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NATIONAL INSTITUTE FOR ASTROPHYSICS

ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA - BOLOGNA

Ricerca di galassie radio giganti in un campione di oggetti selezionati in raggi x di alta energia (Parte 3)

Search of giant radio galaxies in a sample of hard X-ray selected objects (Part 3)

**Filippo Cumoli*, Matteo Rossi*,
L. Bassani**, A. Malizia**.**

***Liceo scientifico Isicast, Castiglione dei Pepoli (BO).
****Iasf Inaf Bologna**

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Area della Ricerca di Bologna – via Piero Gobetti, 101 – 40129 Bologna – ITALY
e-mail: segreteria@iasfbo.inaf.it – PEC: inafiasfbo@pcert.postecert.it – www.iasfbo.inaf.it
Tel. (+39) 051.6398688 – Fax (+39) 051.6398724 - Cod. Fisc. 97220210583 – Part. Iva 06895721006

-What is our aim?

Giant radio galaxies (GRG) are a particular type of radio galaxies with big dimensions and it is thought that they are very old or very powerful objects. Their number is low (~6%) in radio surveys, but recently a large number of them (24%) has been found analyzing a sample of radio galaxies selected between 20 keV and 100 keV by INTEGRAL, an ESA satellite. We are going to search GRGs in a similar sample, using the database of Swift, a NASA satellite. The identification of a group of GRGs will allow the astronomers to study in depth their properties and to understand why they are so extended.

-What do we search with?

After the launch of INTEGRAL and thanks of its instrument IBIS, we start having several hard X-ray surveys of the sky. Analyzing them, Malizia and Bassani discovered a high fraction of giants radio galaxies. Wondering why, they decided to extend their search using data gained by Swift, a NASA satellite. This is a satellite dedicated to the study of Gamma Ray Burst, but its BAT (Burst Alert Telescope) instrument also does hard X-ray surveys of the sky. So we used the results of the 70 months catalogue, recently made public (http://swift.gsfc.nasa.gov/results/bs70mon/) and started to search for radio galaxies with the hope of discovering other giant objects . This recent BAT survey contains more than one thousand objects of which 822 are associated with active galaxies. Only 676 were analyzed during the internship of four students; the choiche was due to the use of the NVSS (NRAO VLA SKY SURVEY) database, which contains images for all radio- emitting objects detected above -40° in declination; this survey is done at the radio frequency of 1.4 GHz (Condon et al. 1998) and its images are easily accessible via the NED (Nasa Extragalactic Database) archive. Among the sample of 676 Swift/BAT detected objects we searched first for radio galaxies.

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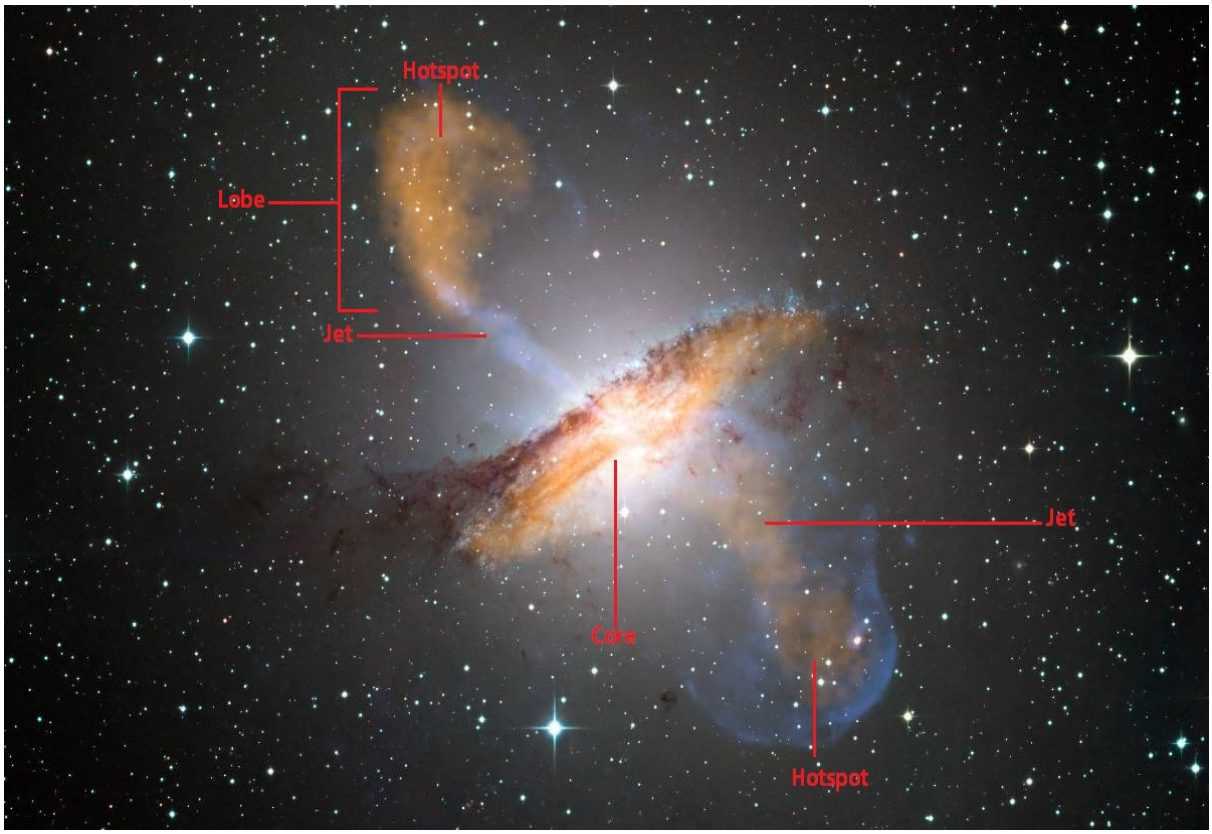
-What is a radio galaxy?

A radio galaxy is an AGN (active galaxy nucleus) that is very luminous at radio wavelengths. This radio emission is due to the synchrotron process: the observed structure in radio emission is determined by the interaction between twin jets and the external medium, modified by the effects of relativistic beaming. A black hole, surrounded by an accretion disk, is the *nucleus* of the radio galaxy, and is able to eject *jets* of particles on either sides of the core. At the end of the jets we can find *hotspots,* which are areas of bright radio emission. Also visible are the *lobes,* which are large scale ellipsoidal structures situated on either sides of the active nucleus. An example of a radio galaxy is shown below with all its components.



-What did we find?

Every member of our team of four students had 169 radio sources to analyze. We searched in everyone of them the typical shape of a Radio Galaxy. The identification was often very easy, due to the evident presence of typical features of a radio galaxy, but for many sources we had to study in depth the object to understand if it was or not a radio galaxy. At the end, every one of us found a number of radio galaxies according to our expectations. In this report the results obtained by Filippo Cumoli and Matteo Rossi are reported.

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Filippo Cumoli

The galaxies reported in the following list are all the radio galaxies found by Filippo Cumoli, one of the interns that followed this project. The yellow line indicates a source that could be a radio galaxy, but we are not completely sure of its nature. Yet further studies in radio will probably help the astronomers to better understand the source properties and to decide if it can be maintained or not in the sample. In the table we report for each source the SWIFT name and coordinates, the alternative name and coordinates of the optical counterpart, the redshift and logarithmic value of the 14-195 Kev luminosity in units of erg/sec.

Swift name	RA (BAT)	Dec (BAT)	Counterpart Name	Counterpart RA	Counterpart Dec	Redshift	Lum
J1829.0+4846	277,405	48,781	3C 380	277,3820	48,7460	0,6920	46,59
J1628.1+5145	247,013	51,774	MRK 1498	247,0169	51,7754	0,0547	44,49
J0753.1+4559	118,274	45,978	B3 0749+460A	118,1842	45,9493	0,0518	43,99
J2124.6+5057	321,181	50,955	4C 50.55	321,0000	50,9735	0,0200	44,26
J1458.9+7143	224,731	71,719	3C 309.1	224,7816	71,6722	0,9050	46,58
J1523.5+6340	230,871	63,674	4C +63,22	230,9411	63,6567	0,2040	45,00
J2114.4+8206	318,493	82,095	2MASK J21140128+8204483	318,5049	82,0801	0,0840	44,80
J0318.7+6828	49,532	68,492	2MASX J03181899+6829322	49,5791	68,4921	0,0901	44,56
J0950.5+7318	147,509	73,265	VII Zw 292	147,4410	73,2400	0,0581	44,10
J2042.3+7507	310,618	74,119	4C +74.26	310,6554	75,1340	0,1040	45,15
J1842.0+7945	280,640	79,775	3C 390.3	280,5375	79,7714	0,0561	44,88
J0742.3+8024	115,564	80,496	3C 184.1	115,7553	80,4406	0,1182	44,64
J1607.4+8502	242,201	84,998	LEDA 100168	241,8490	85,0300	0,1830	45,10

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Matteo Rossi

The galaxies reported in the following list are all the radio galaxies found by Matteo Rossi, one of the interns that followed this project. The yellow line indicates a source that could be a radio galaxy, but we are not completely sure of its nature. Yet further studies in radio will probably help the astronomers to better understand the source properties and to decide if it can be maintained or not in the sample. In the table we report for each source the SWIFT name and coordinates, the alternative name and coordinates of the optical counterpart, the redshift and logarithmic value of the 14-195 Kev luminosity in units of erg/sec.

Swift name	RA (BAT)	Dec (BAT)	Counterpart Name	Counterpart RA	Counterpart Dec	Redshift	Lum
J1959.4+4044	299,880	40,734	Cygnus A	299,8682	40,7339	0,0561	45,01
J0319.7+4132	49,940	41,518	NGC 1275	49,9507	41,5117	0,0176	43,71
J0207.7+2931	31,754	29,509	3C 59	31,7911	29,5280	0,1096	44,72
J1547.5+2050	236,867	20,838	3C 323.1	236,9314	20,8713	0,2640	45,23
J2123.6+2506	320,957	25,095	3C 433	320,9356	25,0700	0,1016	44,62
J0312.9+4121	48,224	41,357	QSO B0309+411	48,2580	41,3330	0,1360	44,94
J0840.2+2947	130,048	29,788	4C +29.30	130,0099	29,8174	0,0647	44,21
J2246.0+3941	341,435	39,685	3C 452	341,4532	39,6866	0,0811	44,72
J0418.3+3800	64,419	38,017	3C 111.0	64,5887	38,0266	0,0485	44,81
J1723.2+3418	260,804	34,295	4C +34.47	260,8367	34,2994	0,2060	45,36
J1835.0+3240	278,766	32,688	3C 382	278,7641	32,6963	0,0579	44,84
J1617.8+3223	244,453	32,379	3C 332	244,4272	32,3763	0,1510	45,16
J1001.8+2848	150,447	28,796	3C 234.0	150,4563	28,7858	0,1849	44,86
J2033.4+2147	308,367	21,785	4C +21.55	308,3835	21,7729	0,1735	45,42
J1742.2+1833	265,563	18,543	4C +18.51	265,5291	18,4557	0,1860	45,07
J2219.7+2614	334,907	26,23	2MASX J22194971+2613277	334,9573	26,2244	0,0850	44,48
J1553.6+2347	328,404	23,792	4C 23.42	238,4316	23,8071	0,1150	44,55

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-Giant radio galaxies

After the discovery of many radio galaxies, our team started to measure their sizes to establish which are giant radio galaxies. We also checked the literature to find previous measures of the size of each radio galaxy in order to make a comparison with our data.
A galaxy is considered giant when its size is over 0,7 Mpc (galaxy size > 700 kpc). Both Filippo and Matteo made a table reporting the sizes of all radio galaxies uncovered both in arcsec and Kpc scales.

Filippo Cumoli

In the following table the sizes in arcsec and kpc of all radio galaxies found by Filippo are listed. The yellow lines highlight those objects that are GRGs. In the table we list the SWIFT name, counterpart name, the largest angular size in arcsec(both from the literature and from our own measurements), the actual size in Kpc (both from the literature and from our own measurements) and the factor used to convert from arcsec to Kpc scale.

We calculated the conversion factor using the following cosmology: H_0=69,6 Kms(-1) Mpc(-1); ΩM=0,286; ΩVac=0,714

Swift name	Counterpart Name	Conversion Factor [Kpc/"]	LAS (literature) [arcsec]	Size (literature) [Kpc]	Redsifht	Our LAS [arcsec]	Our size [Kpc]
J1829.0+4846	3C 380	7,119	7,5 (1)	54 (1)	0,6920	5	36
J1628.1+5145	MRK 1498	1,070	1104 (2)	1181 (2)	0,0547	1125	1204
J0753.1+4559	B3 0749+460A	1,017	112 (3)	124 (3)	0,0518	168	171
J2124.6+5057	4C 50.55	0,408	570 (4)	233 (4)	0,0200	468	191
J1458.9+7143	3C 309.1	7,910	2,1 (1)	17 (1)	0,9050	1,8	14
J1523.5+6340	4C +63,22	3,377	210 (5)	709 (5)	0,2040	210	709
J2114.4+8206	2MASK J21140128+8204483	1,589	360 (5)	572 (5)	0,0840	270	429
J0318.7+6828	2MASX J03181899+6829322	1,692	906 (5)	1533 (5)	0,0901	792	1340
J0950.5+7318	VII Zw 292	1,132	900 (5)	1018 (5)	0,0581	827	936
J2042.3+7507	4C +74.26	1,922	636 (5)	1222 (5)	0,1040	690	1326
J1842.0+7945	3C 390.3	1,096	213 (1)	319 (1)	0,0561	250	274
J0742.3+8024	3C 184.1	2,150	230 (6)	230 (6)	0,1182	252	542
J1607.4+8502	LEDA 100168	3,099	/	/	0,1830	140	434

Notes: (1) Nilsson et al. 1993, (2) Rottgering et al. 1996, (3) Kozieł-Wierzbowska, D., Stasińska, G, 2011, (4) Molina 2007, (5) Lara et al. 2001, (6) Hardcastle et al. 1998.

Five of the thirteen radio galaxies uncovered by Filippo are found to be giant radio galaxies.

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Matteo Rossi

In the following table the sizes in arcsec and kpc of all radio galaxies found by Filippo are listed. The yellow lines highlight those objects that are GRGs. In the table we list the SWIFT name, counterpart name, the largest angular size in arcsec(both from the literature and from our own measurements), the actual size in Kpc (both from the literature and from our own measurements) and the factor used to convert from arcsec to Kpc scale.

We calculated the conversion factor using the following cosmology: H_0=69,6 Kms(-1) Mpc(-1); ΩM=0,286; ΩVac=0,714

Swift name	Counterpart Name	Conversion Factor [Kpc/"]	LAS (literature) [arcsec]	Size (literature) [Kpc]	Redsifht	Our LAS [arcsec]	Our size [Kpc]
J1959.4+4044	Cygnus A	1,096	122 (1)	134 (1)	0,0561	115	126
J0319.7+4132	NGC 1275	0,360	/	/	0,0176	55	20
J0207.7+2931	3C 59	2,013	199 (1)	401 (1)	0,1096	285	574
J1547.5+2050	3C 323.1	4,103	70,5 (1)	383 (1)	0,2640	94	386
J2123.6+2506	3C 433	1,396	68 (6)	95 (6)	0,1016	45,0	63
J0312.9+4121	QSO B0309+411	1,853	570 (7)	1056 (7)	0,1360	405	750
J0840.2+2947	4C +29.30	0,896	520 (8)	466 (8)	0,0647	347	311
J2246.0+3941	3C 452	1,539	280 (6)	431 (6)	0,0811	240	369
J0418.3+3800	3C 111.0	0,674	275 (1)	365 (1)	0,0485	210	142
J1723.2+3418	4C +34.47	3,403	440 (1)	1998 (1)	0,2060	240	817
J1835.0+3240	3C 382	1,129	170 (1)	264 (1)	0,0579	167	189
J1617.8+3223	3C 332	2,648	91 (1)	326 (1)	0,1510	90	238
J1001.8+2848	3C 234.0	3,125	110 (1)	460 (1)	0,1849	120	375
J2033.4+2147	4C +21.55	2,969	/	/	0,1735	192	570
J1742.2+1833	4C +18.51	3,140	212 (1)	891 (1)	0,1860	210	659
J2219.7+2614	2MASX J22194971+2613277	1,606	/	/	0,0850	18	29
J1553.6+2347	4C 23.42	2,099	/	/	0,1150	225	472

Notes: (1) Nilsson et al. 1993, (2) Rottgering et al. 1996, (3) Kozieł-Wierzbowska, D., Stasińska, G, 2011, (4) Molina 2007, (5) Lara et al. 2001, (6) Hardcastle et al. 1998, (7) Ishwara-Chandra & Saikia, 1999, (8) Chandola, Saikia, Neeraj Gupta, 2010.

Three of the sixteen radio galaxies uncovered by Matteo are giant radio galaxies, although one (Swift J1742.2+1833) is just at the border to be considered a GRG.

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Which were the overall results?

All together we analyzed 676 Swift of galaxies discovering that 51 of them have the typical features of radio galaxies. This represents 7,5% of the sample. Among them we uncovered 17 objects with dimension ≥ 0,7 Kpc, which represents 33% of the entire sample of hard X-ray selected radio galaxies. This is very similar to the percentage found in the sample of INTEGRAL selected radio galaxies, confirming that hard X-ray surveys are capable of detecting with great efficiency this type of sources. The sample of radio galaxies and more specifically GRG found during our stage will be used to further studies both type of objects.

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Appendix

In the following pages we show all the NVSS images of the objects listed in the tables

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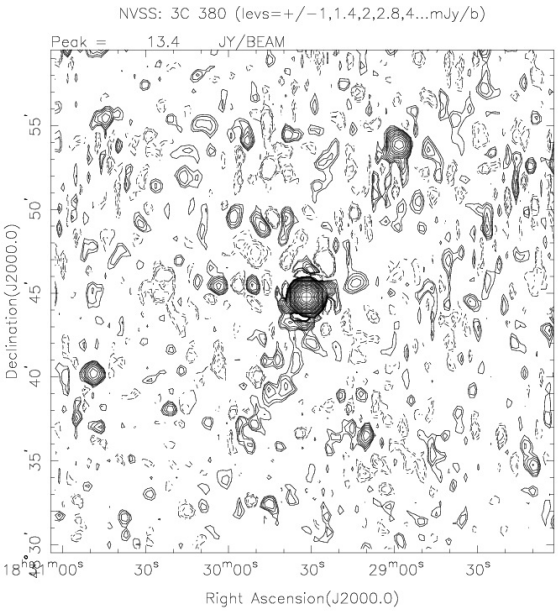
Swift J1829+4846



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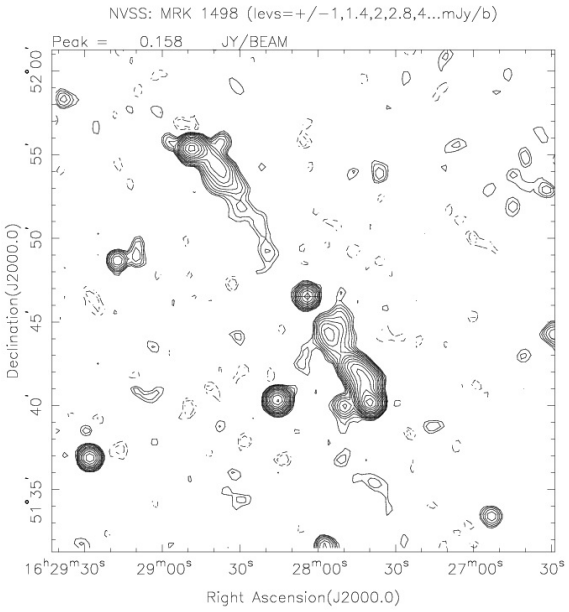

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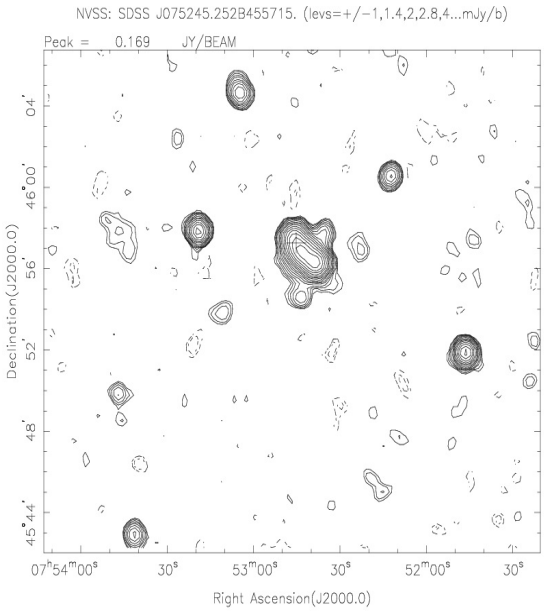
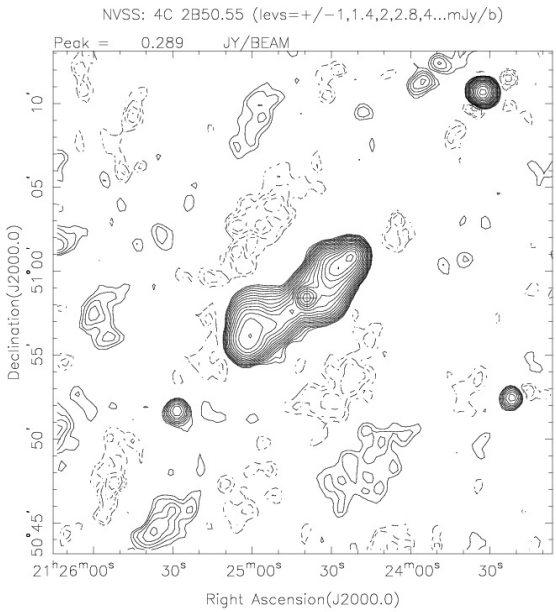
Swift J0753.1+4559



Swift J2124.6+5057



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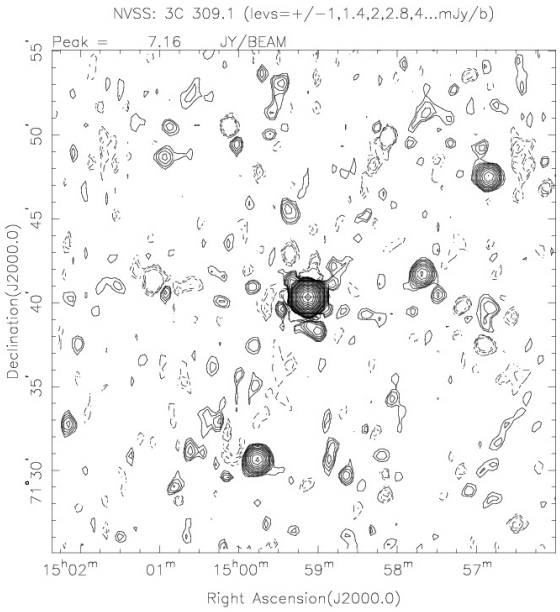
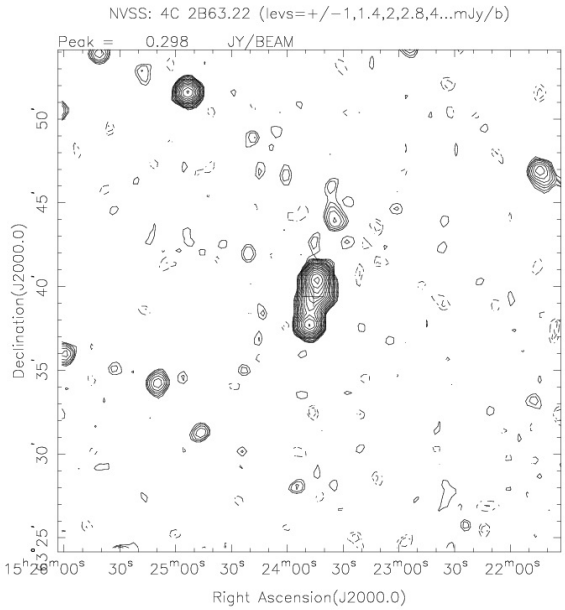
Swift J1458.9+7143



Swift J1523.5+6340



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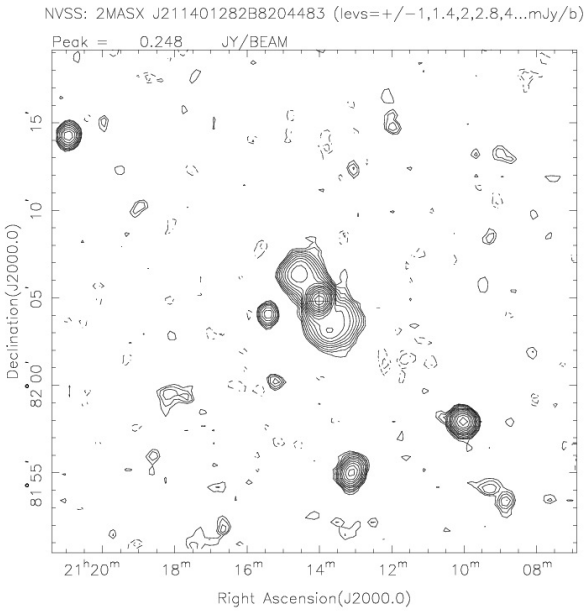
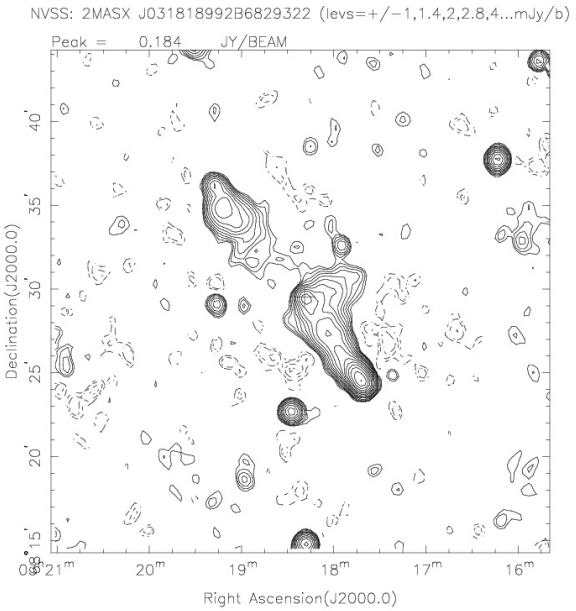
Swift j2114.4+8206



Swift J0318.7+6828



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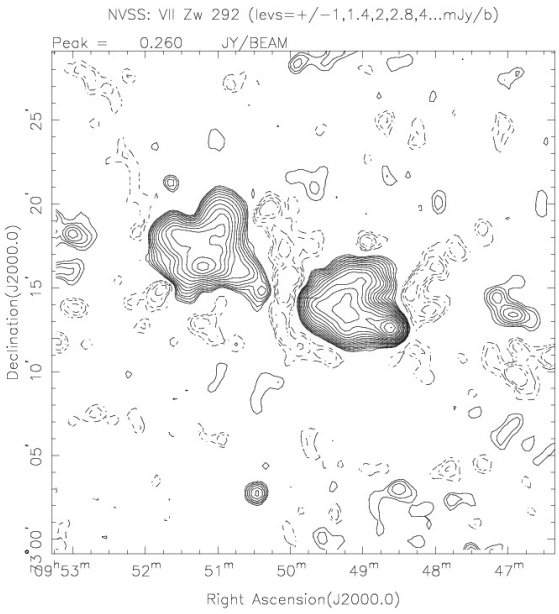
Swift J0950.5+7318



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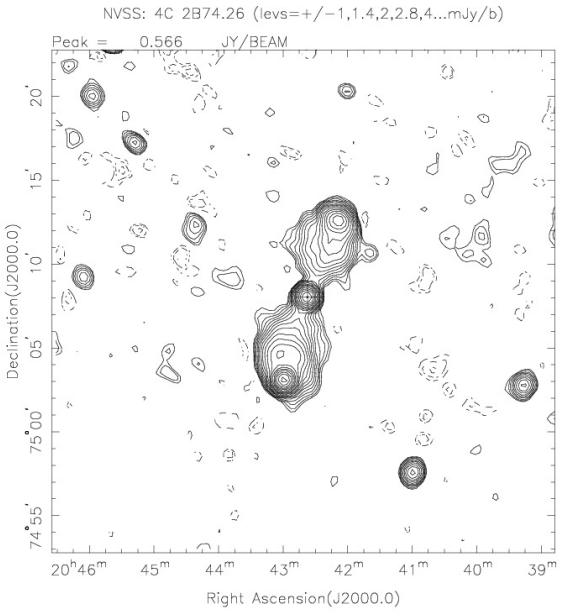

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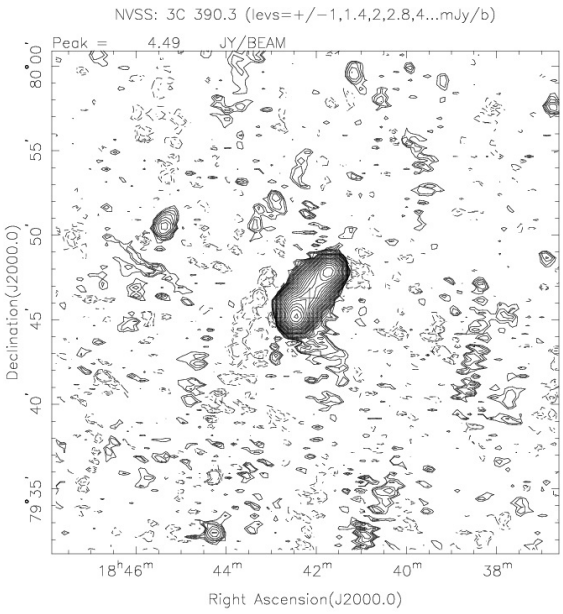

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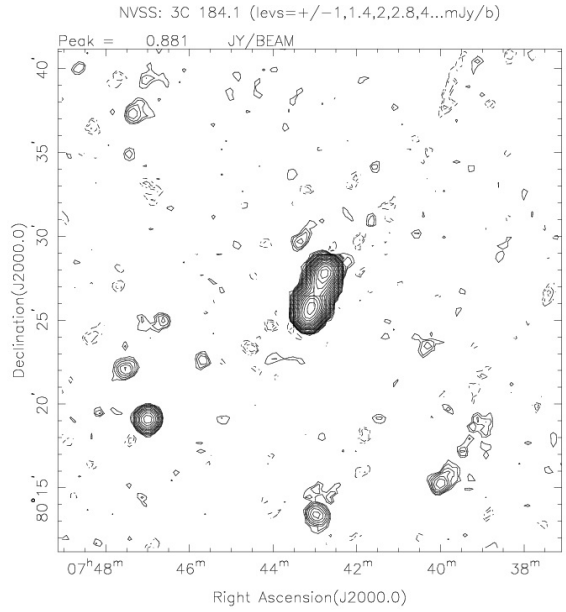

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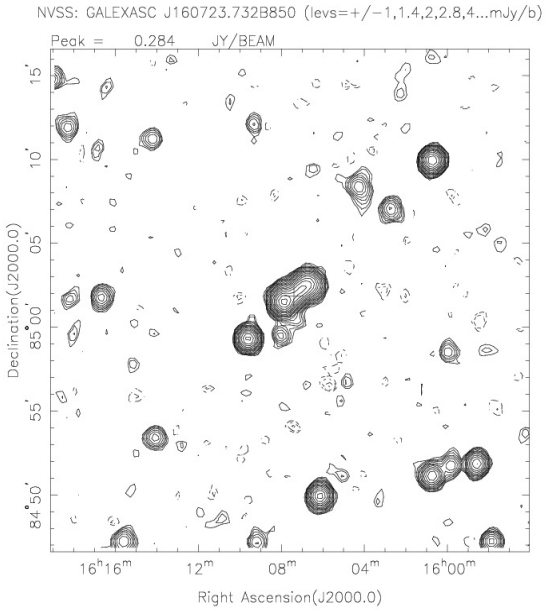

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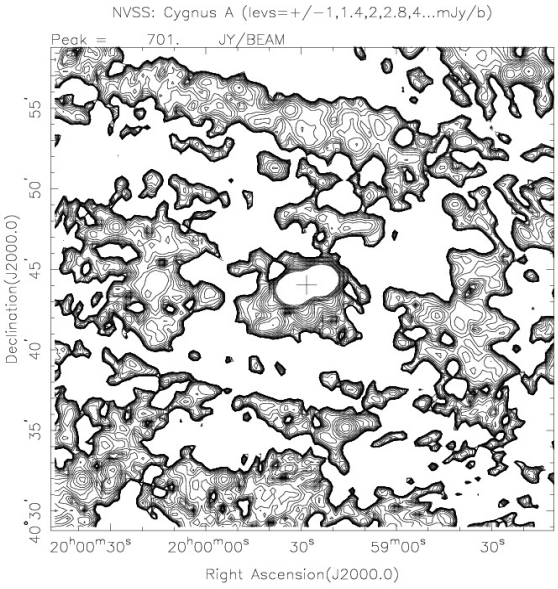

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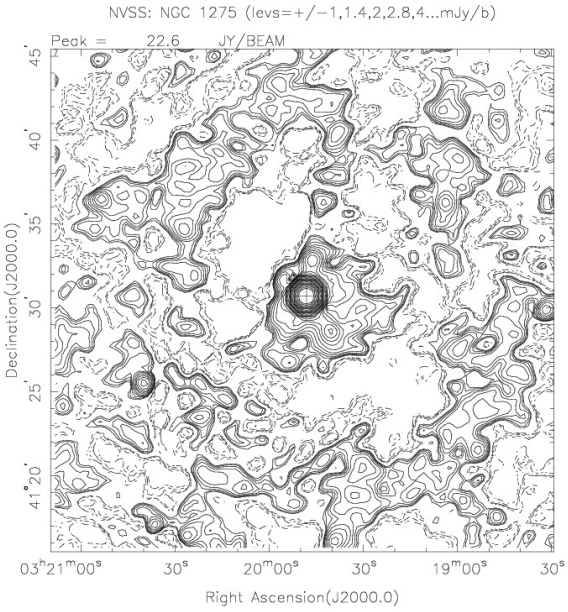
Swift J0319.7+4132



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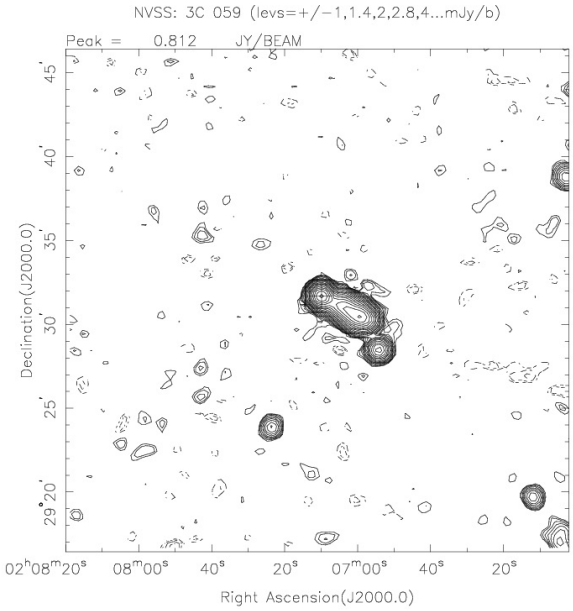

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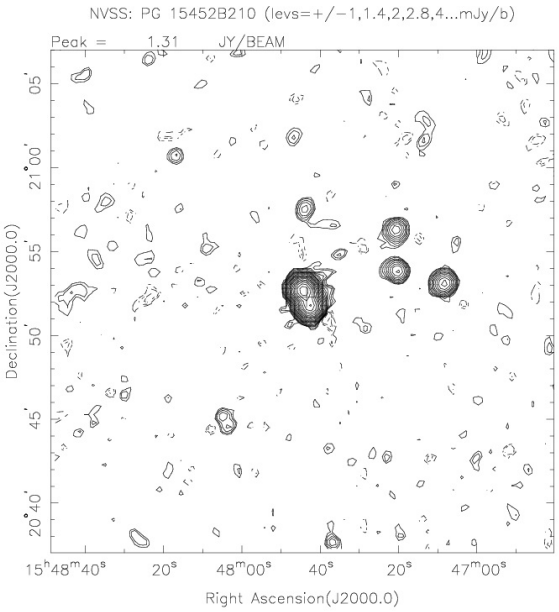

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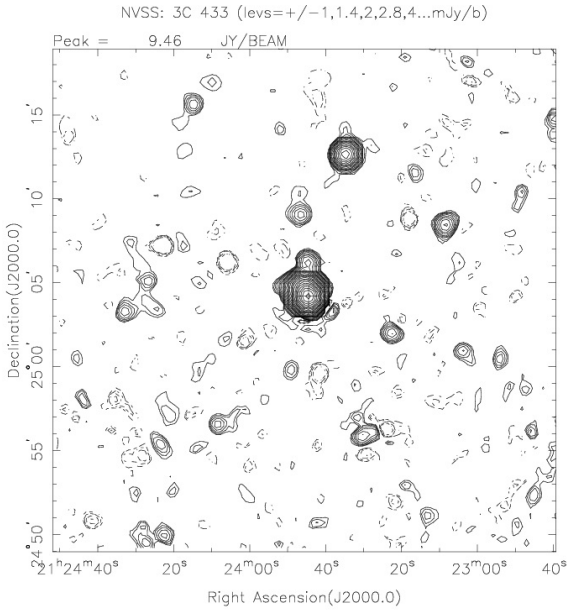

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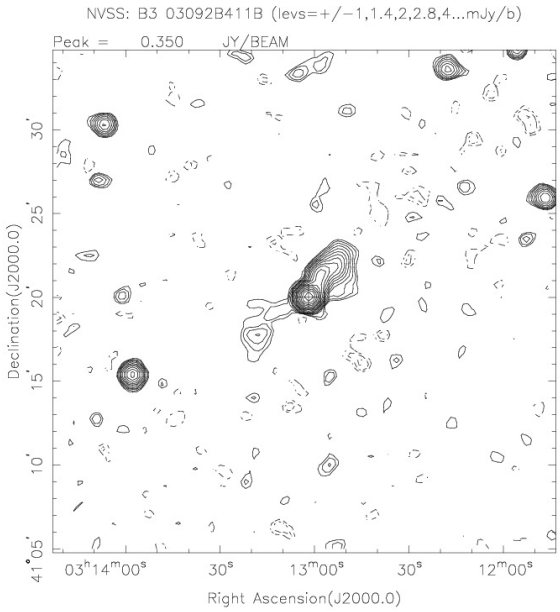

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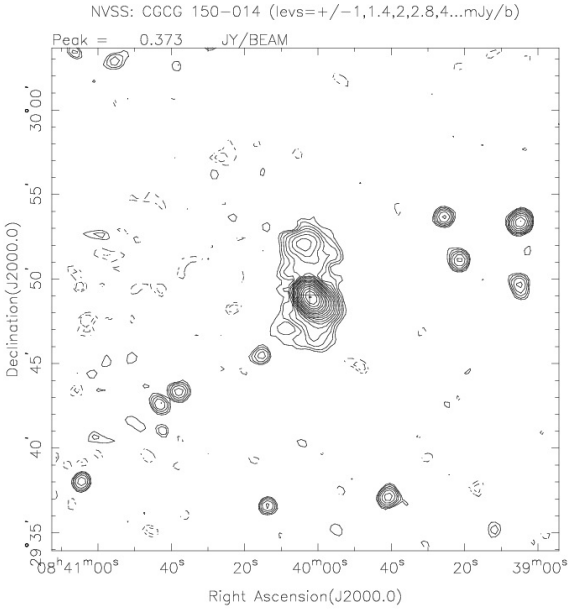

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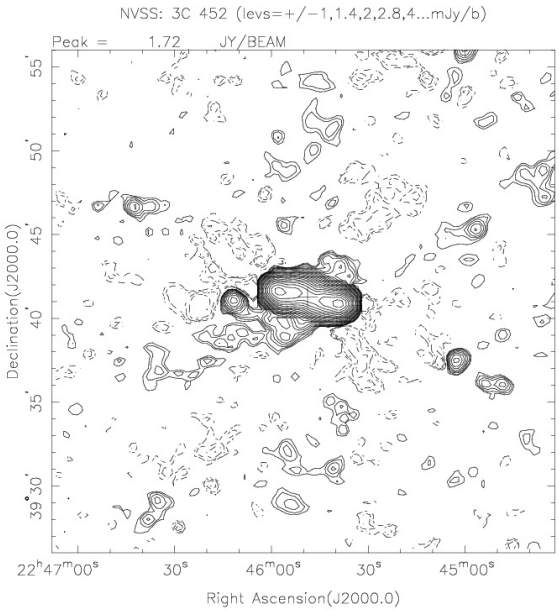

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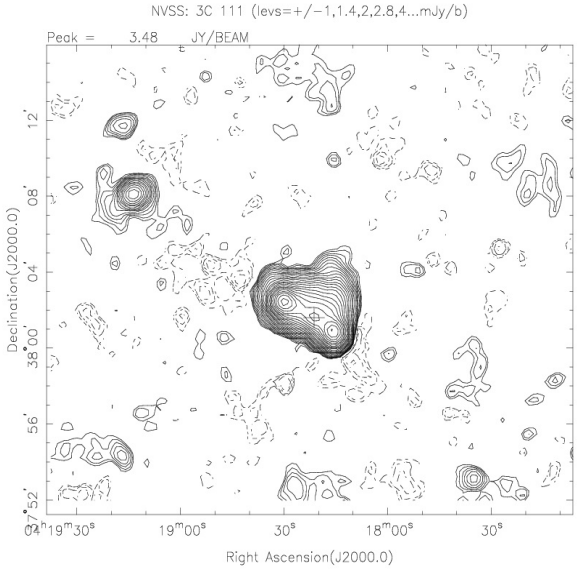

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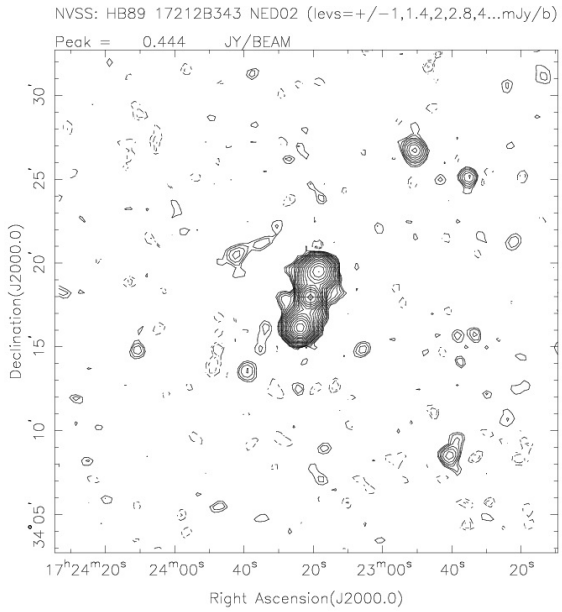

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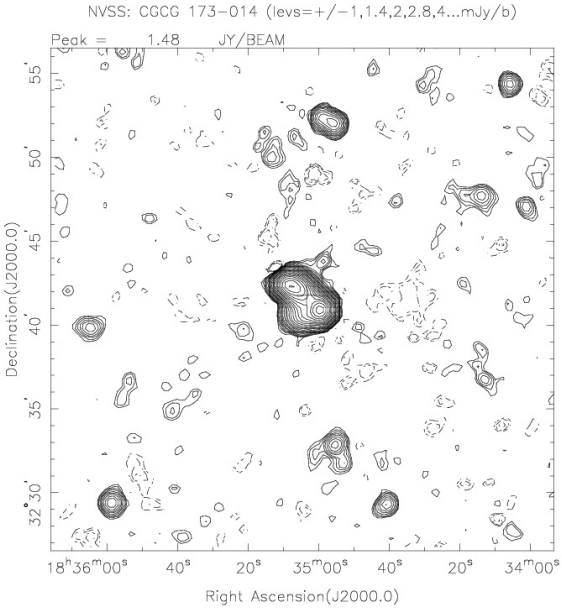

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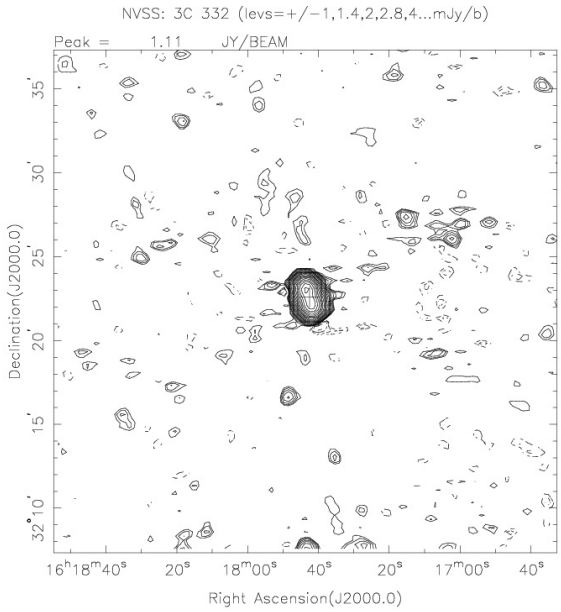

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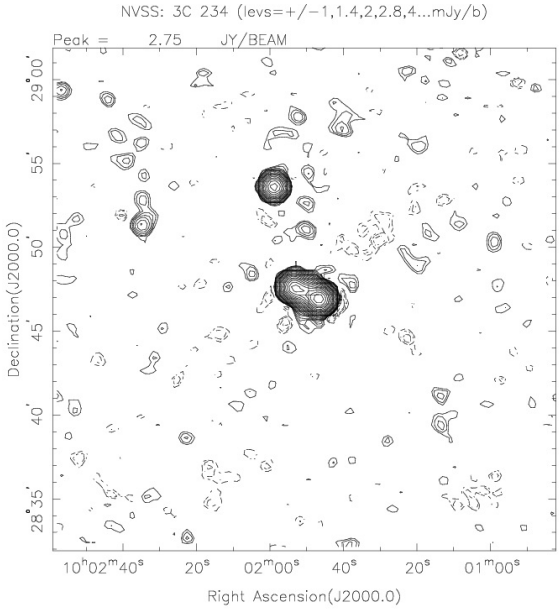

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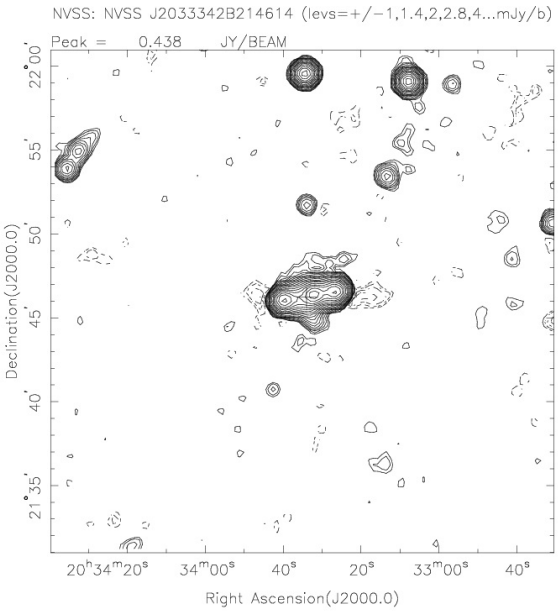

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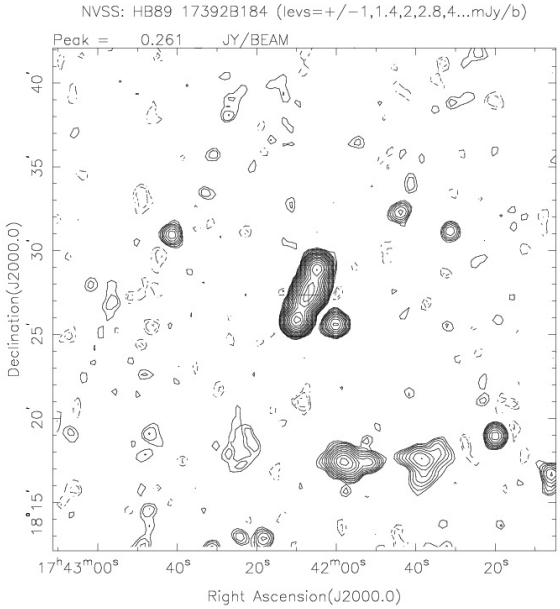

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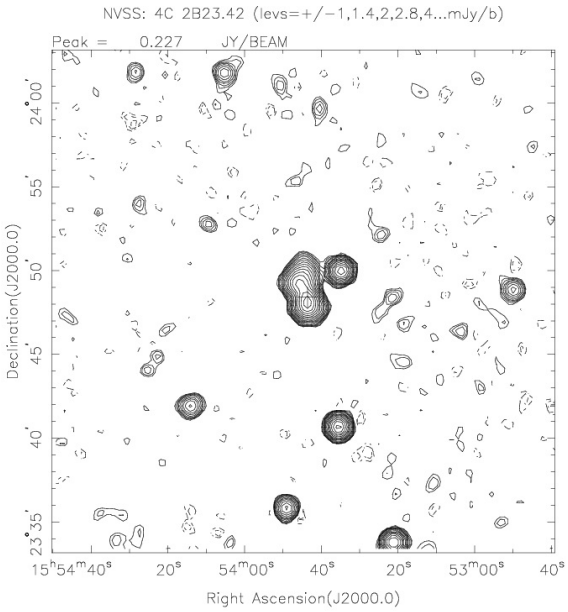

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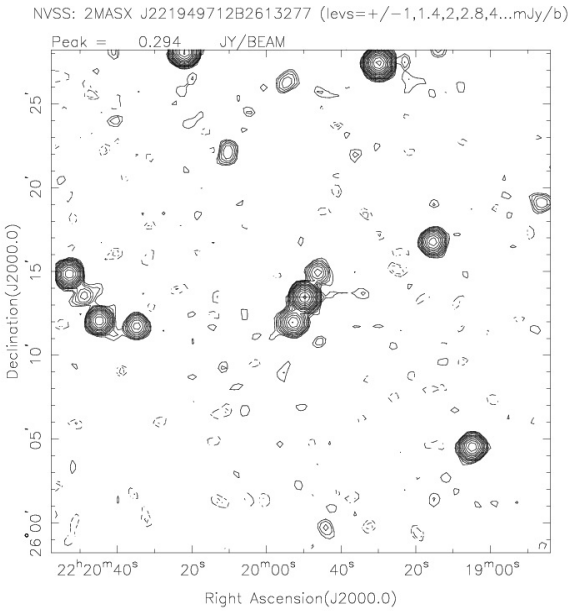

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