Comparison of physical multi-wavelength emission models of active galaxy nuclei from their spectral energy distribution

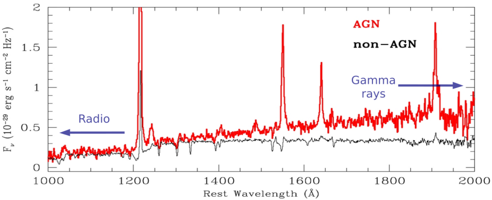
Laura N. Martínez-Ramírez[1,2*], Gabriela Calistro Rivera[2], Juan C. B. Pineda[1], Luis A. Núñez[1,3]

[1]Escuela de Física - Universidad Industrial de Santander, 680002 Bucaramanga-Colombia.
[2]European Southern Observatory, D-85748 Garching-Germany.
[3]Departamento de Física - Universidad de Los Andes, Mérida 5101, Venezuela.
[*]laura.martinez13@correo.uis.edu.co

Talk's outline

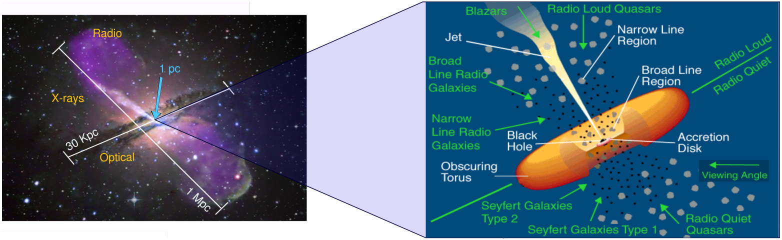
Active galactic nuclei and SEDs

Active galaxies



Why is it important to study AGNs?

- AGN feedback[1].
- Co-evolution with its host galaxy[2].

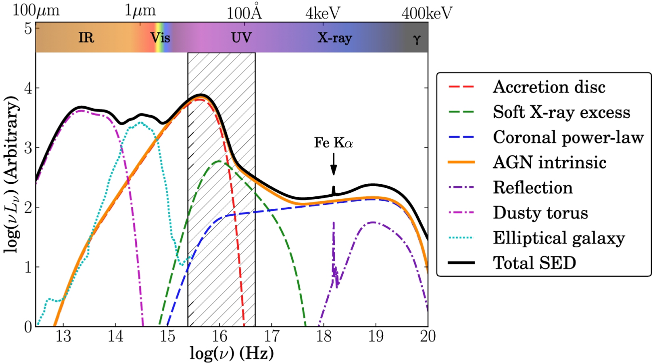


Edited from: Hainline, et al. (2011). Astrophys. J., 733(1), 31, https://apod.nasa.gov/apod/image/0801/cena_comp.jpg y Urry, C & Padovani, P. (1995) Publ. Astron. Soc. Pac., 107(715), 803.

[1] Suresh, J., et al. (2015). Mon. Notices Royal Astron. Soc., 448(1), 895-909.

[2] Kauffmann, G., et al. (2003).Mon. Notices Royal Astron. Soc., 346(4), 1055-1077.

Spectral energy distributions (SED)



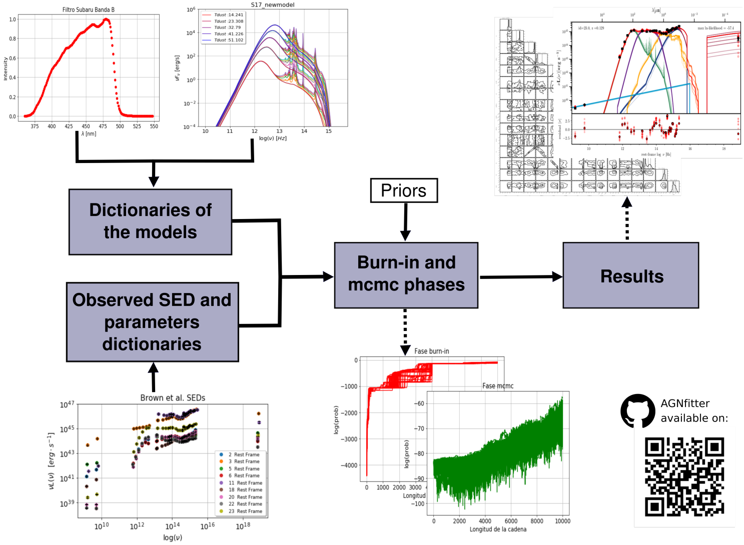
Typical SED of an active galaxy. Taken from: Collinson et al. (2016). Mon. Notices Royal Astron. Soc., stw2666.

Emission components

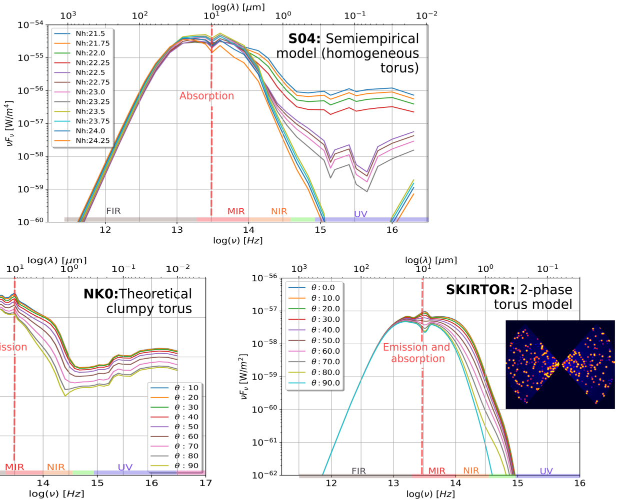
- Accretion disk
- Coronal hot gas
- Relativistic jets
- Stellar population
- Cold dust
- Torus

AGNfitter

How the code works?

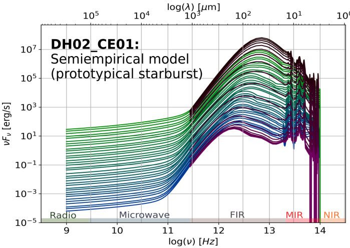


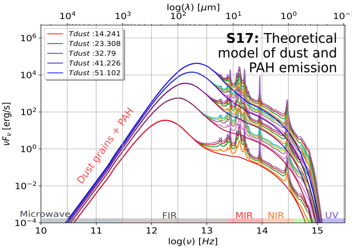
Hot nuclear dust torus



Model S04 by Silva, L., Maiolino, R., & Granato, G. L. (2004). Mon. Notices Royal Astron. Soc., 355(3), 973-985; NK0 by Nenkova, M., et al. (2008). Astrophys. J., 685(1), 160 and SKIRTOR by Stalevski, M., et al. (2016). Mon. Notices Royal Astron. Soc., 458(3), 2288-2302.

Cold dust from star forming regions

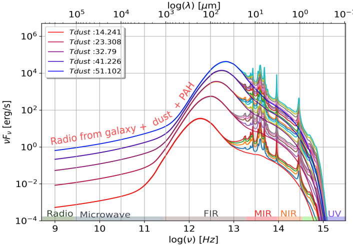




IR-radio correlation

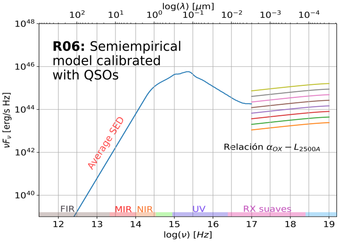
$$q_{IR} = \log(L_{IR} / 3.75\mathrm{x}10^{12}\ L_{1.4GHz})$$
$$q_{IR} = 2.64 \pm 0.26$$

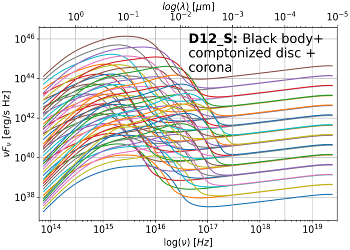
S17_radio: S17+
IR-1.4GHz correlation

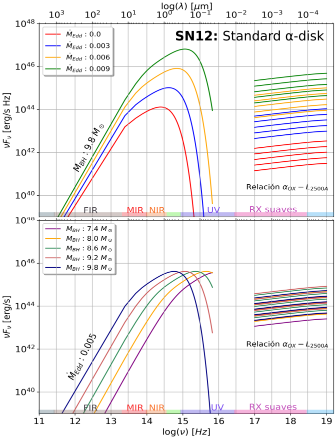


Model DH02_CE01 by Dale, D. A., & Helou, G. (2002). Astrophys. J., 576(1), 159 and Chary, R., & Elbaz, D. (2001). Astrophys. J., 556(2), 562. Model S17_newmodel by Schreiber, C., et al. (2018). Astron. Astrophys., 609, A30.

Accretion disc and corona







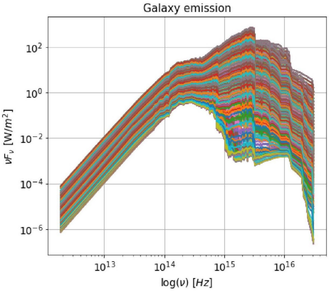
UV-X rays correlation

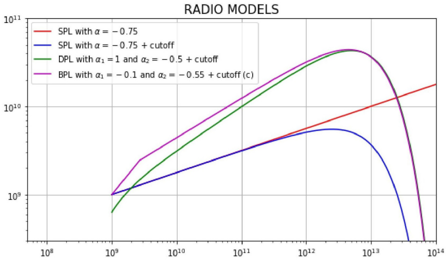
α_{OX} = -0.137 log($L_{2500Å}$)+2.638

α_{OX} = -0.384 log($L_{2500Å}/L_{2keV}$)

Model R06 by Richards, G. T., et al. (2006). Astron. J., 131(6), 2766. SN12 by Slone, O., & Netzer, H. (2012). Mon. Notices Royal Astron. Soc., 426(1), 656-664; and D12_S by Done, C., et al. (2012). Mon. Notices Royal Astron. Soc., 420(3), 1848-1860.

Stellar population and Radio from the AGN





$$L_\nu \propto \left(\frac{\nu}{\nu_t}\right)^{\alpha_1} \left[1 - \exp\left(-\left(\frac{\nu_t}{\nu}\right)^{\alpha_1-\alpha_2}\right)\right] e^{-\frac{\nu}{\nu_{\rm cutoff}}}$$

Stellar population synthesis models by Bruzual & Charlot 2003. The parameters are: tau, age and metallicity

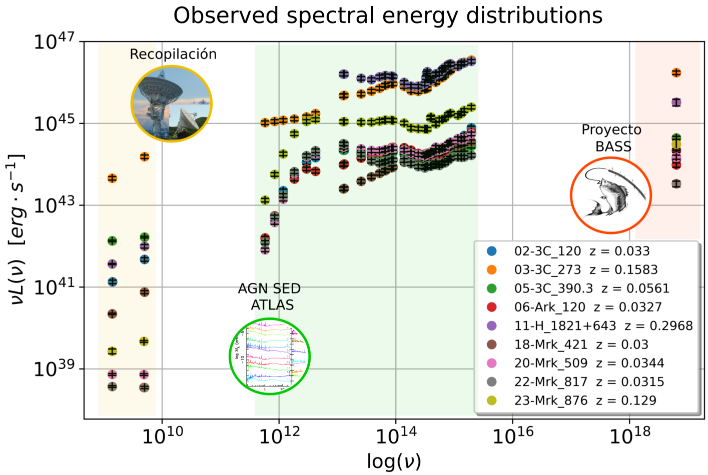
This model consider the existence of optically thin lobes and compact structures such a radio cores and hot spots (Azadi et al 2020)

Fitting parameters

Component	Notation	Description	Range
Galaxy	tau	Exponential SFH time scale [G years]	[0.05, age(z)]
	age	Galaxy age [log years]	[7, age(z)]
	metal	Metallicity [$Z_\odot$]	[0.2, 2]
	EBVgal	Reddening parameter	[0,1]
	GA	Normalization parameter	[-10, 10]
Cold dust	Tdust	Cold dust temperature [K]	[14.24, 42]
	fracPAH	PAHs fraction	[0, 0.05]
	SB	Normalization parameter	[-10, 10]
Torus	incl	Inclination angle of the torus [°]	[0, 90]
	Nh	Torus column density [log cm^{-2}]	[21, 25]
	TO	Normalization parameter	[-10, 10]
Accretion disk	logBHmass	Black hole mass [log $M_\odot$]	[7.4, 9.8]
	logEddra	Eddington Accretion Rate [log M_{Edd}]	[0, 0.011]
	EBVbbb	Reddening parameter	[0,1]
	BB	Normalization parameter	[-10, 10]
X-Rays	**alphaScat**	Correlation dispersion $\alpha_{ox} - L_{2500Å}$	[-0.4, 0.4]
AGN radius	**RAD**	Normalization parameter	[-20, 20]

Results of the thesis

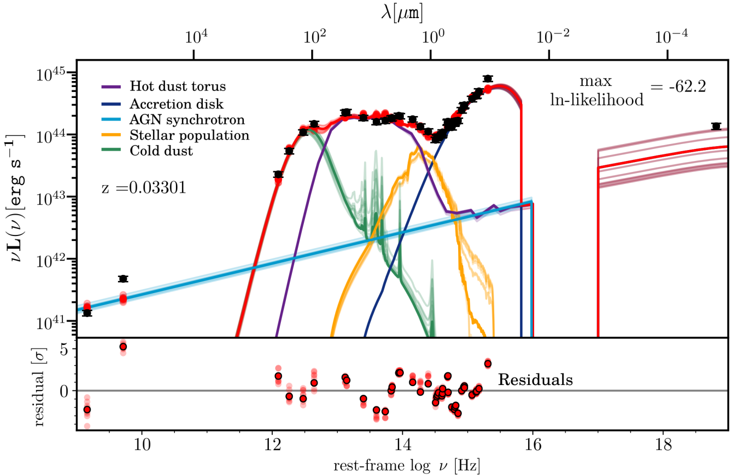
Sample of galaxies



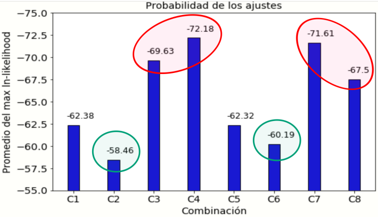
SED from FIR to UV collected by Brown, M. et al. (2019). Mon. Notices Royal Astron. Soc., 489(3), 3351-3367. Data available in `https://archive.stsci.edu/hlsp/agnsedatlas`.

Individual results: Galaxy 3C 120

Galaxy 3C 120: Lenticular, Seyfert 1 and Fanaroff Riley I galaxy with jets.

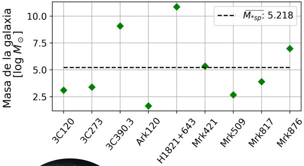


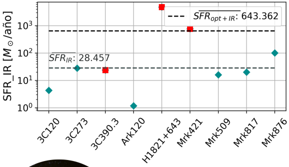
General results: trends

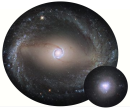


Theoretical model SN12 fails to fully reproduce SEDs

Great improvement with the SKIRTOR model







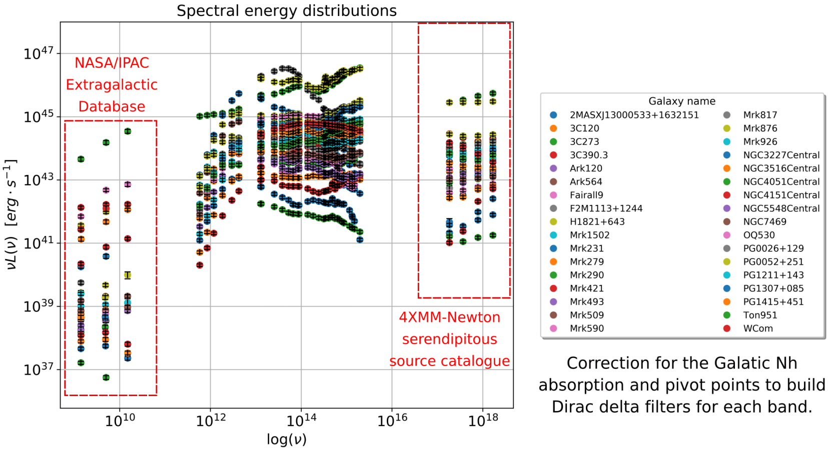
Massive vs dwarf (10^{11} vs 10^{7} M⊙)

Starburst (10-300) M⊙/year

Images taken from: `https://www.spacetelescope.org/images/heic1712a/` (left) and `https://www.jpl.nasa.gov/spaceimages/details.php?id=PIA04229` (right).

Progress during the internship

Sample of galaxies



Correction for the Galatic Nh absorption and pivot points to build Dirac delta filters for each band.

New priors

X-ray to mid-IR relation appropiate from Seyfert regime to powerful quasar regime

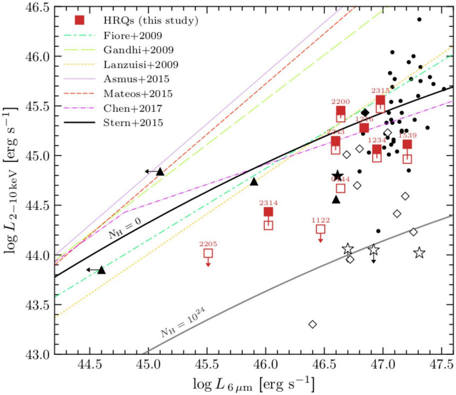
$$\log L(2 - 10\ \mathrm{keV}) = 40.981 + 1.024x - 0.047x^2$$

$$\log(\nu L_\nu(6\ \mu\mathrm{m})/10^{41}\ \mathrm{erg\ s^{-1}})$$

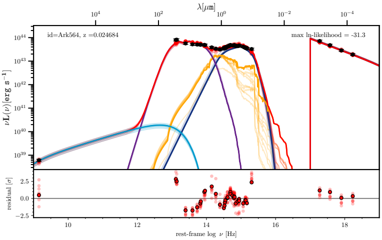
Overcome problems with:

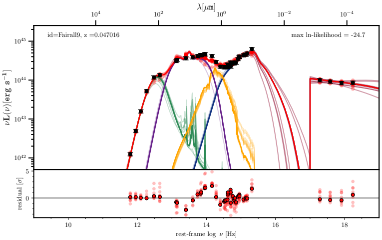
- Hight luminosity quasars
- Systematic errors
- Biased samples

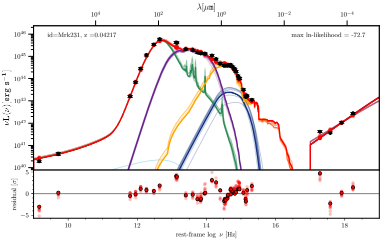
Similar to UV-Xray correlation: less dramatically increases at X-ray energies when mid-IR increases

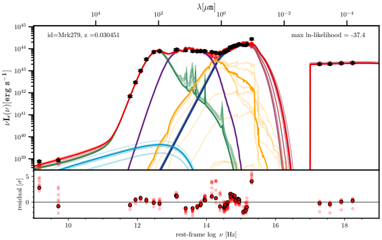


New fits


id=Ark564, z =0.024684
max ln-likelihood = -31.3
λ[μm]
νL(ν)[erg s⁻¹]
residual [σ]
rest-frame log ν [Hz]


id=Fairall9, z =0.047016
max ln-likelihood = -24.7
λ[μm]
νL(ν)[erg s⁻¹]
residual [σ]
rest-frame log ν [Hz]


id=Mrk231, z =0.04217
max ln-likelihood = -72.7
λ[μm]
νL(ν)[erg s⁻¹]
residual [σ]
rest-frame log ν [Hz]


id=Mrk279, z =0.030451
max ln-likelihood = -37.4
λ[μm]
νL(ν)[erg s⁻¹]
residual [σ]
rest-frame log ν [Hz]

Thanks for your attention!

laura.martinez13@correo.uis.edu.co