Kinematics and abundances of circumnuclear star-forming regions

Guillermo F. Hägele

(Universidad Autónoma de Madrid)

...and a lot of collaborators that will appear in the corresponding part of the talk...

Mini Workshop Estallidos with Integral Field Units – IFUS
Granada - IAA. June, 17th - 19th, 2009

Introduction: Overview

CN regions: SF in high metallicity environments

The gas flows in disc of spiral galaxies can be strongly perturbed by the presence of bars, although the total disc SFR does not appear to be significantly affected by them (Kennicutt, 1998).

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These perturbations of the gas flow trigger nuclear star formation in the bulges of some barred spiral galaxies.

Introduction: Overview

CN regions: SF in high metallicity environments

The bulges of some nearby spiral galaxies show *intense star-forming regions* located in a *roughly annular pattern* around their nuclei.

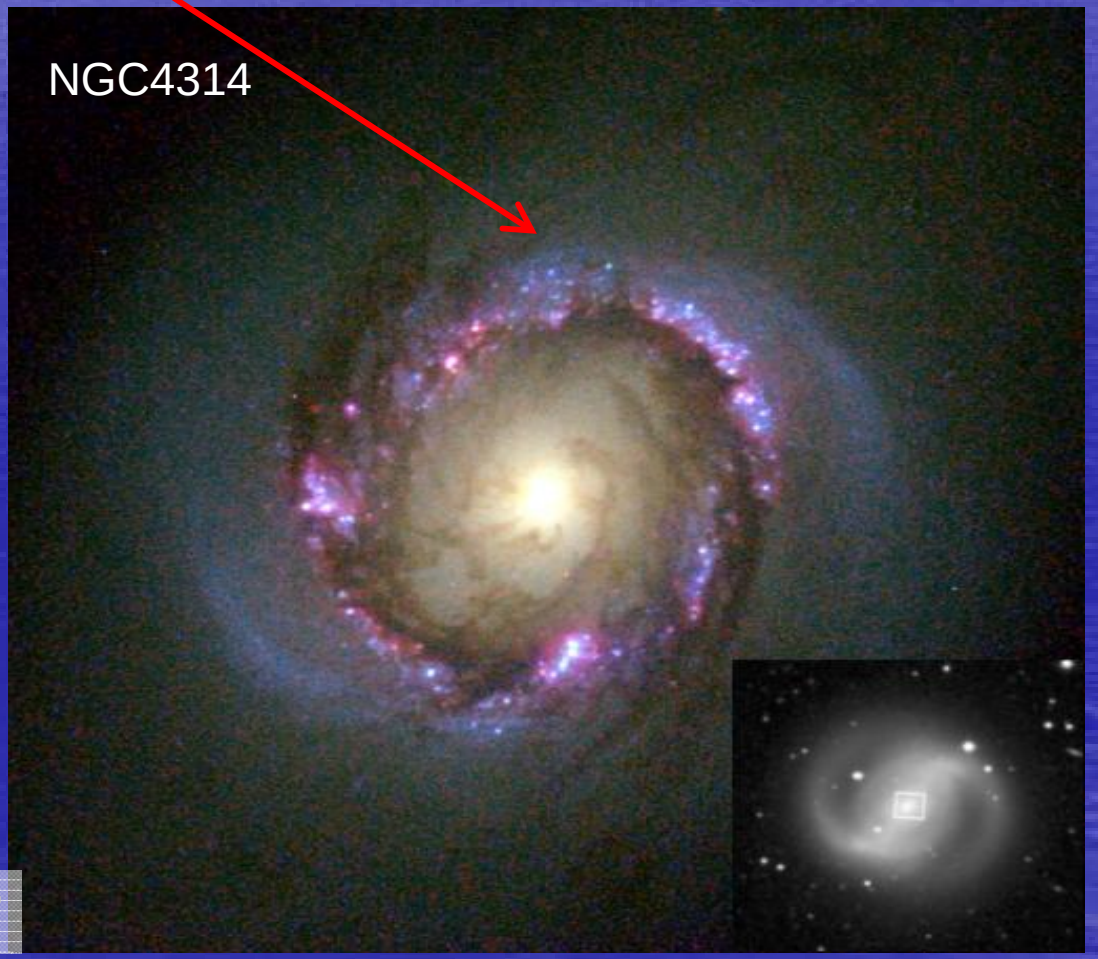
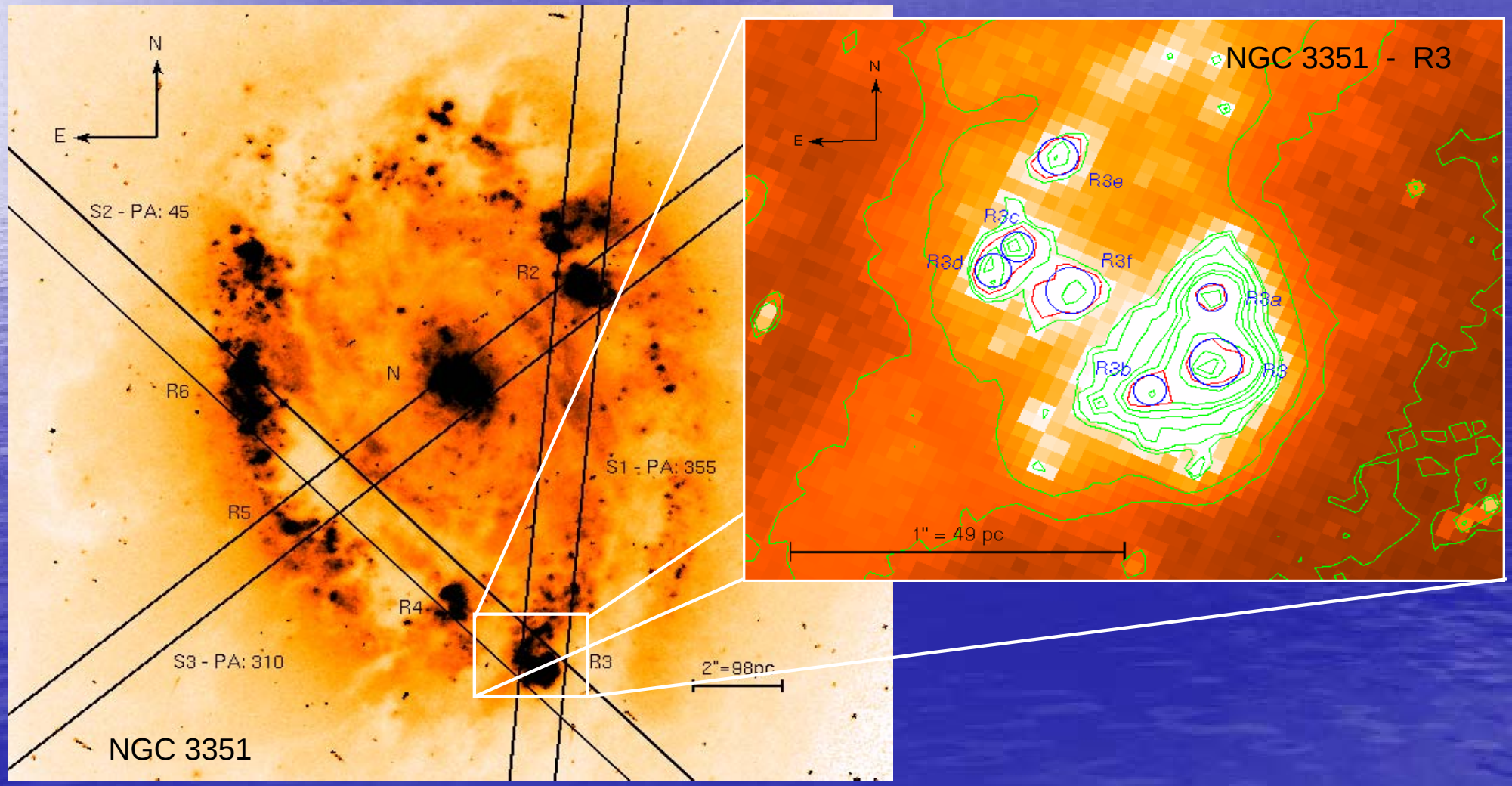


image from HST

Introduction: Overview

CNSFRs, with sizes going from a few tens to a few hundreds of pc (e.g., Díaz & Pérez-Montero, 2000) seem to be made of several HII regions ionized by luminous compact stellar clusters whose sizes, as measured from high spatial resolution HST images, are seen to be of only a few pc.



Introduction: Overview

CN regions: SF in high metallicity environments

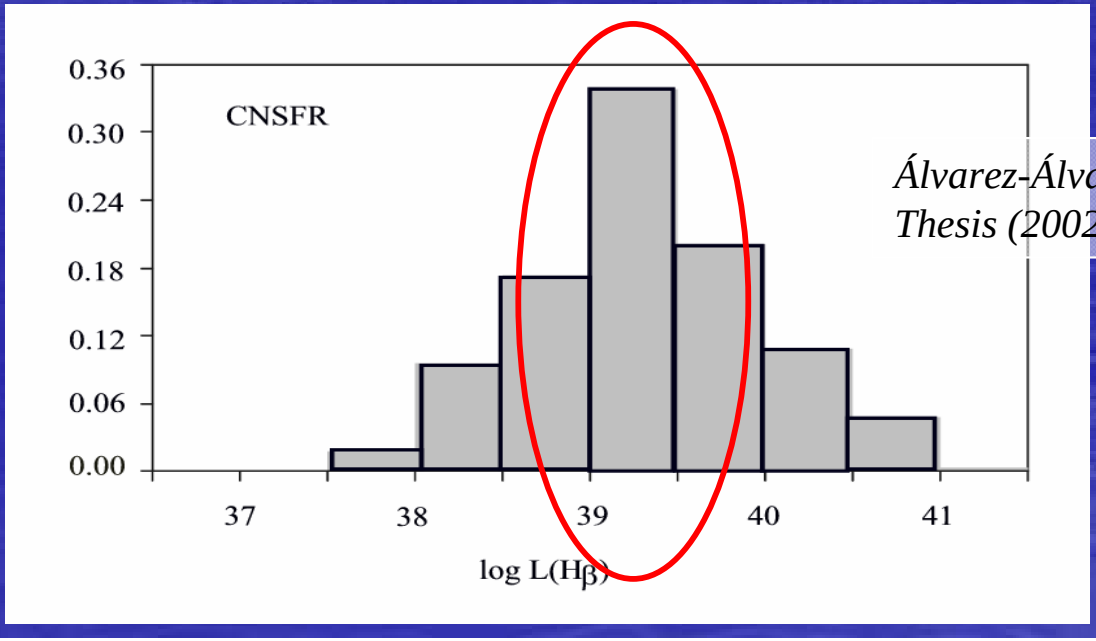
In general, *CNSFRs* and *giant HII regions in the discs of galaxies* are *very much alike*, although the former look *more compact and show higher peak surface brightness* (Kennicutt et al., 1989) than the latter.

Introduction: Overview

CN regions: SF in high metallicity environments

In general, ***CNSFRs*** and ***giant HII regions in the discs of galaxies*** are ***very much alike***, although the former look ***more compact and show higher peak surface brightness*** (Kennicutt et al., 1989) than the latter.

Their large ***Hα luminosities***, typically higher than 10^{39} erg s^{-1}, point to ***relatively massive star clusters as their ionization source***, which minimizes the uncertainties due to small number statistics when applying population synthesis techniques (see e.g. Cerviño et al., 2002).



Álvarez-Álvarez PhD Thesis (2002)

Introduction: Overview

CN regions: SF in high metallicity environments

Added interest in the study of *CNSFRs* comes from the fact that they *are in general of high metal abundance* (Díaz et al., 2006, 2007)

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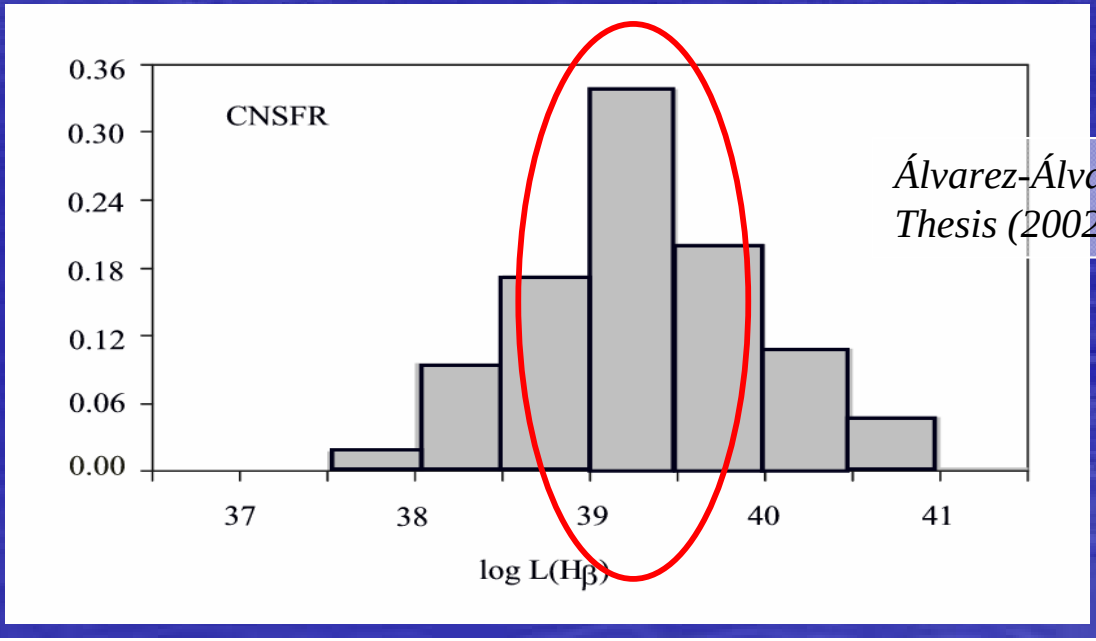

Álvarez-Álvarez PhD Thesis (2002)

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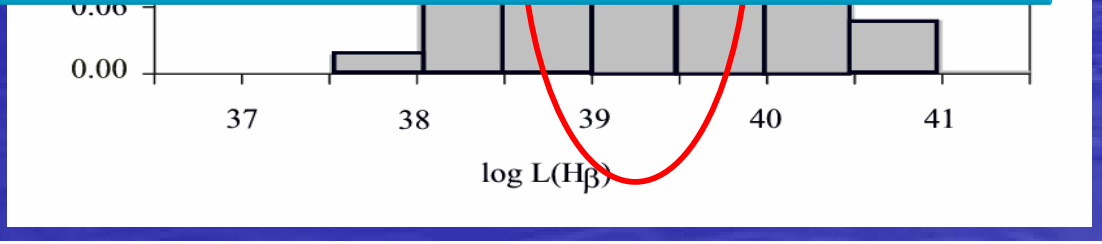
CN regions: SF in high metallicity environments

Added interest in the study of ***CNSFRs*** comes from the fact that they ***are in general of high metal abundance*** (Díaz et al., 2006, 2007)

therefore ***they provide clues for the understanding of star formation phenomena at large metallicities***, ***and***, being close to the nuclear regions, ***for the determination of metallicity gradients in spiral galaxies***.



lvarez PhD
002)

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This project is part of a study of the physics of CNSFRs in spiral galaxies.

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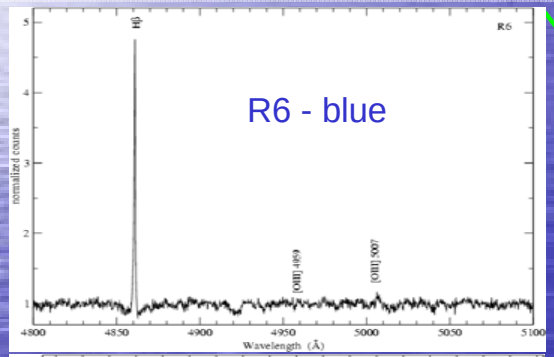
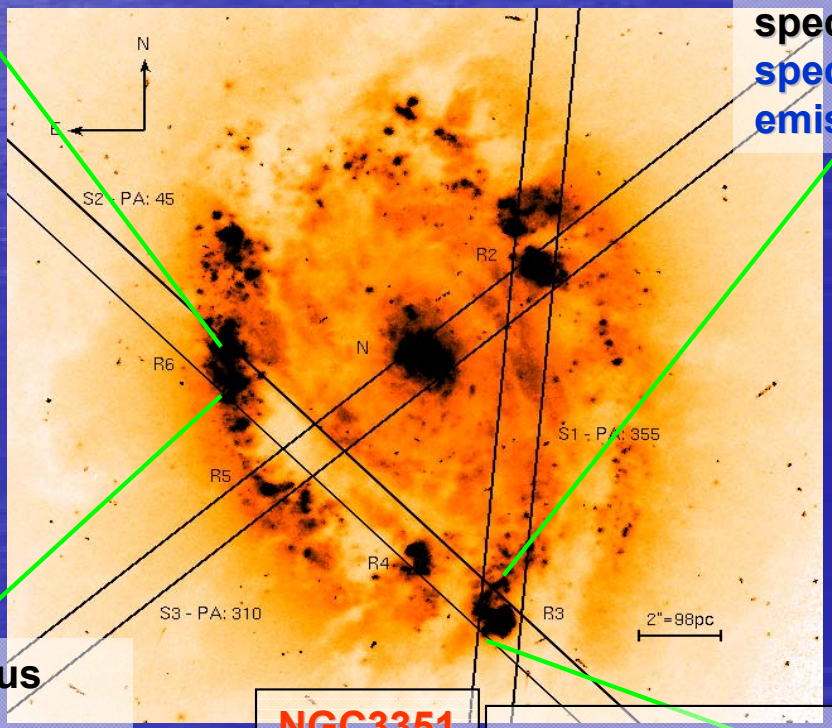
As part of a program designed to measure the dynamical masses of CNSFRs, we have analysed long slit high spectral resolution data obtained with the WHT and the ISIS spectrograph in the blue (Hβ and [OIII]) and the red (CaII triplet lines; CaT) which have allowed to measure star and gas velocity dispersions in several CNSFRs of spiral galaxies.

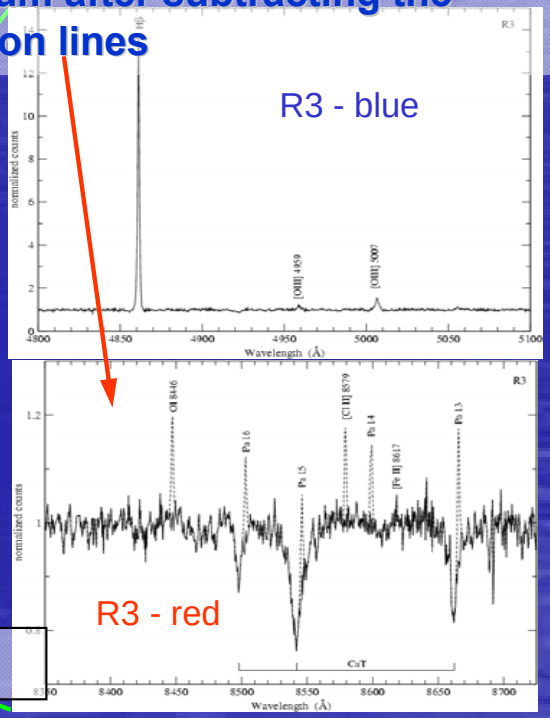




NGC3351

Hägele et al. (2007)

The dashed line shows the obtained spectrum; the solid line represents the spectrum after subtracting the emission lines



Notice the absence of conspicuous emission lines in the red spectral range for this region.

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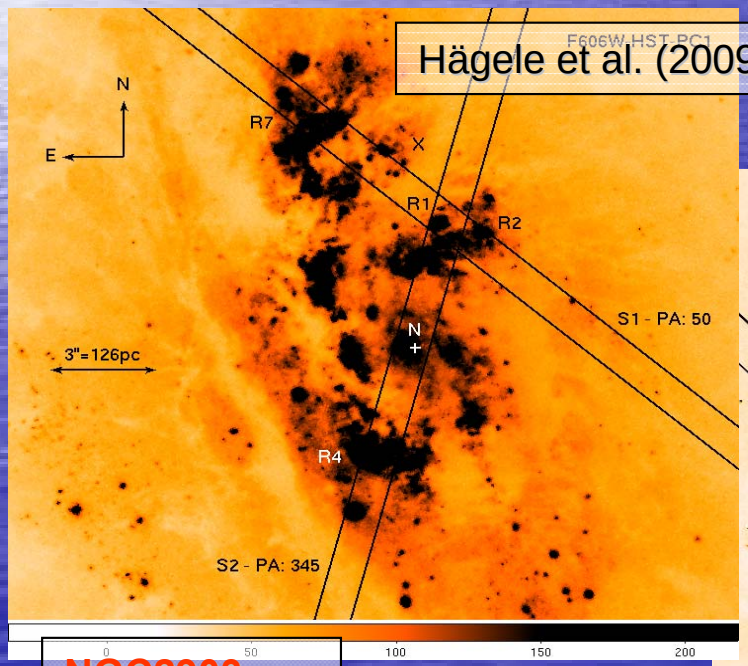
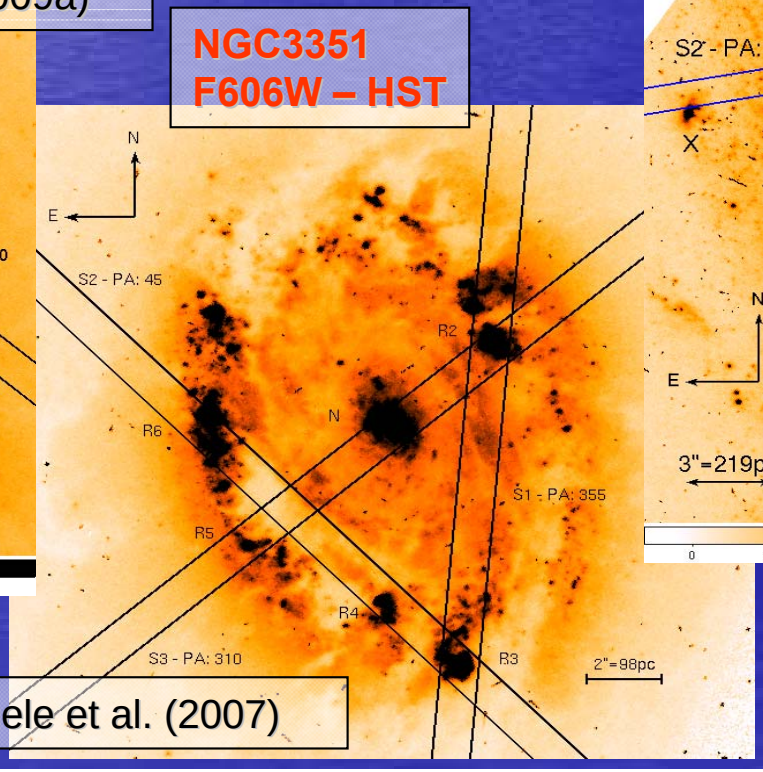


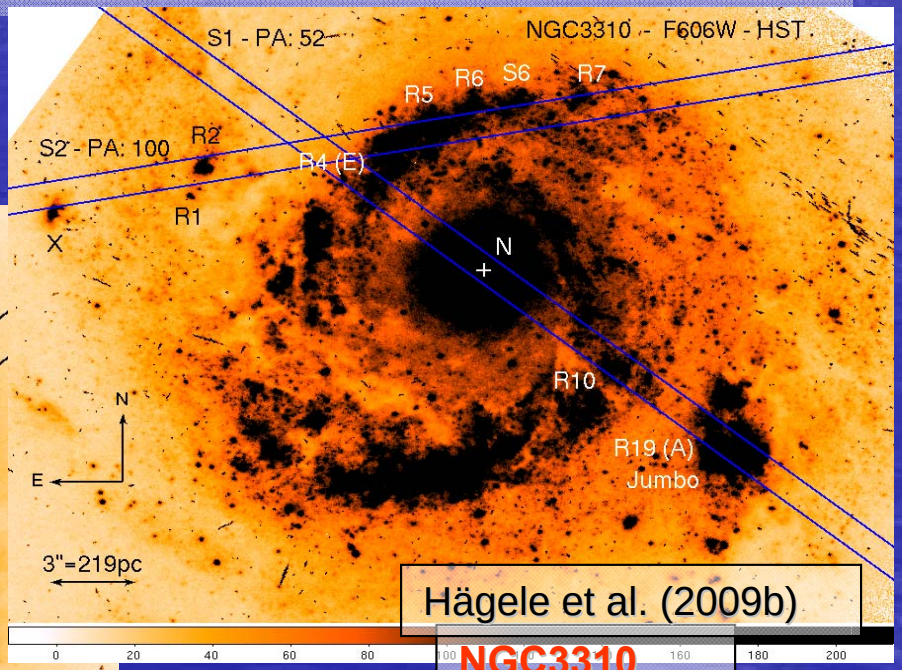
Hägele et al. (2009a)

NGC2903
F606W – HST



NGC3351
F606W – HST

Hägele et al. (2007)



Hägele et al. (2009b)

NGC3310
F606W – HST

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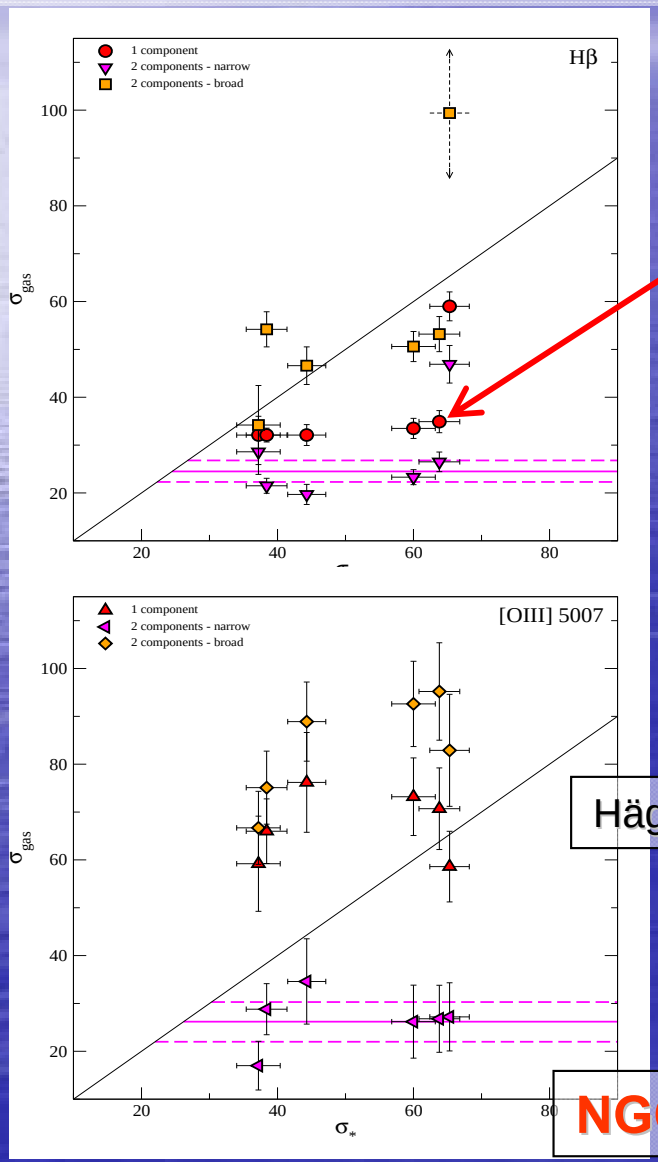
Stellar velocity dispersions are between 31 and 73 km/s. For NGC2903 and NGC3351 these values are about 25 km/s larger than those derived for the gas from the H β emission line using a single Gaussian fit.



Hägele et al. (2009a)

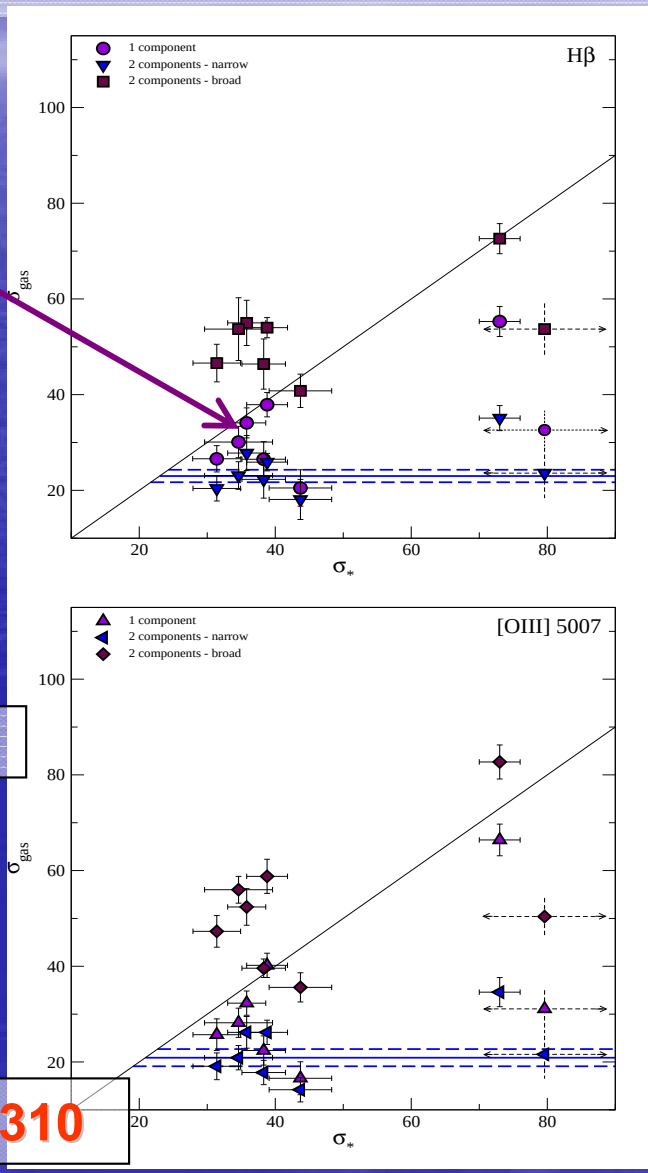
Hägele et al. (2007)

NGC2903

NGC3351

The velocity field of CNSF rings of early type spirals:

Stellar velocity dispersions are between 31 and 73 km/s. For NGC3310 these values and those derived for the gas from the Hβ emission line using a single Gaussian fit are in relatively good agreement.

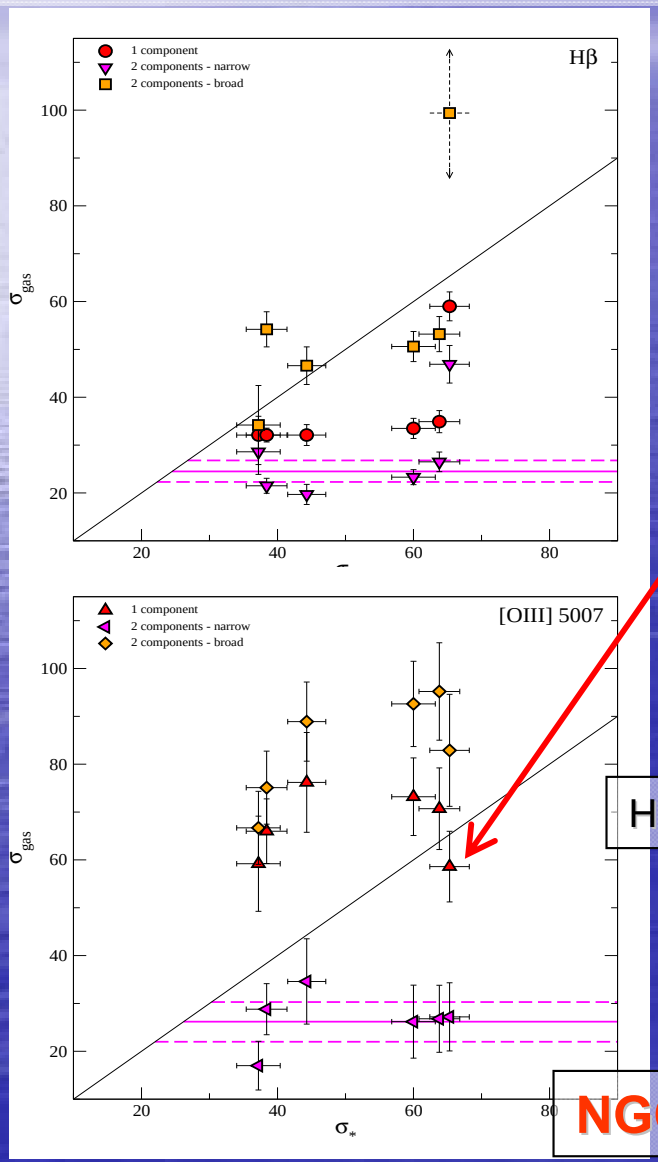


Hägele et al. (2009b)

NGC3310

The velocity field of CNSF rings of early type spirals:

Stellar velocity dispersions are between 31 and 73 km/s. The [OIII]5007Å presents velocity dispersions almost coincident with the stellar ones, or slightly, for NGC2903 and NGC3351,

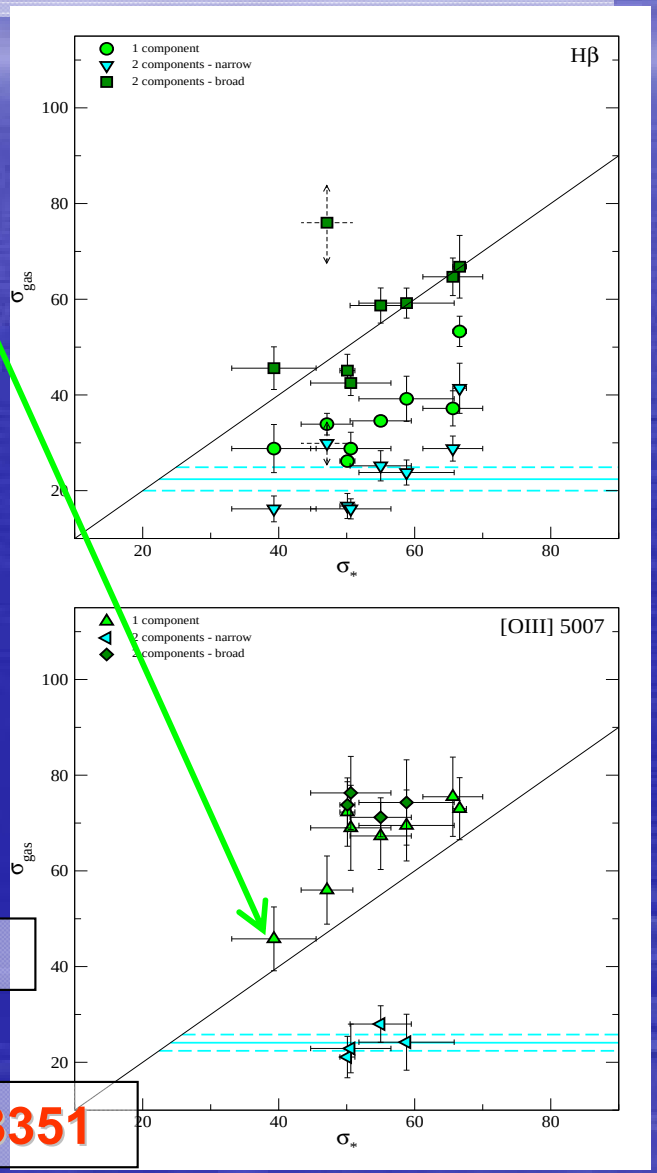


Hägele et al. (2009b)

Hägele et al. (2007)

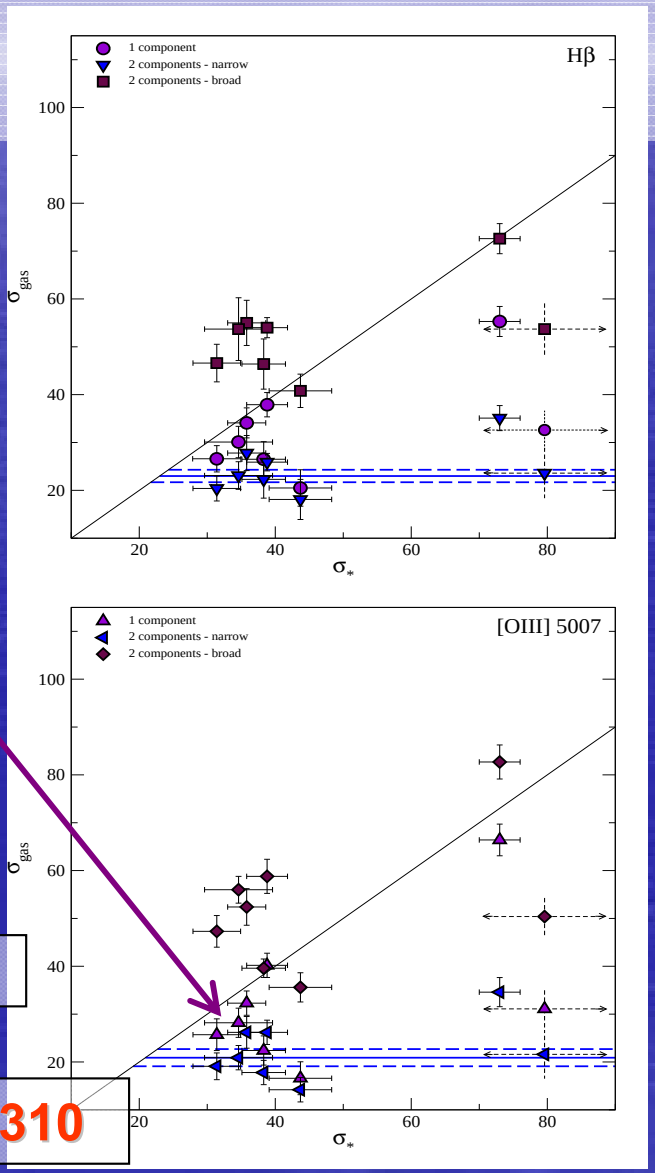
NGC2903

NGC3351



The velocity field of CNSF rings of early type spirals:

Stellar velocity dispersions are between 31 and 73 km/s. The [OIII]5007Å presents velocity dispersions almost coincident with the stellar ones, or slightly, for NGC2903 and NGC3351, while in the case of NGC3310 its behaviour is very similar to that shown by the Hβ line.



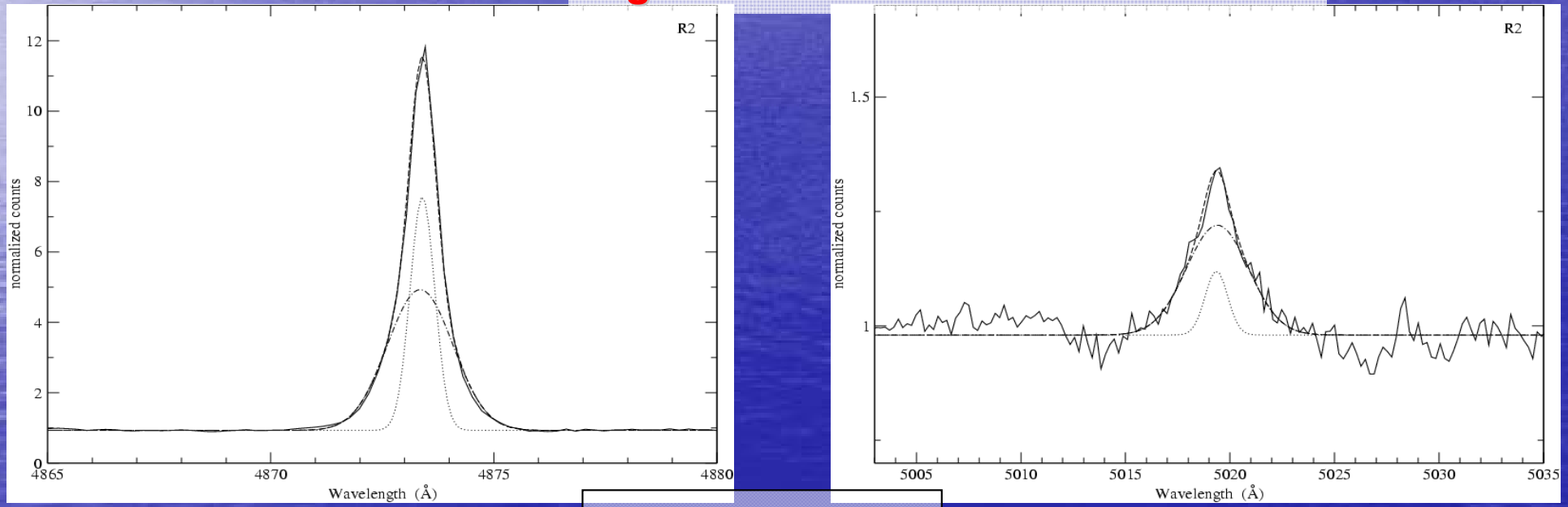
Hägele et al. (2009b)

NGC3310

The velocity field of CNSF rings of early type spirals:

However, the best Gaussian fits involved two different components for the gas:

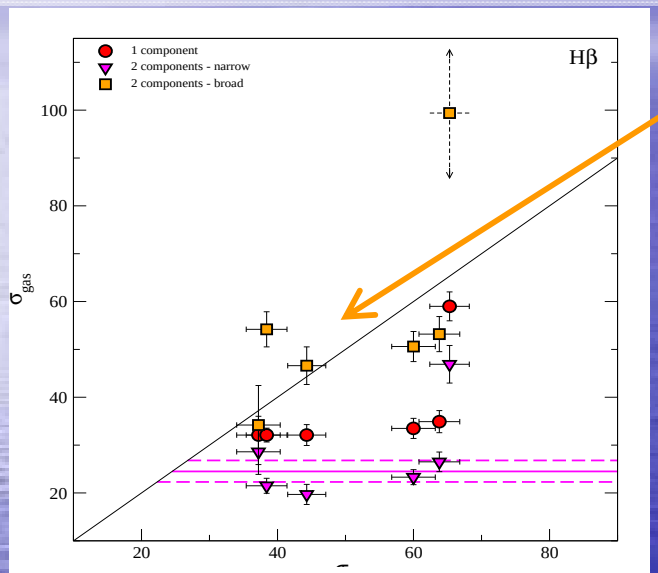
The optimal fit was found for two different components for all the regions.

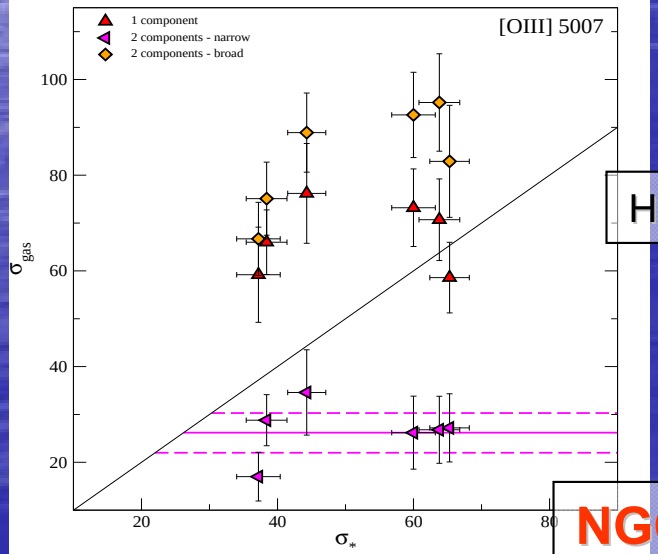


Hägele et al. (2007)

The velocity field of CNSF rings of early type spirals:

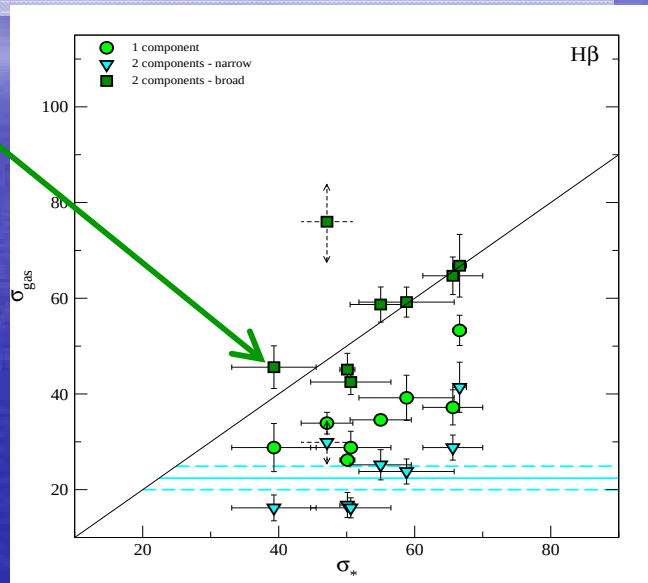
However, the best Gaussian fits involved two different components for the gas: a "broad component" with a velocity dispersion similar to that measured for the stars for NGC2903 and NGC3351

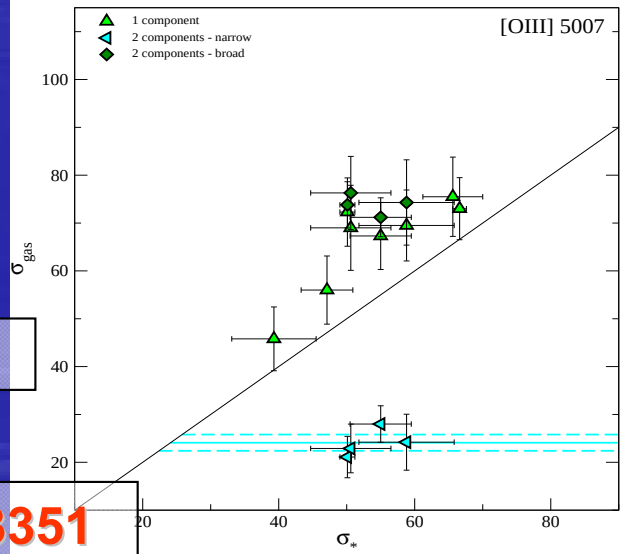




Hägele et al. (2009a)

NGC2903





Hägele et al. (2007)

NGC3351

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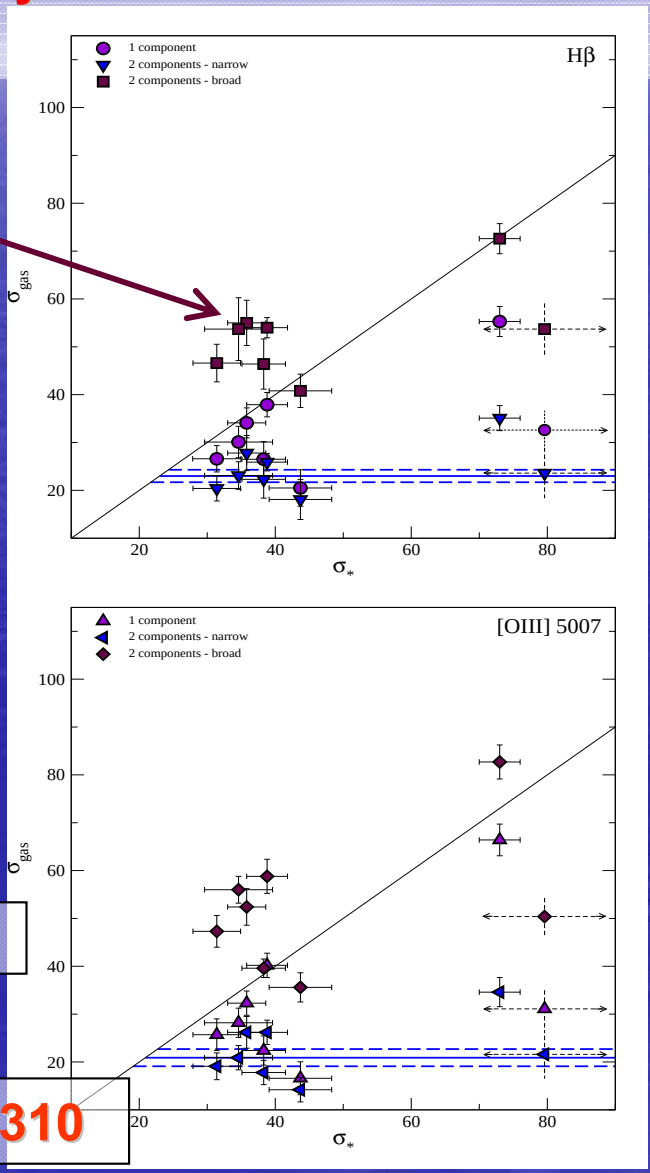
However, the best Gaussian fits involved two different components for the gas: a "broad component" with a velocity dispersion similar to that measured for the stars for NGC2903 and NGC3351, and larger by about 20 km/s for NGC3310.

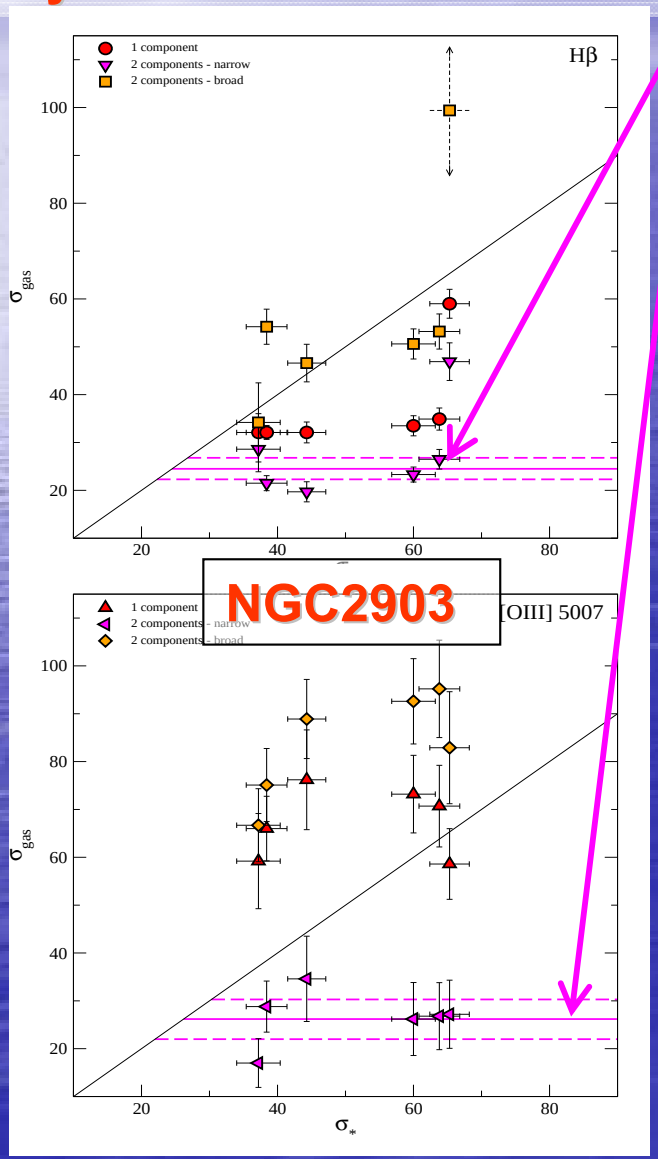


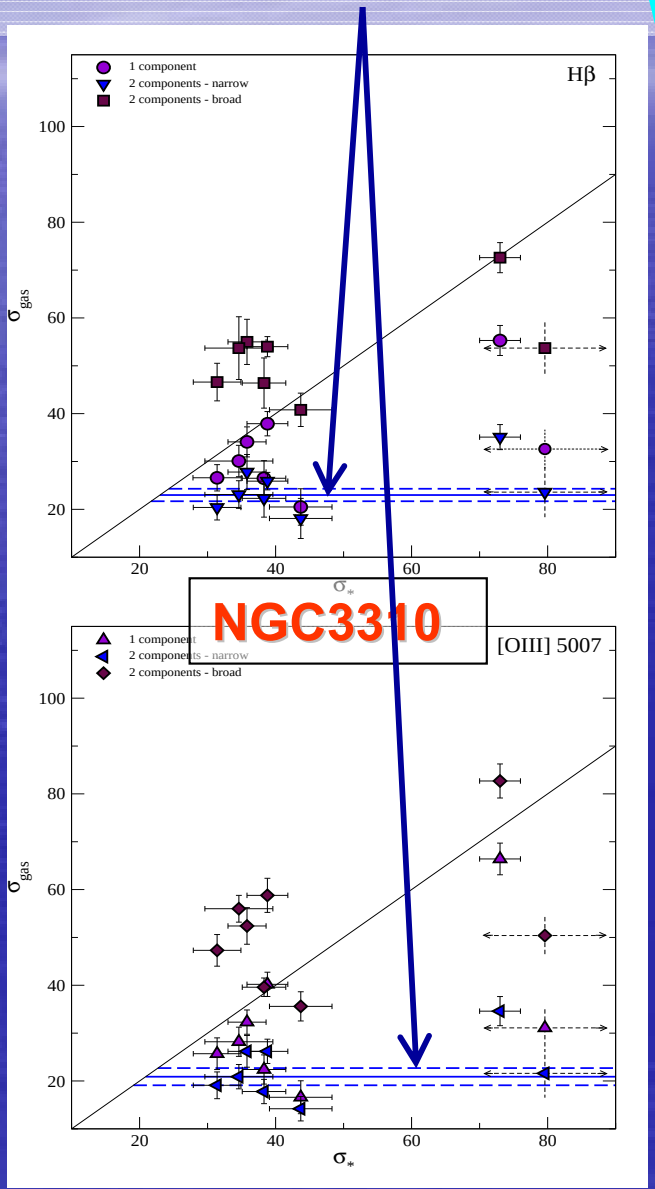
Hägele et al. (2009b)

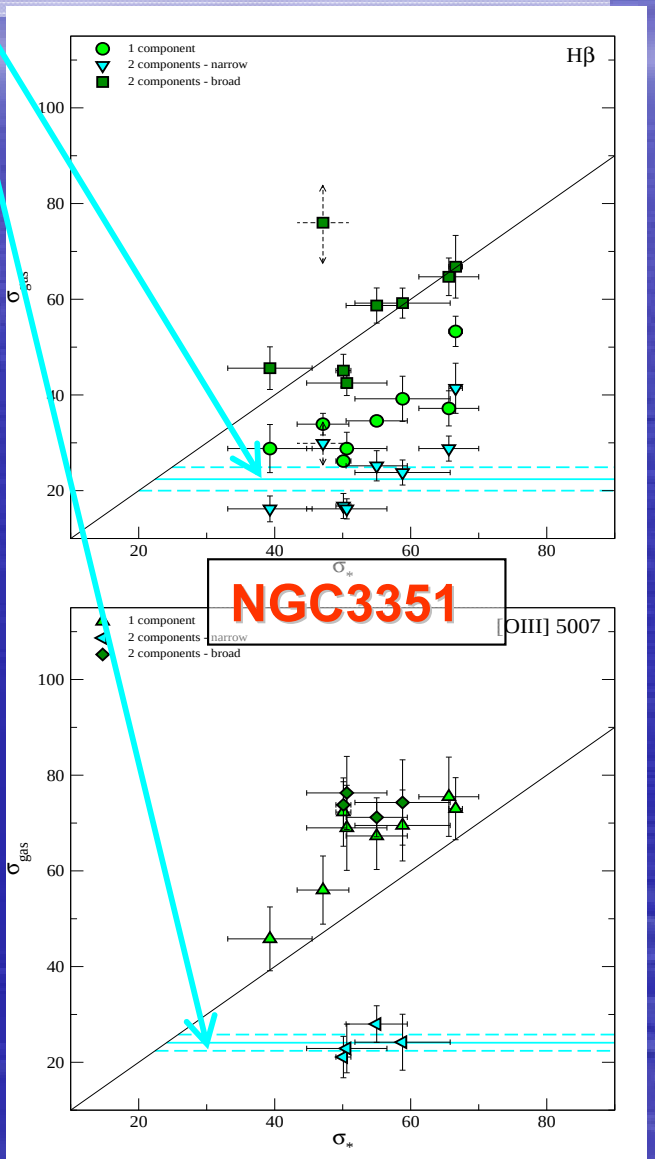
NGC3310

The velocity field of CNSF rings of early type spirals:

However, the best Gaussian fits involved two different components for the gas: and a "narrow component" with velocity dispersions lower than the stellar one by about 30 km/s.







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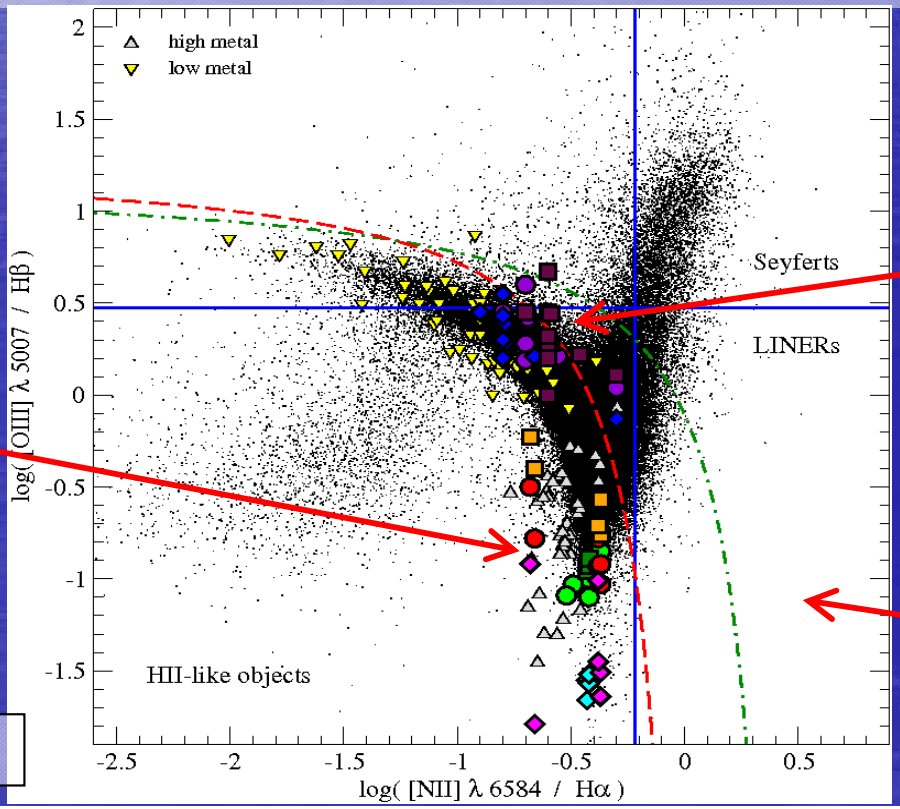
When plotted in a [OIII]/Hβ vs. [NII]/Hα diagram (BPT, Baldwin, Phillips & Terlevich, 1981), the two systems are clearly segregated for the high-metallicity regions of NGC2903 and NGC3351

with the narrow component having the lowest excitation and being among the lowest excitation line ratios detected within the SDSS dataset of starburst systems



In the regions of the low-metallicity galaxy, NGC3310, these two components and those values derived using the single Gaussian fit are very similar

Hägele (2008)

SDSS data from López (2005)

The velocity field of CNSF rings of early type spirals:

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Several results derived from the observations of the different emission lines could be affected, among others: the classification of the activity in the central regions of galaxies, the inferences about the nature of the source of ionization, the gas abundance determinations, the number of ionizing photons from a given region and any quantity derived from them, etc.

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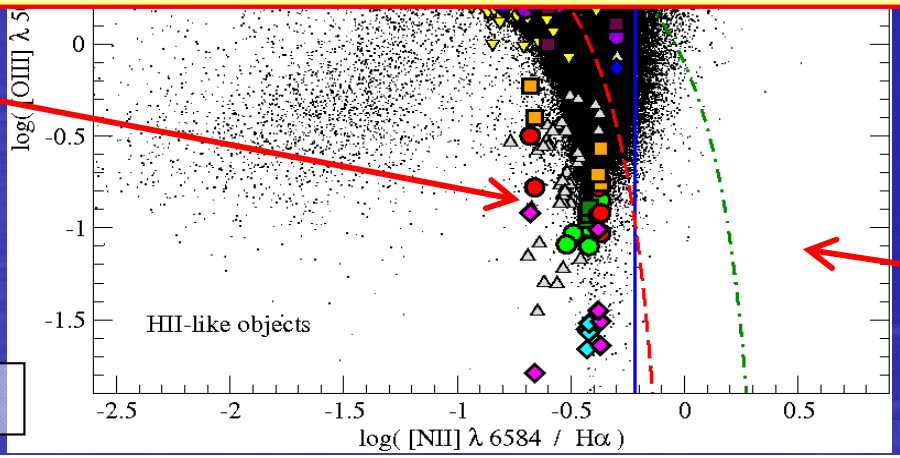

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We therefore propose to observe the circunnuclear region of NGC3351, NGC2903 and NGC3310 with PMAS in lens array configuration at the higher spectral resolution.

NGC2903

NGC3351

NGC3310

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Initial work team: Guillermo Hägele, Ángeles Díaz, Elena Terlevich, Roberto Terlevich and Mónica Cardaci.

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NGC2903

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The average size of the CNSFR in the proposed galaxies, as seen from Hα images is between 0.5 and 1” (Planesas et al. 1997).

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We plan to observe their central circumnuclear regions with PMAS in the lens array configuration at the intermediate spatial resolution of 0.75", since average seeing in CAHA is about 1 arcsec.

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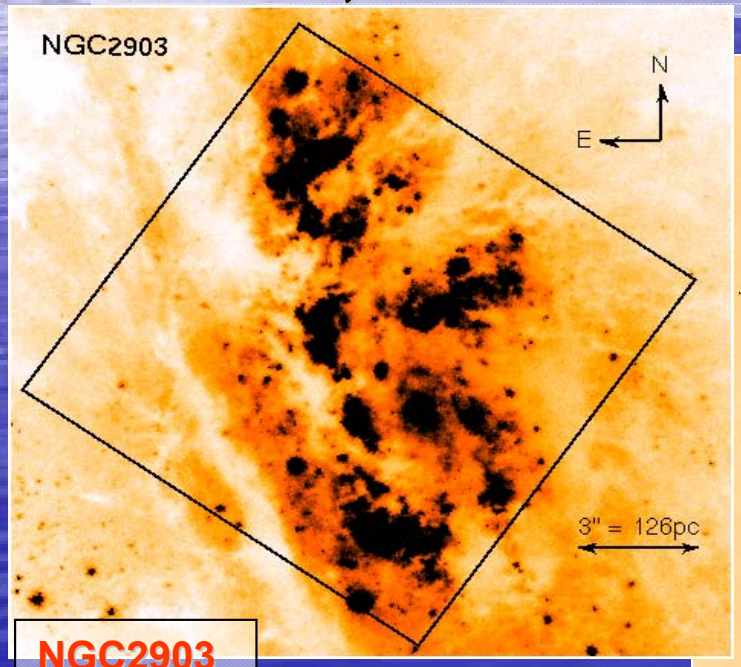
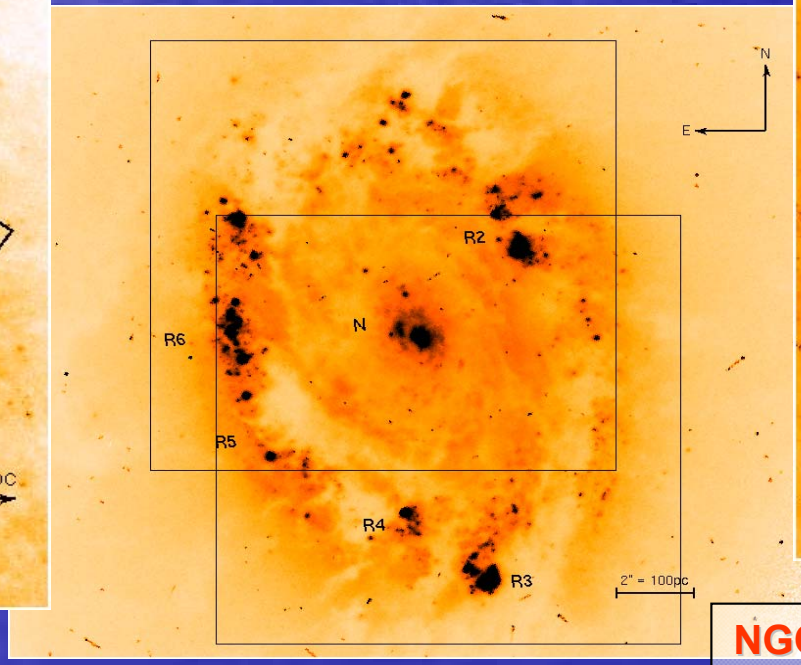
The **average size** of the CNSFR in the proposed galaxies, as seen from Hα images **is between 0.5 and 1”** (Planesas et al. 1997).

We plan to observe their central circumnuclear regions with PMAS in the lens array configuration at the **intermediate spatial resolution of 0.75”**, since average seeing in CAHA is about 1 arcsec.

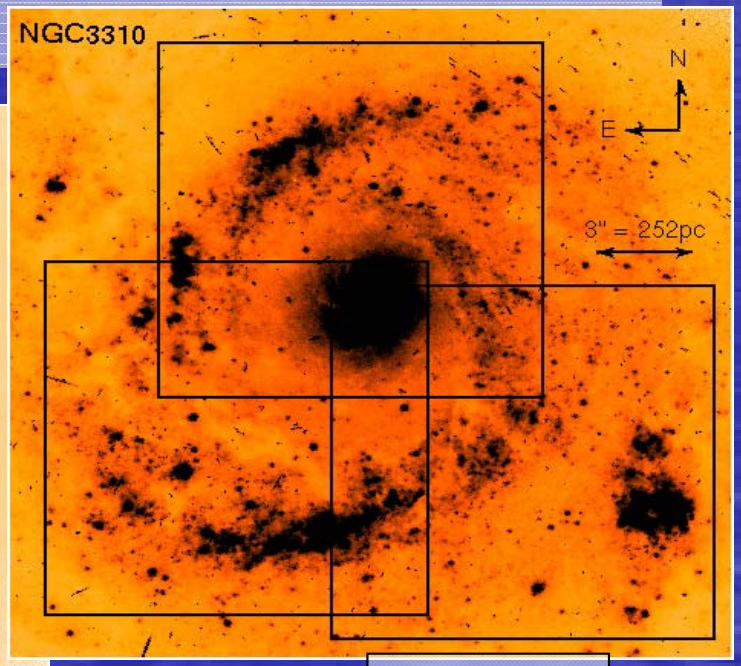
Due to the sizes of the regions to be observed, **one position covers** the cincumnuclear region of **NGC2903**, a **mosaic of two positions** will be needed for **NGC3351**, and **three** for **NGC3310**.



NGC2903



NGC3351



NGC3310

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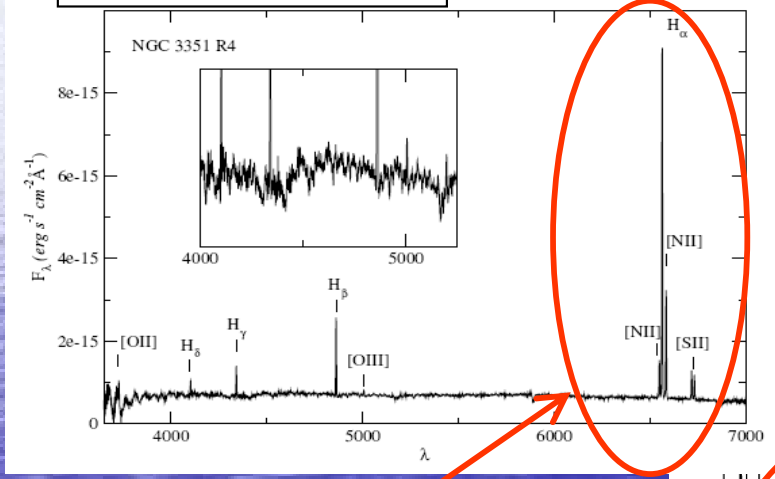
The velocity field of CNSF rings of early type spirals:

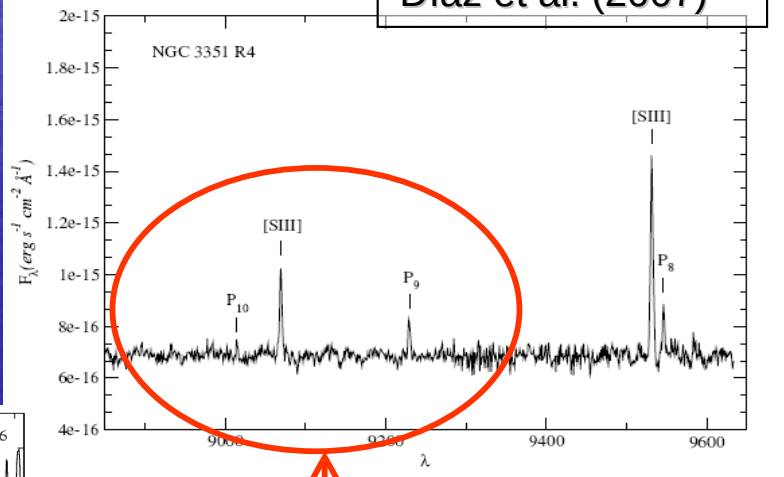
We will use the 1200 lpmm grating in first order (forward blaze) in three different angles, covering the region between 6200 and 9600 Å at different grating angles to include collisionally excited gas of ions in different ionization stages and H recombination lines, and the CaT stellar feature.

Díaz et al. (2007)

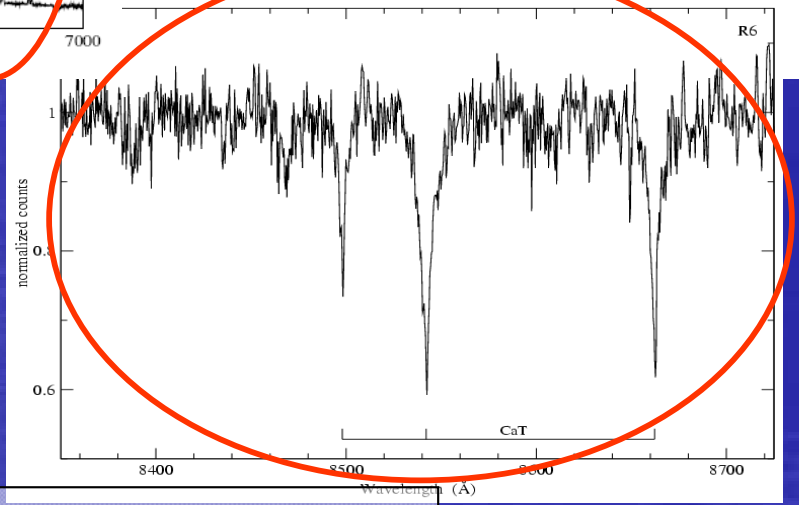


A second one centered at 8452Å covering from 8162 to 8720Å including the CaT stellar lines.

Díaz et al. (2007)



One centered at 6551Å covering from 6212 to 6871Å and including the lines of [OI] λ 6300Å, Hα, [NII] λ λ 6548,6584Å and [SII] λ λ 6717,6731Å.



Hägele et al. (2007)

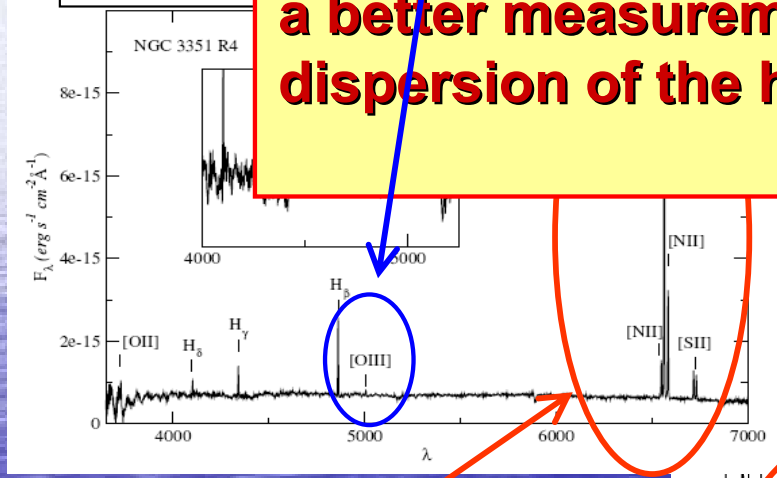
The third one will be centered at 9124Å covering from 8854 to 9371Å including the [SIII] λ 9069Å and Paschen P9 and P10 lines.

The velocity field of CNSF rings of early type spirals:

We will use the 1200 lpmm grating in first order (forward blaze) in three different angles to incl… different grating angles …nization stages and H recom…

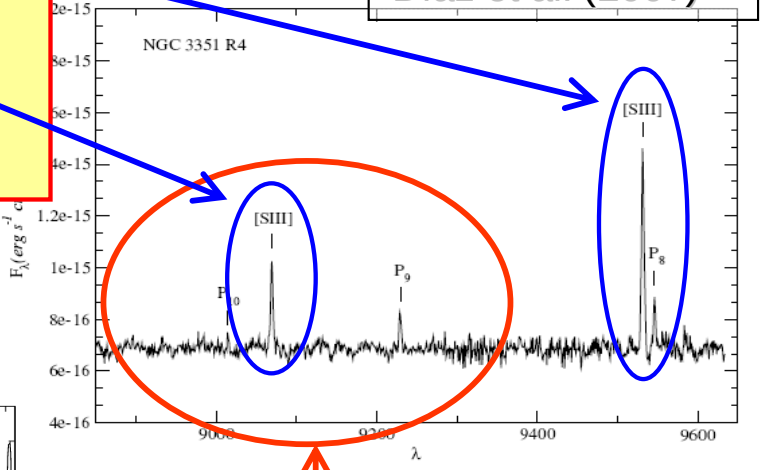
The [SIII] lines are much stronger than the [OIII] λ 5007Å line in high metallicity regions (see Castellanos et al. 2002, Díaz et al. 2007) so their detection would allow a better measurement of the velocity dispersion of the highly ionized gas.

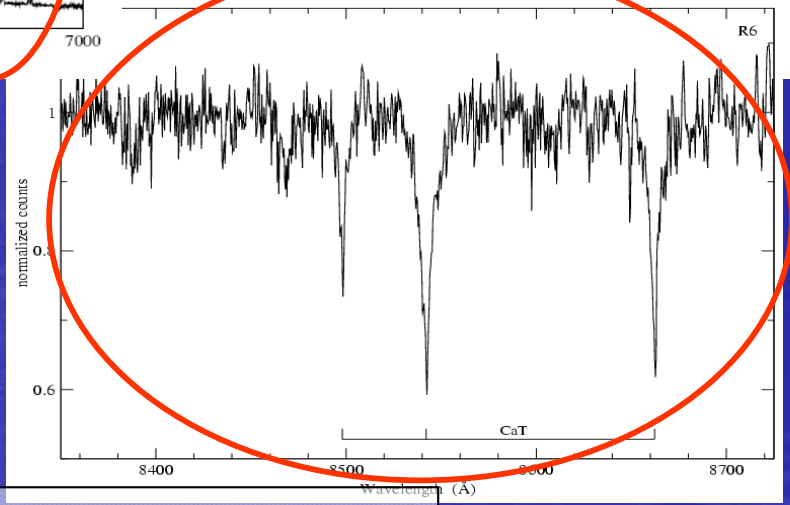
Díaz et al…



…CaT stellar lines.

Díaz et al. (2007)





Hägele et al. (2007)

One centered at 6551Å covering from 6212 to 6871Å and including the lines of [OI] λ 6300Å, Hα, [NII] λ λ 6548,6584Å and [SII] λ λ 6717,6731Å.

The third one will be centered at 9124Å covering from 8854 to 9371Å including the [SIII] λ 9069Å and Paschen P9 and P10 lines.

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This proposal, for NGC3351 only, was awarded 1 night in period F-2007 (F07-3.5-043) that was almost entirely lost by bad weather.

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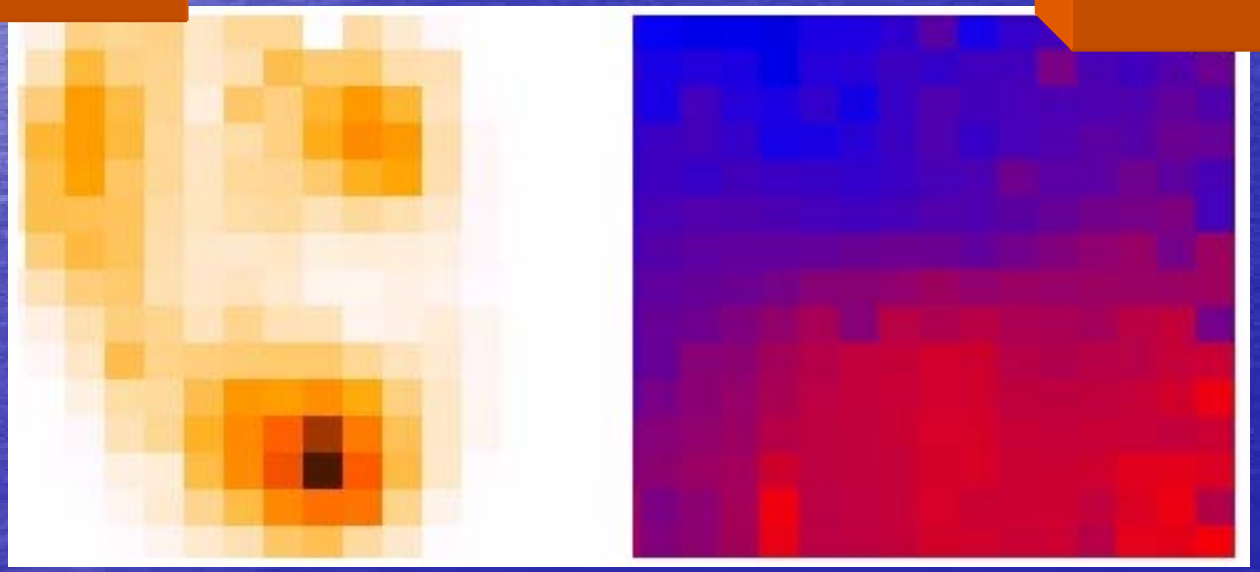
Hα flux map where the main CNSFR can be seen.

radial velocity map showing the inner galaxy rotation.



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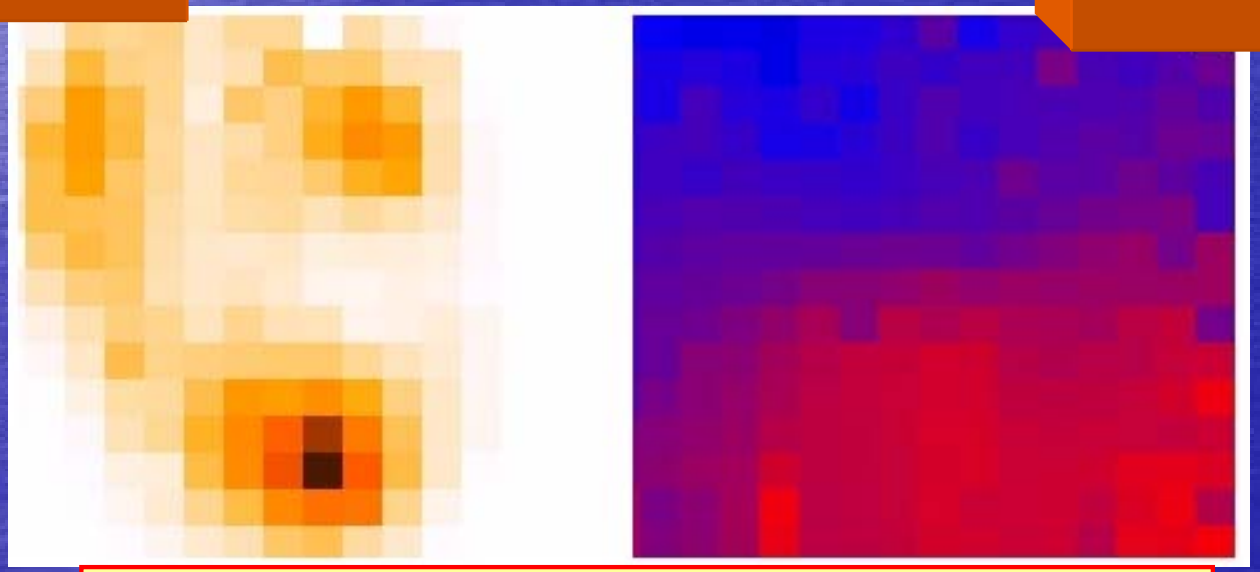

This observation showed that the project is feasible.

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Spectral resolution: 0.8-0.7 Å/px
2x2 binning
FWHM: 3.6-3.7 Å/px
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The data don't have enough spectral resolution to separate the narrow and the broad components of the emission lines, and to derive the stellar velocity dispersion from the CaT with the required accuracy.

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We are planning the "better" way to use these observations. Yago Ascasibar joined the group!!!!! ☺

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In parallel, we have started to analyse near-IR IFU images of NGC1068 taken with the GNIRS GEMINI-South slicer (IFU mode) during an engineering run.

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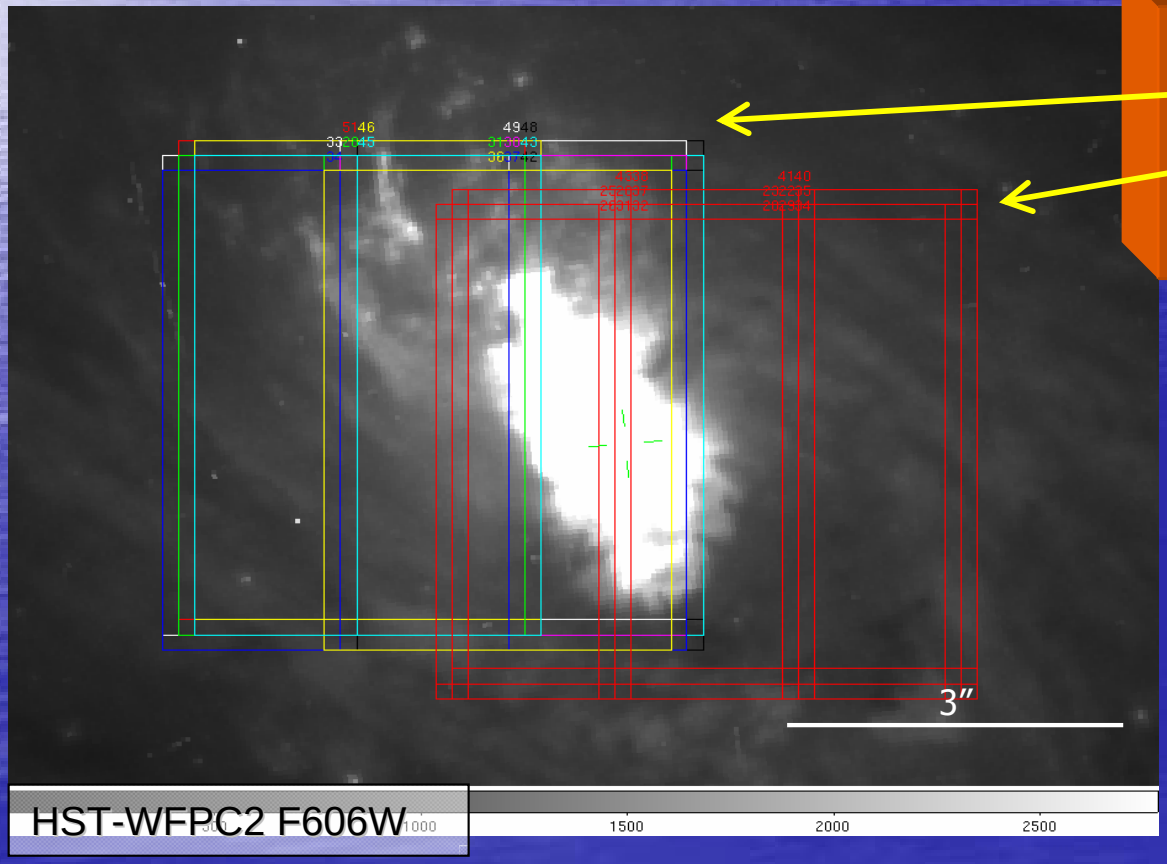

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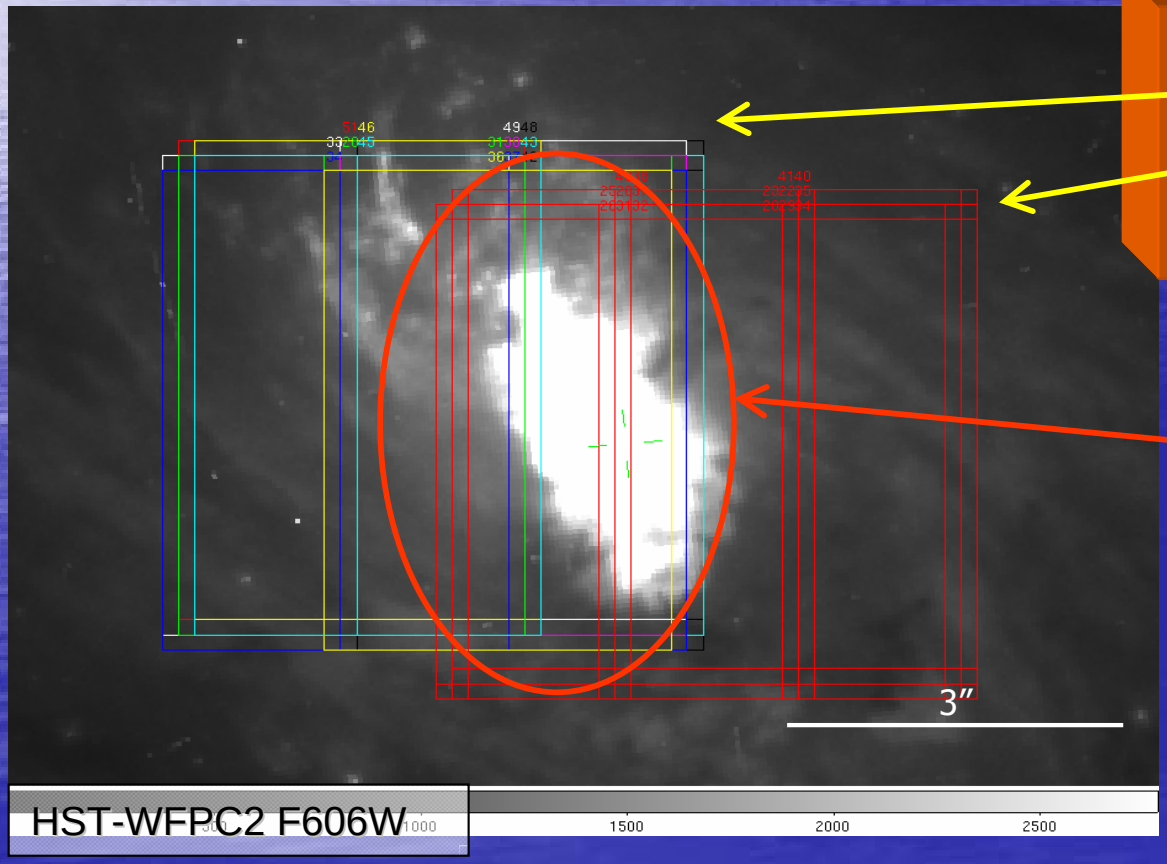

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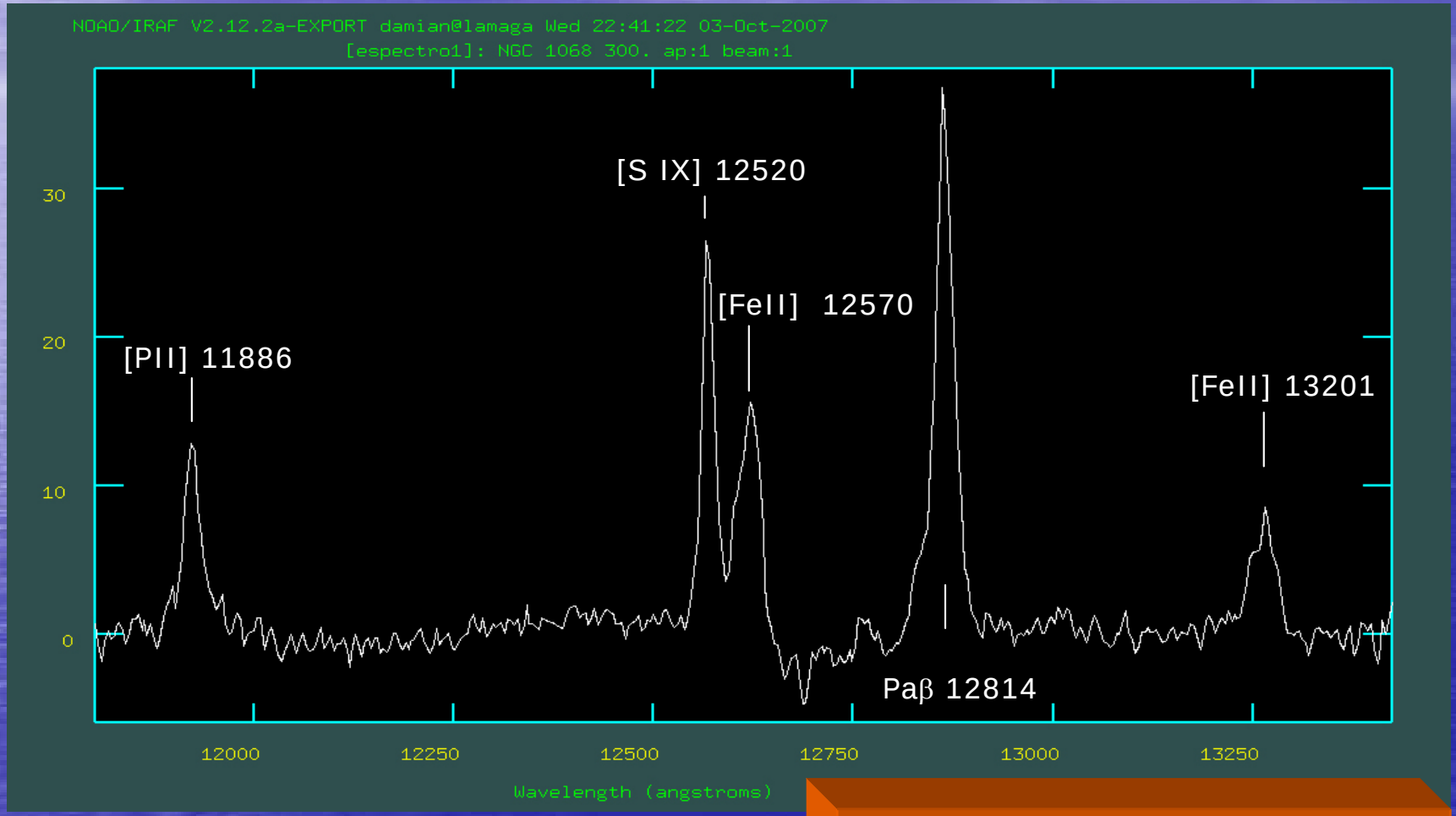
There is a relatively small area observed in both spectral ranges.

The velocity field of the CNSF regions of NGC1068:

Progress report (work slowly in progress)



Example of what we can see in the J-band.

The velocity field of the CNSF regions of NGC1068:

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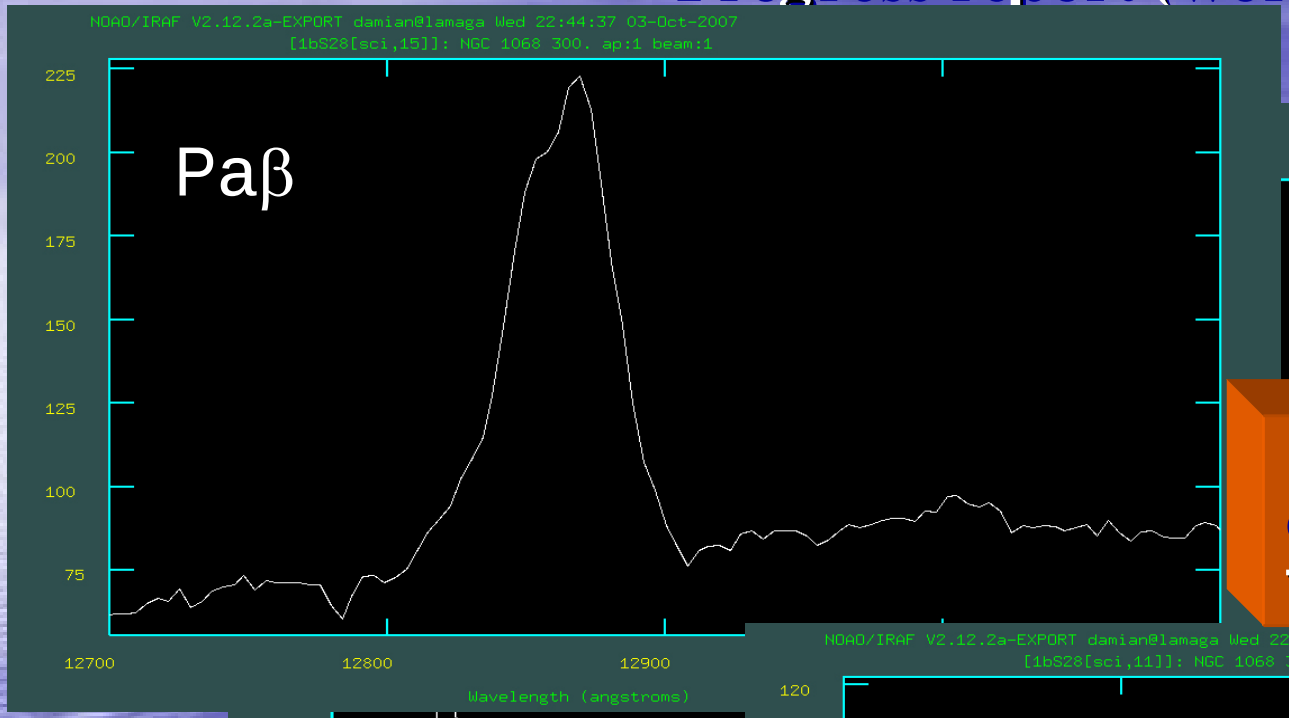
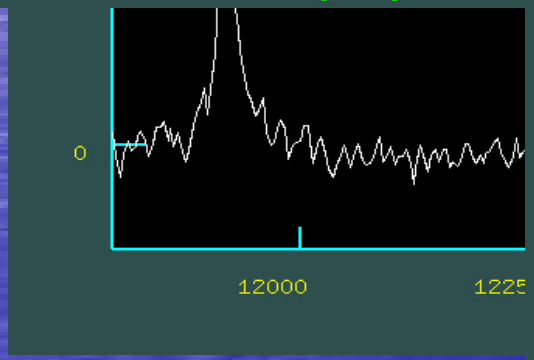
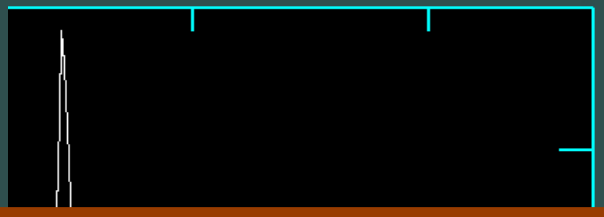
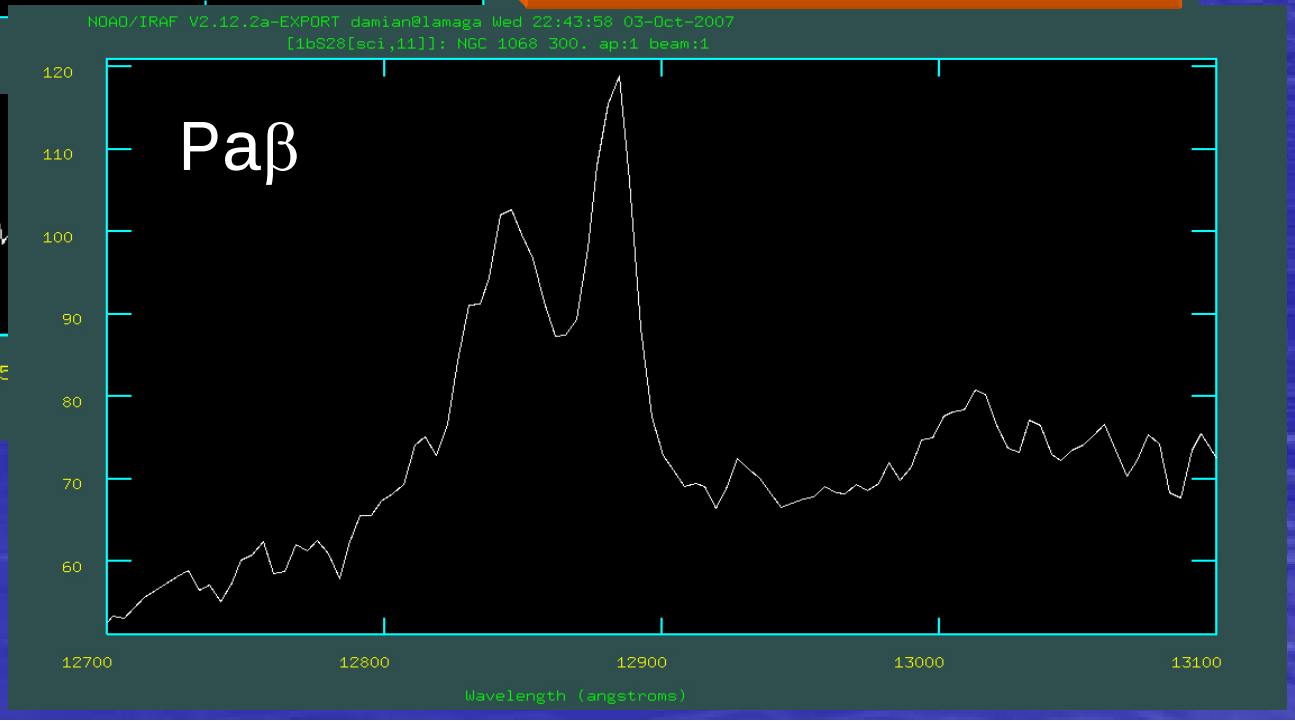






Examples of the multi-components found in the Paβ emission line.



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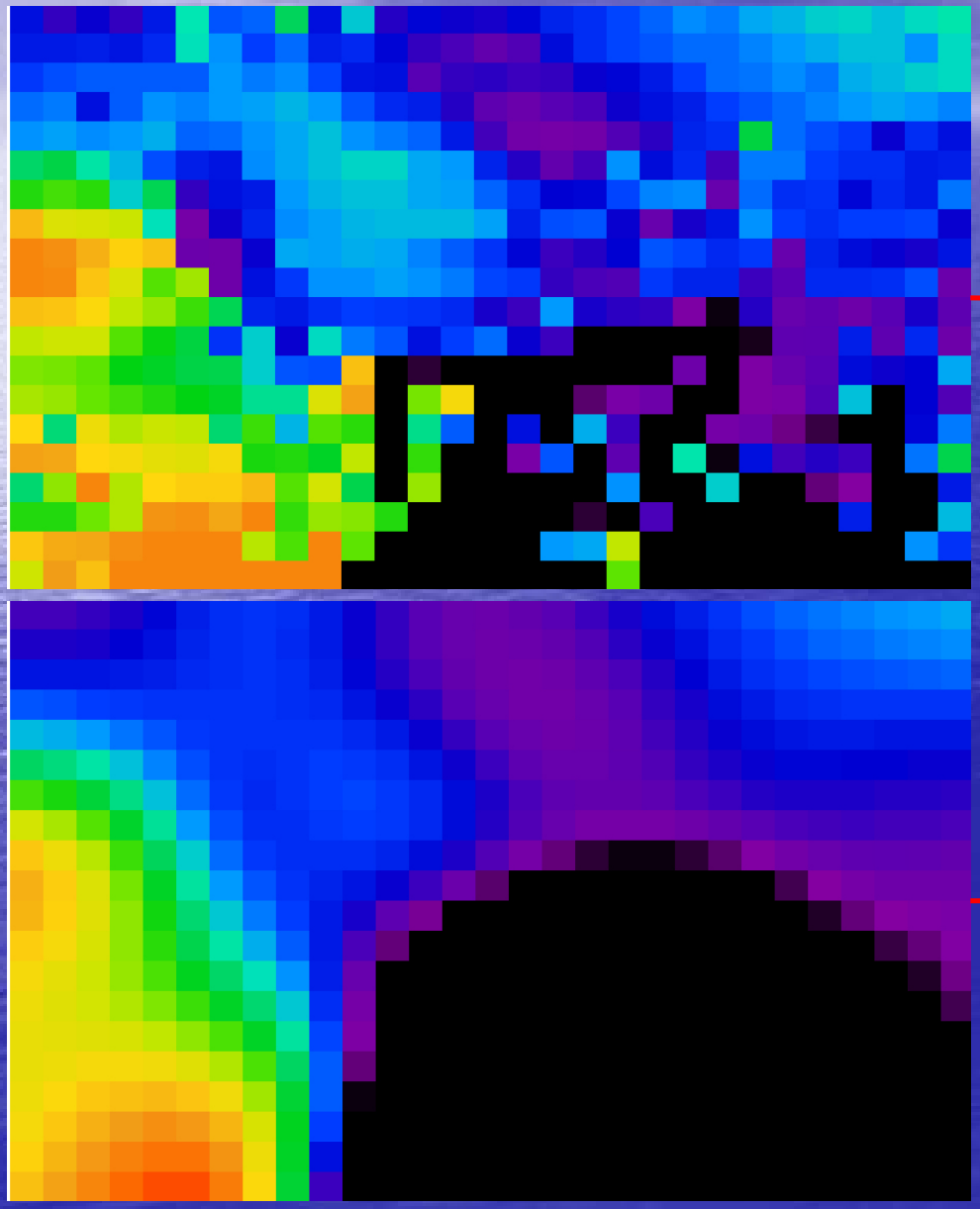

1689 km sec^{-1}

1300 km sec^{-1}

990 km sec^{-1}

Velocity field made using the main Pa β component (obs. 28, a single field of view). Spaxel: 0.15”x0.15”

Rebinned using a 2x2 Gaussian filter

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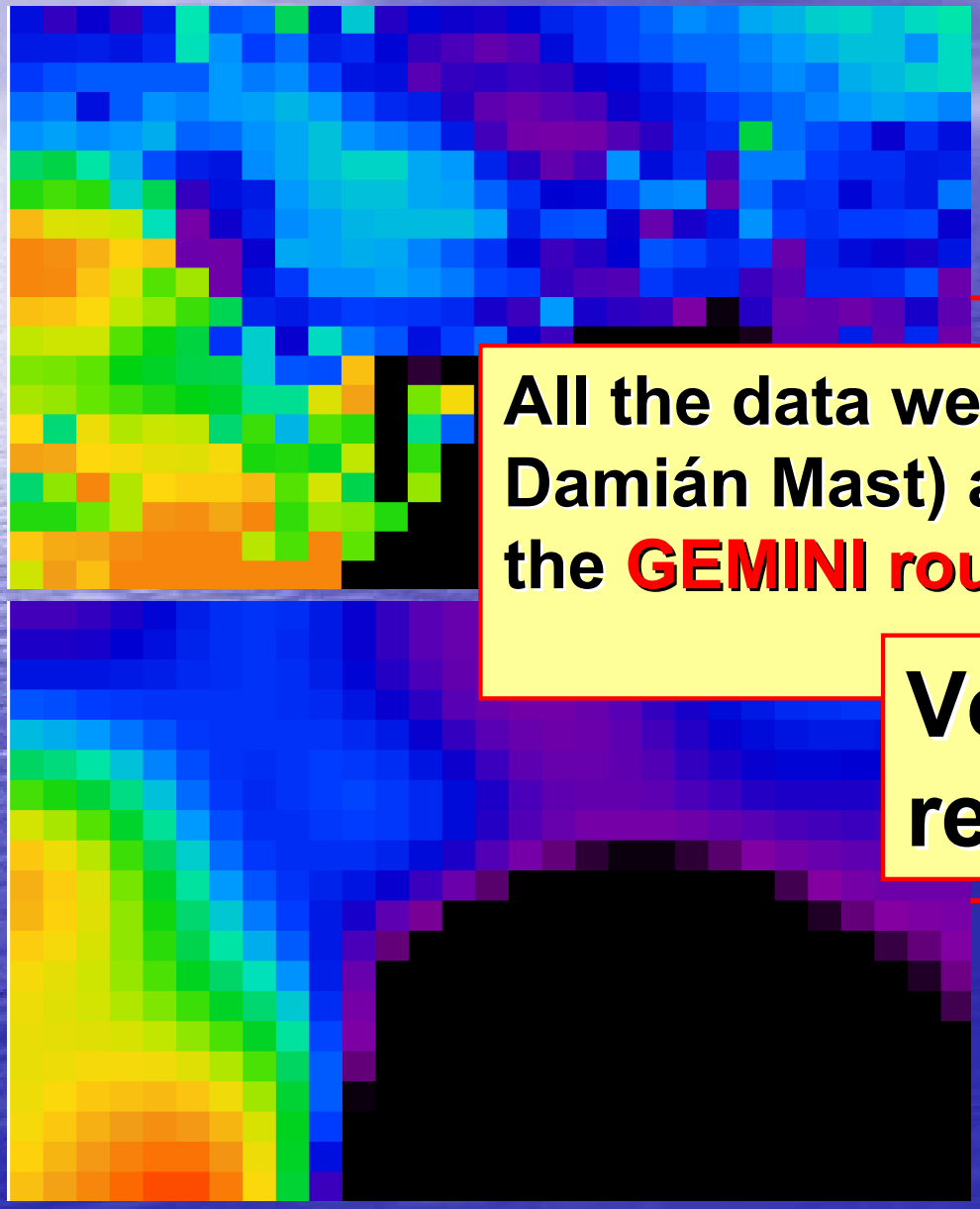

Velocity field made using the main Pa β nt (obs. 28, a d of view). 15"x0.15"

All the data were reduced (by Damián Mast) and analysed using the GEMINI routines for IRAF.

Very preliminary results!!!

The velocity field of CNSF rings of early type spirals:
High spatial resolution study

In a complementary project to the mapping of the entire velocity field of CNSF rings, we have asked high spatial resolution data in order to be able to resolve the contribution that every knot identified in the HST images makes to the overall profile as obtained from WHT ISIS spectra.

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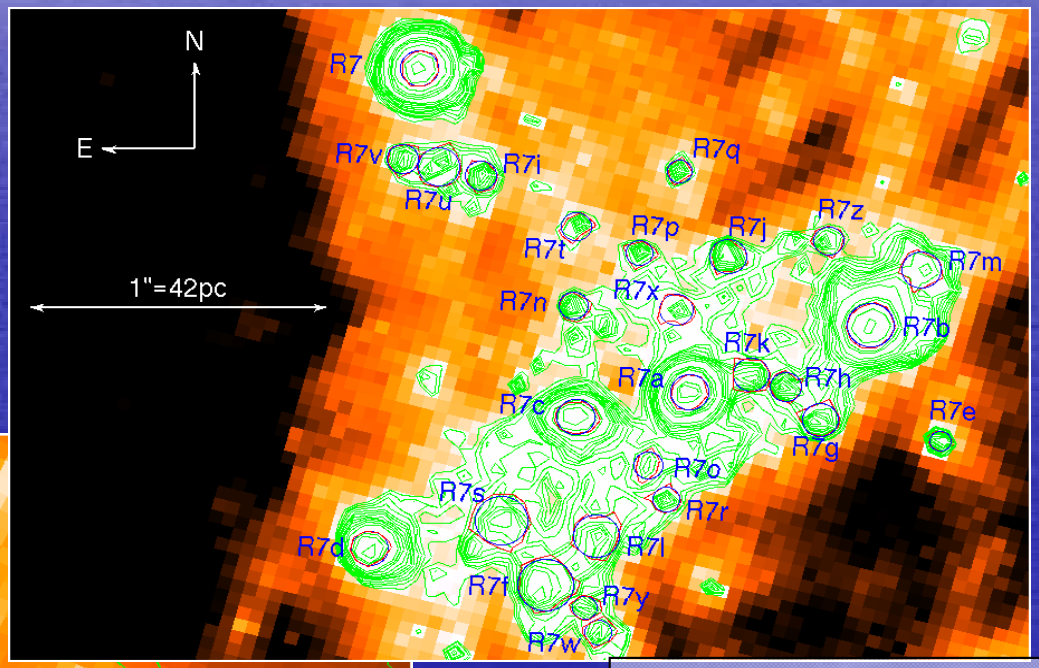
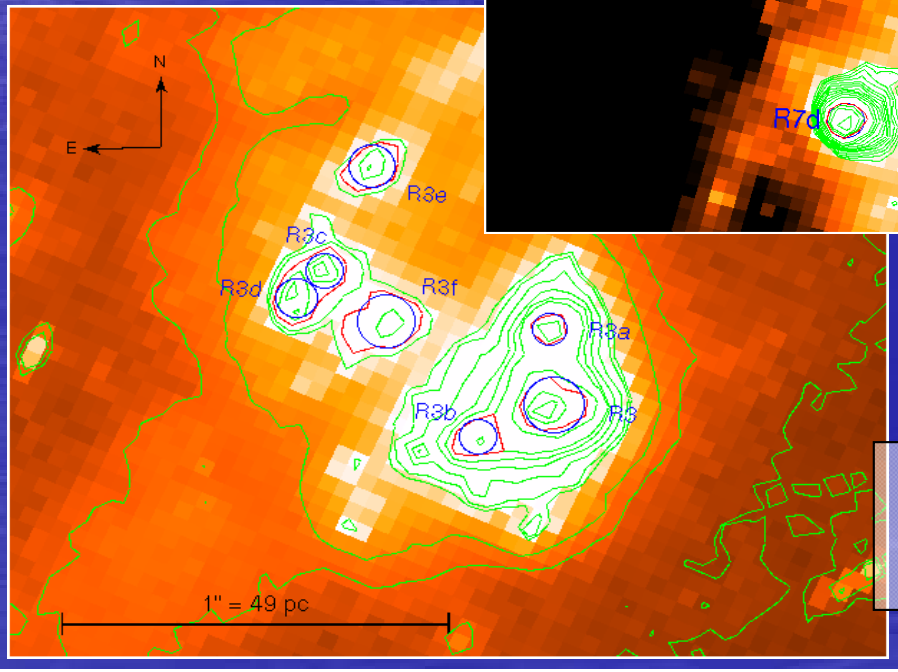
High spatial resolution study

We propose to observe the detailed velocity structure of the numerous knots identified by the HST which have radius of 0.1".



R7 – NGC2903
HST-WFPC2 F606W
Hägele et al. (2009a)



R3 – NGC3351
HST-WFPC2 F606W
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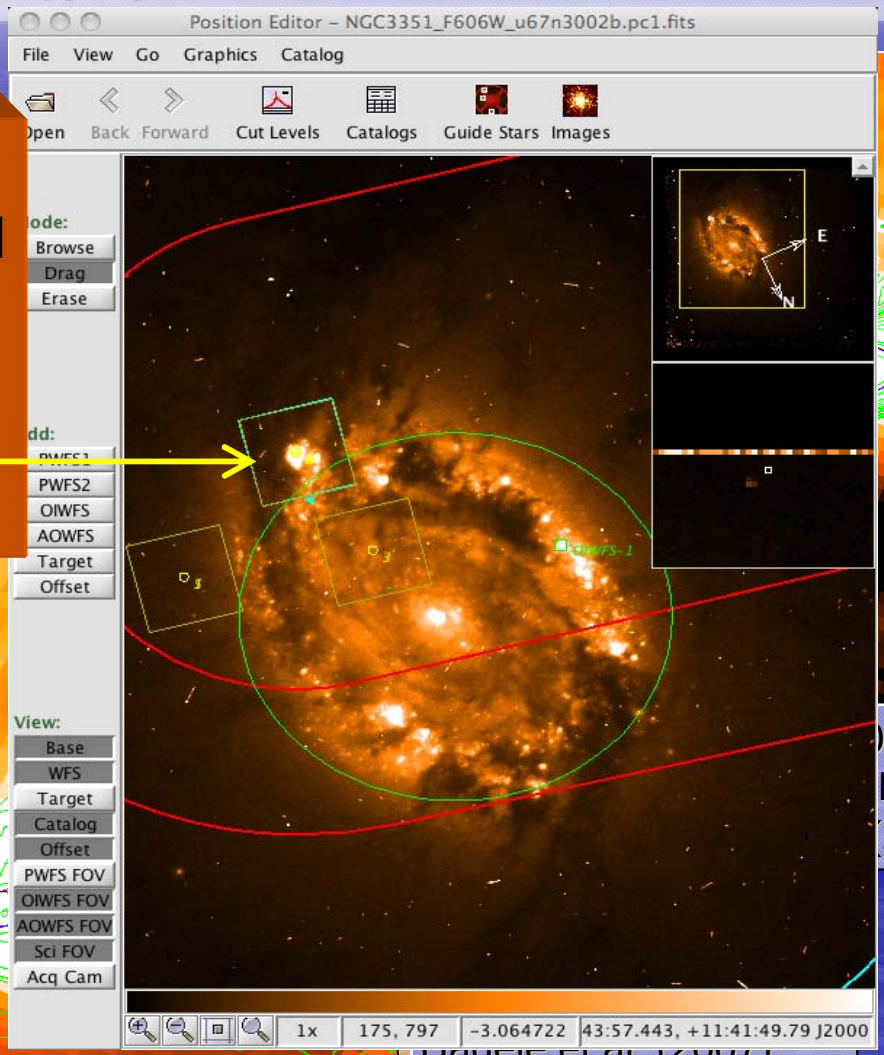
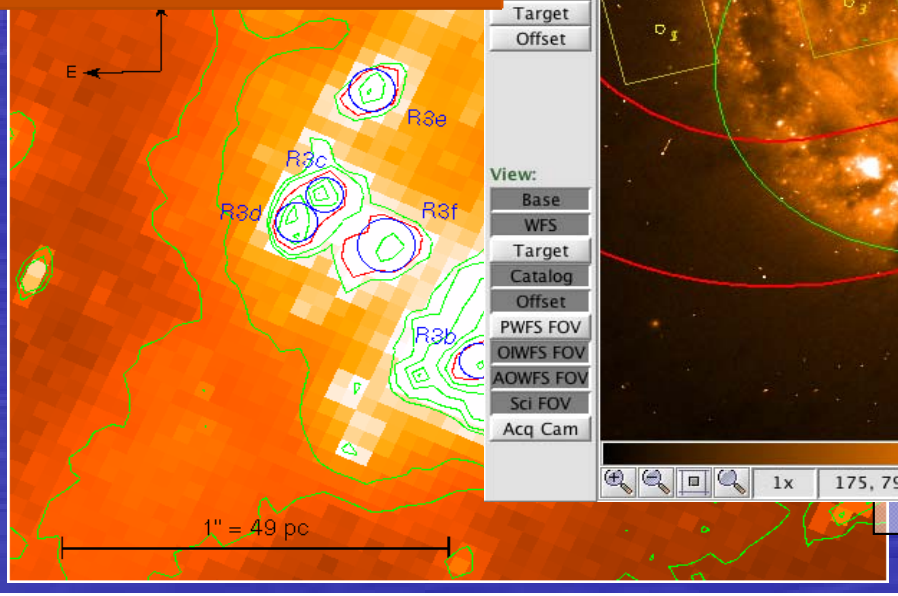
We propose to observe the detailed velocity structure of the numerous knots identified by the HST which have radius of 0.1”.

We need to obtain high spatial resolution data, then we have selected a setup with the Adaptive Optics system, ALTAIR, for obtaining a 0.1”x0.12” resolution element in the IFU field of 3”x3”.





)3
F606W
(2009a)

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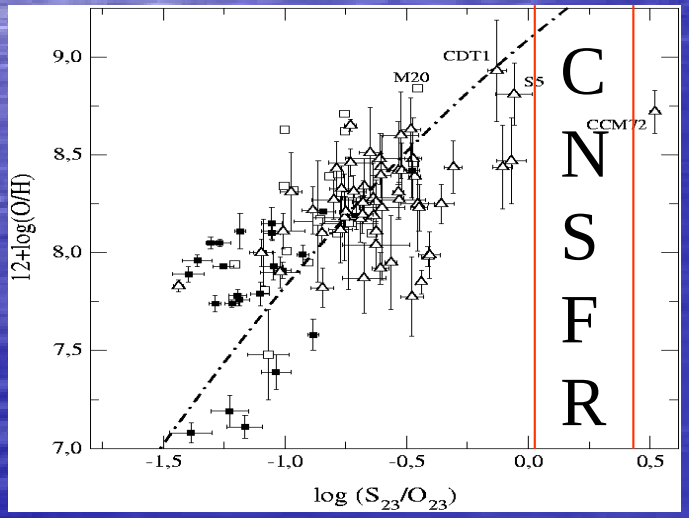
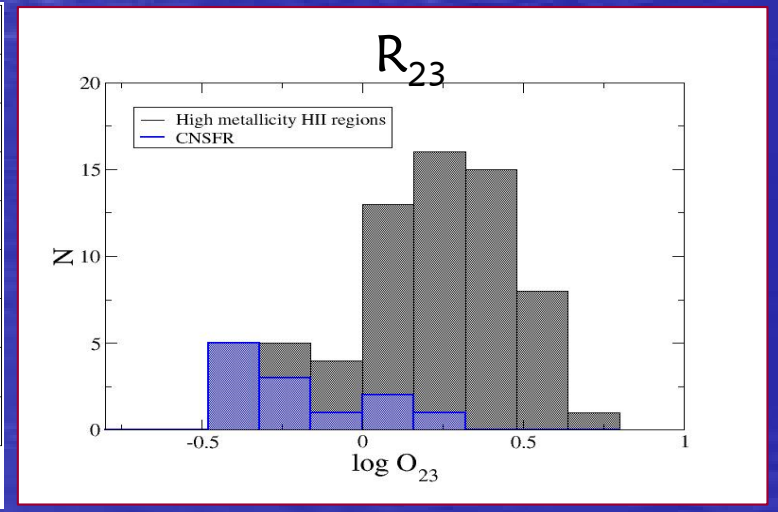
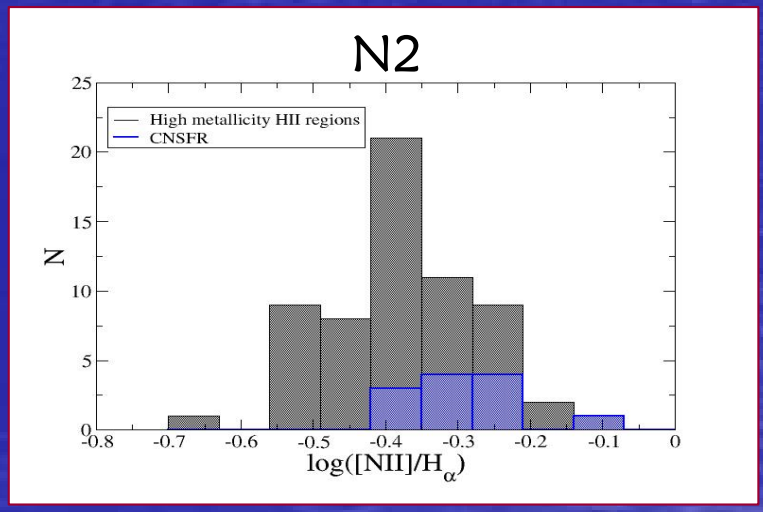
The metal content of the regions have been estimated using different empirical calibrators and turn out to be oversolar.

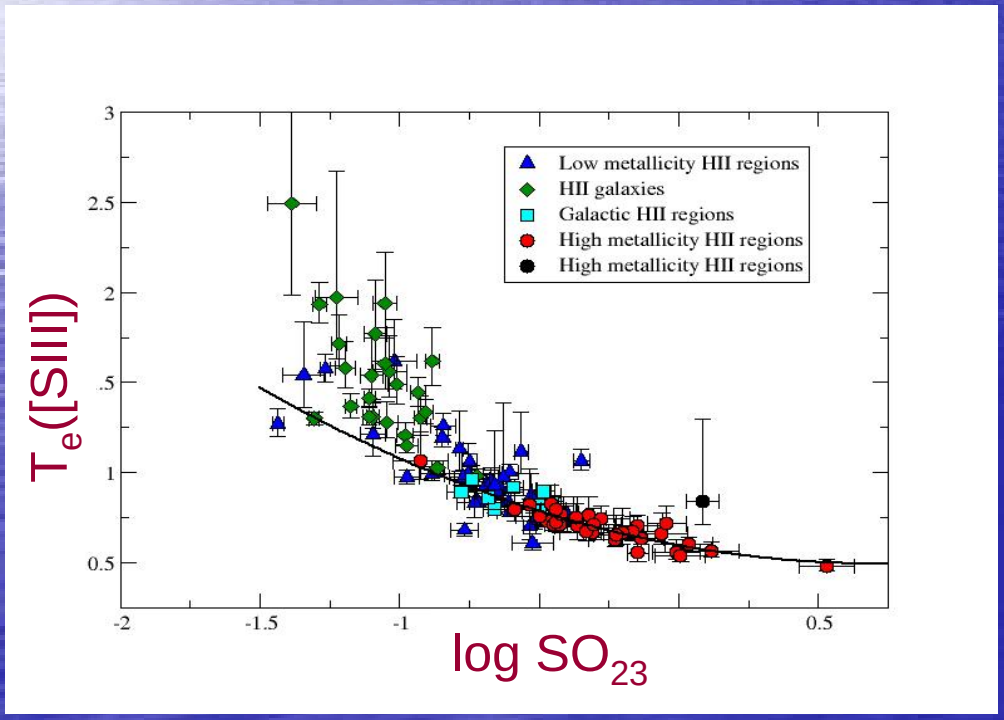






The CNSF rings of Seyfert galaxies:

The amount of available data on sulphur emission lines is increasingly growing, especially in the high metallicity regime. This makes possible for the first time to calibrate the T_e[SIII] in terms of the SO_{23} parameter.



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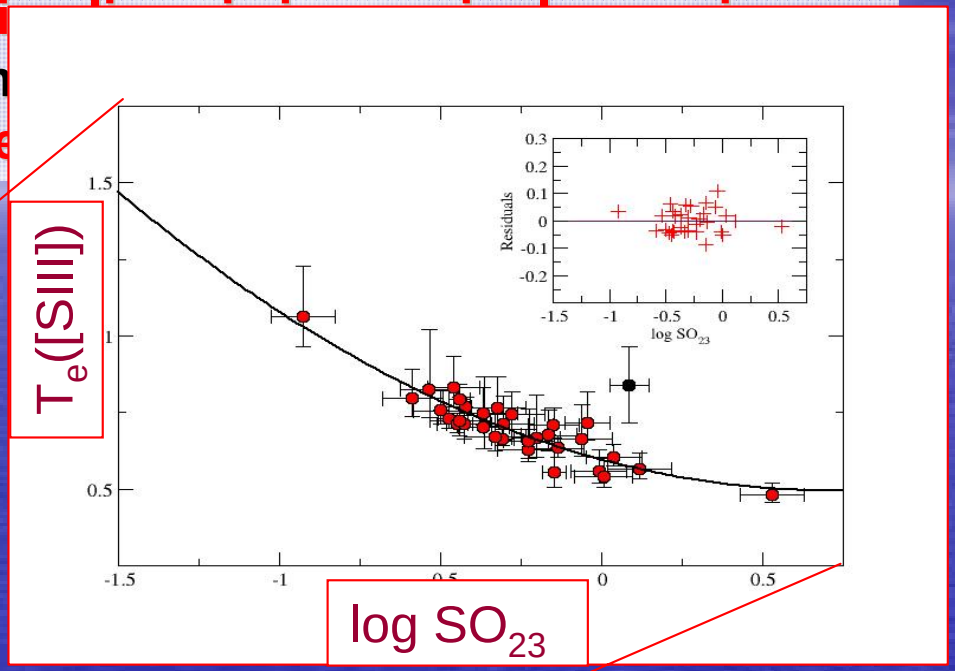
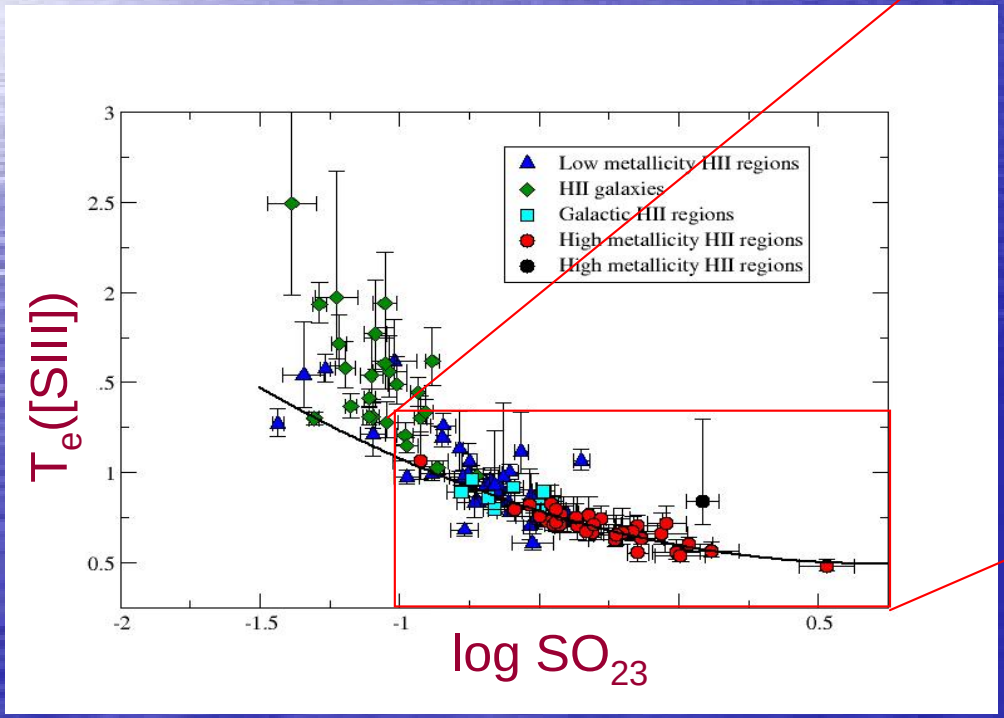
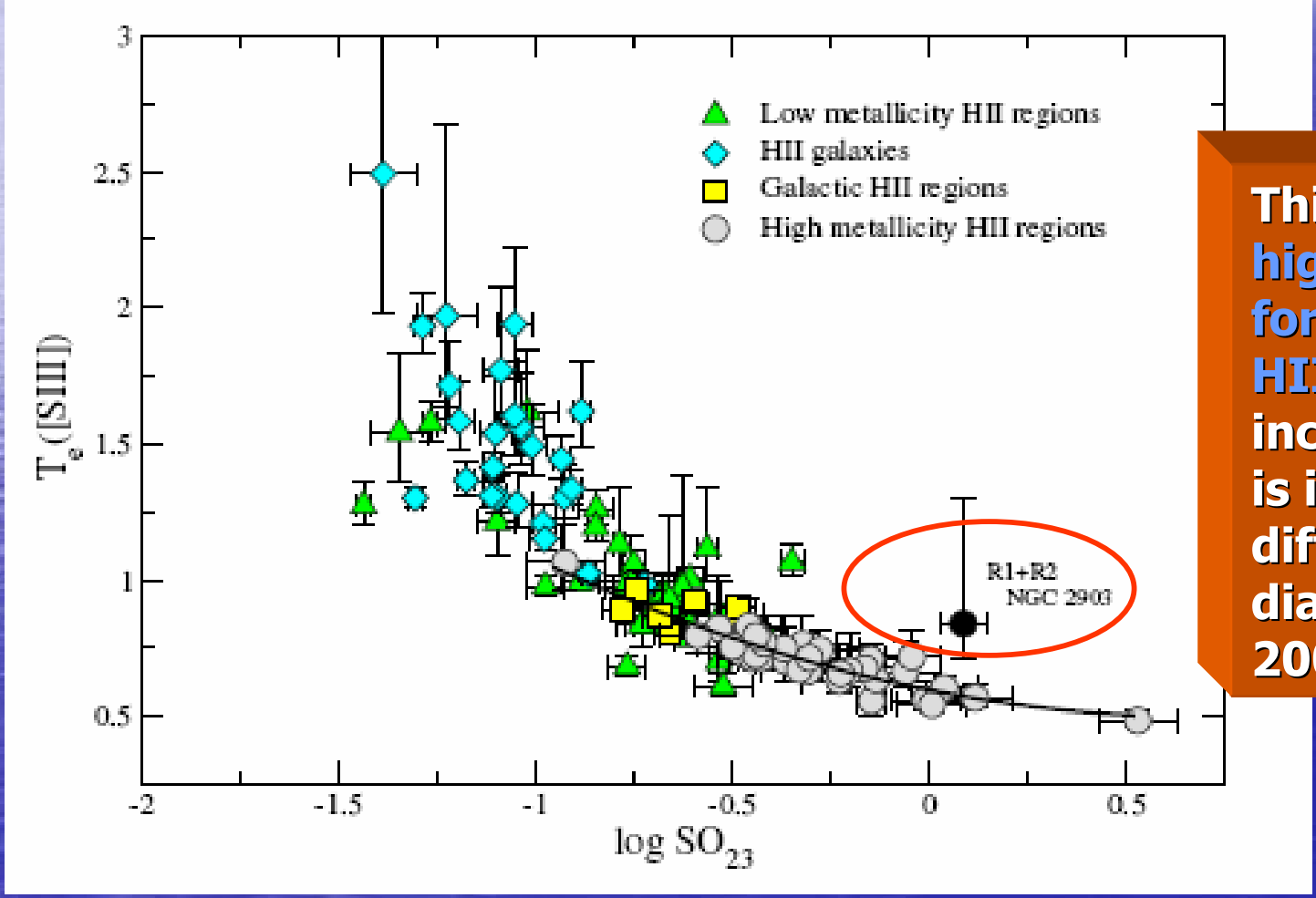




Only for high metallicity HII regions

The CNSF rings of Seyfert galaxies:

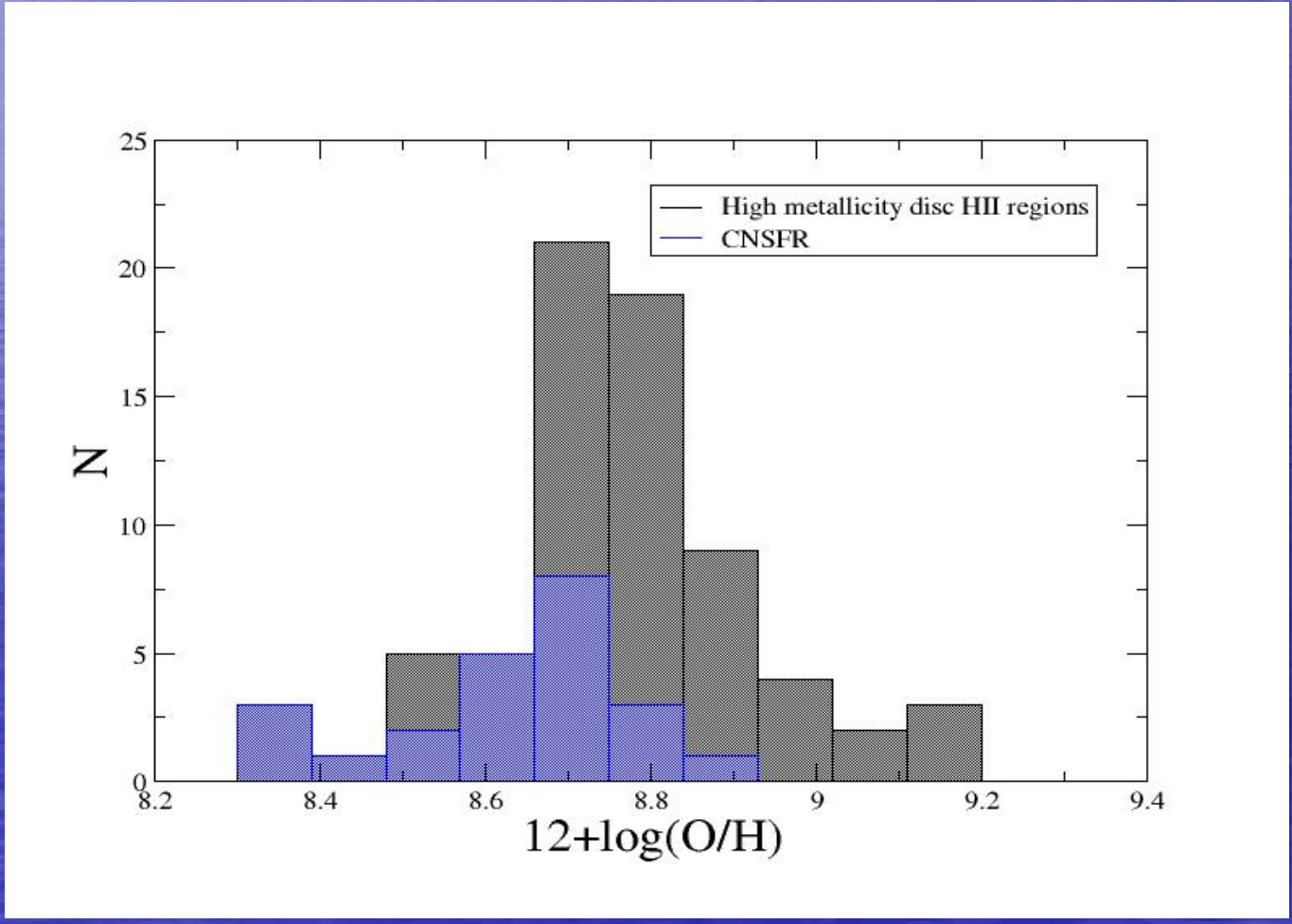
Only for region R1+R2 in NGC2903 we could measure the [SIII]λ6312Å line and derive T_e ([SIII]), temperatrure slightly higher (8400^{+4650}_{-1250}K) than predicted by our proposed fit.



This temperature is higher than expected for a high metallicity HII region and inconsistent with what is indicated from different strong line diagnostics (Díaz et al. 2007).

The CNSF rings of Seyfert galaxies:

The abundances we derive using our T_e([SIII]) calibration are comparable to those found by Bresolin et al. (2005) for their sample of high metallicity HII regions.



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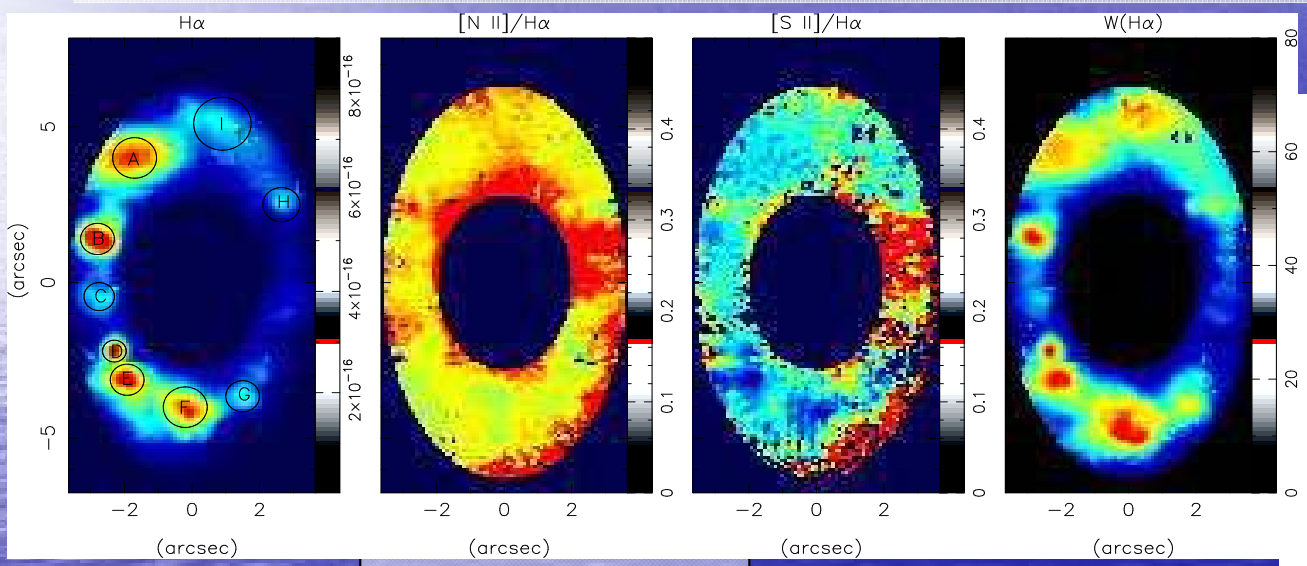
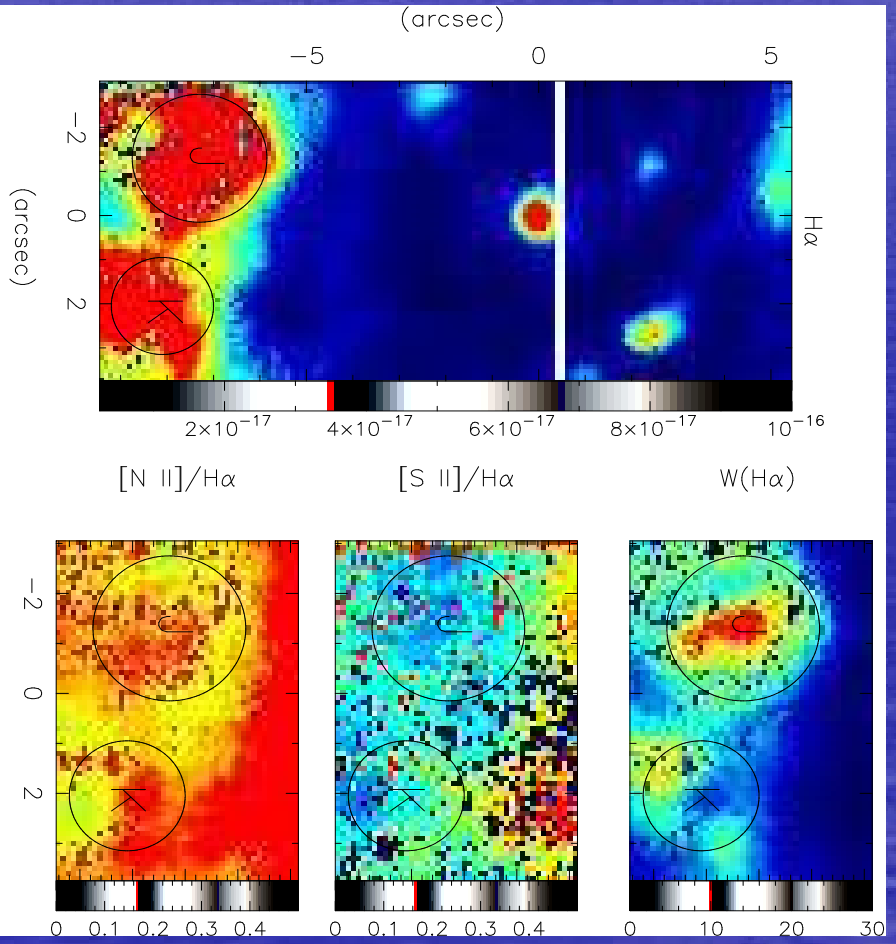
Dors, Storchi-Bergmann, Riffel et al. (2008) combined optical IFU data from GEMINI South (GMOS-IFU) and a grid of photoionization models to determine gas abundances and star formation rates of the CNSFRs of two active galaxies: NGC1097 and NGC6951.



NGC6951
Dors et al. (2008)



NGC1097
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Spectral range: 5600-7000Å
R≈2300
FOV: 3 IFU fields of 15″x7″ in each galaxy.
Spaxel: 0.1″x0.1″

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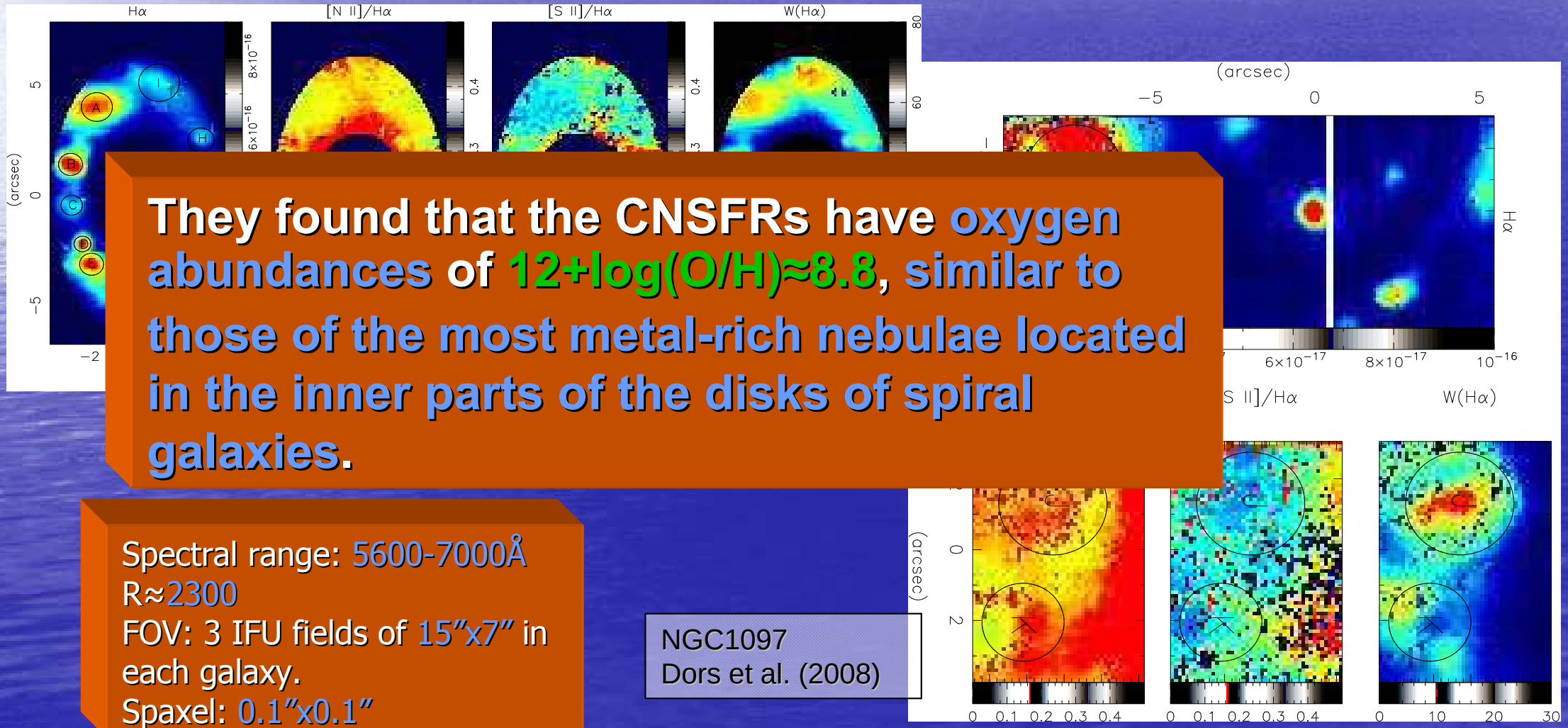

They found that the CNSFRs have oxygen abundances of 12+log(O/H)≈8.8, similar to those of the most metal-rich nebulae located in the inner parts of the disks of spiral galaxies.

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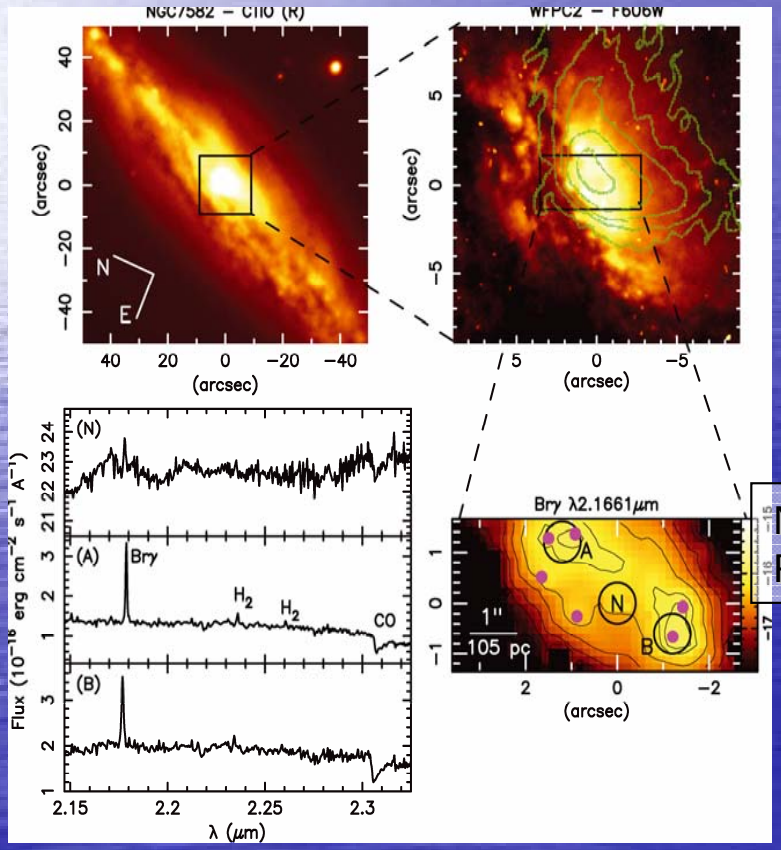
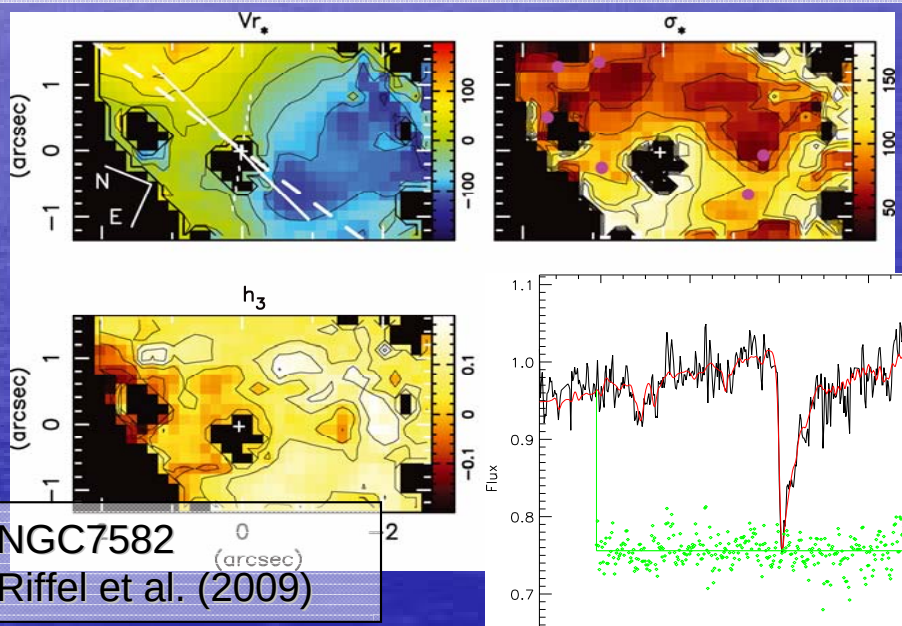
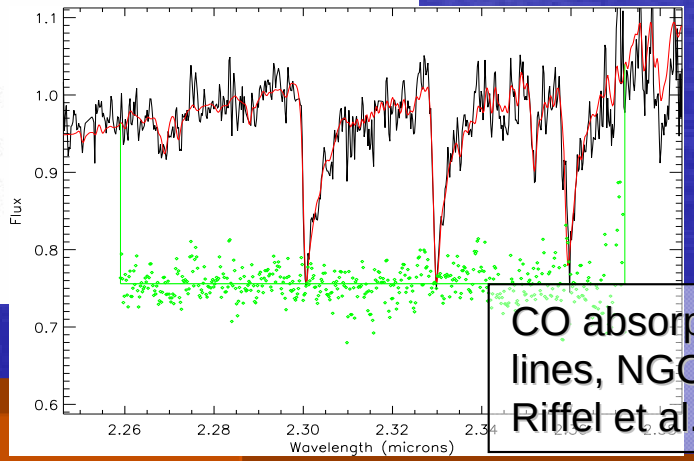




NGC7582
Riffel et al. (2009)



CO absorption lines, NGC4051
Riffel et al. (2008)

NIFS
Spectral range: 2.0-2.4μm
R≈5300
FOV: 3.0"x3.0"
Spaxel: 0.1"x0.12"

GNIRS
Spectral range: 2.1-2.4μm
R≈5900
FOV: 3.2"x4.8"
Spaxel: 0.15"x0.15"

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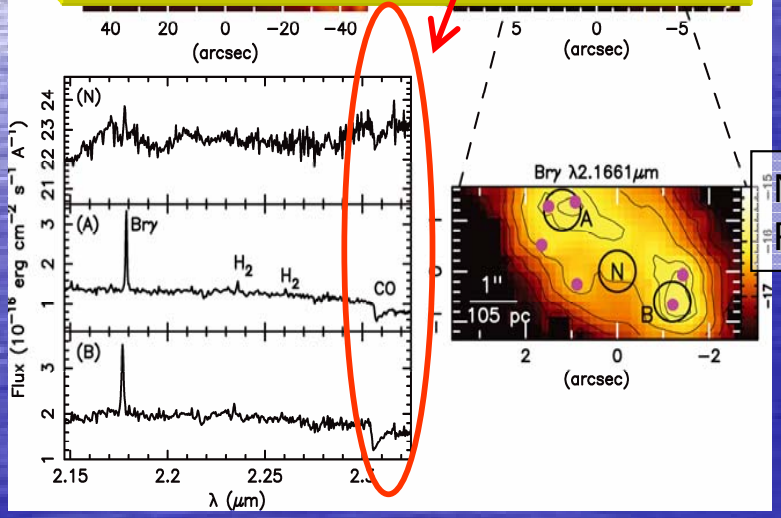
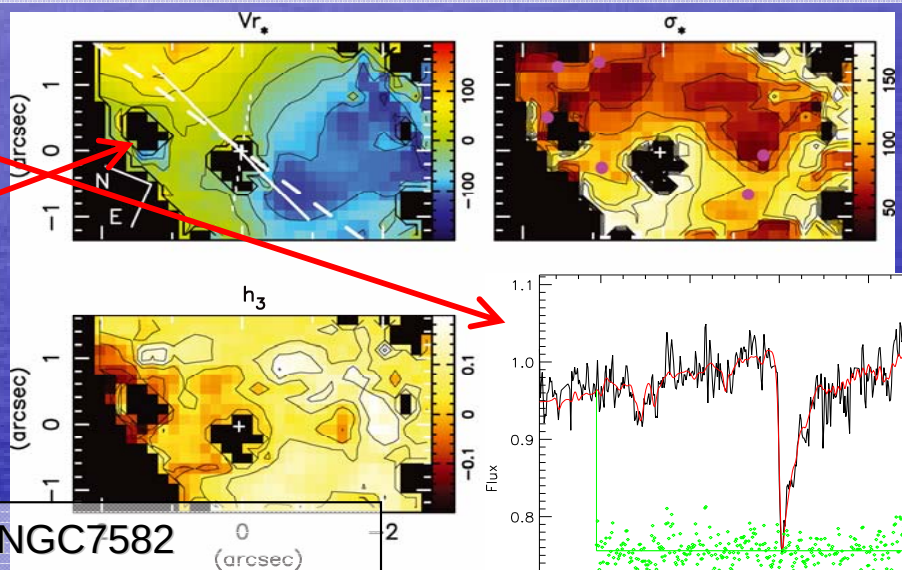
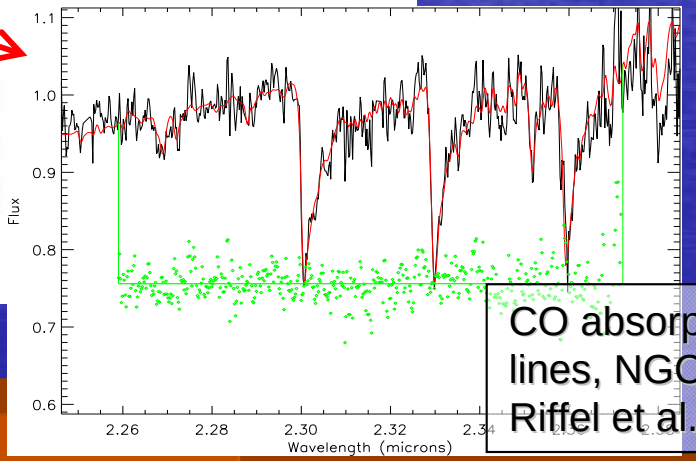
Riffel, Storchi-Bergmann, Dors et al. (2009) and Riffel, Storchi-Bergmann et al. (2008) using the near-IR slicers of GEMINI (GNIRS and NIFS in IFU mode) studied the AGN-starburst connection and the gas kinematics in the active galaxies NGC7582 and NGC4051, respectively.

They used the CO absorption feature to derived the stellar kinematics.





NGC7582
Riffel et al. (2009)



CO absorption lines, NGC4051
Riffel et al. (2008)

NIFS
Spectral range: 2.0-2.4μm
R≈5300
FOV: 3.0"x3.0"
Spaxel: 0.1"x0.12"

GNIRS
Spectral range: 2.1-2.4μm
R≈5900
FOV: 3.2"x4.8"
Spaxel: 0.15"x0.15"

The CNSF rings of Seyfert galaxies:

Taking into account all these results we are planning to ask time (joint proposal Argentina-Brasil) for the optical IFU instruments (GMOS-South and GMOS-North, in the IFU mode) and the near-IR slicers (GNIRS and NIFS, in the IFU mode) from GEMINI South and North.

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Initial work team: Guillermo Hägele, Olí Dors (IAA), Mónica Cardaci, Thaisa Storchi-Bergmann (UFRGS, Brazil), Guillermo Bosch (CONICET, Argentina), Ángeles Díaz, Rogemar Riffel (UFRGS, Brazil), Verónica Firpo (UNLP, Argentina), Damián Mast (at IAA from next september) and Enrique Pérez-Montero (IAA).

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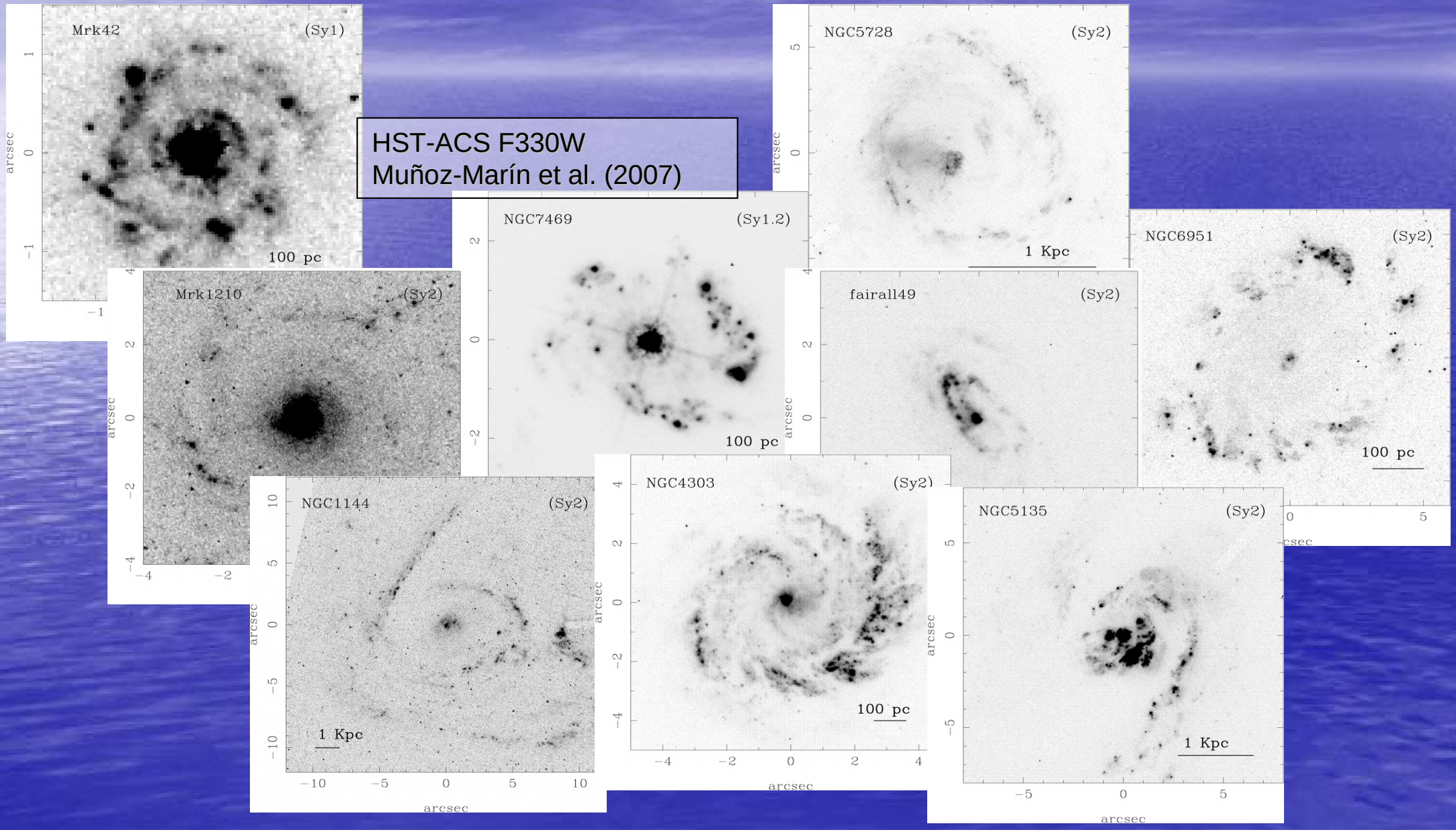
Then we will devide the project in three parts depending on the kind of study (abundances or kinematics), and the angular scale of the CNSFRs and the angular size of the ring.

The CNSF rings of Seyfert galaxies:

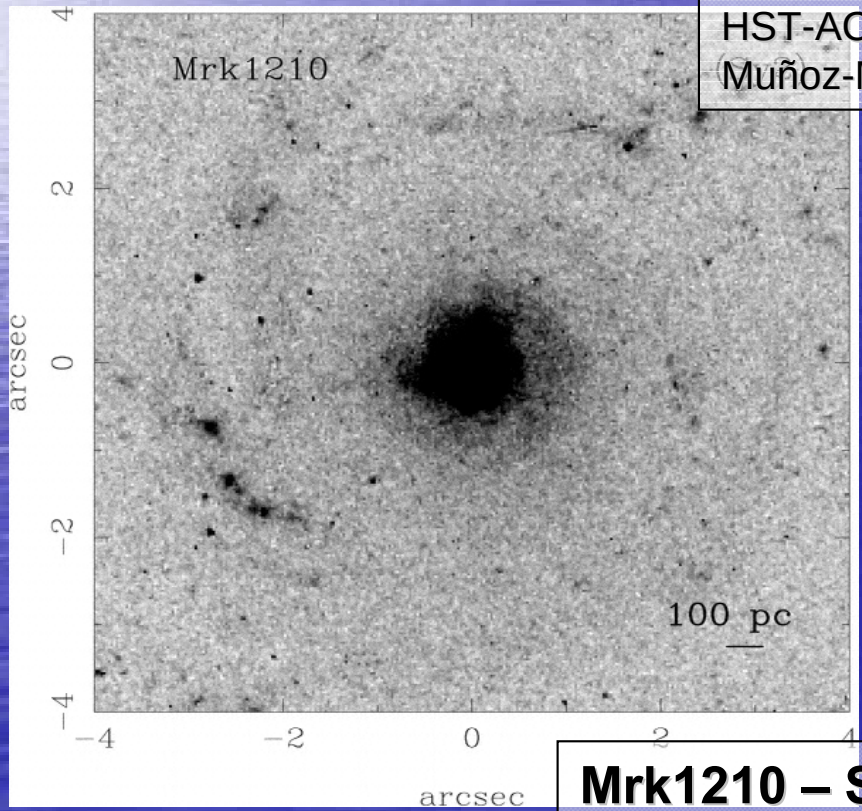
We mainly use the Atlas of Circumnuclear Regions of Seyfert galaxies by Muñoz-Marín et al. (2007) to select our sample.



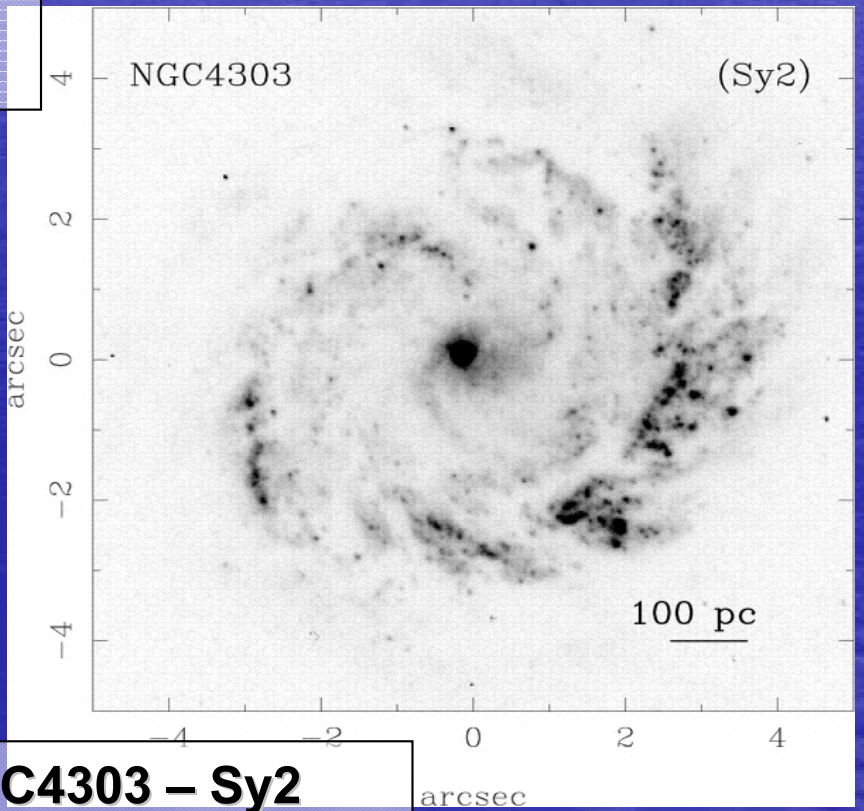
The CNSF rings of Seyfert galaxies:

Parts of the project

1- If the CNSF ring is relatively extended in the sky and the galaxy do not have a very bright nucleus (normal, liners, Seyfert 2 galaxies) we will use GMOS-IFU with a FOV of 5”x7” (1 or 2 fields by object) and a spaxel of 0.2” (the spatial resolution depend on the seeing).



HST-ACS F330W
Muñoz-Marín et al. (2007)



Mrk1210 – Sy2
Ring size ≈ 7”x7”

NGC4303 – Sy2
Ring size ≈ 8”x8”

The CNSF rings of Seyfert galaxies:

Parts of the project

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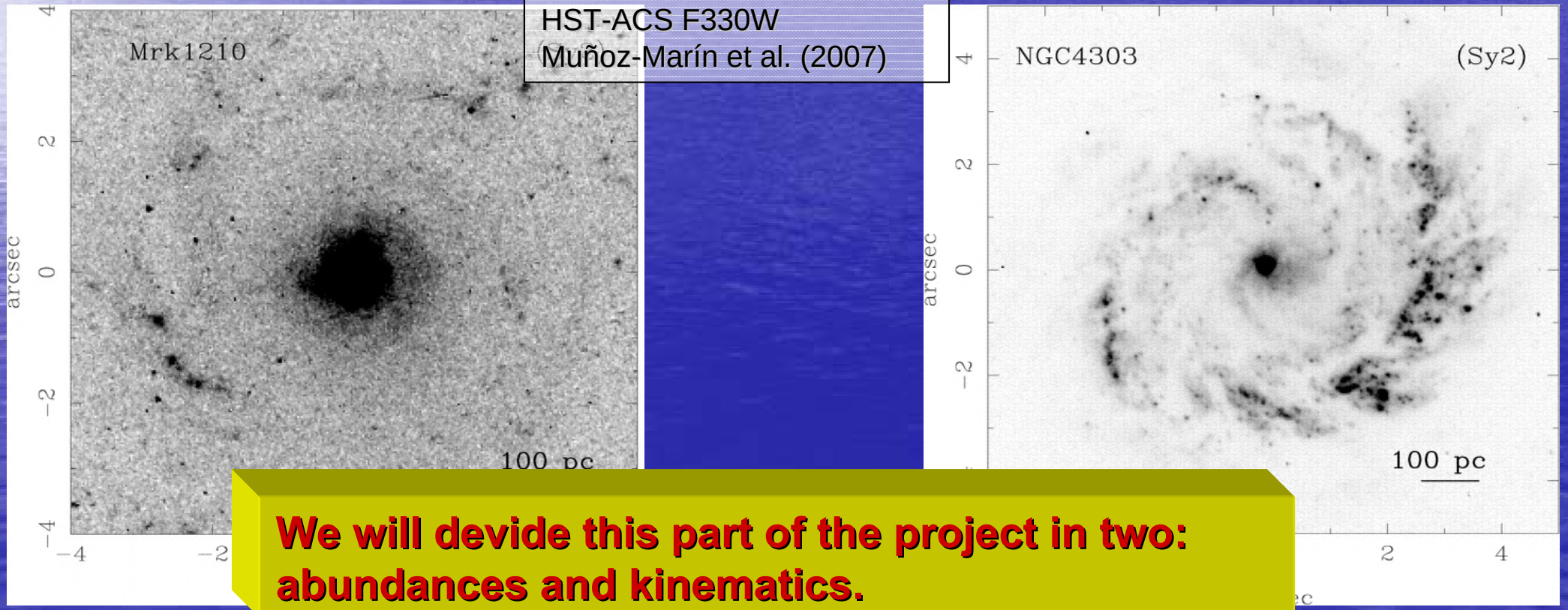


We will devide this part of the project in two: abundances and kinematics.

Ring size ≈ 7”x7”

Ring size ≈ 8”x8”

The CNSF rings of Seyfert galaxies:

Parts of the project

1a- Abundances:

We will use an instrumental configuration with

- wide spectral range (4000-11000Å)
- moderate spectral resolution (R=4300 ~ $\Delta\lambda \approx 1.74$Å/px)

The CNSF rings of Seyfert galaxies:

Parts of the project

1a- Abundances:

We will use an instrumental configuration with

- wide spectral range (4000-11000Å)
- moderate spectral resolution (R=4300 ~ $\Delta\lambda \approx 1.74$Å/px)

We will measure several emission lines (from [OII]λλ3727Å to [SIII]λ9532Å) that will allow us to use empirical and semi-empirical methods (Díaz et al. 2007) and photoionization models (Dors et al. 2008) to derive abundances of the CNSFRs and the AGNs.

The CNSF rings of Seyfert galaxies:

Parts of the project

1b- Kinematics:

We will use an instrumental configuration with

- narrow spectral ranges
- high spectral resolution (R=20000 ~ $\Delta\lambda \approx 0.23$Å/px)

The CNSF rings of Seyfert galaxies:

Parts of the project

1b- Kinematics:

We will use an instrumental configuration with

- narrow spectral ranges
- high spectral resolution (R=20000 ~ $\Delta\lambda \approx 0.23$Å/px)

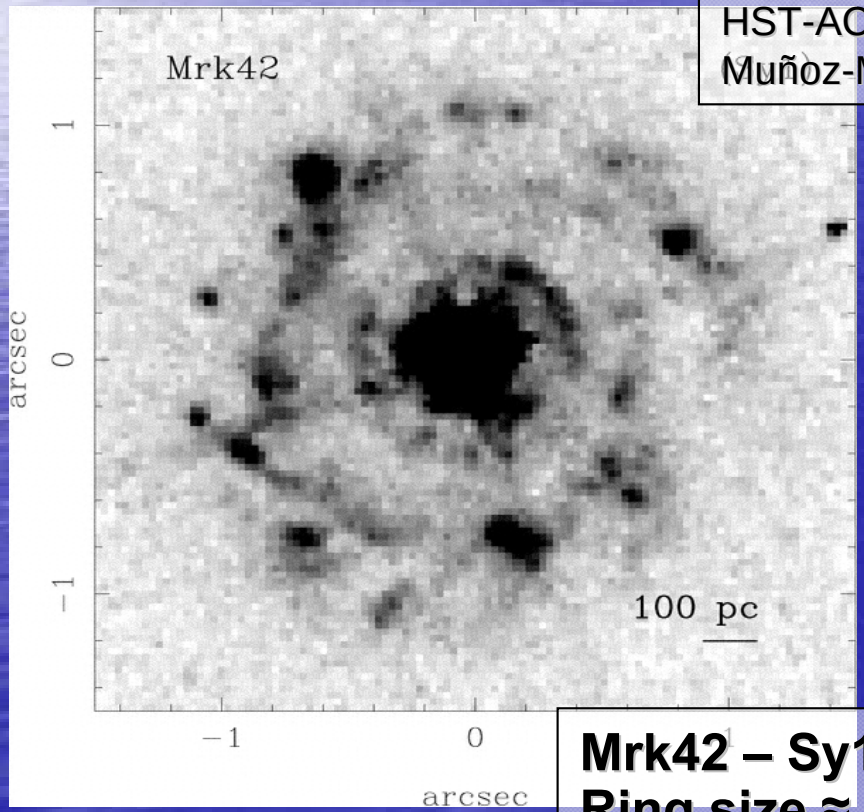
We will measure some particular features: Hα, [NII]λλ6548,6584Å, [SII]λλ6717,6731Å, [SIII]λ9532Å and Pa8 emission lines and the CaT absorption lines to study the gas and stellar kinematics, respectively, and mapping the gas flows probably related with the AGNs.

The CNSF rings of Seyfert galaxies:

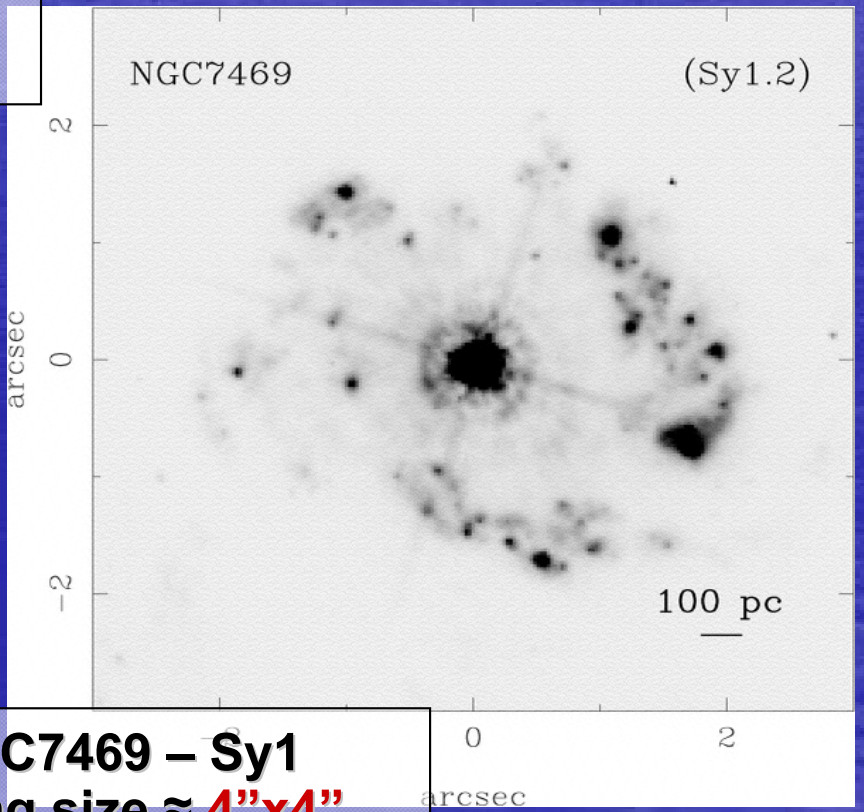
Parts of the project

2- If the CNSF ring is relatively compact in the sky we will use NIFS and GNIRS (the near-IR slicers) with the active optics system and a FOV of 3”x3” and 3.2”x4.8”, respectively (1 or 2 fields by object), and a spaxel of 0.1”x0.04” and 0.15”x0.15”, respectively (the spatial resolution are given by the difraction limit of the instrument + telescope).

HST-ACS F330W
Muñoz-Marín et al. (2007)



Mrk42 – Sy1
Ring size ≈ 2”x2”



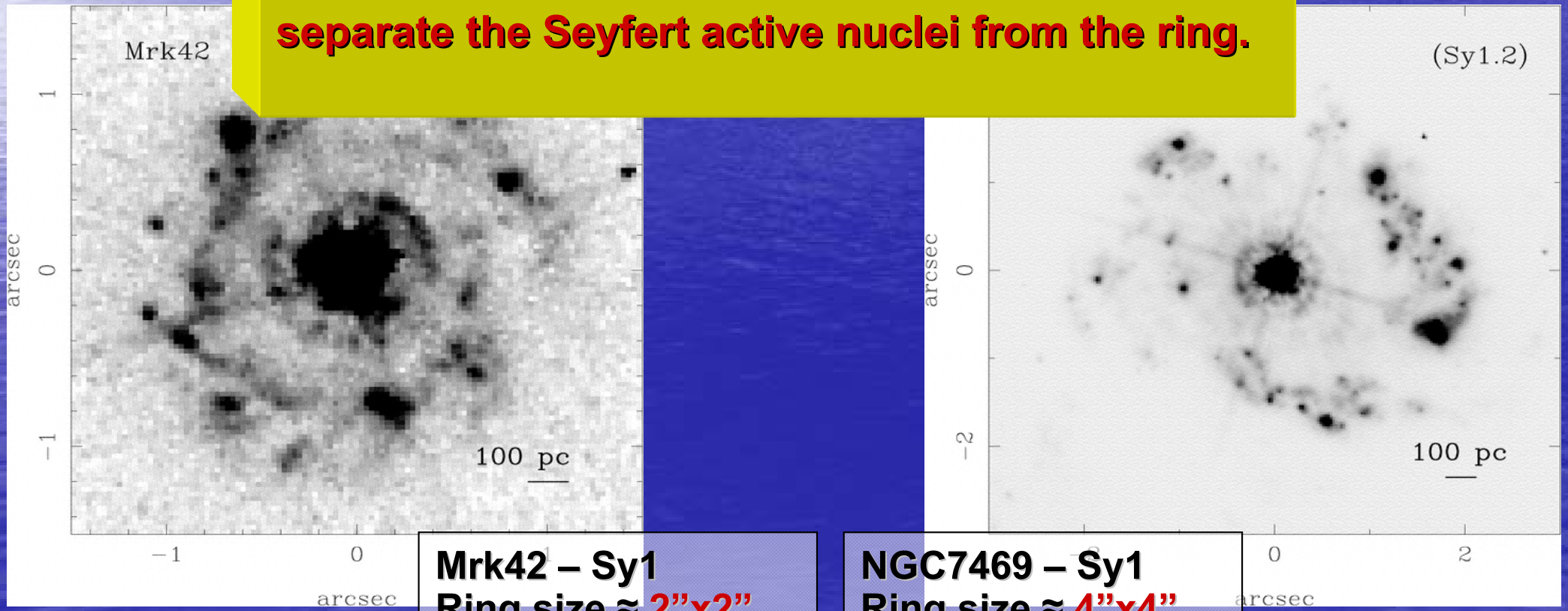
NGC7469 – Sy1
Ring size ≈ 4”x4”

The CNSF rings of Seyfert galaxies:

Parts of the project

2- If the CNSF ring is **relatively compact** in the sky we will use **NIFS** and **GNIRS** (the near-IR slicers) with the **active optics system** and a **FOV of 3”x3” and 3.2”x4.8”**, respectively (1 or 2 fields by object), and a **spaxel of 0.1”x0.04” and 0.15”x0.15”**, respectively (the spatial resolution are given by the difraction limit of the instrum

We need the AO to resolve the CNSFRs and to separate the Seyfert active nuclei from the ring.



Mrk42 – Sy1
Ring size ≈ 2”x2”

NGC7469 – Sy1
Ring size ≈ 4”x4”

The CNSF rings of Seyfert galaxies:

Parts of the project

2- Kinematics:

We will use an instrumental configuration with

- relatively narrow spectral ranges (Z≈0.94-1.15; J≈1.15-1.33; H≈1.49-1.80; K≈~1.49-1.80)
- high spectral resolution (R=5000-6000)

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That´s all folks.

Thanks.