Multi-phase AGN-driven outflow in the NLSy1 IRAS 17020+4544

Unveiling dual-feedback and an energy-conserving ionized outflow with MEGARA/GTC integral field spectroscopy

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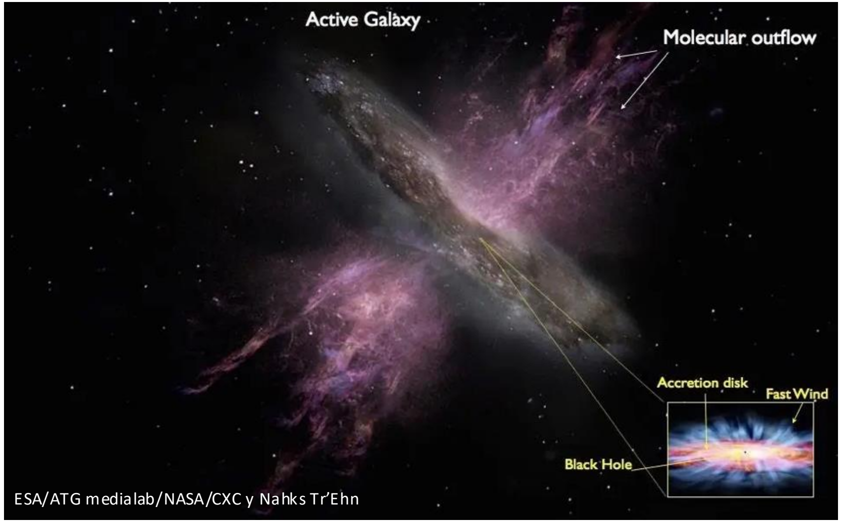
submitted to A&A !



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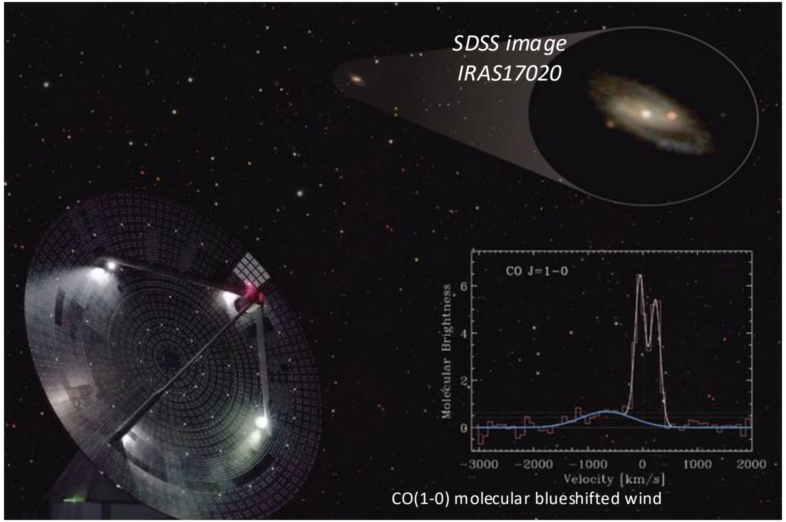


CO(1-0) molecular blueshifted wind

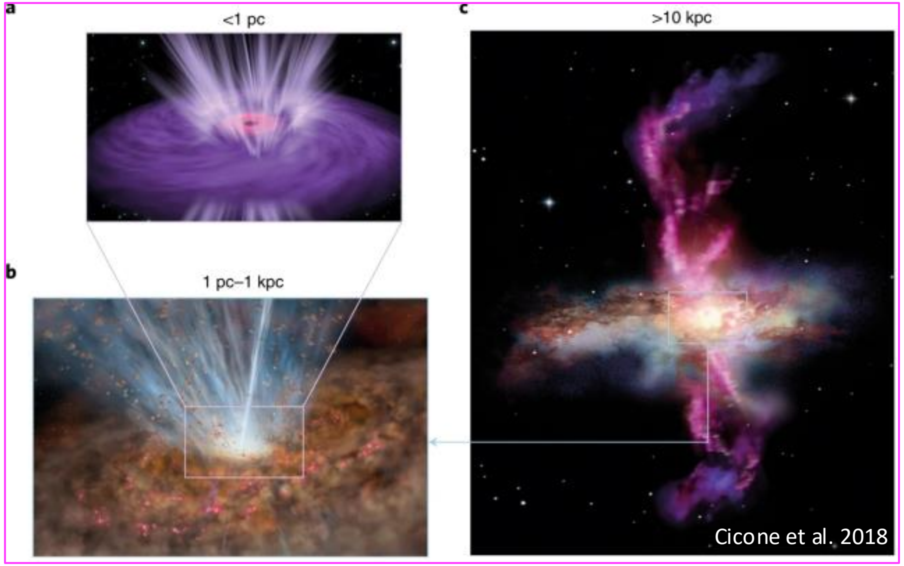
"IV GUAIX meeting", 17th Dec 2025

PID2022-138621NB-I00 and PID2021-123417OB-I00, funded by MCIN/AEI/10.13039/501100011033/FEDER, EU

Why AGN outflow are so important?

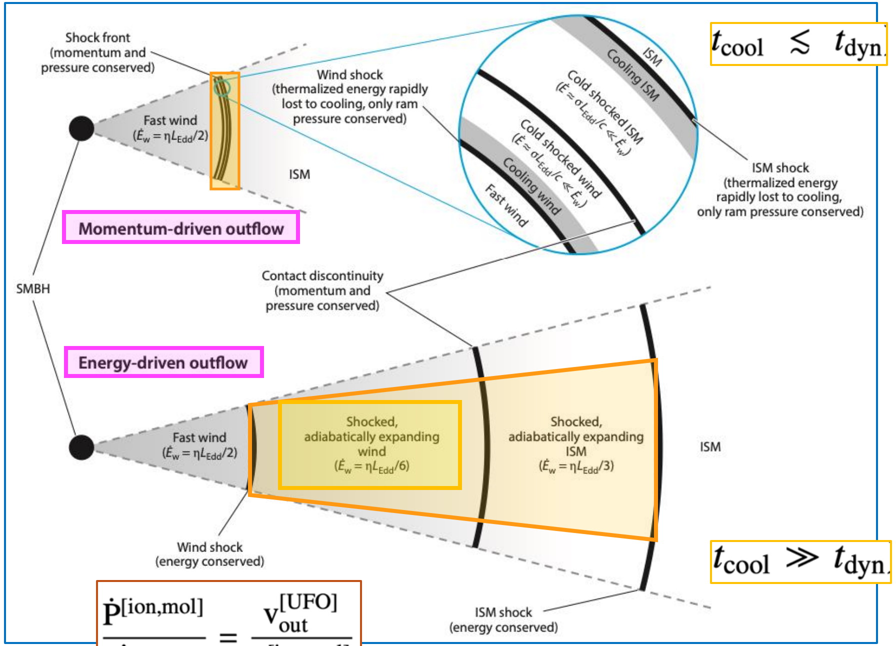
- M_{BH}-$\sigma_\star$ (Kormendy & Ho 2013): nuclear and galaxy scale relation (King et al. 2003) supported by theoretical models and hydrodinamical simulations of galaxy formation and evolution (e.g., Di Matteo et al. 2005, Hopkins & Elvis 2010)
  → **tight coupling** between the growth of the central BH & the bulge of its host Galaxy

- Outflows may provide the connection between BH and host galaxies required to reconcile theory & observations
  → they carry out mass and energy out to larger scales (Silk & Rees 1998; King 2003**)**



Transfer of X-ray wind energy to large scales

Zubovas & King 2012 (Faucher-Giguere+2012, King & Pounds 2015)



$$\frac{\dot{P}^{[ion,mol]}}{\dot{P}^{[UFO]}} = \frac{v_{out}^{[UFO]}}{v_{out}^{[ion,mol]}}$$

→ Momentum boost

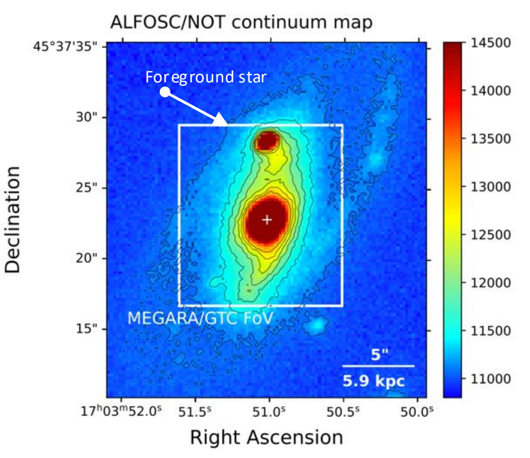
Multi-wavelength campaign is key to understand the effect of a powerful nuclear X-ray wind during its encounter through the ISM

Multi Espectrógrafo en GTC de Alta Resolución para Astronomía

Within the framework of the "MATRIOSKA" Project

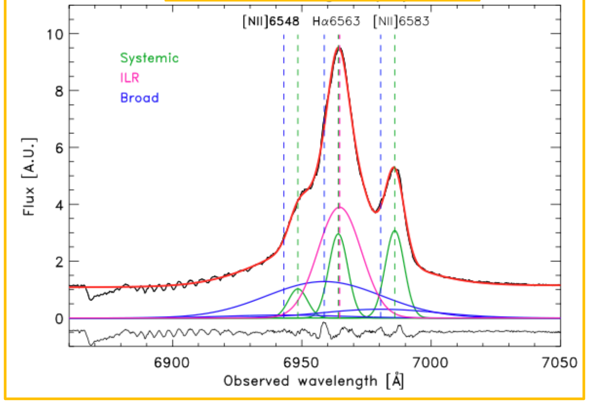
[Multiphase nAture of ulTra-fast outflows in naRrow lIne seyfert 1: the Optical Survey and Kinematic Analysis]

we present the analysis of *IRAS 17020+4544 using MEGARA/GTC*

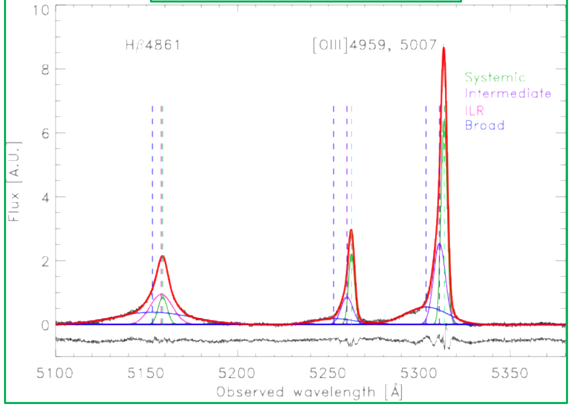


In this work we used MEGARA/GTC IFU to characterize the ionized gas phase in the optical band as traced by the Hα and [OIII] emission lines

Nuclear region (LR-R)



Nuclear region (MR-G)



Gil de Paz, A. et al. 2018
Carrasco et al. 2018
Castillo-Morales, A. et al. 2020

PI: Longinotti A.

Program (1)	Grism (2)	Spectral coverage [Å] (3)	R. L. D. [Å pix^{-1}] (4)	R (5)	Observing Date (6)	t_{exp} [s] (7)	Airmass (8)	Seeing [″] (9)	Atm. Conditions (10)
GTC8-20AMEX	LR-R (VPH675_LR)	6100-7300	0.32	6100	23 June 2020	3×1000	1.31	1.2	Clear
GTC8-20AMEX	MR-G (VPH521_MR)	4970-5445	0.13	12035	23 June 2020	3×1000	1.16	1.2	Clear
GTC1-24AMEX	LR-V (VPH570_LR)	5140-6170	0.27	6080	11 May 2024	6×1120	1.05	0.9	Clear

Deriving the parameters of the ionized outflow

Venturi et al. 2023

$$M_{out} = 6.1 \times 10^8 \left(\frac{L_{H\alpha}}{10^{44}\ \mathrm{erg\ \ s^{-1}}}\right)\left(\frac{500\ \mathrm{cm^{-3}}}{n_e}\right) M_\odot$$

Fiore et al. 2017
(Peralta de Arriba et al. 2023)

$$M_{out}^{[OIII]} = 8.0 \times 10^7 \left(\frac{L_{[OIII]}}{10^{44}\ \mathrm{erg\,s^{-1}}}\right)\left(\frac{500\ \mathrm{cm^{-3}}}{< n_e >}\right)\frac{\mathcal{CF}}{10^{[O/H]-[O/H]_\odot}} M_\odot$$

$$M_{tot}^{out} = 3 \times M_{out}^{[OIII]}$$

Rupke et al. 2005

$$v_{out} = v_{21} + FWHM_2/2 \sim v_{21} + 1.18\sigma_2$$

Lutz et al. 2020

$$\dot{M}_{out} = \frac{M_{out}\ \ v_{out}}{R_{out}}$$

$$E_{kin} = \frac{1}{2}\sigma_{out}^2 M_{out}$$

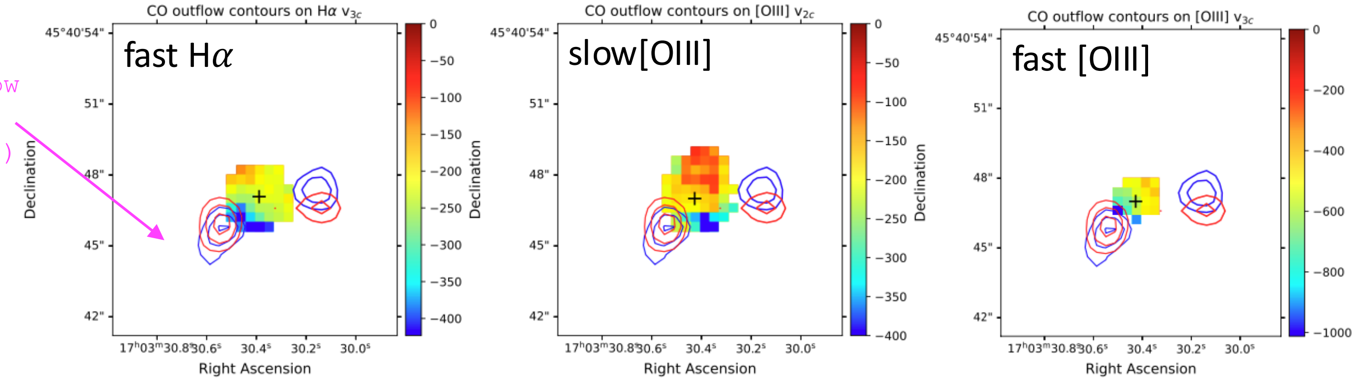
Rose et al. 2018

$$\dot{E}_{kin} = \frac{\dot{M}_{out}}{2}(v_{out}^2 + 3\sigma_{out}^2)$$

$$\dot{P} = \dot{M}_{out}\ v_{out}$$

Ionized ($H\alpha$ & [OIII]5007) outflows are *confined* within the molecular outflow

Molecular outflow
R_{CO}=2.8±0.3 kpc
(Longinotti+2023)



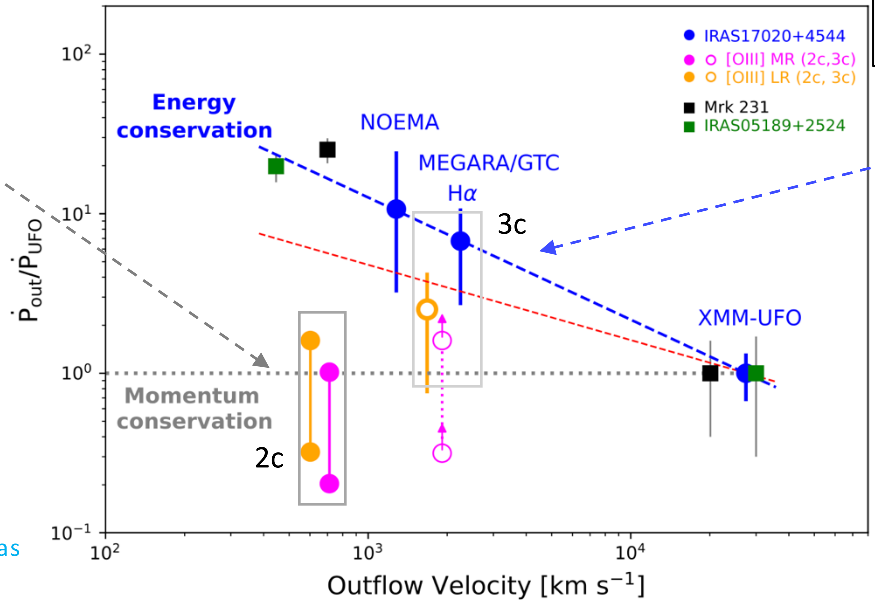
Confirming the "energy-conserving" regime in the optical phase

CO ← (Hα , [OIII]) ← UFO

(NLSy1)
(QSO)
(ULIRG)

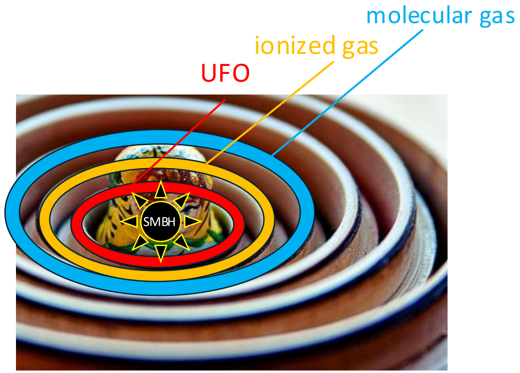
Slower [OIII] = 2c
→ **momentum-conserving**

≲1: likely driven by radiation pressure



Fast Hα and [OIII] = 3c
→ **energy-conserving**

≫1: an AGN-driven wind (via an adiabatic expansion) shocks the surrounding medium and transfers energy efficiently to the ISM, resulting in a momentum boost



Radial ("Matrioska") stratification in density, ionization, and velocity:

- ✓ Ionized (Hα & [OIII]5007) outflows are *confined* within the molecular outflow
  → *in situ* molecular formation? (see Richings et al. 2018 a,b)
- ✓ 2c = Slower [OIII], v_{out}~450 km/s → disk gas partially accelerated and compressed (i.e., entrained) by the AGN outflow (3c)
- ✓ 3c = Fast outflow, similar v_{out} ~1500 km/s (Hα and [OIII])

Conclusions and Future work

- ✓ Highly accreting NLSy1 galaxies provide excellent laboratories to study, trace, and potentially unravel the impact of a powerful nuclear X-ray (UFO) wind as it interacts with the surrounding ISM

- ✓ The ionized AGN-driven outflow, traced by Hα and [OIII] lines, follows the "energy-conserving" regime previously inferred for the molecular powerful outflow by NOEMA

- ✓ Using MEGARA/GTC we provide new (2D) spatial information on the distribution of the ionized outflow (i.e., confined within the molecular outflow) → finding a radial ("Matrioska") stratification in density, ionization, and velocity between the different phases ("*in situ*" molecular formation?)

- ✓ Studying a large number of NLSy1s (e.g., Ark 564…) hosting UFOs with MEGARA/GTC

- ✓ Exploring the *warm molecular gas phase in IRAS17* with EMIR/GTC (next: JWST follow-up !)