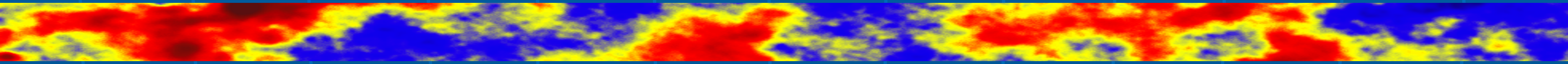
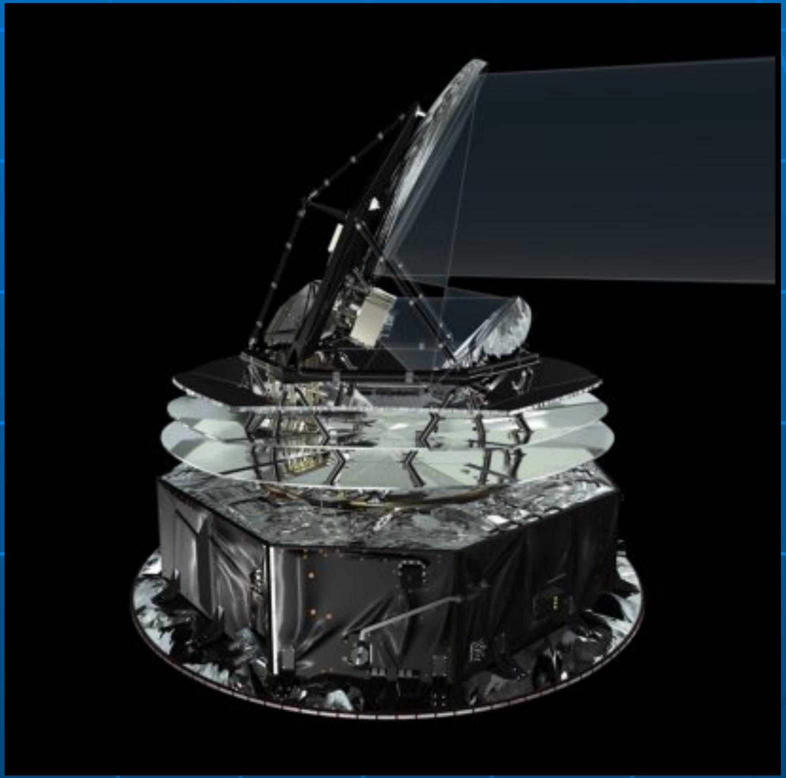
Multifrequency studies of active galactic nuclei in the *Planck* satellite era



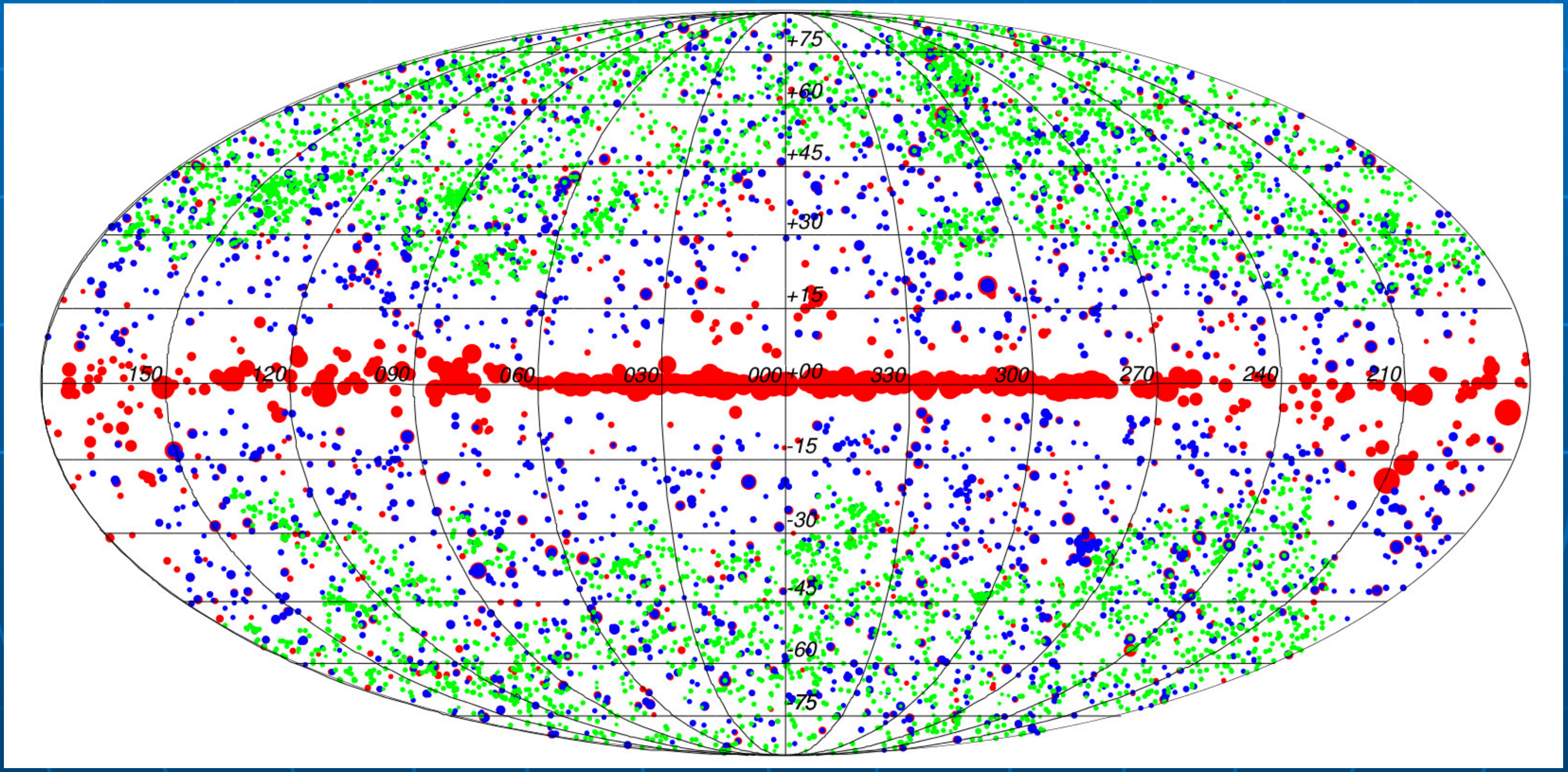
Anne Lähteenmäki
Aalto University Metsähovi Radio Observatory
& Dept of Radio Science and Engineering
&
Planck Collaboration


Planck satellite

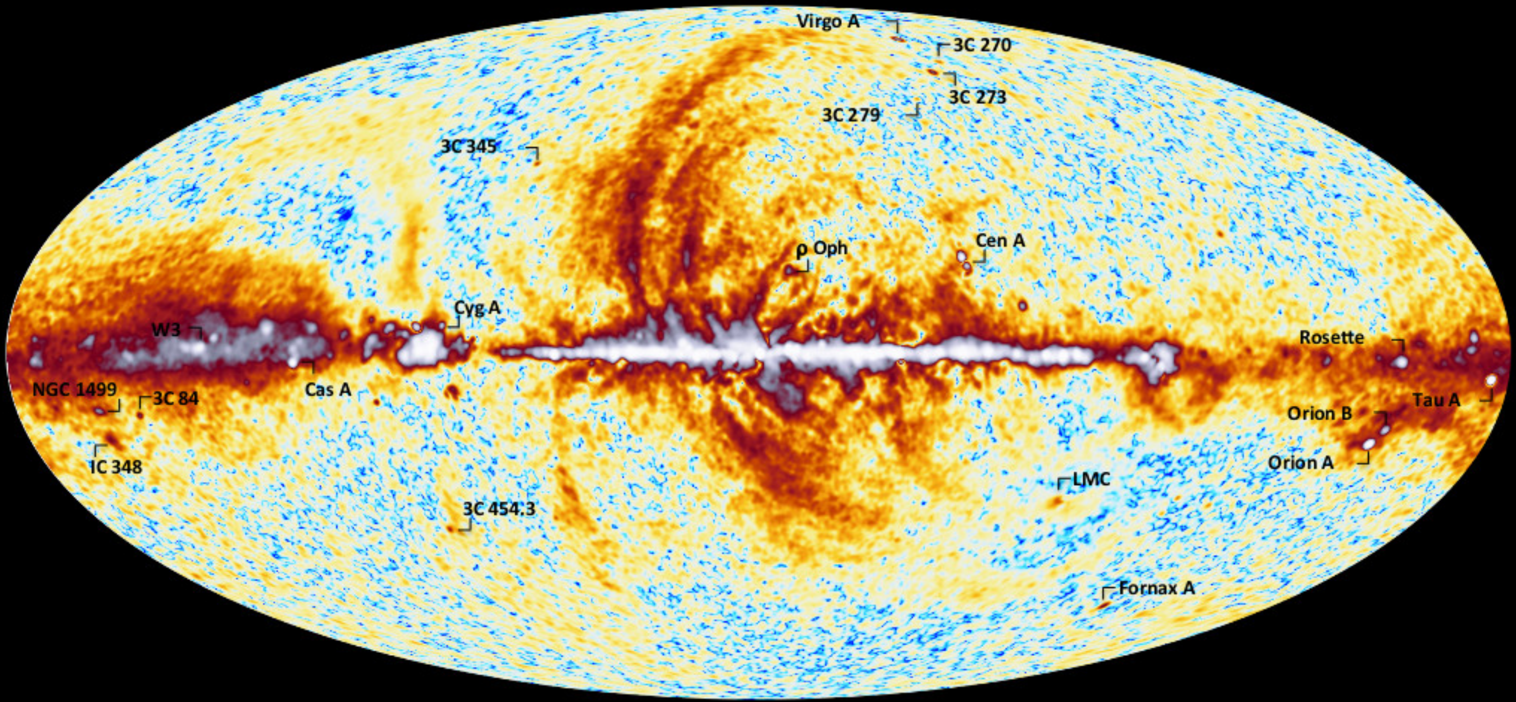
- 14.5.2009 – 23.10.2013
- CMB + foreground sources
- 9 frequencies 30 – 857 GHz
  - Low Frequency Instrument
  - High Frequency Instrument
- 5 to 8 full sky surveys
  - every six months



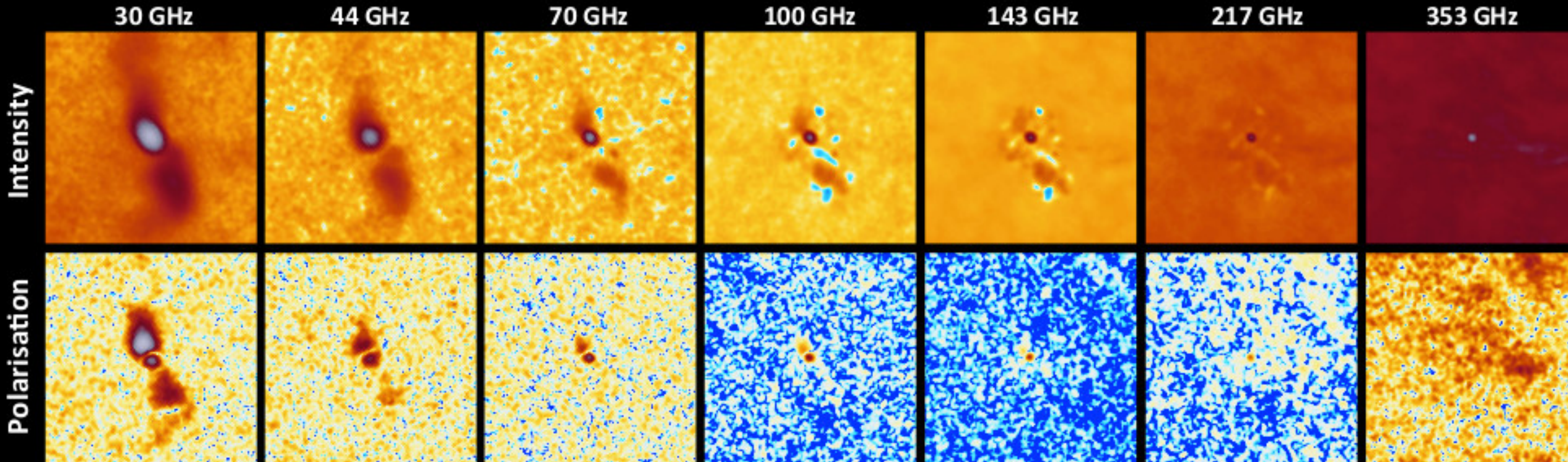
The second *Planck* catalogue of compact sources released (A&A in press)

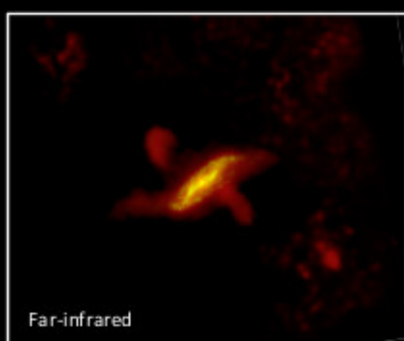


The *Planck* 30 GHz Sky in Polarisation



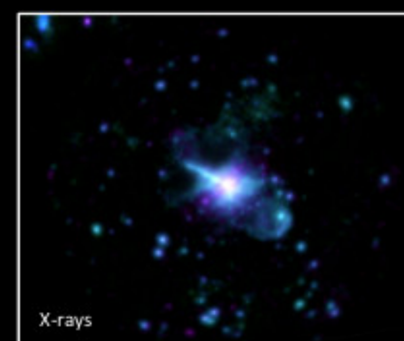
Planck's view of Centaurus A





ESA/Herschel/SPIRE/PACS

ESO



ESA/XMM-Newton/EPIC

Astronomy & Astrophysics manuscript no. Lahteenmaki_Planck_PIP_XLV
May 19, 2016

in press

Planck intermediate results. XLV. Radio spectra of northern extragalactic radio sources

Planck Collaboration: P. A. R. Ade[84], N. Aghanim[57], H. D. Aller[6], M. F. Aller[6], M. Arnaud[71], J. Aumont[57], C. Baccigalupi[82], A. J. Banday[93,11], R. B. Barreiro[62], N. Bartolo[29,63], E. Battaner[94,95], K. Benabed[58,92], A. Benoit-Lévy[23,58,92], J.-P. Bernard[93,11], M. Bersanelli[32,49], P. Bielewicz[79,11,82], A. Bonaldi[65], L. Bonavera[62], J. R. Bond[10], J. Borrill[15,88], F. R. Bouchet[58,85], C. Burigana[48,30,50], E. Calabrese[90], A. Catalano[72,70], H. C. Chiang[26,8], P. R. Christensen[80,34], D. L. Clements[54], L. P. L. Colombo[22,64], F. Couchot[69], B. P. Crill[64,13], A. Curto[62,7,67], F. Cuttaia[48], L. Danese[82], R. D. Davies[65], R. J. Davis[65], P. de Bernardis[31], A. de Rosa[48], G. de Zotti[45,82], J. Delabrouille[1], C. Dickinson[65], J. M. Diego[62], H. Dole[57,56], S. Donzelli[49], O. Doré[64,13], A. Ducout[58,54], X. Dupac[36], G. Efstathiou[59], F. Elsner[23,58,92], H. K. Eriksen[60], F. Finelli[48,50], O. Forni[93,11], M. Frailis[47], A. A. Fraisse[26], E. Franceschi[48], S. Galeotta[47], S. Galli[66], K. Ganga[1], M. Giard[93,11], Y. Giraud-Héraud[1], E. Gjerløw[60], J. González-Nuevo[20,62], K. M. Górski[64,96], A. Gruppuso[48], M. A. Gurwell[42], F. K. Hansen[60], D. L. Harrison[59,67], S. Henrot-Versillé[69], C. Hernández-Monteagudo[14,76], S. R. Hildebrandt[64,13], M. Hobson[7], A. Hornstrup[17], T. Hovatta[3,12], W. Hovest[76], K. M. Huffenberger[24], G. Hurier[57], A. H. Jaffe[54], T. R. Jaffe[93,11], E. Järvelä[2], E. Keihänen[25], R. Keskitalo[15], T. S. Kisner[74], R. Kneissl[35,9], J. Knoche[76], M. Kunz[18,57,4], H. Kurki-Suonio[25,44], A. Lähteenmäki[2,44*], J.-M. Lamarre[70], A. Lasenby[7,67], M. Lattanzi[30], C. R. Lawrence[64], R. Leonardi[36], F. Levrier[70], M. Liguori[29,63], P. B. Lilje[60], M. Linden-Vørnle[17], M. López-Caniego[36,62], P. M. Lubin[28], J. F. Macías-Pérez[72], B. Maffei[65], D. Maino[32,49], N. Mandolesi[48,30], M. Maris[47], P. G. Martin[10], E. Martínez-González[62], S. Masi[31], S. Matarrese[29,63,40], W. Max-Moerbeck[12,77], P. R. Meinhold[28], A. Melchiorri[31,51], A. Mennella[32,49], M. Migliaccio[59,67], M. Mingaliev[89,68], M.-A. Miville-Deschênes[57,10], A. Moneti[58], L. Montier[93,11], G. Morgante[48], D. Mortlock[54], D. Munshi[84], J. A. Murphy[78], F. Nati[26], P. Natoli[30,5,48], E. Nieppola[3,39], F. Noviello[65], D. Novikov[75], I. Novikov[80,75], L. Pagano[31,51], F. Pajot[57], D. Paoletti[48,50], B. Partridge[43], F. Pasian[47], T. J. Pearson[13,55], O. Perdereau[69], L. Perotto[72], V. Pettorino[41], F. Piacentini[31], M. Piat[1], E. Pierpaoli[22], S. Plaszczynski[69], E. Pointecouteau[93,11], G. Polenta[5,46], G. W. Pratt[71], V. Ramakrishnan[3], E. A. Rastorgueva-Foi[83], A. C. S Readhead[12], M. Reinecke[76], M. Remazeilles[65,57,1], C. Renault[72], A. Renzi[33,52], J. L. Richards[12,27], I. Ristorcelli[93,11], G. Rocha[64,13], M. Rossetti[32,49], G. Roudier[1,70,64], J. A. Rubiño-Martín[61,19], B. Rusholme[55], M. Sandri[48], M. Savelainen[25,44], G. Savini[81], D. Scott[21], Y. Sotnikova[89], V. Stolyarov[7,89,68], R. Sunyaev[76,86], D. Sutton[59,67], A.-S. Suur-Uski[25,44], J.-F. Sygnet[58], J. Tammi[3], J. A. Tauber[37], L. Terenzi[38,48], L. Toffolatti[20,62,48], M. Tomasi[32,49], M. Tornikoski[3], M. Tristram[69], M. Tucci[18], M. Türler[53], L. Valenziano[48], J. Valiviita[25,44], E. Valtaoja[91], B. Van Tent[73], P. Vielva[62], F. Villa[48], L. A. Wade[64], A. E. Wehrle[87], I. K. Wehus[64], D. Yvon[16], A. Zacchei[47], and A. Zonca[28]

x 11.69 in

Planck early results. XV. Spectral energy distributions and radio continuum spectra of northern extragalactic radio sources (Planck Collaboration 2011)

Simultaneous radio data: four epochs

- Planck 30 – 857 GHz single-survey data
- Metsähovi 37 GHz
- RATAN-600 1 – 22 GHz
- OVRO 15 GHz
- UMRAO 4.8, 8, 14.5 GHz
- SMA 230, 345 GHz (five sources)

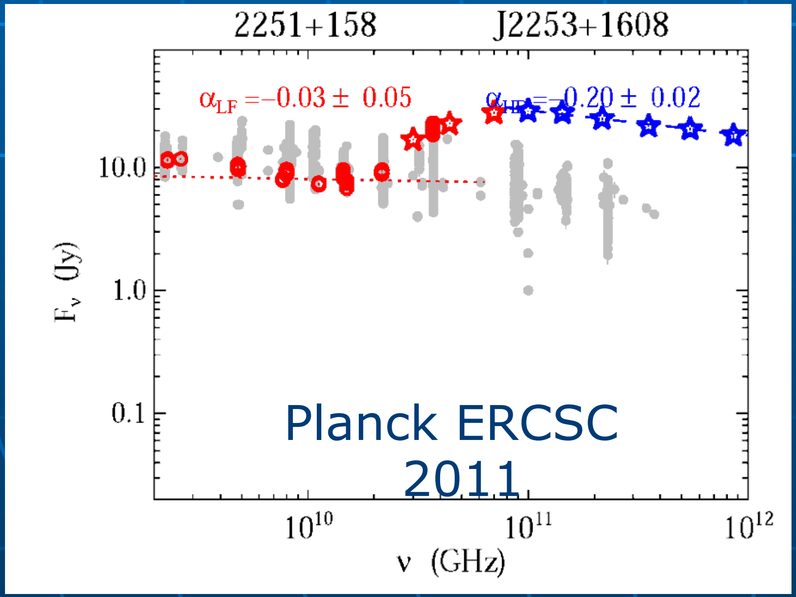
- 104 sources

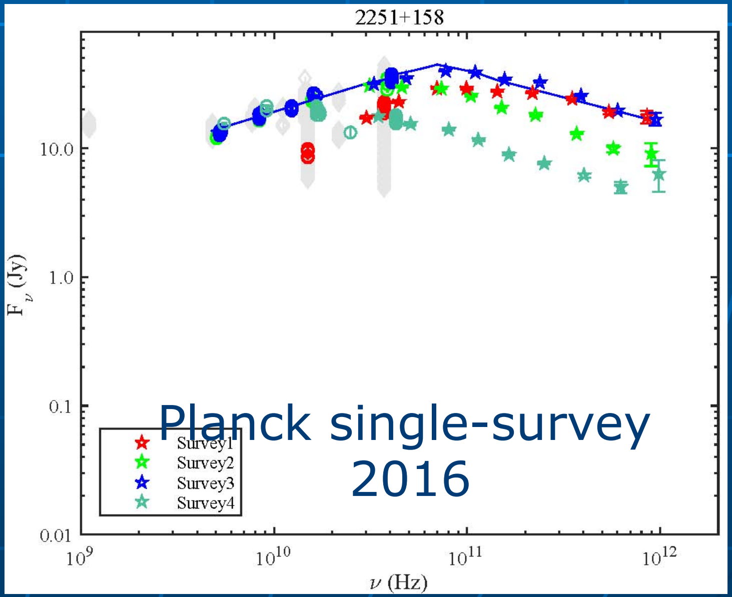
40 HPQ	24 BLO
14 LPQ	8 GAL
17 QSO	1 UN

Fitted with a broken power-law model

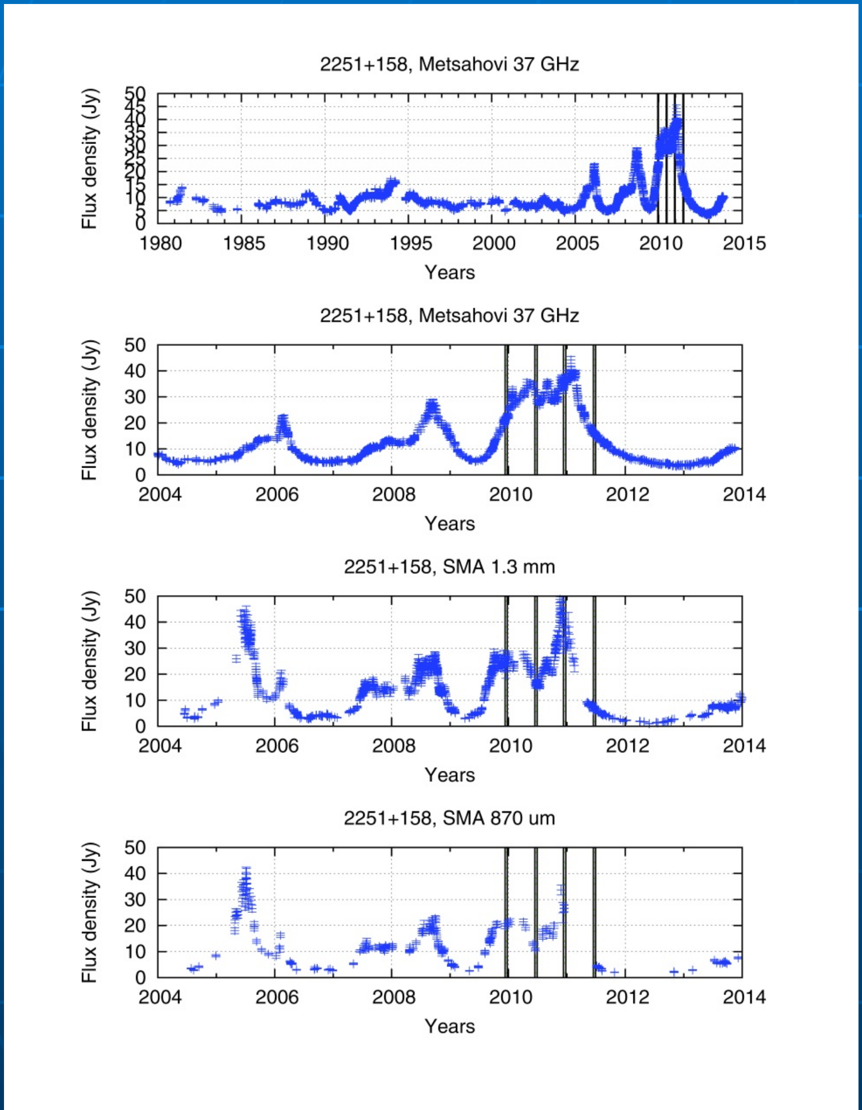
What kind of radio spectra do we see over 2 years?

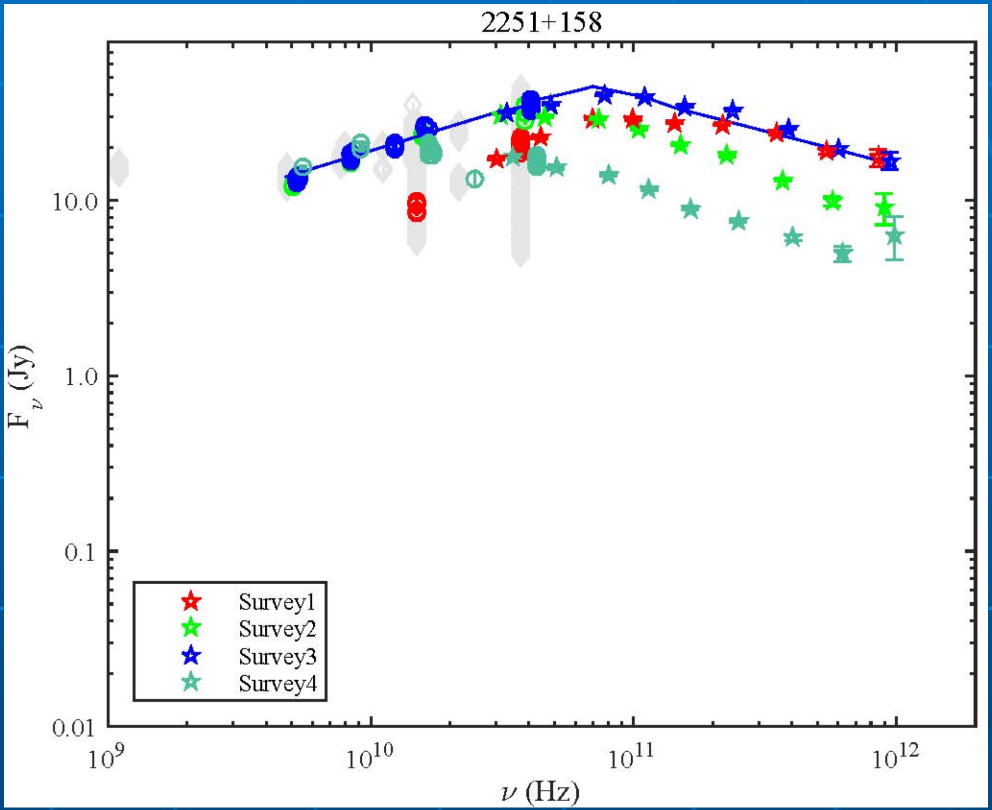
- Evolving shocks, achromatic variations, non-variable
  - Very few good examples of isolated, complete flares.
  - Sampling every six months is too sparse to follow the evolution of a flare from beginning to end.





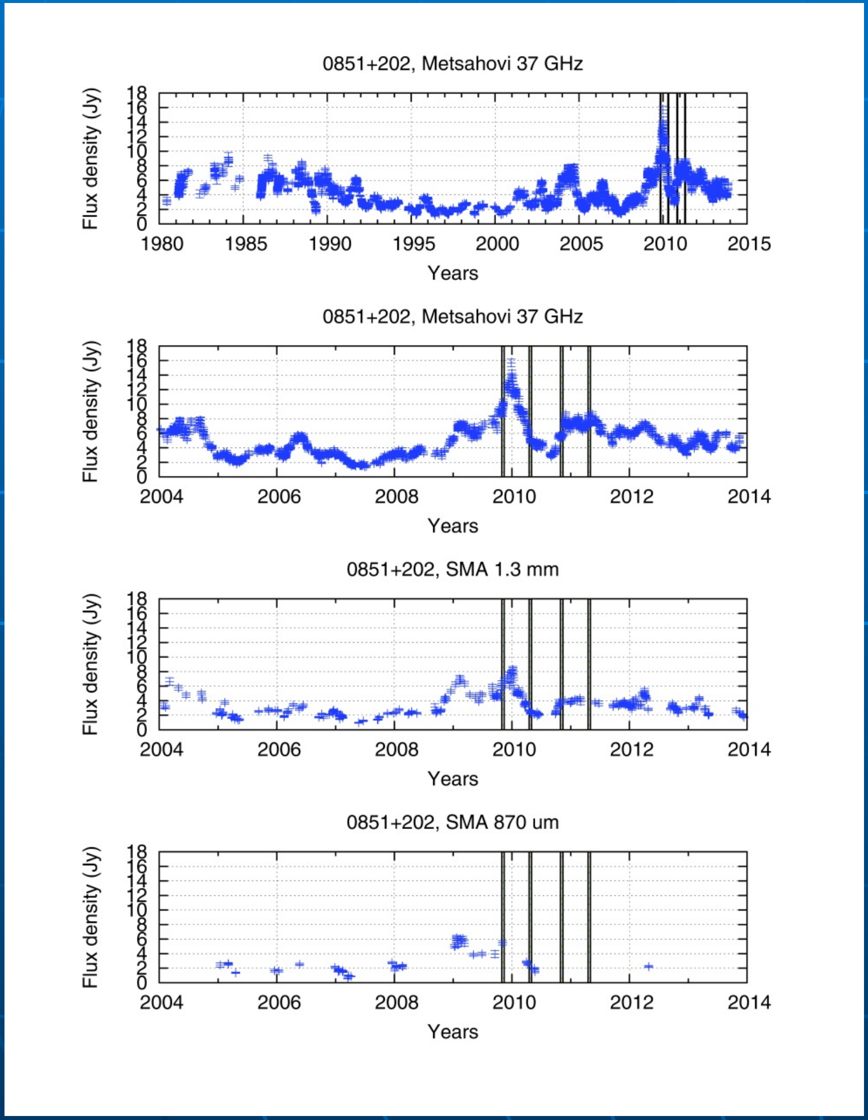
3C 454.3

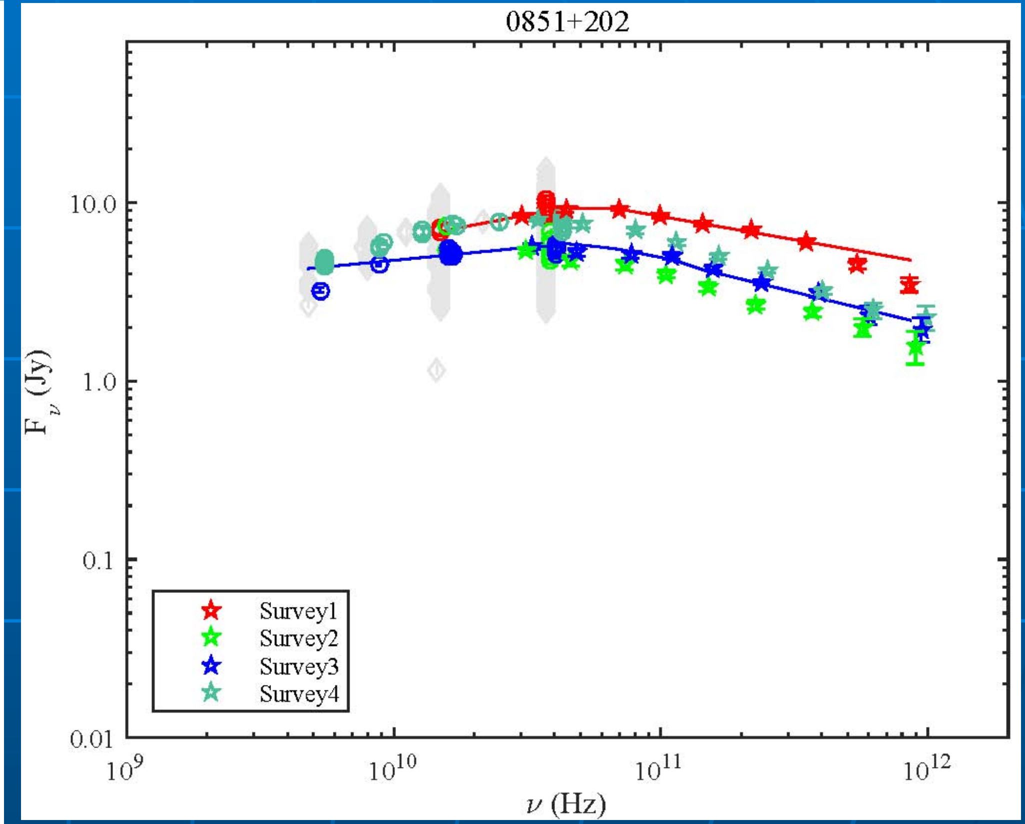




Planck spectra

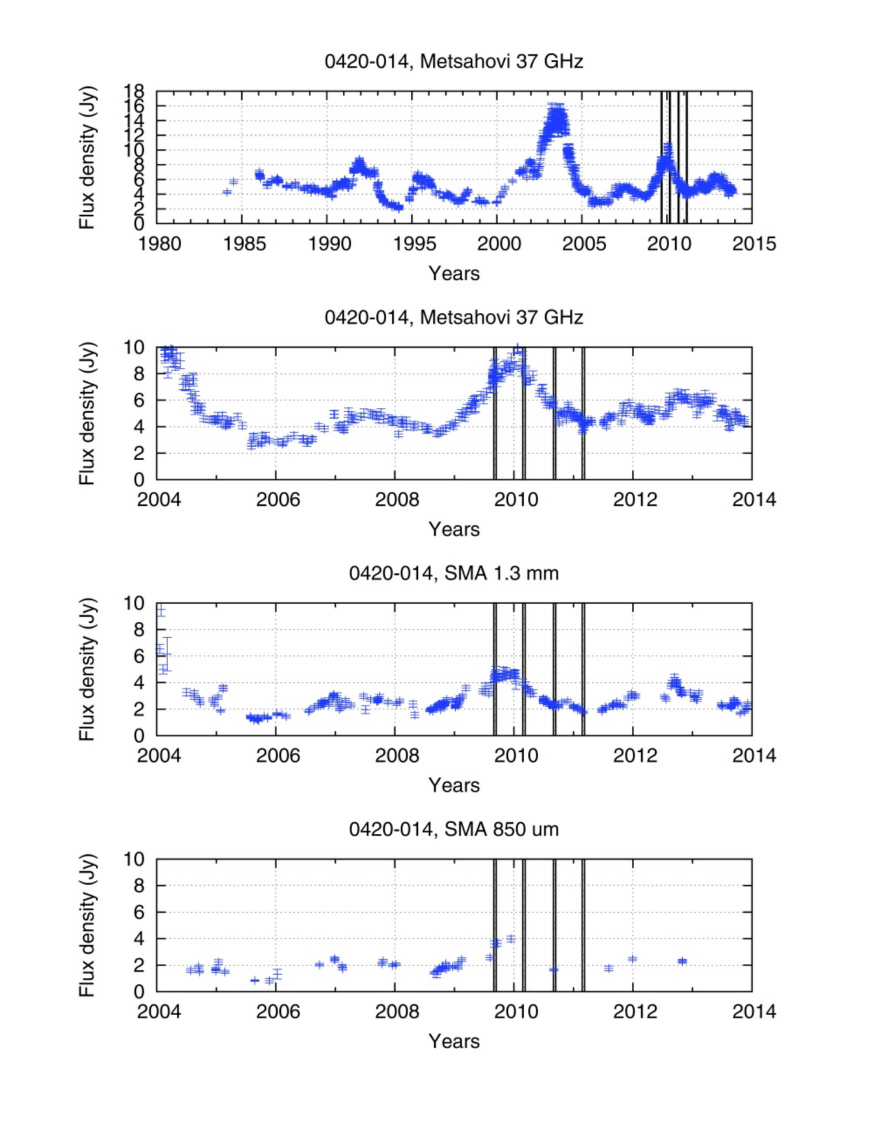
OJ 287

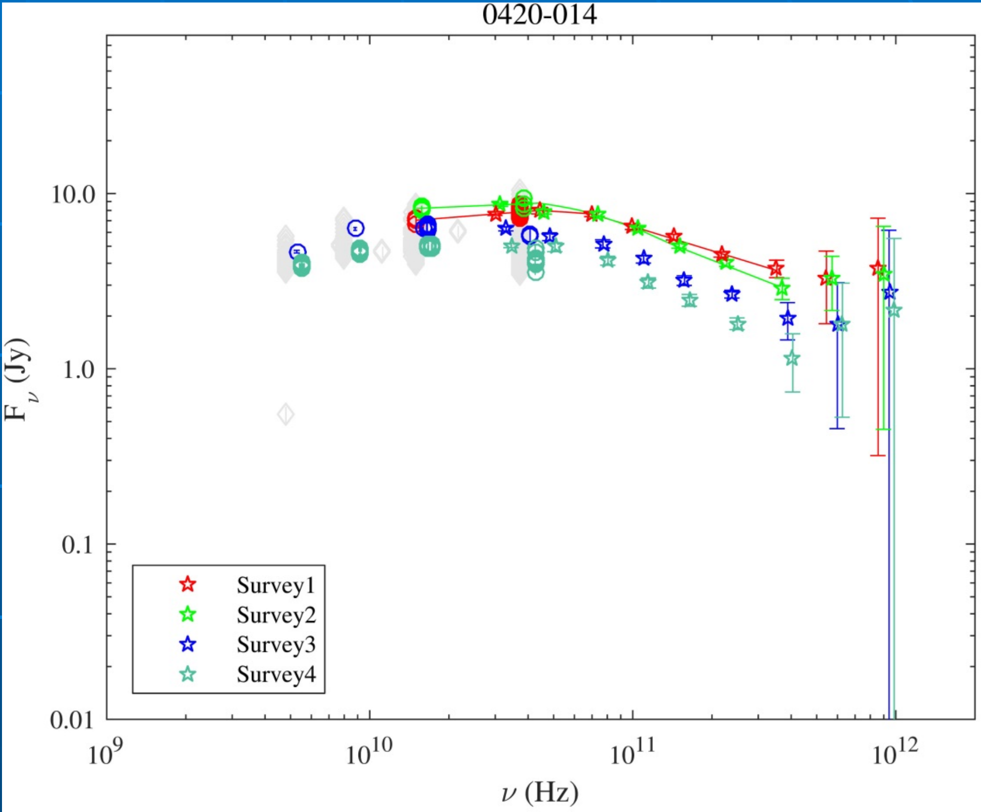




Planck spectra

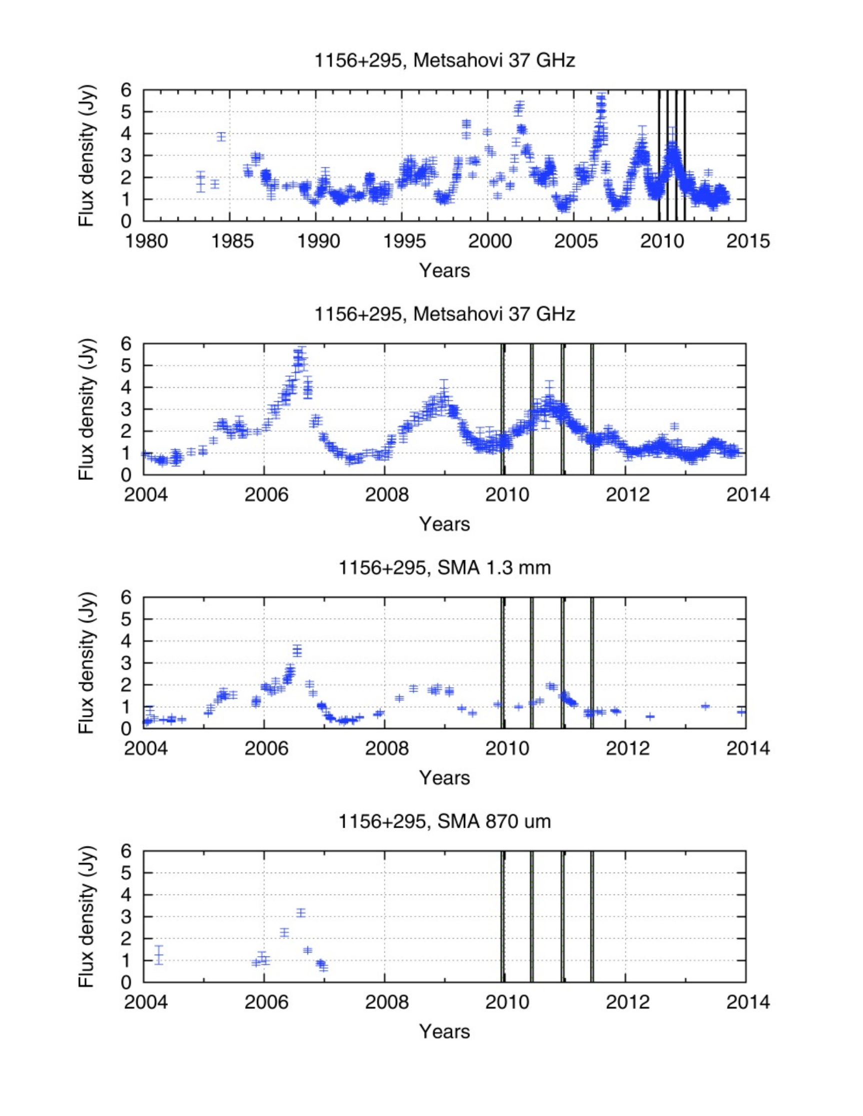
0420-014

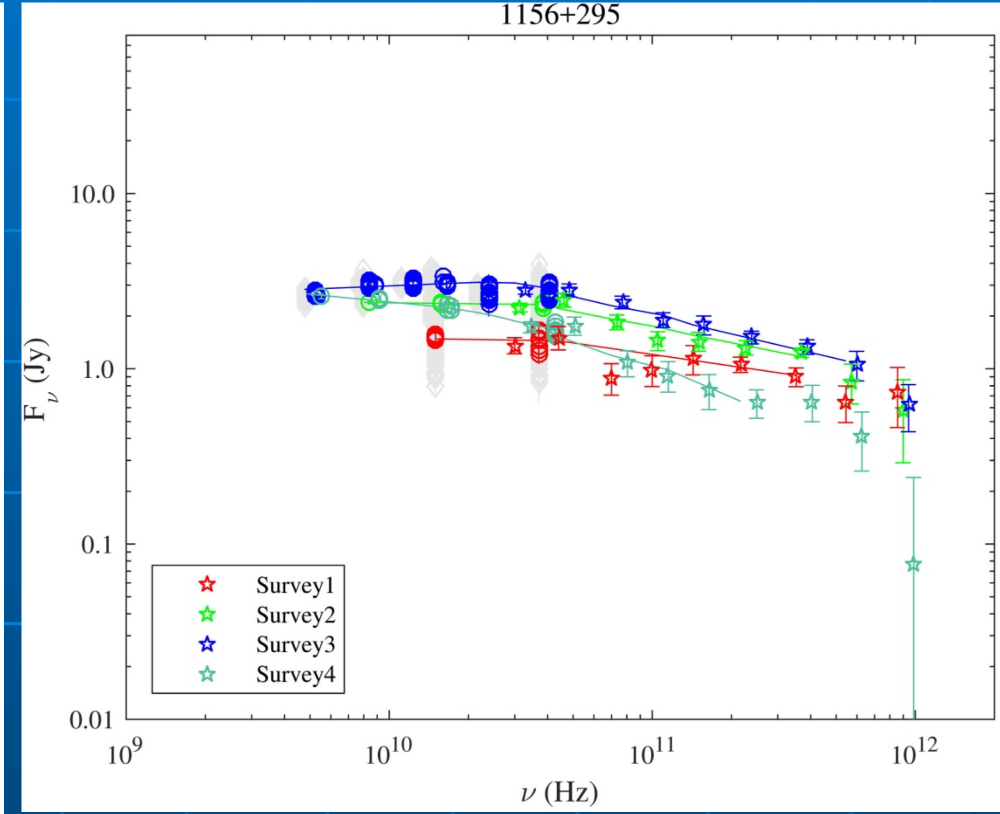




Planck spectra

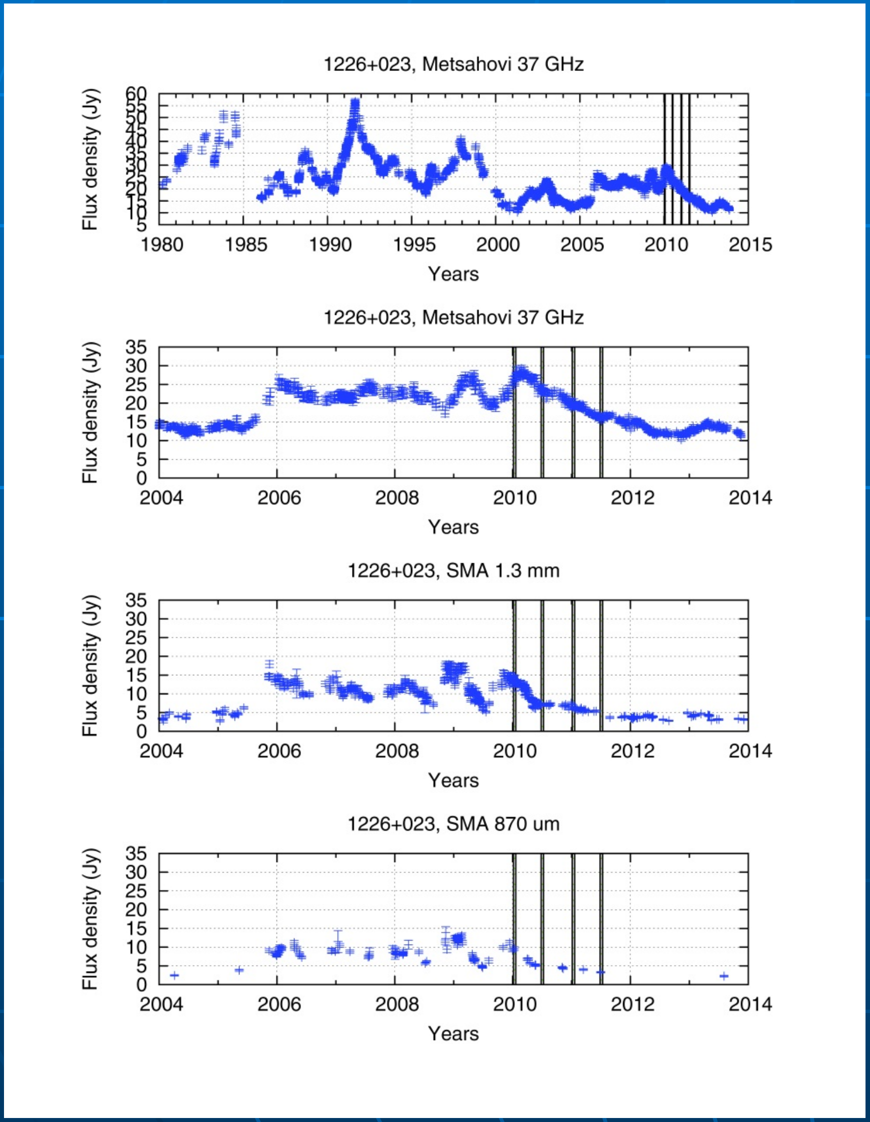
1156+295

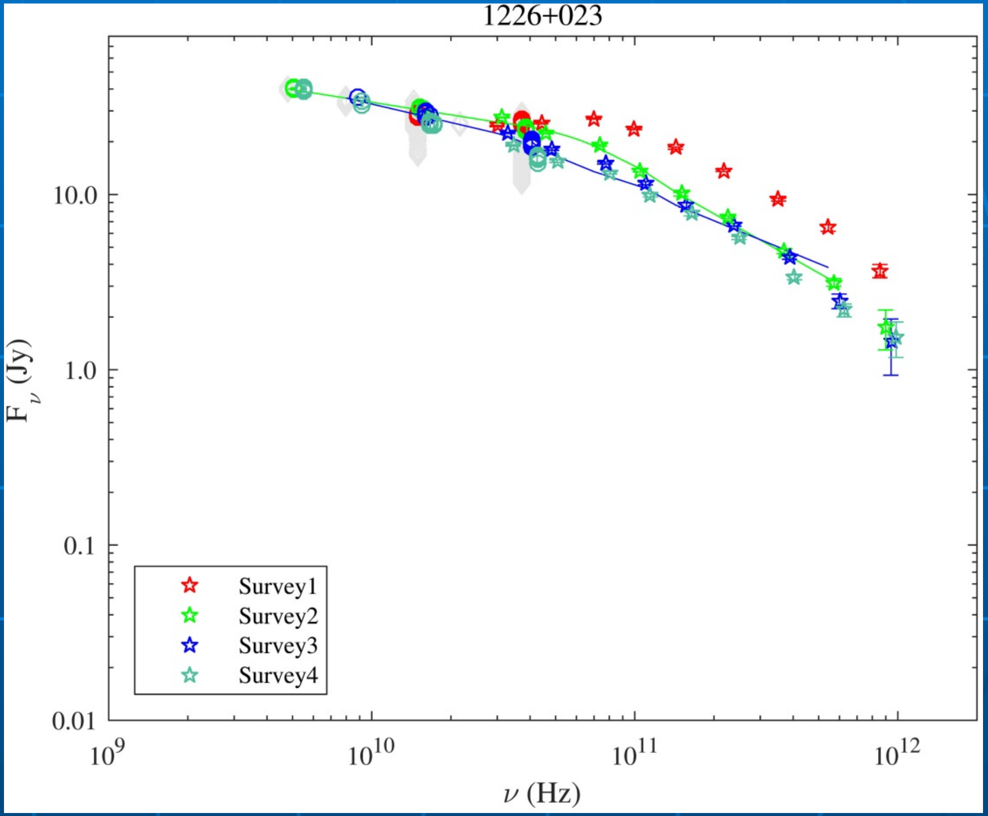




Planck spectra

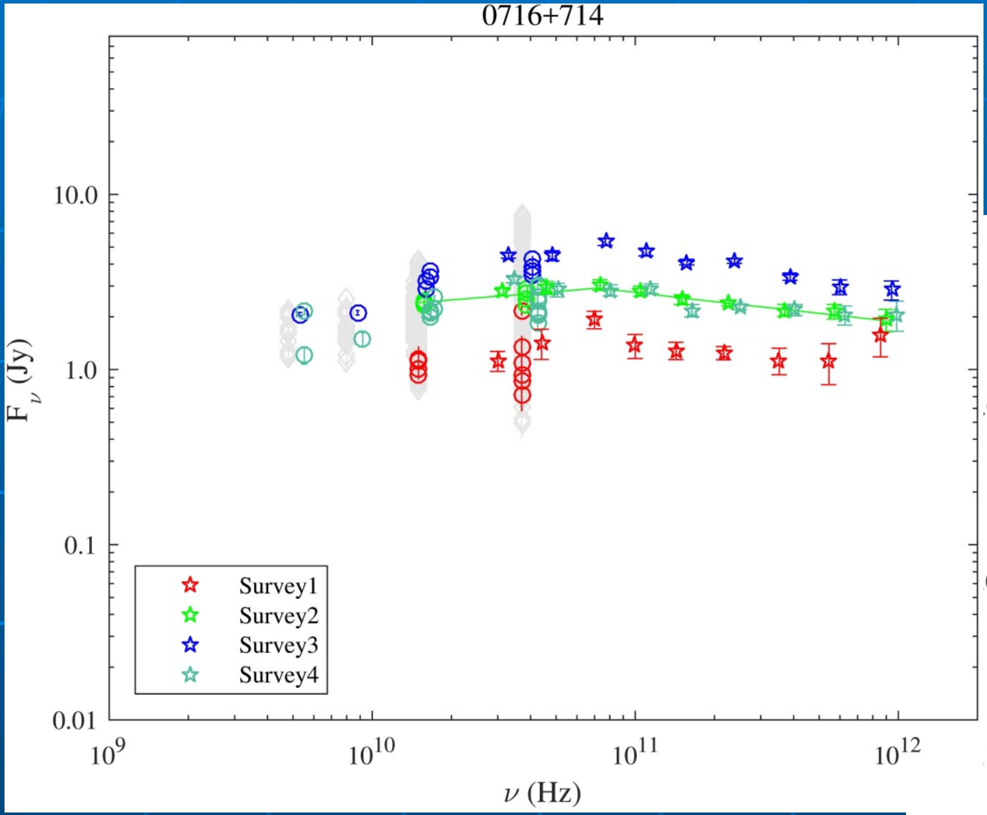
3C 273

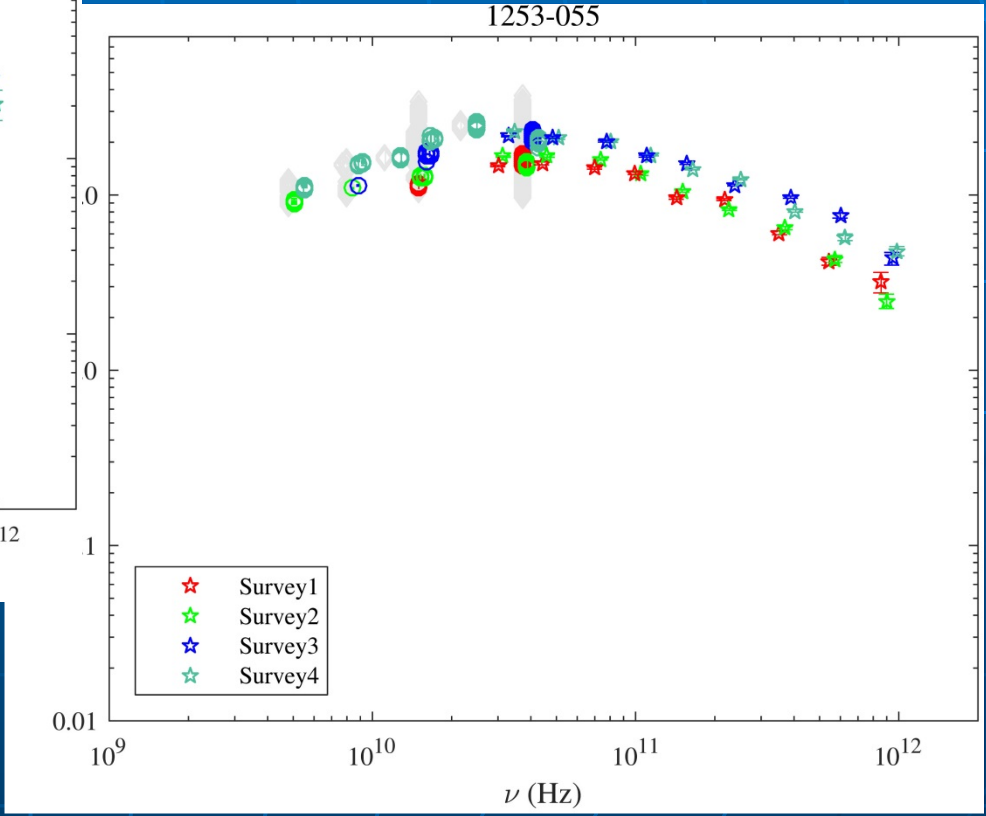




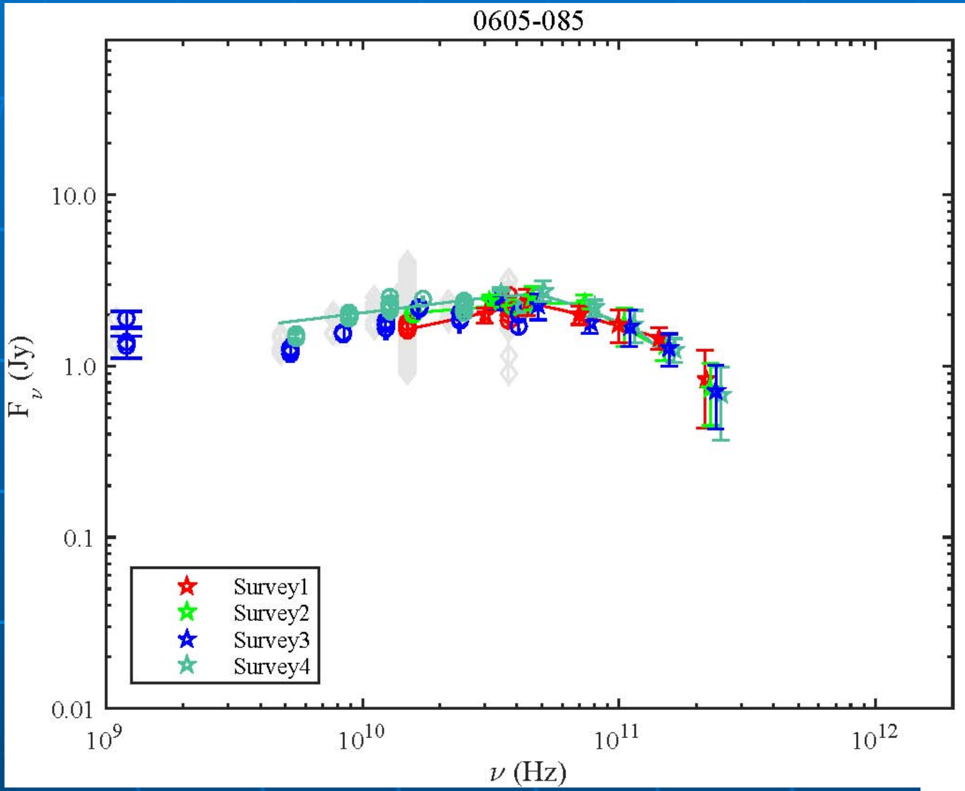
Planck spectra

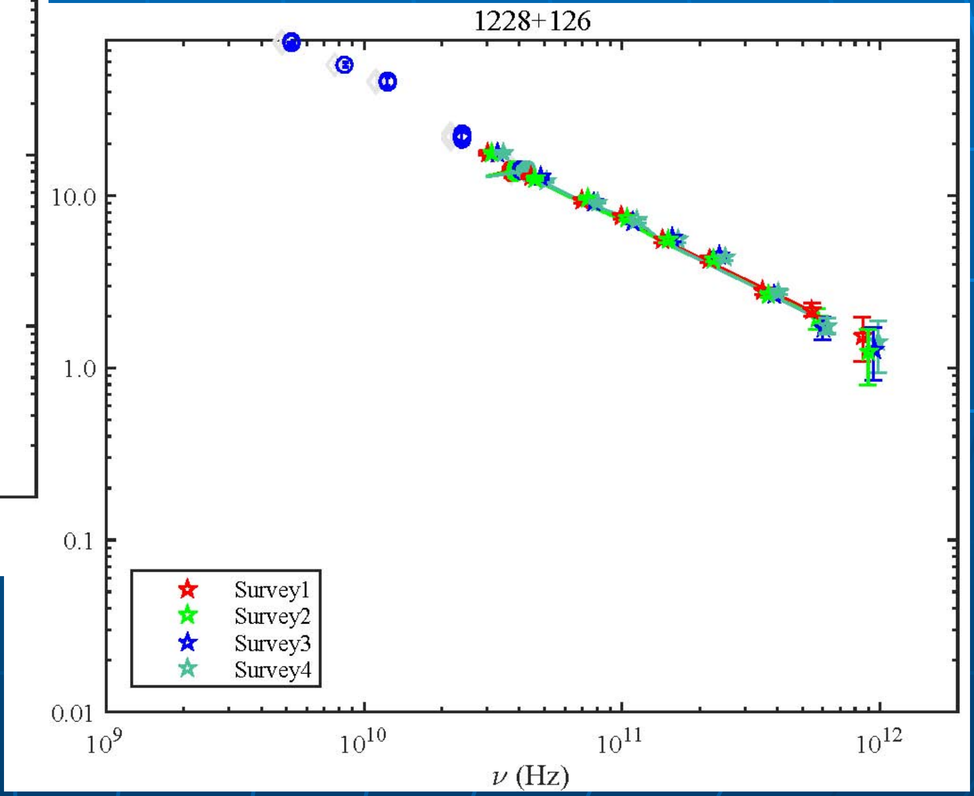
Examples of Planck spectra





Examples of Planck spectra





Variability models

Marscher & Gear shocked jet model

- Evolving shocks in the strongest outbursts only?

Turbulent extreme multi-zone (TEMZ) model

- Explains essentially both of the above.

Achromatic variations

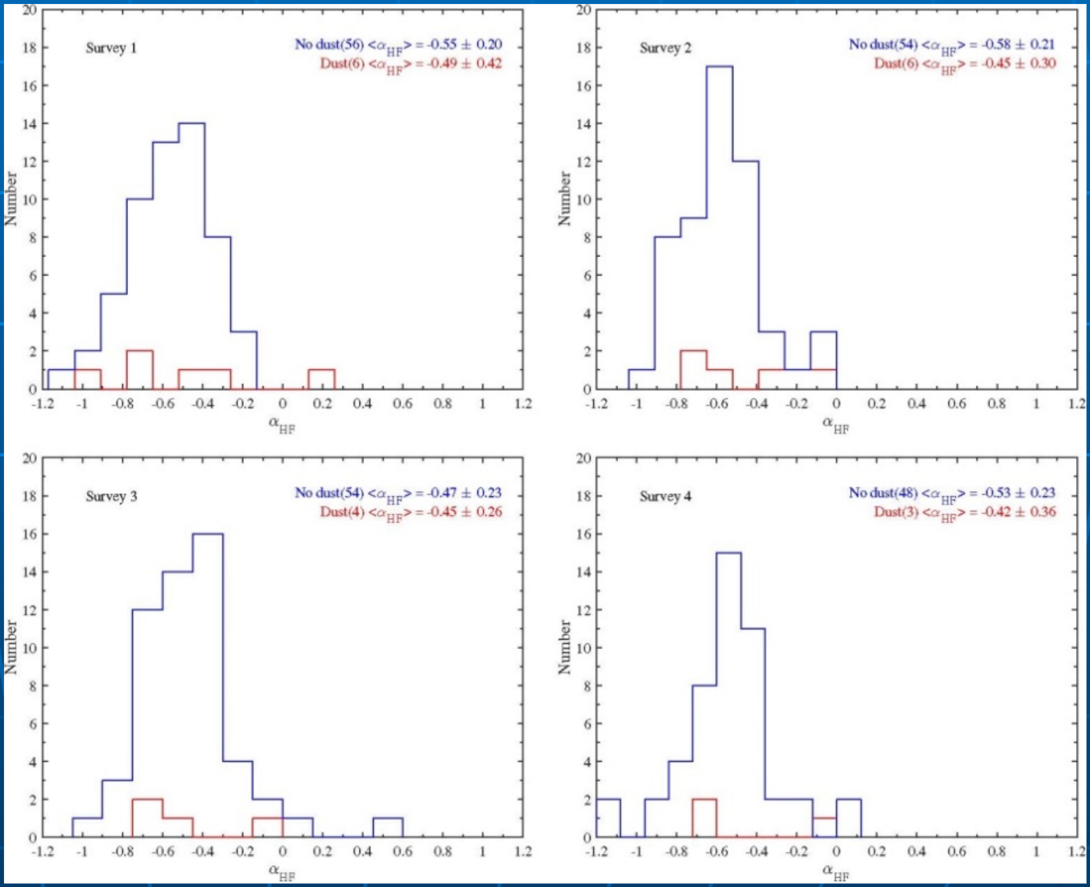
- This study says *yes*, some others *no*.
- Sampling too sparse for catching entire flares.

~~**Geometric models**~~

- ~~Predicts periodicities which are not observed over long time scales.~~

Flat high frequency spectra

- Original electron acceleration spectrum index is hard, 1.5
- Acceleration mechanism?



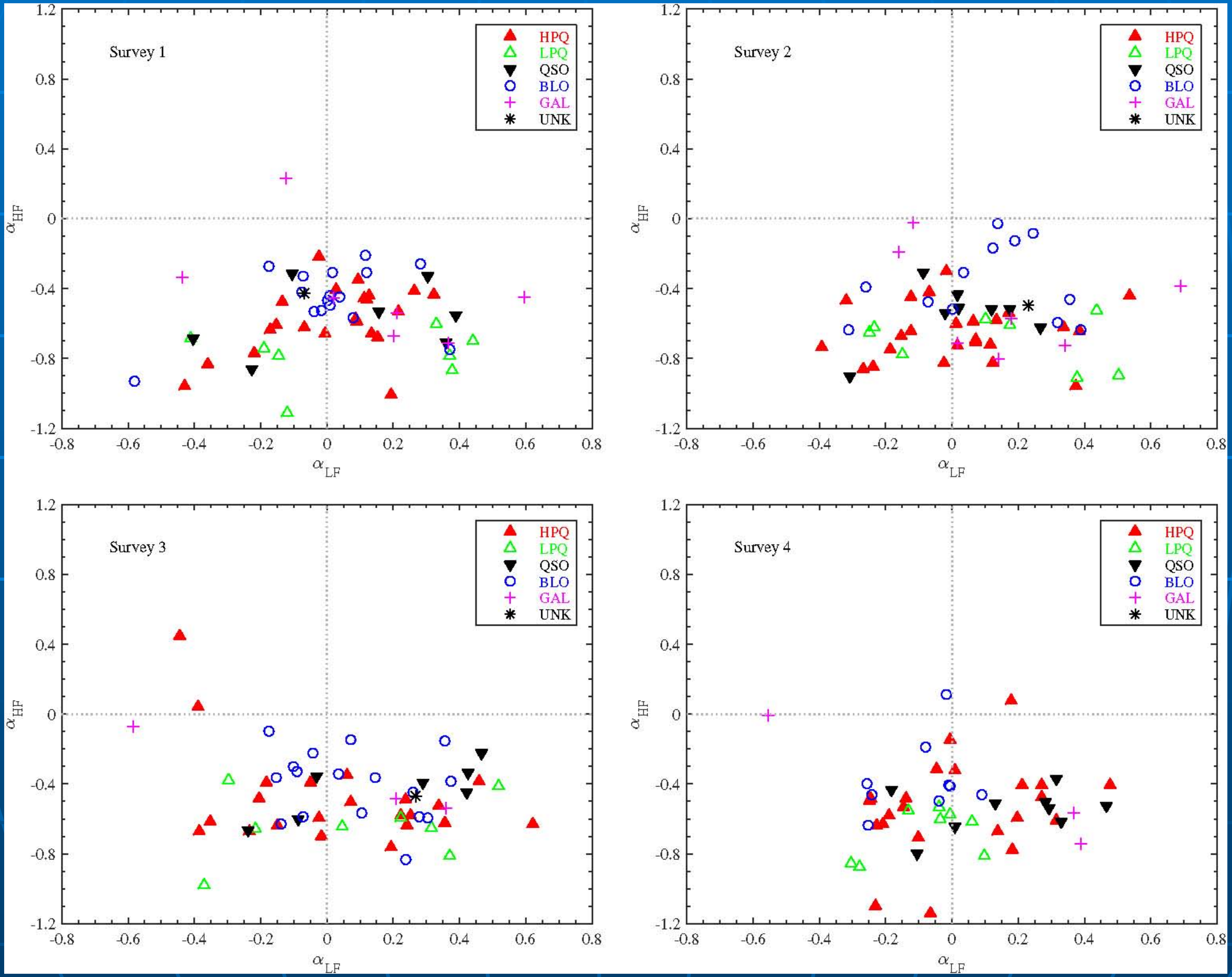
AGN classes

- Differences in spectral indices between AGN classes
  - BL Lac objects vs. Low Polarization Quasars
- High break frequencies
  - All sources

	Survey 1			Survey 2			Survey 3			Survey 4		
Class	α_{LF}	α_{HF}	α_{bf}	α_{LF}	α_{HF}	α_{bf}	α_{LF}	α_{HF}	α_{bf}	α_{LF}	α_{HF}	α_{bf}
BLO	0.005	−0.454	81.5	0.096	−0.369	61.3	0.082	−0.409	57.2	−0.090	−0.371	37.2
HPQ	0.008	−0.560	61.2	0.030	−0.647	65.2	0.000	−0.481	61.2	0.027	−0.535	55.0
LPQ	0.081	−0.784	54.1	0.120	−0.695	48.8	0.074	−0.640	42.0	−0.080	−0.679	43.2
QSO	0.205	−0.495	55.5	0.017	−0.530	72.6	0.230	−0.410	44.7	0.150	−0.541	43.5

Spectral shapes

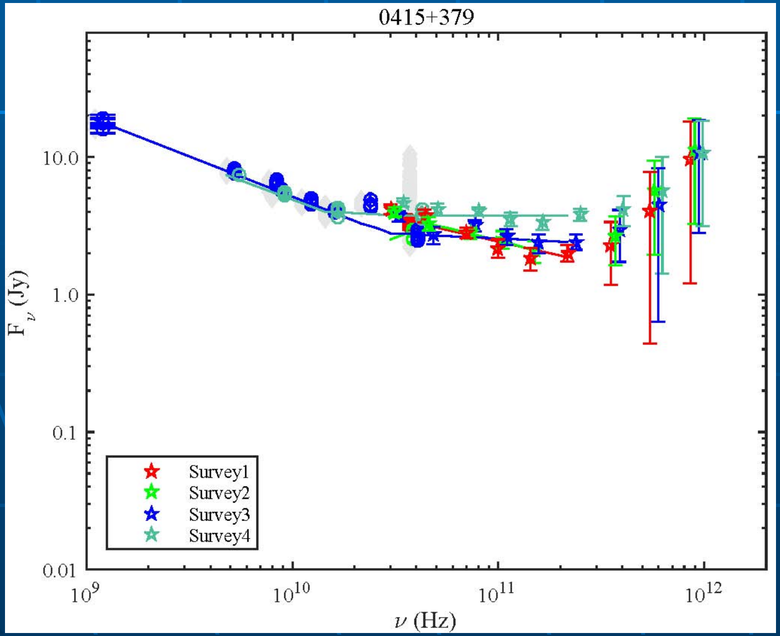
upturn inverted
steep peaking

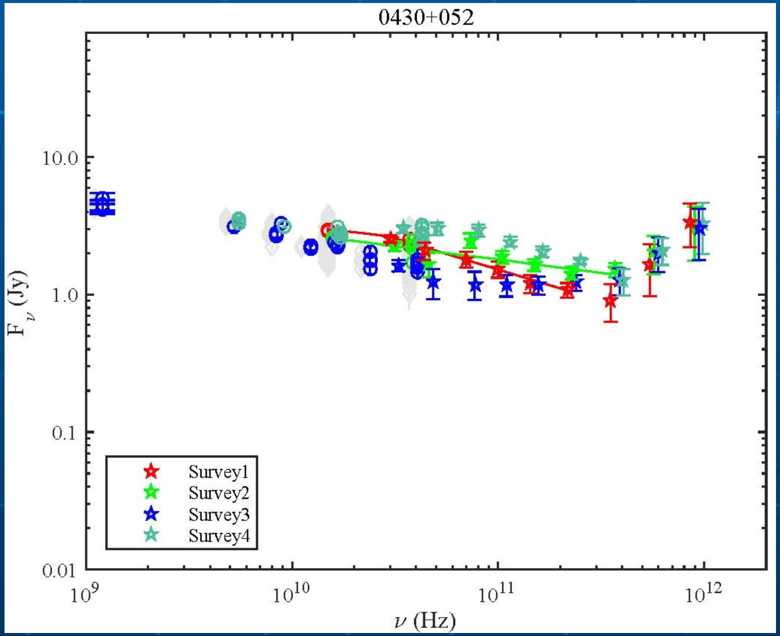


Dusty sources aka Dirty blazars

- A clear upturn at the highest frequencies
- Galactic contamination or intrinsic cold (15 to 20 K) dust left from the starburst phase?

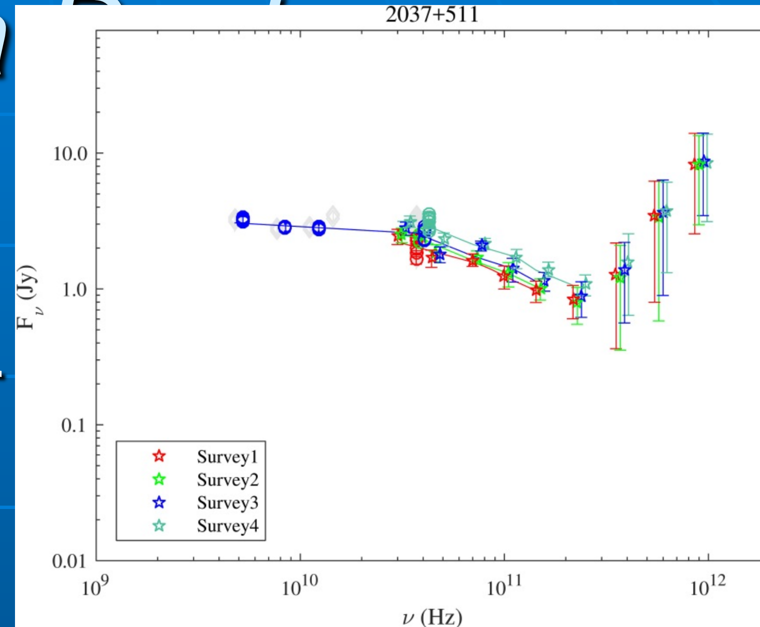
Source	z	Optical class	Fig.
0238-084	0.005	Seyfert 2	23
0333+321	1.258	Quasar	26
0415+379	0.049	Seyfert 1	29
0430+052	0.033	Seyfert 1	31
0446+112	1.207	BL Lac	32
1954+513	1.223	Quasar	93
2037+511	1.686	Quasar	97

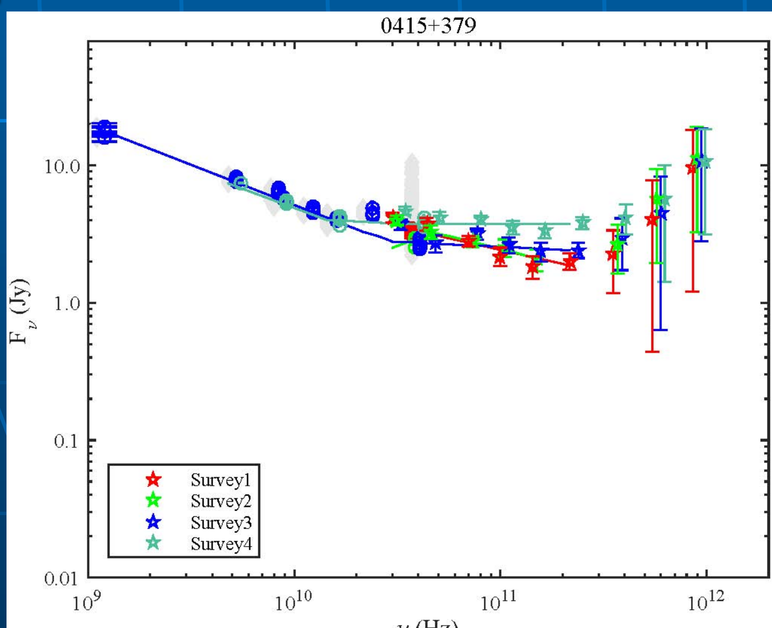


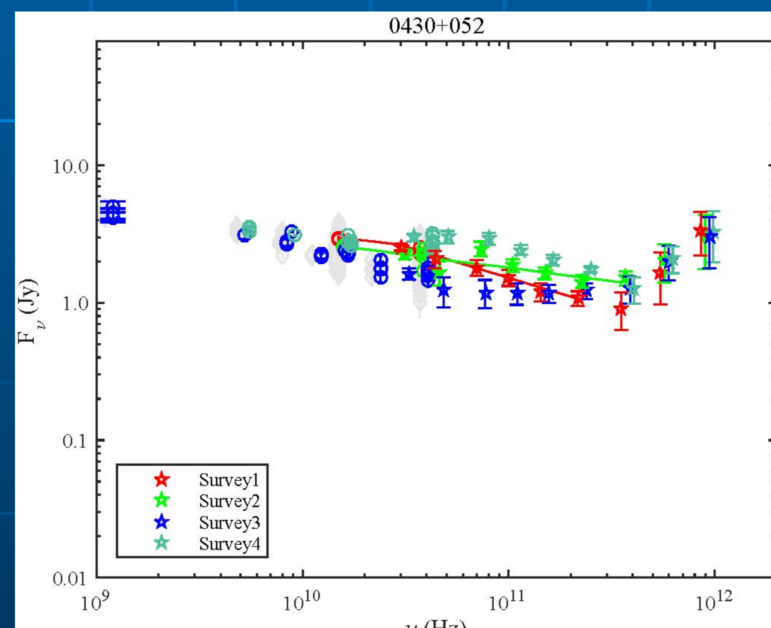


Dirty blazars aka

- A clear upturn at the highest frequencies
- Galactic contamination or intrinsic cold (20 K) dust left from the starburst phase?





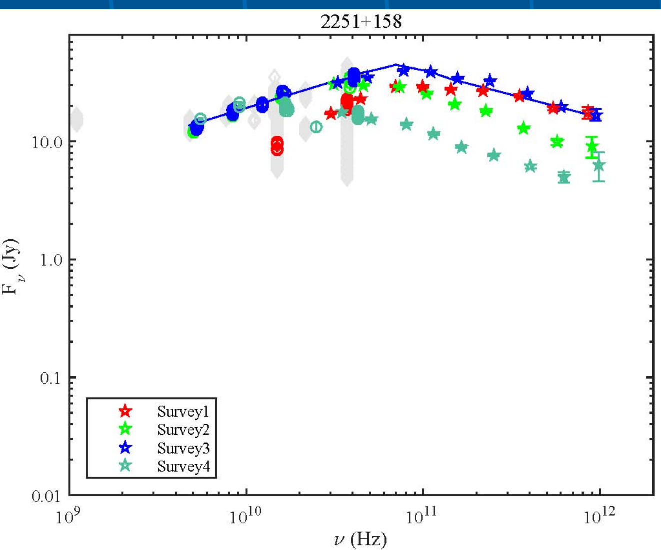


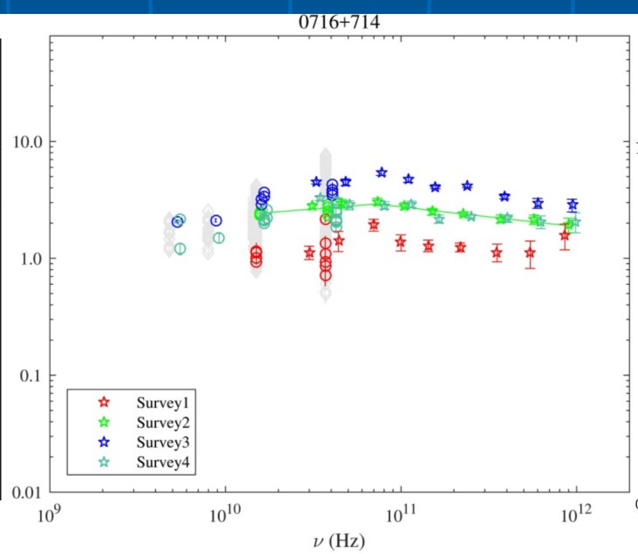
Future work

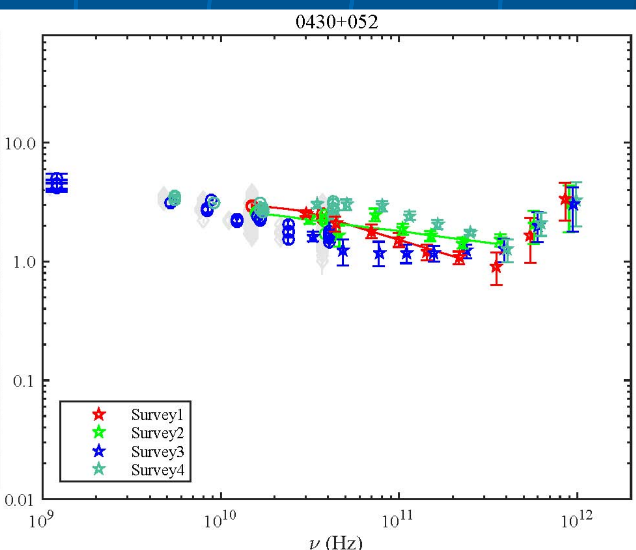
- SEDs for the full sample
- ”Flaring sources”
- Specific source samples
  - Narrow-line Seyfert 1 galaxies (see poster by Järvelä & Lähteenmäki)
  - …
- …

Summary

1. Evolving shocks in jet vs. achromatic variations? TEMZ?
2. Flat high frequency radio spectra
3. High break frequencies
4. BLOs vs. LPQs
5. Intrinsic cold dust in low-*z* AGN







The scientific results that we present today are a product of the Planck Collaboration, including individuals from more than 50 scientific institutes in Europe, the USA and Canada

Planck is a project of the European Space Agency -- ESA -- with instruments provided by two scientific Consortia funded by ESA member states (in particular the lead countries: France and Italy) with contributions from NASA (USA), and telescope reflectors provided in a collaboration between ESA and a scientific Consortium led and funded by Denmark.