

How common are outflows in low-luminosity AGNs?

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NOT – a telescope for the future

09/06/2022

Credit photo: L. Hermosa Muñoz



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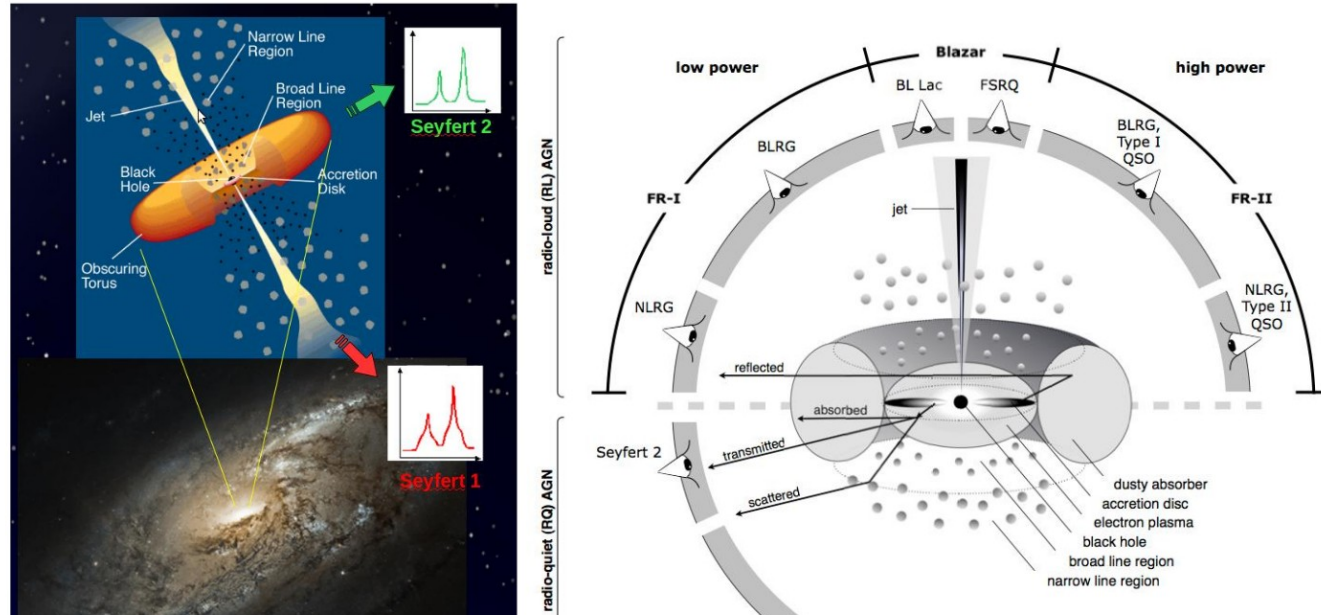


Active Galactic Nuclei (AGNs)

- Compact region around the supermassive black hole at the center of galaxies.
- Different characteristics depending on the line-of-sight and accretion rate.

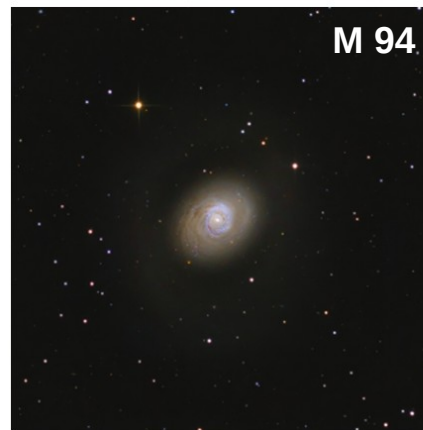
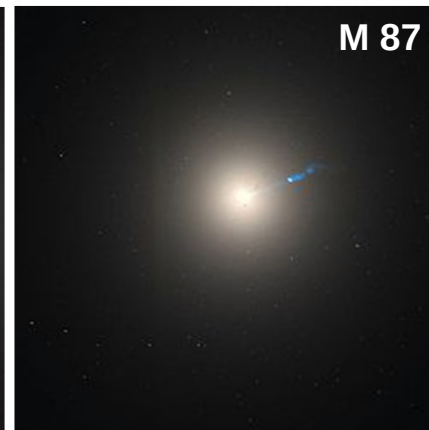
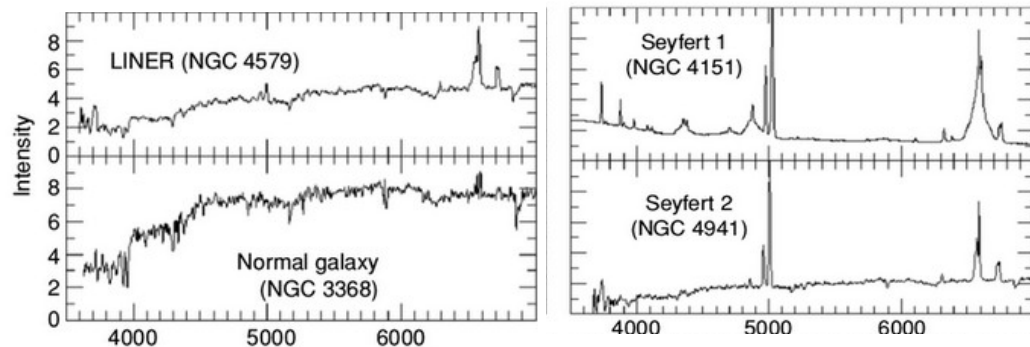
The Unified Model

1995, Meg Urry & Padovani.....2013, Marie-Luise Menzel



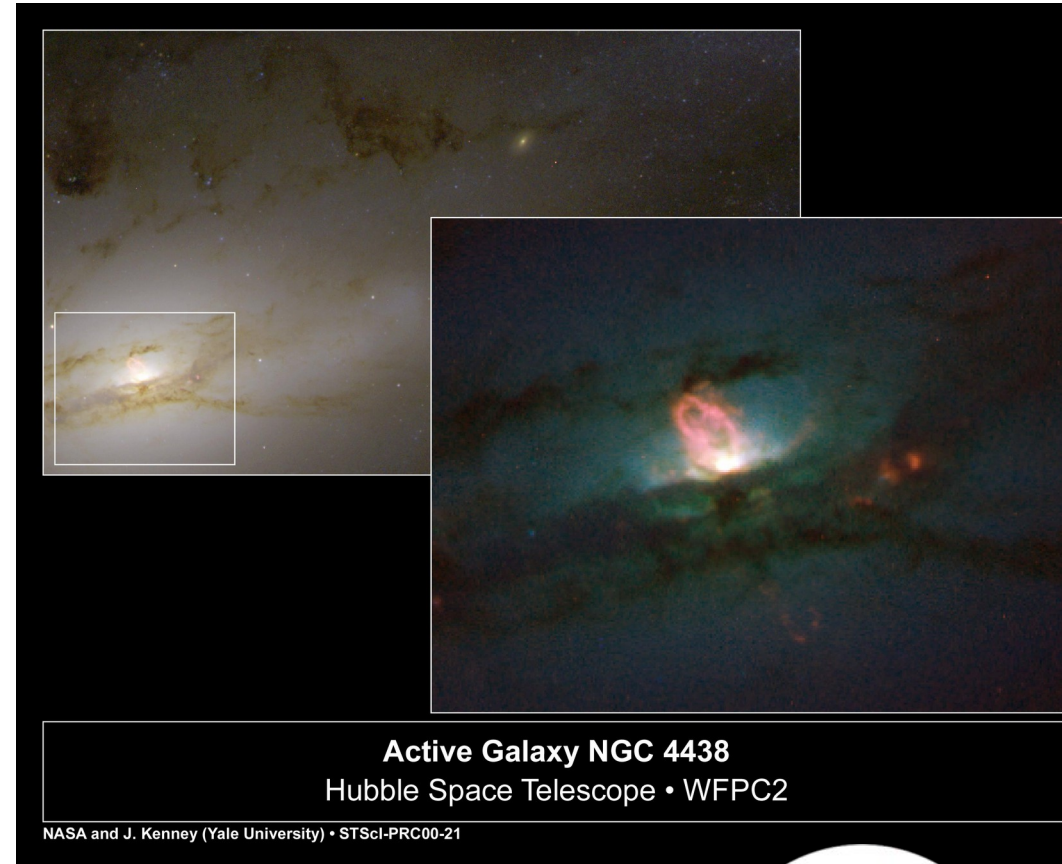
Low luminosity AGNs: **LINERs**

- Low-Ionisation Nuclear Emission-line Regions (**LINERs**) (*Heckman 1980*)
- Most numerous AGN population in the nearby Universe (*Ho et al. 1997*)



How common are **outflows** in LINERs?

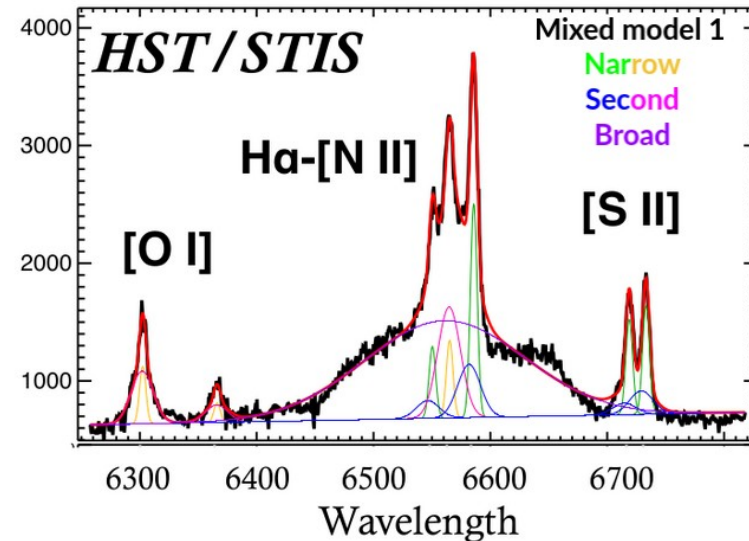
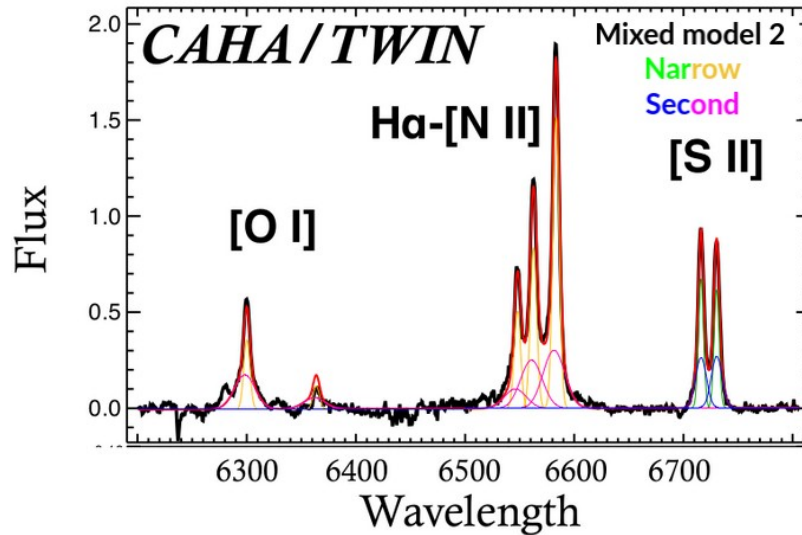
- Suggested to be **ubiquitous** within the AGN population (*e.g. Veilleux et al. 2005*)
- Expected to be less powerful than in high-luminosity AGNs (*e.g. Fluetsch et al. 2019*)
- No systematic studies except for *Cazzoli+2018* and *Hermosa Muñoz+2020*
- Mainly **individual** discoveries



How common are **outflows** in LINERs?

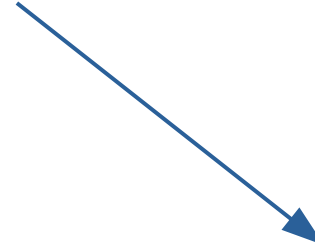
22 type-1 LINERs (*Cazzoli et al. 2018*) and 9 type-2 LINERs (*Hermosa Muñoz et al. 2020*)

- Several kinematical components
- Signatures of outflows in the emission lines for **11/31** targets



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Outflows in LINERs: what now?



Spectroscopic data: long-slit



Cazzoli et al. (2018)
Hermosa Muñoz et al. (2020)

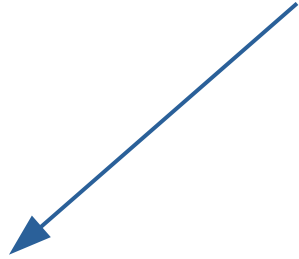
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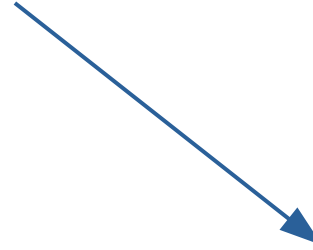


Outflows in LINERs: what now?



Imaging data

Masegosa et al. (2011)
Hermosa Muñoz et al. (2022)



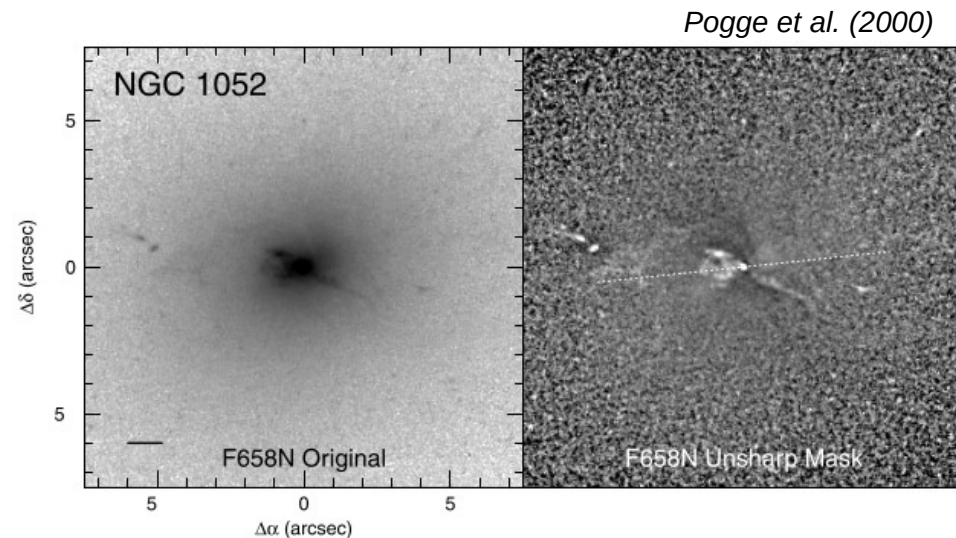
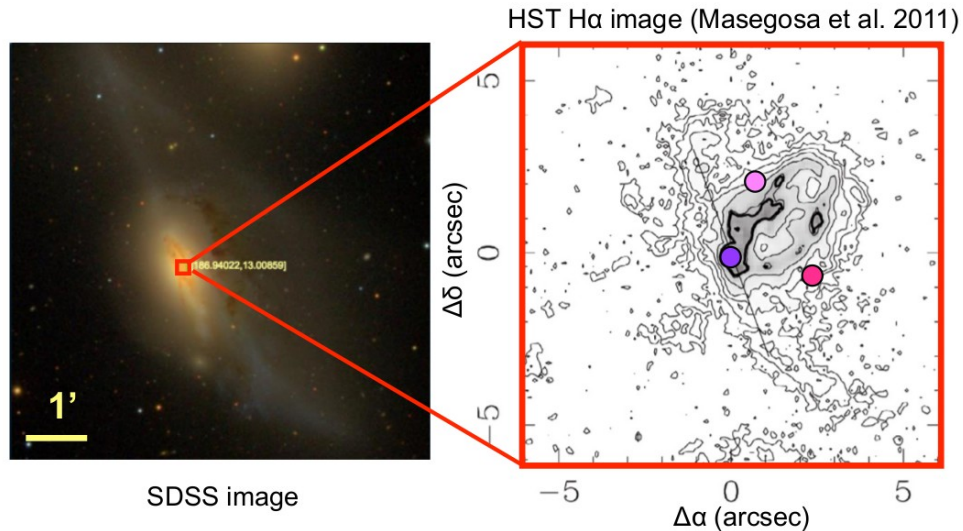
Spectroscopic data: long-slit

Cazzoli et al. (2018)
Hermosa Muñoz et al. (2020)



Morphological signatures of outflows

Outflows may be detected (or glimpsed) with imaging techniques, even when the activity of the host galaxy is low (*Masegosa et al. 2011, Pogge et al. 2000*).

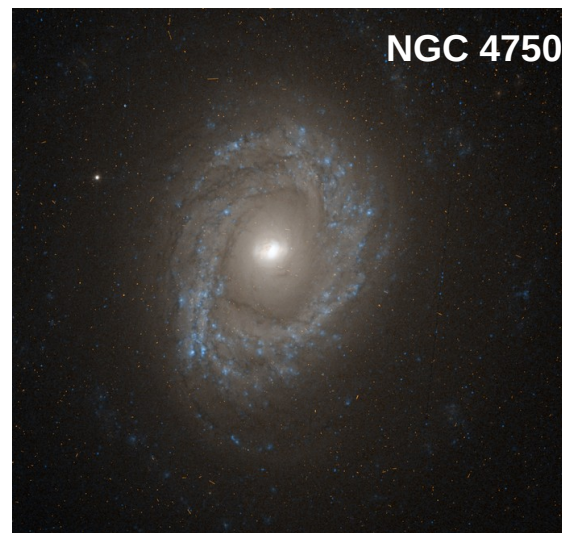


Morphological signatures of outflows

Hermosa Muñoz et al. (2022)

ALFOSC/NOT and HST imaging data of the H α ionised gas for **70 nearby** ($z < 0.025$) **LINERs**.
(34 from Masegosa et al. 2011, Pogge et al. 2000)

We aimed to perform a systematic search of outflows in the largest atlas of ionised gas morphologies.



Credits: (NGC 3628) Paul Gardner, Great Basin Observatory / (NGC 2685) SDSS / (NGC 4750) NASA-ESA / (NGC 4457) SDSS

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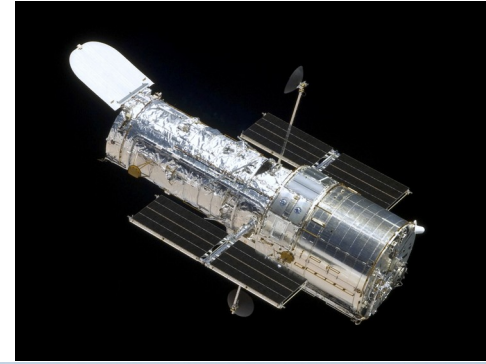


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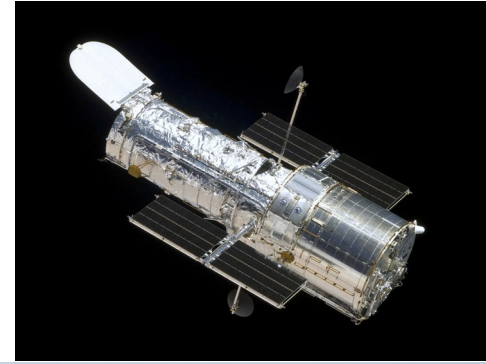
Data gathering

- Archival **HST** data for 34 (*Masegosa et al. 2011*) + 6 galaxies (H α)
- Observed data with **ALFOSC/NOT** for 32 galaxies (H α)



Data gathering

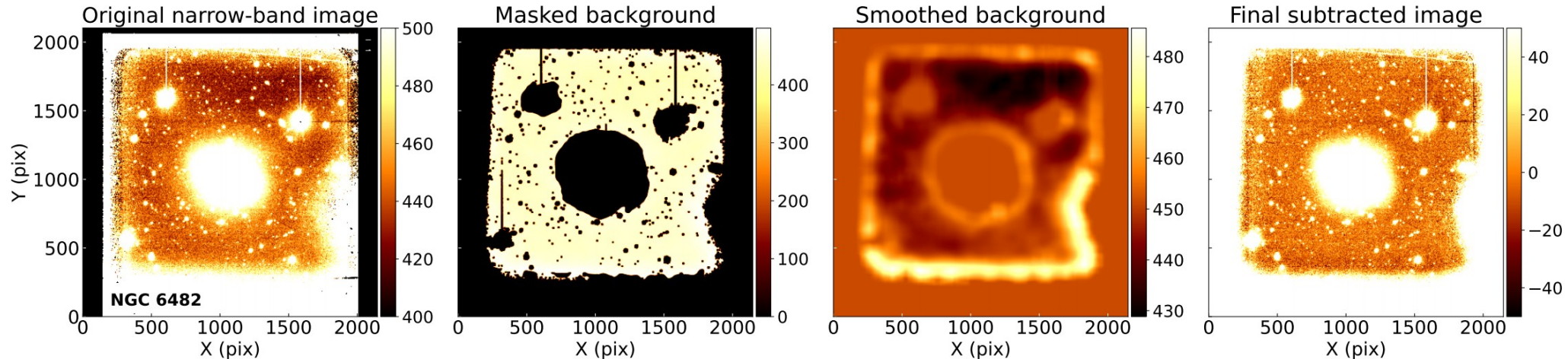
- Archival **HST** data for 34 (*Masegosa et al. 2011*) + 6 galaxies (H α)
- Observed data with **ALFOSC/NOT** for 32 galaxies (H α)
- Archival **Chandra** data for 28 objects (X-rays) complemented with *Masegosa et al. (2011)*



Data reduction process

We performed a **dedicated background subtraction** of the ALFOSC images.

Eliminate possible additional structures in the background that could affect the morphologies.



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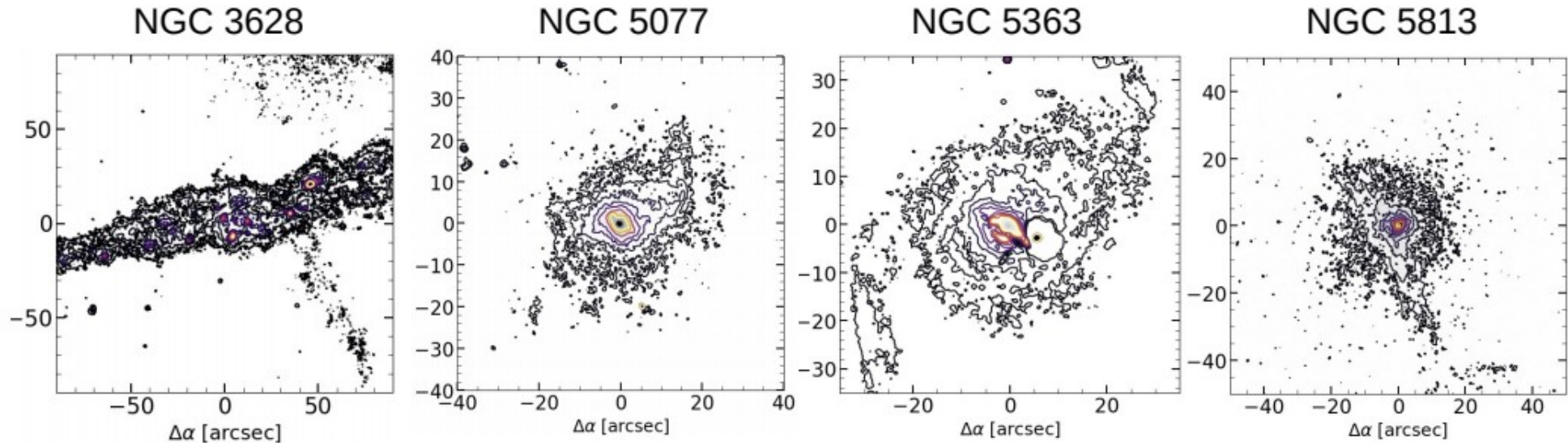


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Data reduction process

We subtracted the BF image from the NF image, to obtain exclusively the H α emission.



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Morphological categories

Morphological categories for the ionised gas emission of the galaxies defined by *Masegosa et al. (2011)*

1. CORE-HALO

Unresolved nuclear structure surrounded by diffuse emission.

2. DISK-HALO

Face-on structures with H α emission in the spiral arms, with rings or diffuse emission in the disc.

3. BUBBLE

Nuclear outflows seen as biconical or bubble-like structures or filamentary extensions.

4. DUSTY

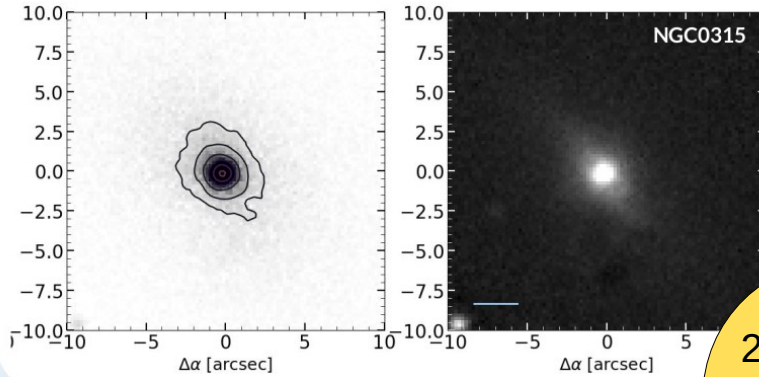
Clear dust layers obscuring the H α structure in the inner regions.

5. UNCLEAR

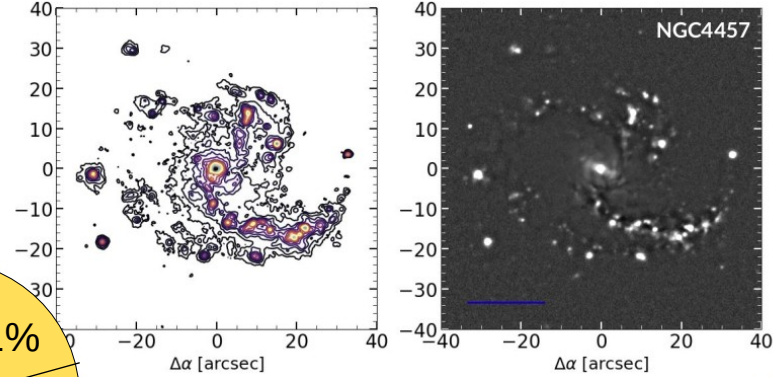
Non-clear morphological structure, that could be associated to several of the other classes

H α morphologies: results & examples

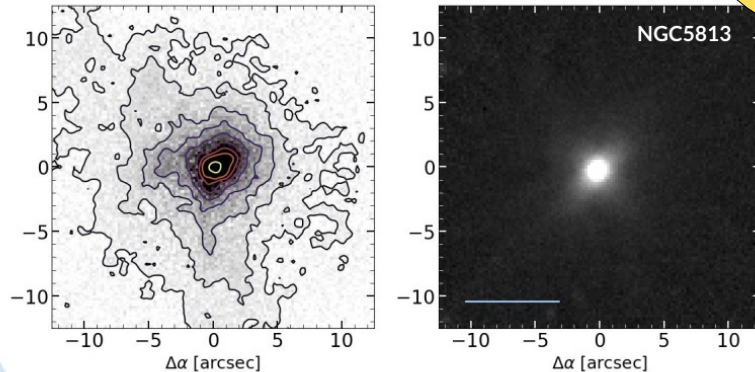
CORE-HALO EXAMPLE



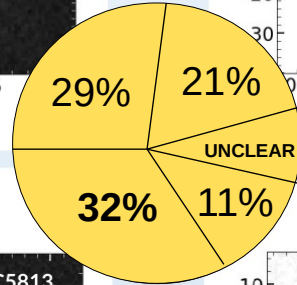
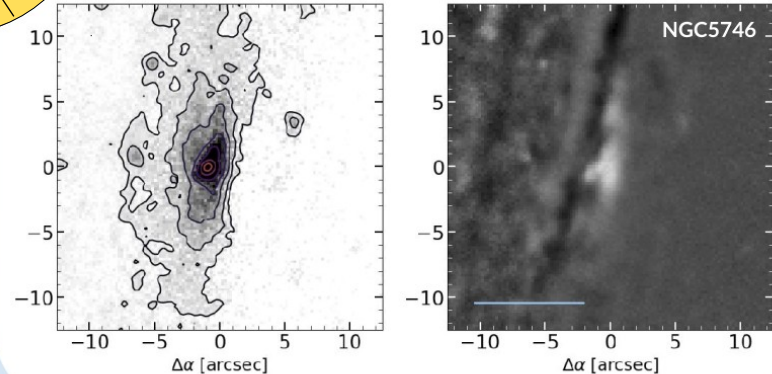
DISK-HALO EXAMPLE



BUBBLE-LIKE EXAMPLE

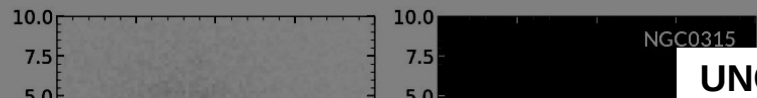


DUSTY EXAMPLE

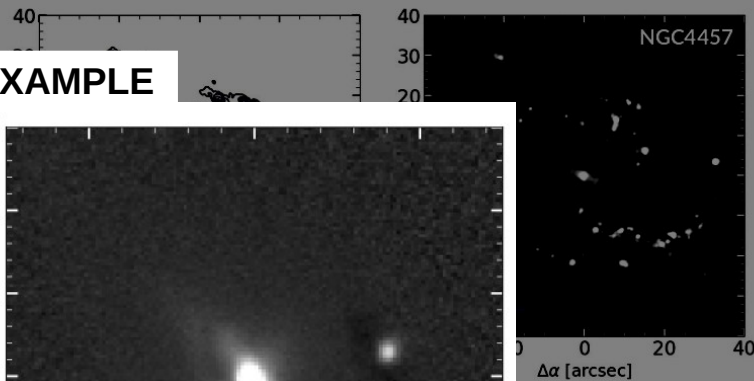


H α morphologies: results & examples

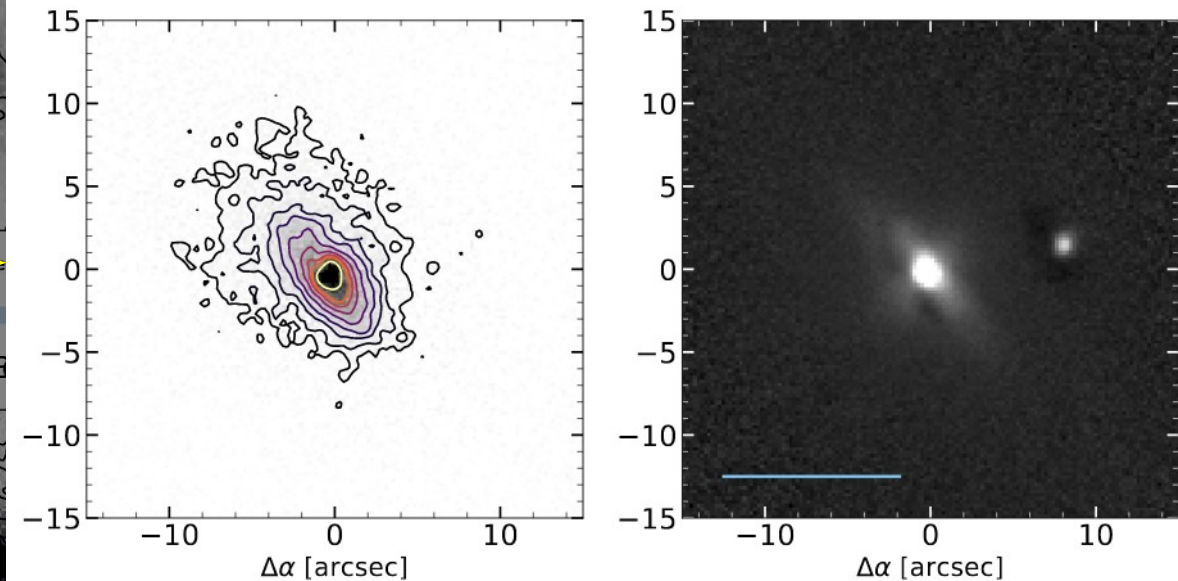
CORE-HALO EXAMPLE



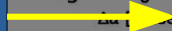
DISK-HALO EXAMPLE



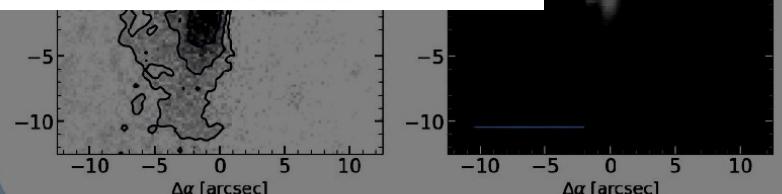
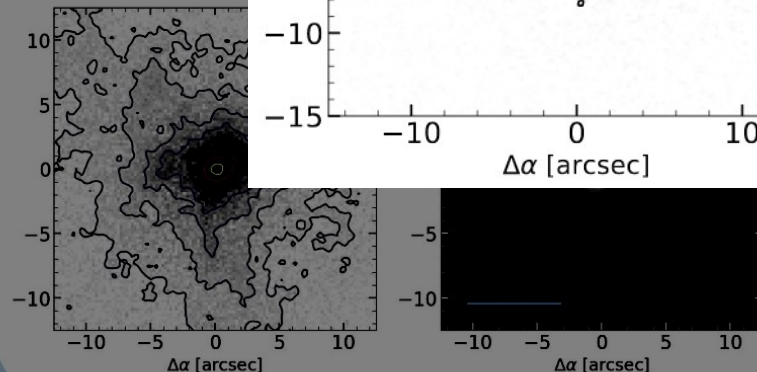
UNCLEAR EXAMPLE



Disky?
Bubble?

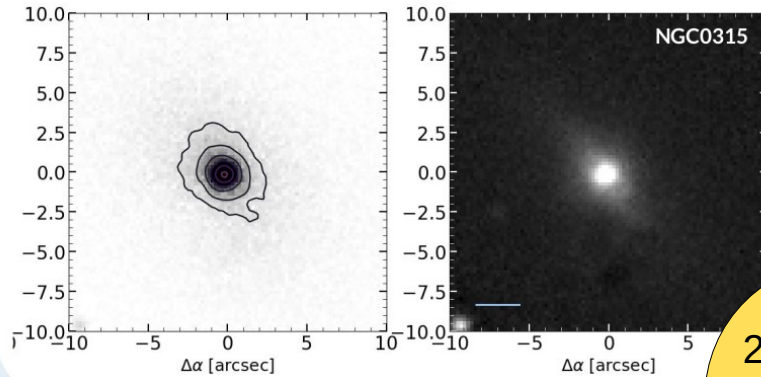


BUB

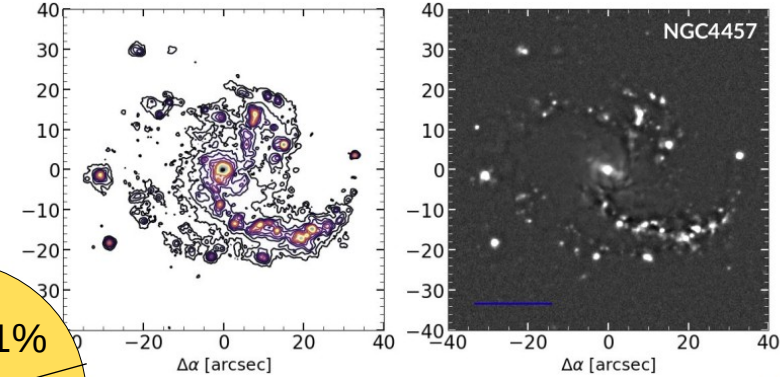


H α morphologies: results & examples

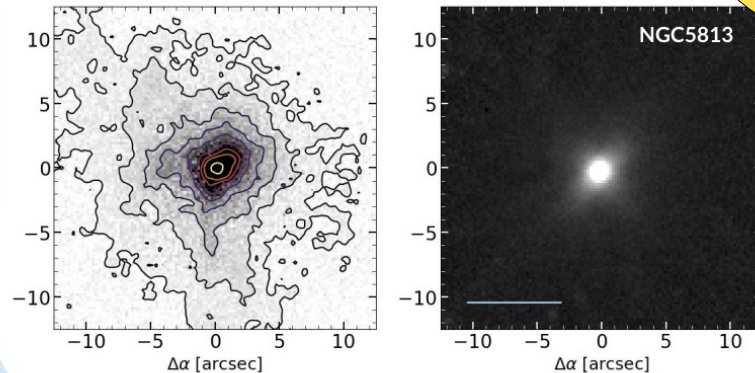
CORE-HALO EXAMPLE



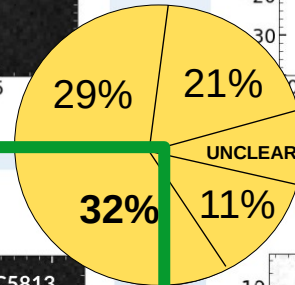
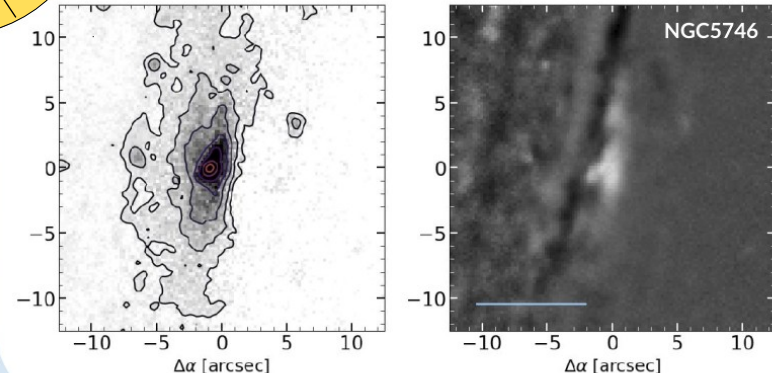
DISK-HALO EXAMPLE



BUBBLE-LIKE EXAMPLE



DUSTY EXAMPLE



Is there kinematic information for them?

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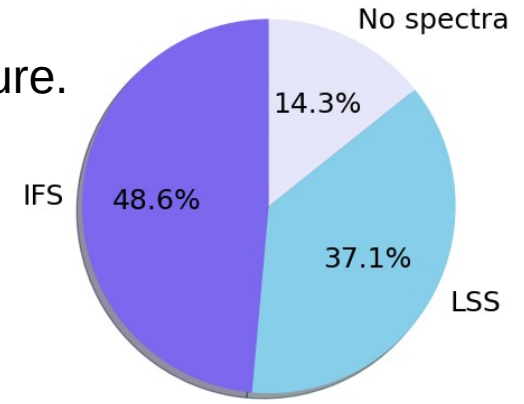
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Is there kinematic information for them?

60 out of 70 (86%) LINERs have kinematic information in the literature.

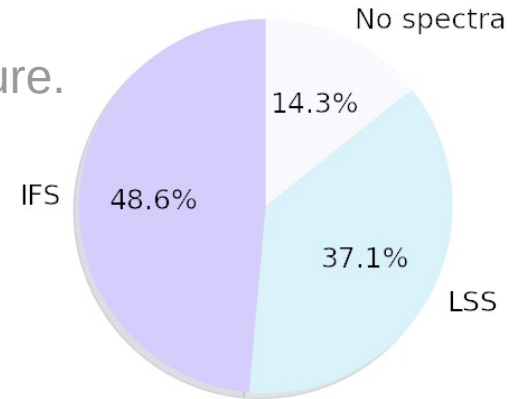
- 34 from IFS
- 26 from LSS (mainly *Cazzoli et al. 2018* & *Hermosa Muñoz et al. 2020*)



Is there kinematic information for them?

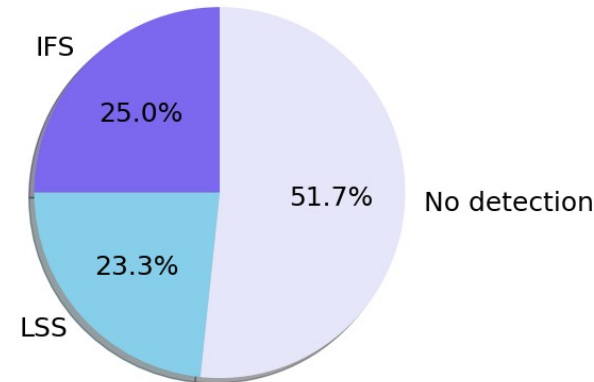
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29 out of 60 (48%) have a detection of an **outflow**/inflow in any of its phases (*molecular, neutral or ionised gas*)

- 15 from IFS (6 Bubble-like morphologies)
- 14 from LSS (4 Bubble-like morphologies)



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Is there kinematic information for them?

60 out of 70 (86%) LINERs have kinematic information in the literature.

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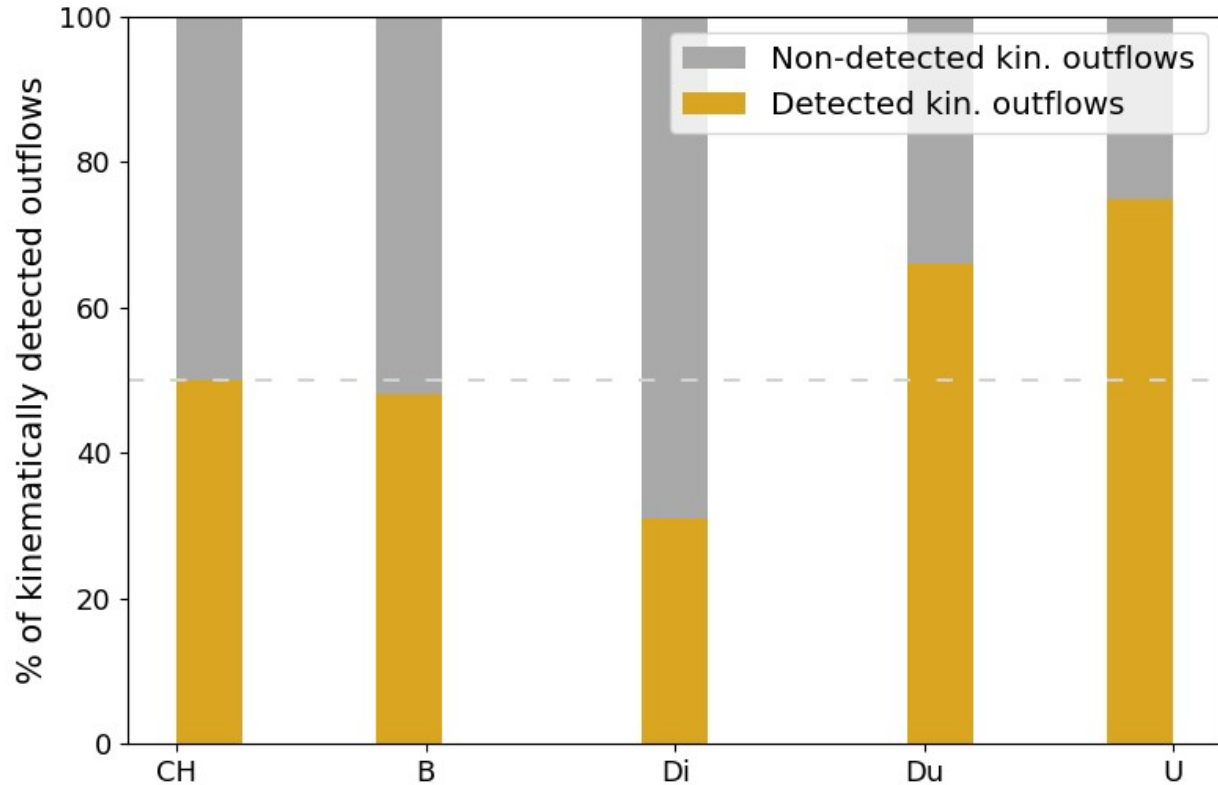
1 out of 2 LINERs in the nearby Universe

Kinematic vs imaging comparison

Core-halo
50% (8/16)

Bubble-like
48% (10/21)

Disky
31% (4/13)



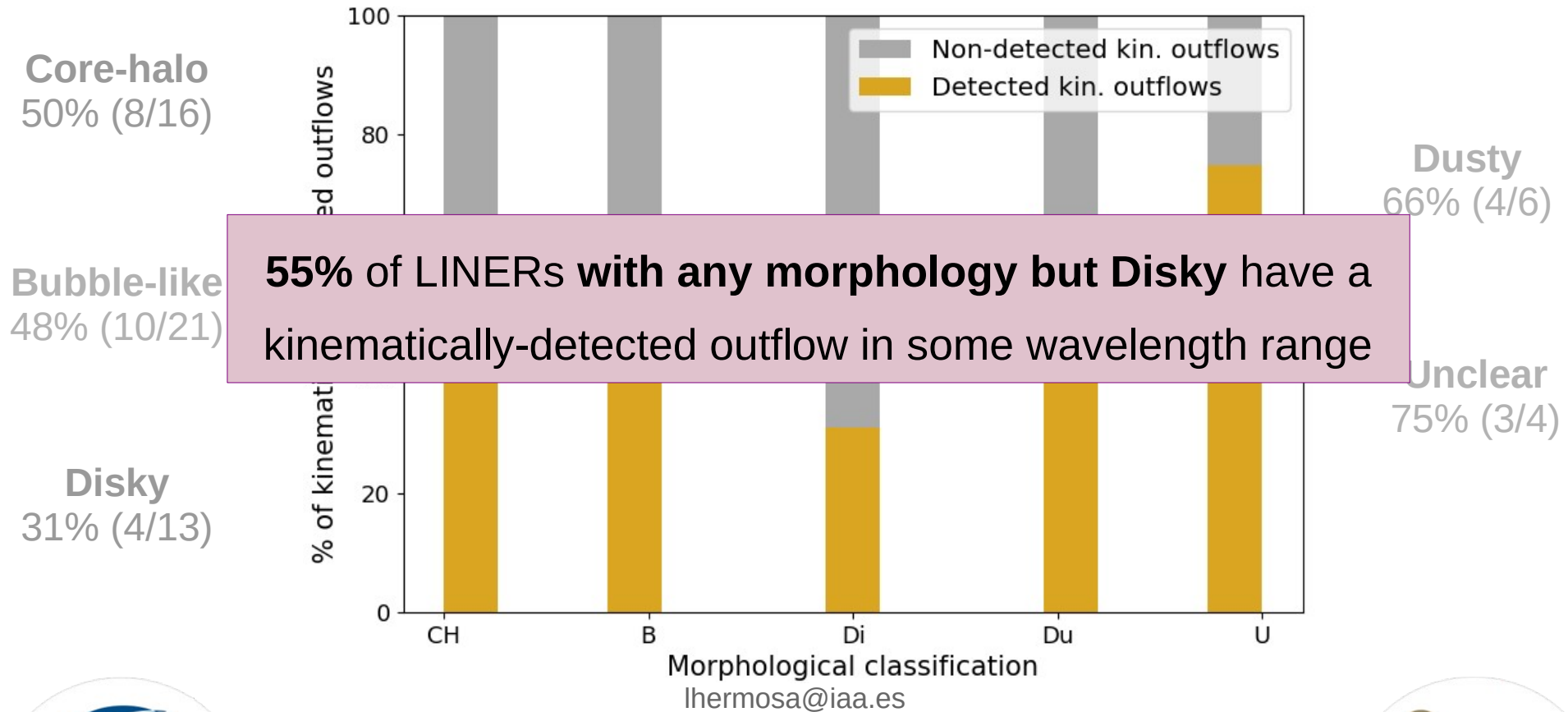
Dusty
66% (4/6)

Unclear
75% (3/4)

Morphological classification

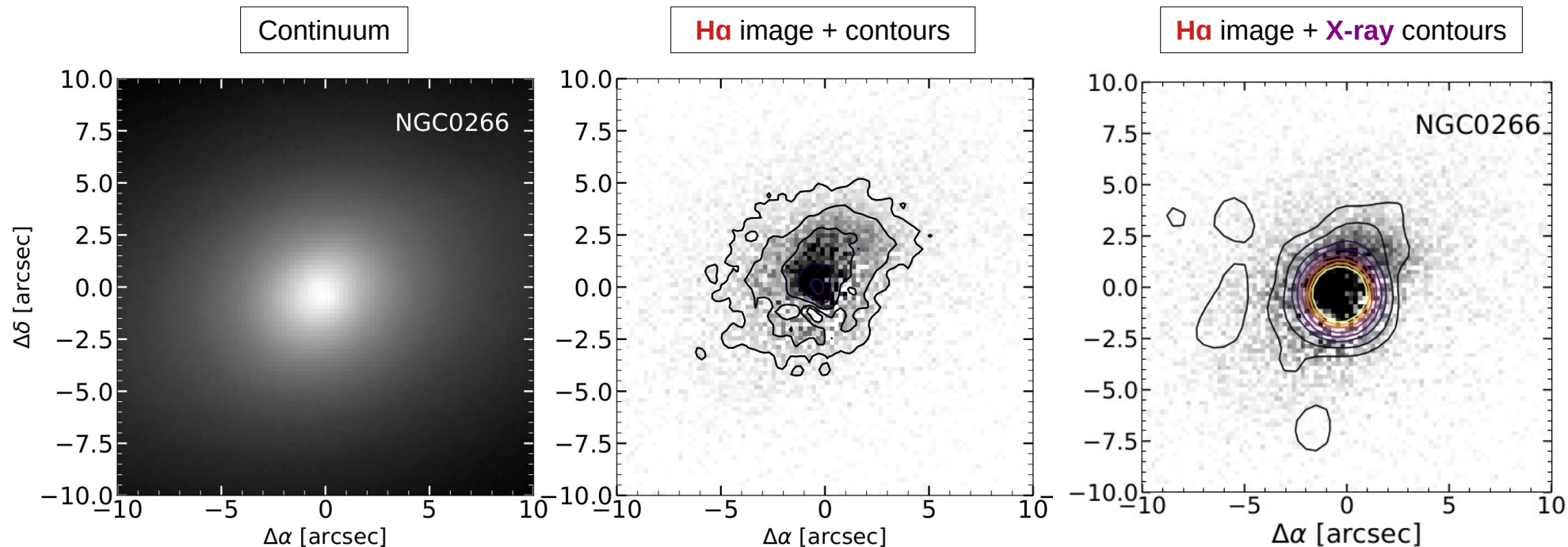
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Kinematic vs imaging comparison



H α vs X-ray emission

Ionised gas and soft X-ray emission from Seyfert galaxies have been proposed to be raised in the same region of the AGN, within the narrow line region (*Bianchi et al. 2000*).



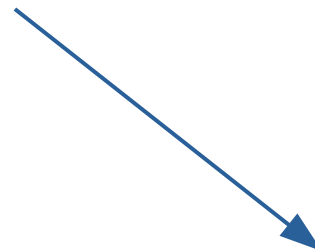
60% of coincidence between both emissions

Outflows in Low luminosity AGNs



Imaging data

Masegosa et al. (2011)
Hermosa Muñoz et al. (2022)

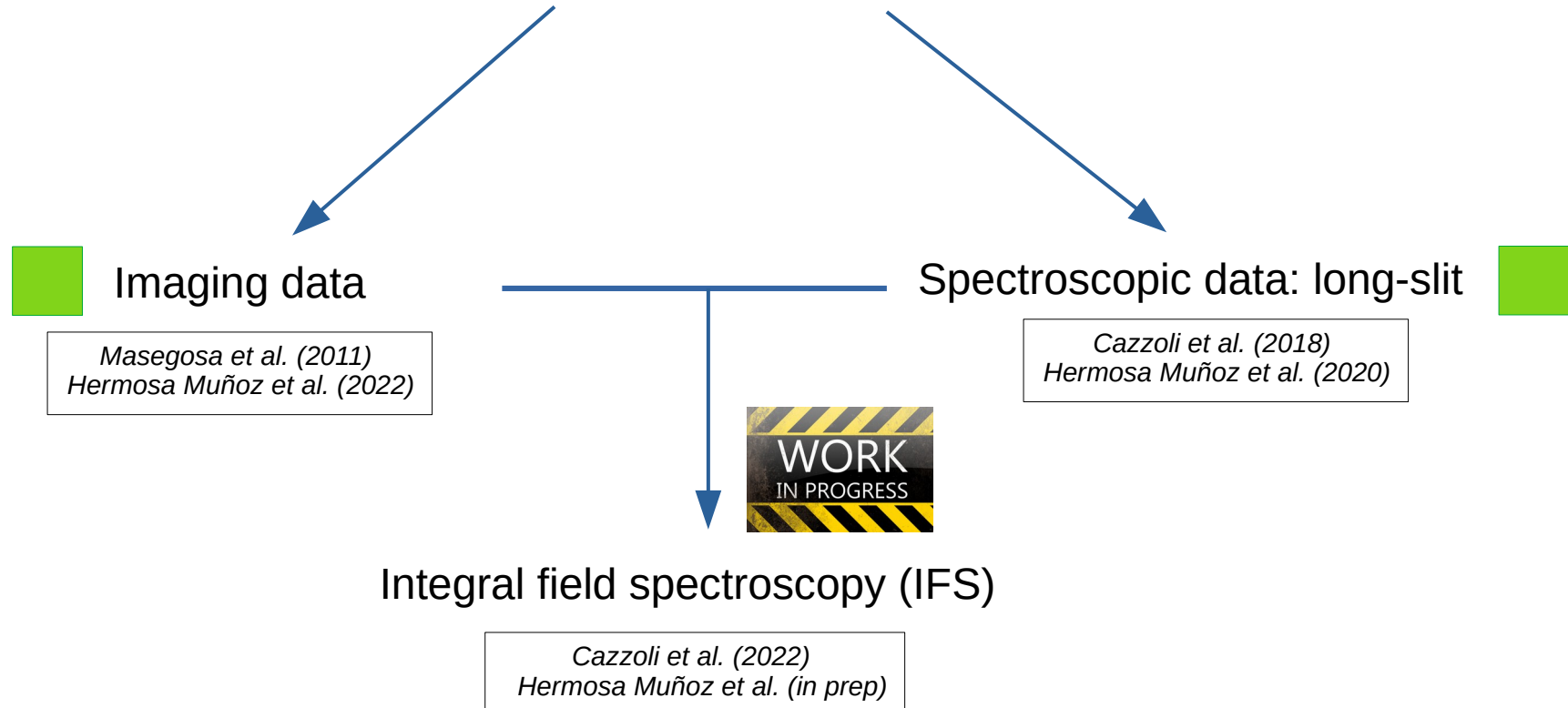


Spectroscopic data: long-slit

Cazzoli et al. (2018)
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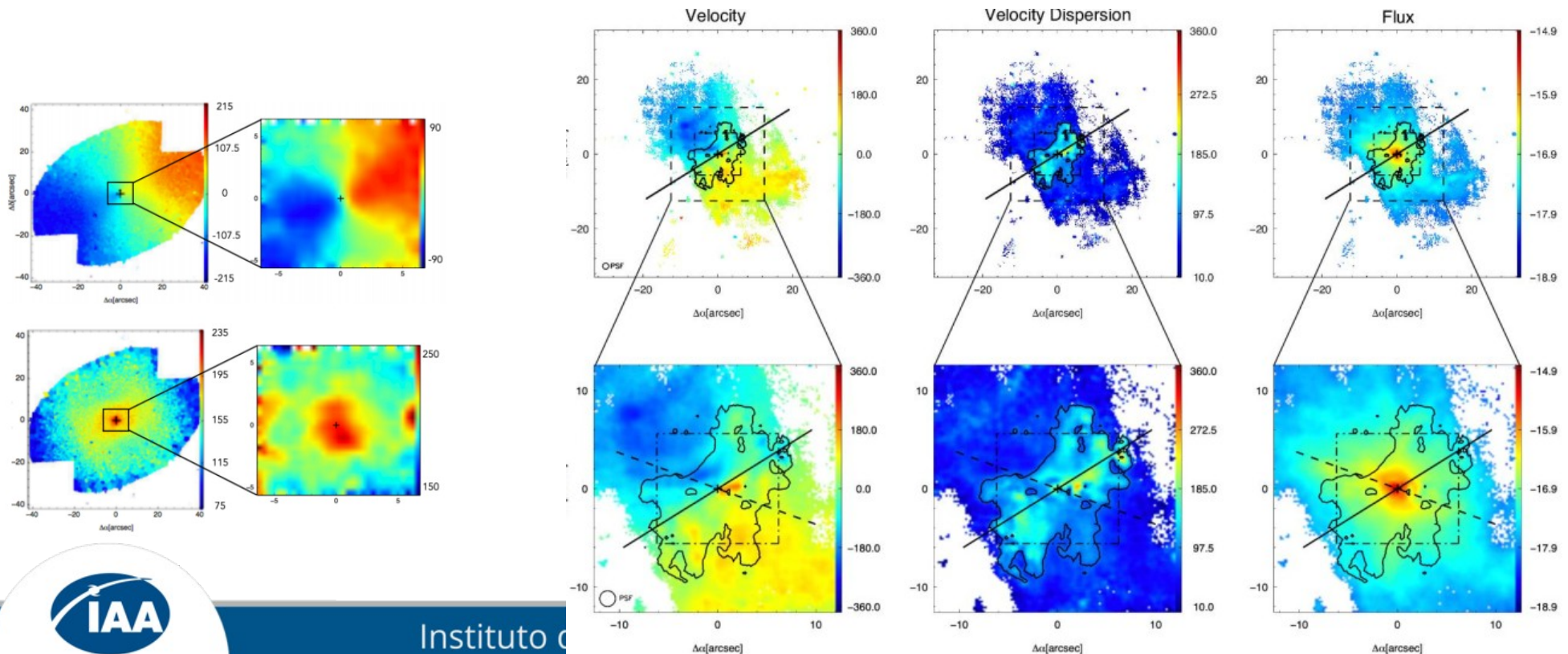
Outflows in Low luminosity AGNs



Future prospects

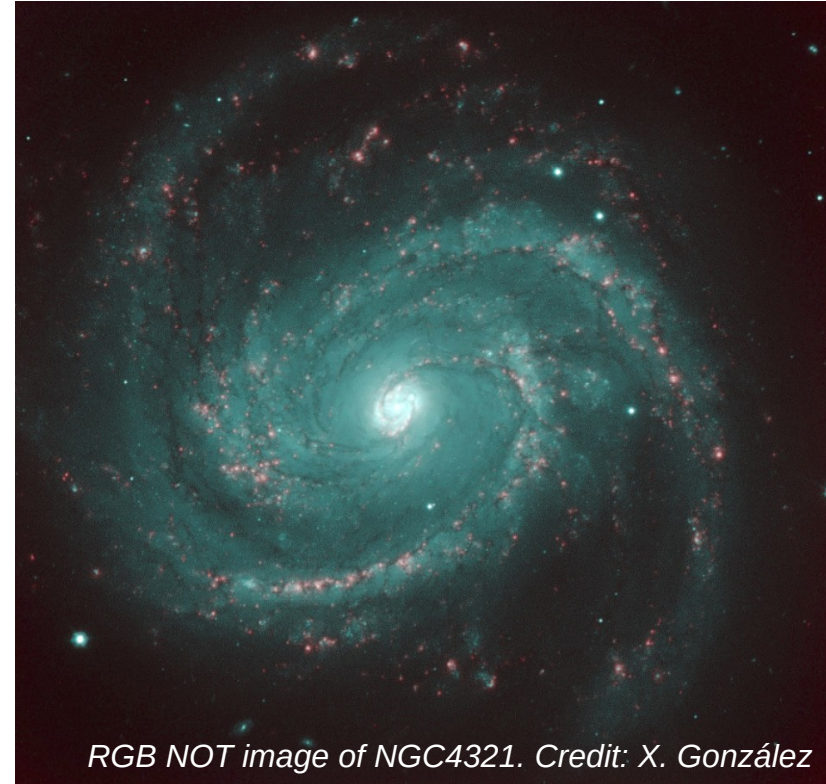
We have gathered MEGARA/GTC IFS data for the most promising outflow candidates (11)

→ the case of NGC1052 (*Cazzoli et al. 2022*)



Conclusions

- **48%** of LINERs in the nearby Universe ($z < 0.025$) **have** kinematic signatures of **outflows/inflows**.
- There is a probability of 55% to find an outflow in a LINER with any ionised gas morphology except Disky-like.
- The **soft X-ray emission follows that from the ionised gas** in the majority ($\sim 60\%$) of the objects, but is not associated to kinematically-identified outflows.
- We would benefit of IFS data for all targets to confirm our results.



RGB NOT image of NGC4321. Credit: X. González

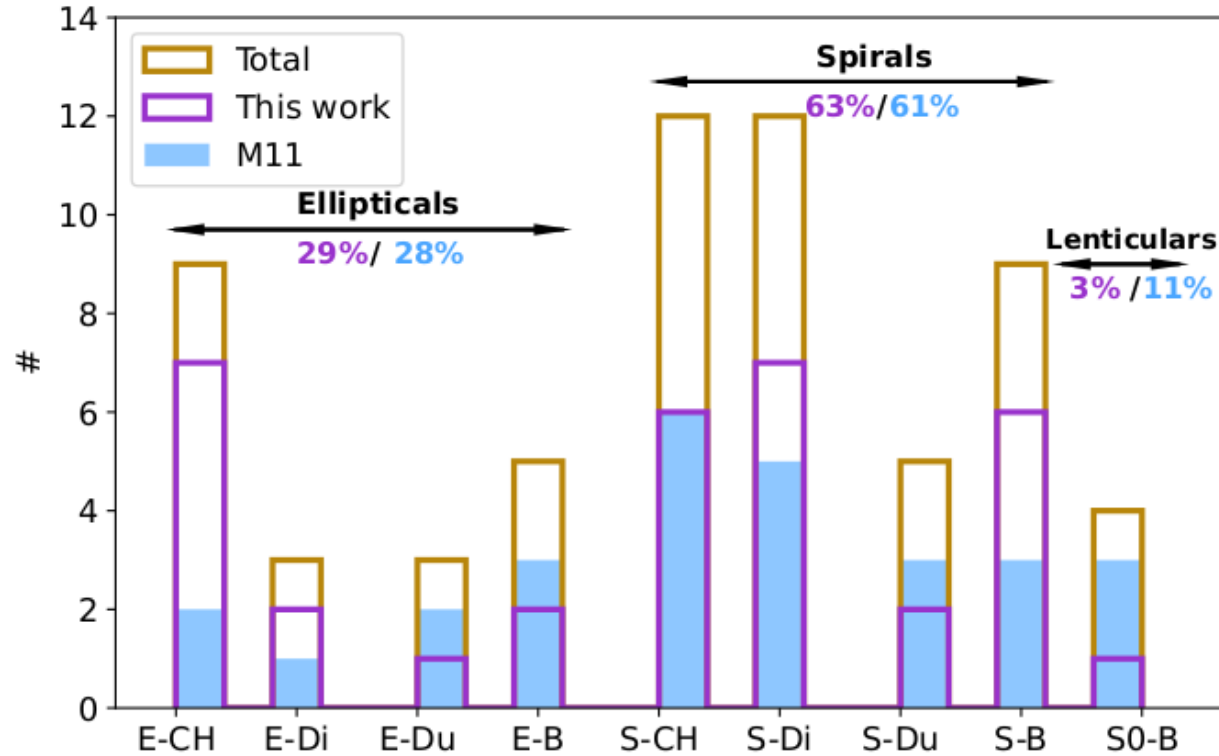
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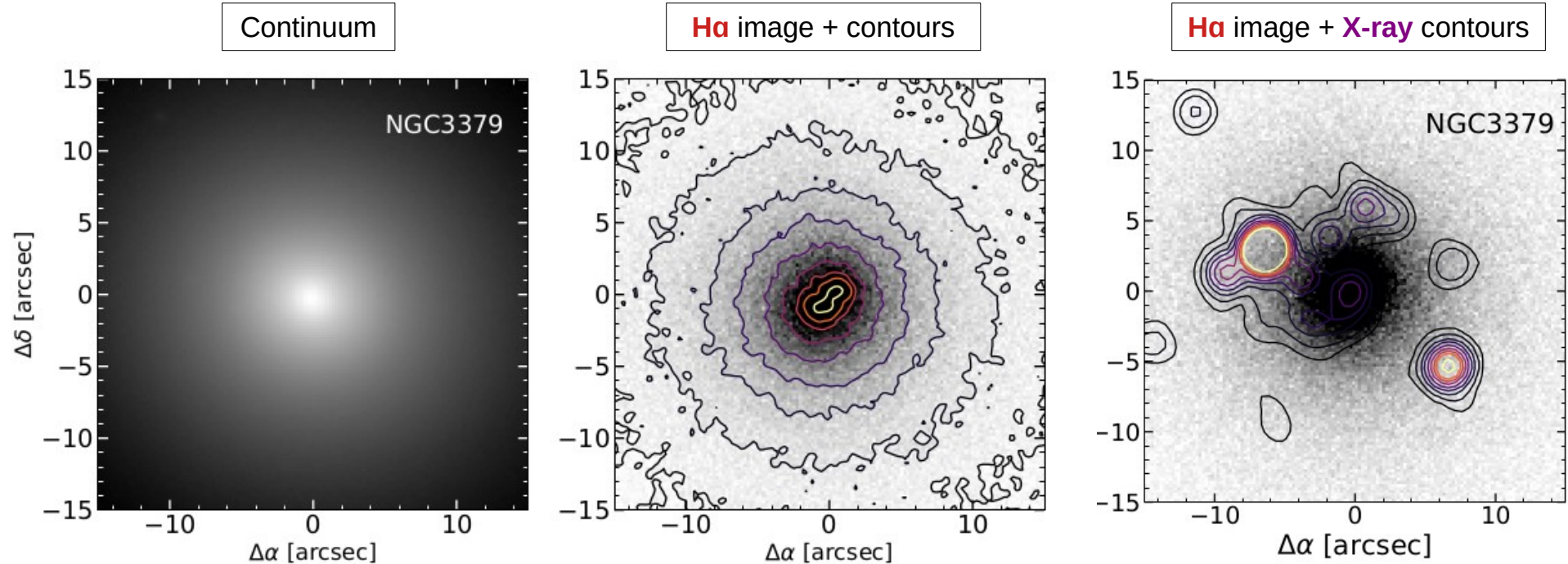


Gas morphology vs host morphological type



H α vs X-ray emission

Ionised gas and soft X-ray emission from Seyfert galaxies have been proposed to be raised in the same region of the AGN, within the narrow line region (*Bianchi et al. 2000*).



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H α vs X-ray emission

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60% of coincidence between both emissions

Not apparent correlation between X-ray emission and (kinematic) outflows within our sample → 23%

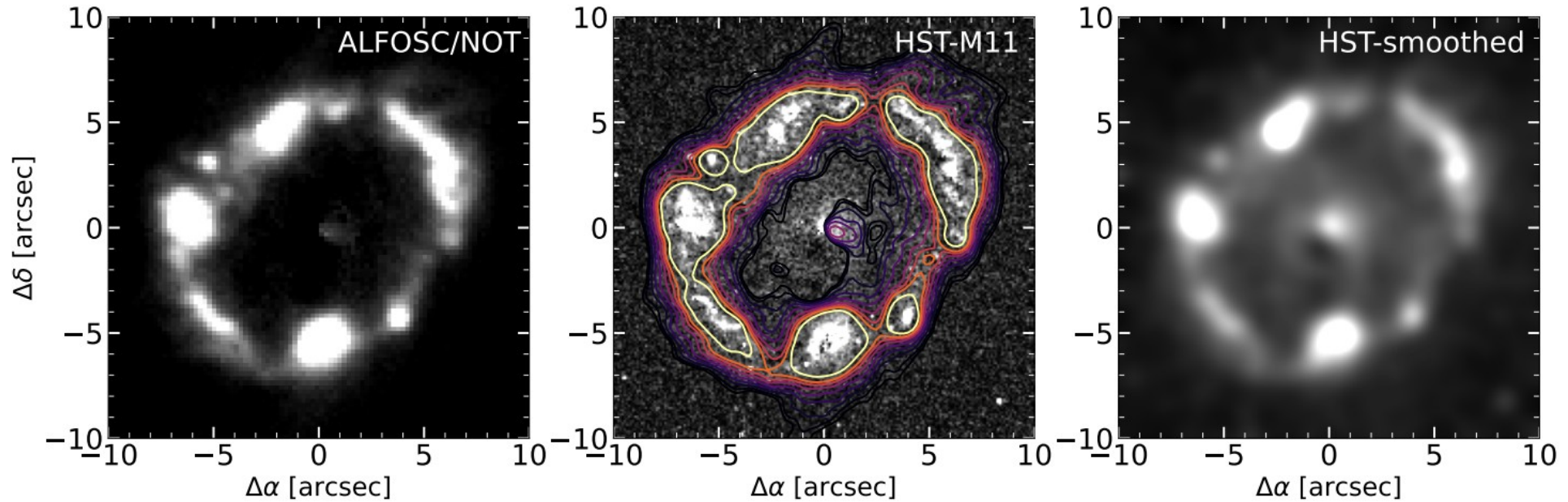
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Different spatial resolutions HST/NOT



Different spatial resolutions HST/NOT

