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Isolated galaxies with AGNs as the UV-faintest objects of the Local Universe

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*Abstract.

The sample of 61 isolated galaxies with AGNs was formed by cross-matching the 2MIG (2MASS isolated galaxy) catalogue with the Veron-Cetty catalogue of quasars and AGNs, where limited parameters were assigned to $K_s \leq 12.0$ mag and $V_r < 15\ 000$ km/s (Pulatova et al. 2015, Karachentseva et al. 2010, Veron-Cetty+2010). It could be considered as the unique laboratory for recognizing their internal multiwavelength properties and physical parameters of accretion on the supermassive black holes outside of the environment. A priori these host galaxies had no merging at least 3 Gyrs.

They were classified into several categories (pure and weak isolated AGNs, composites, and with faint companions) to reveal their multiwavelength properties including all the available archived data from literature & data bases.

The 2MIG isolated AGNs are faint UV-sources: the measured UV magnitudes are available only for 12 objects; the mean UV-mag is 16±1.47 (Catinella et al. 2010, Munoz Marın et al. 2007, Gil de Paz et al. 2007, Buat et al. 2007, Lemonias et al. 2011, Smith & Struck 2010, Vavilova et al. 2020). We discuss these results and principal explanation of importance to prepare a proposal for future UV-observations of the isolated AGNs in the Local Universe in sense of the newest approach to the decaying AGN (AGN models, which have no influence of environment).

*Sample.

2MIG No.	Name	RA h:m:s	DEC d:m:s	V_h km/s	Morph Type	N	Radio mJy	IR Jy	Opt mJy	UV mag	X-ray	R	Sp Type
					Pure Isolated AGNs								
1522	UGC 06087	11:00:32.50	+02:06:57.3	11824	SBb				4.7	16.9[1]			Sy1
1646	CGCG 243-024	11:53:41.76	+46:12:42.6	7385	SB(r)a			0.9	1.5	15.6[2]	0.12		Sy1n
2811	NGC 6951	20:37:14.07	+66:06:20.3	1424	SAB(rs)bc		70.4	37.5[6]	100	17.5[3]	.005	0.7	Sy2
3118	NGC 7479	23:04:56.66	+12:19:22.3	2381	SB(s)c	4	101	25.8	104	14.8[3]	0.023 1.9	0.9	Sy1.9
3128	IC 5287	23:09:20.28	+00:45:23.0	9715	(R)SB(r)b8			<0.3	5.8	17.1[3]			Sy1
					Weak Isolated AGNS								
9	IC 1529	00:05:13.22	−11:30:09.3	6751	(R)SA0(r)		3.4		11.4	16.7[4]		0.3	AGN
287	NGC 0918	02:25:50.22	+18:29:56.1	1508	SAB(rs)c	1		6.9	1.8	14[4]			AGN
					Composite Isolated AGNs								
70	NGC 0157	00:34:46.75	−08:23:47.3	1673	SAB(rs)bc		136		453	13.4[4]		0.3	Sy2, HII
2357	UGC 10774	17:14:09.07	+58:49:06.7	8873	SBAbc	1	1.5	0.5	0.08	17.5[5]		18.75	Sy3, HII
					Isolated AGNs with faint nearby companions (according to NED search)								
1873	NGC 5231	13:35:48.25	+02:59:55.6	6523	SBa	5	11.7	1.3	9	17.1[6]	1.8	1.3	Sy2
1915	NGC 5347	13:53:17.85	+33:29:26.7	2384	(R)SB(rs)ab	2	5.6 3.1	2.6	18.7	16.9[2]	0.03	0.3	Sy2
2183	UGC10120	15:59:09.67	+35:01:47.3	9438	SB(r)b	2	5.9	1.37	2.4	14.5[2]	0.3	2.5	Sy1n

[1] – Catinella et al. (2010), [2] – Munez Morin et al. 2007, [3] – Gil de Paz et al. 2007,

[4] – Buat et al. 2007, [5] – Lemonias et al. 2011, [6] – Smith & Struck 2010

RA, DEC - Eq. coord. (J2000.0).
Vh - radial velocity, km/s.
N - number of faint galaxies-companions.
Radio flux at 1.4 GHz in mJy (for some galaxies a second flux, at 5GHz), in mJy.
Infrared flux, inJy.
Optical flux, in mJy, calculated from B=−2.5 logO − 48.36 (Kellermann et al.1989).
Ultraviolet flux in UV-mag.
X-ray fluxes from the literature in 2-10 keV and 15-150 keV are presented in 10^{-11}erg $cm^{-2}s^{-1}$
R ratio of radio to optical flux density (Kellermann et al.1989).
Spectral type of nuclear activity.

*Relation “Optical – UV – X ray”

- **The X-ray** emission of AGNs is produced in a compact area near their SMBHs. There are a couple of strong spectral lines in X-ray spectra of AGNs, the most important is the Fe Kα line. We performed a spectral analysis of a sample of 20 from 36 2MIG isolated AGNs observed by X-ray observatories. We found that the Fe Kα line is detected in a 75 per cent of the sample with a mean equivalent width of approximately 75 eV. On the other hand, about40 per cent of selected 2MIG isolated AGNs show a relativistic broad line that might be explained by the presence of the emission from an accretion disc. One of the significant properties of the Fe Kα line is variability of shape and intensity. Observed variations of this line are less then variations of the high-energy continuum, which is assumed to induce the line emission. In addition, it seems that there is a lack of line response to the continuum variations on the time-scales from couple minutes to several days.
- We note that the observed X-ray continuum of Sy1-type galaxies from our sample is stronger as compared with Sy2-type galaxies, i.e. Sy1-type galaxies appear to be more luminous. Most of the normal galaxies harbour strarburst nuclei and LINER, and together with low-luminosity AGN (X-ray luminosity is less than 10^{42}erg s^{-1}) are a class of low-activity galaxies. Normal AGNs only comprise about 10 per cent of all galaxies, while most AGNs in the Local Universe are in a low-luminosity state.
- It is consistent with our results on X-ray activity of the isolated AGNs, which are mostly faint in this spectral range: mean flux is 9.4×10^{-12}erg $cm^{-2}s^{-1}$ for 13 the 2MIG isolated AGNs without companions in the soft 2–10 keV range.
- **UV-range**. 2MIG isolated AGNs are faint UV-sources. For 12 objects with the available measured UV magnitude the mean UV-mag is 16±1.47. All the isolated galaxies with AGNs with available UV-data has a bar as morphological feature. We revealed that pure isolated AGNs of Sy1 type also have bar morphological features. It allows us for the conclusion that the BLR in isolated AGNs could be connected with presence of bar in the host galaxy that provides transfer of gas and dust from galaxy’s disc to nuclear regions. As follows from this inference, the interaction is not necessary condition for BLR formation (Pulatova et al. 2015, Vavilova et al. 2020). This result is consistent with results on the simultaneous X-ray/optical/UV spectral energy distributions proposed in earlier work by Vasudevan & Fabian (2009) for SMBH mass calculations. In any case, the UV is lagging the X-rays, if the correlated UV variations were produced by the reprocessing of X-ray emission (see, also, Buisson et al. 2018).

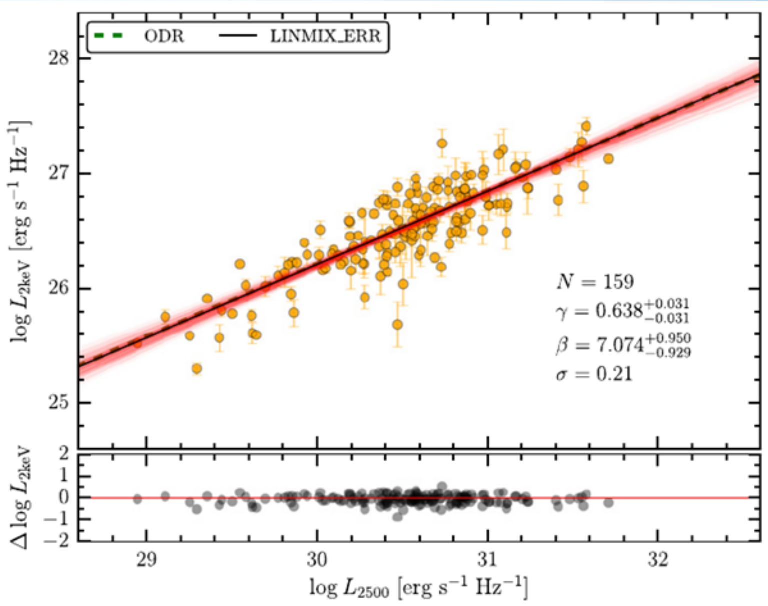
*Relation “Optical – UV – X ray”

The UV to optical continuum emission of AGNs is widely believed to be emitted by a geometrically thin but optically thick accretion disk (i.e., the classical standard thin disk, see, e.g. Shakura & Sunyaev 1973; Czerny & Elvis 1987). Thus, we can have a potential tool for study of accretion physics straightforwardly.

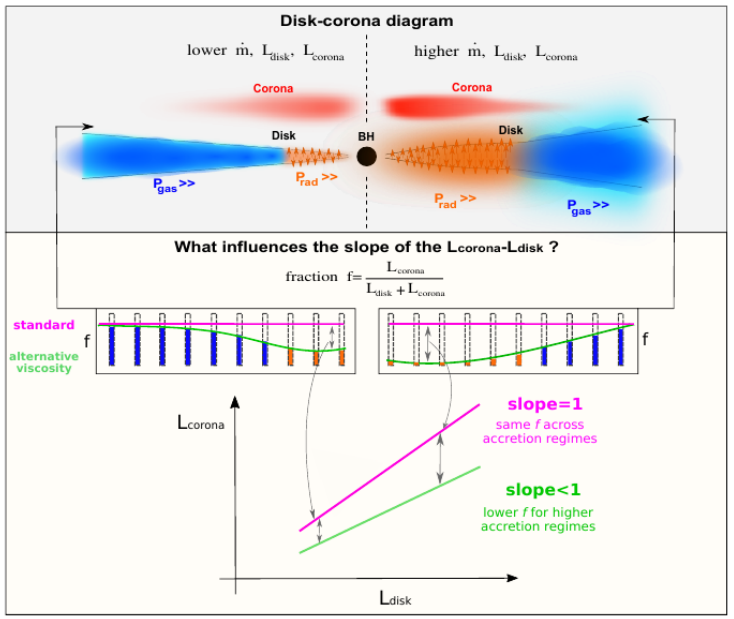
The X-ray to optical non-linear relation (e.g. Lusso & Risaliti, 2016) > disk-corona interplay (e.g. Arcodia et al. 2019; Sun et al. 2020 (CHAR model))? Influence of accretion rate?

$$\alpha_{\rm ox} = \frac{\log (L_{2\ \rm keV}/L_{2500})}{\log (\nu_{2\ \rm keV}/\nu_{2500})}$$

The understanding of connection between UV and X-ray emission, their relative variability should provide us an opportunity to get the final goals — obtaining the fundamental quantities like Eddington ratio, black-hole mass and sizes of central constitutients subsystems as an accretion disk, a coronae, and BLR.



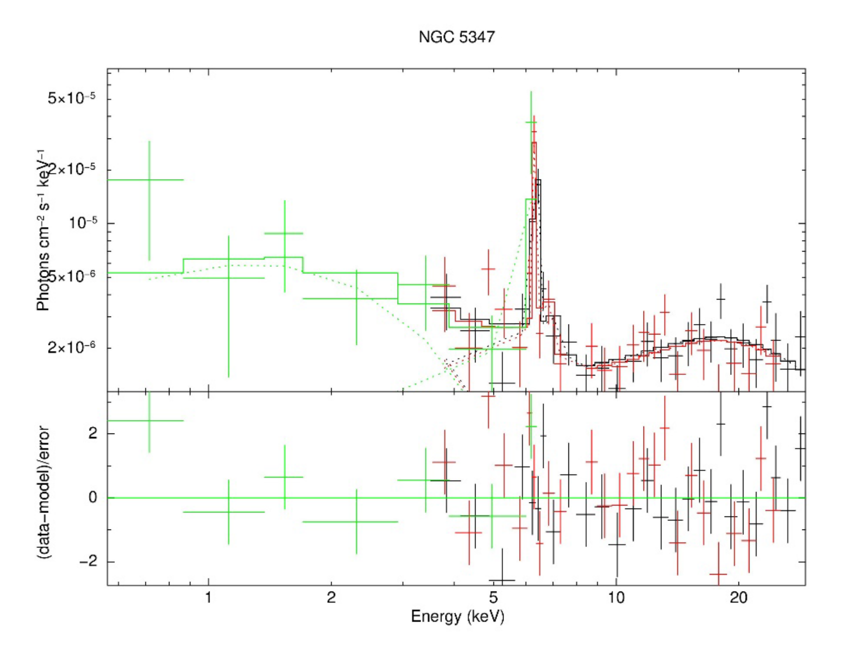
Credit: Fig 6. in paper by Lusso & Risaliti 2016



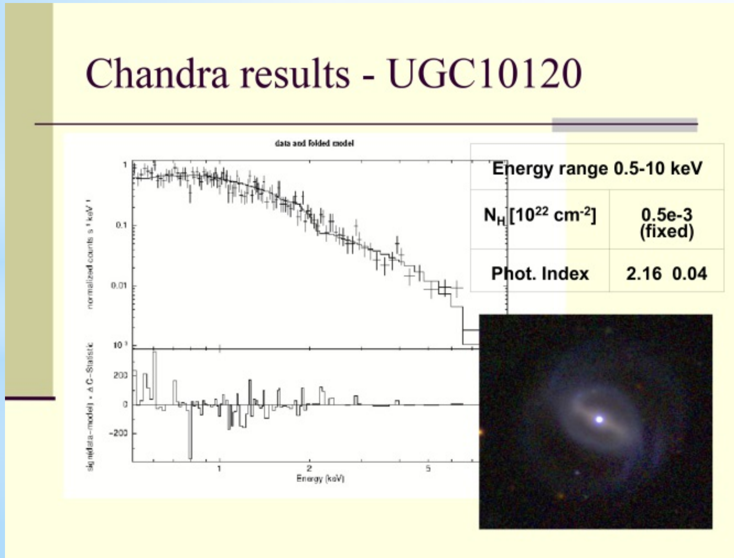
Credit: Schematic model of disk-corona interaction by Arcodia et al. 2019

*Examples: NGC 5347 and UGC 10120. SMBHs

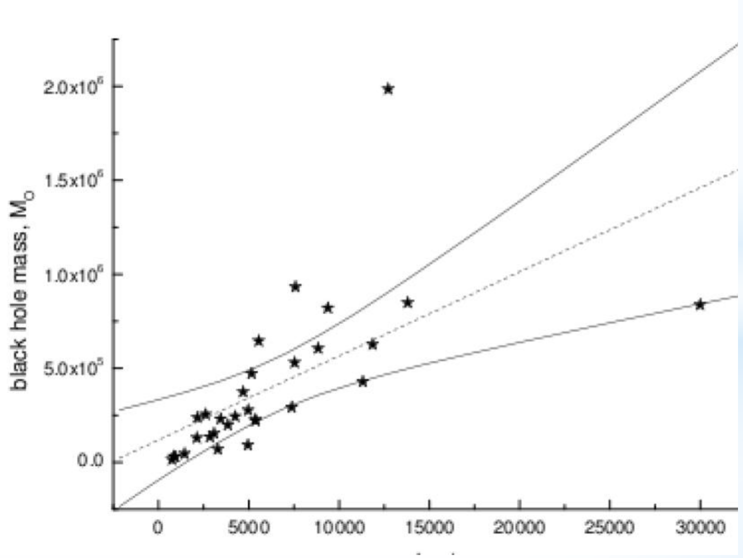
Example of the combined NuSTAR and Swift/XRT spectrum for NGC 5347, which was fitted (C-stat=55/52) by {pexmon} model in the pure reflection regime with a {zbbody} component for describing the soft emission
($kT_e = 0.77_{-0.18}^{+0.17}$ keV). The spectral index is $\Gamma = 1.60_{-0.27}^{+0.37}$
and cut-off energy is constrained to be $E_{cut} > 63$ keV.
The unabsorbed (i.e., absorption-corrected) luminosity are
$L_{2\text{-}10\text{~}keV} = 2.89_{-0.19}^{+0.22} \times 10^{41}$ erg/s
and $L_{10\text{-}40keV} = 5.93_{-0.14}^{+0.16} \times 10^{41}$ erg/s.



Following the estimation of SMBH mass for ESO 438-009 as $\log M_{BH}/M_{æ} = 7.97$ (Koss et al. 2017) and corresponding L_{Edd} 1.2 x 10^{46} erg/s, we calculated the Eddington ratio for this galaxy NGC 5347 as L_{bol}/L_{Edd} ~ 0.004.
(Vasylenko, Vavilova, Pulatova 2020)



Example of the Chandra spectrum for UGC 10120
(Vavilova, Vasylenko, Babyk, Pulatova 2016)



The estimates of SMBH masses for isolated AGNs show that their values are systematically lower than
the SMBH masses of AGNs
located in a dense environment

* **Evolutional models.** There are several evolutionary models of transforming one spectral type of AGN into another. They may be considered as an opposite or complementary theories to the Unified Model to generalize and to describe the variability of AGNs. The basic idea is that interaction between normal galaxies can cause major changes in their properties such as activate their nuclei. Types of this activity will change with time. It is believed, that after interaction galaxy should start an definite sequence of changing its type of nuclear activity. See, for example, Ho (2009), on the study of the bolometric luminosities and Eddington ratios of the nearby galaxies from the Palomar survey. The bolometric luminosities vary systematically with a nuclear spectral classification, increasing along the sequence 'absorption line - nuclei – transition objects – LINER – Seyferts'.
* The type of nuclear activity can change during stage of merger. Besides it, a nuclear activity of galaxy can be connected with the properties of host galaxy. It is worth emphasizing that more than half of 2MIG isolated AGNs belongs to Sy2 and Sy1types has a bar morphological feature. The formation of BLR in isolated AGNs can be driven by bar which provides a mechanism for transferring gas and dust to the nuclear region.
* The isolated AGNs are good laboratories for study of the decaying AGN engine, at least, the isolated galaxies of Local Universe had no influence of environment during last 3 Gyrs. For comparison, see the results of the SAGE model application (Marshall et al. 2018) to show a role of the ram pressure in triggering AGN in rich environment (galaxy cluster).
* The new long-awaited UV-space missions will help to fill a gap in data on the Optical-UV-X-ray relation and understand deeply the accretion physics of AGNs.


Thanks for your attention!
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