ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA - BOLOGNA

Ricerca di galassie in interazione/fusione in un campione di oggetti selezionati in raggi X di alta energia

Search for galaxies in interaction/merging in a sample of hard X-Ray selected objects

Part 3

Tommaso Bonaiti[1], A. Malizia[2], L. Bassani[2]

[1] Liceo Luigi Galvani - Bologna
[2] IASF – INAF - Bologna

Report N. 660/2015

Student Stage June-July 2015

ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA – BOLOGNA
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

Introduction

An Active Galactic Nucleus (AGN) is a compact region in the center of a galaxy that has a much higher than normal luminosity and that emits about 100 times more energy, as electromagnetic radiation, than the rest of the galaxy. A galaxy which hosts an AGN is an active galaxy; in the local Universe about 10% of all galaxies are active.The radiation from AGN is believed to be the result of accretion of mass by a supermassive black hole (SMBH) at the center of its host galaxy.
In order for a SMBH to shine as an AGN, it needs a supply of gas to fuel its activity. Two main mechanisms have been suggested to trigger AGN activity: an internal mechanism through a dynamical instability inside the galaxy and **an external mechanism through galaxy-galaxy interaction or merging**. However, it is not yet clear which one is the dominant mechanism, even after many observational studies have been carried out.

The internal mechanism is such that a gas inflow to the central part occurs as a result of instability in the internal structure of a galaxy. For example, a galaxy bar can move gas from the outer regions of a galaxy into its center, and then the gas inflow can trigger the AGN phase.
On the other hand, the external mechanism is represented by galaxy-galaxy encounter and collision. In such a mechanism, gas infall during a major galaxy merging triggers the AGN. There are a number of observational results that support this idea. Studies of galaxy pairs or galaxies in interaction find that the AGN fraction increases in such systems. Binary SMBH in some AGN demonstrate that two or more SMBH can merge into one SMBH. After all, many AGN host galaxies are found to be elliptical galaxies, which do not possess bars or disk instabilities and hence must have been triggered by galaxy-galaxy collisions.
One promising way to investigate the AGN and merger connection is to study objects with merging features. When two galaxies with comparable mass merge, the merging produces an early-type galaxy leaving a trace of the past merging activity in the form of tidal tails, shells, and dust lanes. In support of this theoretical expectation, very deep imaging of early-type galaxies find merging features in many cases (15%–80%, depending on the depth of the image).

Recently a large number (20-25%) of these systems has been found analyzing samples of active galaxies (see Koss et al. 2010 and Cotini et al. 2013)selected in the hard X-ray band (20-100 keV). This fraction is much higher than the one (a few percent only) seen in control samples of normal galaxies and indicates that the AGN activity can indeed be triggered by galaxy-galaxy encounters.

Aim of the present project is to search for interacting/merging galaxies in a similar but much larger sample of AGN compared to the ones used by Koss et al. and Cotini et al. In fact, we have made our search using the latest survey made by the instrument BAT on board Swift, a NASA satellite. The identification of a group of AGN in interaction

ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA – BOLOGNA
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

and/or merging selected in the hard X-ray band will allow the astronomers to study in depth their properties and to understand the merging mechanism in more detail.

object	companion name(s)	redshift	class *	morphology
SWIFT J1614.0+6544 (Mrk 876)	PG 1613+658:[YG87] 24	0,129000	Seyfert 1	double system of a spherical (E0) merging galaxy (two nuclei) with a dwarf companion**
SWIFT J1617.8+3223 (3C 332)	SDSS J161742.41+322231.1	0,151019	Seyfert 1	double system of an elliptical galaxy with a smaller companion
SWIFT J1631.7+2353 (2MASX J16311554 +2352577)	SDSS J163115.41+235308.4	0,059001	Seyfert 1	irregular (?) merging galaxy (three nuclei)
SWIFT J1650.5+0434 (NGC 6230 NED01)	NGC 6230 NED02	0,032059	Seyfert 2	double system of paired galaxies
SWIFT J1652.9+0223 (NGC 6240)	binary black hole	0,024480	Seyfert 2 or LINER	irregular** merging galaxy
SWIFT J1708.6+2155 (2MASS J17085913+2153083)	SDSS J170859.42+215313.5/2MASX J17085841+2153052	0,072290	Seyfert 1	triple system of merging galaxies
SWIFT J1719.7+4900 (Arp 102 B)	Arp 102 A	0,024167	Seyfert 1 or LINER	double system of a spherical (E0) galaxy and a spiral galaxies
SWIFT J1747.8+6837A (MRK 0507)	There are two AGNs with similar redshift (z=0.0537 and z=0.0540) (2003, ApJS, 149,29)	0,055900	Seyfert 1 / Seyfert 1	double system of spiral merging galaxies
SWIFT J1816.0+4236 (UGC 11185 NED02)	UGC 11185 NED01	0,041205	Seyfert 2 / Seyfert 2	double merging system of an irregular elliptical

ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA – BOLOGNA
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

				galaxy and a spherical galaxy
SWIFT J1825.7+7215 (VII Zw 800)	VII Zw 800 NOTES02	?	?	pair of galaxies
SWIFT J1835.0+3240 (3C382)	G2	0,057870	Seyfert 1	double system of an elliptical or spiral galaxy and a barred spiral galaxy
SWIFT J1940.4-3015	6dFGS gJ194014.4-301601	0,052000	Seyfert 2	pair of galaxies
SWIFT J1952.4+0237 (3C 403)	Elliptical galaxy with a close companion to the southeast. (Madrid et al. 2006, ApJ, 164,307)	0,059000	Seyfert 2	double system of an elliptical galaxy and a dwarf galaxy**
SWIFT J2001.0-1811	?	0,037119	Seyfert 1.9	double system of merging galaxies
SWIFT J2007.0-3433	ESO 399-IG 020 NED01	0,024951	Seyfert 1	double or triple system (?) of merging irregular galaxies
SWIFT J2028.5+2543	NGC 6921	0,013900	Seyfert 2 / Seyfert 2	double system of spiral galaxies
SWIFT J2040.2-5126 (ESO 234-IG 063)	MRSS 234-075046 / MRSS 234-075405	0,053747	Seyfert 2	double or triple system of two merging galaxies with a smaller companion (?) in a cluster
SWIFT J2123.6+2506 (3C 433)	[PCd91] 212130.83+245139.2	0,101600	Seyfert 2	double merging system of an elliptical galaxy with a smaller companion in a cluster
SWIFT J2134.9-2729 (IRAS F21318-2739)	2MASX J21344464-2725397	0,066649	Seyfert 1.5	double merging system of a spiral (S0) galaxy with an elliptical** or spiral** (?) galaxy
SWIFT J2137.8-1433	PKS 2135-14:[HBC97] 01/	0,200470	Seyfert 1.5 or	elliptical merging galaxy (two nuclei)

ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA – BOLOGNA
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

	PKS 2135-14:[HBC97] 02/ PKS 2135-14:[HBC97] 12		quasar	with many companions
SWIFT J2148.3-3454 (NGC 7130)	IC 5131	0,016151	Seyfert 1.9	spiral galaxy
SWIFT J2200.9+1032	UGC 11871 NED02	0,026612	Seyfert 1.9	double system of merging galaxies
SWIFT J2207.3+1013 (NGC 7212)	NGC 7212 NED01/ NGC 7212 NED03	0,026632	Seyfert 2 / Seyfert 1h / GTRPL	triple system of three merging galaxies, one of which is a spiral galaxy
SWIFT J2209.1-2747	VV 700 NED02/ ESO 467- G 013	0,023128	Seyfert 1.2	triple system with two merging barred spiral (SB0) galaxies and a spiral galaxy
SWIFT J2211.7+1843	2MASX J22115247+1841322	0,070000	Seyfert 1	double system of a spherical (E0) and an elliptical** or spiral** (?) galaxy
SWIFT J2235.9+3358 (Stephan's Quintet)	NGC 7318A/ NGC 7318B/ NGC 7317	0,022507	Seyfert 2	quadruple merging system of two elliptical galaxies and two barred spiral galaxies
SWIFT J2236.7-1233 (Mrk 915)	2MASS J22364719-1232330	0,024109	Seyfert 1	double system of a spiral galaxy and a dwarf galaxy**
SWIFT J2250.7-0854	SDSS J225052.65-085452.8/ SDSS J225050.92-085445.4/ SDSS J225050.02-085456.3	0,064886	Seyfert 1.5	multiple system with a spiral** galaxy with up to three minor companions
SWIFT J2254.2+1147A/ SWIFT J2254.2+1147B	SWIFT J2254.2+1147B/ SWIFT J2254.2+1147A	0,028273	Seyfert 1 / Seyfert 2	double system of spiral galaxies
SWIFT J2302.1+1557	NGC 7464/ NGC 7463	0,006538	Seyfert 2 or LINER	triple system with an elliptical galaxy, a spiral galaxy and a dwarf galaxy**

ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA – BOLOGNA
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

SWIFT J2303.3+0852 (NGC 7469)	IC 5283	0,016317	Seyfert 1.2	double system of (non-interacting) spiral galaxies
SWIFT J2304.8-0843 (Mrk 926)	2MASX J23044397-0842114	0,046860	Seyfert 1.5 / AGN	double system of spiral galaxies
SWIFT J2318.4-4223 (NGC 7582)	2MASX J23181913-4222355/ NGC 7590/ NGC 7599	0,005254	Seyfert 1i / Seyfert 2 / Seyfert 2	quadruple system of a barred spiral galaxy with a smaller companion ad two spiral galaxies
SWIFT J2318.9+0013 (NGC 7603)	2MASX J23190110+0016516	0,029524	Seyfert 1.5	double system of a spiral galaxy and a dwarf galaxy** (galactic cannibalism)**
SWIFT J2328.9+0328 (NGC 7679)	NGC 7682	0,016048	Seyfert 2 / Seyfert 2	double system of barred spiral (SB0) galaxies
SWIFT J2351.9-0109	[KSS94] J235156.0-010914 20/ SDSS J235158.39-011024.6	0,173740	Seyfert 1.2 or quasar	double or triple (?) system with a spherical or elliptical galaxy with one or two smaller companions

Data Analysis and Results

The work for this project was divided among the 4 high school students who attended the summer stage named "Search for galaxies in interaction/merging in a sample of high hard X-ray selected objects" at IASF/INAF in Bologna. To search for interacting/merging galaxies, we have used the Swift BAT 70-Month Hard X-ray survey catalogue (http://swift.gsfc.nasa.gov/results/bs70mon): this survey contains a total of 1210 high energy objects, the majority of which are of extragalactic nature; in particular 822 sources are associated with active galaxies. Each student analyzed a set of 204 or 206 galaxies: my set included all the objects located from RA(J2000)=241,782 degrees, to RA(J2000)=359,756 degrees. For each of these objects, I have analyzed the optical/infrared images available in the archives to look for signs of interaction/merger and have searched the literature to back up my findings. In this project I have used two main databases (NED or NASA/IPAC Extragalactic Database and SIMBAD or Set of

ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA – BOLOGNA
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

Identification, Measurements, and Bibliography for Astronomical Data), as well as the Aladin software to visualize images. I have also searched these databases by coordinates to confirm that the counterpart analysed was the same as that reported in the Swift catalogue. Sources that were found to display signs of interaction, perturbation or the presence of a nearby companion/s were then further investigated in the archives to find confirmation that they were indeed the type of systems I was looking for.

In NED I also checked notes and references to individual sources to see if someone else had already observed and studied them in order to compare our results.
Finally I checked that eventual companion to interesting sources were at the same distance or redshift. I found 37 galaxies in pair, merging or interaction from my initial sample of 206 galaxies. These objects are listed in Table 1 where I report the name of the object, the name of the companion(s), the redshift of the system, the class of the object studied and the morphology of the system.

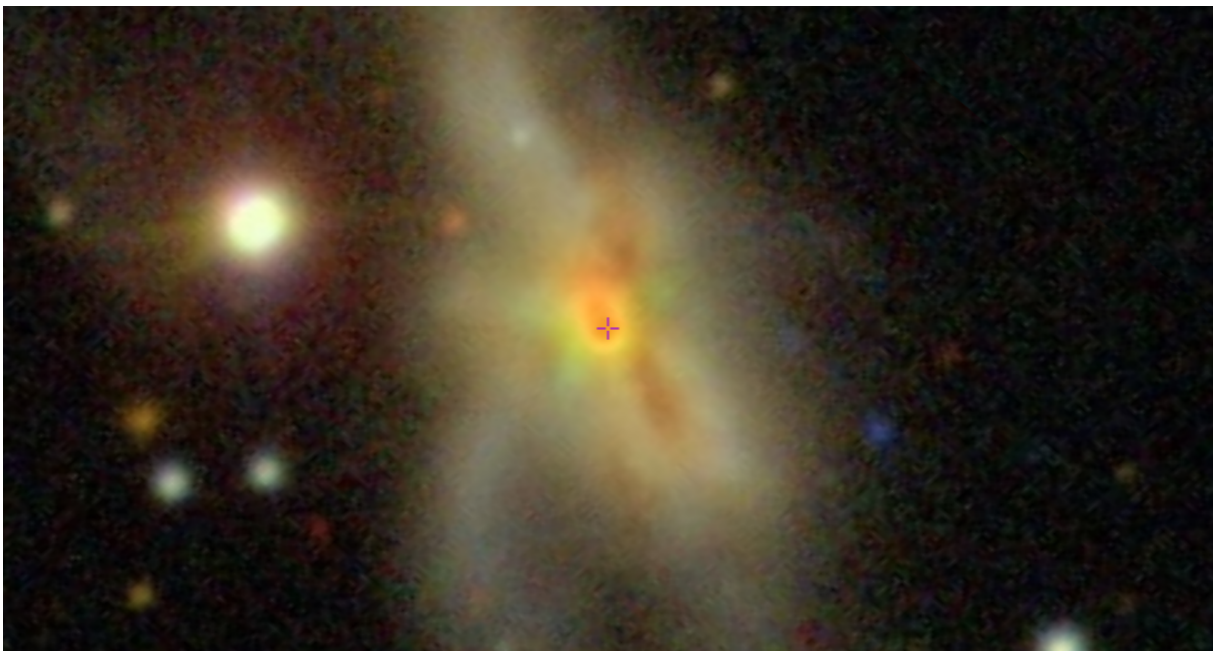
Tab. 1

* if only one class is mentioned, it refers to the main object, as the class of minor objects is unknown or was not found.

**object classified according to the pictures available on SIMBAD and Aladin, informations not found in the literature

(?)the morphology classification of the object is not definitive

ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA – BOLOGNA
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



A few examples of the sources found are displayed in the following images:

Image 1: SWIFT J1652.9+0223 (NGC 6240)

Image 2: SWIFT J1816.0+4236 (UGC 11185 NED02)

ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA – BOLOGNA
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

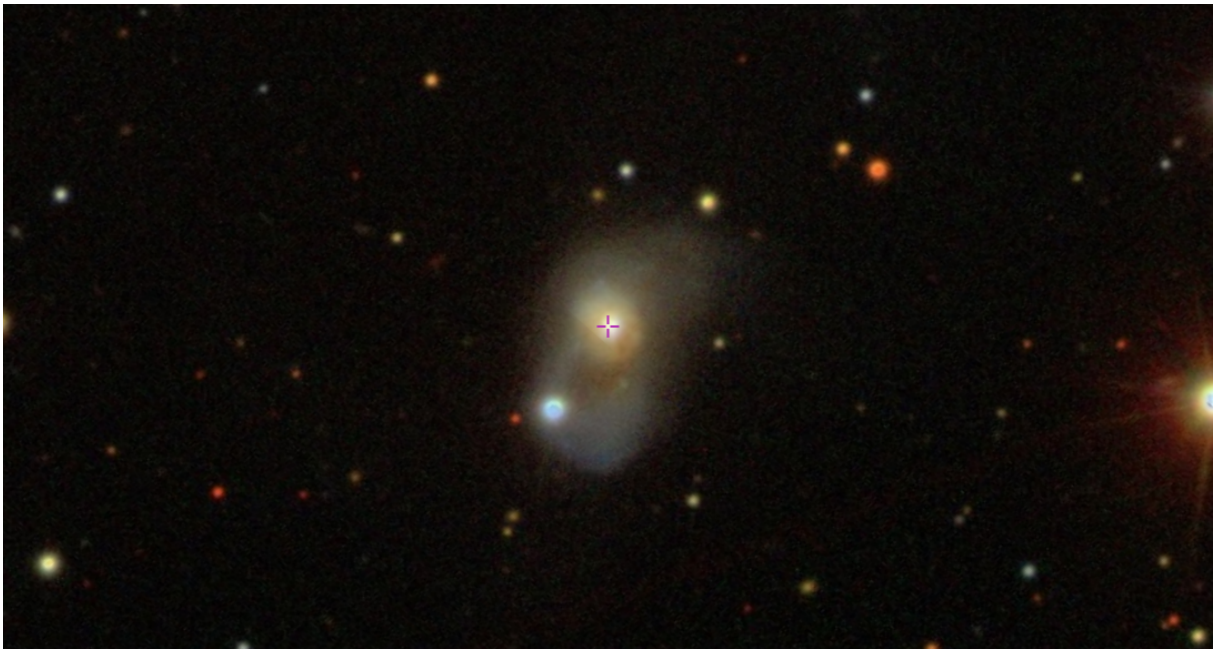


Image 3: SWIFT J2200.9+1032

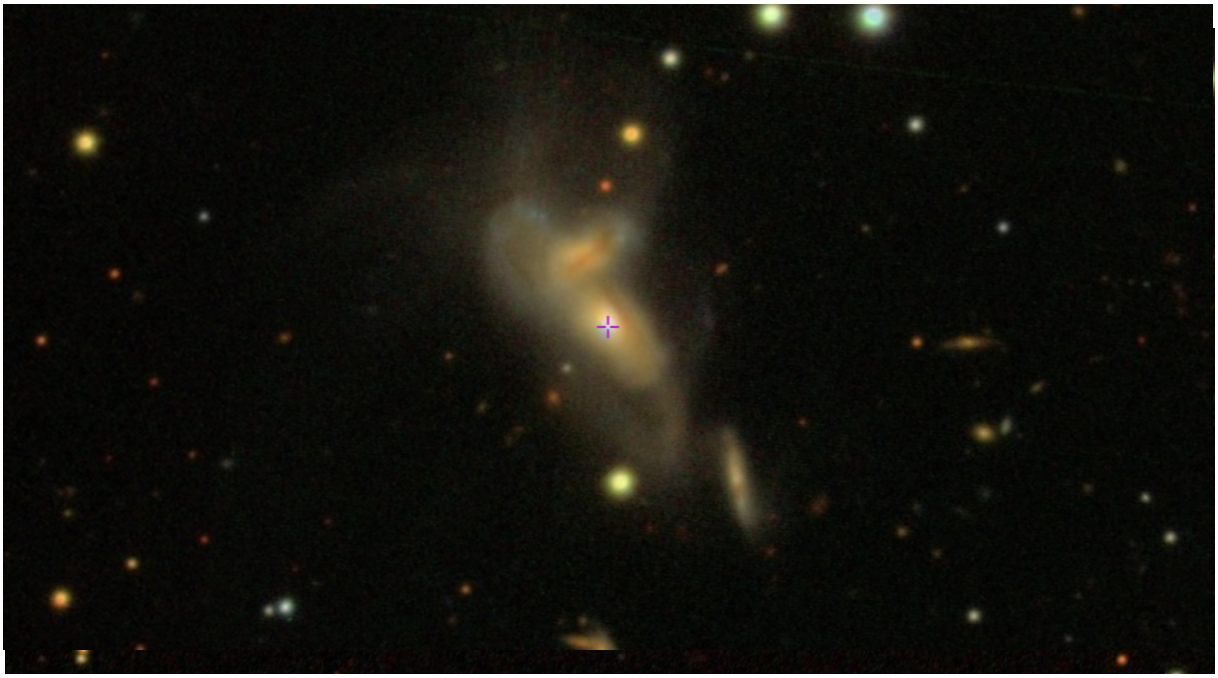


Image 4: SWIFT J2207.3+1013 (NGC 7212)

ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA – BOLOGNA
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

Image 5: SWIFT J2235.9+3358 (Stephan's Quintet)

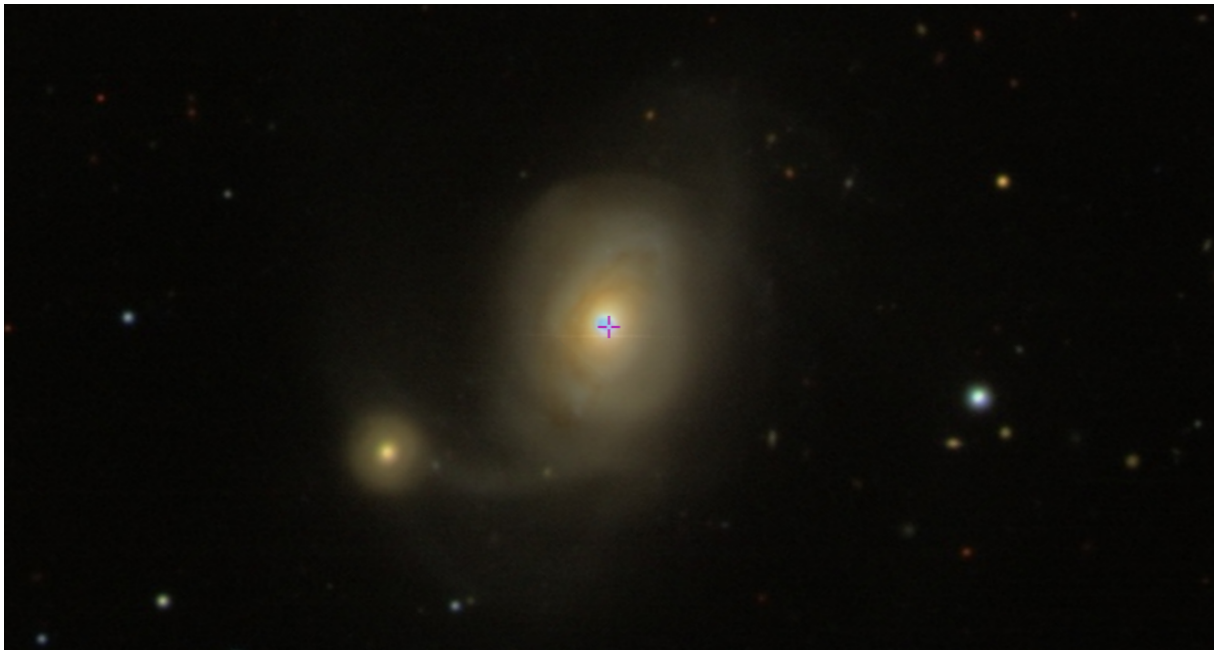


Image 6: SWIFT J2318.9+0013 (NGC 7603)

ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA – BOLOGNA
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

Conclusions

17.5% of the 206 galaxies that I have analyzed have been found to be in pair, interaction or merging; this ratio is similar to the fraction found in previous studies by Koss et al. (2010) and Cotini et al. (2013). All together the 4 students attending the stage found 152 galaxies in pair, interaction or merging in the total sample of 822 galaxies analysed: this represents a fraction of 18.5%. Thus our research totally confirms previous studies made by the above authors and further indicates that indeed the encounter between galaxies may play a role in the activation of an AGN.

References

Koss, M. et al. (2010) Ap. J. 716, L125
Cotini et al. (2013)MNRAS 431, 266

ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA – BOLOGNA
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