Studying neutral and ionized phases of galactic winds with MEGARA

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Outline:

1. Galactic winds and search techniques

2. Detection of GW in M100

3. Science case for MEGARA

4. MEGARA comissioning data

Show cases: UGC10205, NGC7025

1. Galactic winds and search techniques

- Outflows have a major role in the evolution of galaxies across cosmic times, regulating star formation and AGN activity [Veilleux et al. 2005].

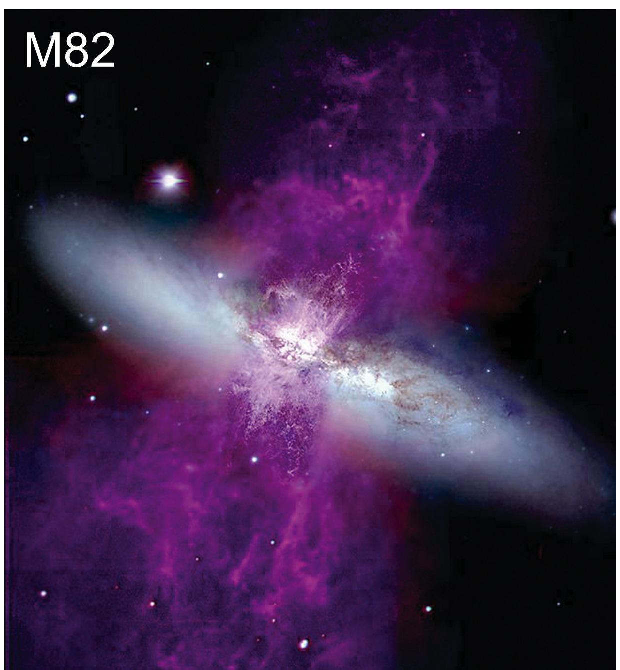
- These galactic winds are the main mechanism by which metals, energy and dust are redistributed, not only within the source galaxy itself, but also into the IGM.

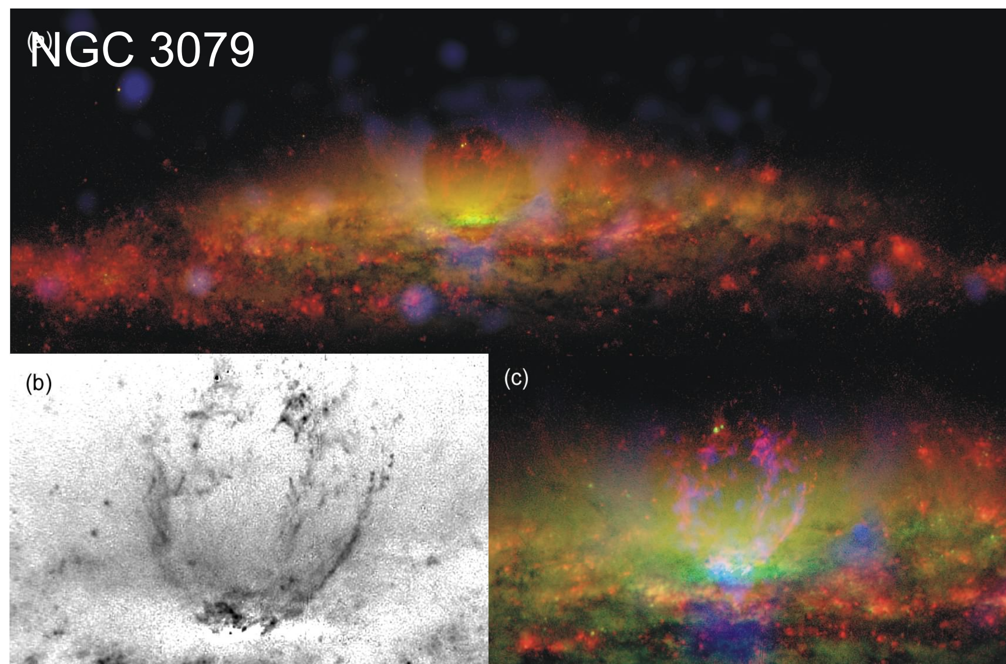
- Despite their importance, there are still huge gaps in our understanding of this phenomenon:

1. Galactic winds and search techniques

- Most galactic winds are studied by means of two complementary approaches:

(i) <u>**Searches for extra-planar gas**</u> in galaxies have been carried out in the hot (X-ray emission, e.g. Dahlem, et al., 1998) or warm phases (optical emission lines, e.g. Lehnert & Heckman, 1996).





Multi Espectrógrafo en GTC de Alta Resolución para Astronomía

1. Galactic winds and search techniques

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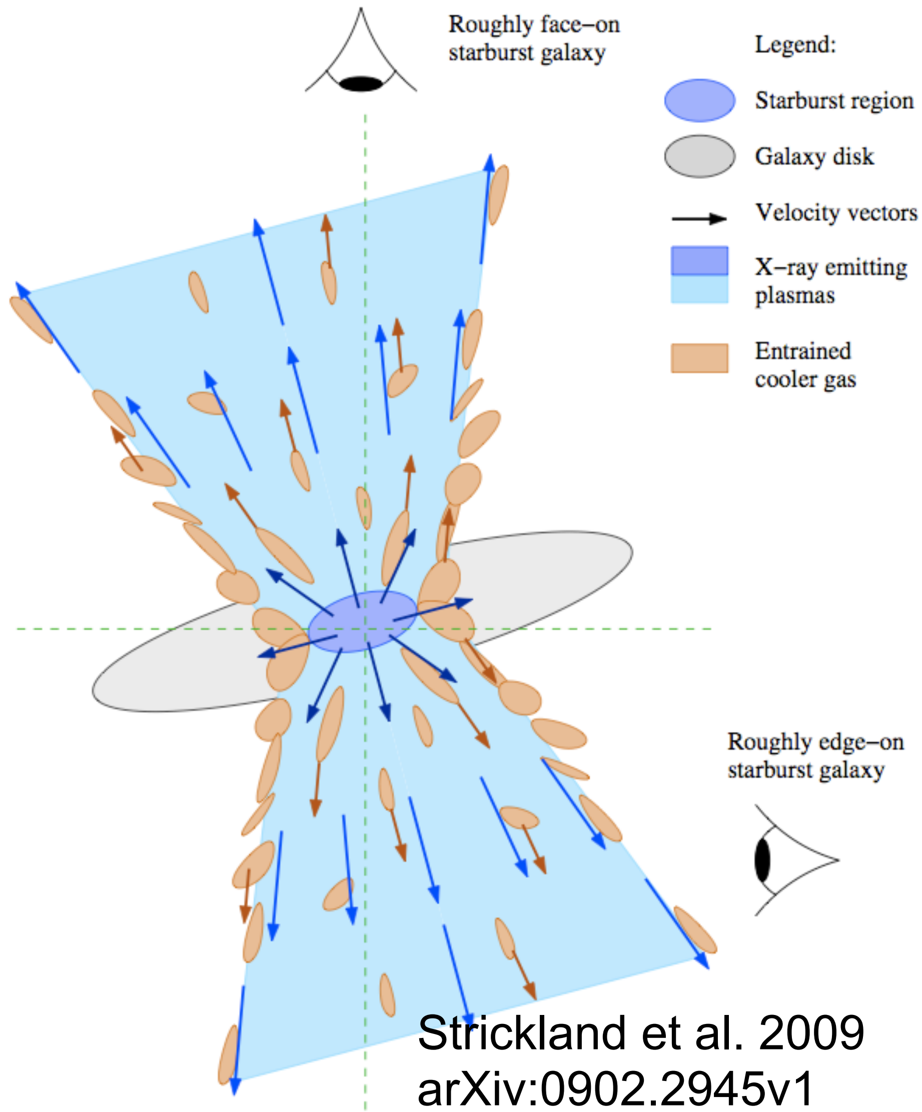
(i) **Searches for extra-planar gas** in galaxies have been carried out in the hot (X-ray emission, e.g. Dahlem, et al., 1998) or warm phases (optical emission lines, e.g. Lehnert & Heckman, 1996).

(ii) To look for **interstellar absorption lines** to probe the cooler phase of the outflowing gas (e.g. Heckman et al., 2000). Most useful interstellar lines (SiII and CII but also OVI) lie in the UV region of the spectrum, but a few are found at optical wavelengths (NaI and KI).

Absorption line probes of galactic winds

- Na I “D” λλ5890, 5896
- Ionization Potential~5 eV
- Low covering factor - needs to be shielded by dust
- Na I lines are prominent in oldish stellar populations (K and M stars) → Beware!!!



Strickland et al. 2009
arXiv:0902.2945v1

Multi
Espectrógrafo en
GTC de
Alta
Resolución para
Astronomía

1. Galactic winds and search techniques

- Absorption line studies (Martin et al. 2005, Rupke, 2006, etc...) have proven very powerful in studying winds, as absorption is more sensitive to lower densities.

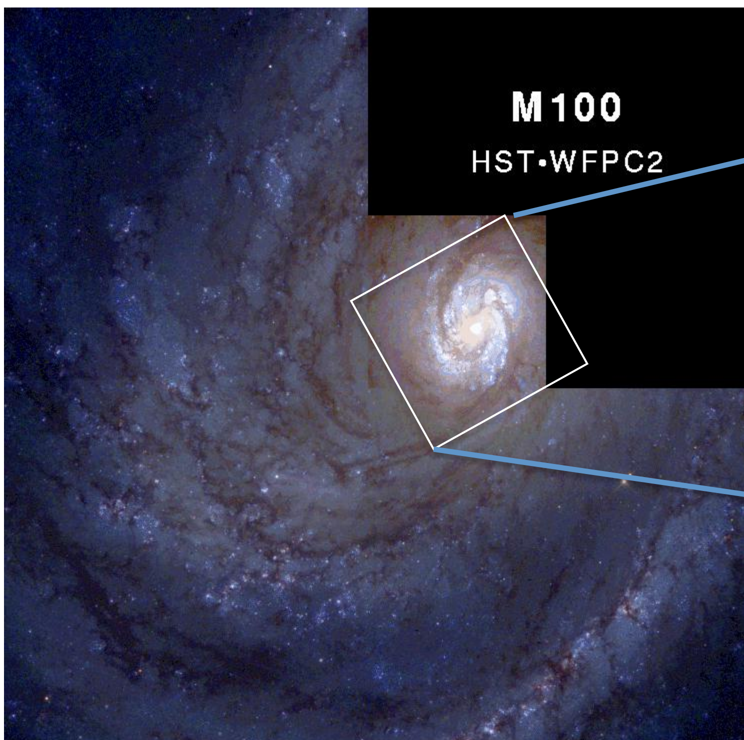
- But these studies, having provided valuable information on the velocities and mass estimates of the winds, lack essential information on the wind geometry which is needed to better understand the phenomenon.

- Being a complex multi-phase kinematical phenomenon, resolved 2D information is needed in order to be able to understand many relevant details of the winds.

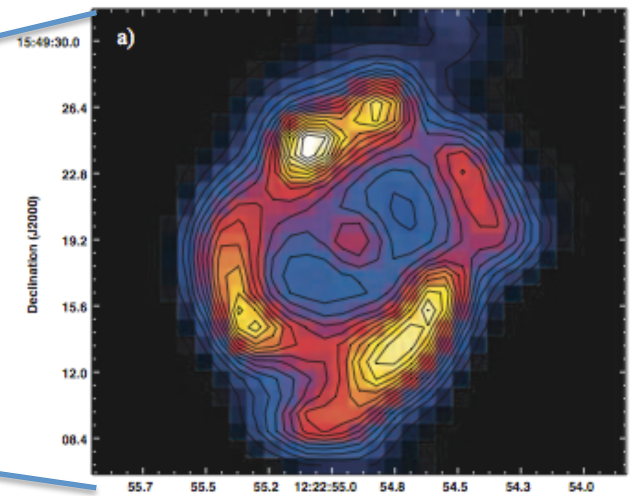
2. Studing galactic winds by means of interestellar absorption (Na I) observed with IFS: NGC 4321

- Detection and 2D study (INTEGRAL at WHT) of galactic wind in the nearby galaxy NGC 4321 (M100).

  "Discovery of a galactic wind in the central region of M100", (Jiménez-Vicente et al. 2007)



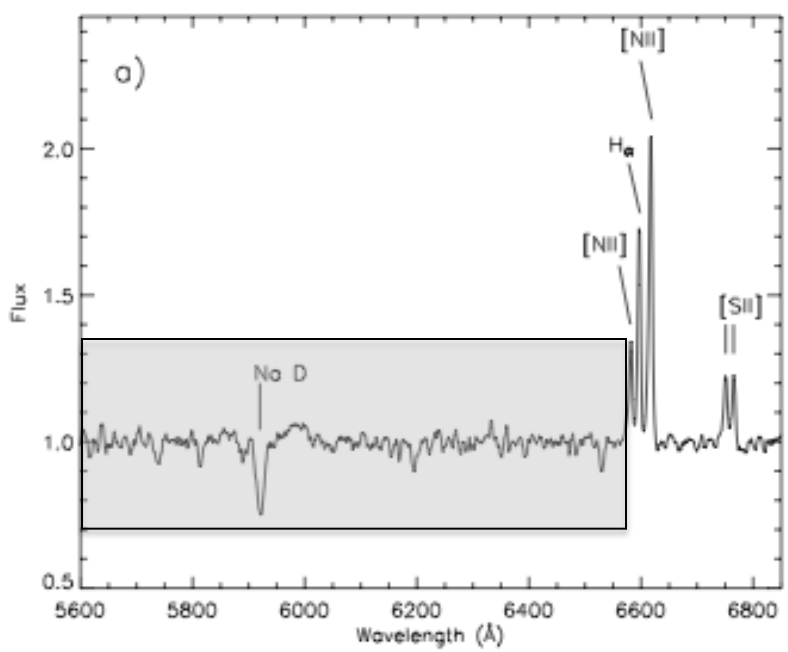
INTEGRAL Ha intensity map



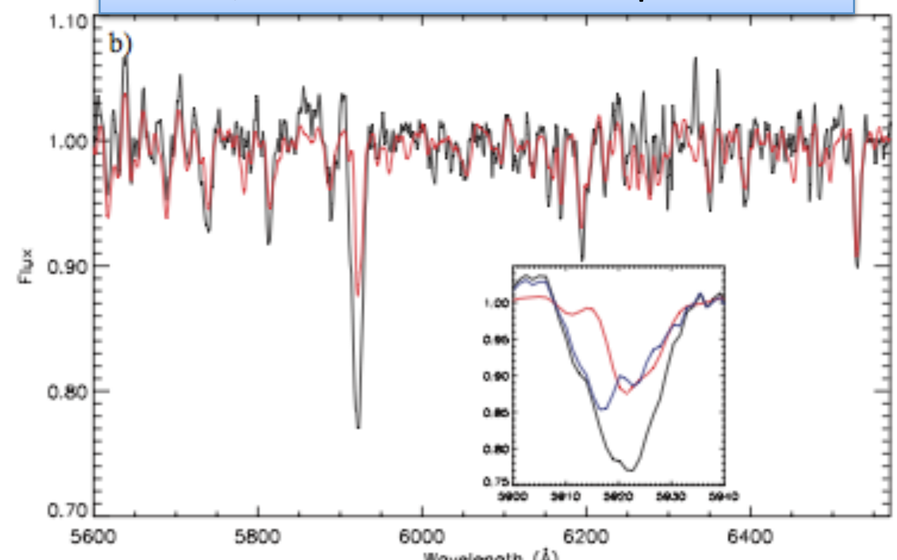
Instrumental set-up: $\lambda \in$ [5600-6860]
4.8Å (R≈1300) for SB3 (31x28 arcsec^2)
2.8Å (R≈2200) for SB2 (16x12 arcsec^2)

2. Studing galactic winds by means of interestellar absorption (Na I) observed with IFS: NGC 4321

- We have been able to spatially separate the stellar and interstellar components of the NaI absorption.
- We find strongly blueshifted component in the neutral gas traced by the NaI lines.



M100, INTEGRAL nuclear spectrum

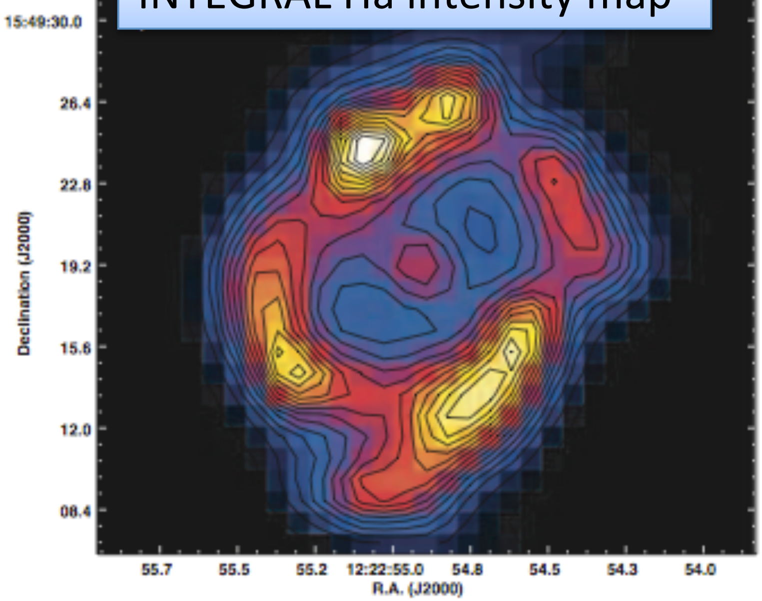


Multi Espectrógrafo en GTC de Alta Resolución para Astronomía

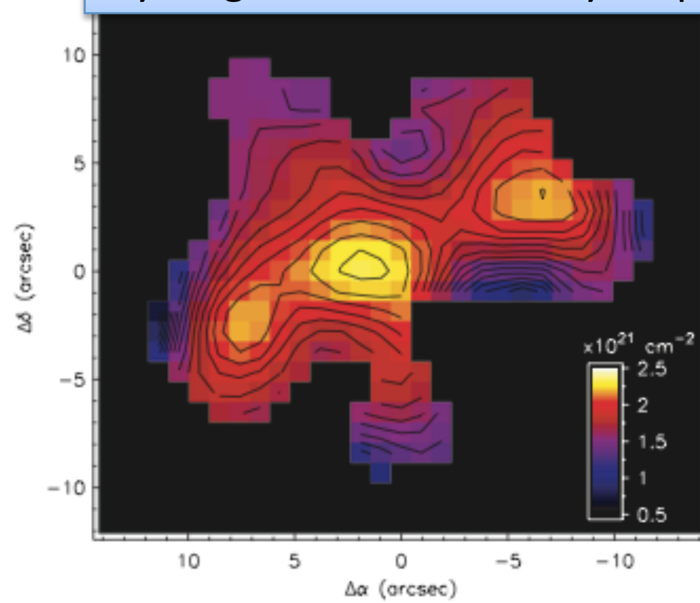
2. Studing galactic winds by means of interestellar absorption (Na I) observed with IFS: NGC 4321

- 2D spectroscopy has been critical in detecting the wind.
- The distribution of Na I in the map is clearly elongated along the bar position angle with a central maximum and two knots.
- From this map we have calculated the total hydrogen mass in the wind to be ~2.4 × 10^6 $M_\odot$.

INTEGRAL Ha intensity map



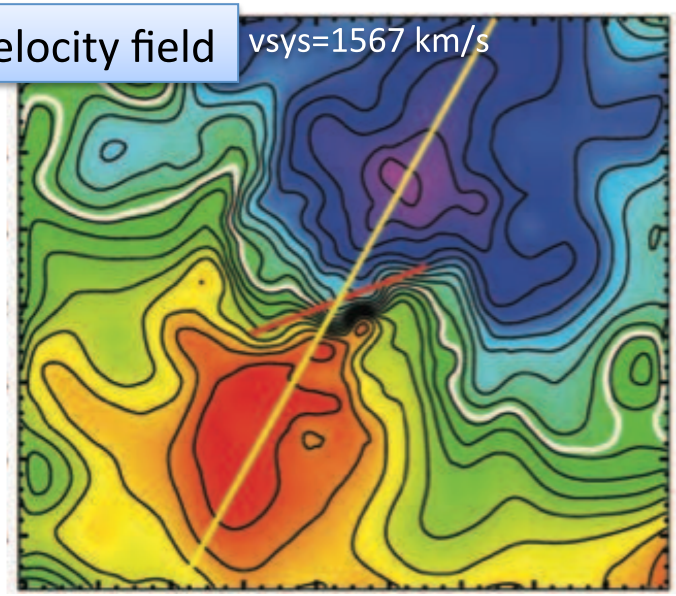
Hydrogen column density map



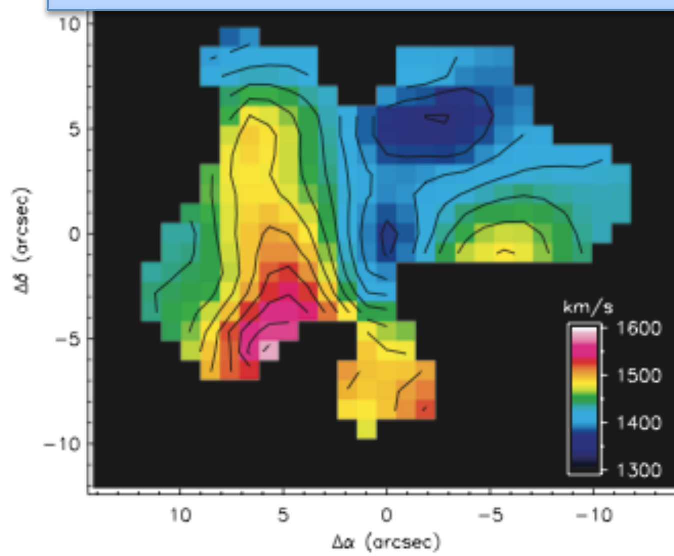
2. Studing galactic winds by means of interestellar absorption (Na I) observed with IFS: NGC 4321

- The velocity map of the absorbing gas presents a rotation pattern with a major kinematic axis orientation and velocity amplitude that clearly resembles that of the ionized gas in the disc.
- This rotation pattern is globally blueshifted with respect to the underlying ionized gas in the galactic disc by ~115 km s^{-1}

Hα velocity field



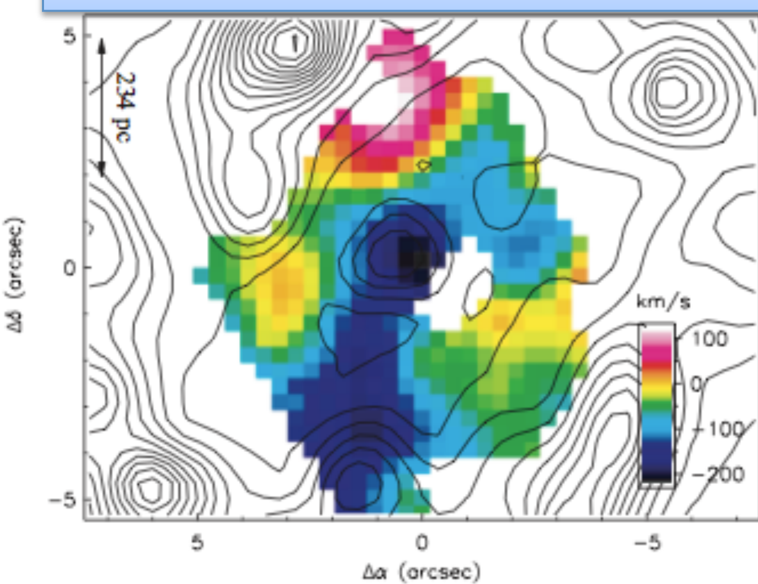
Na I absorbing gas velocity field

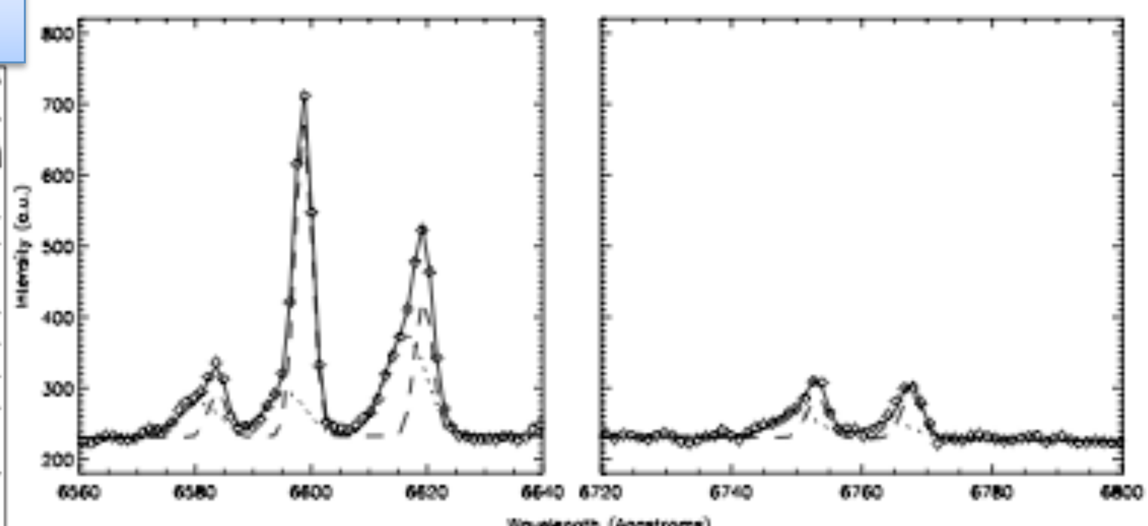


2. Studing galactic winds by means of interestellar absorption (Na I) observed with IFS: NGC 4321

- The outflowing gas has an ionized counterpart.
- In order to study this blueward component we try to fit two kinematical components to the emission lines of each spectra. To do this we simultaneously fit two sets of five spectral lines (Hα, [N II]λλ6548, 6584, [S II]λλ6716, 6731).

Velocity field of the ionized component of the wind with respect to the underlying galaxy





3. Science case for MEGARA

GALACTIC WINDS in NEARBY SF-GALAXIES

Most surveys of galactic winds are biased towards strong starbursts or active galaxies, but very little is known about winds in "normal", quiescent galaxies.

We propose to study the existence, frequency and strength of winds in a sample of local star forming galaxies including objects with little or not detected nuclear activity for which this phenomenon remains mostly unexplored, and how they compare to active galaxies.

3. Science case for MEGARA

We intend to use MEGARA at GTC for studying the physics of the winds in quiescent and non-quiescent galaxies to answer questions such as:

✓How much gas/metals/dust are put into play by the outflows/winds?

✓Is the wind material able to escape the host galaxies? How much?

✓How fast is the wind and what is its geometry?

✓Are they mainly originated at a few localized spots or spread throughout the entire host galaxy?

✓Are winds originated by AGN and starbursts different? Which of these mechanisms is more important/efficient in producing winds?

✓How do the characteristics of the wind relate to other properties of the host galaxy like total mass, star formation rate, etc?

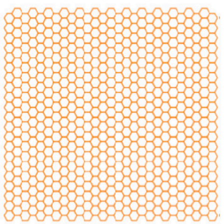
Sample and observing strategy

GALACTIC WINDS in NEARBY SF-GALAXIES

Our targets have been chosen from **S4G survey** (d < 40 Mpc):
large galaxies (2' < D_{25} < 5')
low inclination (i < 40º)
late type (star-forming, with 1 < Morph. Type < 8)
and objects with δ > -30º

~ 80 galaxies

Large Compact Bundle



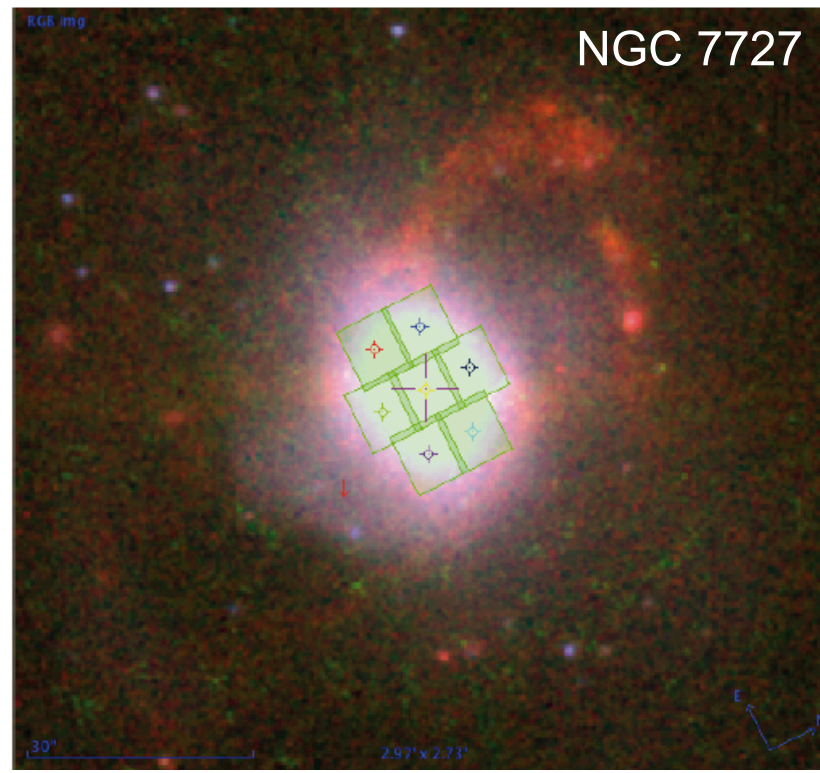
12.5" x 11.3"

MEGARA Large Compact Bundle IFU (12.5x11.3 $arcsec^2$):

✓good spatial sampling

✓in only one pointing we will map the central region of the galaxy.

✓for those interesting targets (where the detection of the galactic wind is positive), several pointings will be needed in order to perform a more detailed study of the wind.



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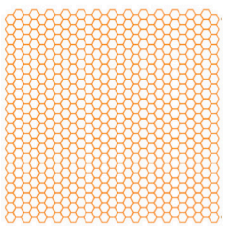
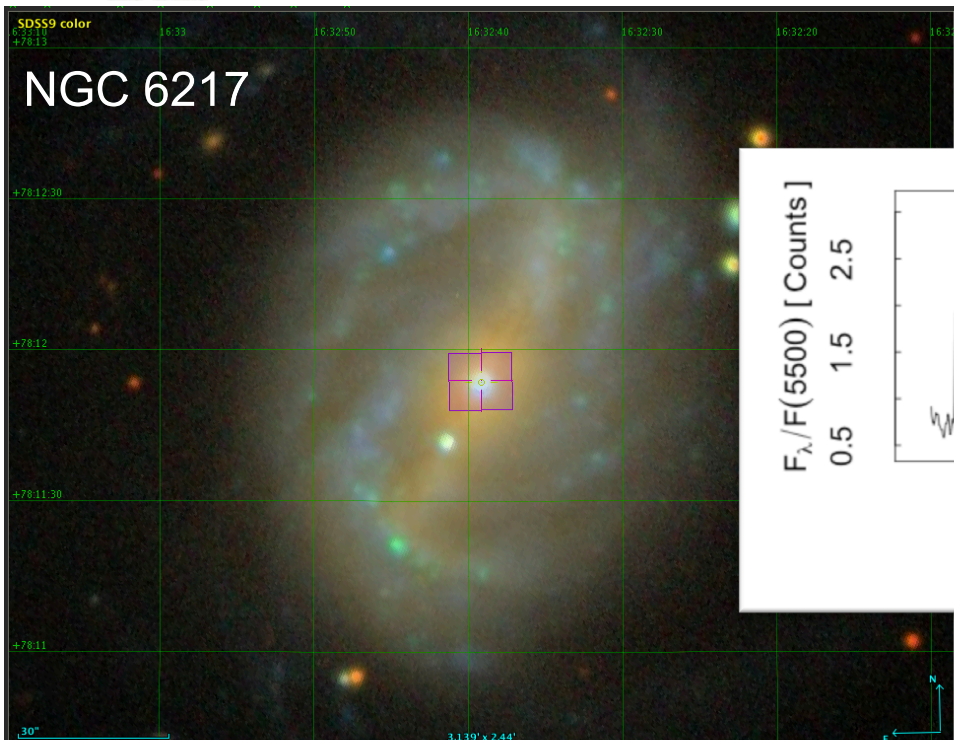
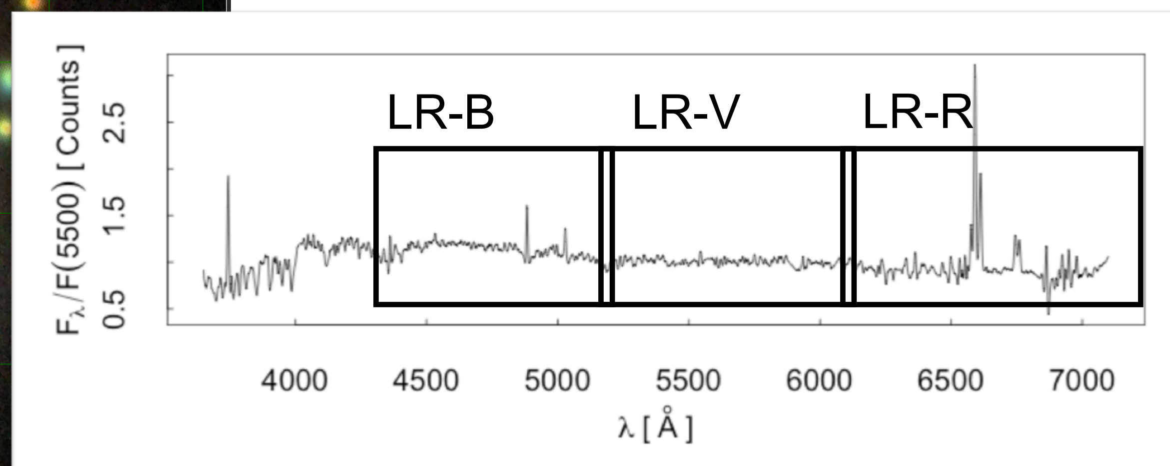
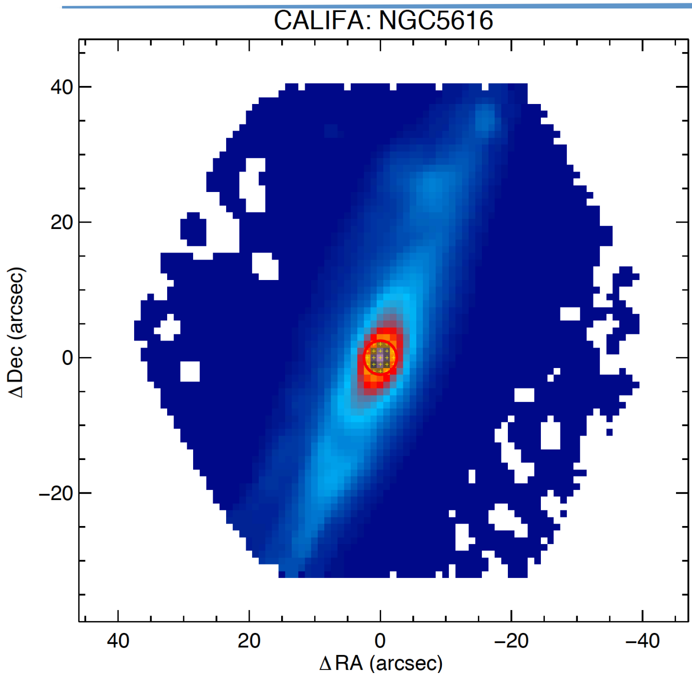


12.5” x 11.3”





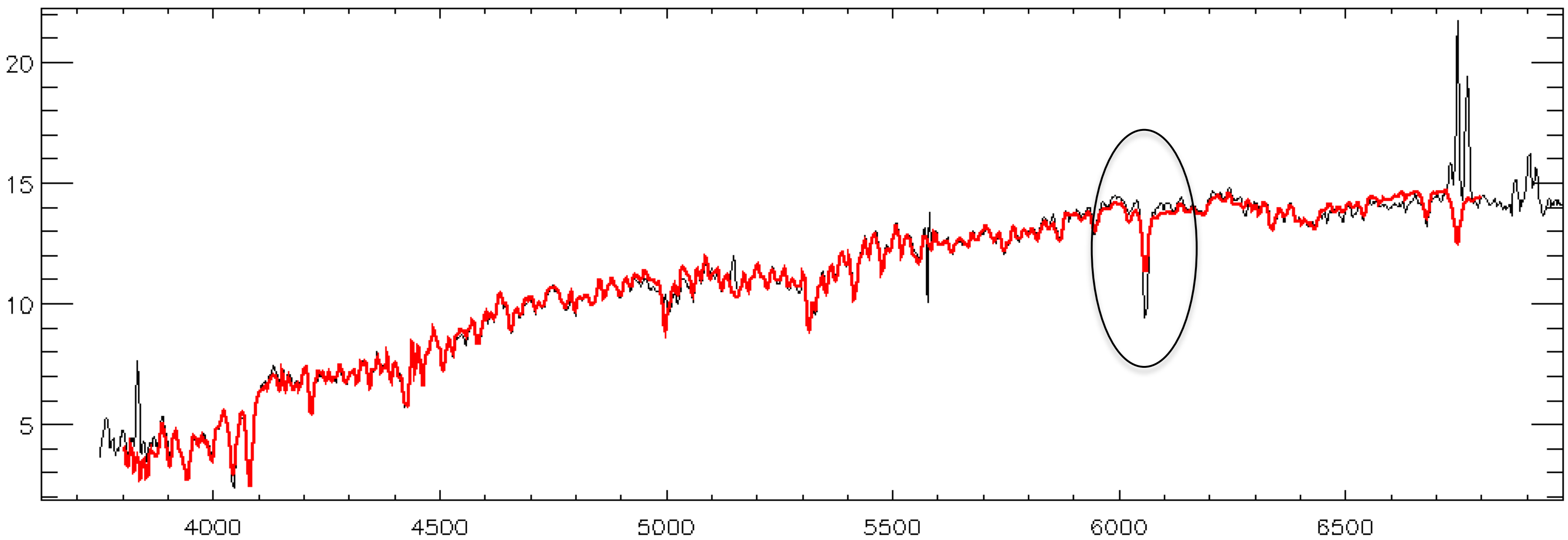
Detecting neutral GWs in CALIFA sample



Third CALIFA Data Release (Sánchez et al. 2012)

646 data cubes with V500, R=850, 3750 and 7500 Å observed with the PMAS spectrograph in the PPAK mode

Nuclear spectrum (3 arcsecs) NGC 5616



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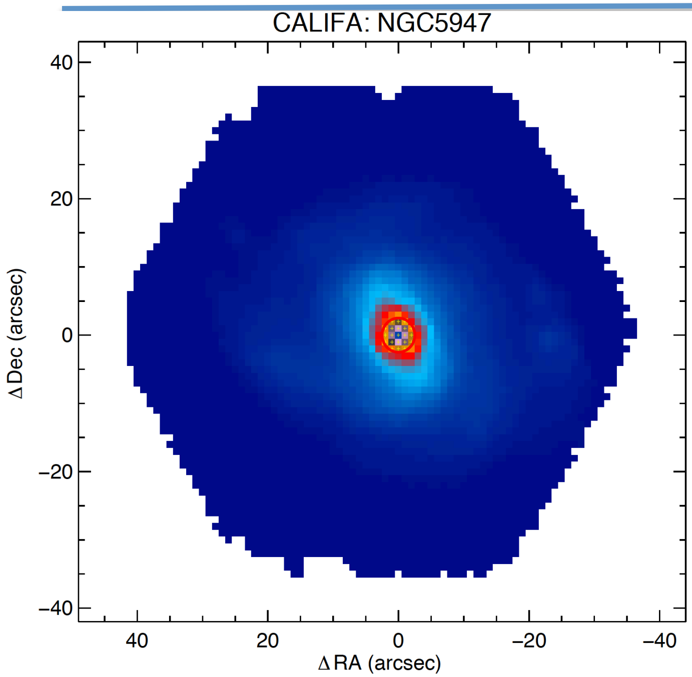

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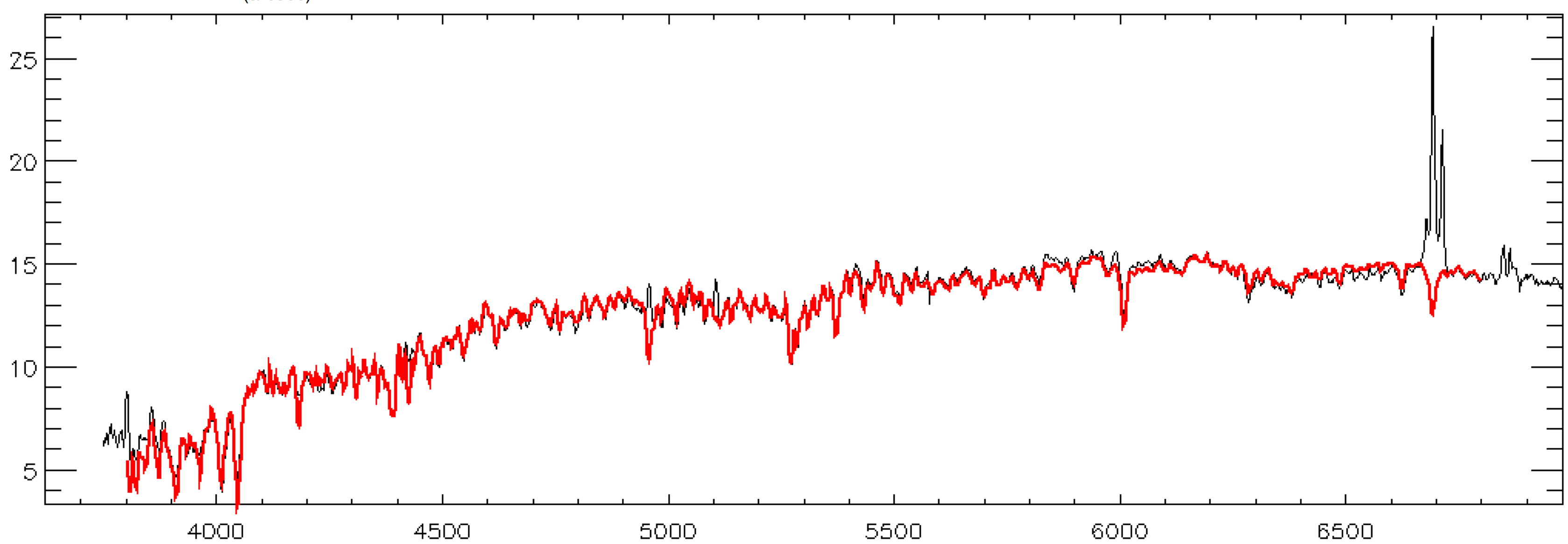
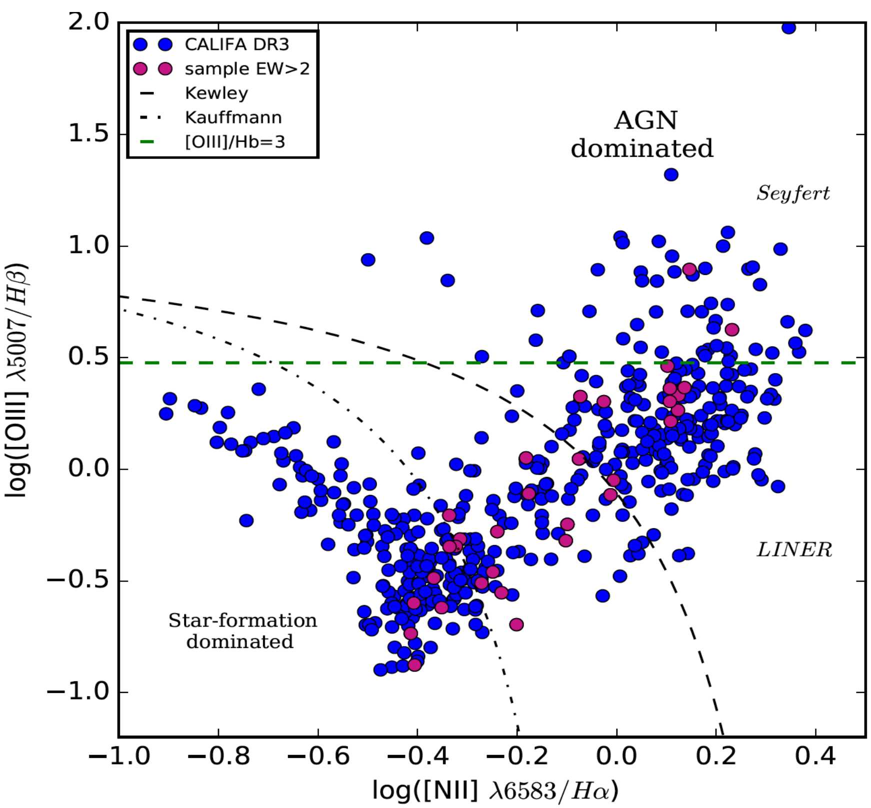
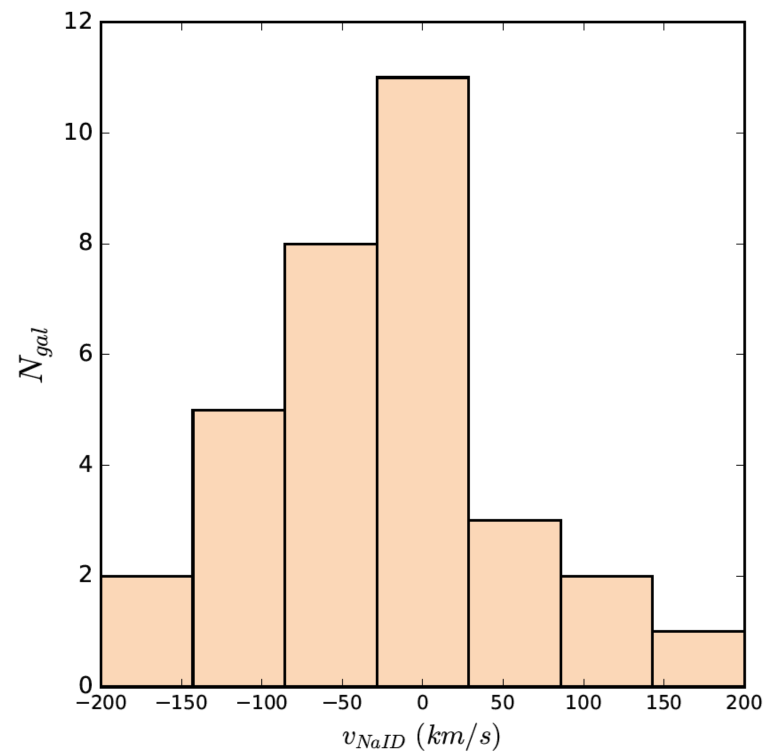
Nuclear spectrum (3 arcsecs) NGC 5947



Detecting neutral GWs in CALIFA sample

Tipo de actividad nuclear	N_{gal} ($EW > 2$Å)	%	N_{gal} CALIFA V500	%
Composite	9	28,1	75	14,2
Star-forming	12	37,5	276	52,4
LINER	9	28,1	133	25,2
Seyfert	2	6,3	43	8,2

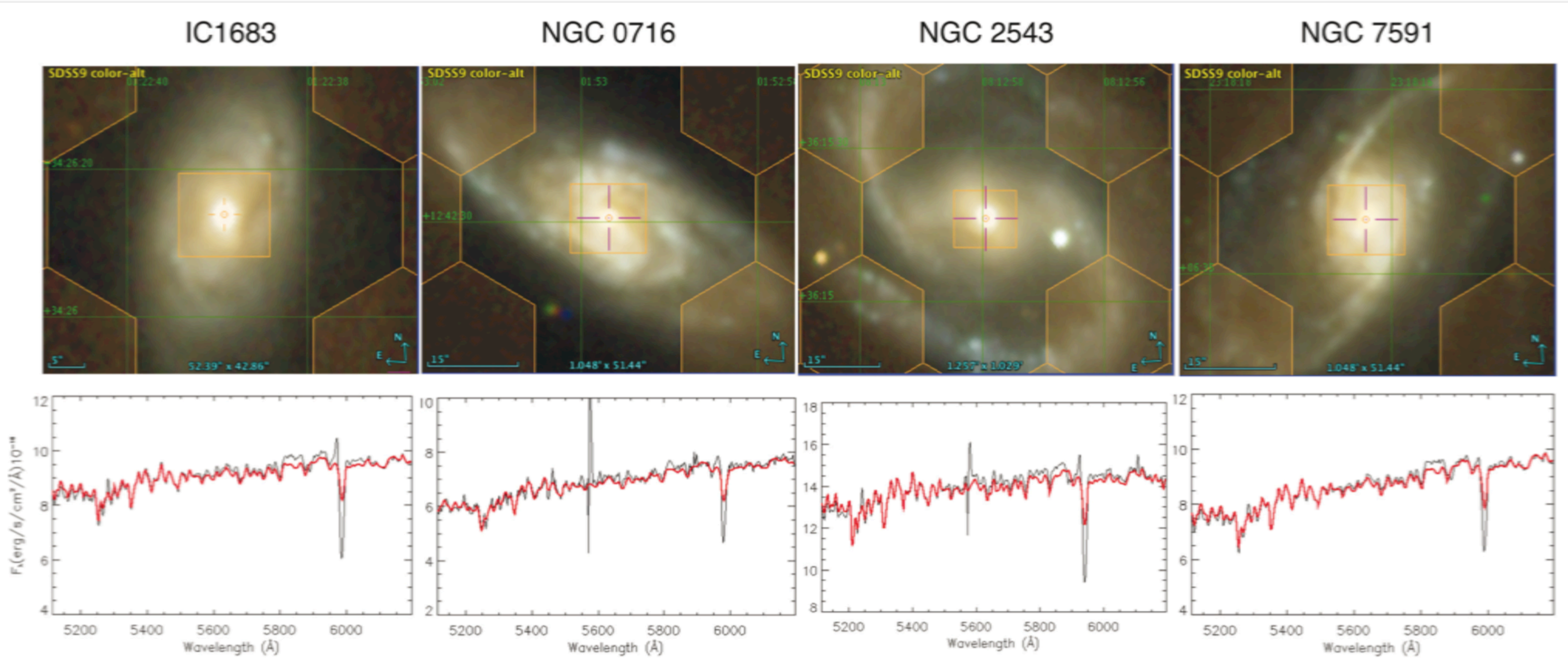




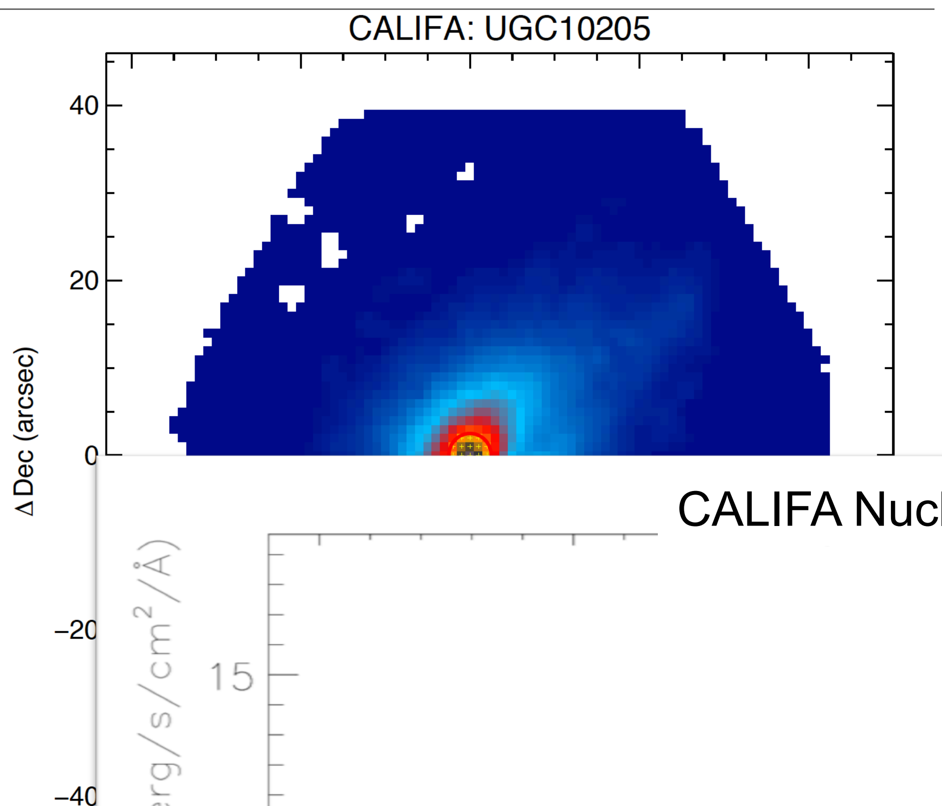
L. López's TFM, 2017

Detecting neutral GWs in CALIFA sample

MEGARA OT, 2018B (11.2 h): LR-V & MR-R, 2.8h / target

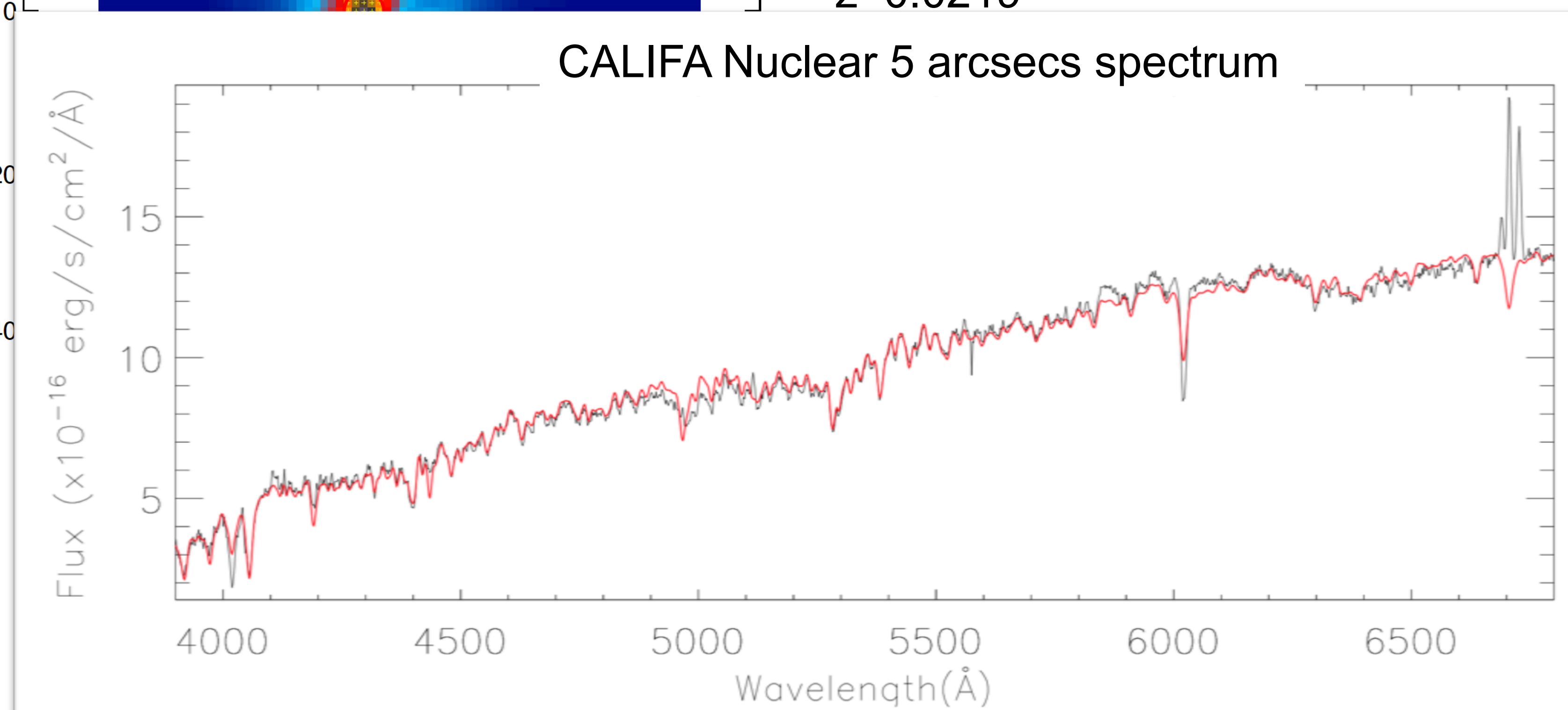


4. Show case: UGC 10205. MEGARA data



PPAK setup:
3 pointing (dithering) x 900 s
V500, 3750-7000 A, R=850

UGC 10205:
Sa, incl = 60º
B-band = 14.4 mag
z=0.0219



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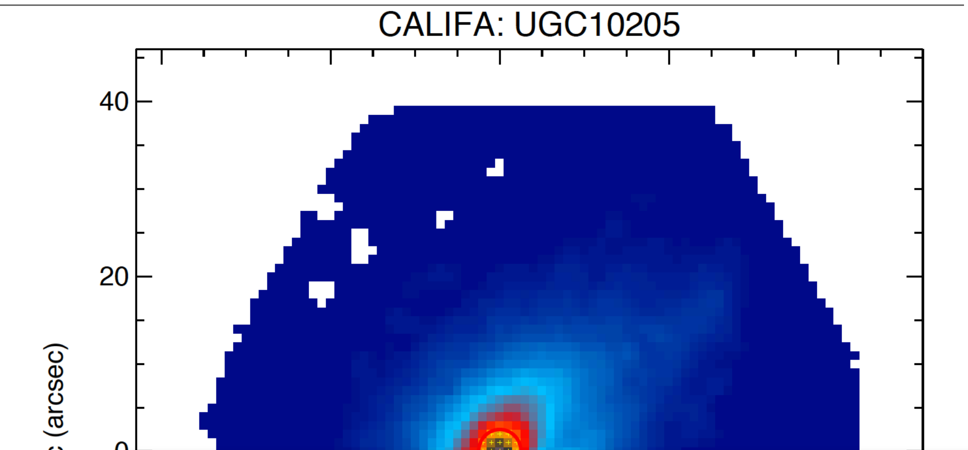

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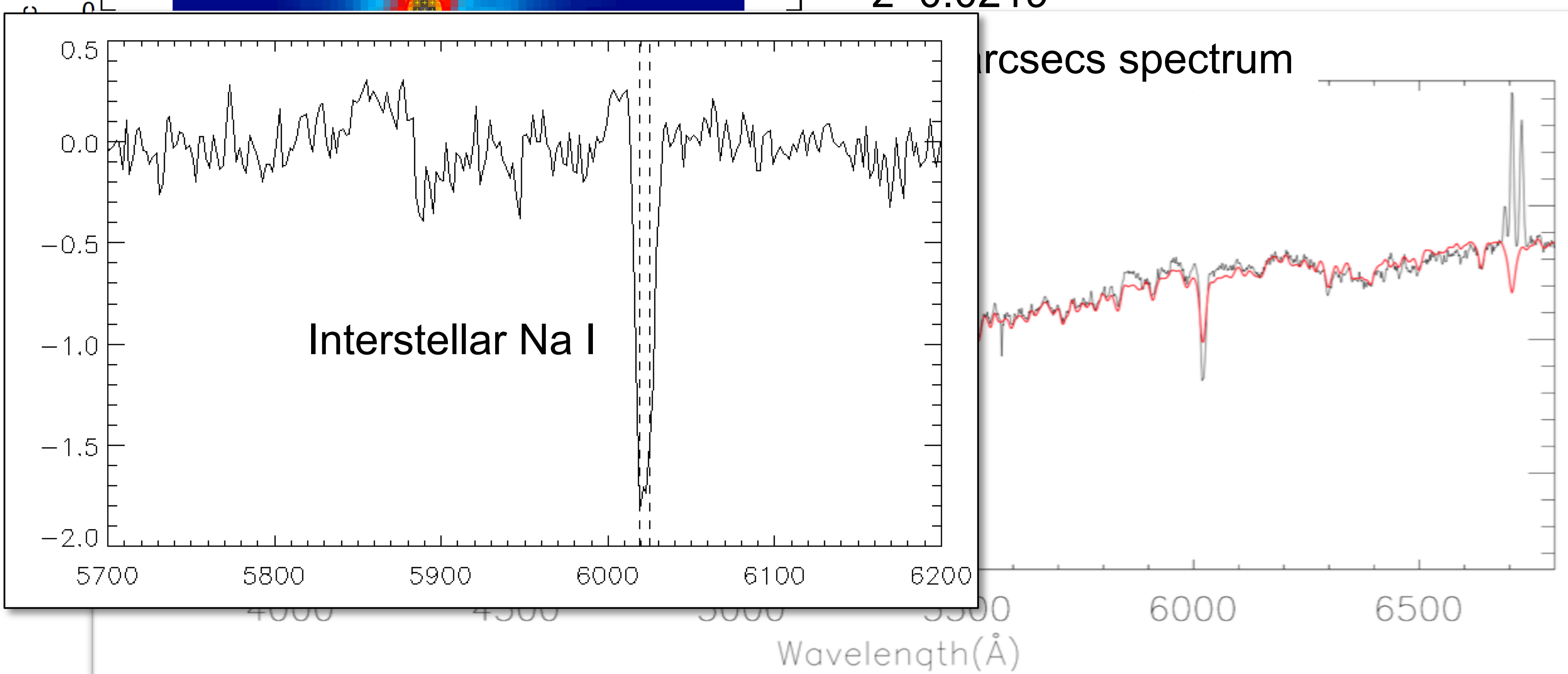

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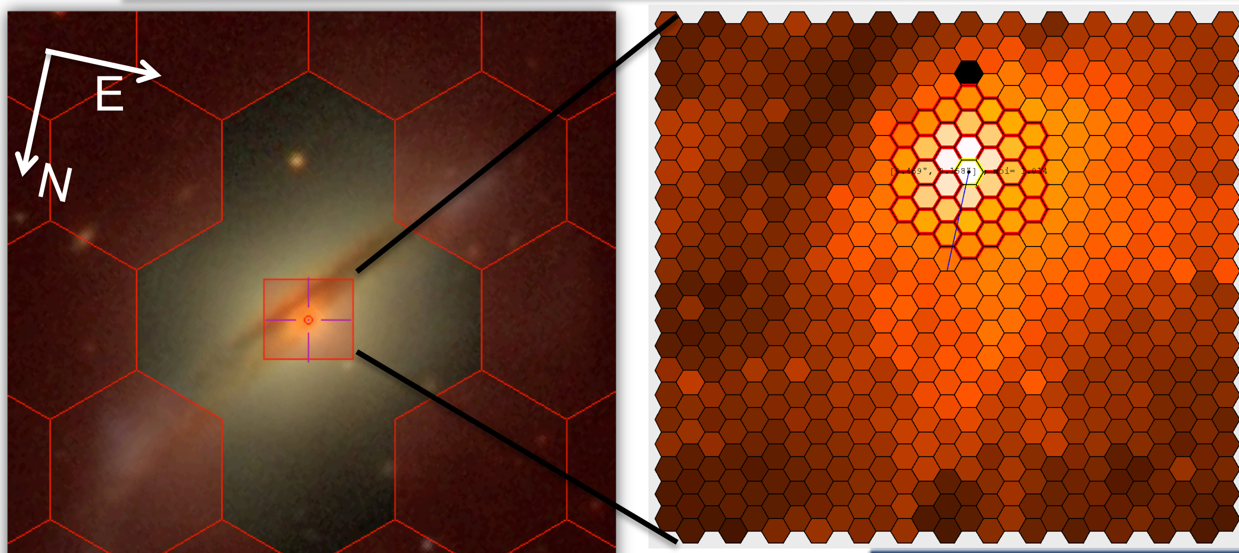
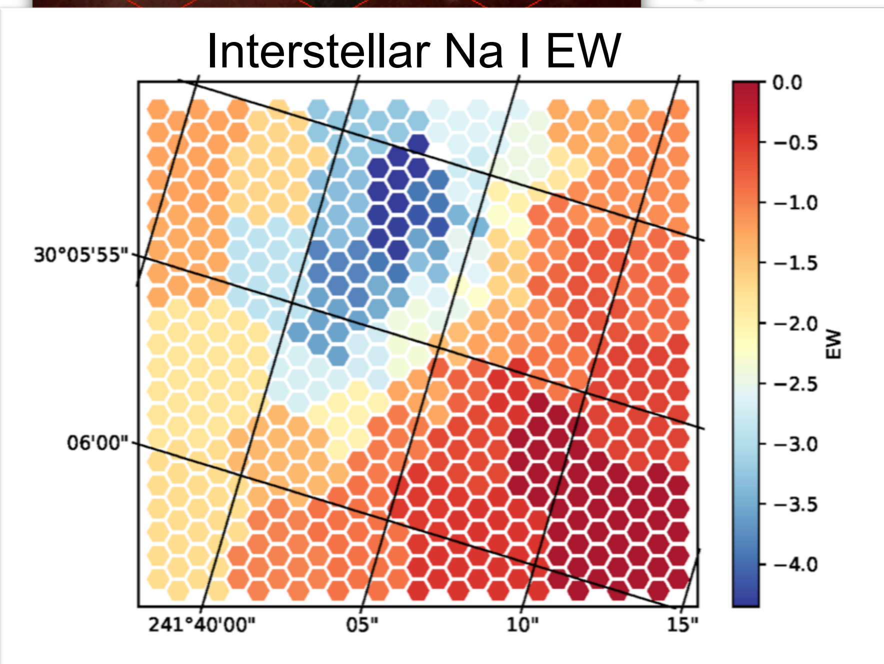
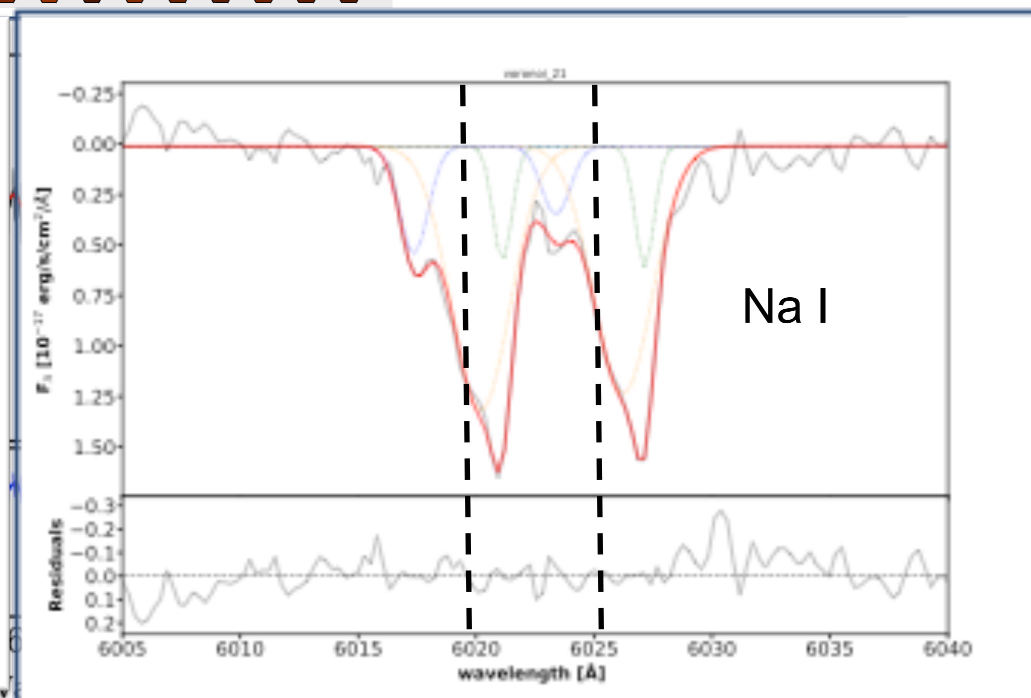


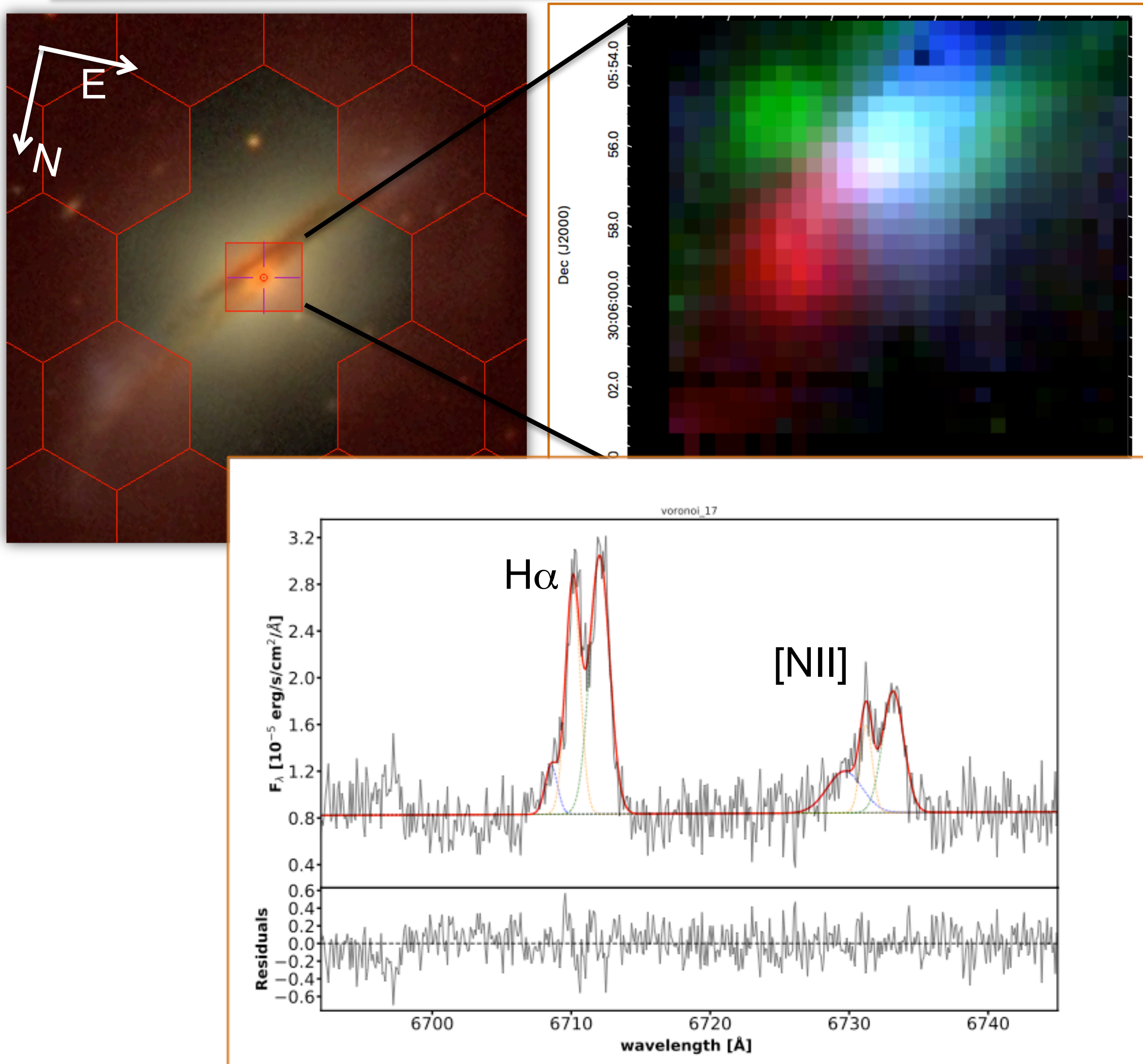
Catalán-Torrecilla et al. 2018 in prep.

MEGARA setup:
LCB, LR-V, 4 x 1200 s
R=6100 (50 km/s)





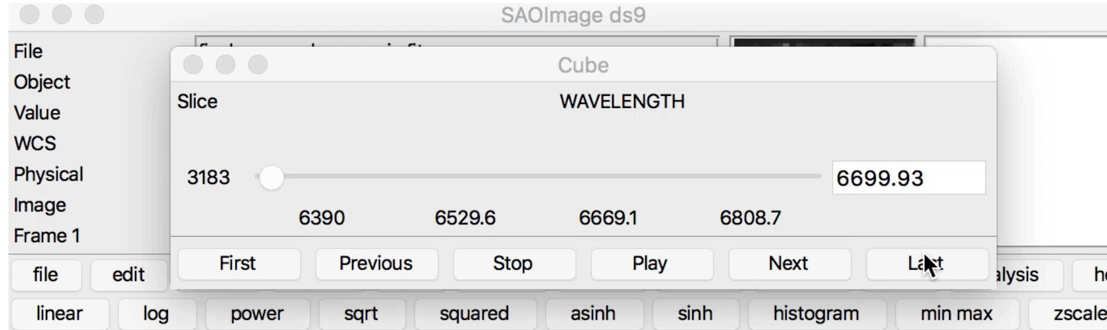
4. Show case: UGC 10205. MEGARA data



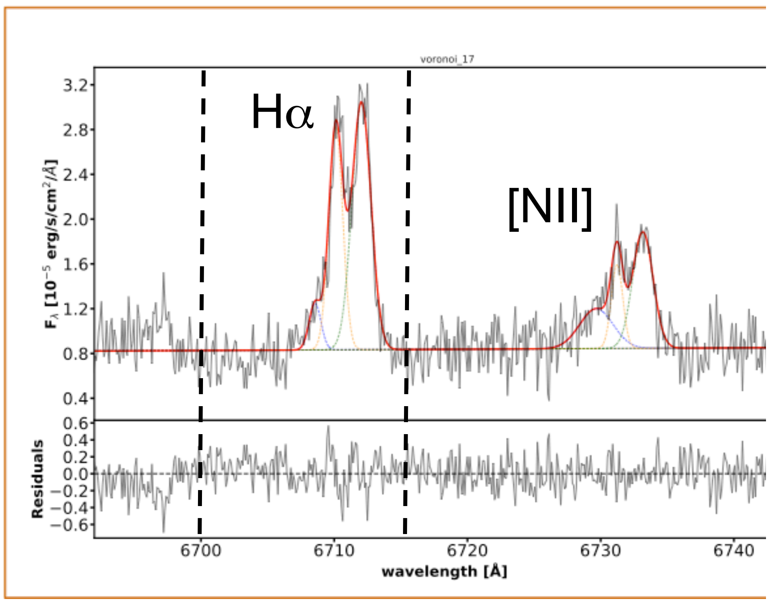
Ionized gas map that represents the spatial distribution of the three components in the Hα emission line profiles

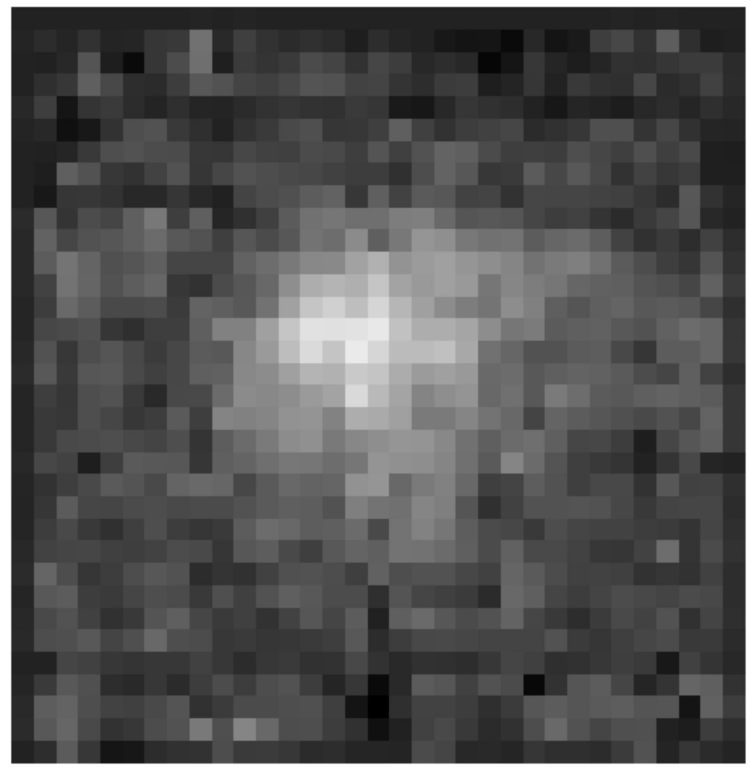
MEGARA setup:
LCB
HR-R, 1200 + 900 s
R=19000 (16 km/s)

3. Show case: UGC 10205. MEGARA data



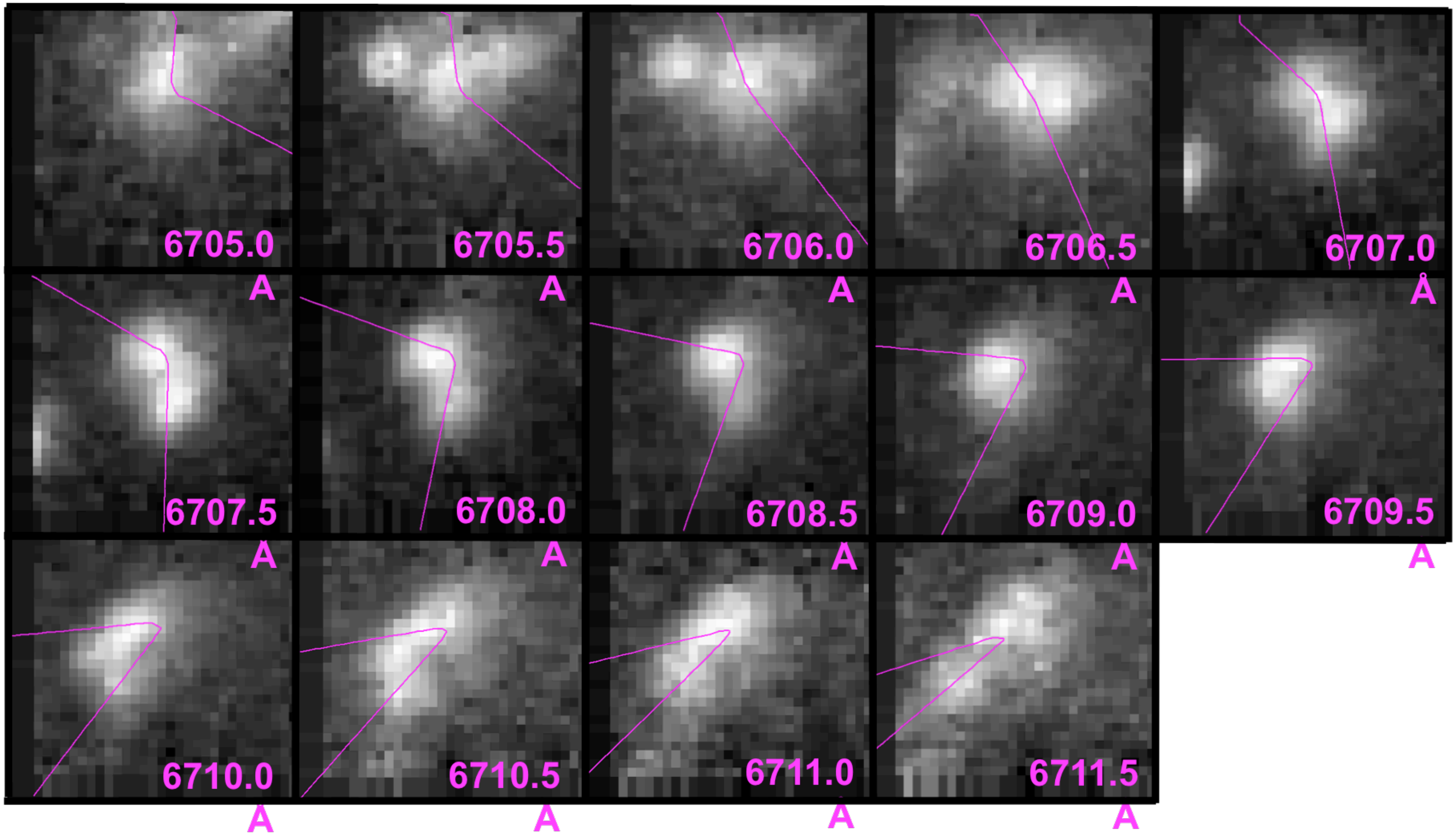
Spatial distribution of different kinematical ionized gas components.





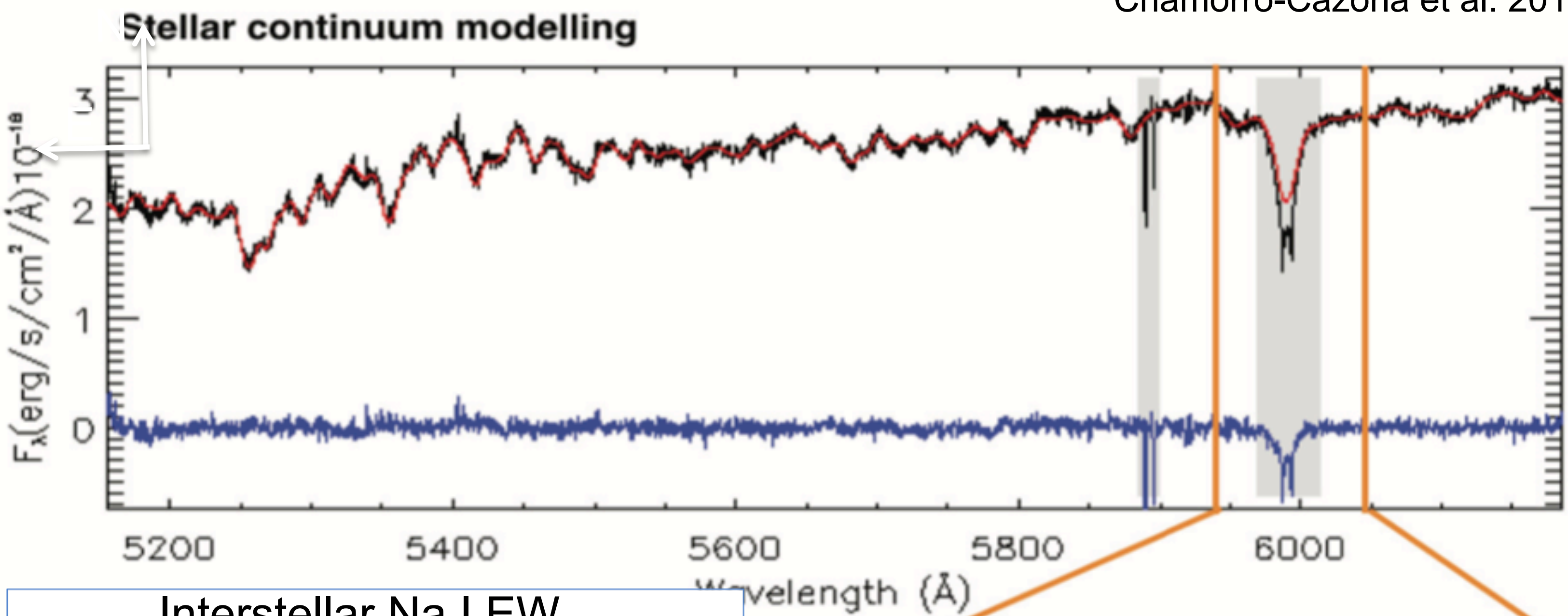
4. Show case: UGC 10205. MEGARA data

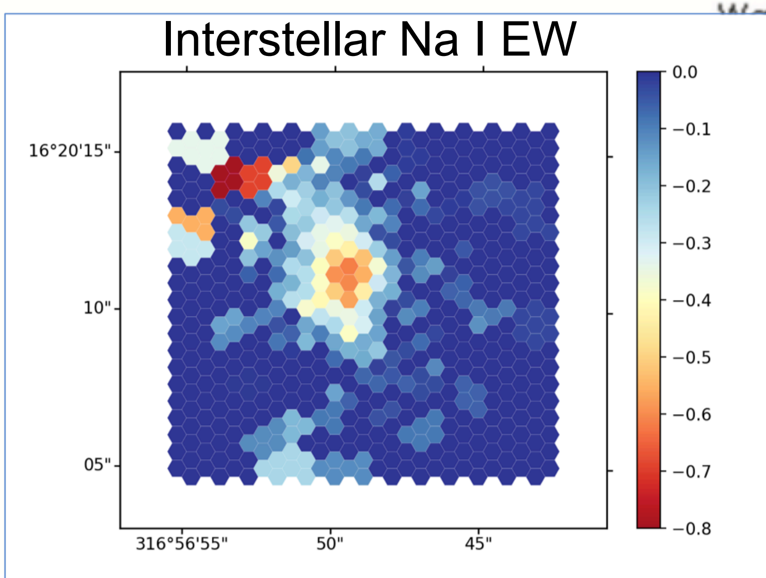
Hα velocity channel maps for the central part of the galaxy UGC 10205. Pink lines represent the isovelocity curves for a thin disk model with inclination of 70 degrees.

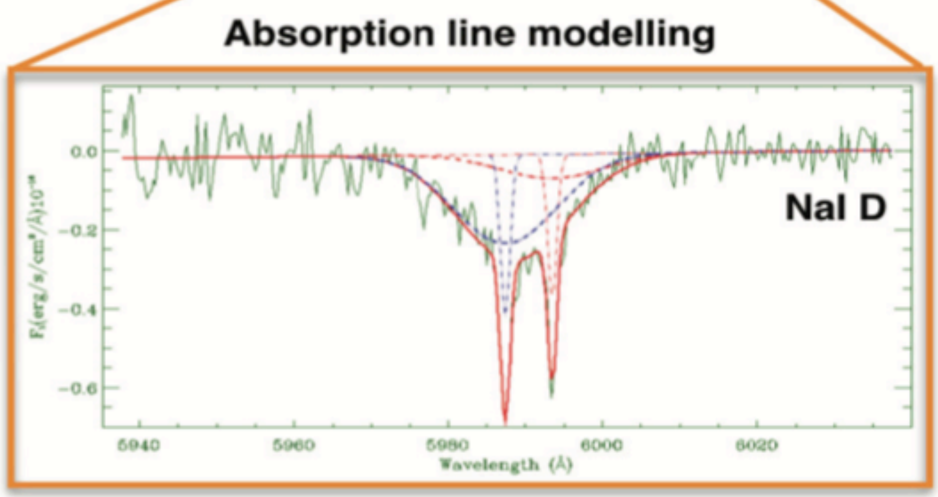


4. Show case: NGC 7025. MEGARA data

Chamorro-Cazorla et al. 2018 in prep.







Multi Espectrógrafo en GTC de Alta Resolución para Astronomía

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