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X-RAY EMISSION OF ICRF SOURCES

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ABSTRACT. Considering increasing requirements to the coordinates measurement precision by the end of XX century International Astronomical Union commenced implementation of the new astrometric system ICRF (International Celestial Reference Frame). This quasi-inertial reference frame system centered in the barycenter of the Solar System and has axes defined by the positions of distant extragalactic sources – frames. Unlike equatorial system ICRF has no shortcomings of the coordinates identification due to the Earth axis precession, stellar proper motions and other factors. Extragalactic frames of the ICRF system are mostly quasars, radio galaxies, blazars and Seyfert galaxies i.e. different types of the active galaxy nuclei (AGN). Active galaxy nuclei are characterized by processes with significant. Such processes quite often are followed by X-ray emission generation. The purpose of this work is to consider X-ray emission of ICRF sources and features of their possible proper motions. Among 295 selected reference frames of the system we identified 54 X-ray sources which were observed by space observatory XMM Newton and noticed rapid variability of the blazars 2E 2673 (W Com) and 2E 1802 which enables to conclude that they have some very active processes in the sources centers. With regards to the future more detailed analysis we beleive that evidences of the objects proper motion could be found in their spectra. Based on the constructed luminosity and spectral graphs we could conclude that apart from above mentioned AGNs rest 52 objects do not show veriability and special attention should be paid to blazars within ICRF system development and use. Major part of the X-ray sources between the reference frames are stable.

Keywords: ICRF, reference systems, galaxies: active, X-rays: galaxies.

АБСТРАКТ. Зважаючи на зростаючі вимоги до точності вимірювання координат, наприкінці XX століття Міжнародний Астрономічний союз запровадив нову астрометричну систему ICRF (International Celestial Reference Frame). Ця квазіінерціальна система координат має центр в барицентрі Сонячної системи та її вісі визначаються положенням віддалених позагалактичних джерел - фреймів. На відміну від екваторіальної системи, ICRF позбавлена недоліків визначення координат, що повязані з прецесією, власним рухом зірок та іншими факторами. Позагалактичні джерела системи ICRF являють собою, як правило, квазари, радіогалактики, блазари і сейфертівські галактики, тобто різні типи активних ядер галактик. Активні ядра галактик (АЯГ) характеризуються процесами з значними швидкими рухами. Такі процеси часто супроводжуються виникненням рентгенівського випромінення. Метою даної роботи є вивчення рентгенівського випромінювання джерел ICRF та особливості їх можливого власного руху. Серед 295 визначених опорних фреймів системи ми знайшли 54 рентгенівських джерела, які спостерігалися космічною обсерваторією XMM-Newton та встановили, що швидку мінливість спектру мають блазари 2E 2673 (W Com) та 2E 1802, що дозволяє зробити висновок про дуже активні процеси в центрі джерел. З огляду на проведення більш повного аналізу ми вважаємо, що можуть знайтися свідоцтва власних рухів в їх спектрах. Базуючись на побудованих кривих блиску та спектрах можна зазначити, що окрім вищенаведених активних ядер галактик 52 об'єкти не демонструють змінності. Ми прийшли до висновку, що в рамках розробки та використання системи ICRF необхідно приділяти особливу увагу блазарам. Більшість рентгенівських джерел в опорних фреймах системи є стабільними.

Ключові слова: ICRF, система опорних координат, галактики: активні, рентгенівське випромінення: галактики.

1. Introduction

ICRF is a frame of reference defined by the positions of extragalactic sources. The most appropriate extragalactic sources should be very luminous so it is obvious that many of them are active galactic nuclei (AGNs). They always has some active processes and rapid motion in the center.

Active galactic nuclei are complex phenomena. At the heart of an AGN there is a relativistic accretion disk around the spinning supermassive black hole. In the center of the galaxy the emissions of relativistic particles occurs as narrow and uniform brightness jets. Curious that, their observation may indicate that the center of image is moving with speed over the speed of light (Schneider, 2006). The explanation of this effect is that we can only observe the movement of a projection on area perpendicular to the field of vision. The effect of "superluminal" expansion is observed in jets moving toward the observer at a small angle to the line of sight. Blazars has the smallest value of this angle among other types of AGNs, so we considered to check spectra for available BL Lacs in ICRF to identify possible motion.

The accuracy of ICRF is 40 microarcsec[1]. AGN with typical redshift z=1 may have relativistic radiojet with knots passing through this angle in few years. Such relativistic motion in the AGNs could be detected by astrometric methods in the nearest future. Some signs of these processes can be checked in X-ray band. X-ray emission is generated in the very center of AGN and is influenced by the fastest motion of the matter. The aim of this work is to consider X-ray emission of ICRF sources and to look for signs of their possible proper motion. For this purpose we used 3XMM-DR4 catalog (Rosen et al., 2015) of X-ray sources based on observational data from modern space observatory XMM-Newton. We checked light curves of all X-ray ICRF sources and made certain conclusions about their stability.

2. Identification and analysis of X-ray ICRF sources

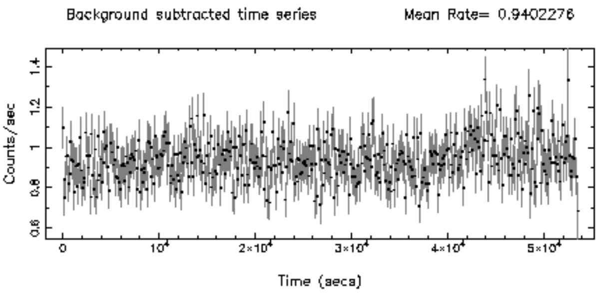

Figure 1: Light curve of OJ287. Example of stable X-ray source.

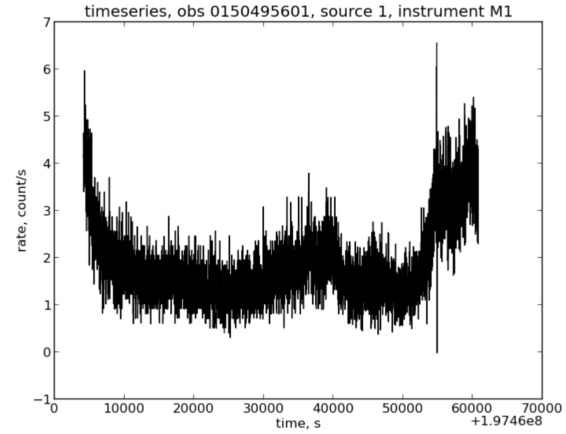

Figure 2: Light curve of 2E 1802 from MOS1 camera. The time at Fig. 2 and 3 is measured in seconds from 01.01.1998.

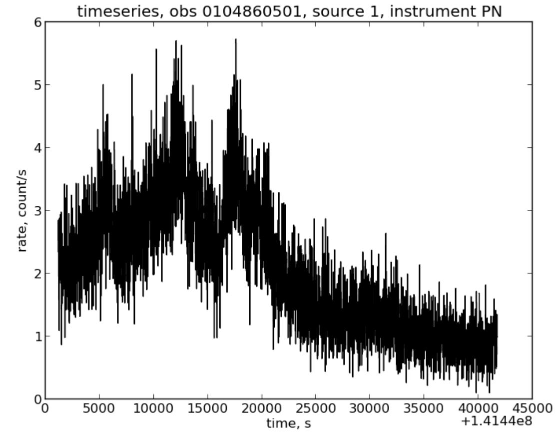

Figure 3: Light curve of W Com from PN camera.

Initial phase of our work was to find ICRF sources in 3XMM-DR4 catalog. Current version of ICRF (ICRF2) composed by 3414 sources[2] and 3XMM-DR4 catalog contains 372728 individual sources. Using X-ray and optical galaxies from cross-identification sample (Tugay, 2012) we found that 54 of ICRF sources are listed in the 3XMM-DR4 catalog. 33 sources of the sample have only one XMM observation and the rest 21 sources have two observations each. General parameters of these sources are presented in the Table 1 below. We reviewed X-ray light curves of these sources using LEDAS database and found that most of them are constant. The deviation of mean X-ray flux of 52 objects during the whole observation does not exceed the half of rms scatter. The example of constant X-ray light curve is presented at Fig. 1. However, we found X-ray variability of 2E 1802 and

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[1] http://hpiers.obspm.fr/icrs-pc/, 'ICRF2' chapter

[2] http://rorf.usno.navy.mil/ICRF2/

Table 1: List of X-ray ICRF sources.

N	XMM ID	SIMBAD type	Name	z
1.	J001031.0+105829	Seyfert 1	Mrk 1501	0.090
2.	J003824.8+413706	Quasar	5C 3.50	1.353
3.	J005748.8+302108	Galaxy	IAU 0057+3021	0.016
4.	J012642.7+255901	Quasar	4C 25.05	2.358
5.	J014922.3+055553	Quasar	QSO B0146+056	2.347
6.	J015002.6-072548	Seyfert 2	IAU 0150-0725	0.017
7.	J022239.6+430207	BL Lac	3C 66A	0.340
8.	J023838.9+163659	BL Lac	2E 618	0.940
9.	J024008.1-230915	Quasar	2E 638	2.225
10.	J024457.6+622806	Seyfert 1	2E 653	0.044
11.	J031155.2-765150	BL Lac	2E 746	0.223
12.	J031301.9+412001	Seyfert 1	QSO B0309+411	0.136
13.	J040748.4-121136	Seyfert 1	2E 938	0.572
14.	J044017.1-433308	Quasar	2E 1127	2.852
15.	J052257.9-362730	BL Lac	2E 1263	0.055
16.	J053056.4+133155	Quasar	2E 1289	2.070
17.	J053954.2-283955	Quasar	2E 1496	3.103
18.	J072153.4+712036	BL Lac	2E 1802	0.300
19.	J084124.3+705342	Quasar	4C 71.0	2.172
20.	J085448.8+200630	BL Lac	OJ 287	0.306
21.	J095456.8+174331	Quasar	QSO B0952+179	1.475
22.	J095524.7+690113	Super Nova	SN 1993J	0.0001
23.	J104117.1+061016	Quasar	2E 2303	1.270
24.	J105829.6+013358	BL Lac	4C 01.28	0.185
25.	J112027.8+142054	LINER	4C 14.41	0.362
26.	J113007.0-144927	Quasar	2E 2471	1.189
27.	J121923.2+054929	LINER	NGC 4261	0.007
28.	J122006.8+291650	LINER	NGC 4278	0.002
29.	J122131.6+281358	BL Lac	2E 2673	0.102
30.	J122222.5+041315	Quasar	4C 04.42	0.965
31.	J122906.6+020308	BL Lac	3C 273	0.173
32.	J123959.4-113722	LINER	M 104	0.003
33.	J124646.8-254749	Quasar	QSO B1244-25	0.638
34.	J125359.5-405930	Quasar	QSO B1251-407	4.464
35.	J125611.1-054721	Quasar	3C 279	0.536
36.	J130533.0-103319	Seyfert 1	2E 2966	0.278
37.	J131028.6+322043	BL Lac	2E 2979	0.997
38.	J132527.6-430108	Seyfert 2	CENTAURUS A	0.001
39.	J132616.5+315409	Radio Galaxy	4C 32.44	0.370
40.	J140700.3+282714	BL Lac	Mrk 668	0.076
41.	J140856.4-075226	Quasar	QSO B1406-076	1.493
42.	J143023.7+420436	Quasar	7C 1428+4218	4.705
43.	J151002.9+570243	Quasar	1E 1508.7+5714	3.880
44.	J160913.3+264129	Radio Galaxy	PKS 1607+268	0.473
45.	J165352.2+394536	BL Lac	Mrk 501	0.033
46.	J170934.3-172853	Quasar	IAU 1709-1728	0.560
47.	J184208.9+794617	Seyfert 1	2E 4136	0.056
48.	J201114.2-064403	Radio Galaxy	PKS 2008-068	0.547
49.	J212912.1-153841	Quasar	2E 4479	3.268
50.	J213032.8+050217	Quasar	IAU 2130+0502	0.990
51.	J215155.5-302753	Quasar	QSO B2149-307	2.344
52.	J220314.9+314538	BL Lac	4C 31.63	0.295
53.	J225357.7+160853	Quasar	3C 454.3	0.859
54.	J235509.4+495008	Seyfert 2	IAU 2355+4950	0.237

Table 2: Spectral properties of ICRF BL Lacs. Normalisation unit is $10^{-5}cm^{-2}s^{-1}keV^{-1}$

Object	$n_H, 10^{20}cm^{-2}$	Normalisation	*PhotonIndex*	χ^2/d.o.f.
3C66A	7.47 ± 0.49	66.2 ± 2.9	2.5 ± 0.04	1.0698 / 173
2E618 (Grandi, 2006)	1.34 ± 0.03		1.55 ± 0.02	0.857 / 109
2E1263 (Winter, 2010; Cusumano, 2010)	6 ± 1		2.14 ± 0.01	3.65 / 336
2E1802 (Baumgartner, 2012)	3.81 ± 0.42		2.7 ± 0.01	9.22 / 89
OJ287	20 ± 4	44.6 ± 1.1	1.75 ± 0.01	3.046 / 324
4C01.28	1.89 ± 0.23	55.8 ± 1.5	1.814 ± 0.018	1.0073 / 305
2E2673 (Piconcelli, 2002)	0.64 ± 0.37		1.32 ± 0.09	1.73 / 196
3C273 (Reeves, 2000; Donato, 2001)	1.79 ± 0.2		1.55 ± 0.02	0.857 / 1093
2E2979	0.432 ± 1.28	74.5 ± 1.3	1.668 ± 0.011	1.0655 / 399
Mrk668	<0.01	2.2 ± 0.66	0.98 ± 0.13	2.905 / 8
Mrk501	2.70 ± 0.07	991 ± 40	2.49 ± 0.06	1.7800 / 316

2E 2673 (W Com) blazars during XMM observations dated 04.04.2004 and 22.06.2002 respectively (Fig. 2-3). Such variability can not be explained by soft proton solar flares which were observed for a number of other ICRF sources. So these two blazars are typical examples of the most active galactic nuclei with rapid and powerful processes in the center. Other blazars may also have variability out of XMM observation time. We analyzed spectra of all blazars from our sample to check any possible special features and to reveal some additional unusual objects. We applied standard XMM SAS software to fit two-parametric power law model of X-ray continuum with hydrogen absorption at low energies. The results of spectral fitting are given in the Table 2 and some examples of spectra are shown on Figs. 4-6. All blazar spectra have a good approximation by our simple model. We assume that if the spectrum of any blazar is not fitted by such simple model then there is a reason to expect some complex structure of the source and possible variability. Otherwise, we consider the blazar as a typical source and appropriate for ICRF usage.

Spectral parameters are constant in all available XMM observations. So we have found out that X-ray spectra makes no reasons to expect any image motion of these sources in the nearest future. We conclude that current state of spectral analysis doesn't allow to predict a correlation between the spectra parameters and variability.

3. Results and conclusions

In the result of our analysis of light curves and spectral characteristics of ICRF blazars in X-ray band we found rapid variability for 2E 2673 (W Com) and 2E 1802 but no special features in the spectra.

Assuming that the variability of a source in any band should be connected with possible motion of the source (and the center of its image) we might predict that stable source should not have significant motion.

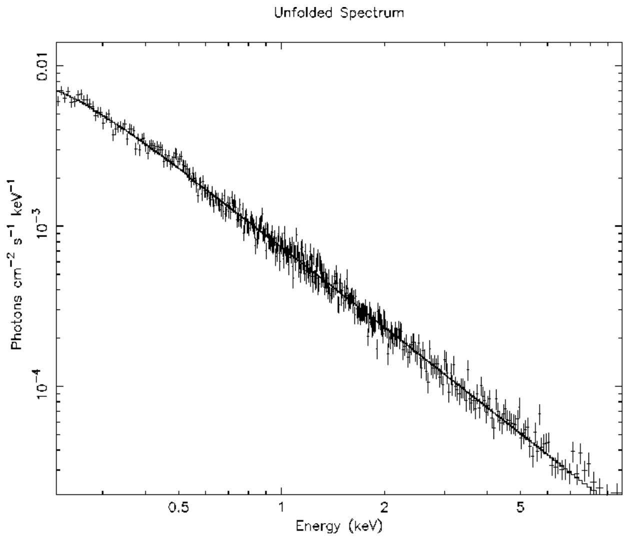

Figure 4: Spectrum of 2E 2979. Example of unabsorbed source.

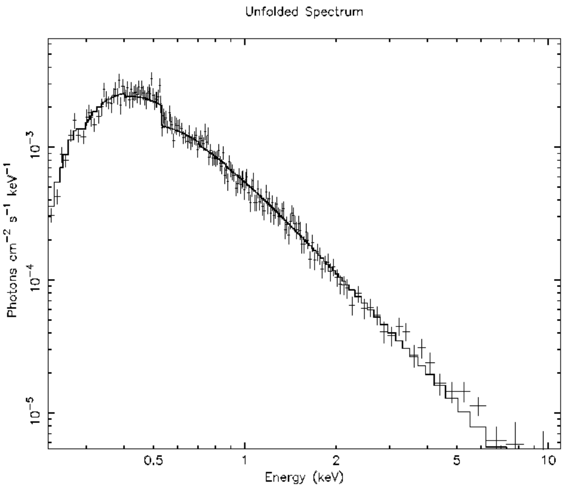

Figure 5: Spectrum of 4C 01.28. Example of absorbed source.

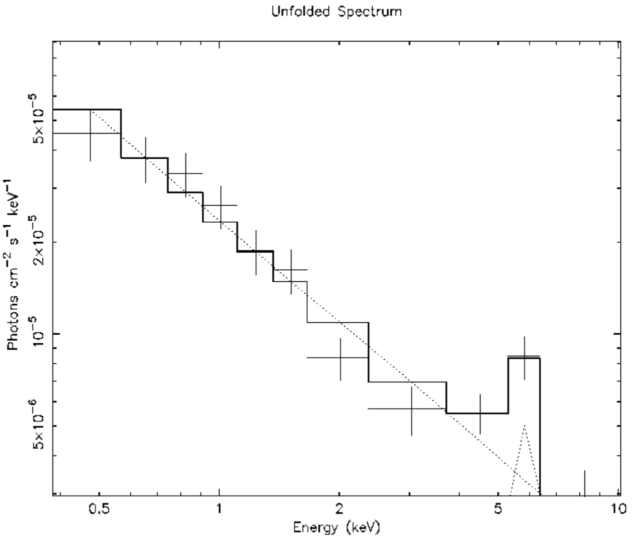

Figure 6: Spectrum of Mrk 668. Example of faint source.

So we conclude (for the moment) that the most of ICRF sources are stable and appropriate as defined sources for astrometric reference systems. Keeping in mind all possible extreme physical processes related to active galactic nuclei, the issue of possible image motion of ICRF sources remains persistent. W Com and 2E 1802 should still be considered as 'suspicious' ICRF sources. Their X-ray variability reveals fast processes in the very center of AGN that could cause detection of the image shift in the future. Future radiotelescopic studies of astrometric defined sources should review more thoroughly not only these two objects but any blazars, since the luminosity variability or even a motion could be detected.

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References

Baumgartner W. H., Tueller J., Markwardt C. et al.: 2012, *ApJ SS*, **207**, 19.

Cusumano G., LaParola V., Segreto A. et al.: 2010, *A& A*, **524**, A64.

Donato D., Ghisellini G., Tagliaferri G. et al.: 2001, *A& A*, **375**, 739.

Grandi P. & Malaguti G. 2006, *ApJ,* **642**, 113.

Ma C., Arias E.F., Eubanks T.F. et al. 1998, *ApJ,* **116**, 516.

Piconcelli E., Cappi M., Bassani L. et al.: 2002, *A&A*, **394**, 835.

Reeves J. N. & Turner M. L.: 2000, *Mon. Not. R. Astron. Soc.,* **316**, 234.

Rosen S., Watson M., Pye J. et al.: 2015, *ADASS XXIV Proc.,* 319.

Schneider P. 2006. 'Extragalactic Astronomy and Cosmology', Springer, Berlin Heidelberg New York.

Tugay A. 2012. *Odessa Astron. Publ.,* **25**, 142.

Winter L., Muschoztky R., Reynolds C. R. et al.: 2010, *AIP Conference Proceedings,* **369**, 1248.