. S. 1994, ApJ **426**, 51.

Figures

The newpage command is intended to force the figure(s) onto the last page to prevent LaTeX from inserting them randomly in the text. If you have no figures, delete this section to save paper.

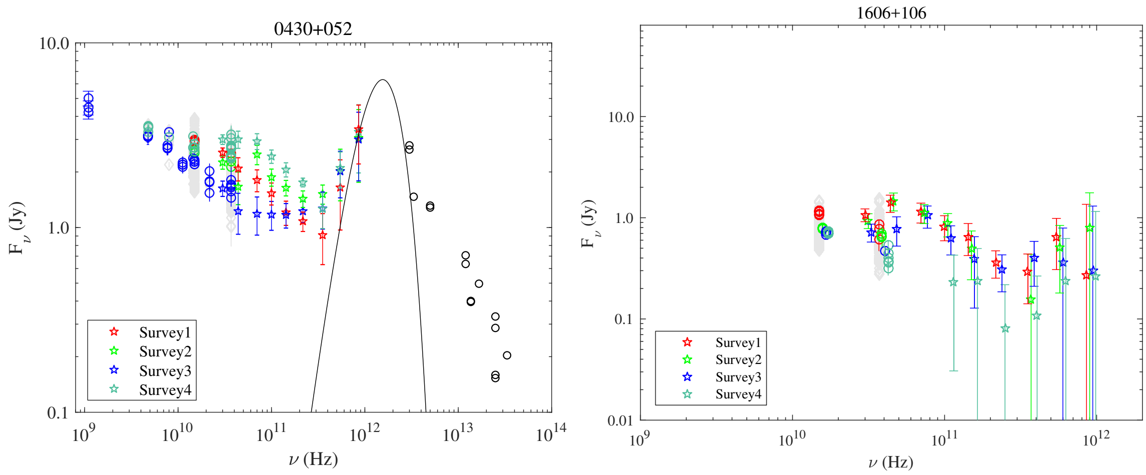

Figure 1: *Left:* The radio to infrared spectra of the Seyfert galaxy 3C 120. The radio spectra is reproduced from the paper Planck Collaboration et al. (2016) along with the infrared and optical observations from the NED database. The Planck data are denoted by star symbol, while the data at other bands in circles. The colour denotes the Planck survey that are separated by about 6 months. The solid line denotes the modified greybody fit with a emissivity index of 2 and a temperature of 15 K. *Right:* Radio spectrum of source 1606+106 obtained as part of the Planck campaign. The non-detections at frequencies > 100 GHz can be inferred from the large error-bars.

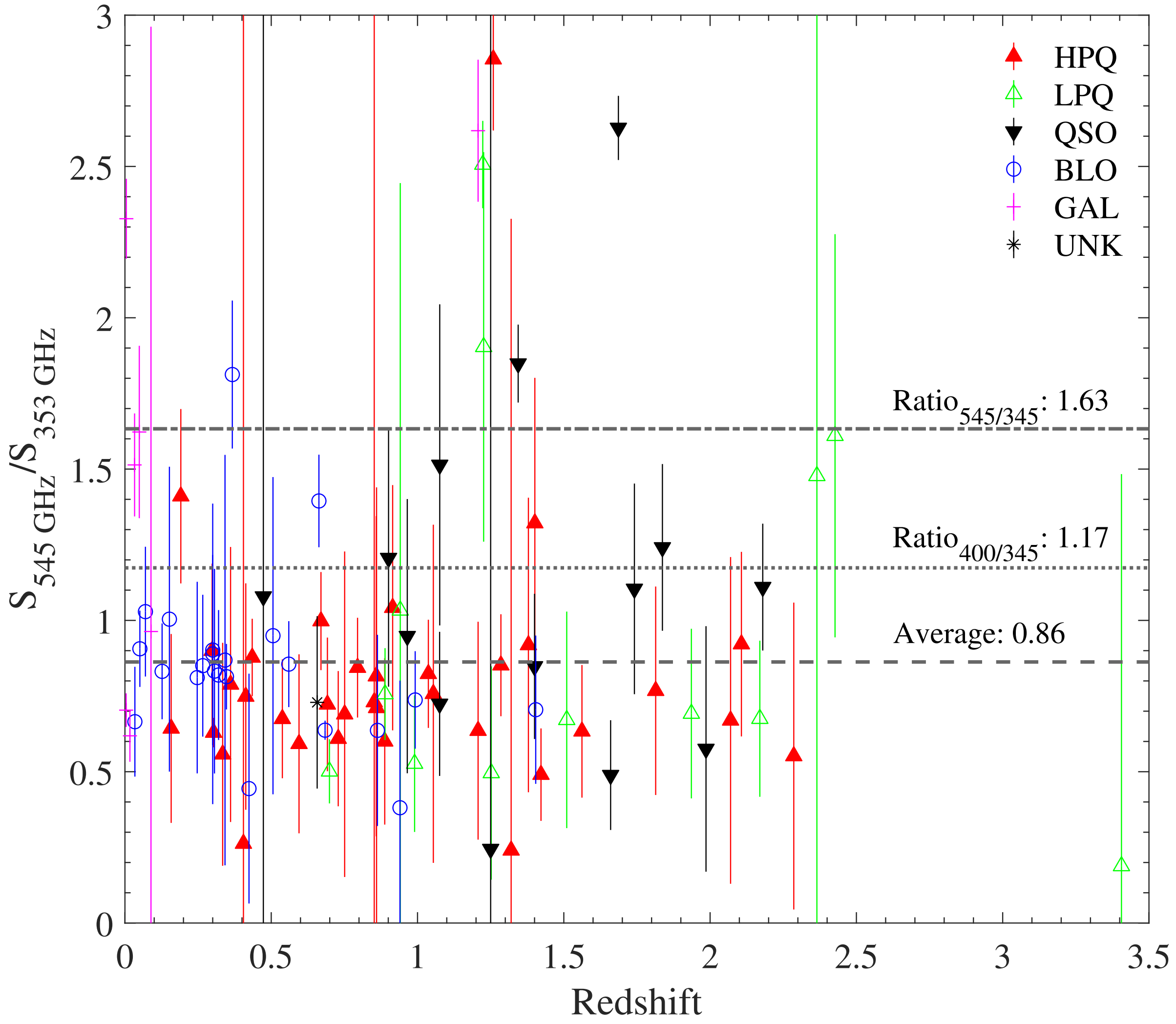

Figure 2: The flux ratios (545/353 GHz) of all 104 sources in the Planck Collaboration et al. (2016) study are shown as a function of redshift. The different source classes are denoted by coloured markers. The weighted mean of the flux ratio from the observation corresponds to 0.86 as marked by the dashed line. The dotted and dot-dashed lines correspond to the flux ratios obtained at [400/345] and [545/345] GHz, respectively, under the assumption of a 15K dust temperature and an optical spectral index of 1.8. We propose for those sources with a flux ratio ≥ 1.

No PhD Students involved

Linked proposal submitted to this TAC: No

Linked proposal submitted to other TACs: No

Relevant previous Allocations: No

Additional remarks

ESO=venkatessh

Observing run info :

Targets

Source	RA	Dec	Epoch	Vlsr (km/s)	Duration (min)	Runs	Comments
1606+106	16:08:46.20	+10:29:07.8	J2000	367562.0	1	A	
1502+106	15:04:24.98	+10:29:39.2	J2000	551124.0	12	C	
0528+134	05:30:56.42	+13:31:55.1	J2000	617558.0	1	A	
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1413+135	14:15:58.82	+13:20:23.7	J2000	73973.0	12	C	
1502+106	15:04:24.98	+10:29:39.2	J2000	551124.0	1	A	
0528+134	05:30:56.42	+13:31:55.1	J2000	617558.0	2	B	
0430+052	04:33:11.10	+05:21:15.6	J2000	9881.0	12	C	
0827+243	08:25:50.34	+03:09:24.5	J2000	282216.0	1	A	
0336-019	03:39:30.94	-01:46:35.8	J2000	255409.0	12	C	
0048-097	00:50:41.32	-09:29:05.2	J2000	190363.0	2	B	
0238-084	02:41:04.80	-08:15:20.8	J2000	1498.0	12	C	
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0430+052	04:33:11.10	+05:21:15.6	J2000	9881.0	2	B	
1413+135	14:15:58.82	+13:20:23.7	J2000	73973.0	2	B	
0735+178	07:38:07.39	+17:42:19.0	J2000	127100.0	12	C	
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