Galaxy Evolution & Environment (GEE5)

Nov 16, 2017 - Arcetri

Ionized gas outflows and star formation in active galactic nuclei: a detailed study from the MAGNUM survey

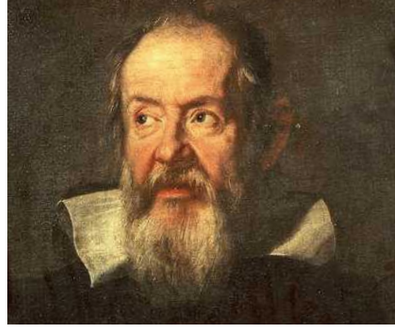
Giacomo Venturi

PhD student @ UniFi/INAF-Arcetri

A. Marconi (P.I.), M. Mingozzi, G. Cresci,

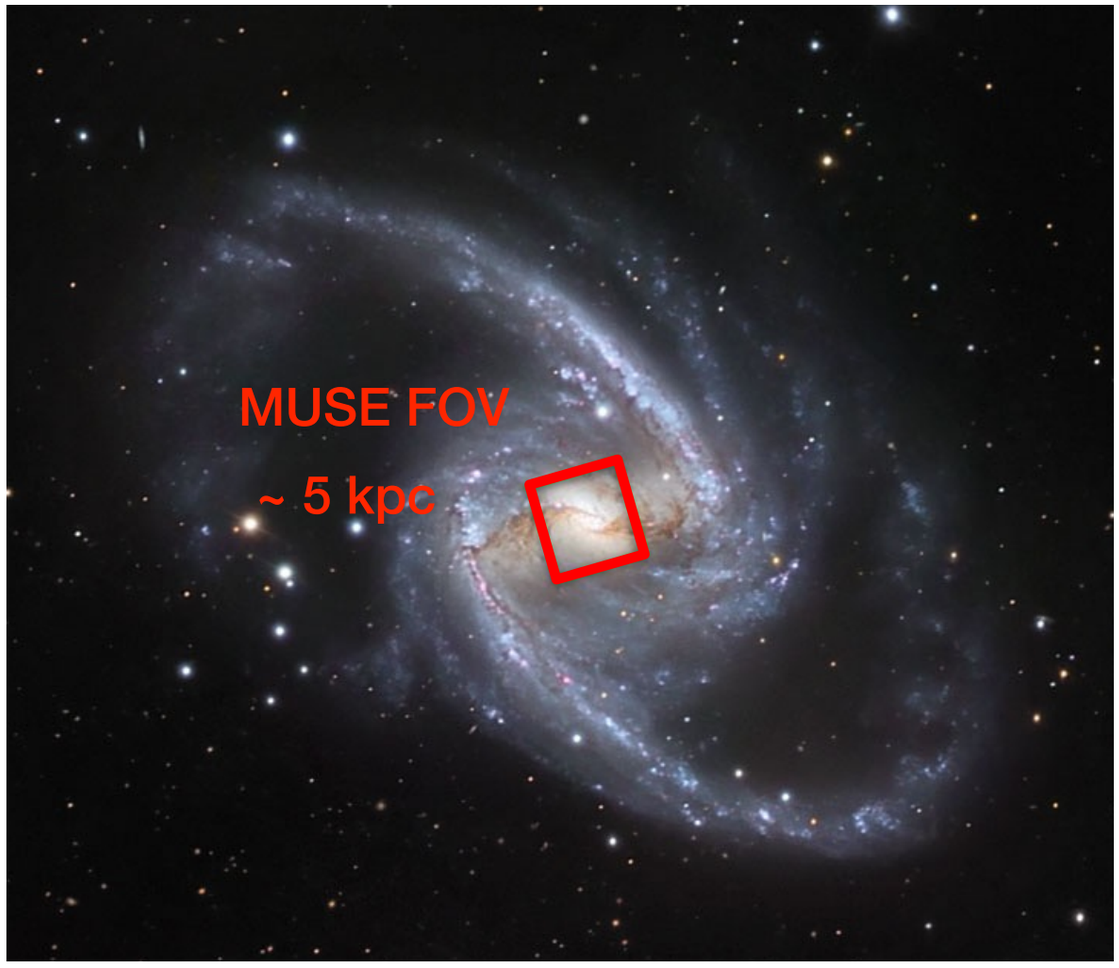
G. Risaliti, S. Carniani, E. Nardini, F. Mannucci

MAGNUM survey



- Introduced by M. Mingozzi
- M. Mingozzi —> resolved gas ionization
- G. Venturi —> resolved ionized gas outflows
  - NGC 1365: MUSE (optical) vs Chandra (X-rays)
  - Outflow structure
  - Outflows vs radio jets

NGC 1365: the Great Barred Galaxy



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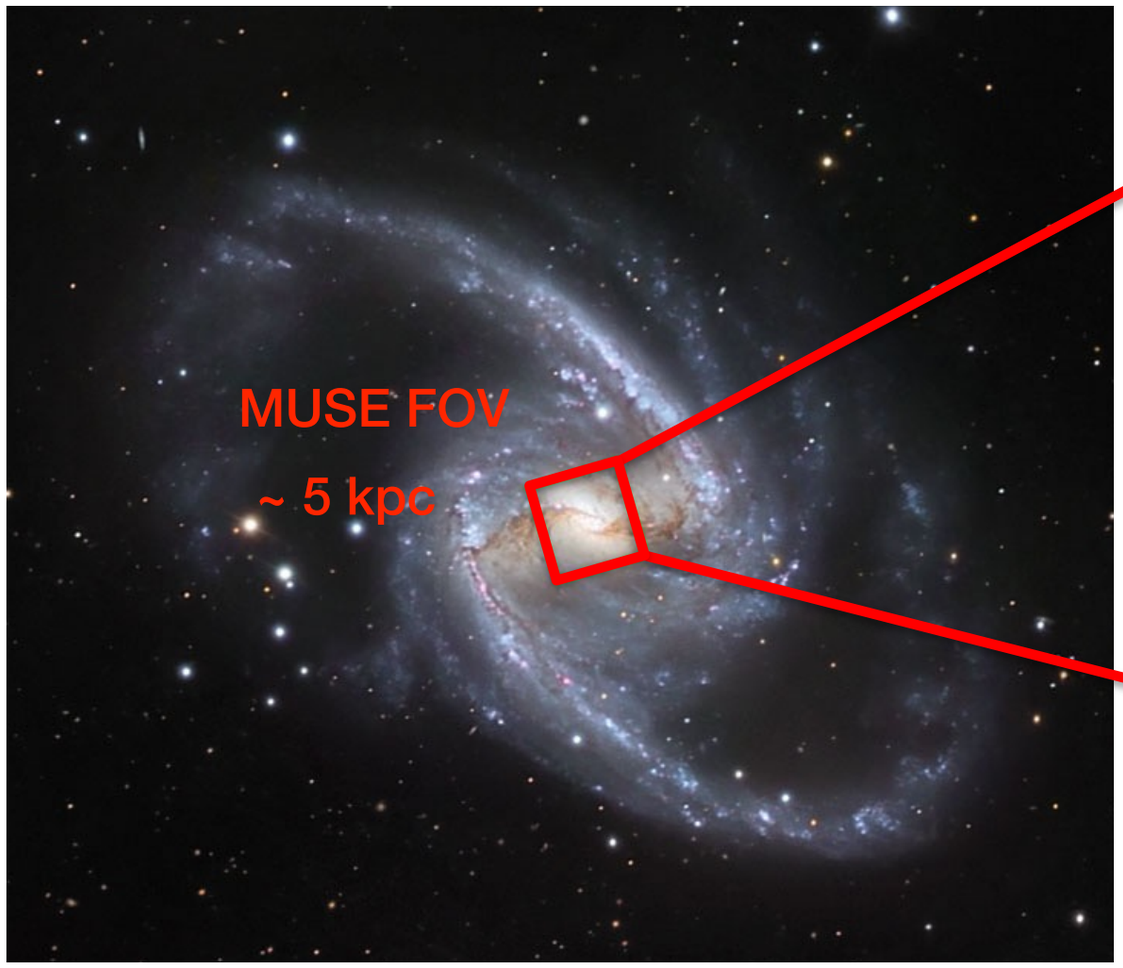

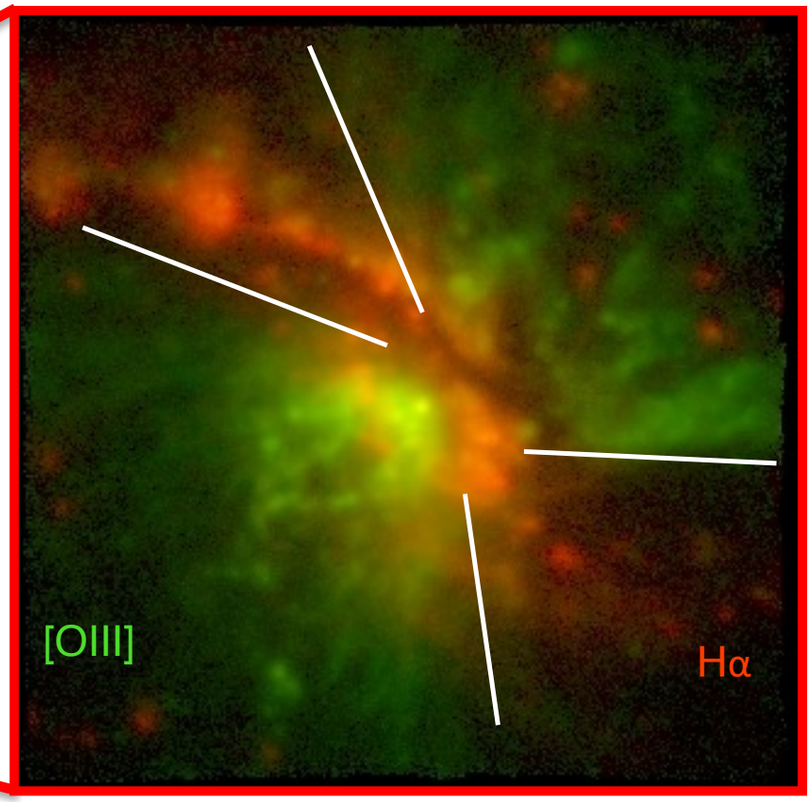

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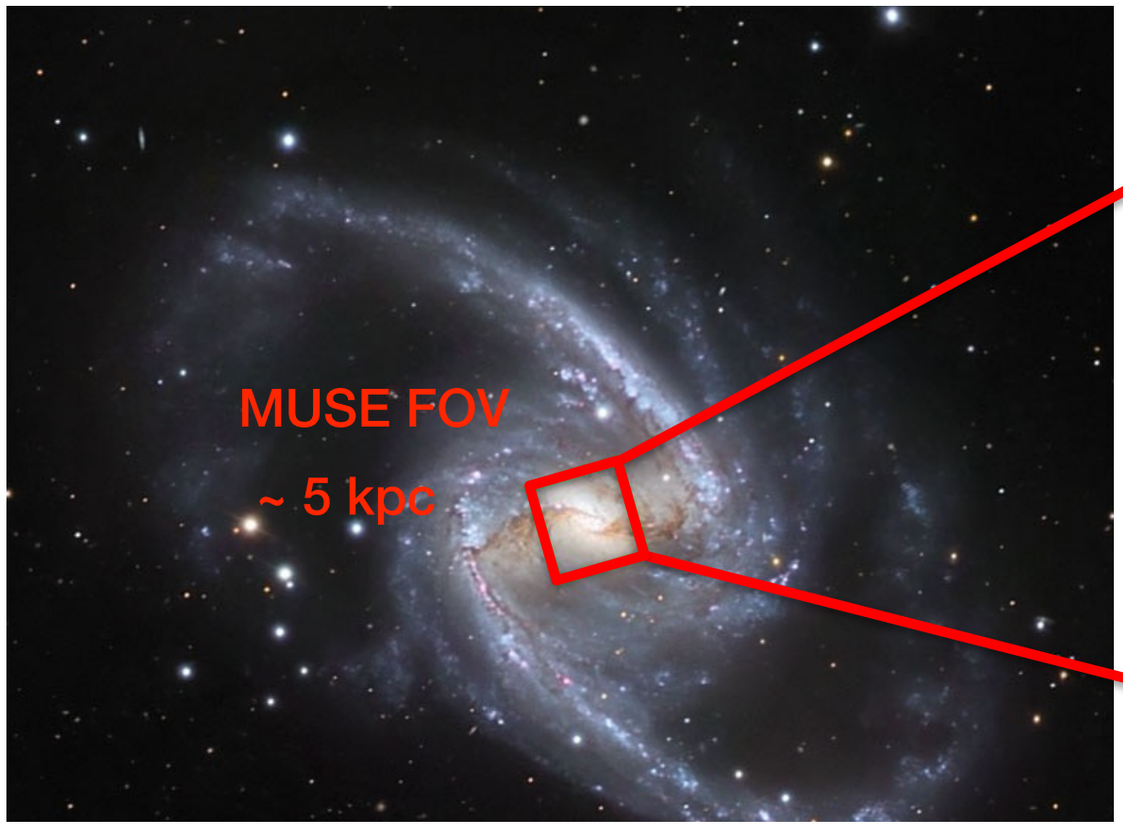
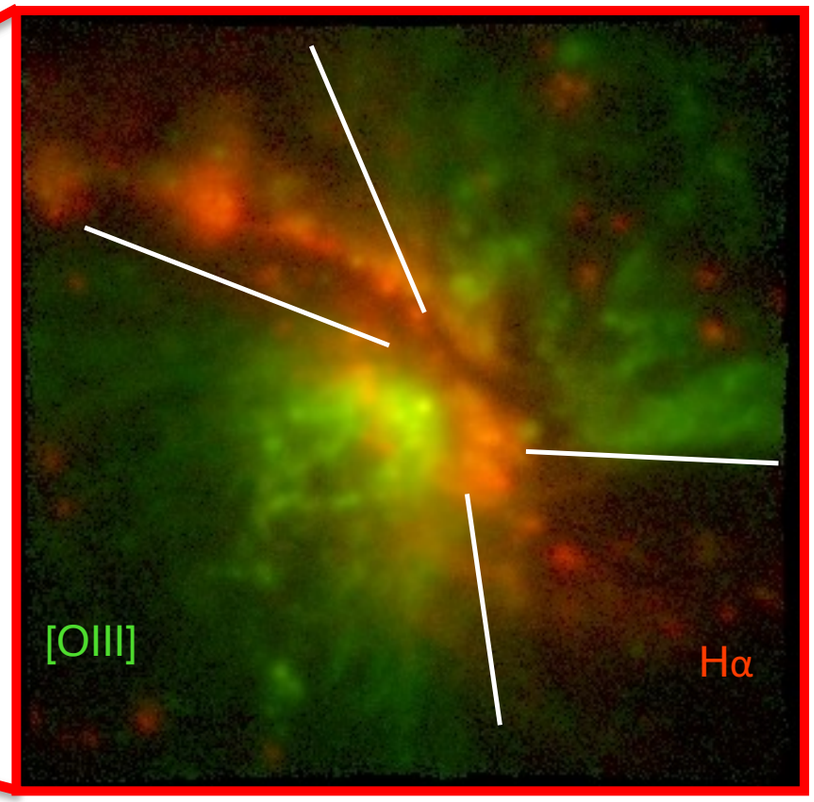
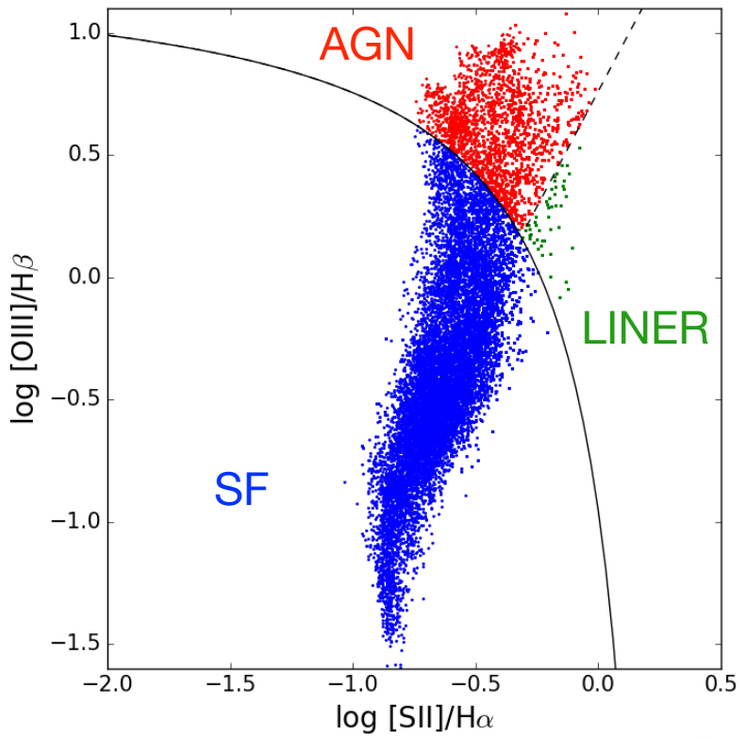


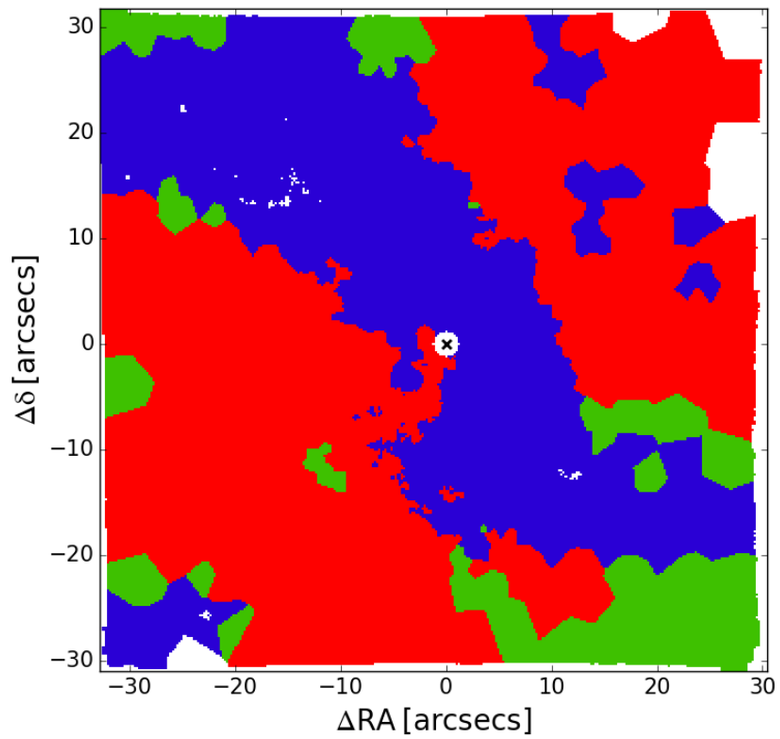


[SII] BPT diagram

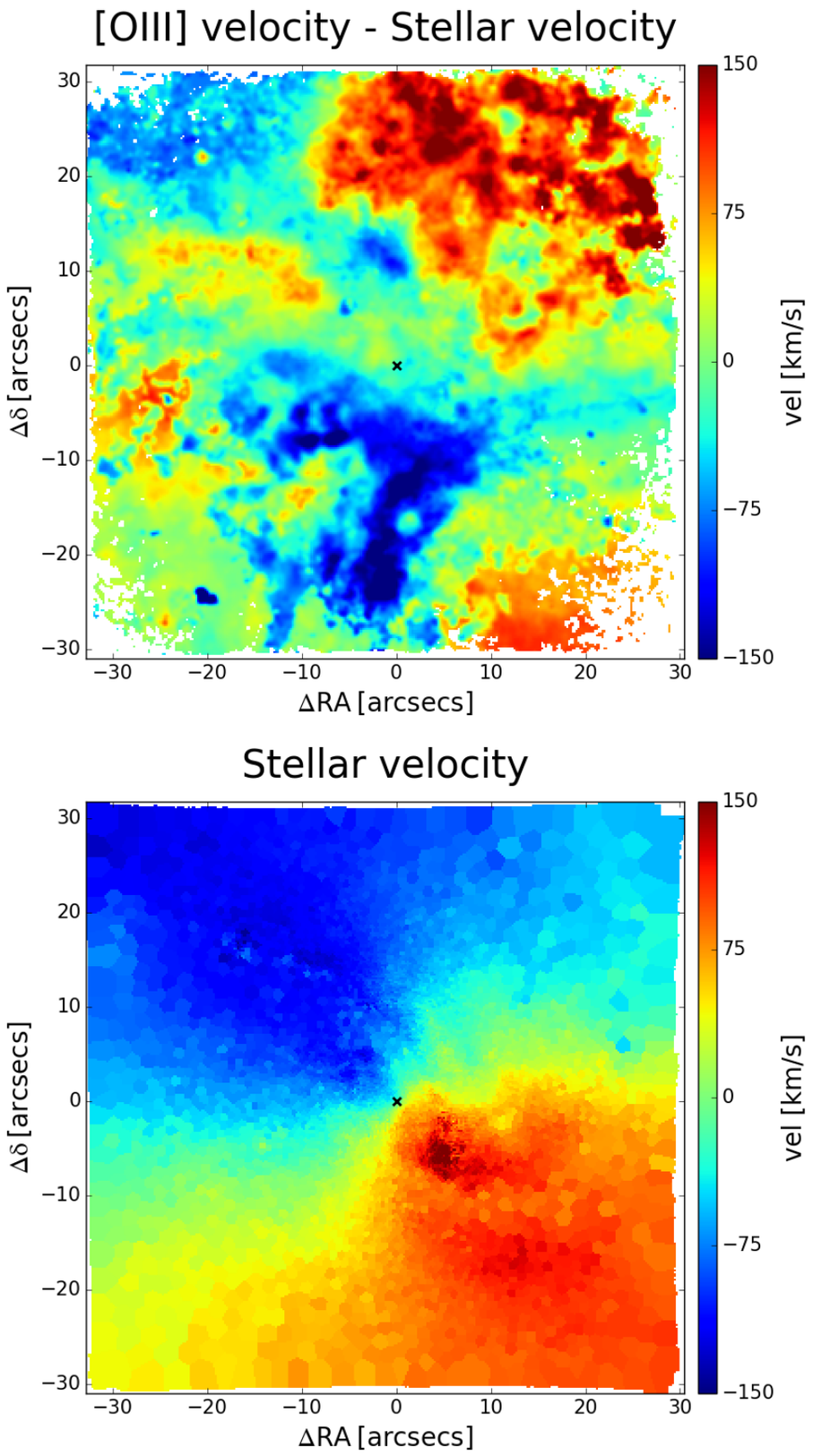


Resolved [SII] BPT diagram

[SII] BPT spatial distribution



NGC 1365: kinematics



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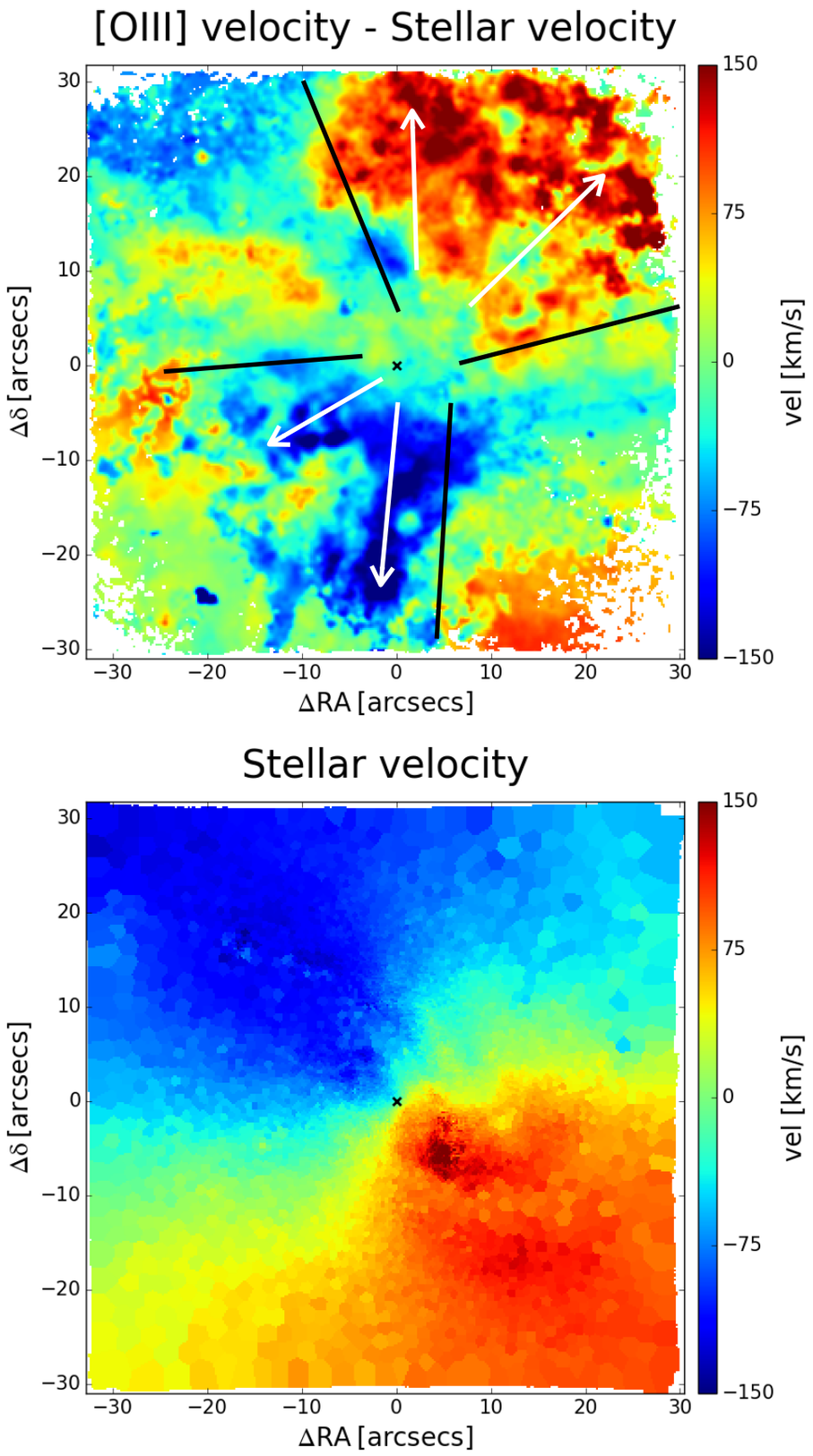
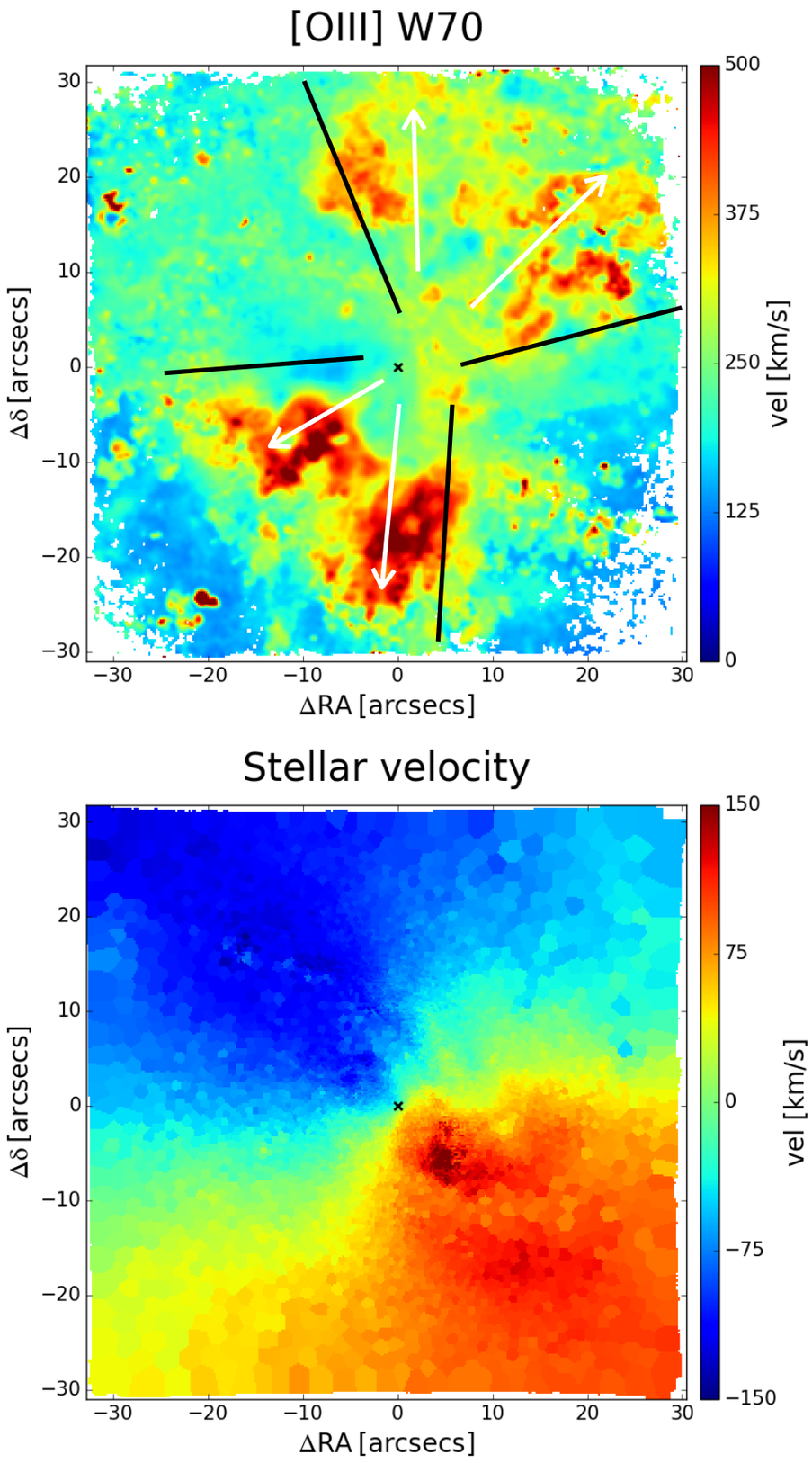


Outflow

NGC 1365: kinematics



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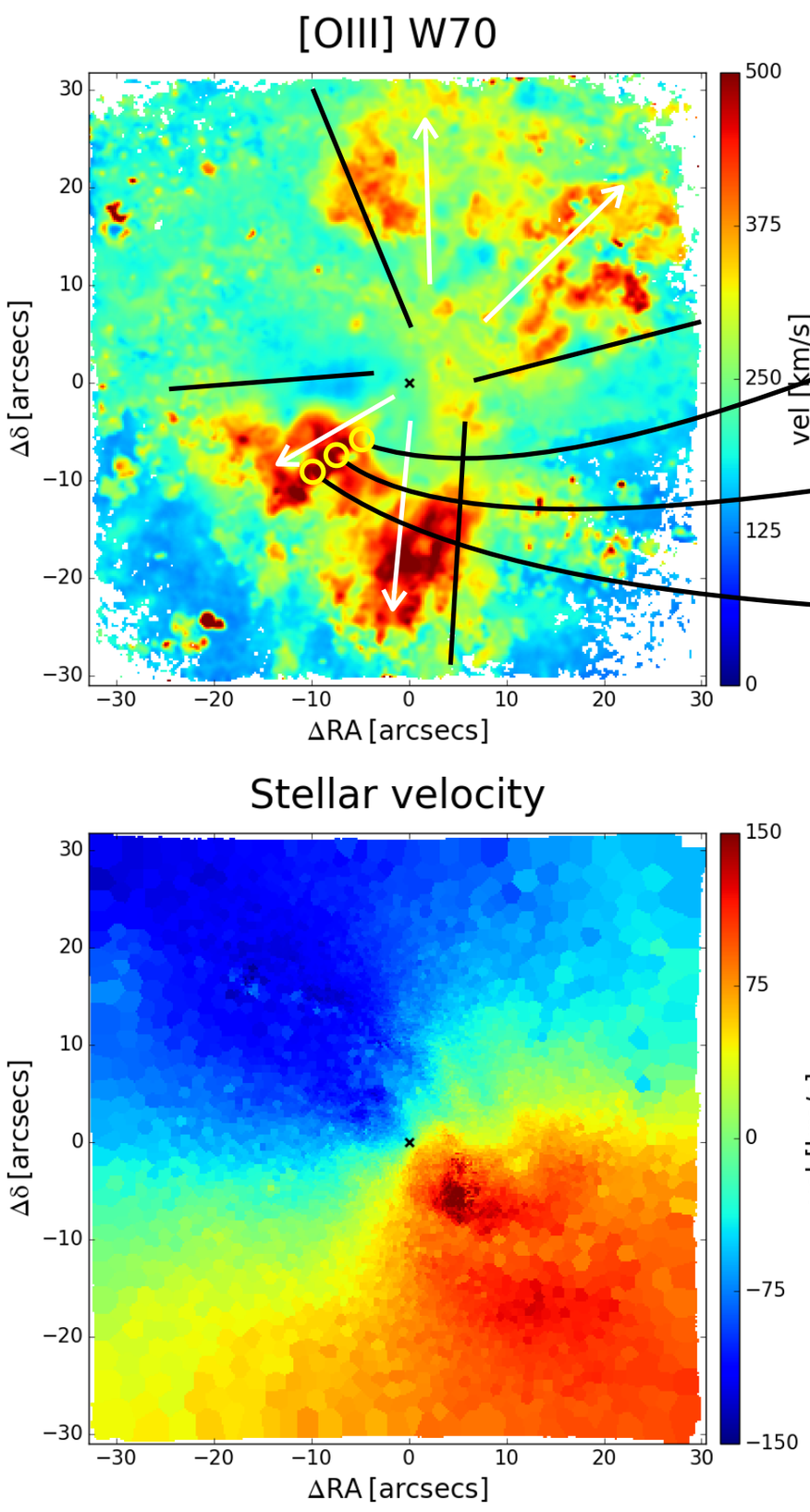
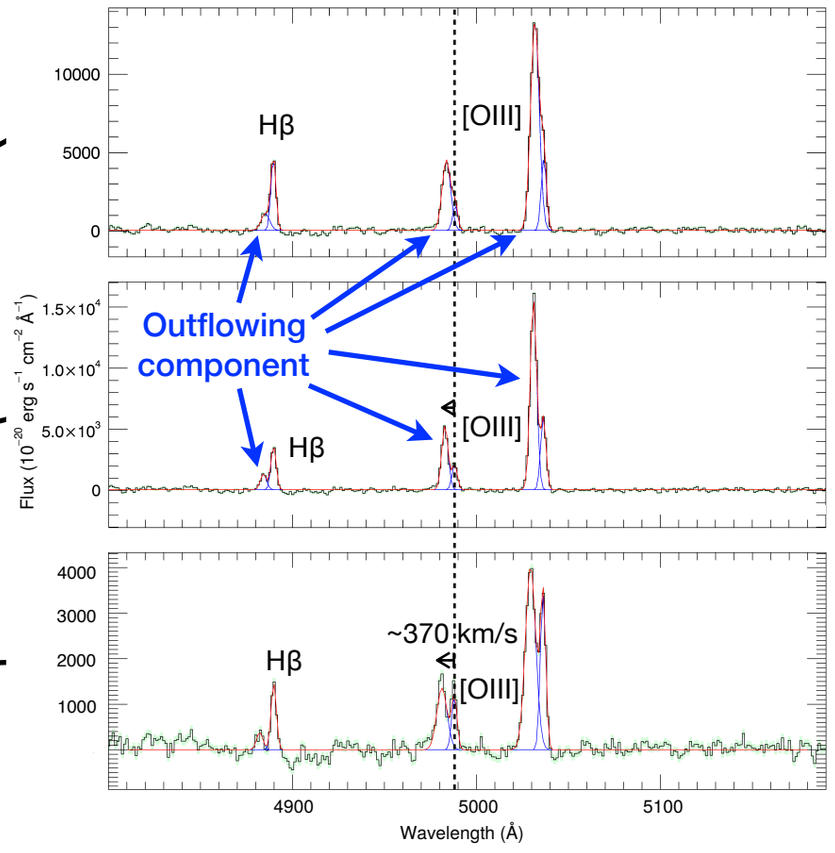


Outflow



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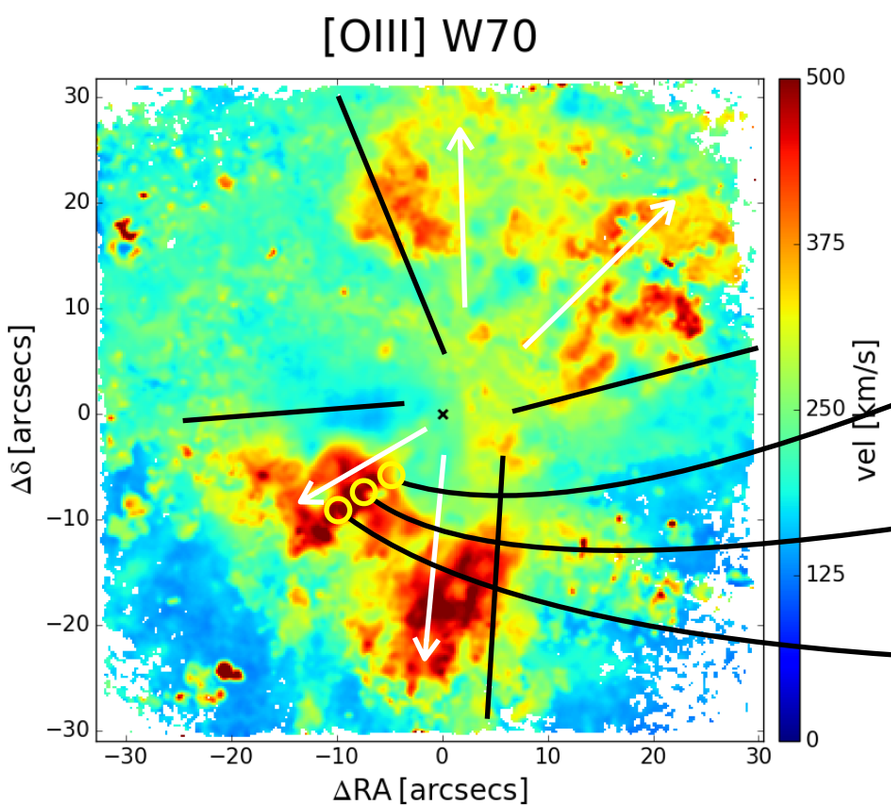

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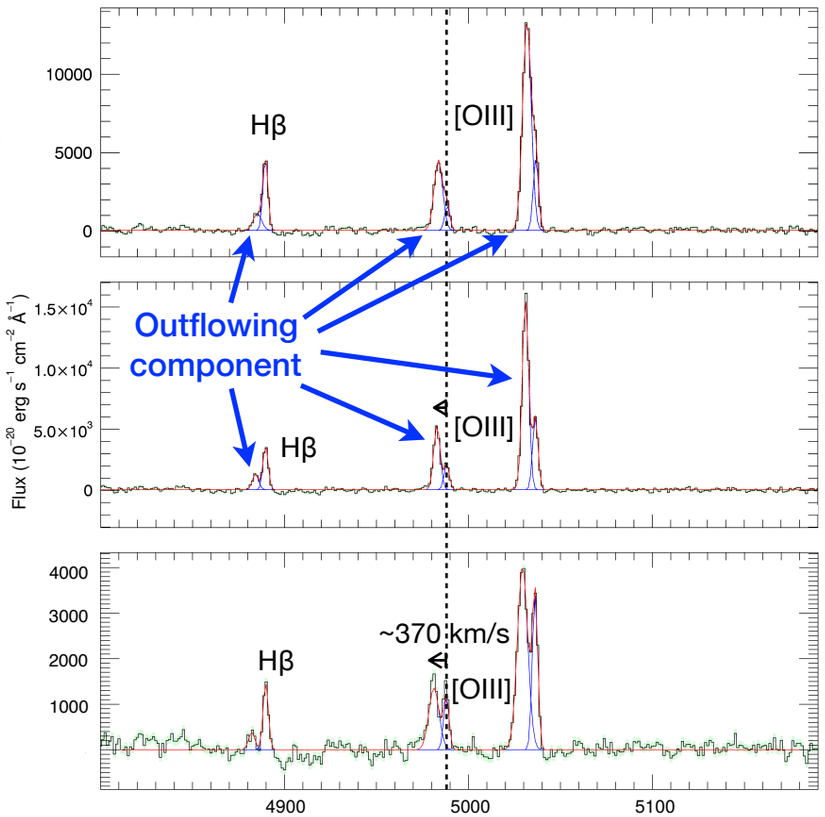

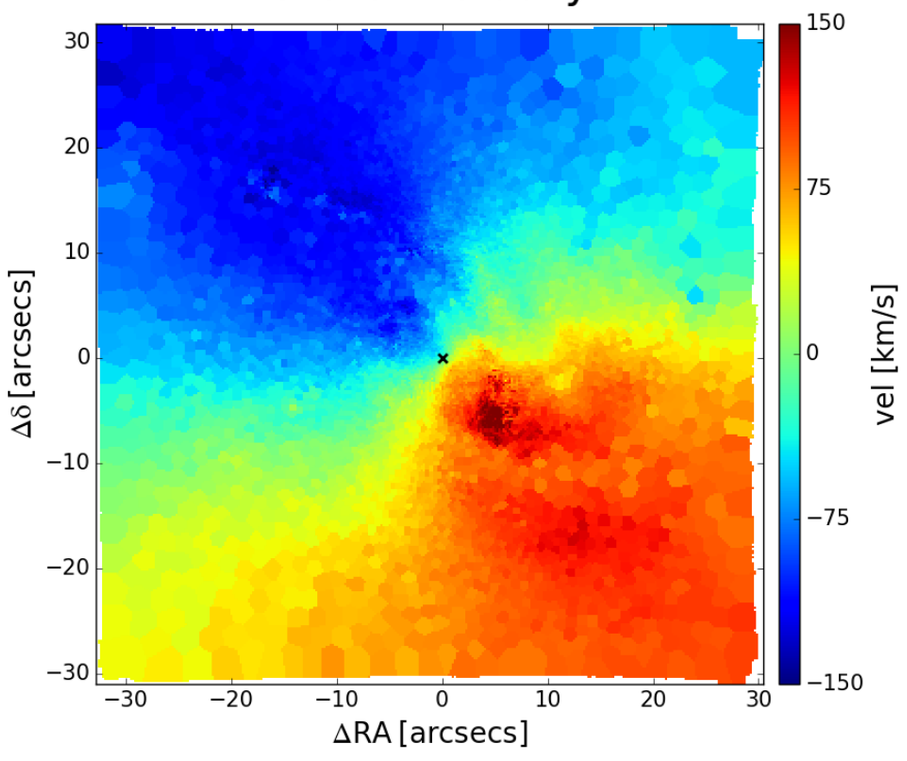

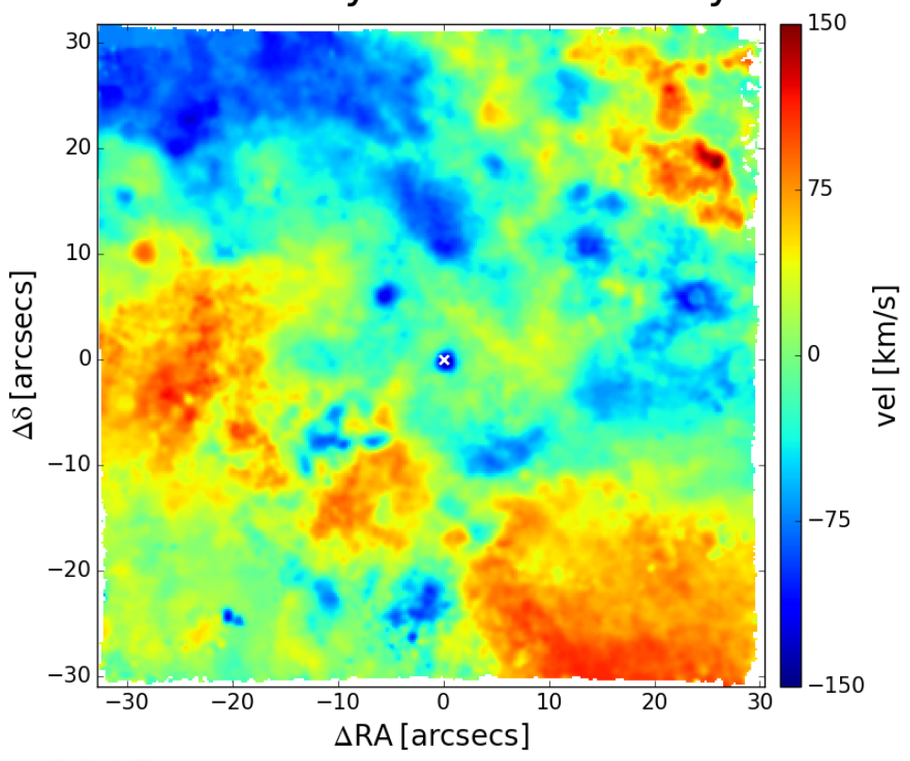

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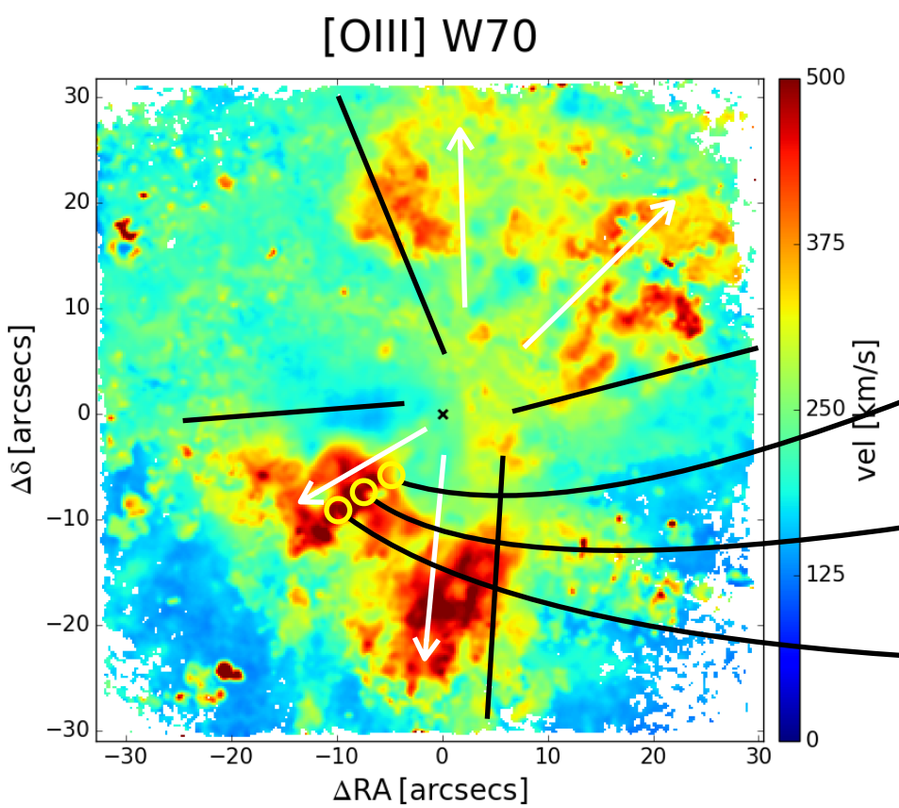

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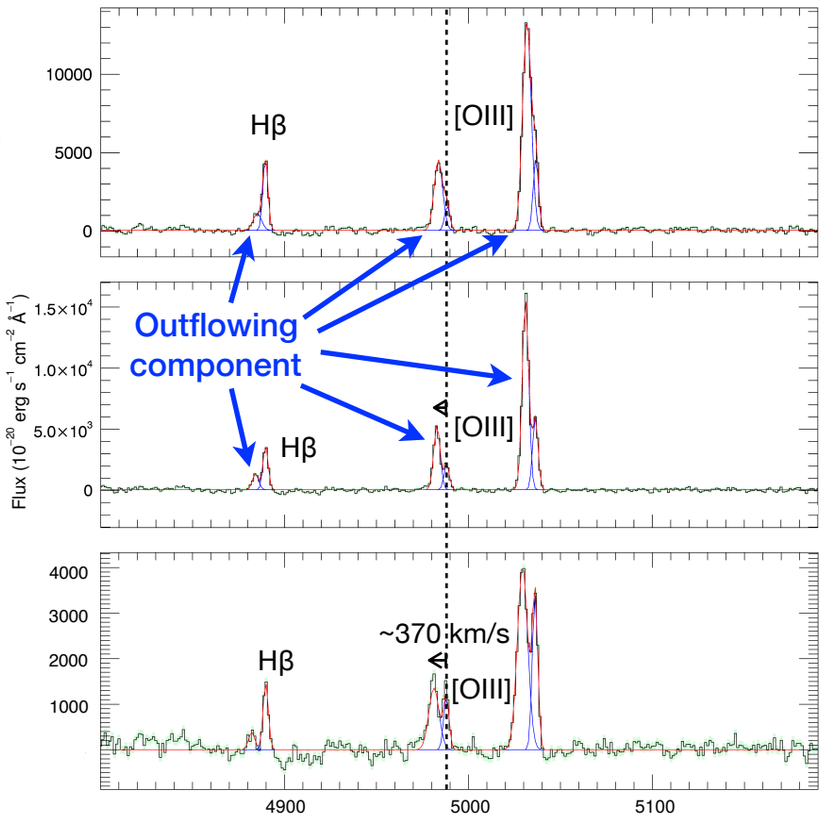

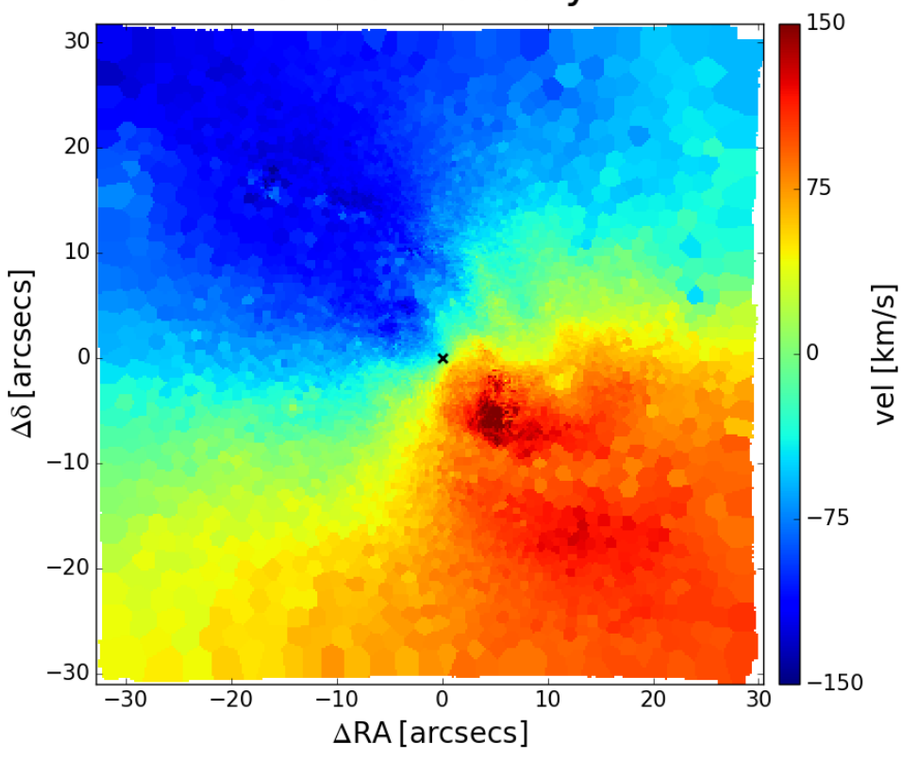

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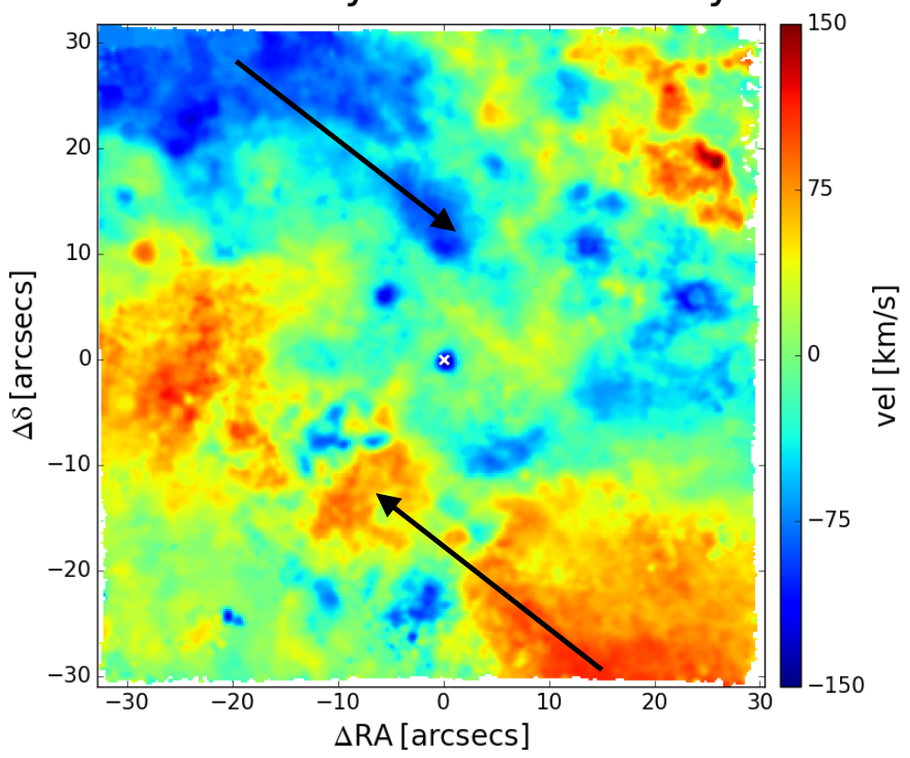
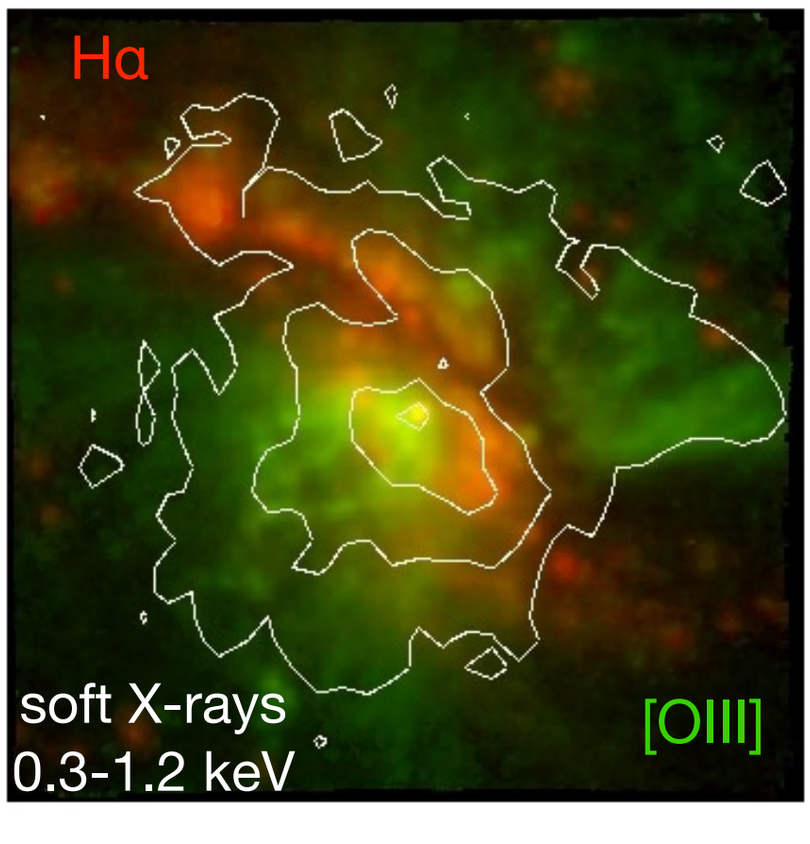


NGC 1365: MUSE-Chandra matching



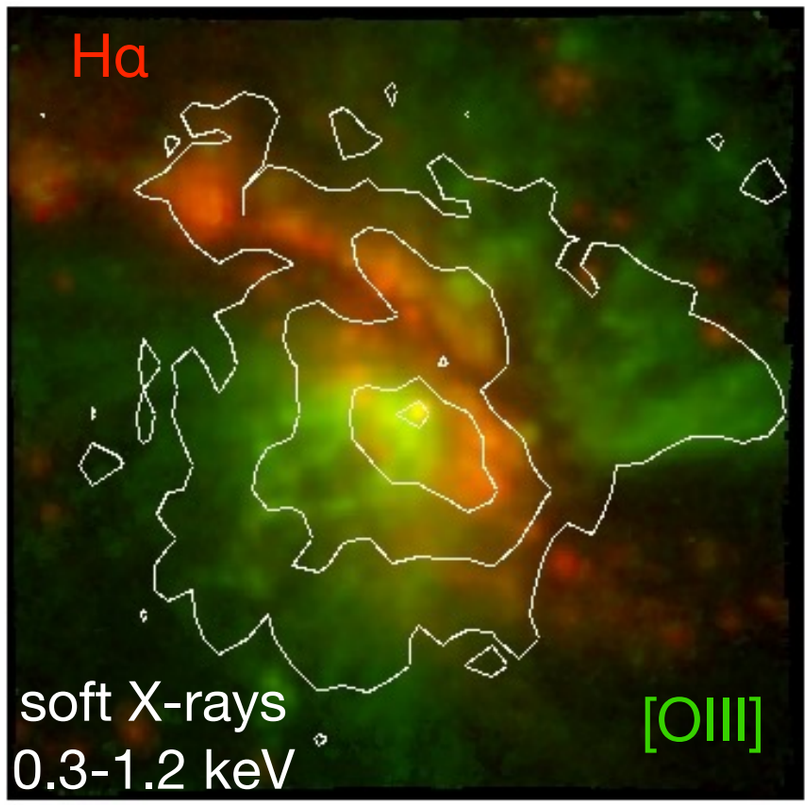
Cospatiality Chandra-MUSE [OIII]&Hα

2-phase gas

colder
denser
([OIII], Hα)

hotter, less dense
(X-rays, both
photoionized by AGN and
collisionally-ionized by SF)

NGC 1365: MUSE-Chandra matching



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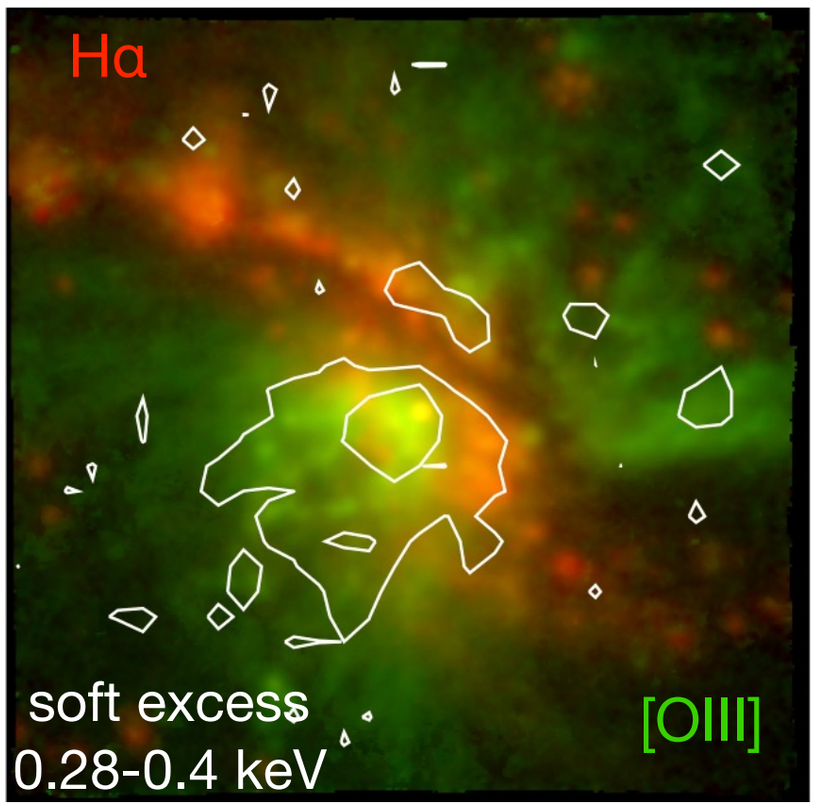
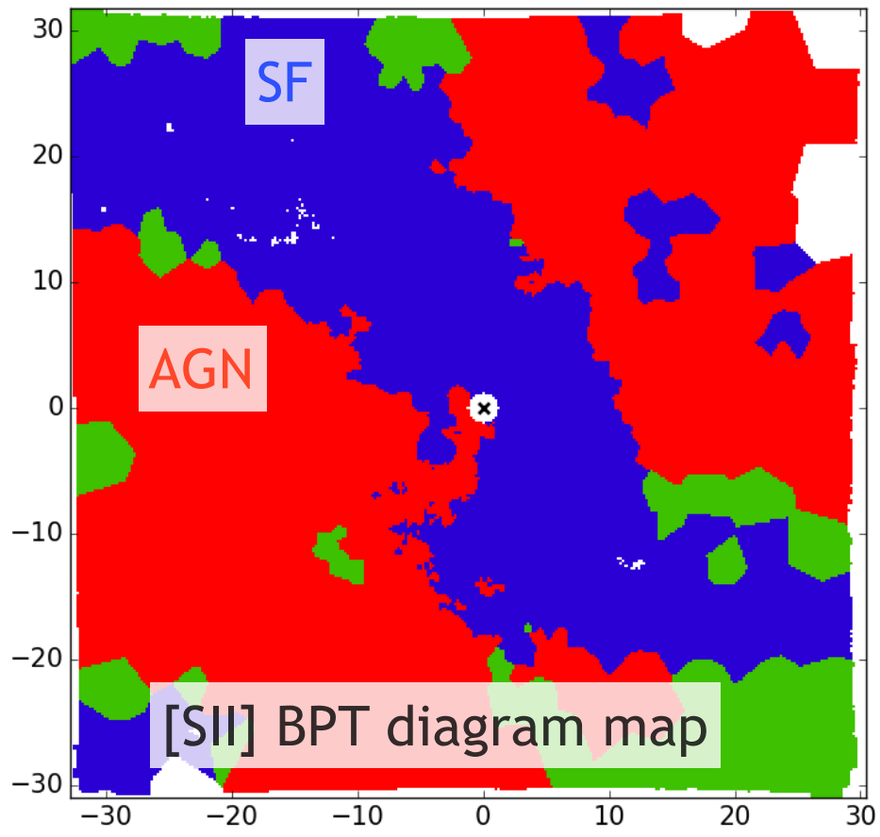
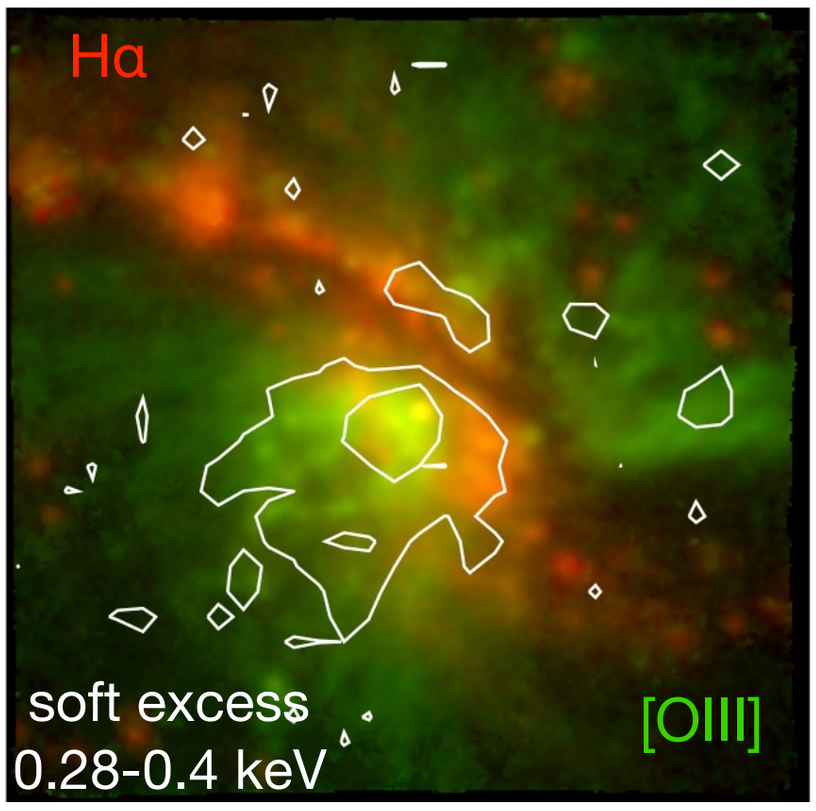


softer X-ray tail

[OIII] —> AGN

NGC 1365: MUSE-Chandra matching





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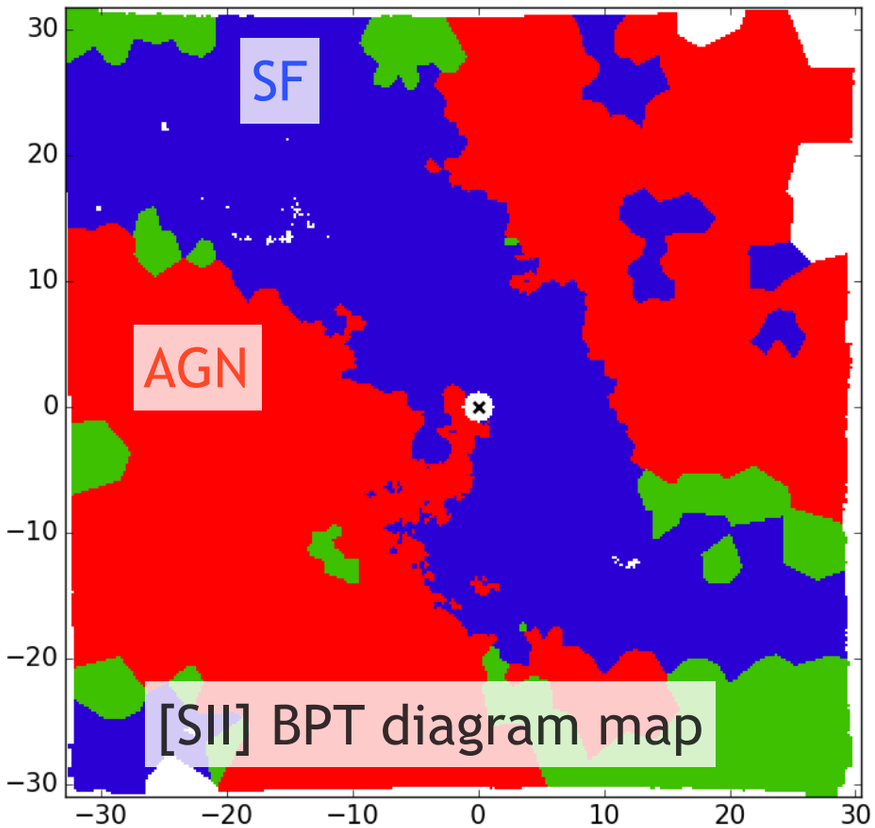
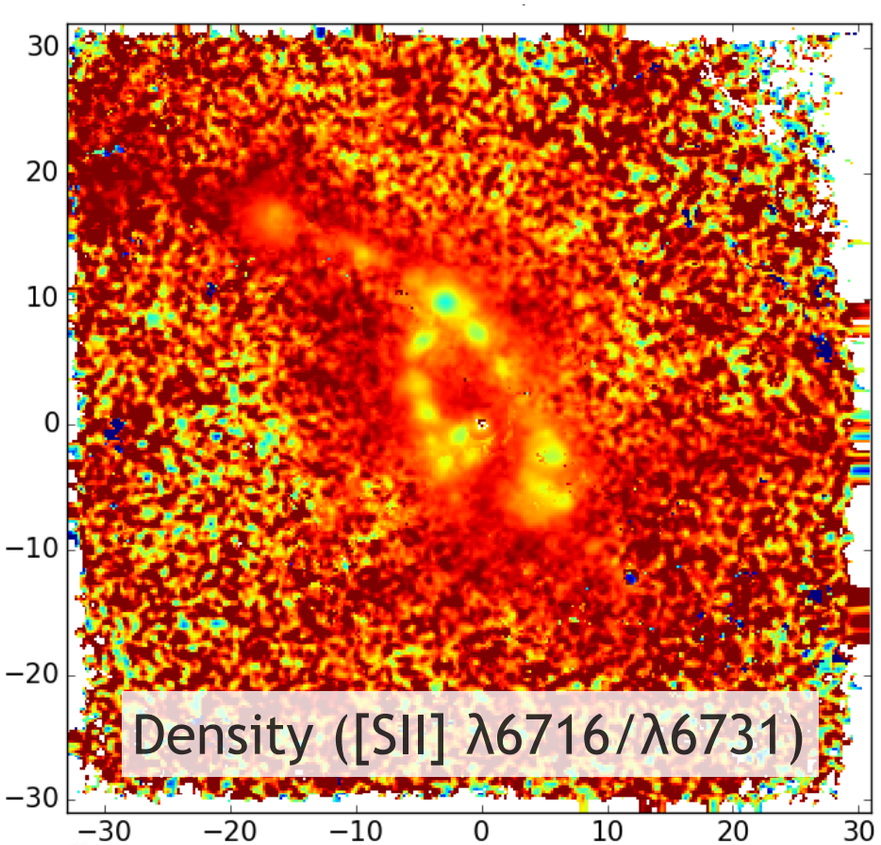
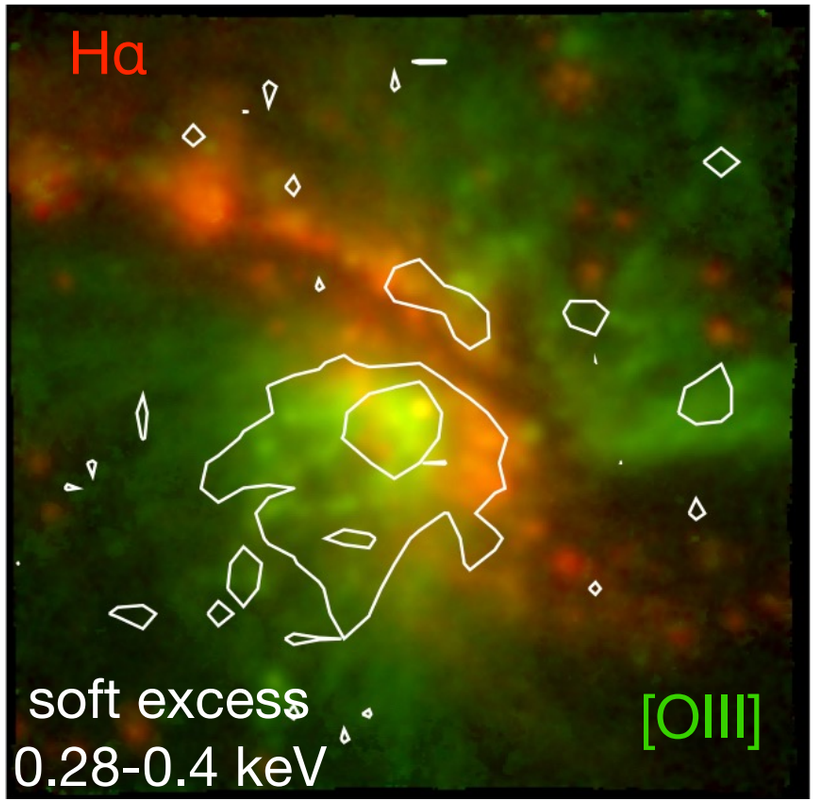




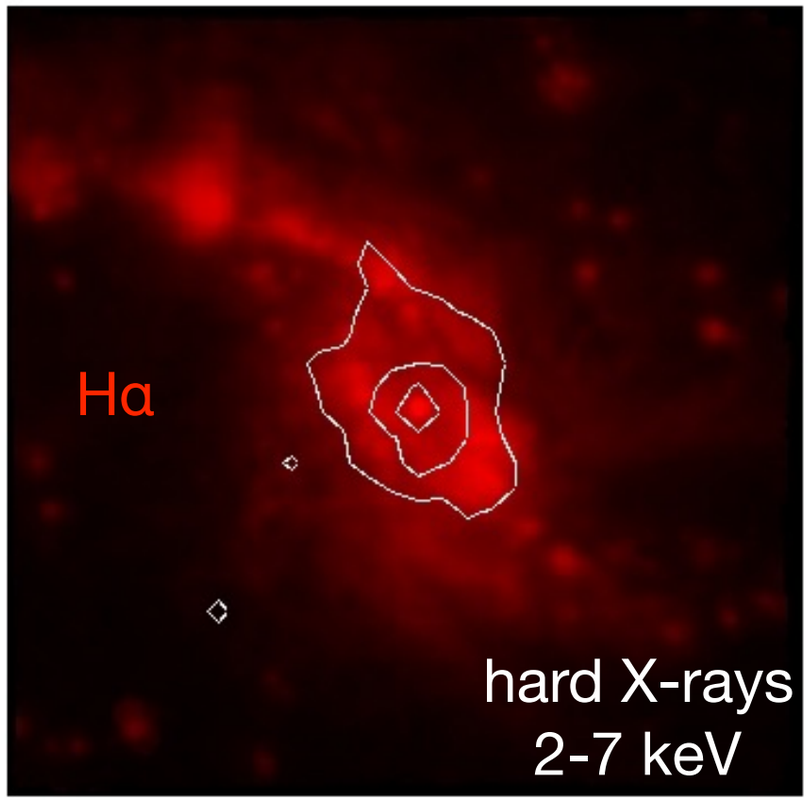


softer X-ray tail

[OIII] —> AGN

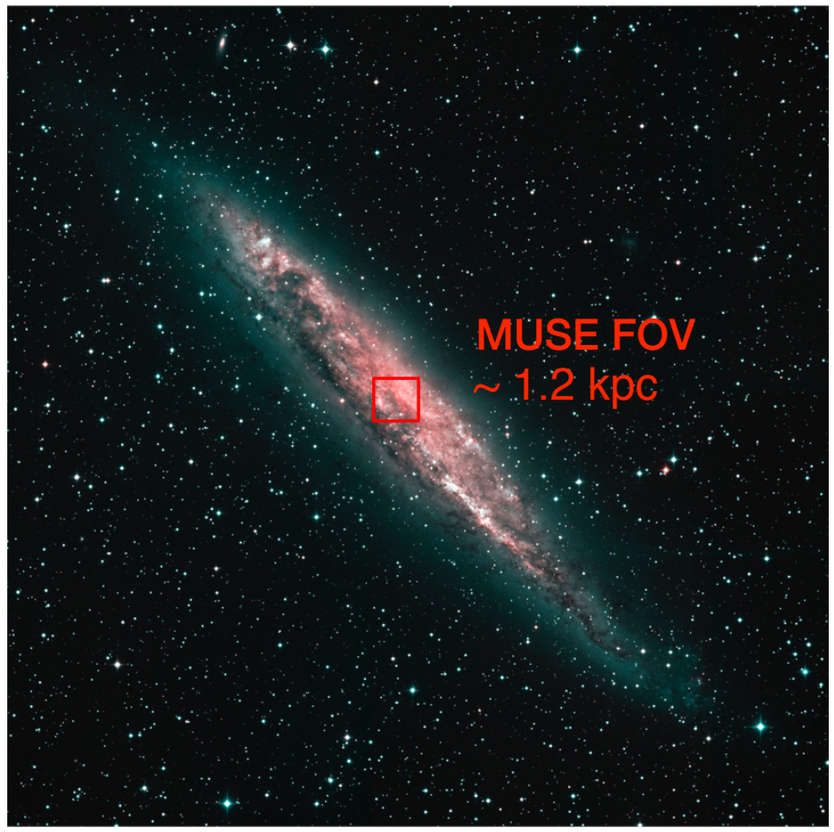
harder X-ray tail

Hα —> SF



Outflow structure

NGC 4945



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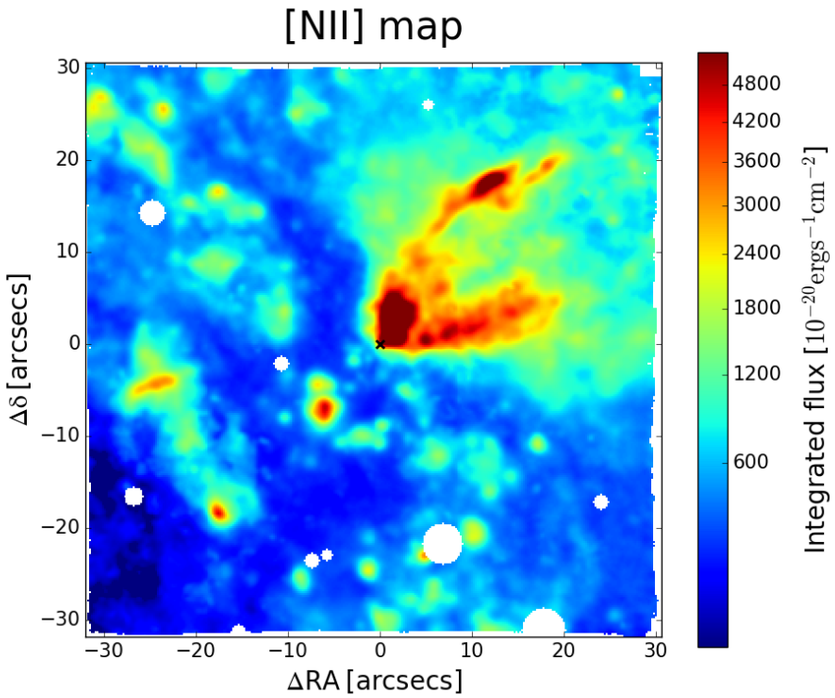

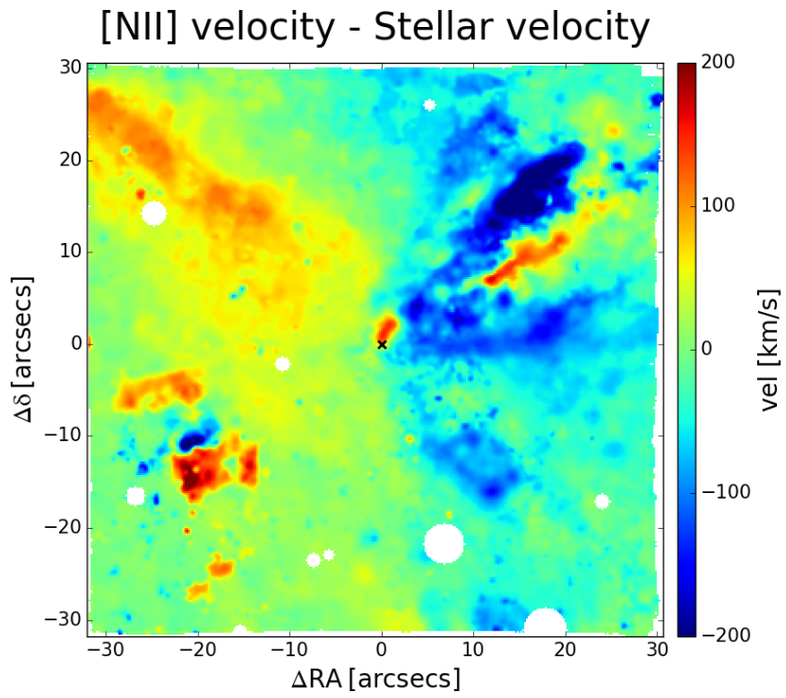

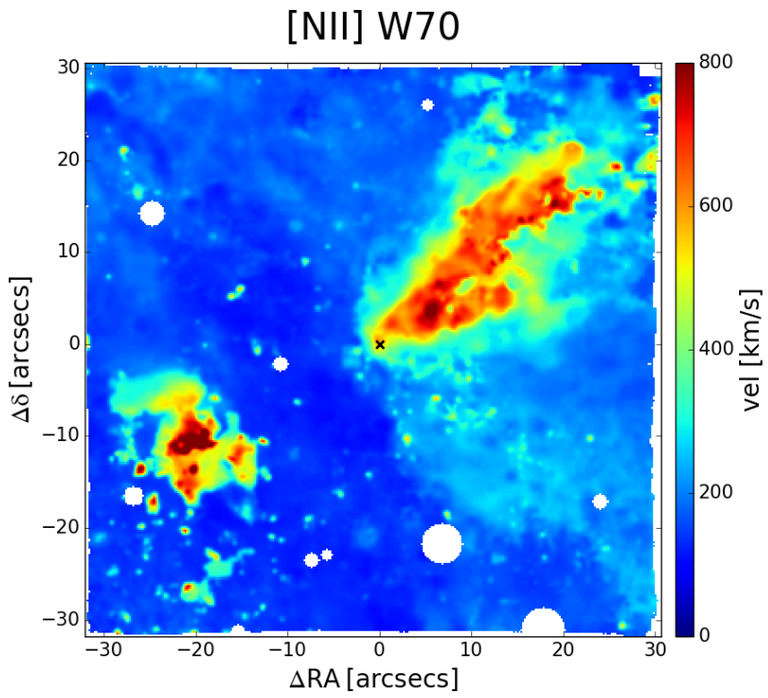

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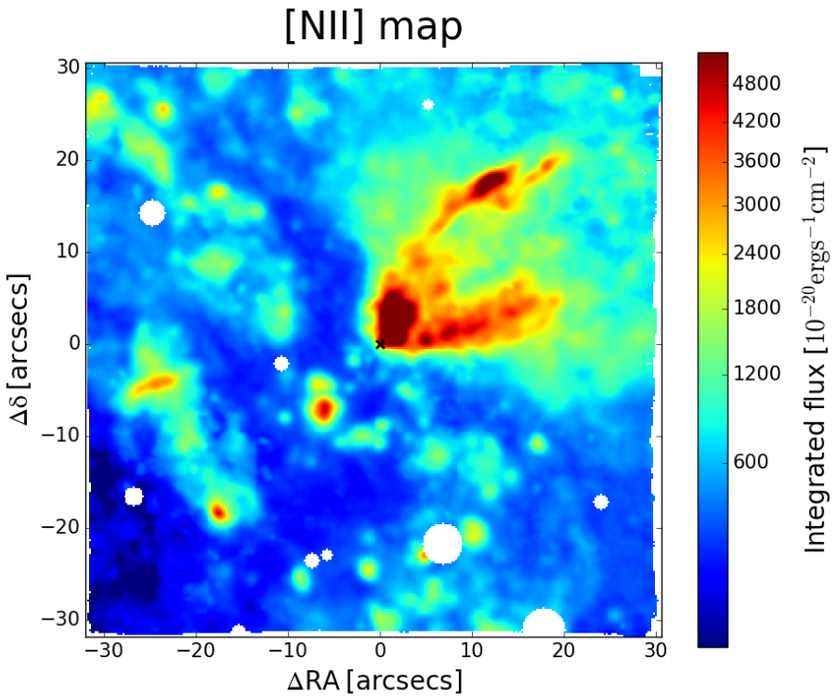

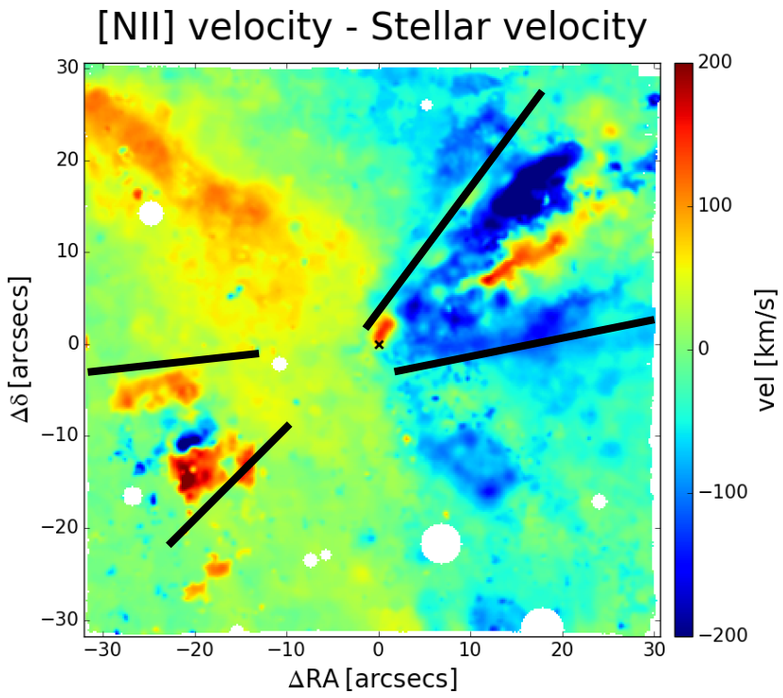

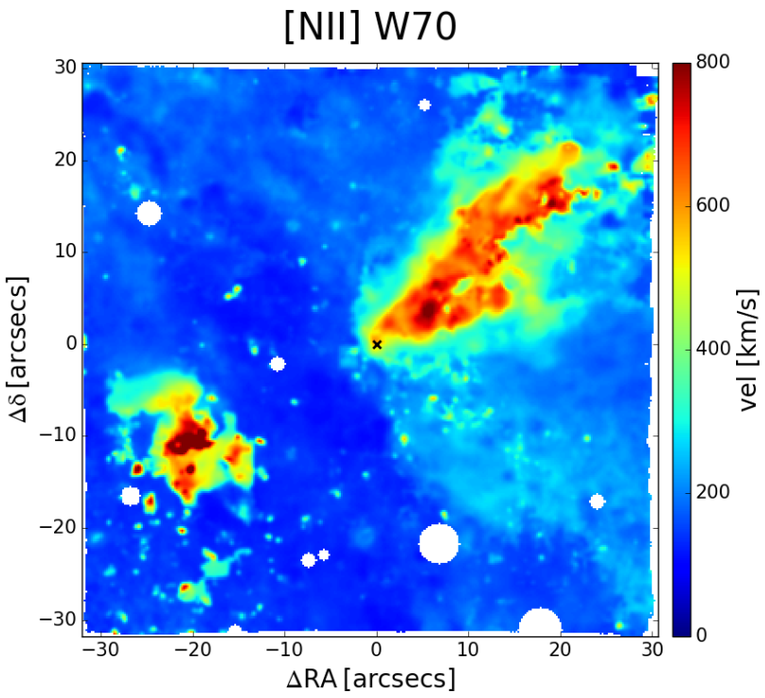

Outflow structure

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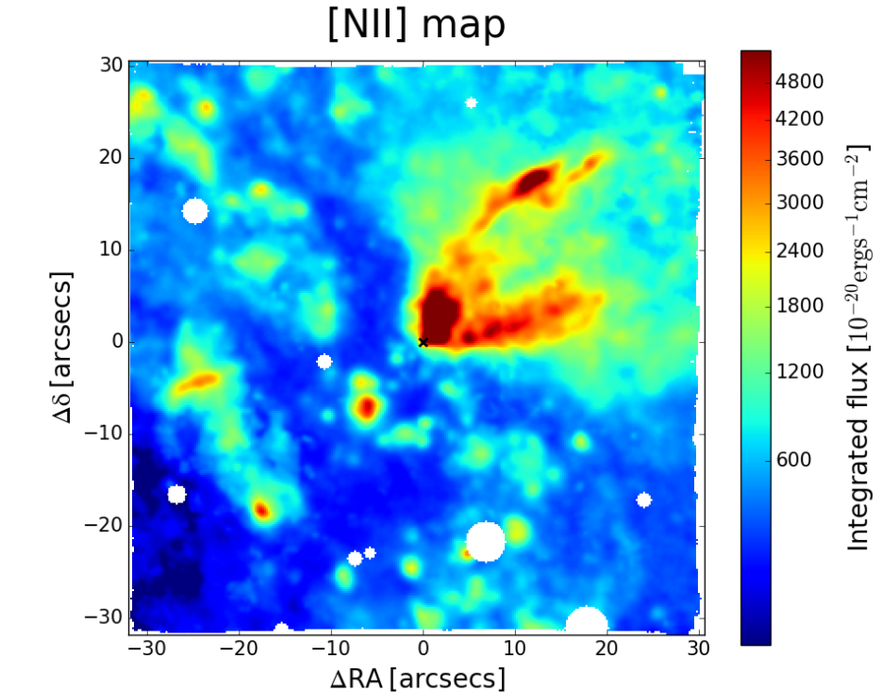
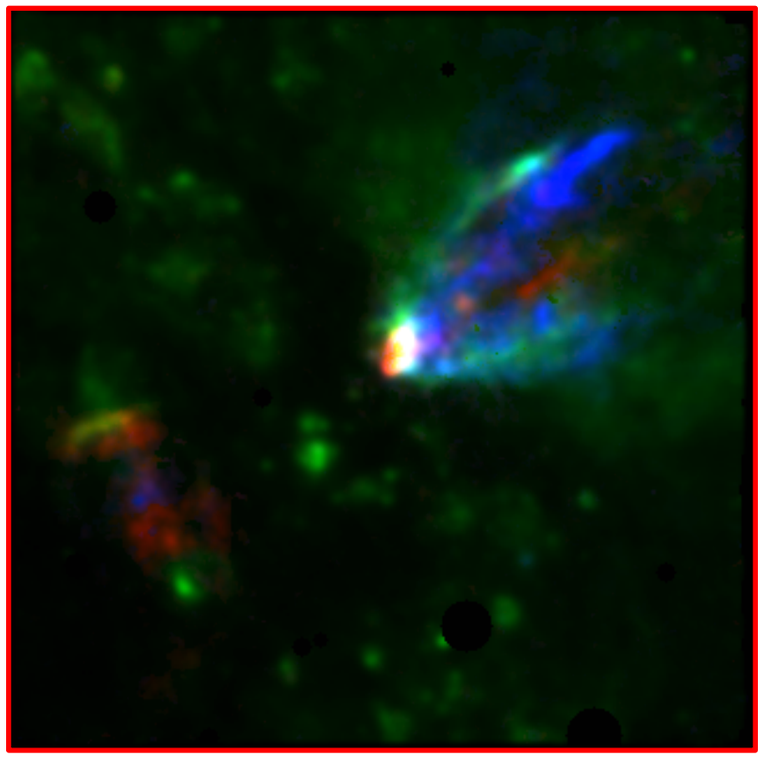


Double conical outflow with complex structure



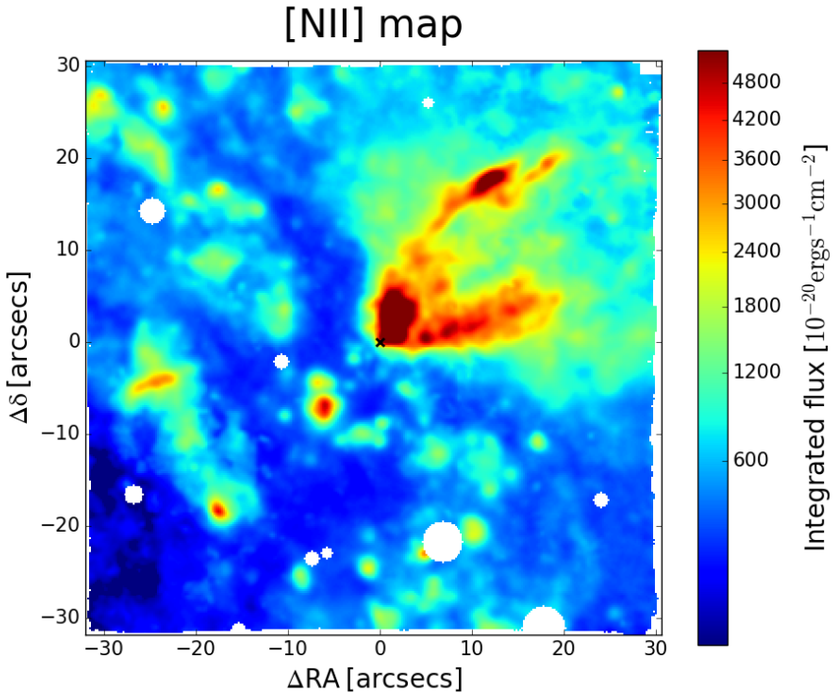
Blue: $Flux_{[NII]} < -300$ km/s

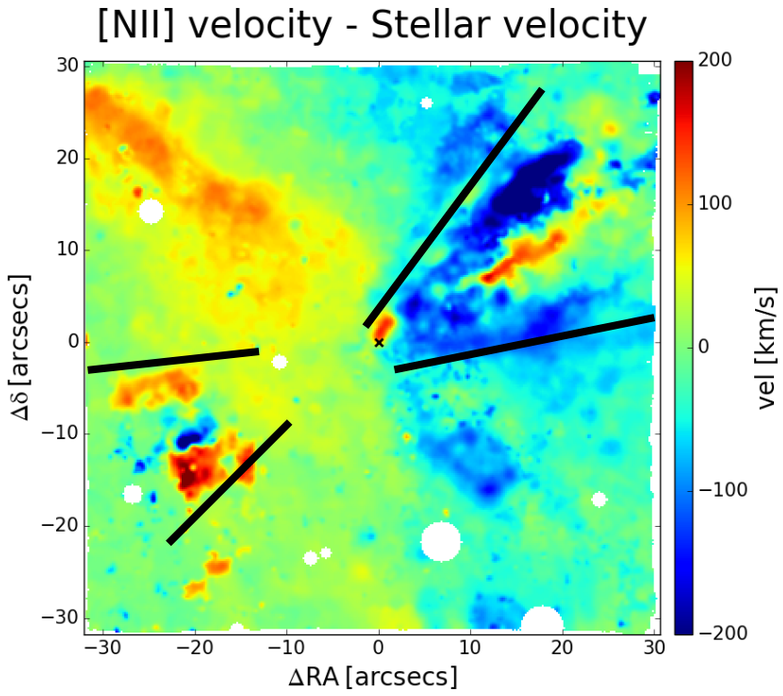
Green: -300 km/s $< Flux_{[NII]} < 300$ km/s

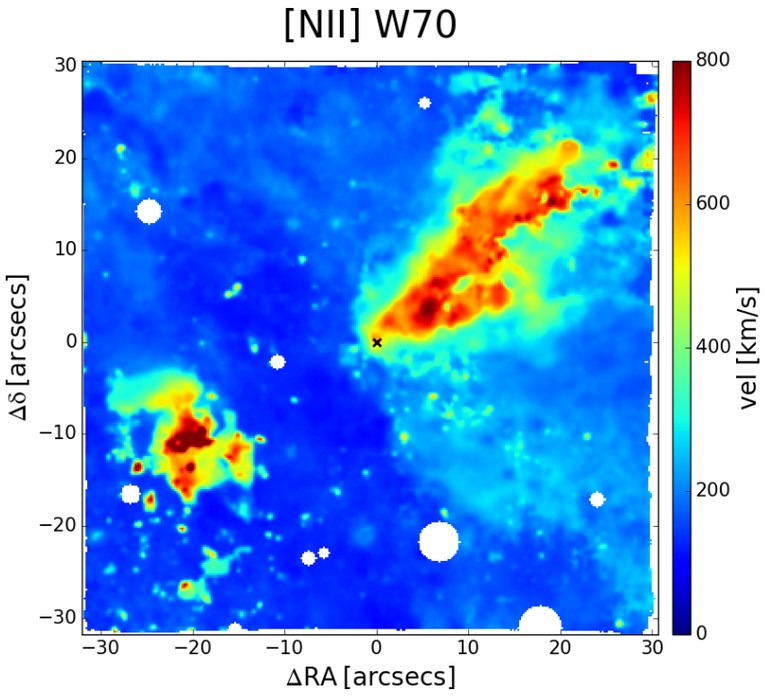
Red: $Flux_{[NII]} > 300$ km/s

Outflow structure

NGC 4945

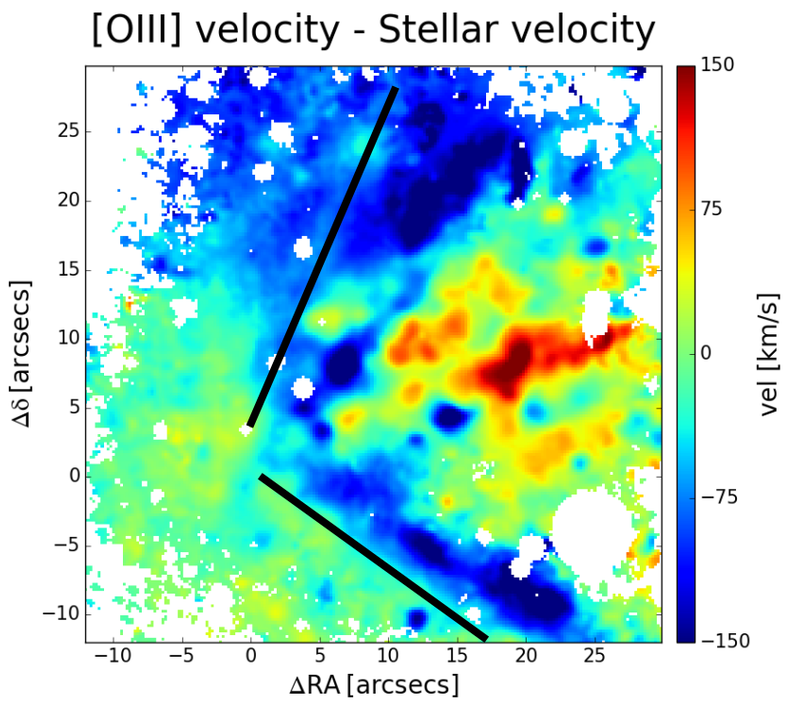






Circinus

FOV ~ 850 pc

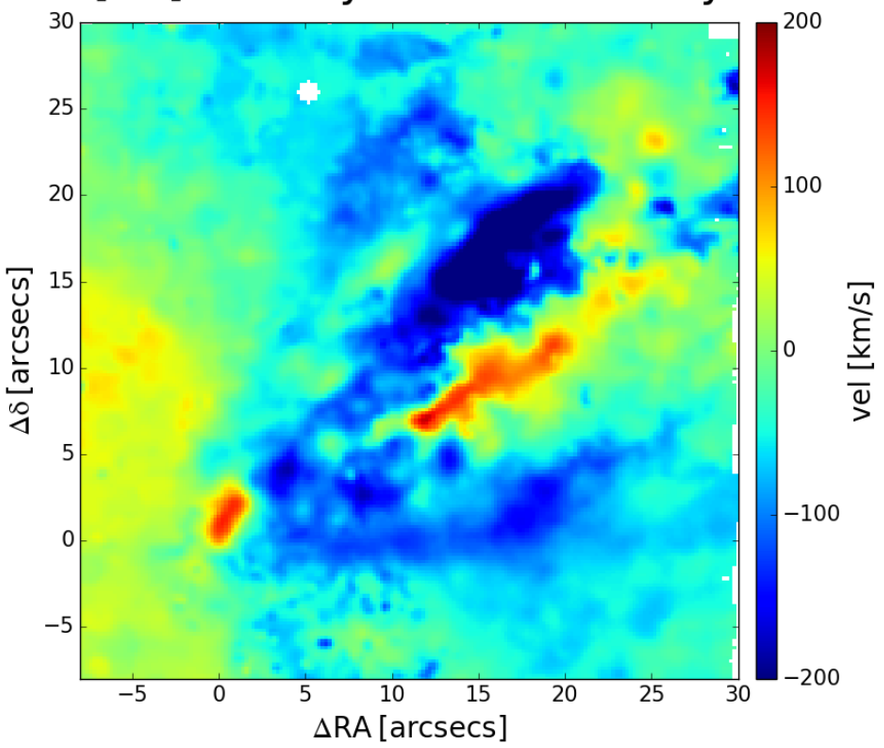


Zoom on the cone:
same velocity structure
of the outflow

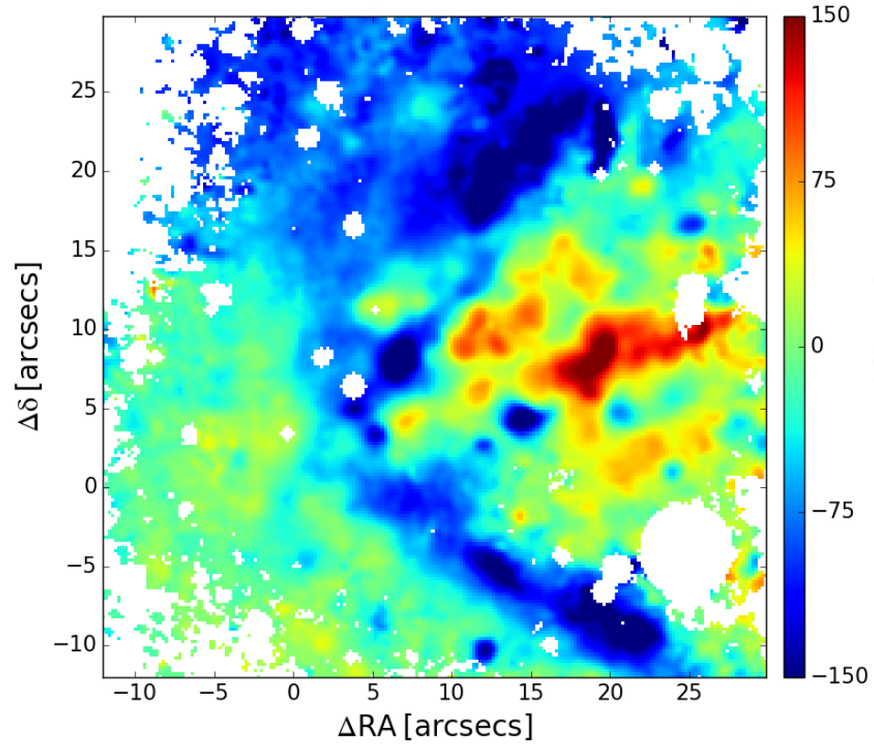
Edges —> approaching
Axis —> receding

Outflow structure

NGC 4945

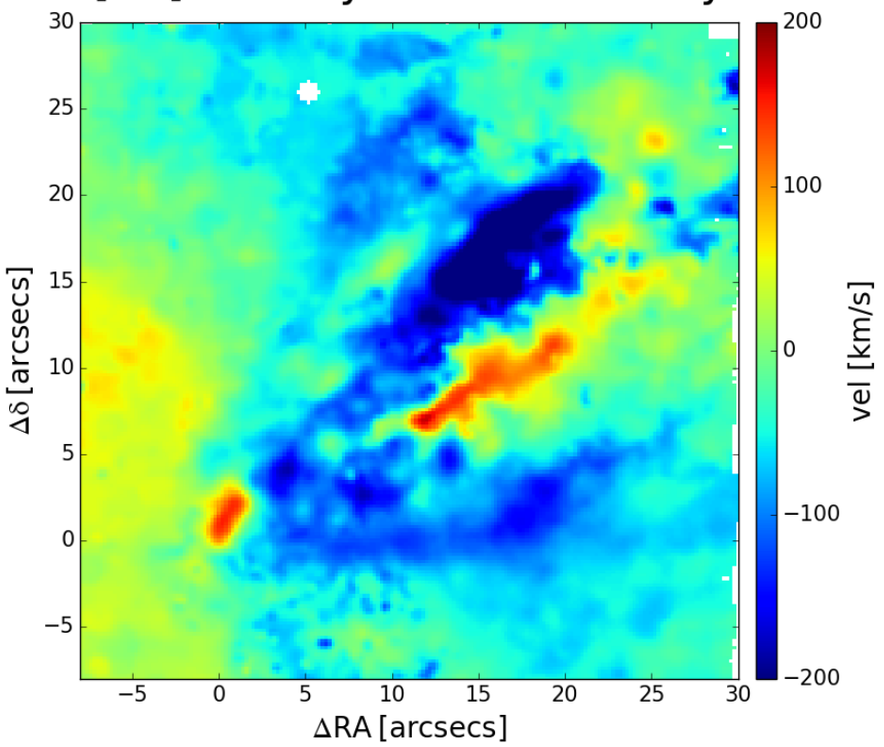


Circinus

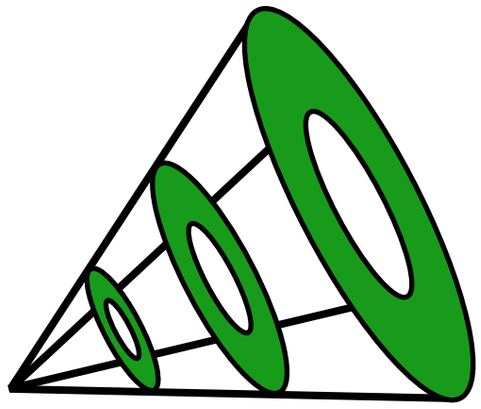


Outflow structure

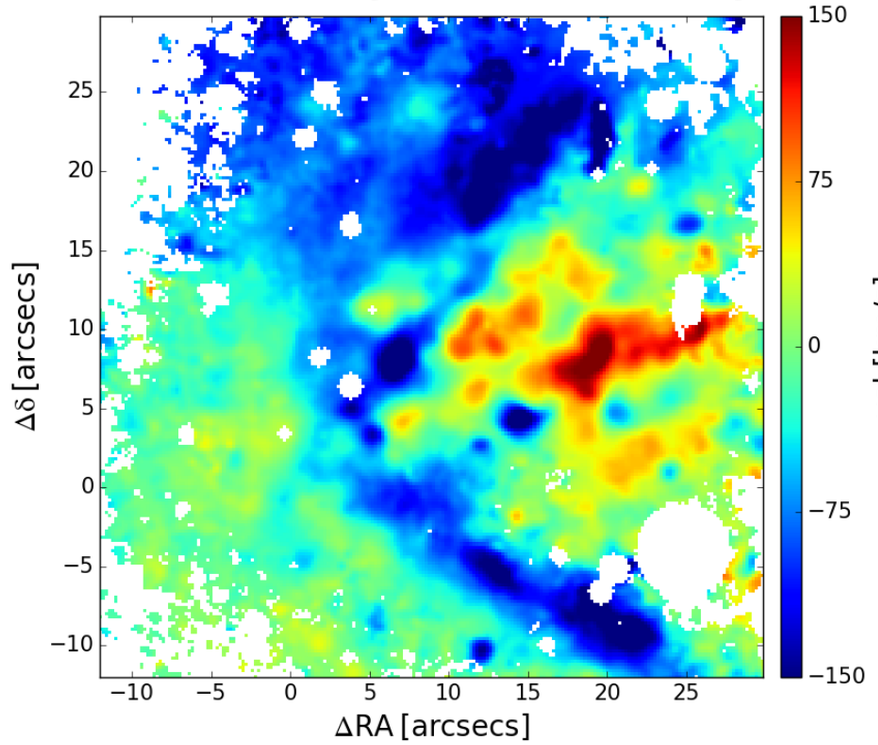
NGC 4945



A hollow conical outflow?



Circinus



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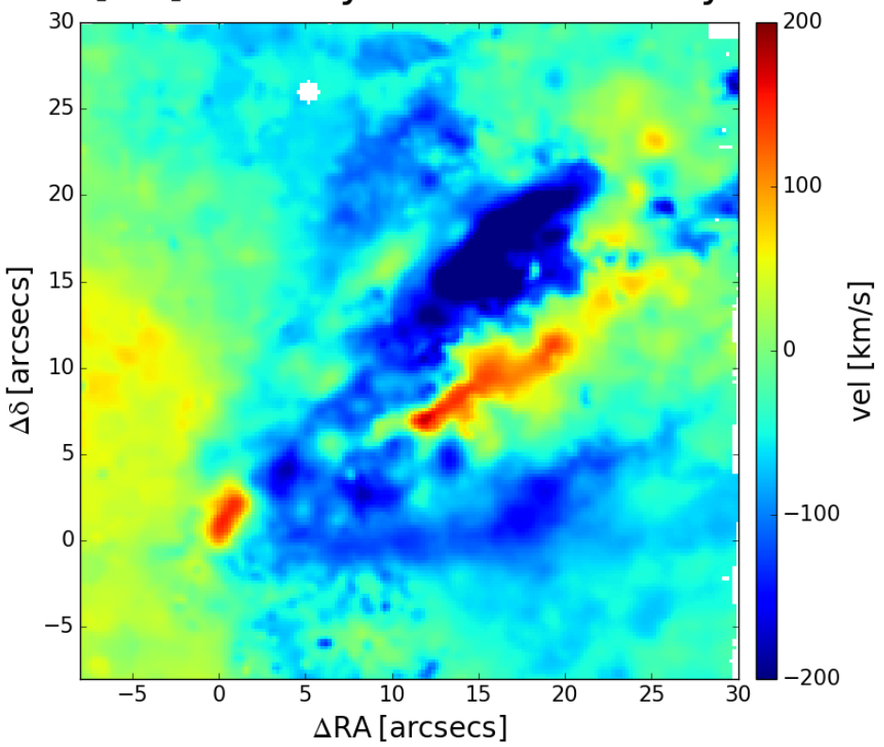

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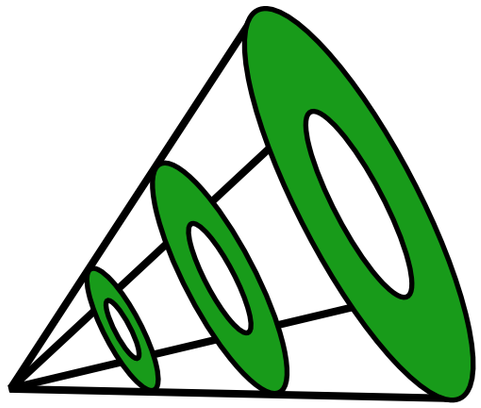

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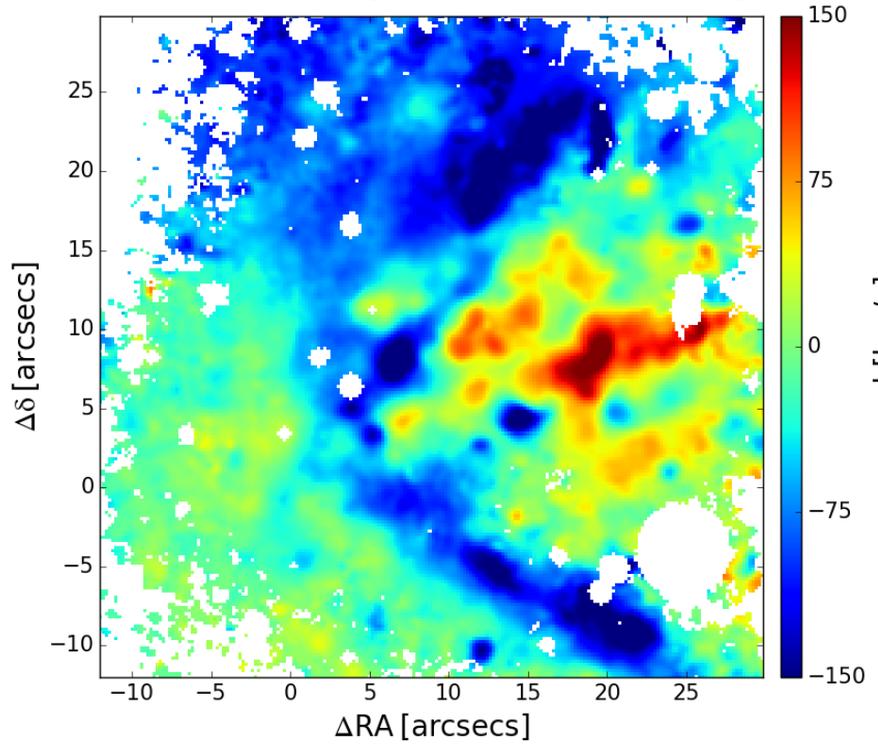
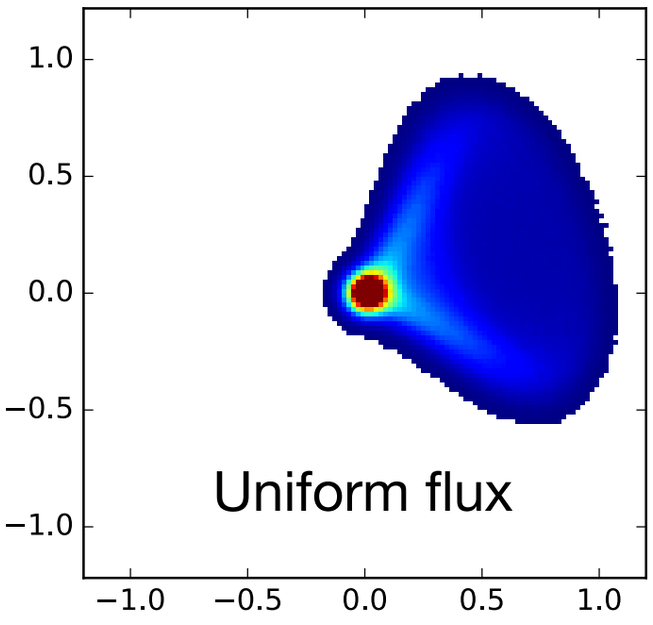
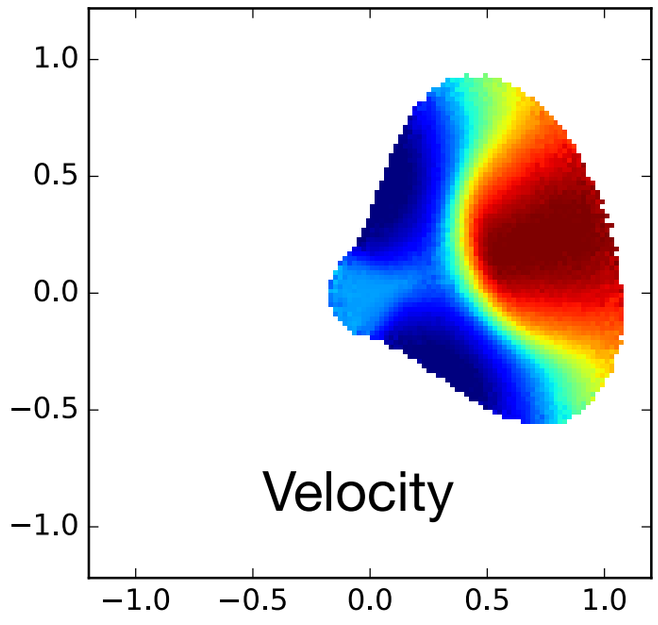
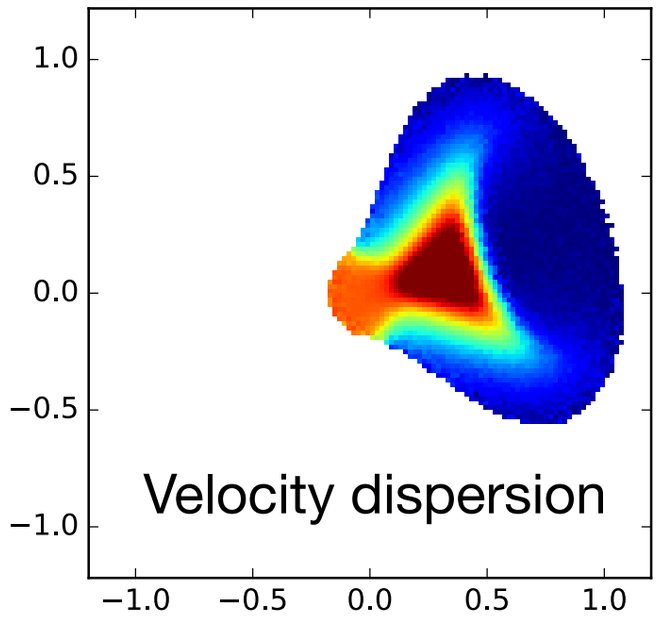


A simple kinematical model: hollow cone







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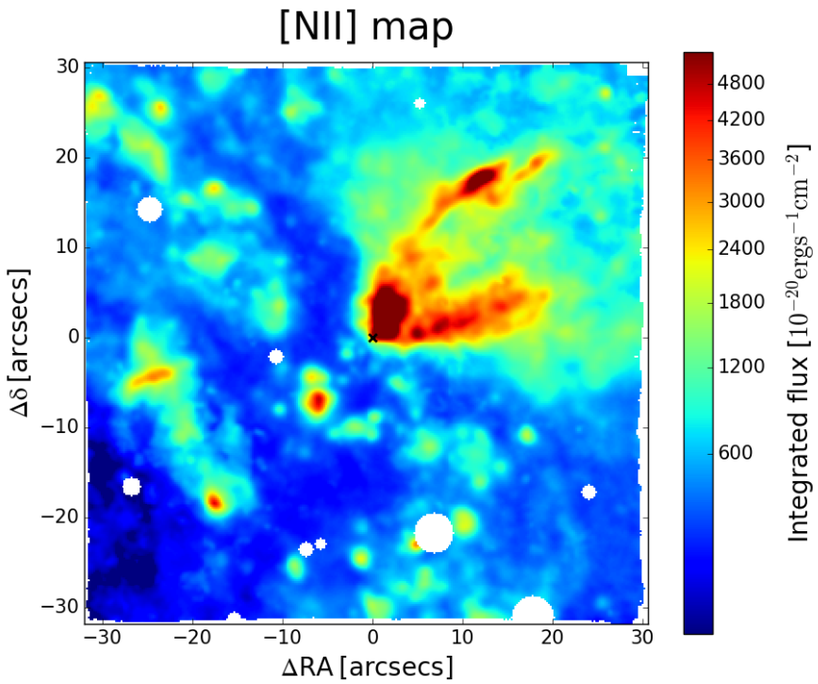
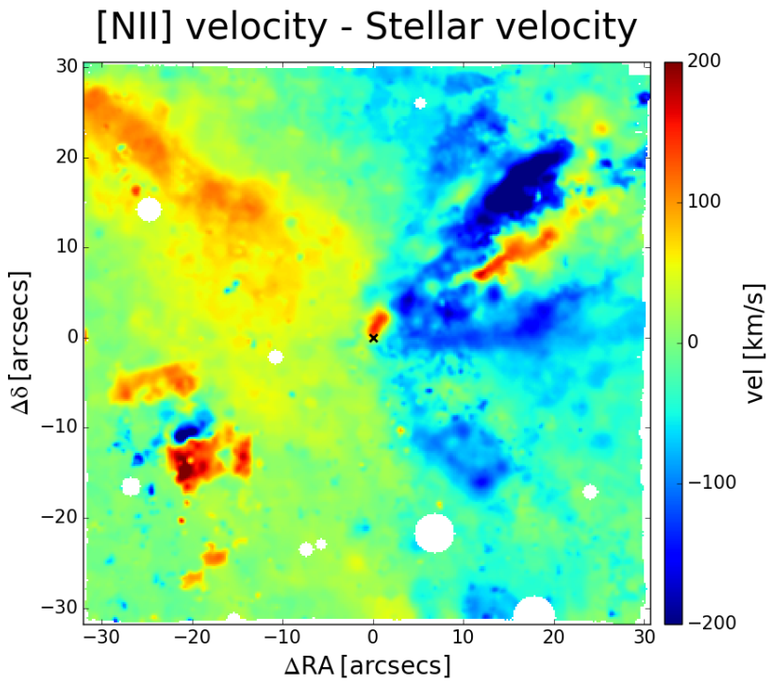
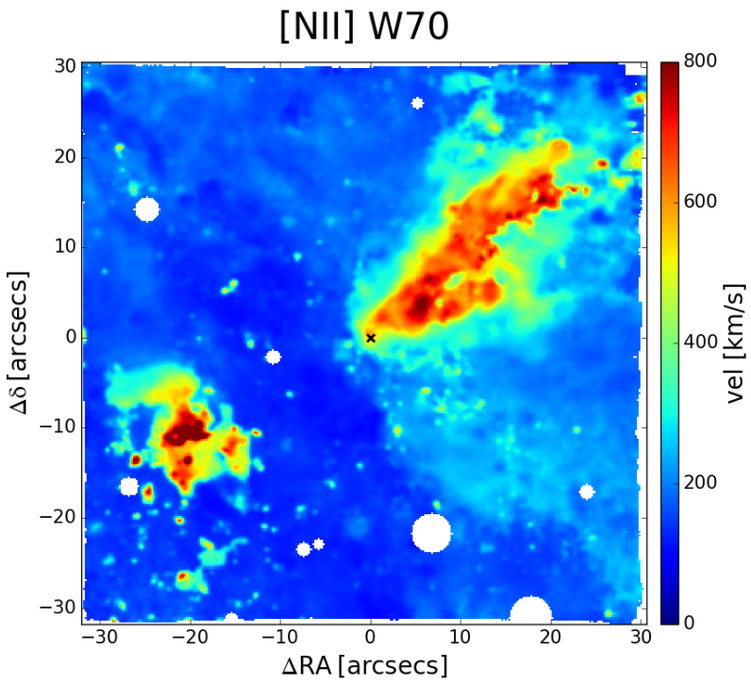
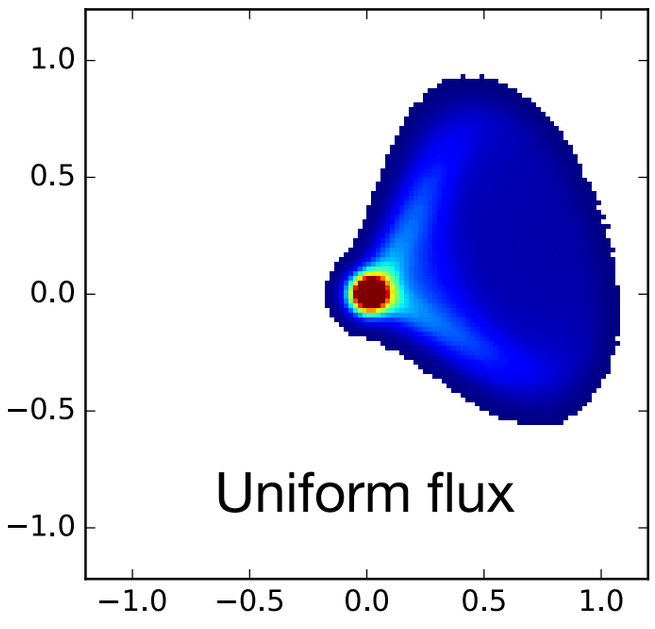
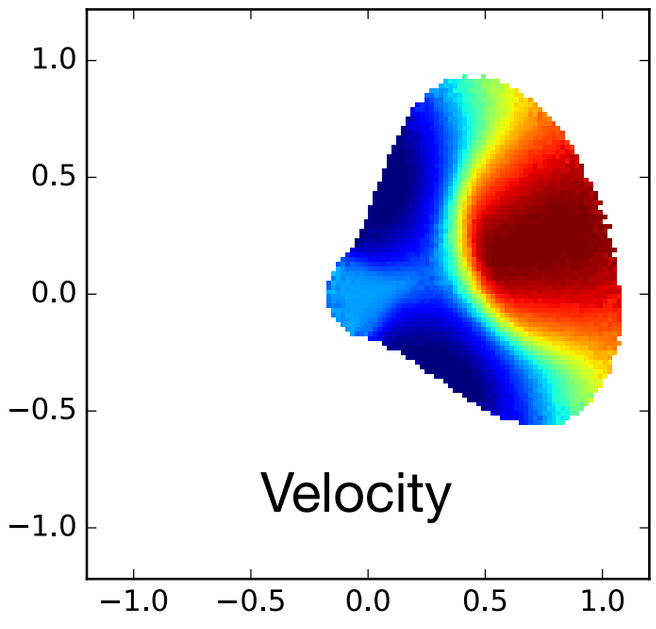


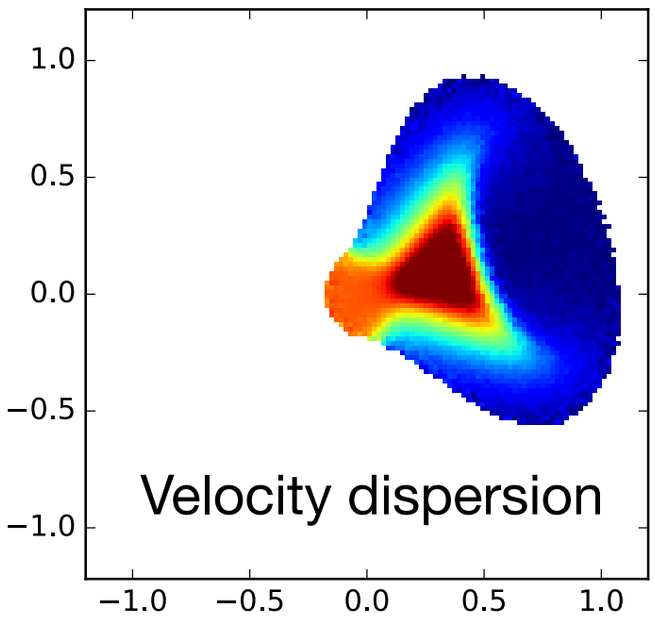




A simple kinematical model: hollow cone







New outflow 3D reconstruction

But **real gas is clumpy**, not uniform!

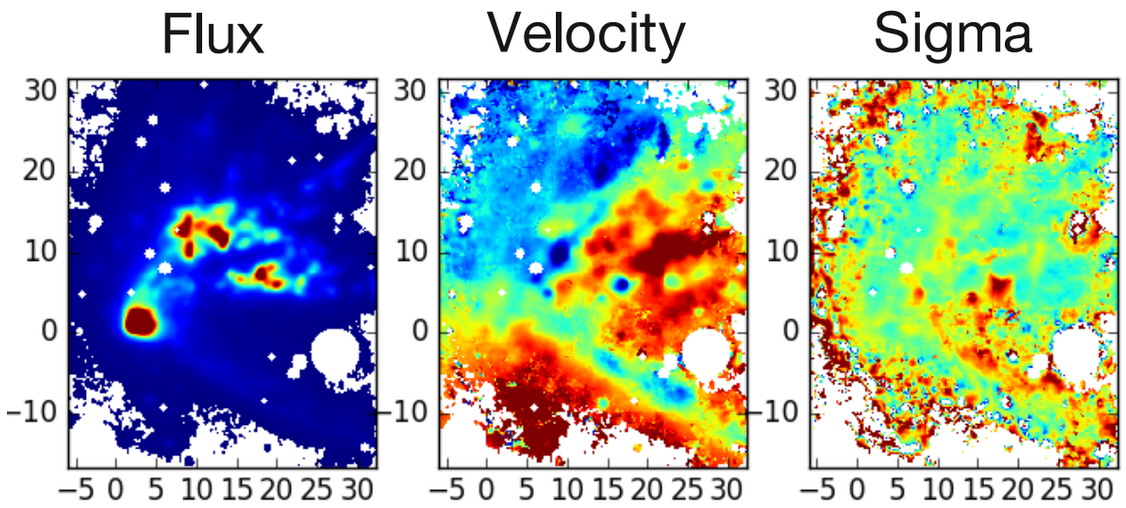
Our new outflow tomographic reconstruction: test on **Circinus** MUSE data

New outflow 3D reconstruction

But **real gas is clumpy**, not uniform!

Our new outflow tomographic reconstruction: test on **Circinus** MUSE data

Data: [OIII] maps



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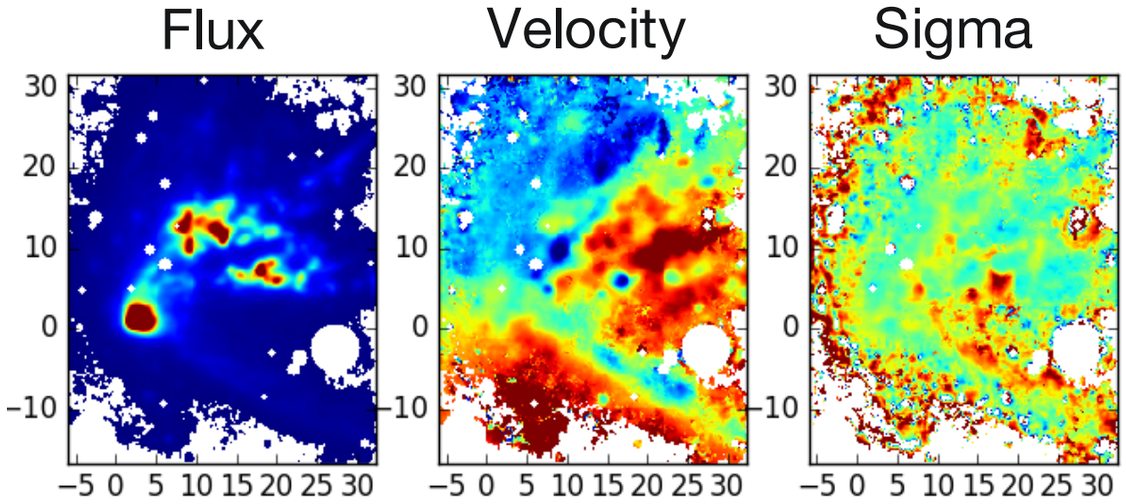
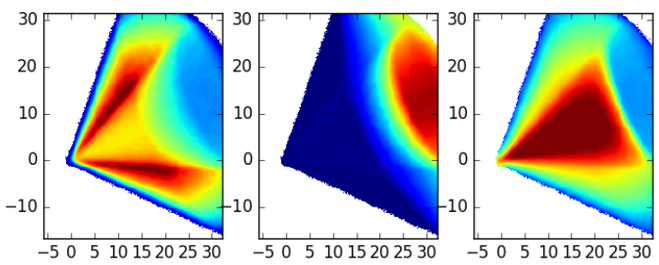


Model parameters:

- Hollow cone
- Constant velocity field
- Inclination 70° w.r.t. l.o.s.



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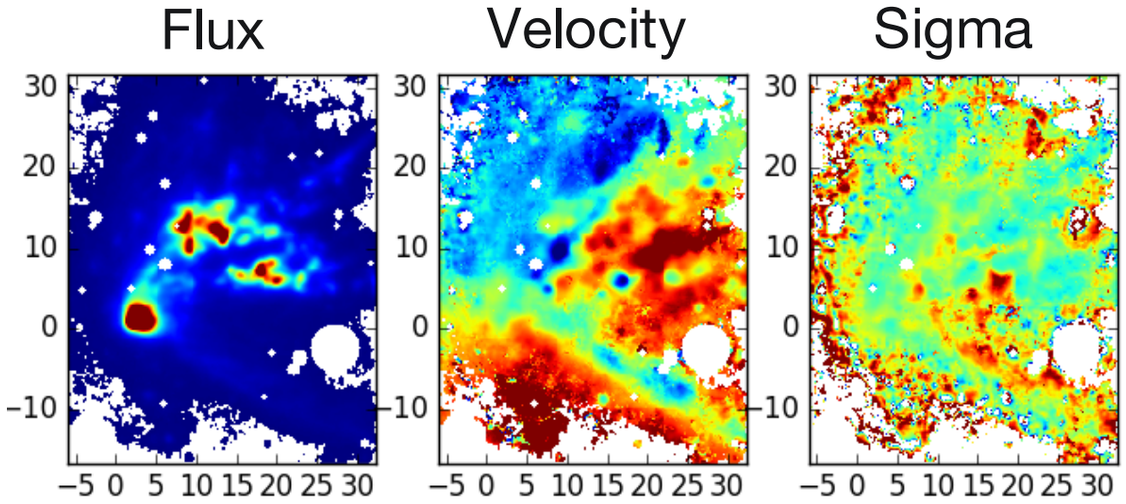
Our new outflow tomographic reconstruction: test on **Circinus** MUSE data

3D reconstruction based on (x,y,v) observed data, assuming velocity field:

Data: [OIII] maps



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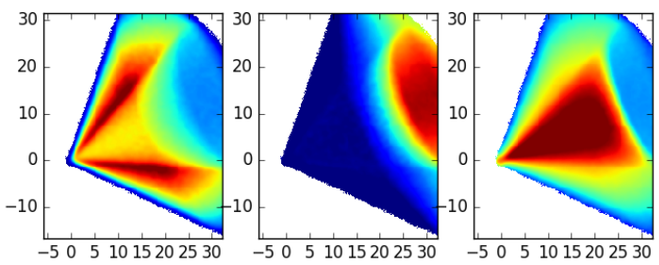
- Hollow cone
- Constant velocity field
- Inclination 70° w.r.t. l.o.s.



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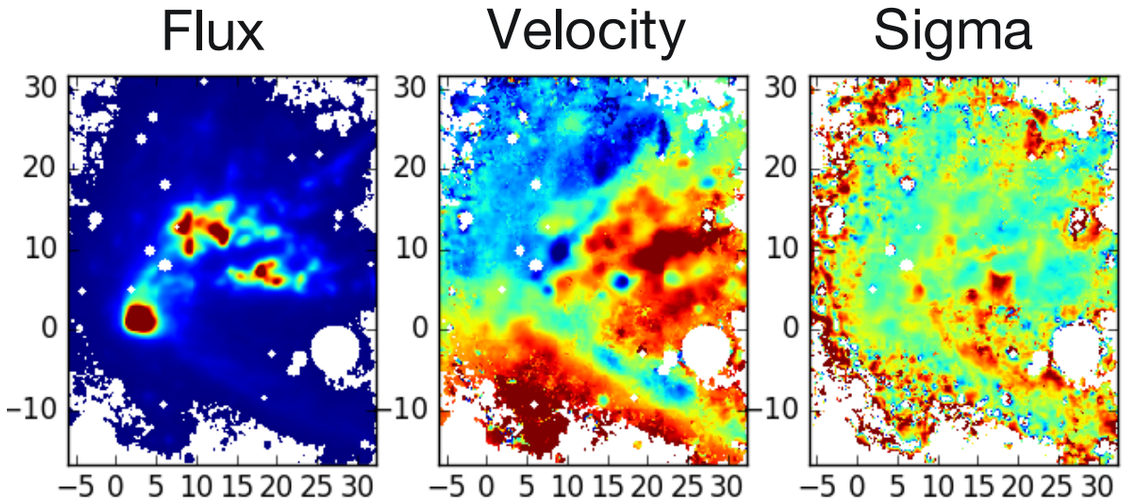
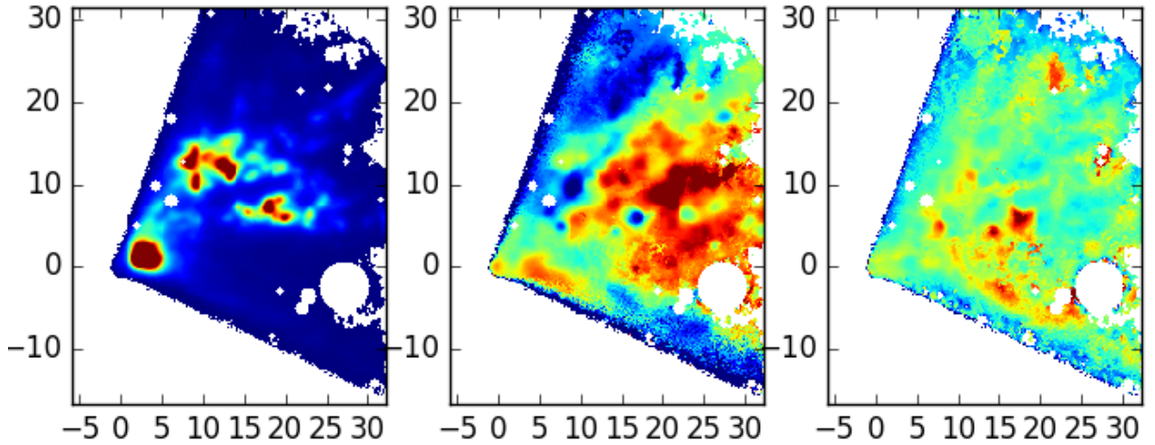
3D reconstruction based on (x,y,v) observed data, assuming velocity field:

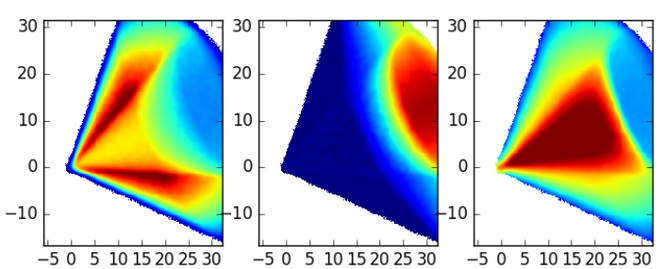
Data: [OIII] maps





Model parameters:

- Hollow cone
- Constant velocity field
- Inclination 70° w.r.t. l.o.s.



Wow! It's almost identical to the observed maps!

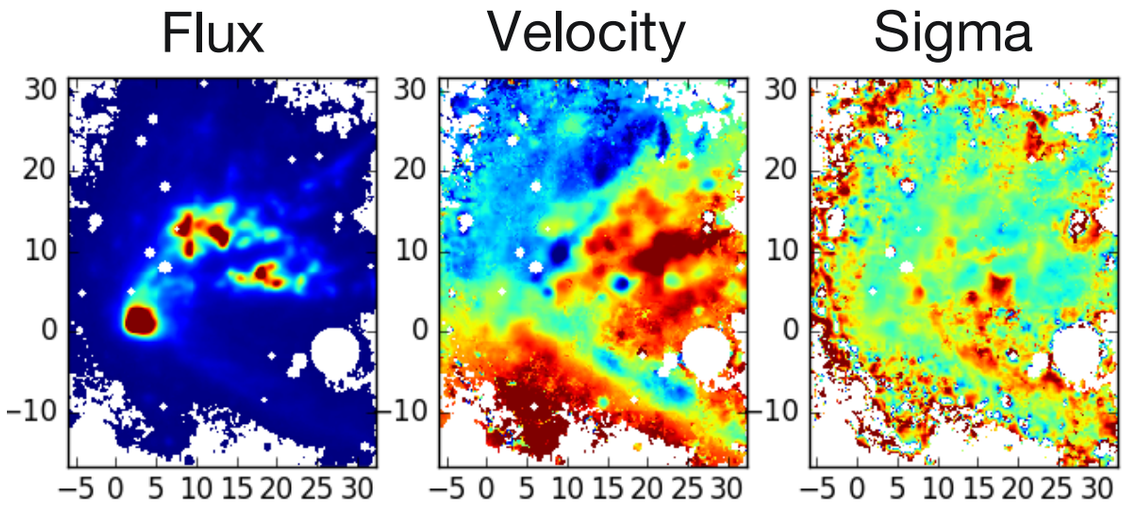
New outflow 3D reconstruction

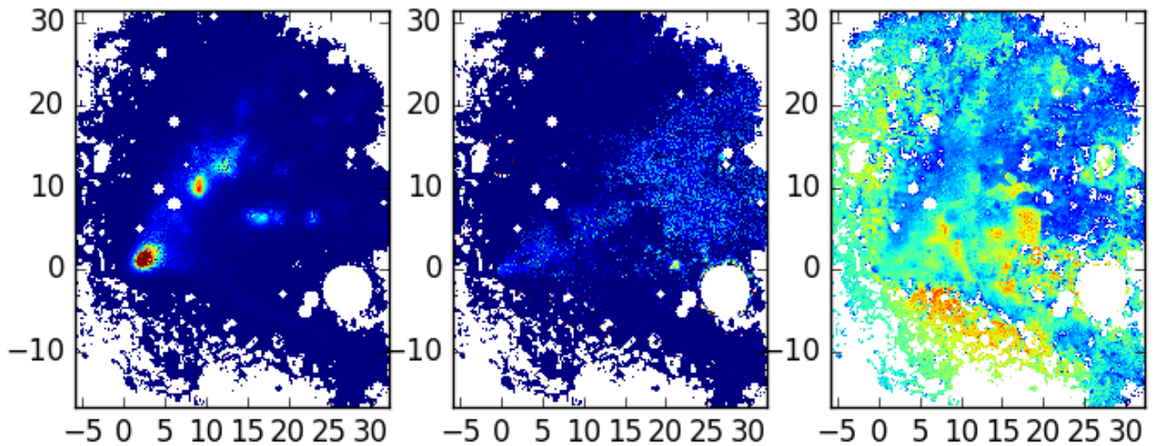
But **real gas is clumpy**, not uniform!

Our new outflow tomographic reconstruction: test on Circinus MUSE data

3D reconstruction based on (x,y,v) observed data, assuming velocity field:

Data: [OIII] maps





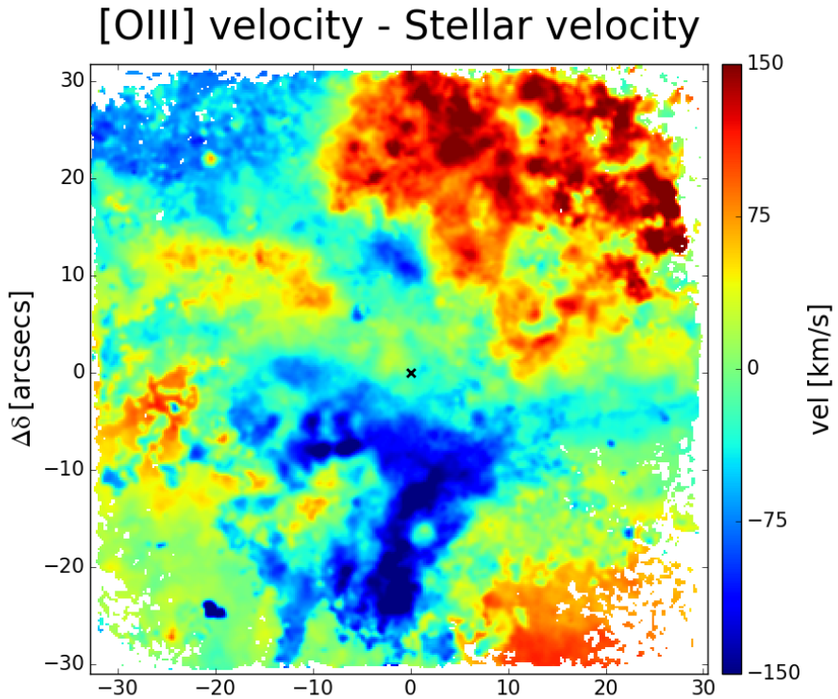
Model parameters:

- Hollow cone
- Constant velocity field
- Inclination 30° w.r.t. l.o.s.

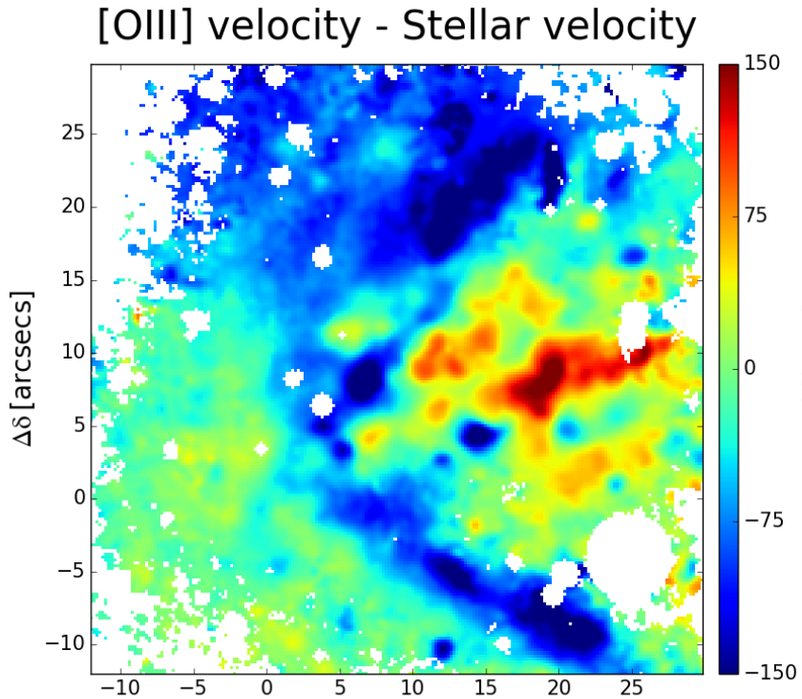
Now observed maps are not reproduced anymore by the 3D reconstruction

Outflows and gas ionization

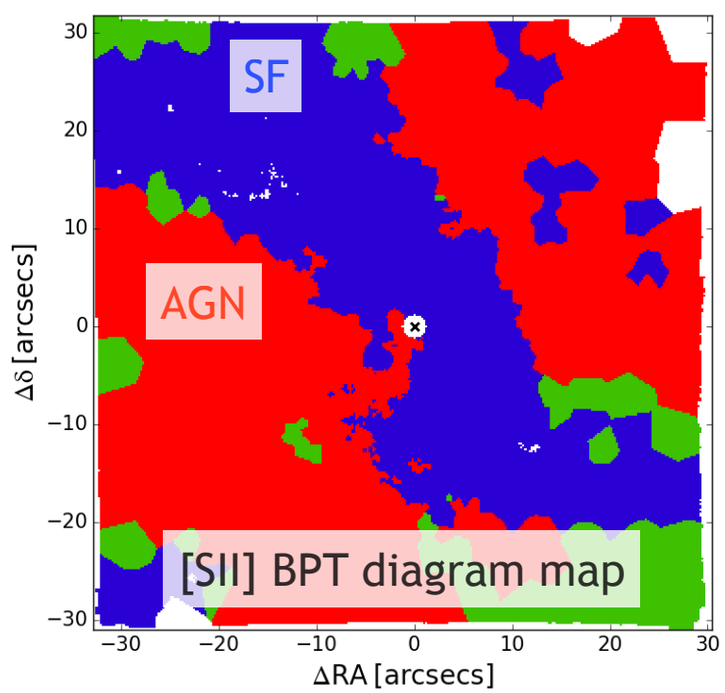
Outflows are associated with AGN ionization



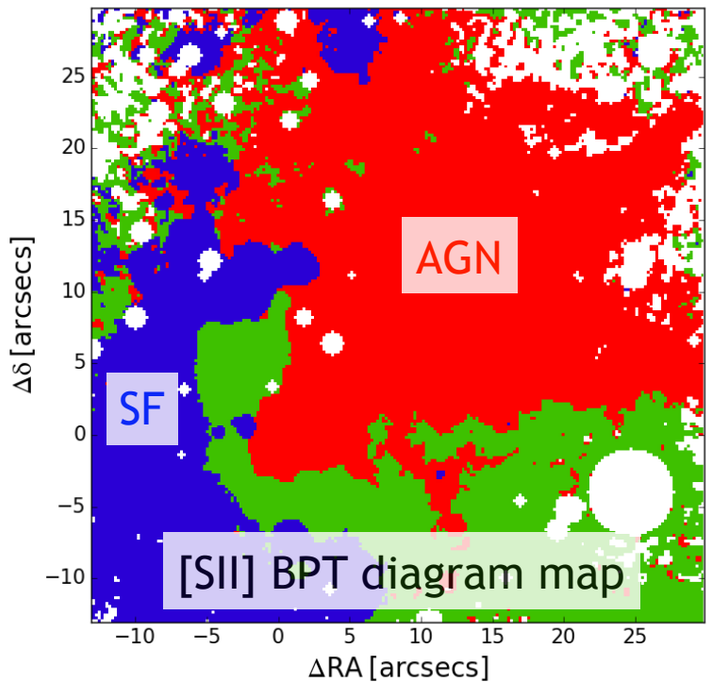
e.g.



NGC 1365



Circinus



Outflows and gas ionization

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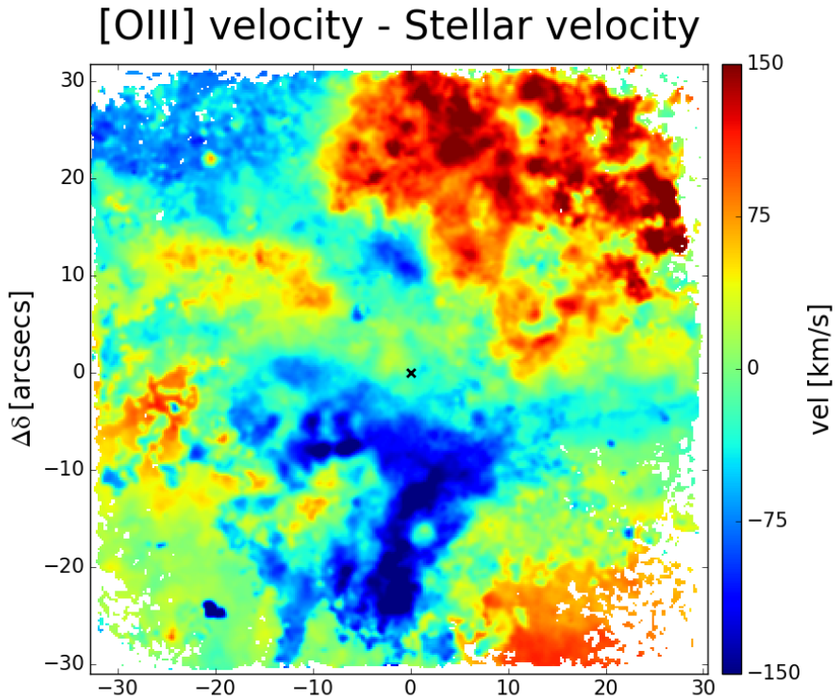
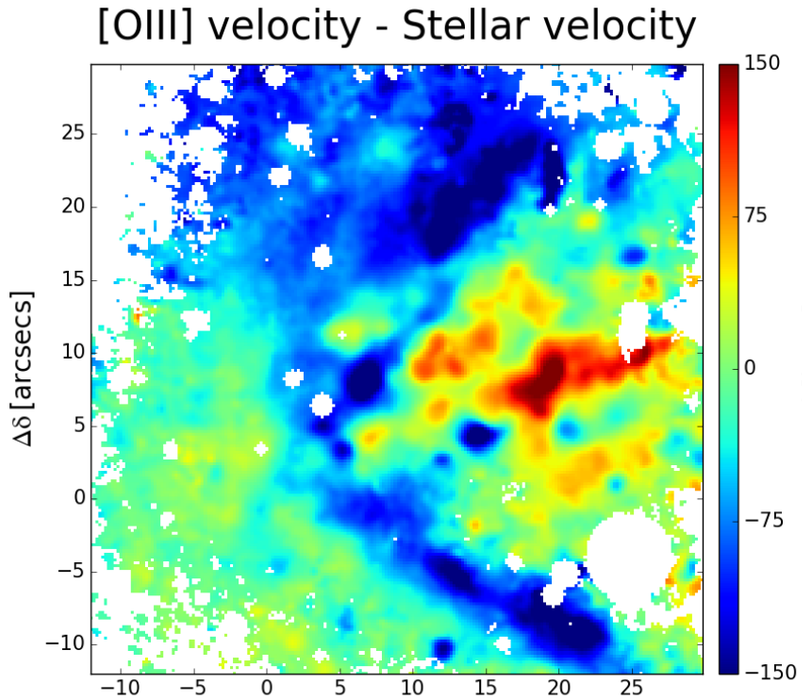
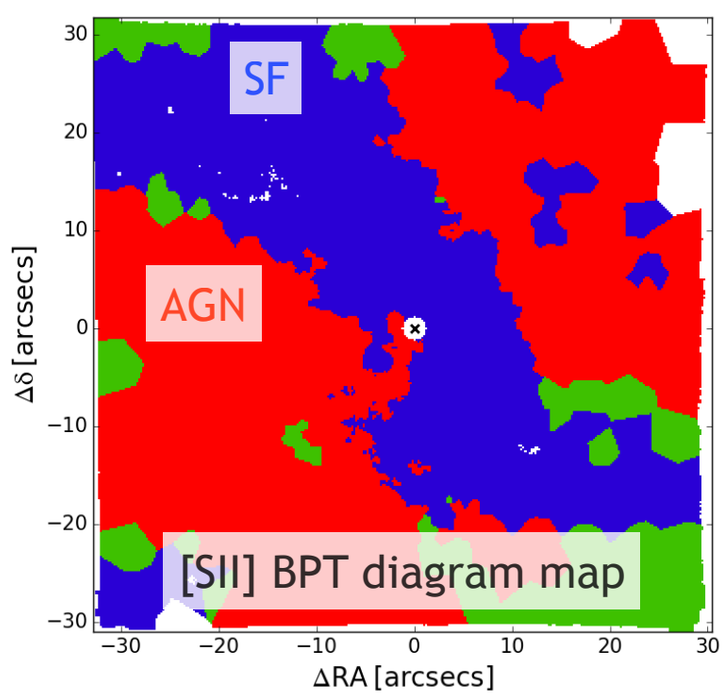


e.g.

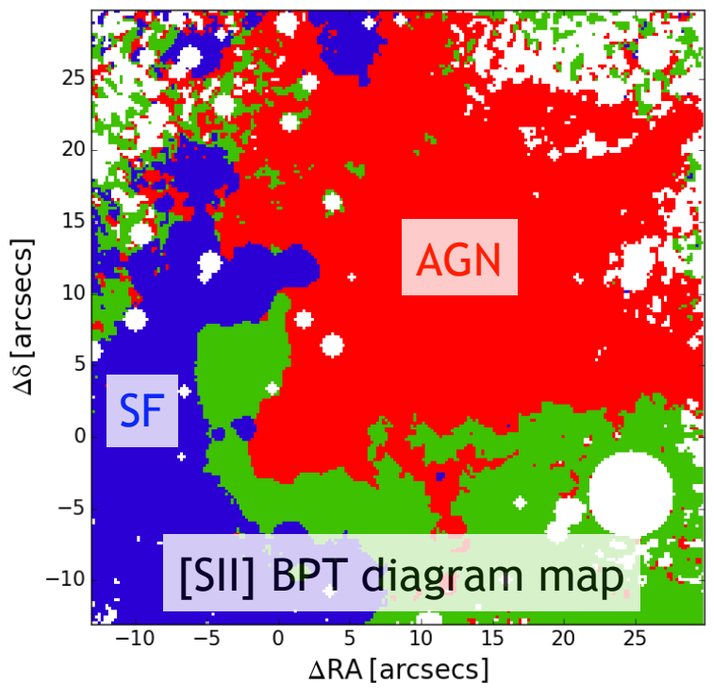


NGC 1365

Circinus



but…

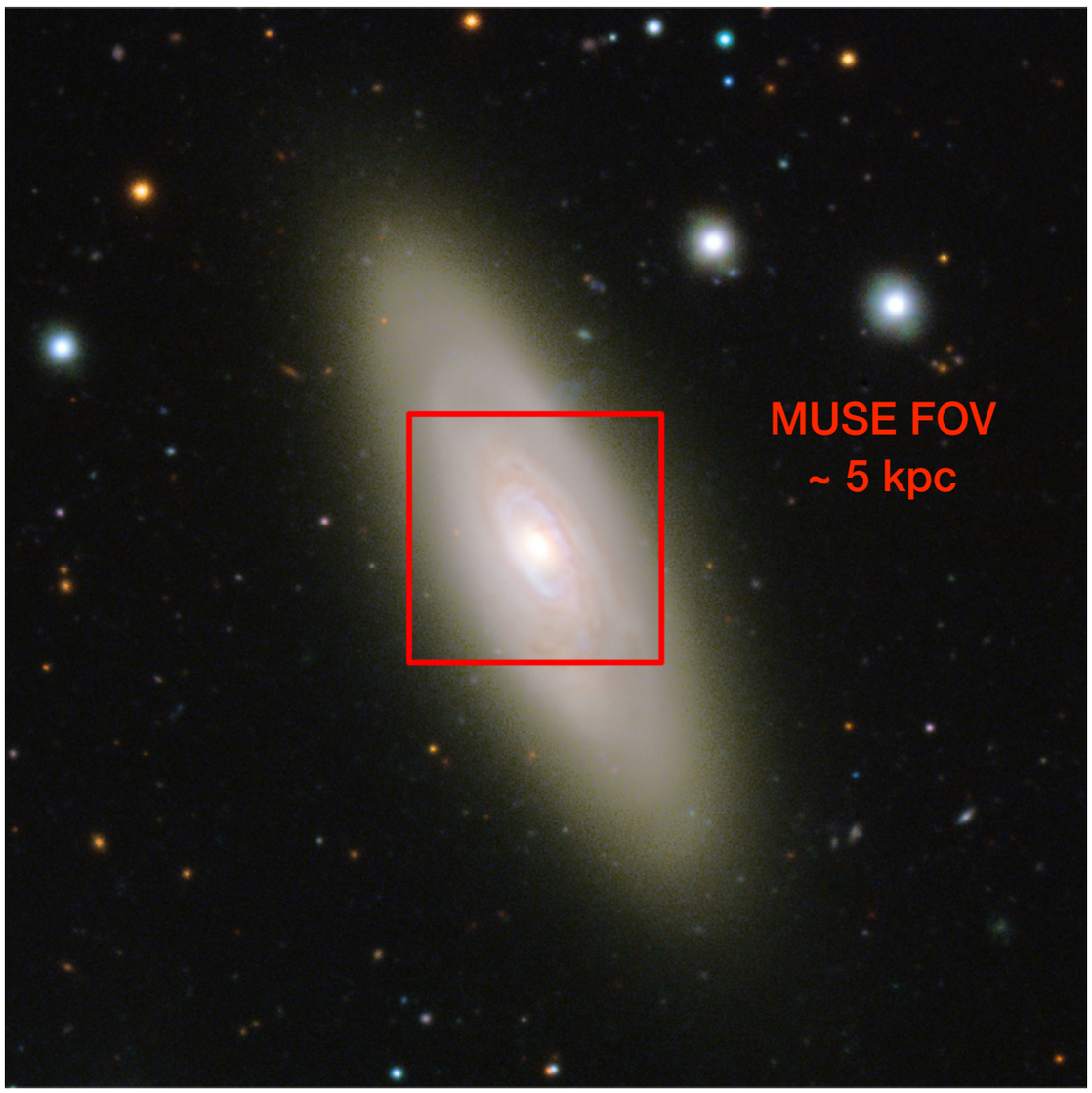


Outflows vs jets

Outflows vs jets

…not in all MAGNUM galaxies

NGC 1386

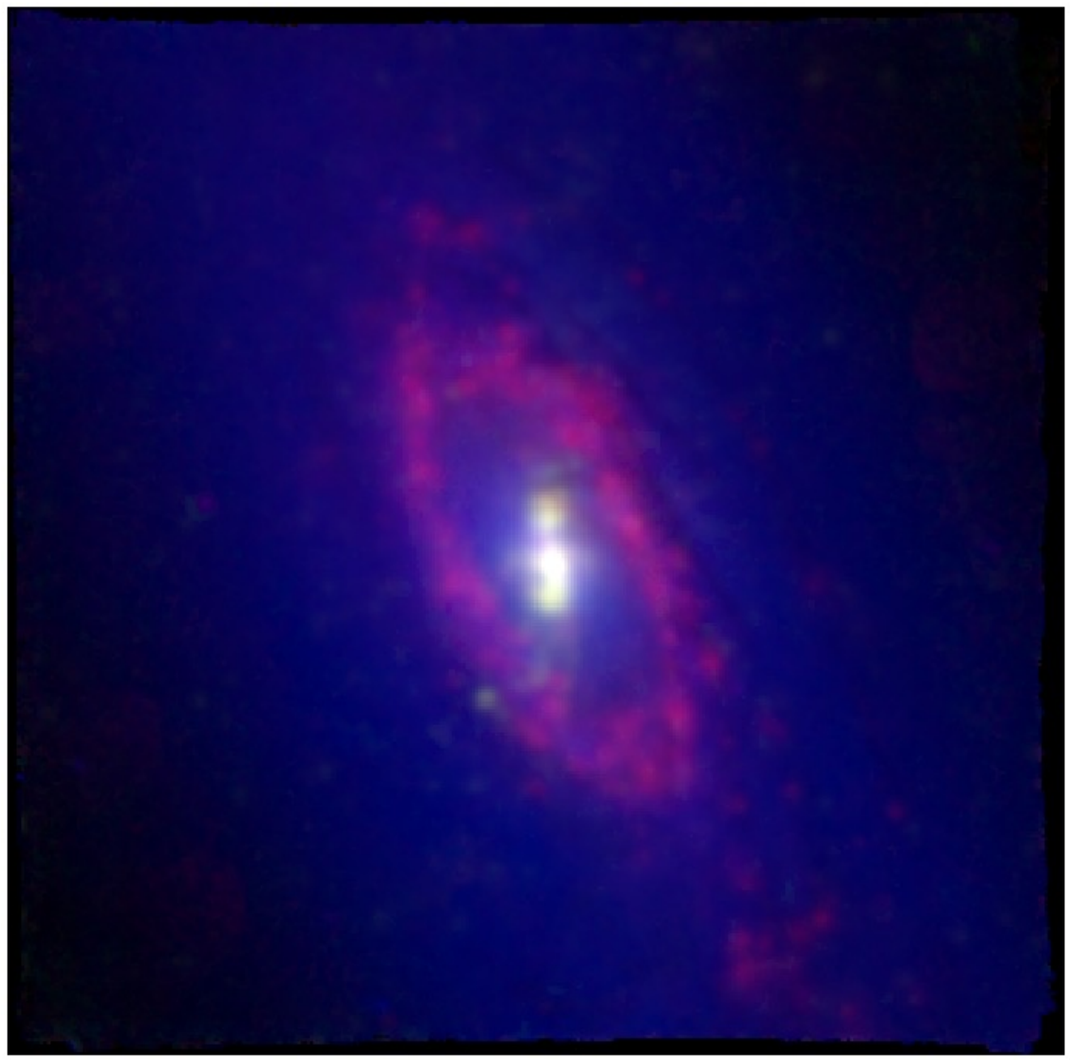


Outflows vs jets

…not in all MAGNUM galaxies

Red: Hα, green: [OIII],
blue: blue stellar continuum

NGC 1386



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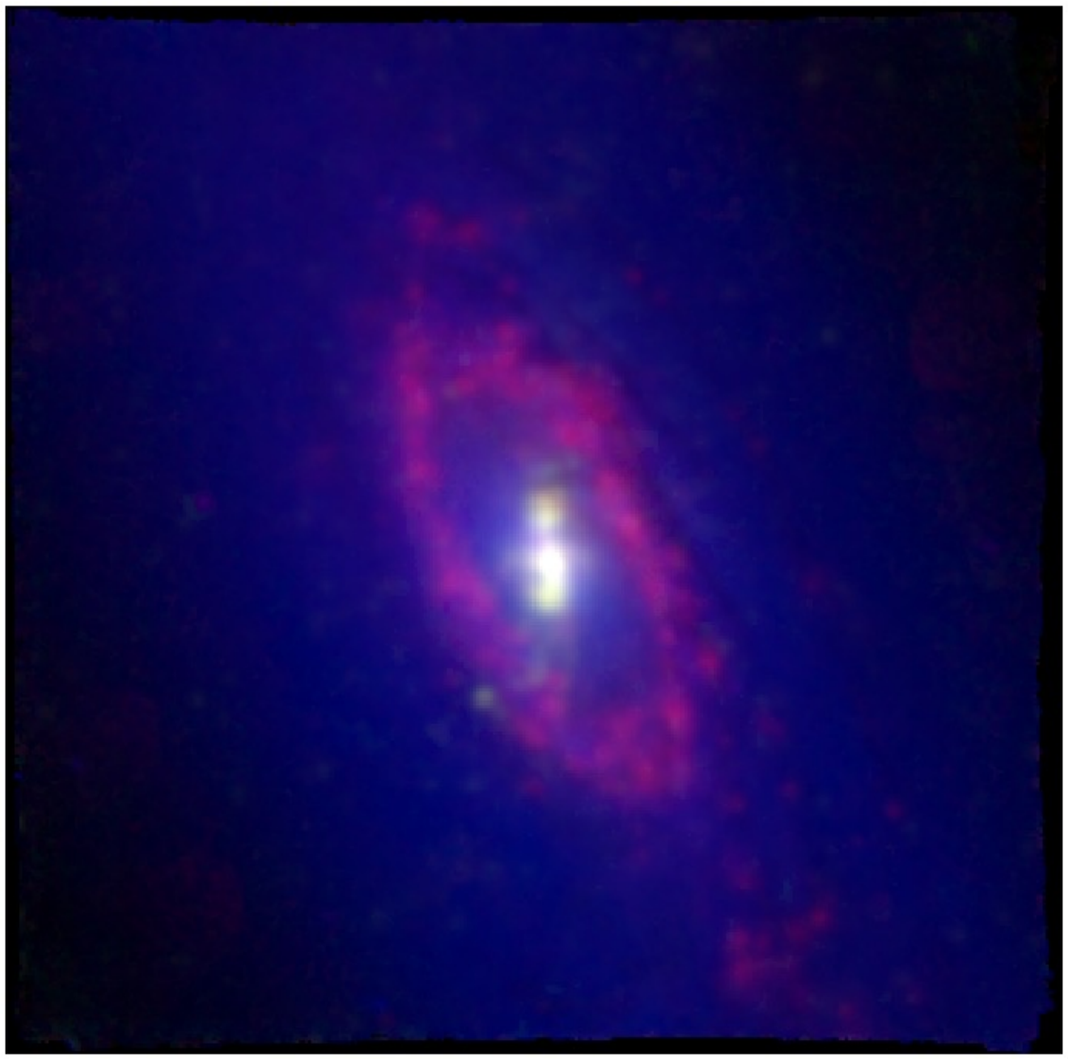
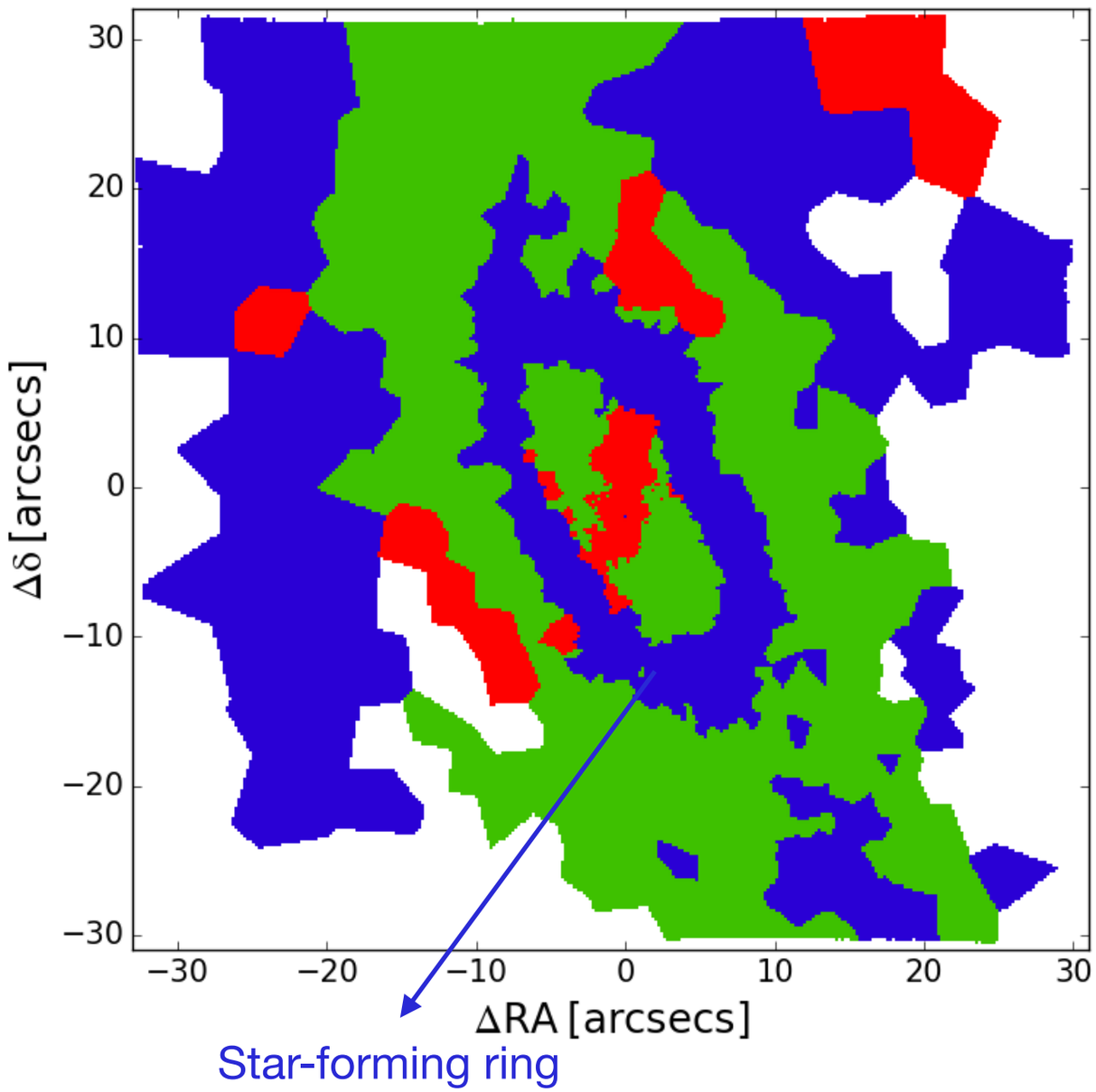


NGC 1386

Photoionization from
[SII] BPT diagram



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…not in all MAGNUM galaxies

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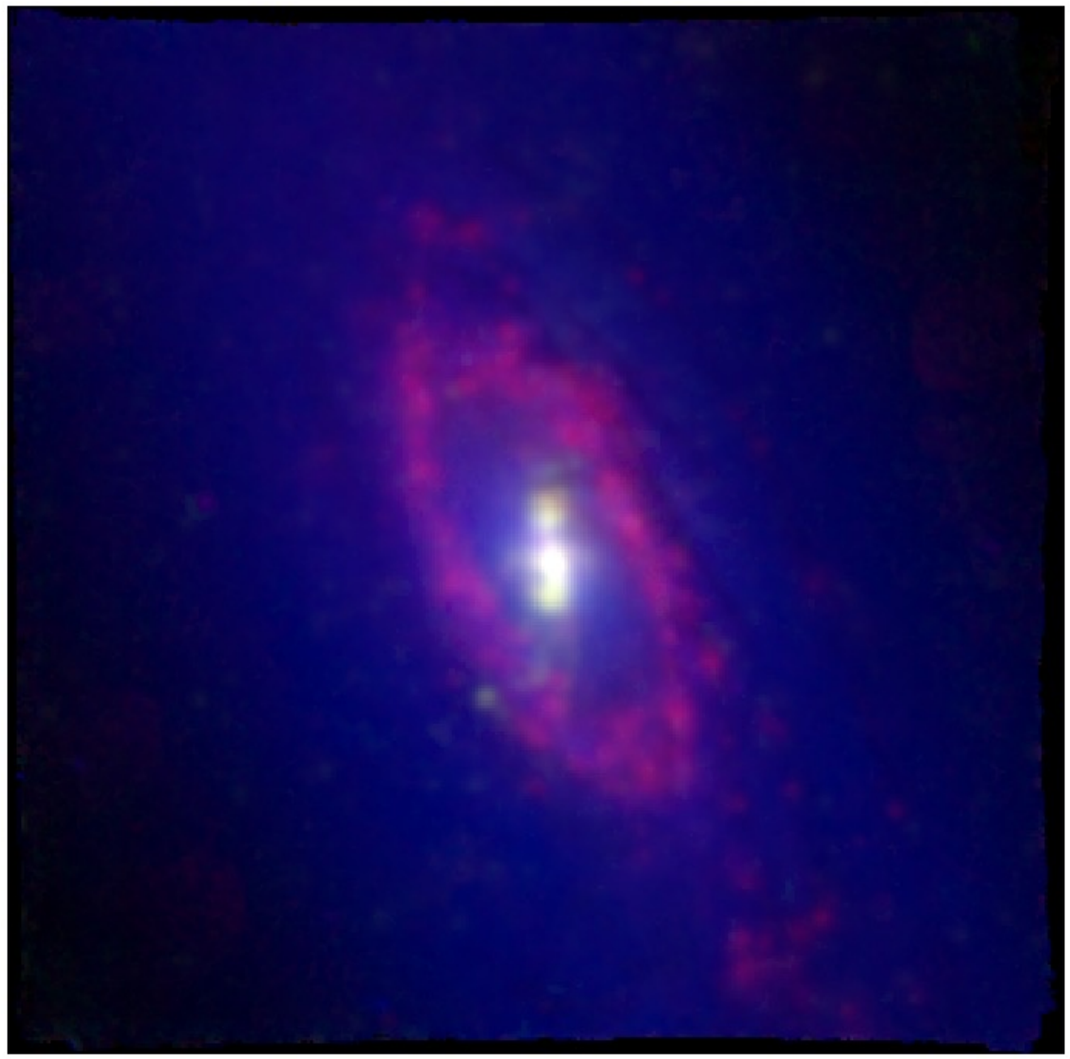
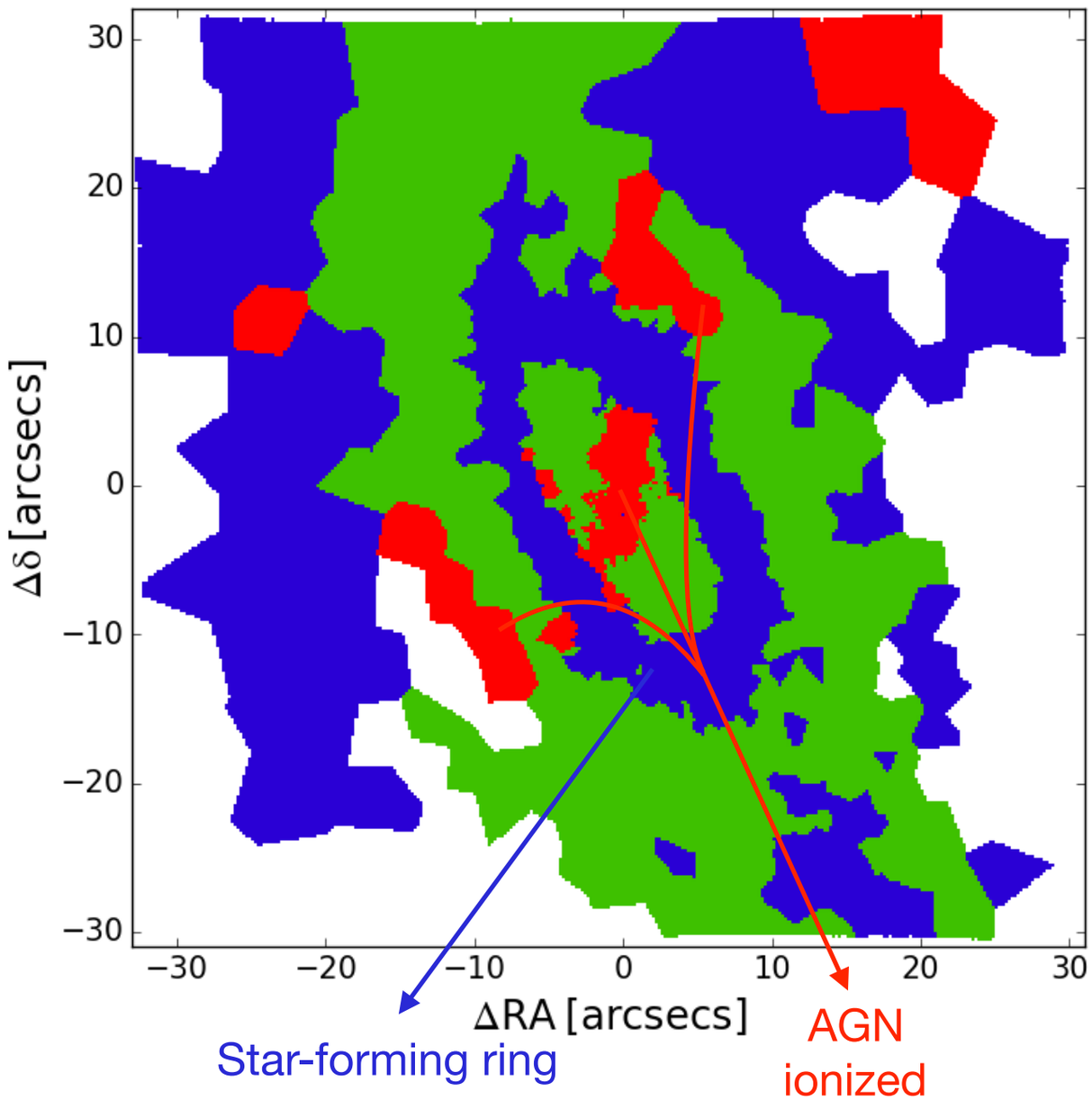


NGC 1386

Photoionization from
[SII] BPT diagram



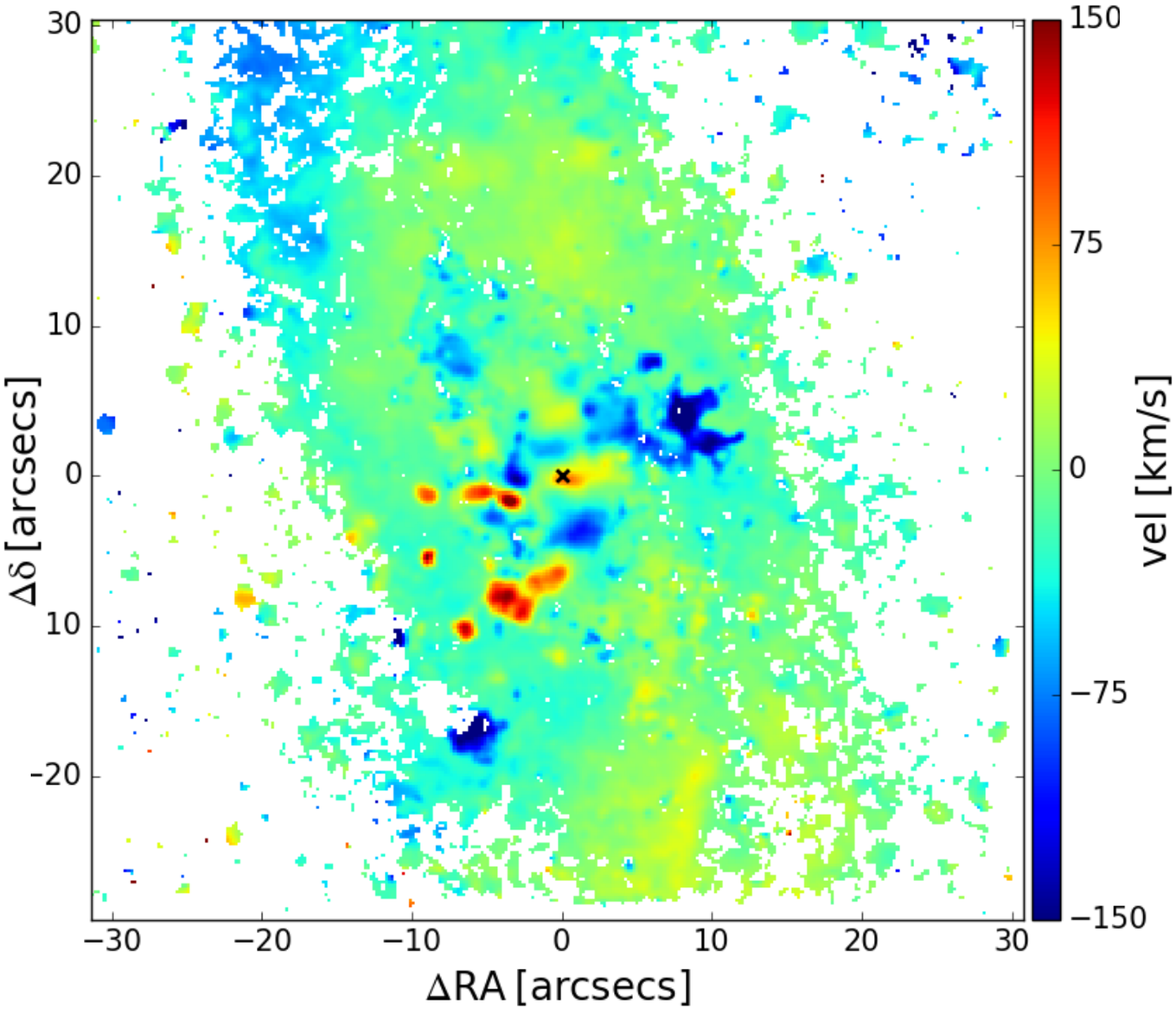
Outflows vs jets

…not in all MAGNUM galaxies

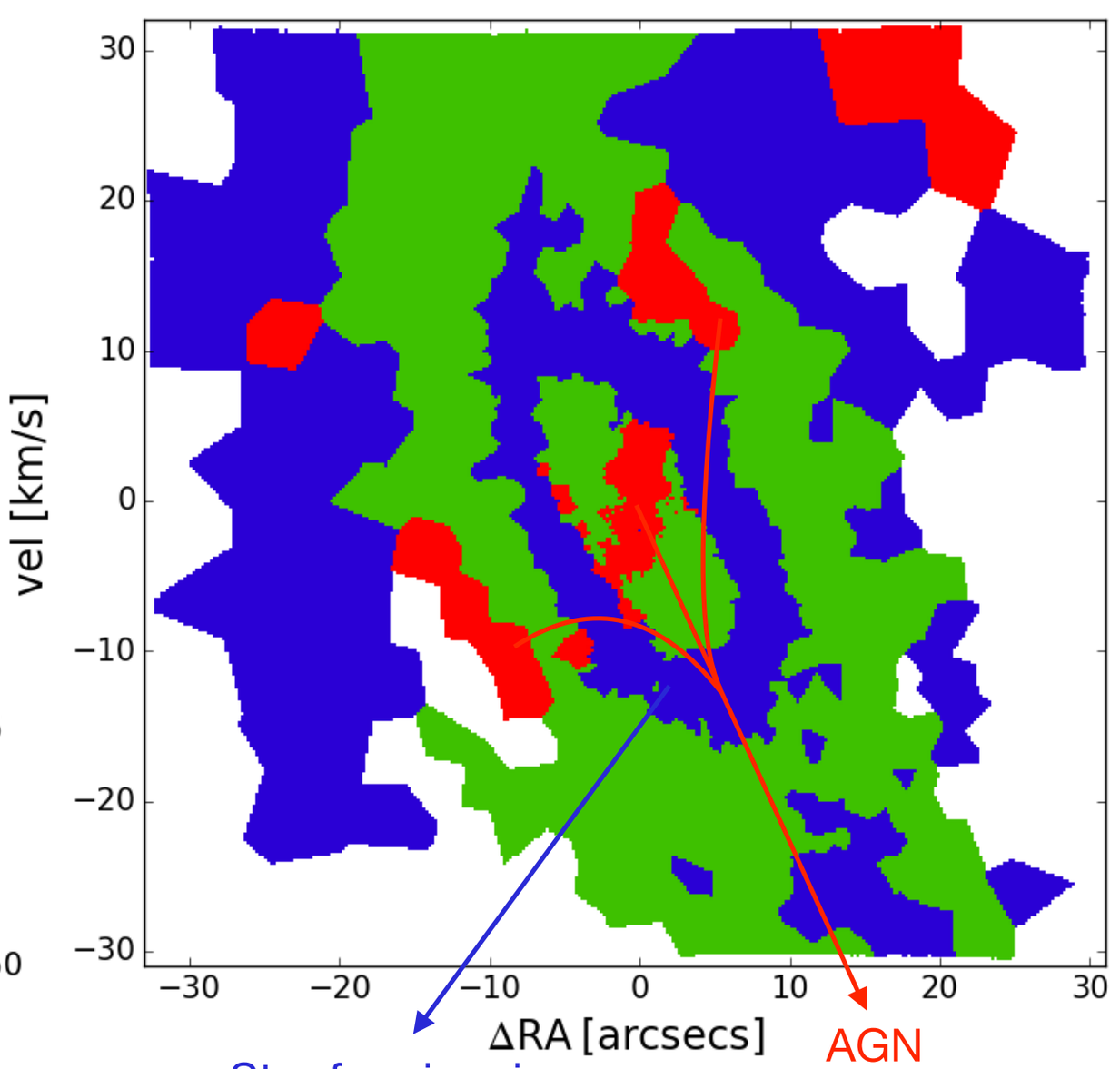
Outflow not aligned with AGN ionization —> almost perpendicular

NGC 1386

[OIII] velocity - stellar velocity



Photoionization from [SII] BPT diagram



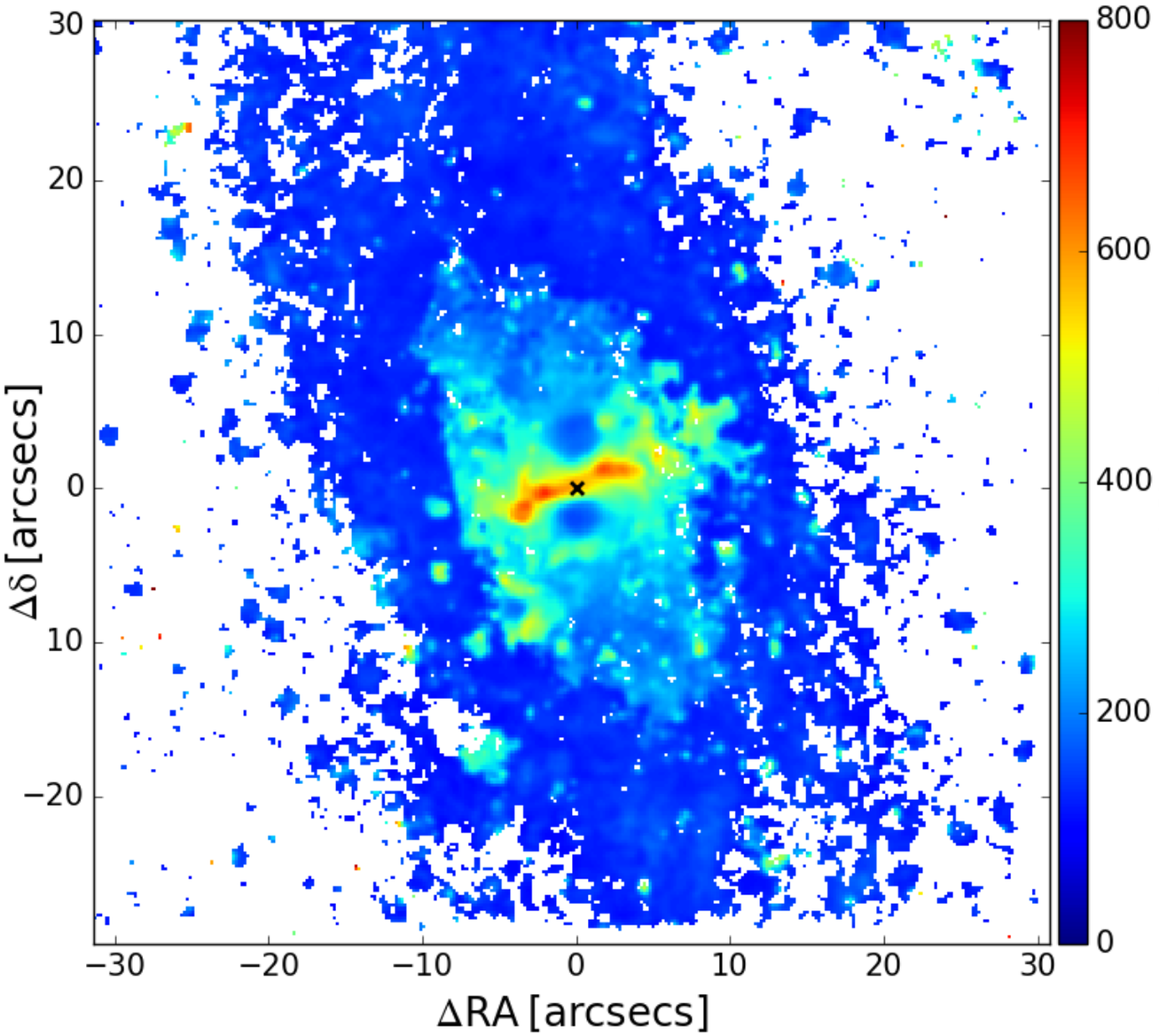
Outflows vs jets

…not in all MAGNUM galaxies

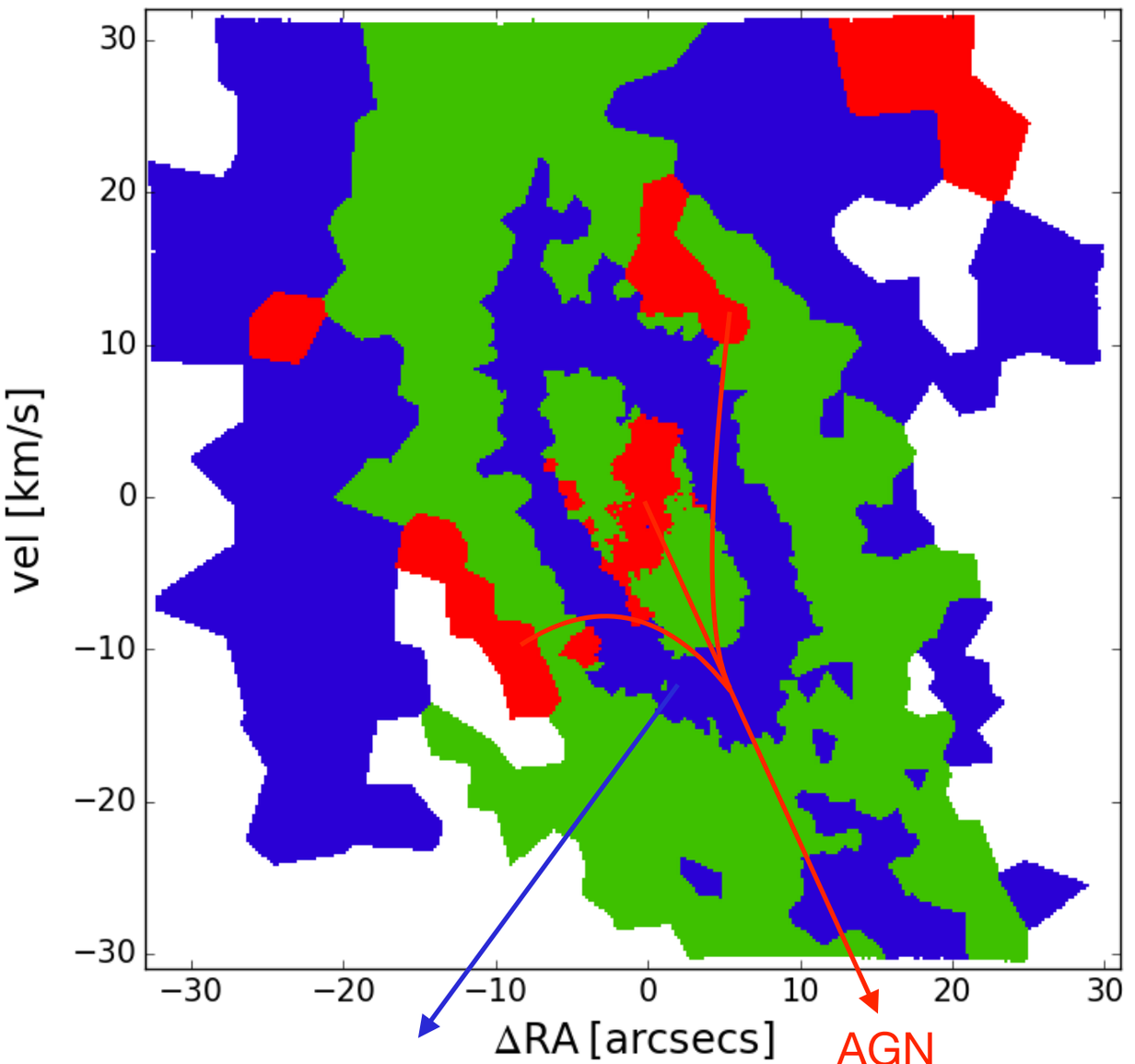
Outflow not aligned with AGN ionization —> almost perpendicular

NGC 1386

[OIII] W70



Photoionization from [SII] BPT diagram



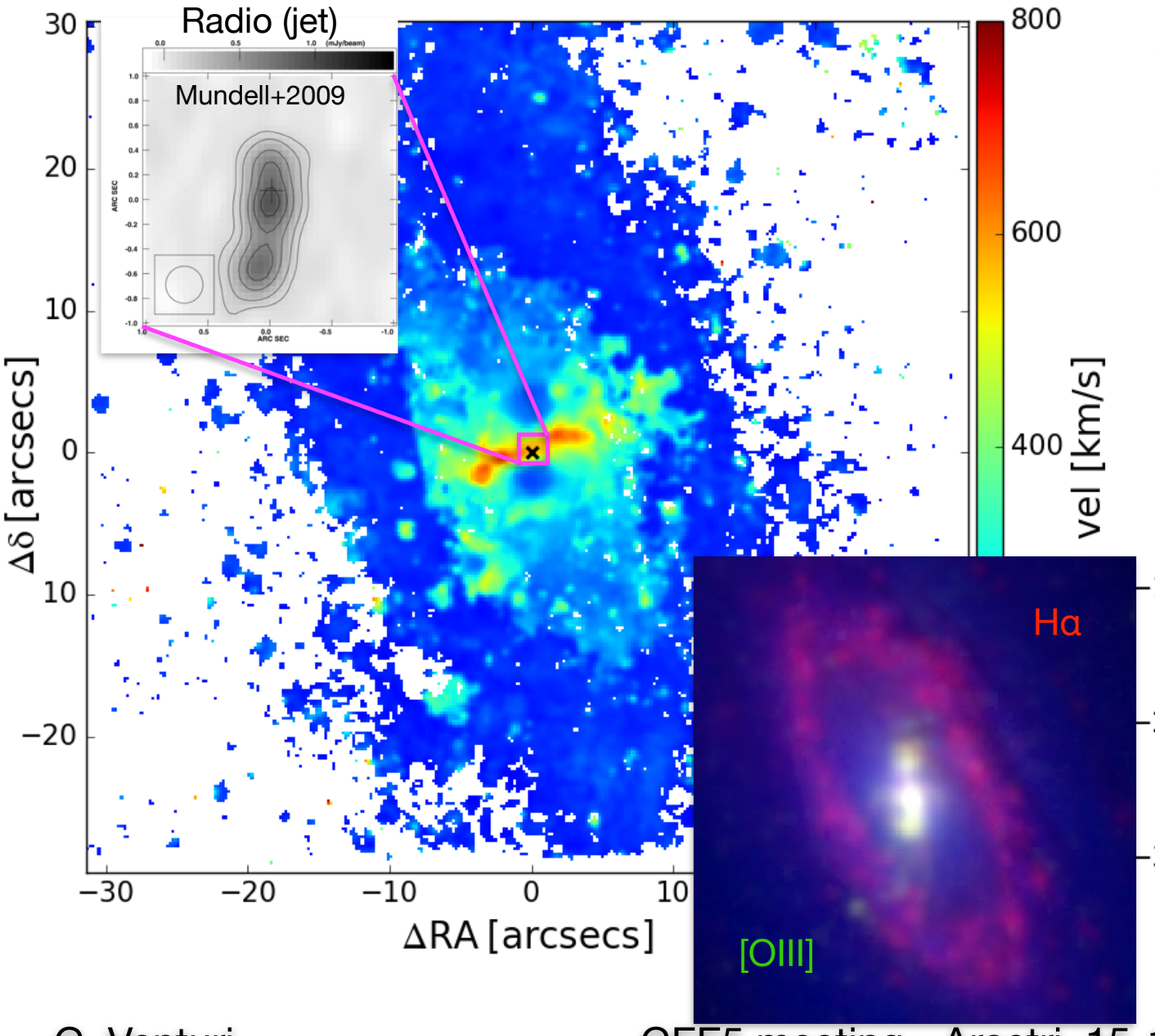
Outflows vs jets

…not in all MAGNUM galaxies

Outflow not aligned with AGN ionization —> almost perpendicular

NGC 1386

[OIII] W70



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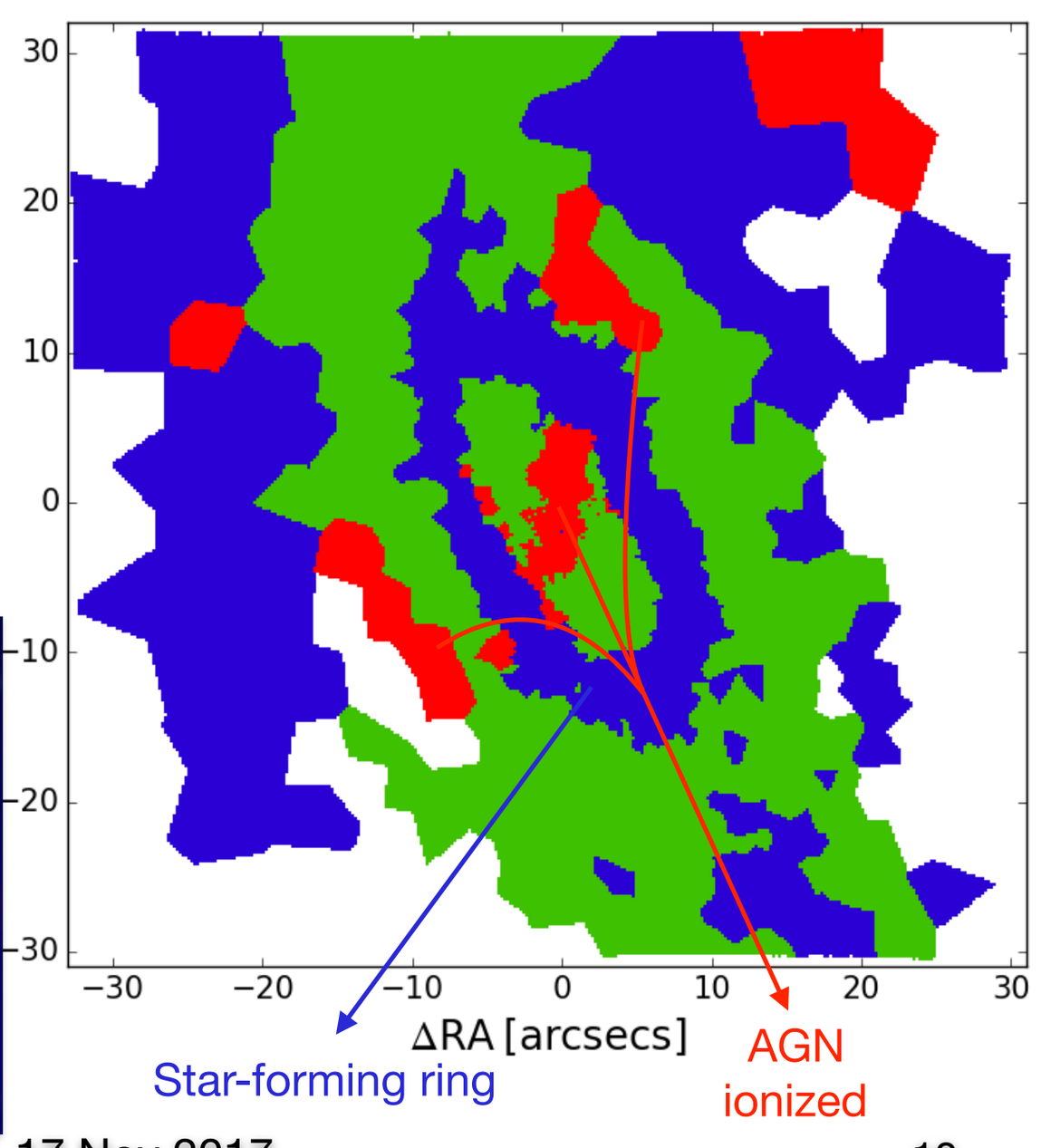


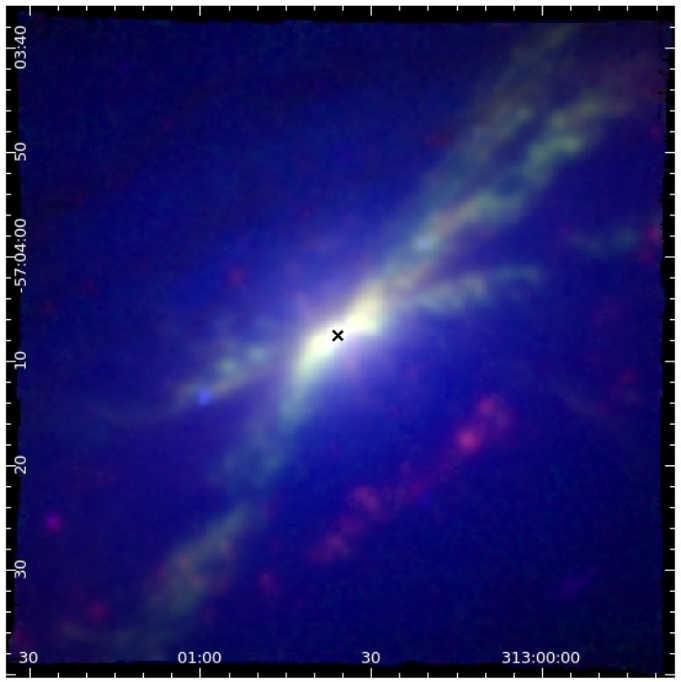
Outflows vs jets

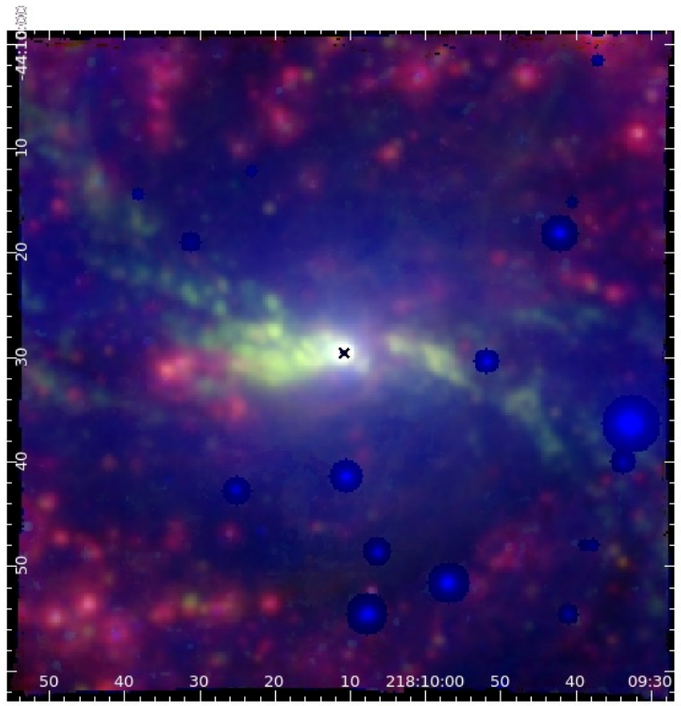
In 2 other galaxies we observe outflows perpendicular to AGN cone and radio jet!

IC 5063

FOV ~ 14 kpc

Green: [OIII]
Red: Hα
Blue: stars



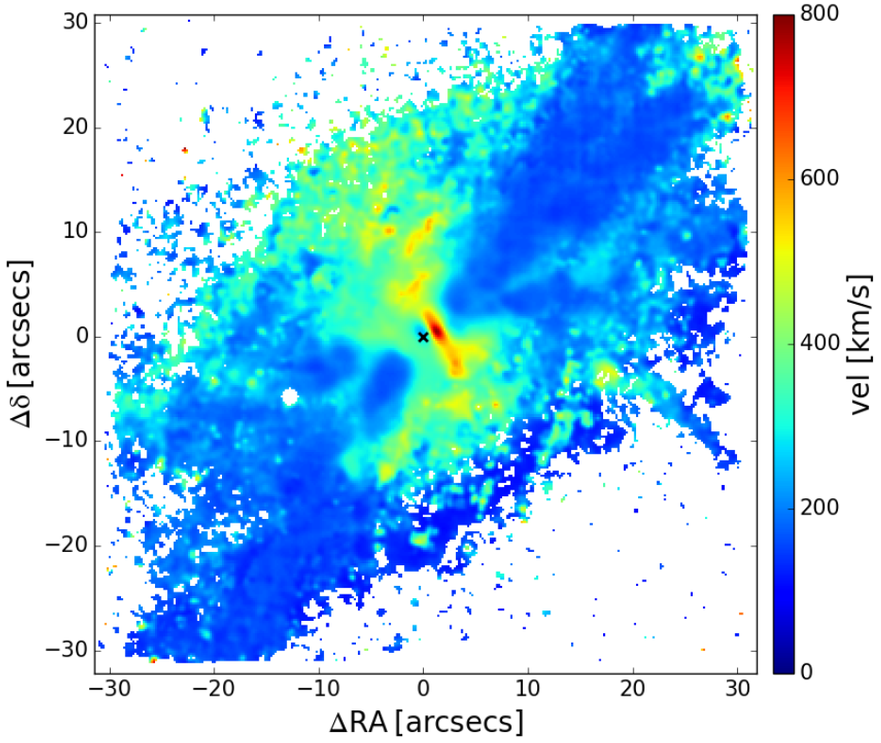


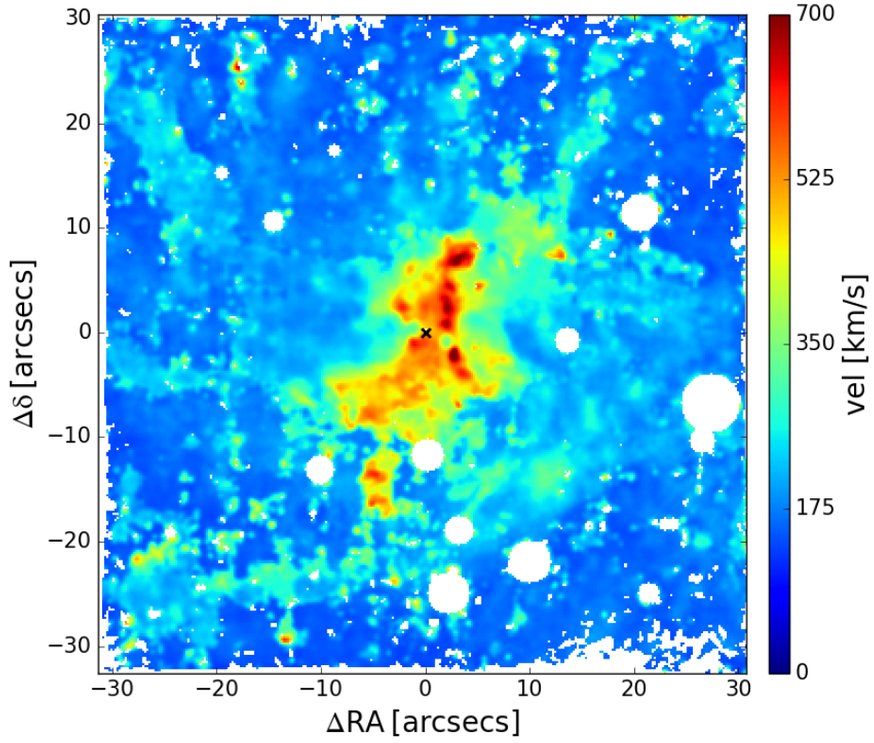
NGC 5643

FOV ~ 5 kpc

Green: [OIII]
Red: Hα
Blue: stars

[OIII] W70





[OIII] W70

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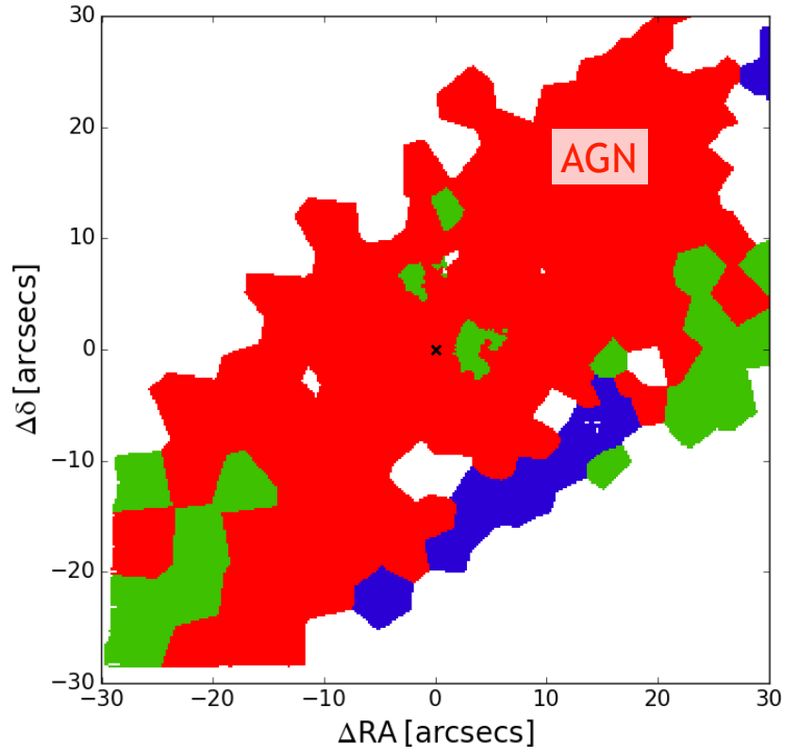
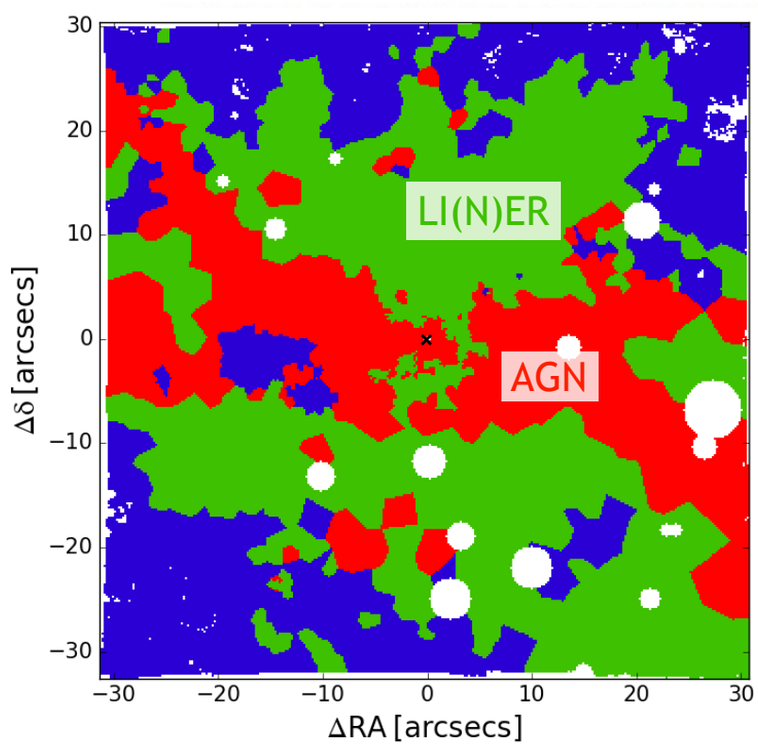
FOV ~ 14 kpc

[SII] BPT map



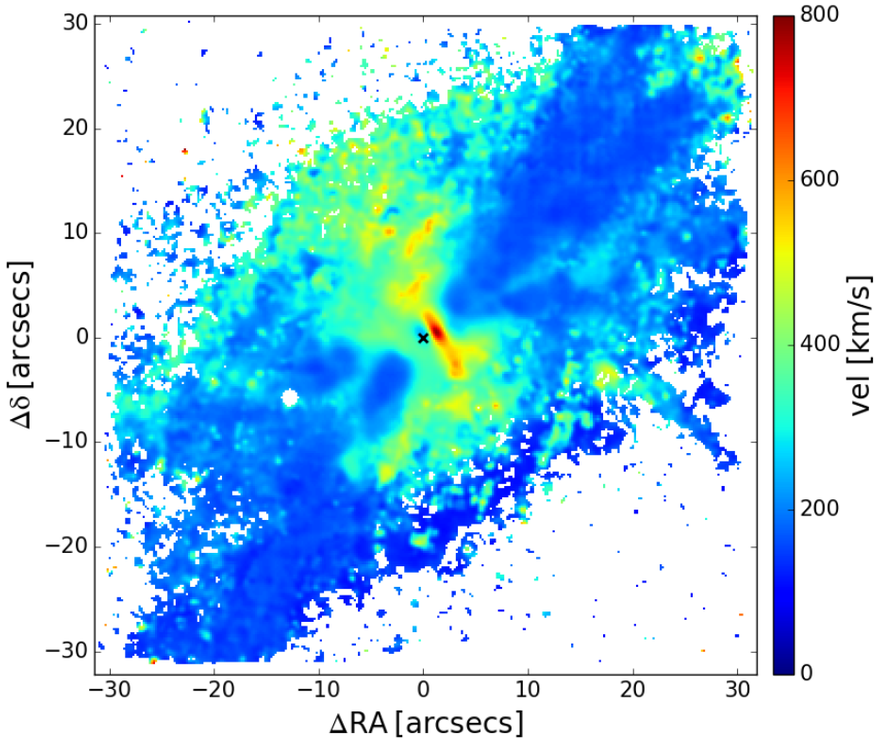


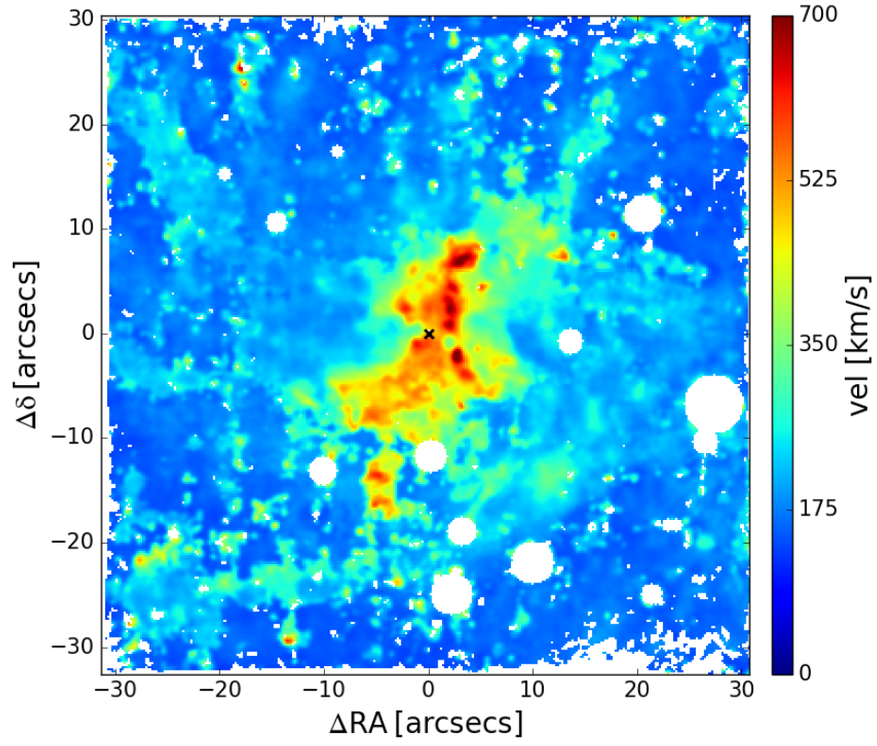
NGC 5643

FOV ~ 5 kpc

[SII] BPT map

[OIII] W70





[OIII] W70

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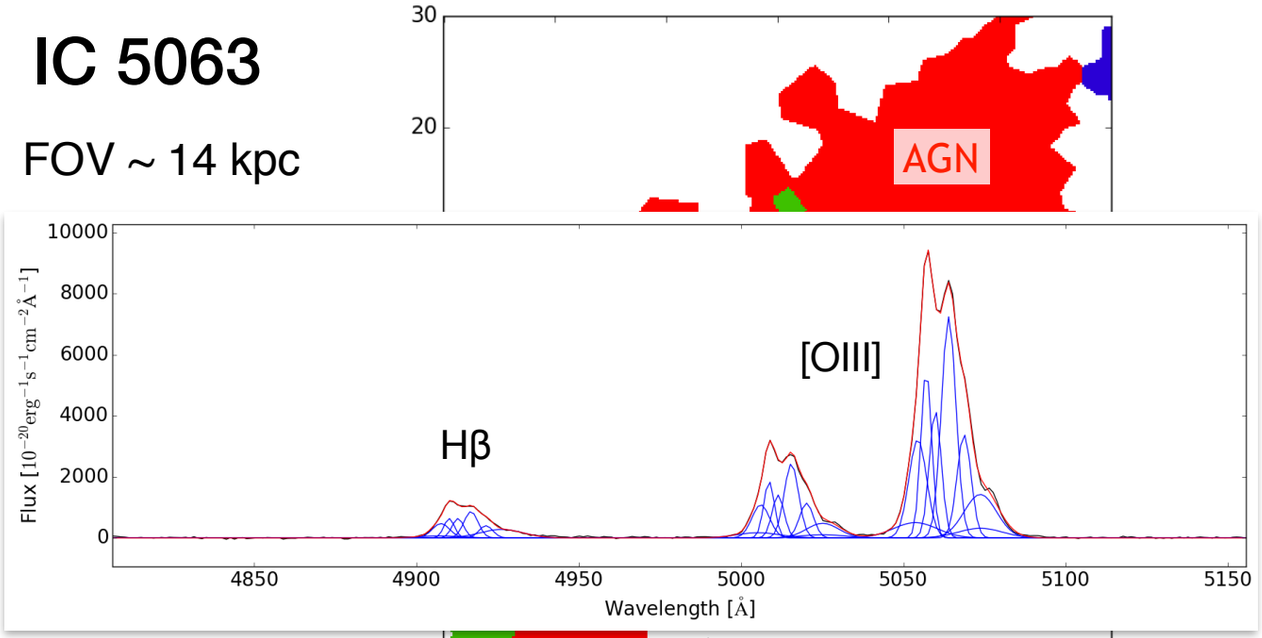
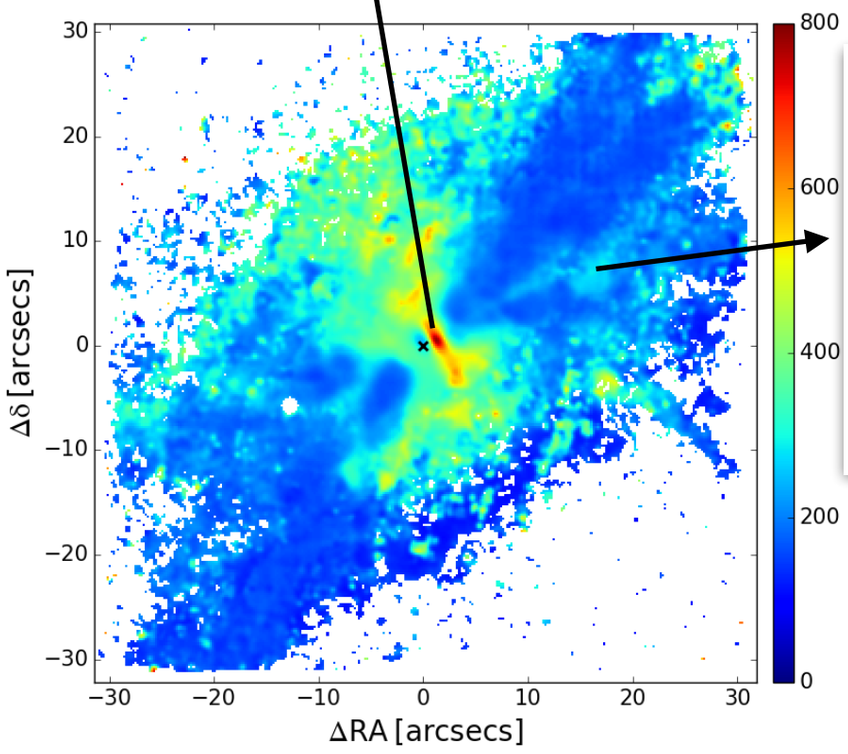


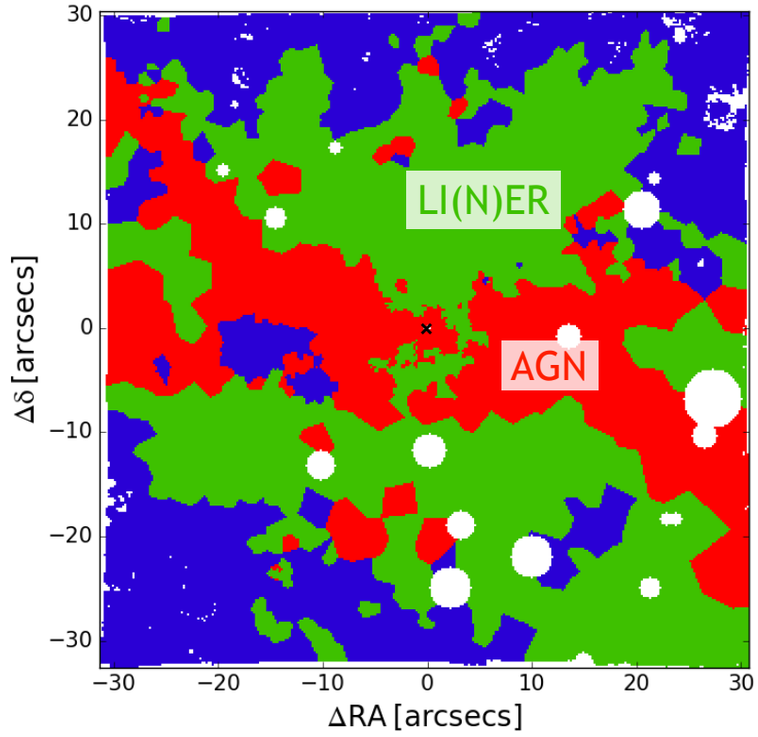
[OIII] W70

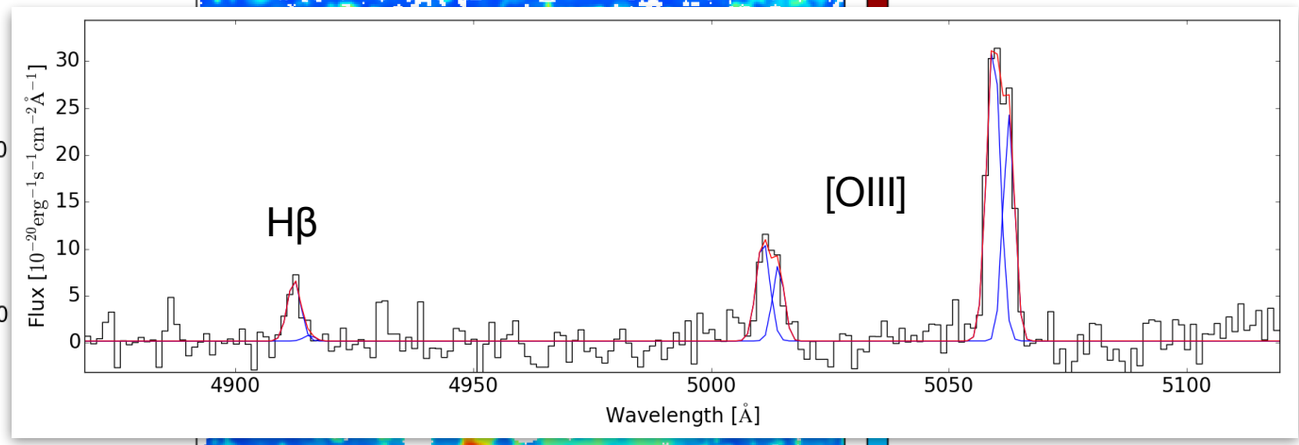


NGC 5643

FOV ~ 5 kpc

[SII] BPT map





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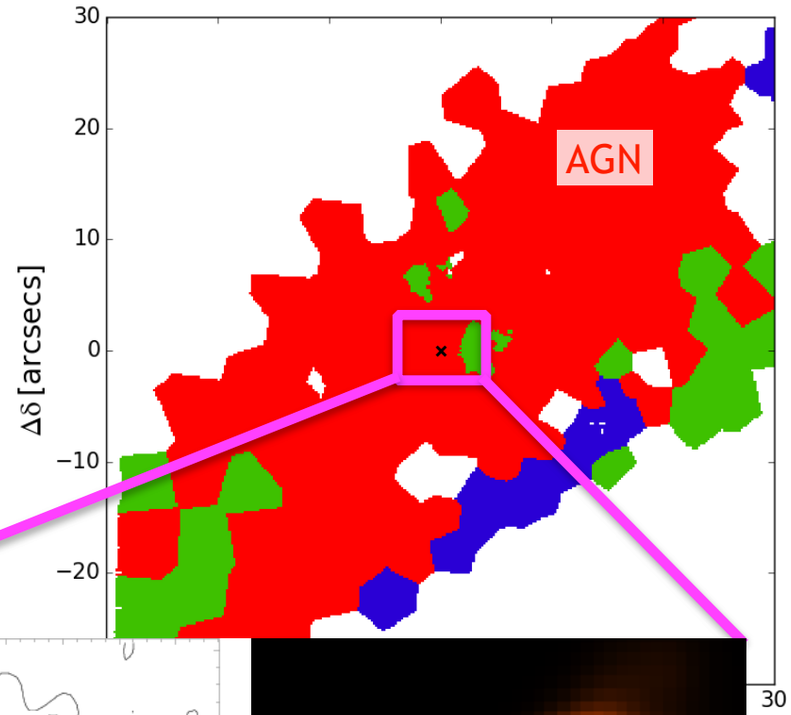
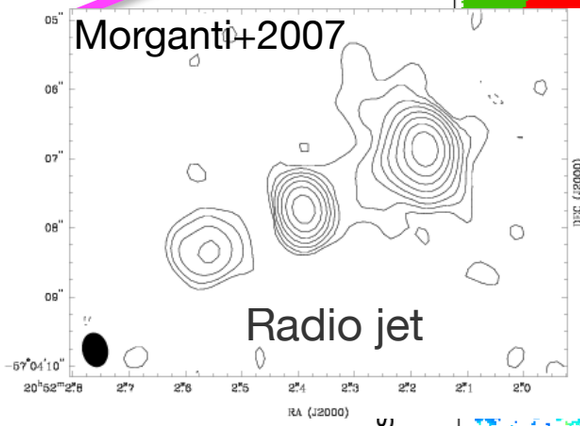
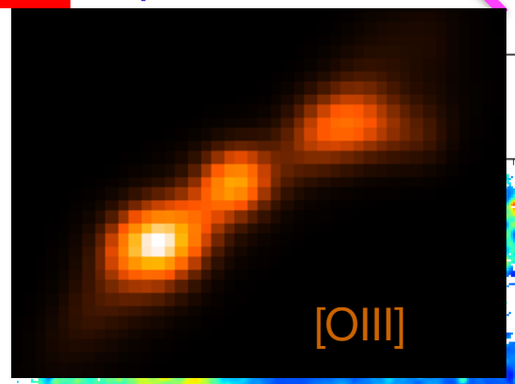
IC 5063

FOV ~ 14 kpc

[SII] BPT map





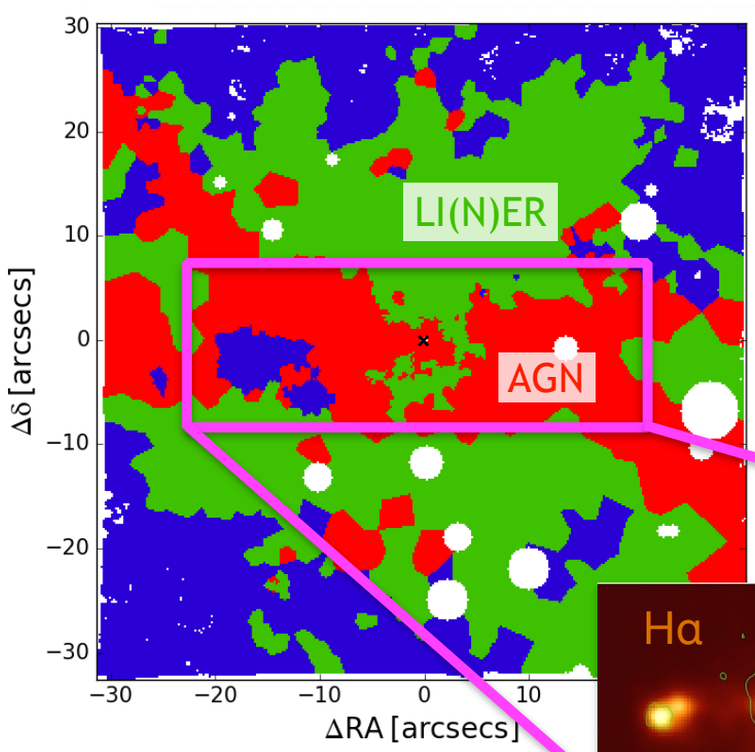


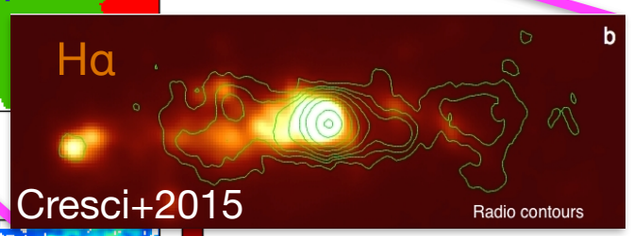
[OIII] W70

NGC 5643

FOV ~ 5 kpc

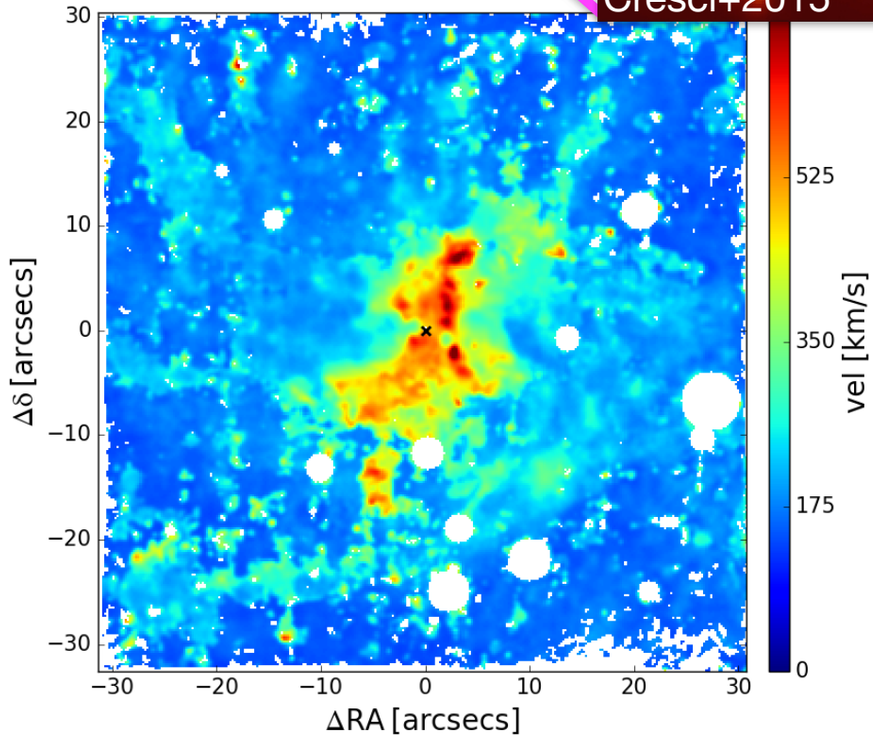
[SII] BPT map





Radio jet

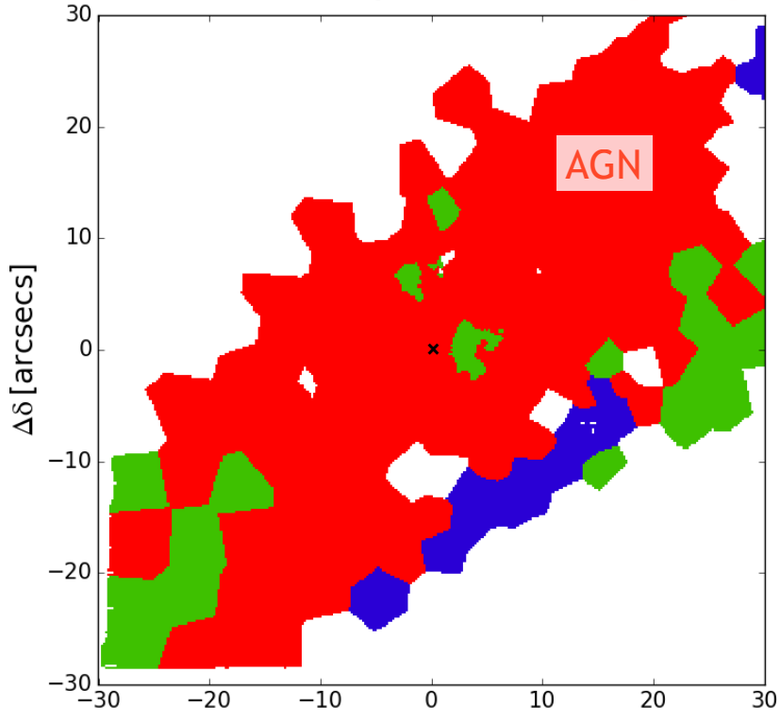
[OIII] W70



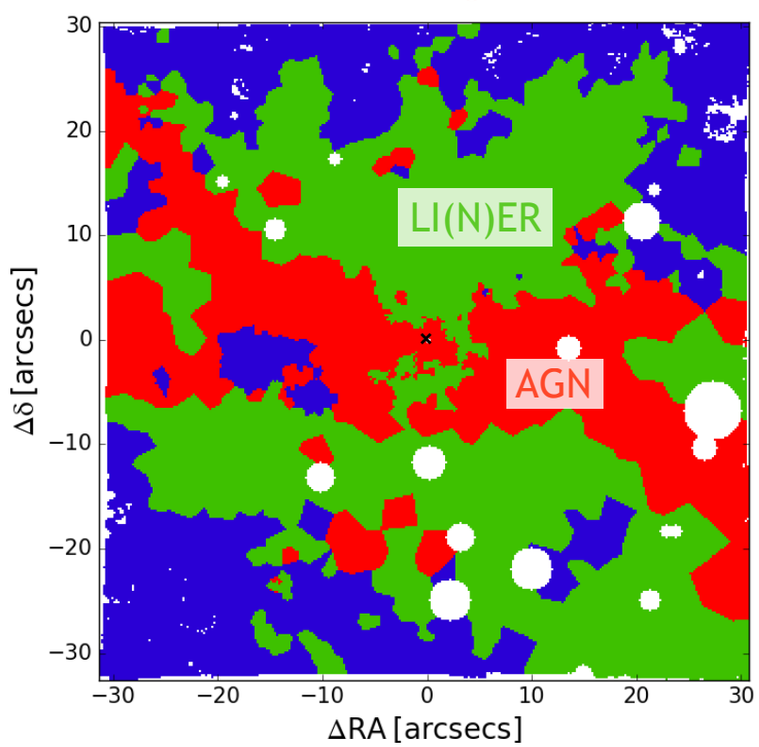
Outflows vs jets

So, **outflows aligned with radio jets**, but **more prominent outflows** (where line profiles are broader) almost **perpendicular** and **not fully AGN-dominated**…

[SII] BPT map



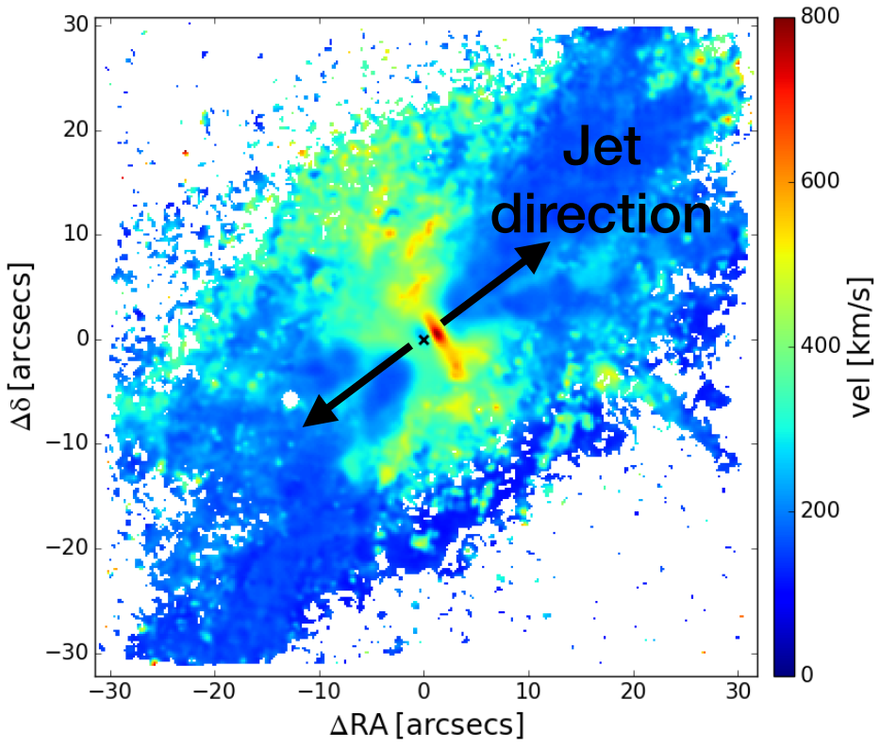
IC 5063

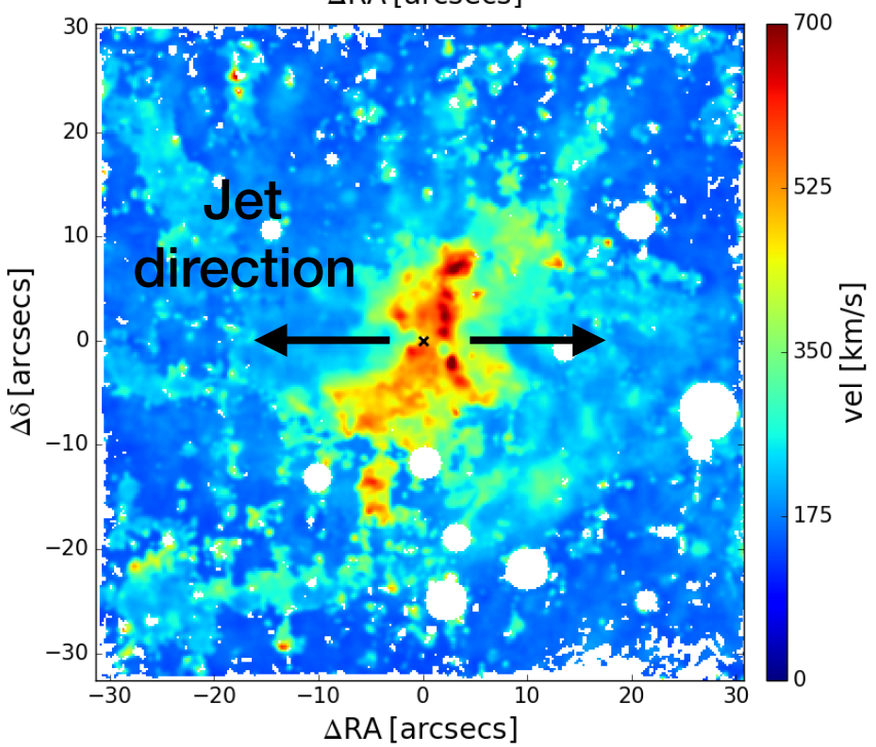


NGC 5643

[SII] BPT map

[OIII] W70



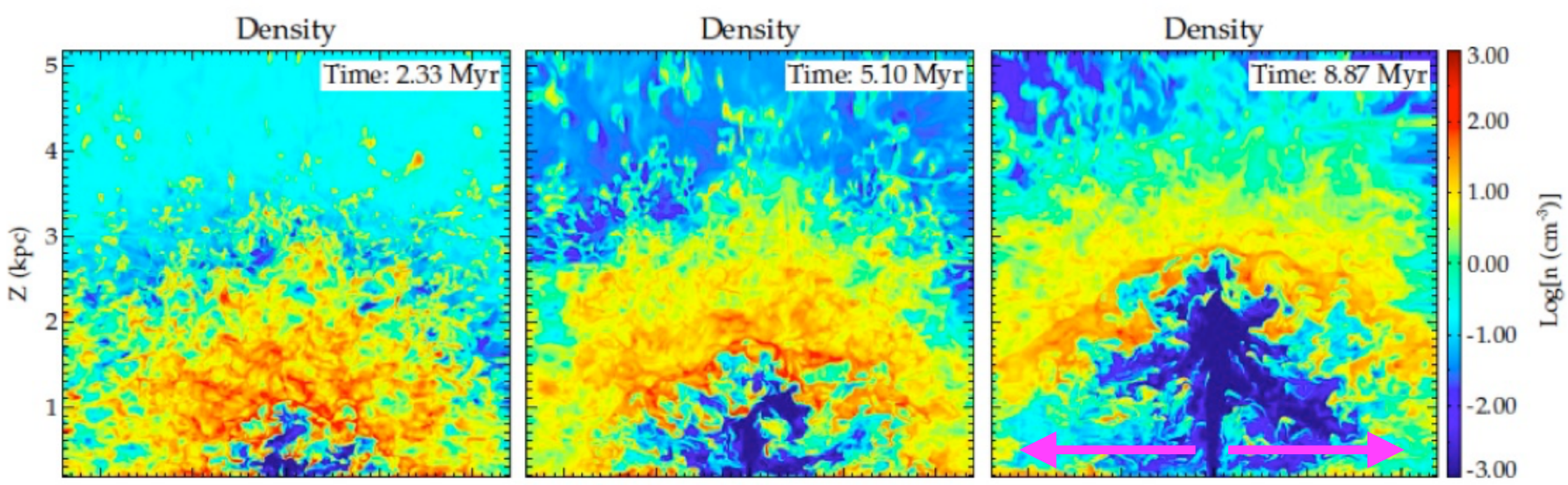


[OIII] W70

Outflows vs jets

Low power radio jets can push gas in the perpendicular direction too!

Low power radio jet
10^{43} erg/s



Simulation from Mukherjee, Bicknell et al. 2016

Summary

MUSE data of nearby AGN provide huge amount of information on the physics of the central kpc-scale regions:

- detailed kinematical study of outflow structures in the ionization cone
- modelling to reconstruct outflow 3D shape from observed maps
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- spatially and velocity resolved BPT diagrams (M. Mingozzi)
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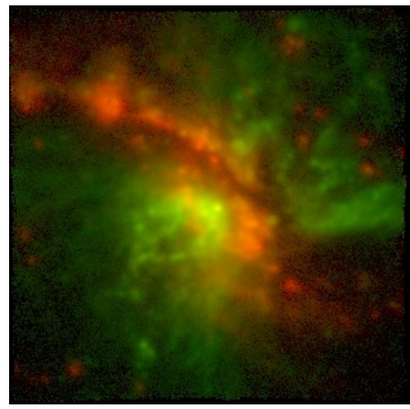

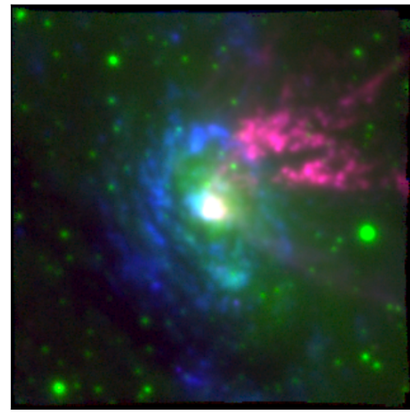

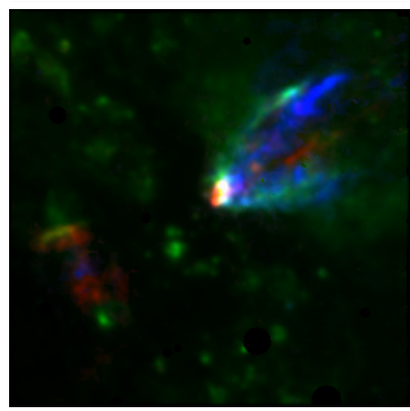

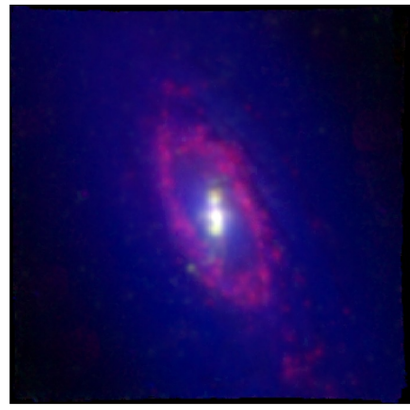

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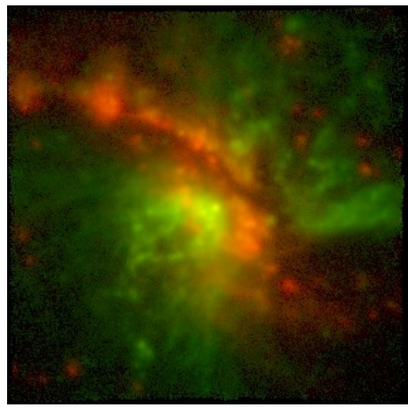

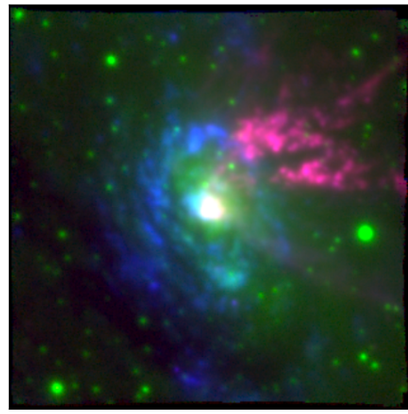

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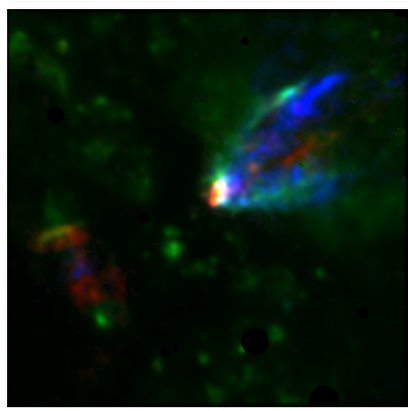

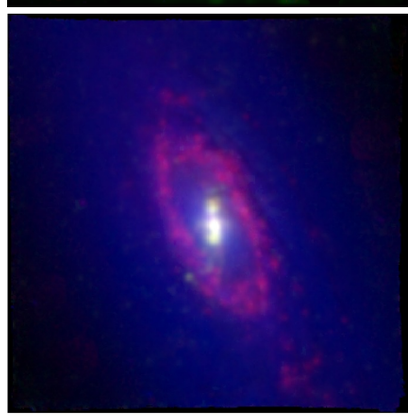

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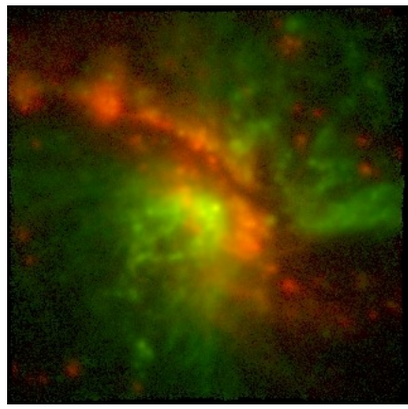

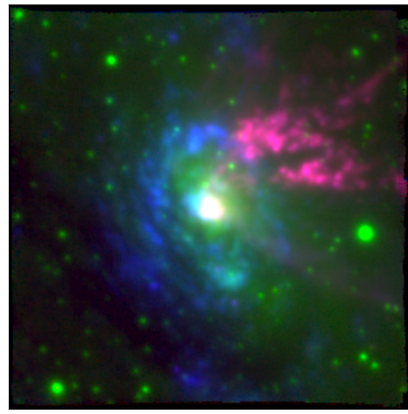

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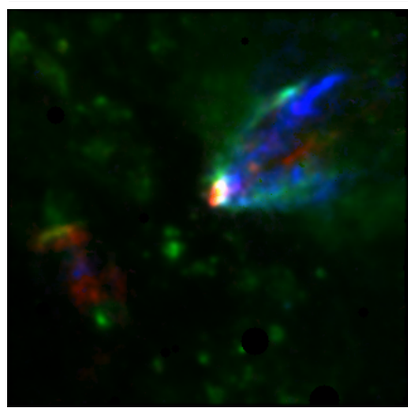

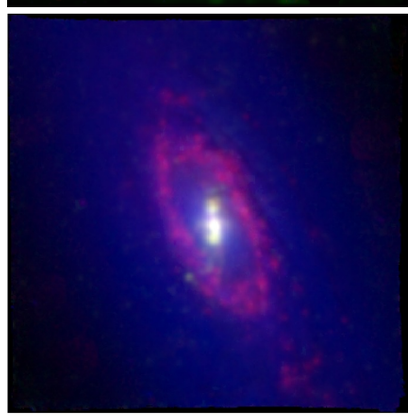

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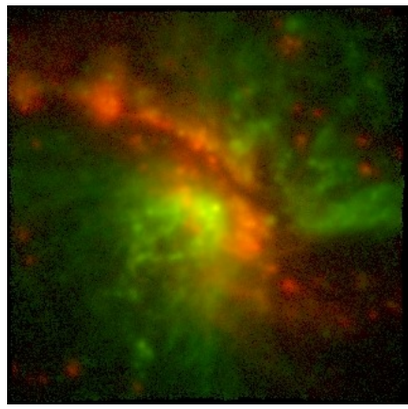

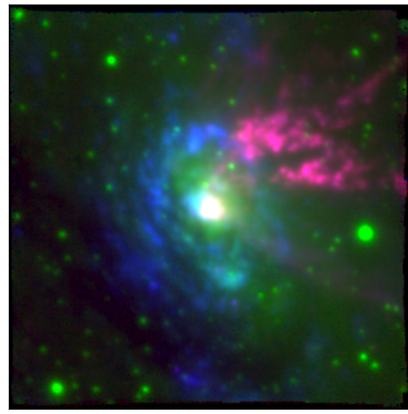

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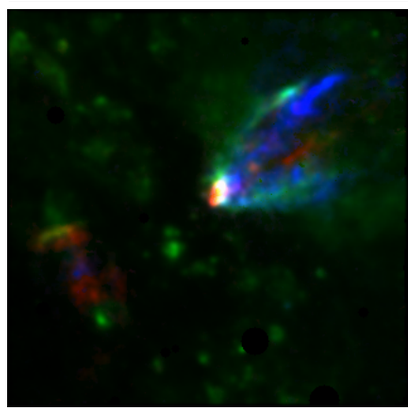

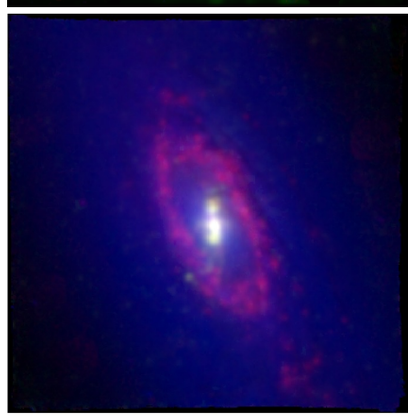

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