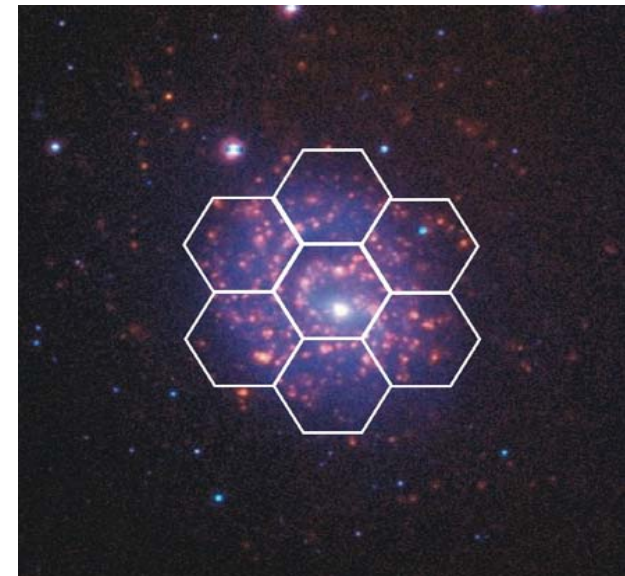


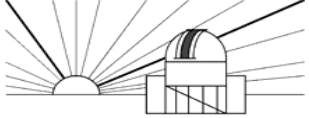
# PINGS: a nearby galaxy survey with PPAK

Ángeles I. Díaz

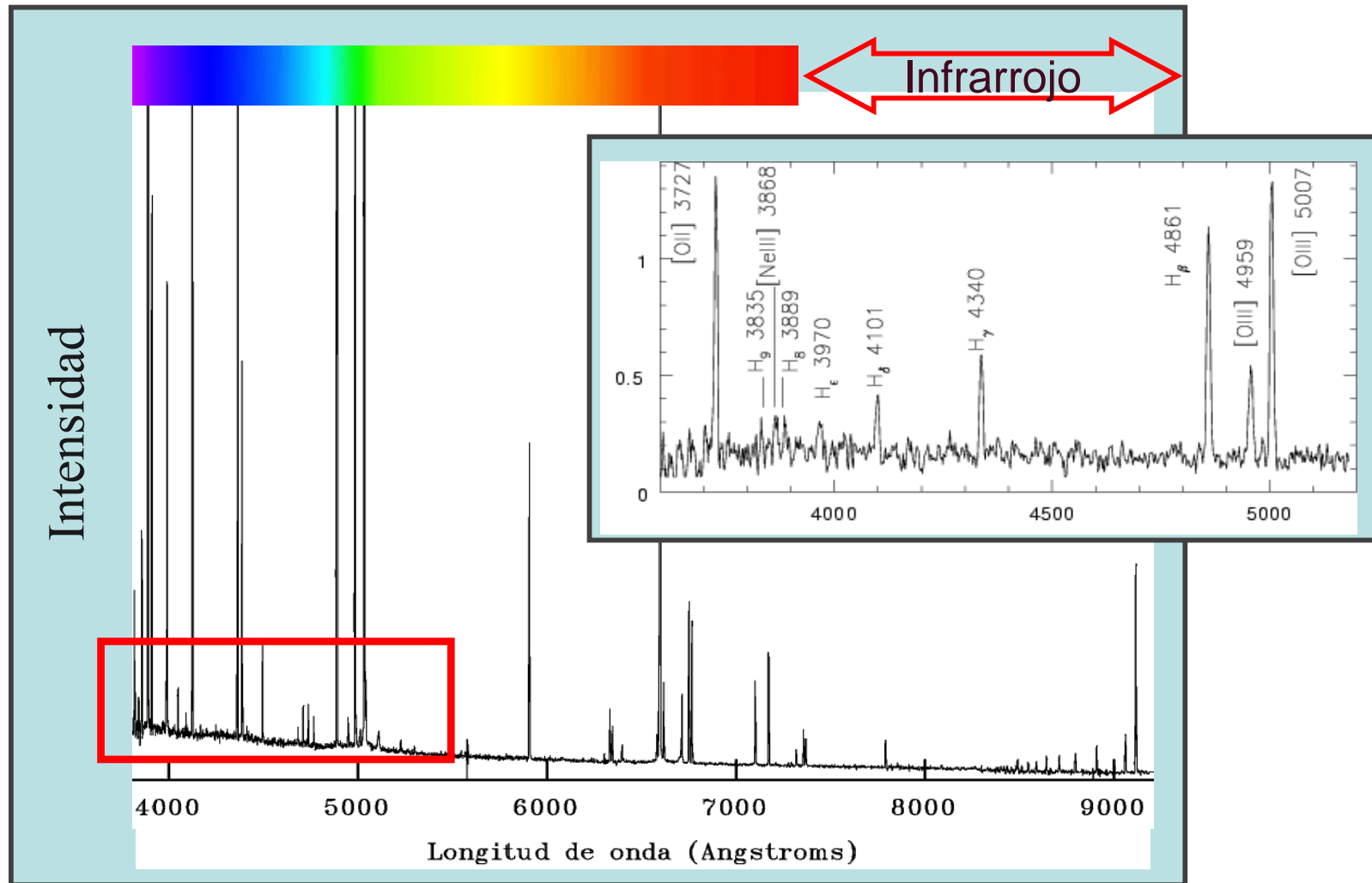
Rest of the team:

- R.C. Kennicutt (IoA)
- Fabián Rosales (IoA)
- Anna Pasquali (MPIA)
- Sebastián Sánchez (CAHA)
- Ben Johnson (IoA)
- Caina Hao (IoA)

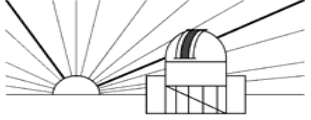




# HII region spectra



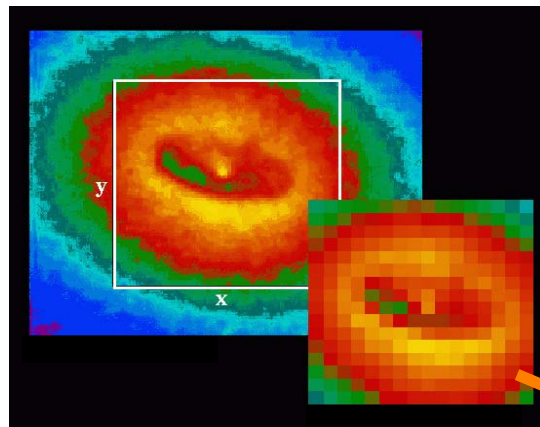




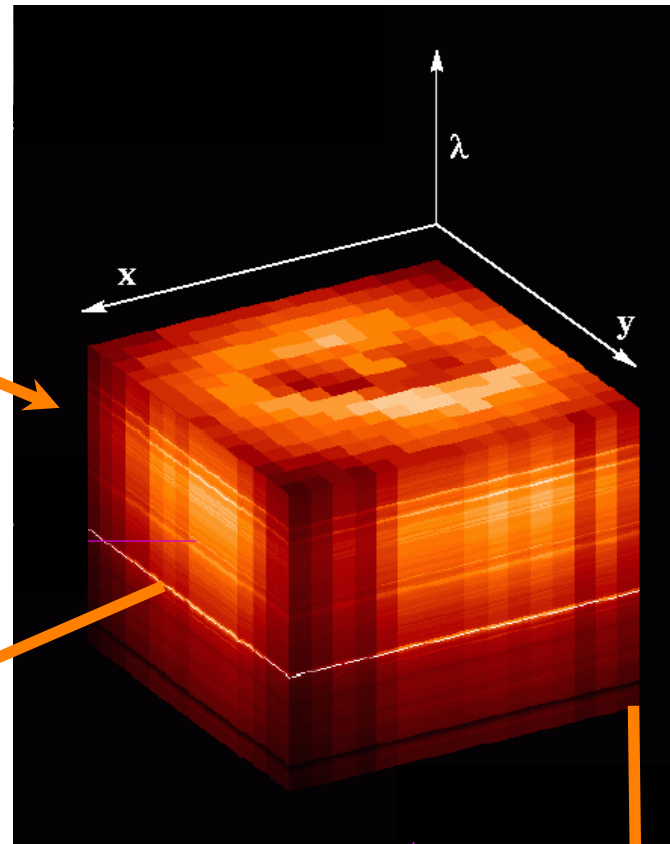
# Bidimensional spectroscopy



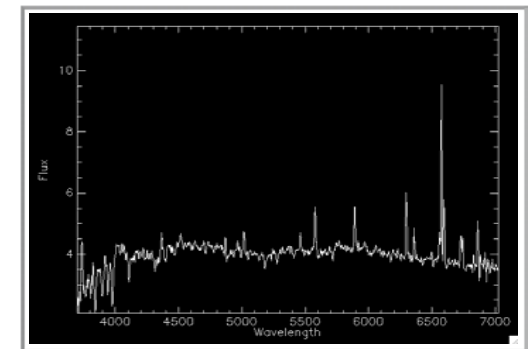
Integral Field Spectroscopy sample each spatial dimension both **spatially** and **spectrally**



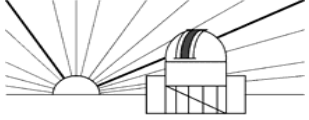
Object on the sky and sampled FOV



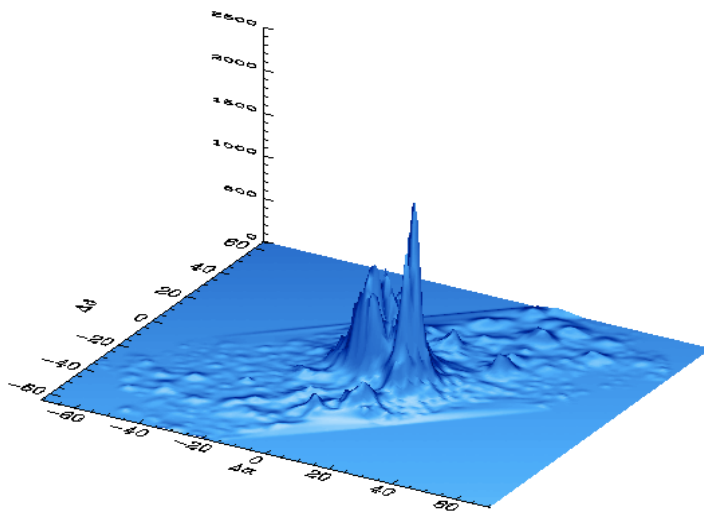
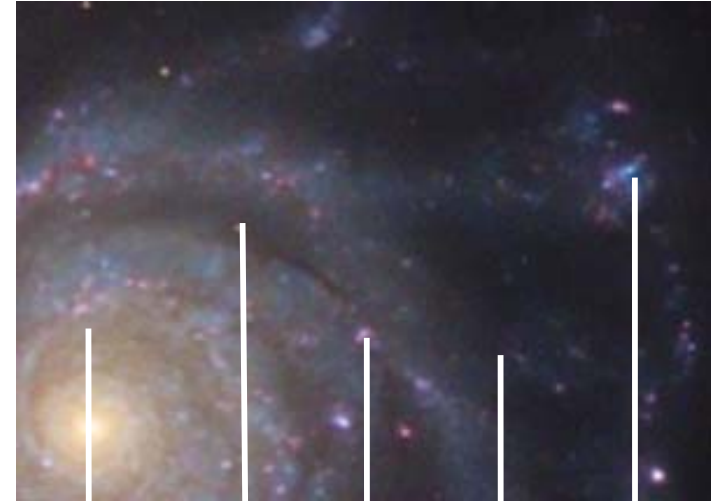
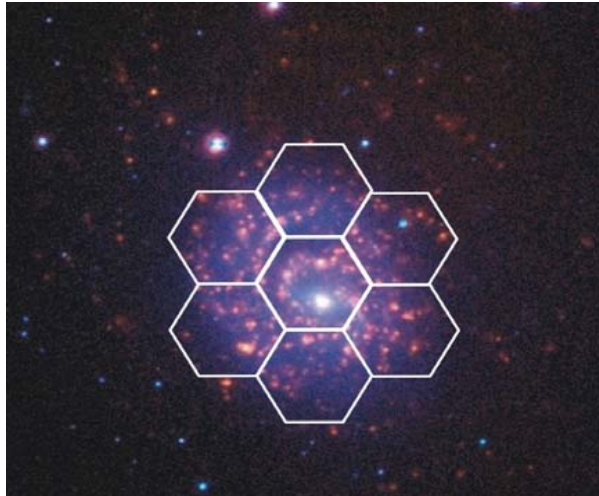
Spectroscopic datacube



Each column represents a spectrum



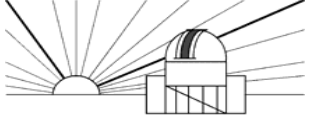
# distribution of physical properties



O/H



Radius



# Project objectives



- ✦ Galaxies disc spaxel-resolved emission line maps
- ✦ Moderate resolution spectra of underlying stars
- ✦ Oxygen abundance distributions based on a suit of strong-line diagnostic and calibrations
- ✦ Local nebular reddening estimates based on Balmer decrements
- ✦ Measurements of the ionization structure in HII regions and diffuse ionized gas





## Previous attempts

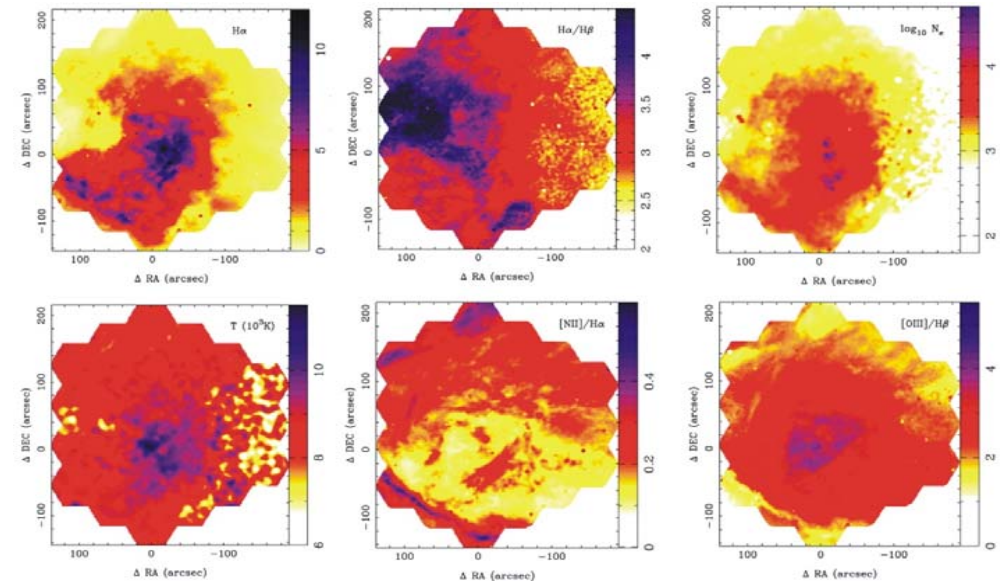
- Multi-object instruments  
 e.g. Roy & Walsh 1998, Kennicutt & Garnett, 1996, Moustakas & Kennicutt 2006
- Narrow band imaging  
 e.g. Scowen et al 1996
- Orion nebula survey  
 Sánchez et al 2007
- HII galaxy II Zw 70  
 Kherig et al 2008

## M33 Metallicity project

Rosolowsky & Simon 2008

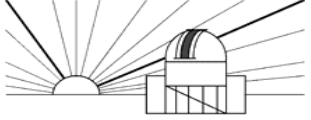
- Multi-slit observations
- ~ 1000 HII regions
- status: 30% completion

## IFS study of the Orion nebula



**NO attempt to obtain 2D spectra of the whole surface of a nearby spiral galaxy**

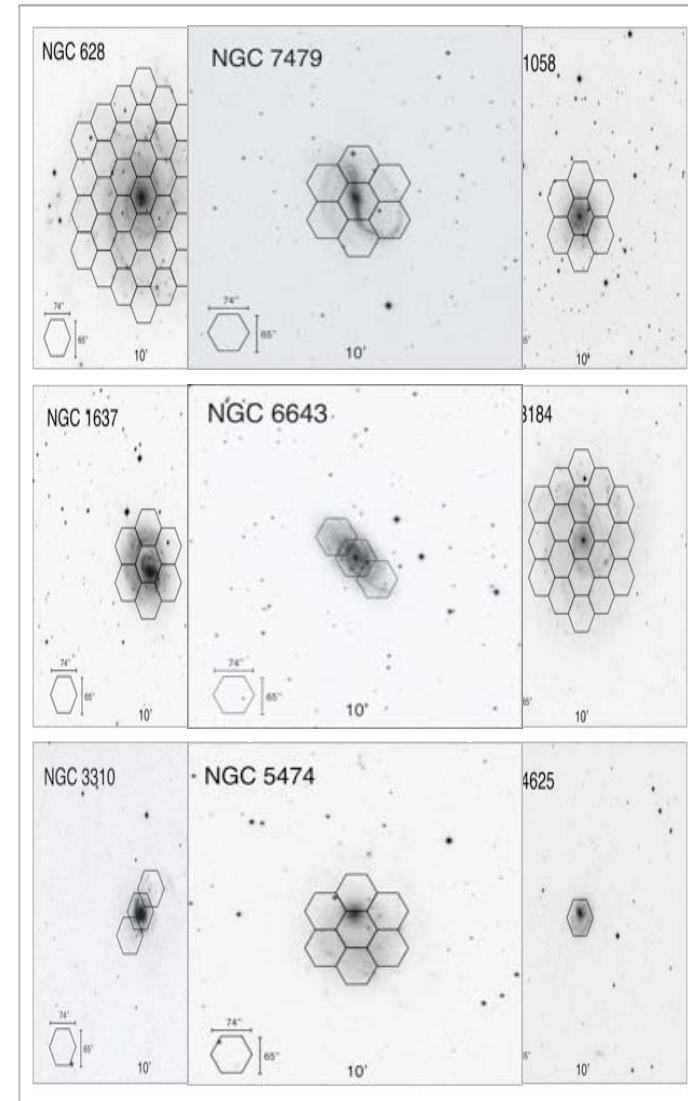
- Limited FOV
- Spectral coverage
- Time expensive
- Complex data reduction



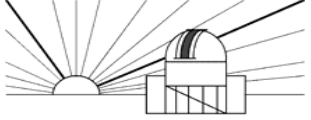
# The galaxy sample



- ★ Significantly representative of different galaxy types at  $z < 0.01$ 
  - Normal
  - Lopsided
  - Barred
  - Interacting
  - Good range of galactic properties and SF environments
  
- ★ Typical angular size of few arcmin ( $>$  any IFU FOV)
  
- ★ Rich ancillary of multi-wavelength observations
  - Optical broad band imaging
  - IR (SINGS)
  - UV
  - HI



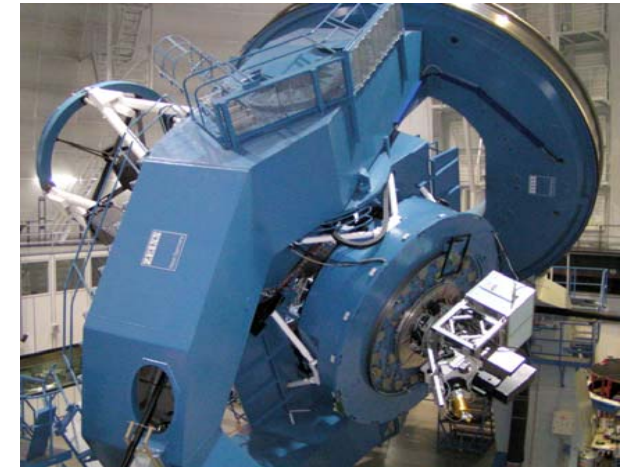




# PMAS/PPAK instrument



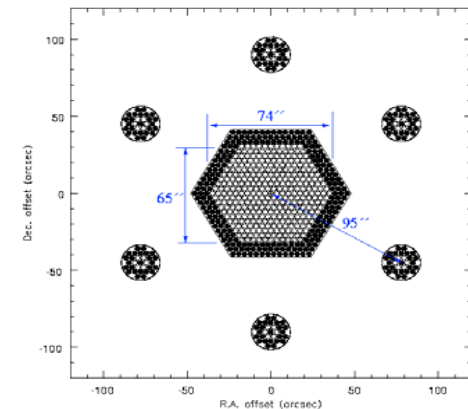
- PMAS: integral field spectrophotometer in the range 0.3-1 microns
- PPAK: world's widest integral field unit (IFU)
- FOV: 65 x 74 arcsec
- Central hexagonal bundle of 331 optical fibres
- 2.7 arcsec per fibre



3.5m telescope at CAHA

**PMAS:** Postdam Multi-Aperture Spectrophotometer

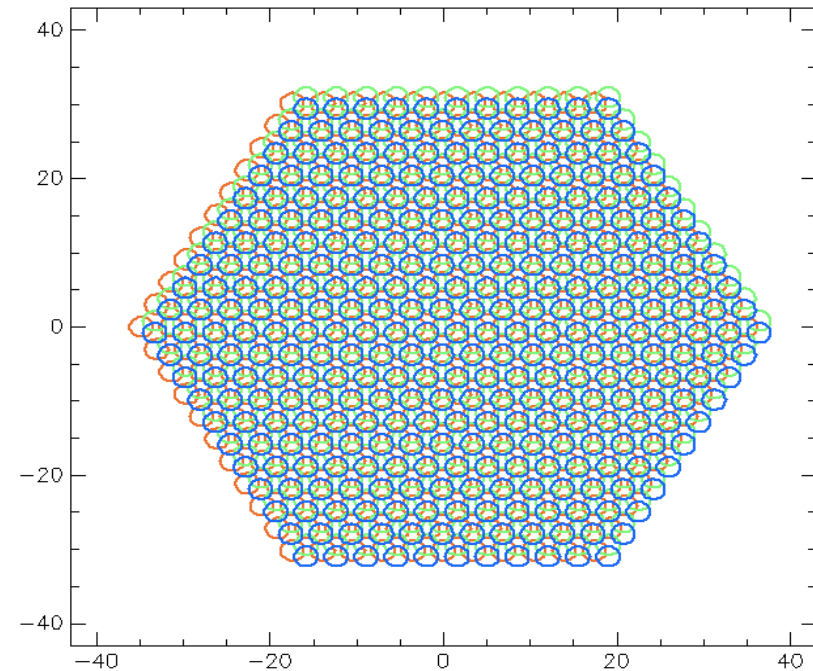
**PPAK:** PMAS fiber PAcK



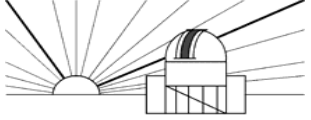
PPAK-IFU diagram



- ✦ Mosaicing is required
- ✦ Dithering in some cases to improve spatial sampling
- ✦ Spectral range:  $\lambda 3700-7000 \text{ \AA}$
- ✦ FWHM:  $10 \text{ \AA}$
- ✦ All bright lines for chemical empirical calibrations:
  - ✦  $[\text{OII}] \lambda 3727 - [\text{SII}] \lambda \lambda 6717, 31$
  - ✦ Age-Metallicity indicators
  - ✦  $\text{H}\alpha$ ,  $\text{H}\delta$ , D4000, Mgb, Mg2, Fe absorptions
- ✦ Observations span from 2006-2009 (5 runs)



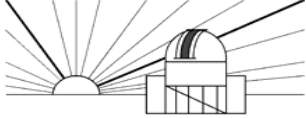
Dithering shifts for PPAK



# Data reduction



- ★ Data reduced with R3D software  
Sanchez, S. Astron. Nachr. (2006)
- ★ Problems with sky subtraction
- ★ Rigorous treatment of the flux calibration
- ★ Almost one year to complete the reduction
- ★ We have reached the limit of refinement in reduction and calibration for this sort of data

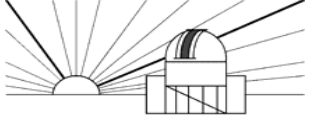


# PIGS sample: observations

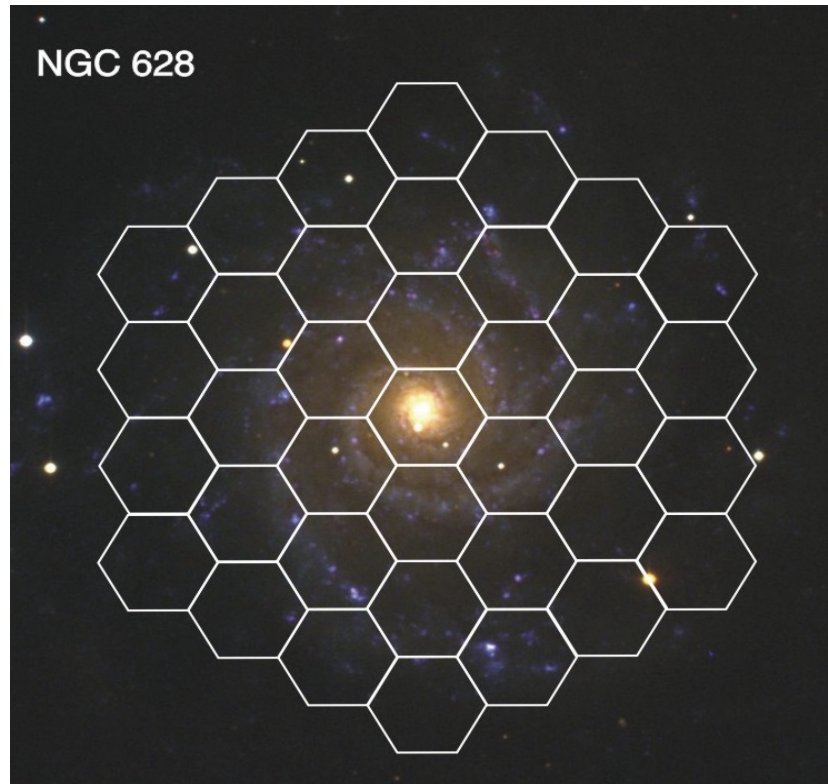


**Total number of spectra: 44,685**

	Object	Status	Positions	Spectra	Comments
1	NGC 628	92% coverage	34/37	13571	SINGS, GALEX
2	NGC 1058	complete	8	7944	in dithering
3	NGC 1637	complete	7	6951	in dithering
4	NGC 2976	20% coverage	2/9	662	SINGS
5	NGC 3184	37% coverage	7/19	2317	SINGS
6	NGC 3310	complete	3	2979	in dithering
7	NGC 4625	complete	1	993	in dithering, SINGS, GALEX
8	NGC 5474	43% coverage	3/7	2979	in dithering, SINGS
9	NGC 6643	complete	3	2979	in dithering
10	NGC 6701	complete	1	993	in dithering
11	NGC 7771	complete	3	993	NGC 7770 in the field
12	Stephan's Quintet	complete	4	1324	NGC 7317, NGC 7318, NGC 7319, NGC 7320



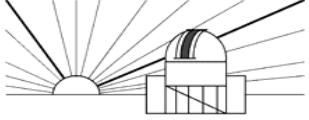
# NGC 628



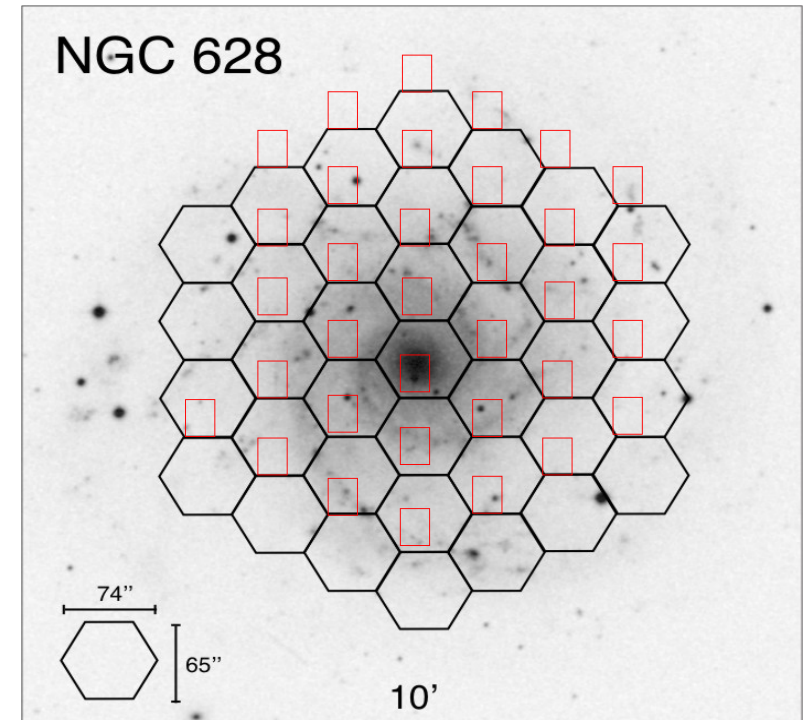
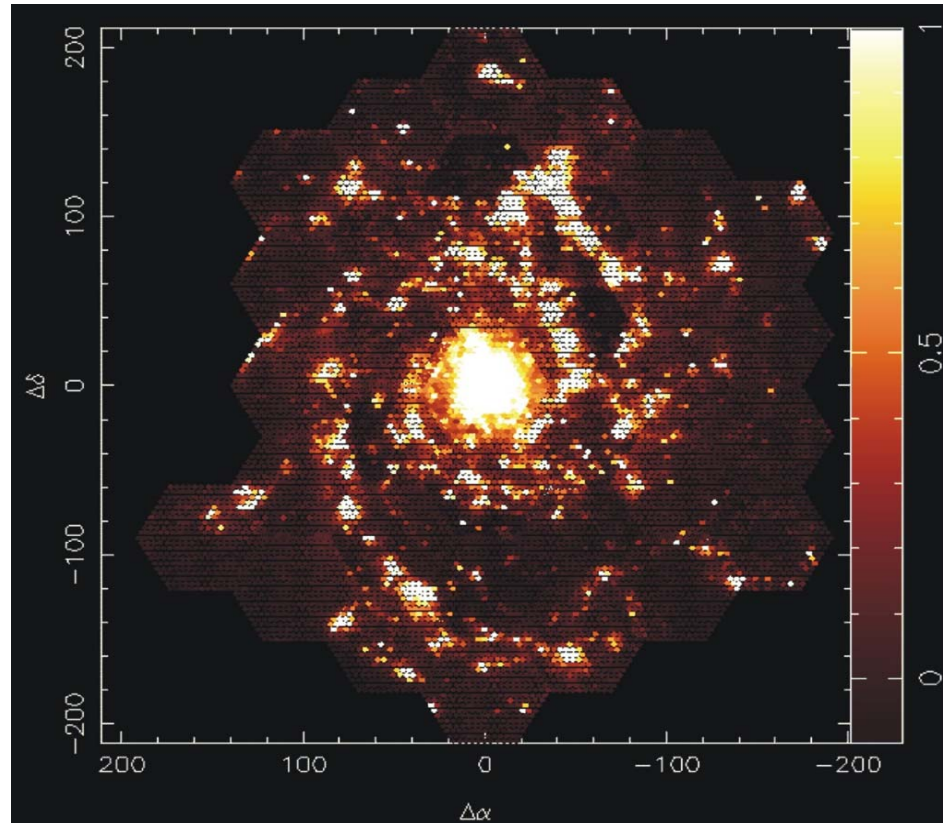
- Largest galaxy in the sample  
( $\sim 8 \times 8$  arcmin)
- $z \sim 0.002$
- $V = 9.9$
- Central region in dithering mode

**Biggest sky field covered by an IFU up to now**



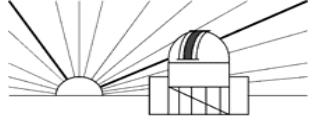


# NGC 628

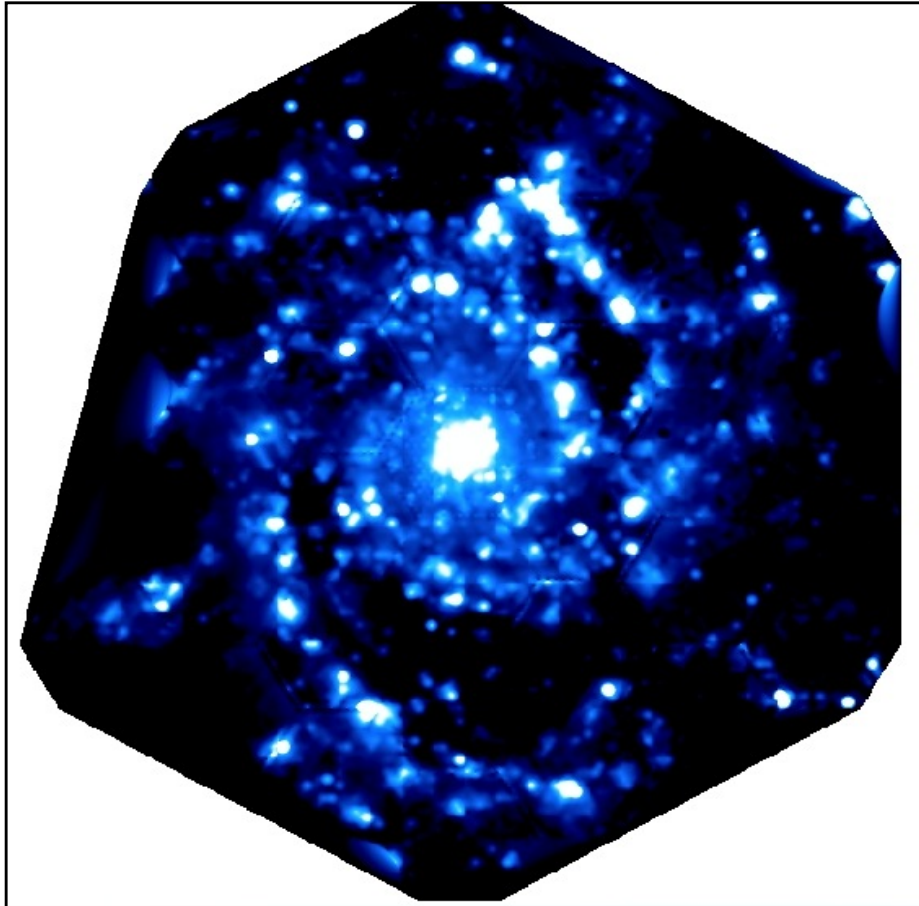


34/37

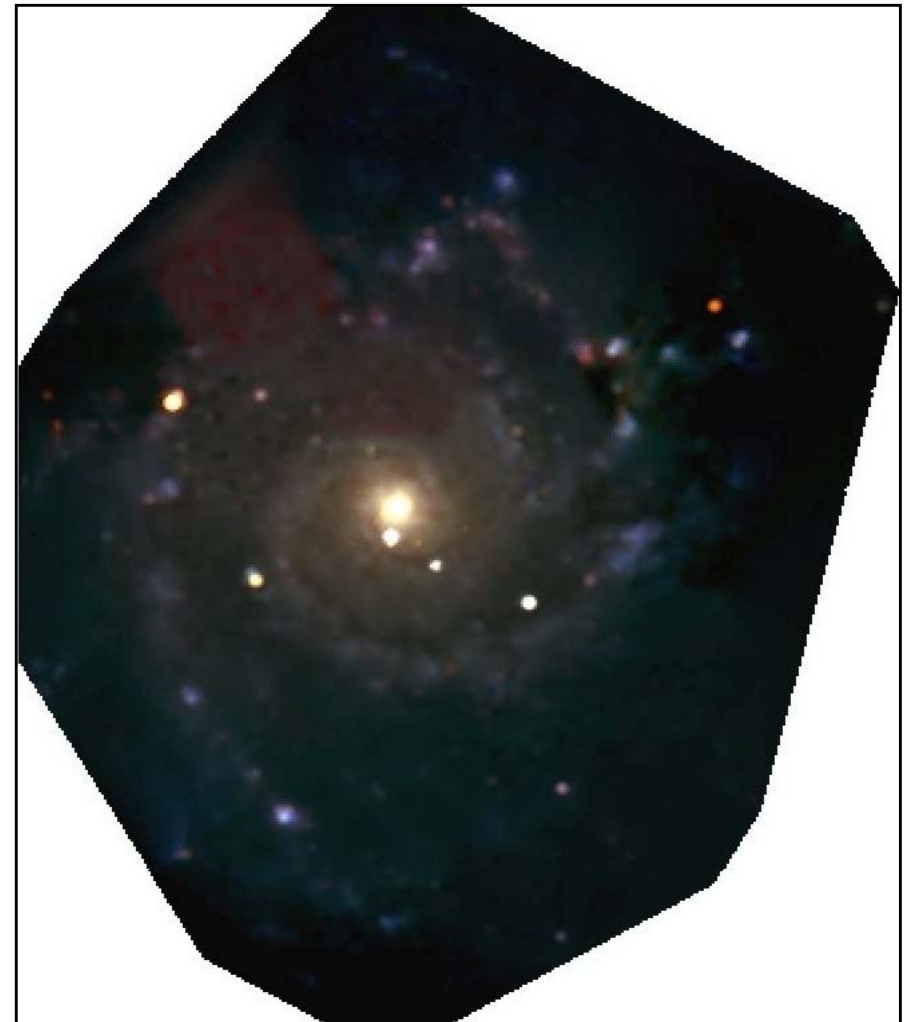
12,578 spectra



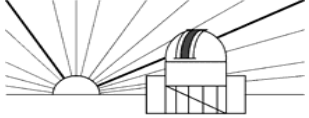
# NGC 628



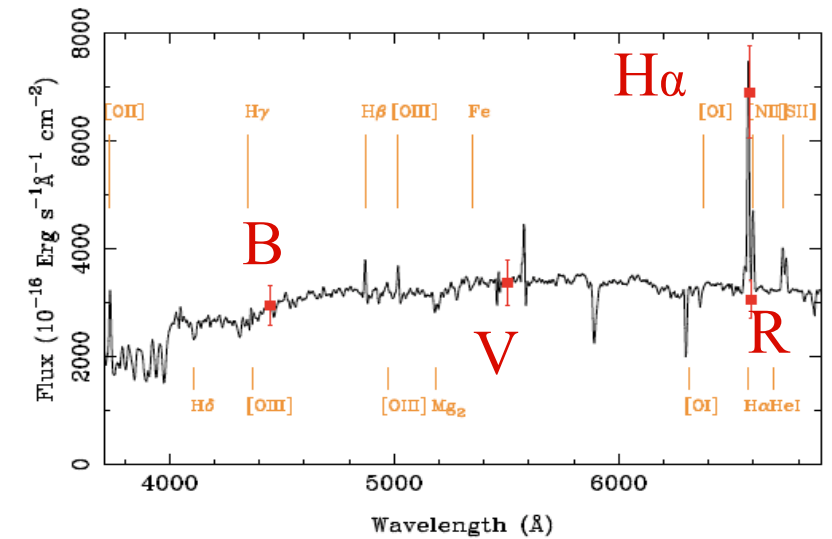
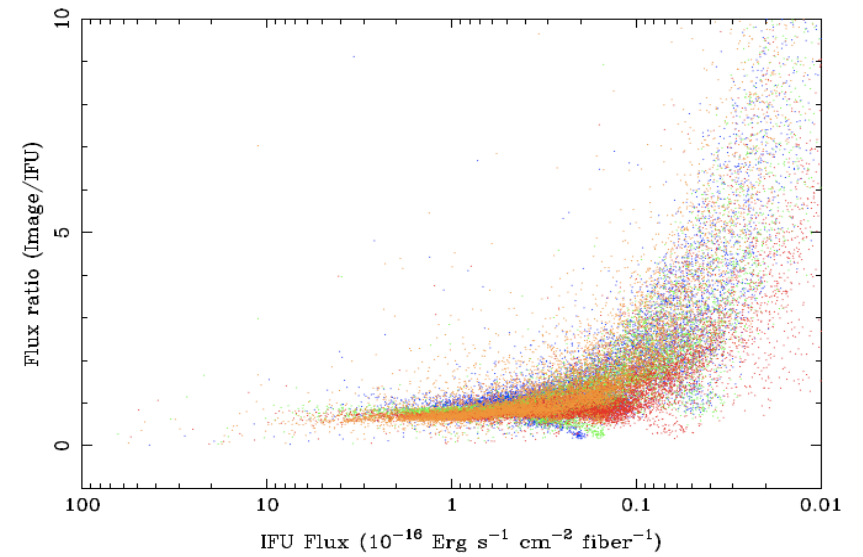
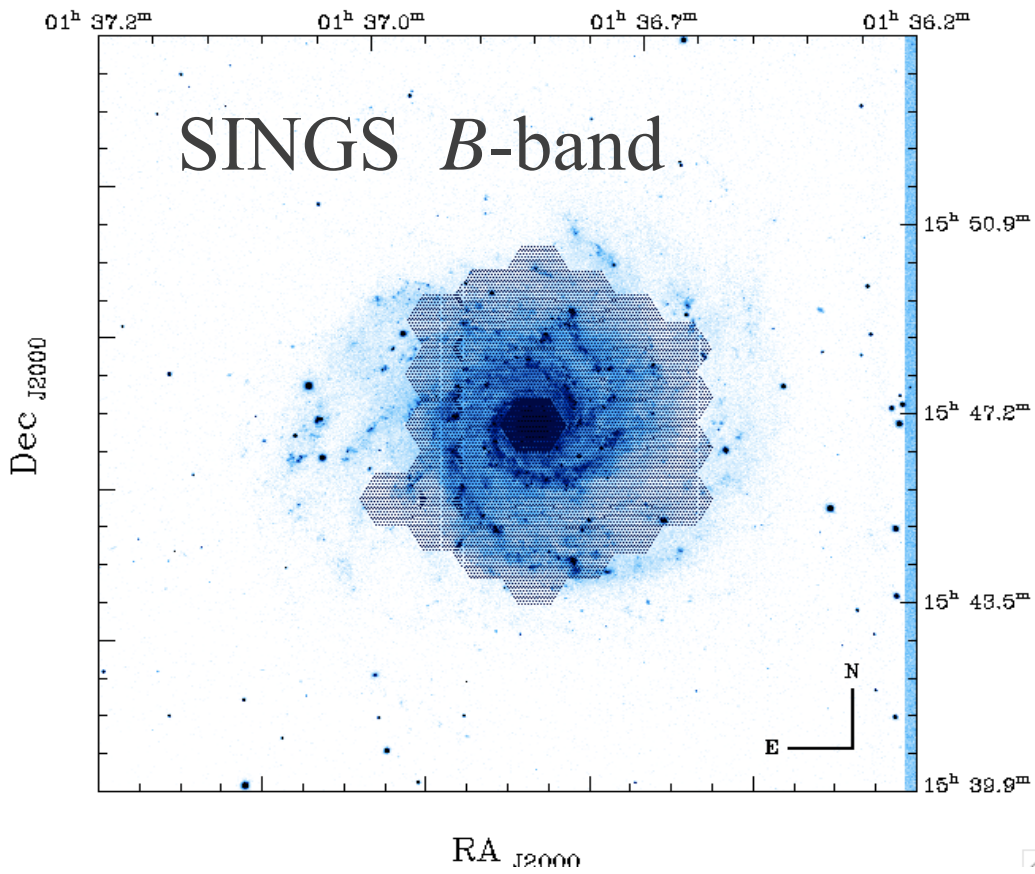
$H\alpha$  + continuum map



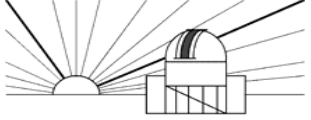
Extracted RGB *image*



# NGC 628







# Data Analysis



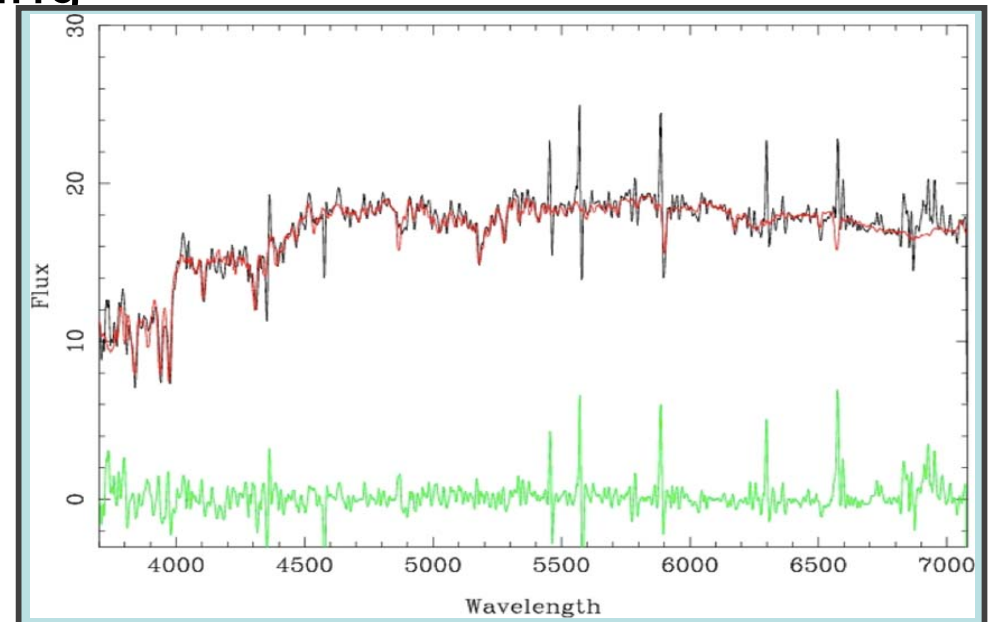
★ Data cube analysed spectrum by spectrum

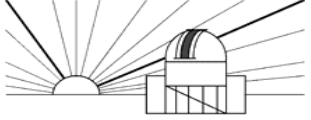
★ Continuum/gas emission de-blending

- Mask emission lines
- Fit continuum with a multi-component SSP
- Dust extinction applied to each SSP

Continuum:  $F(\text{Age}, Z, A_v)$

Residual: pure emission line spectra

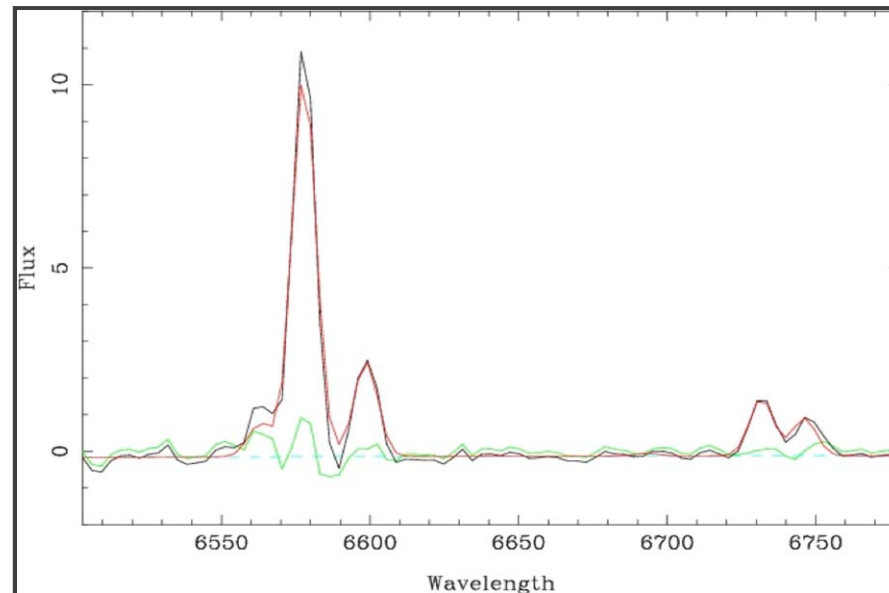




# Emission line measurement



- ✦ Residual spectra fitted with emission line models to derive flux intensities
- ✦ S/N criteria & S/N threshold masks
- ✦ Intensity maps can be created by interpolating discrete intensity data







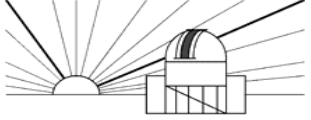
## ★ Row Stacked Spectra (RSS) FITS files + position tables

- Original spectra
- Model (fitted SSP continuum)
- Residual (emission lines spectra)

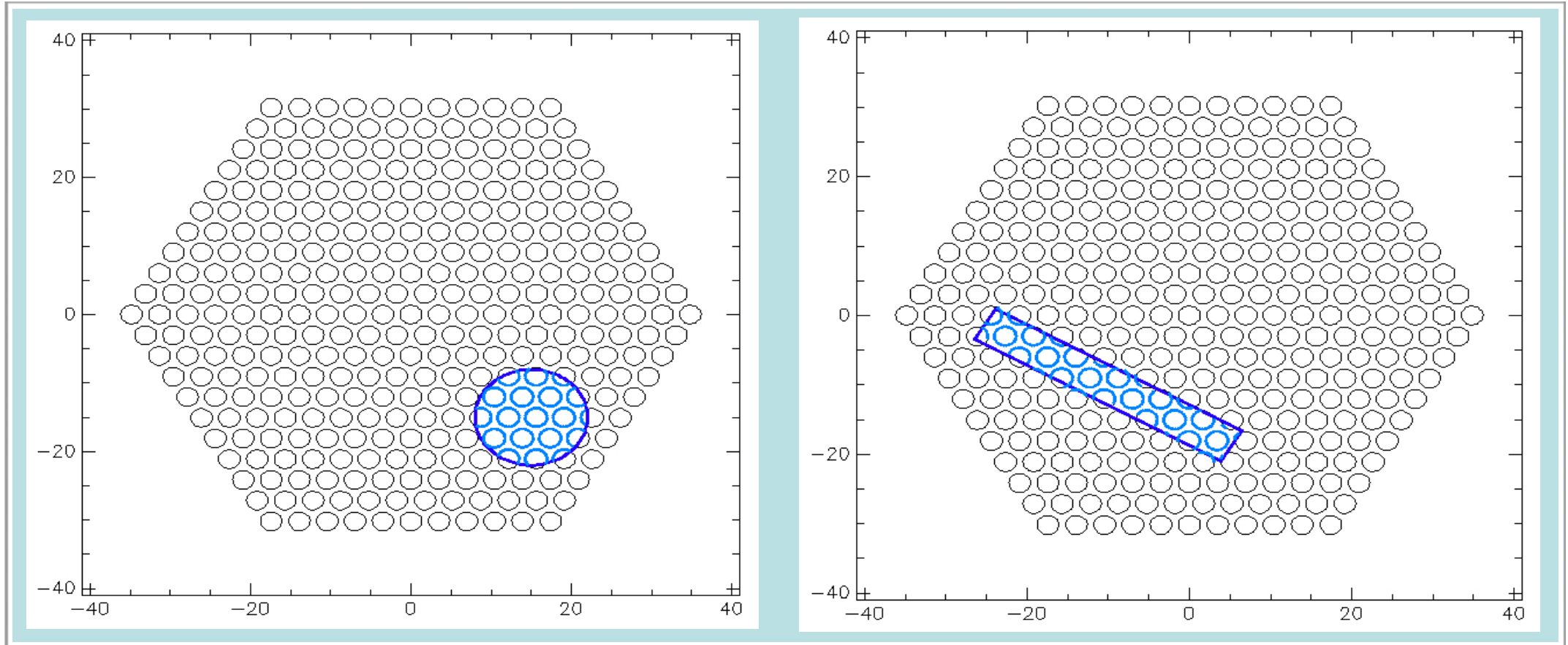
## ★ Emission line maps

⇒ H $\alpha$ , H $\beta$ , H $\gamma$ , H $\delta$ , [OII] $\lambda$ 3727, [NeIII] $\lambda$ 3869, [OIII]  $\lambda$ 4363\*, HeI  $\lambda$ 4471, [OIII]  $\lambda$ 4959,5007, [OI]  $\lambda$ 6300\*, [SIII]  $\lambda$ 6312\*, HeI  $\lambda$ 5876, [NII]  $\lambda$ 6548,6584, HeI  $\lambda$ 6678, [SII]  $\lambda$ 6717, 6731

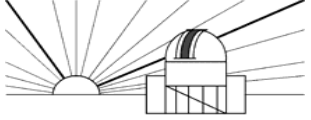
\* Only on regions with extremely good S/N and good sky subtraction



# Data Products



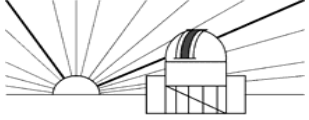
Simulation of different apertures at any position  
(offsets in arcsec from the center)



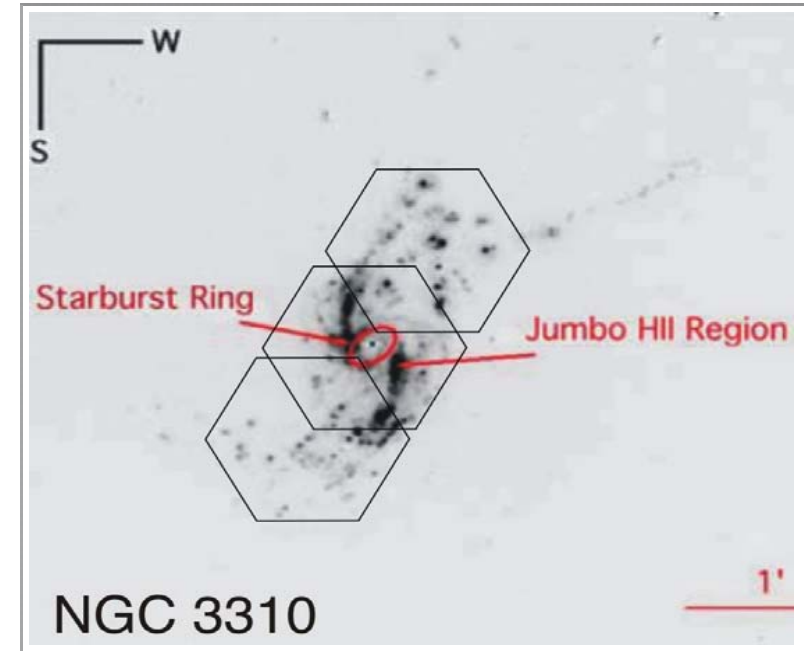
---

## General topics/questions

- Nearby Galaxies as laboratories to study star formation, metallicity transfer, star evolution and mass growth
  - How/where star forms? How mass is settled?
  - How metals are transfer throw the galaxies?
  - Dust distribution in galaxies
  - Integrated/resolved properties
  - Ionization processes in galaxies
  - Detailed Star formation History
-



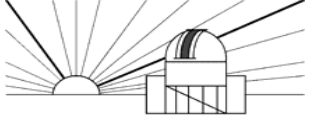
# NGC 3310



**complete**

all positions in  
dithering mode

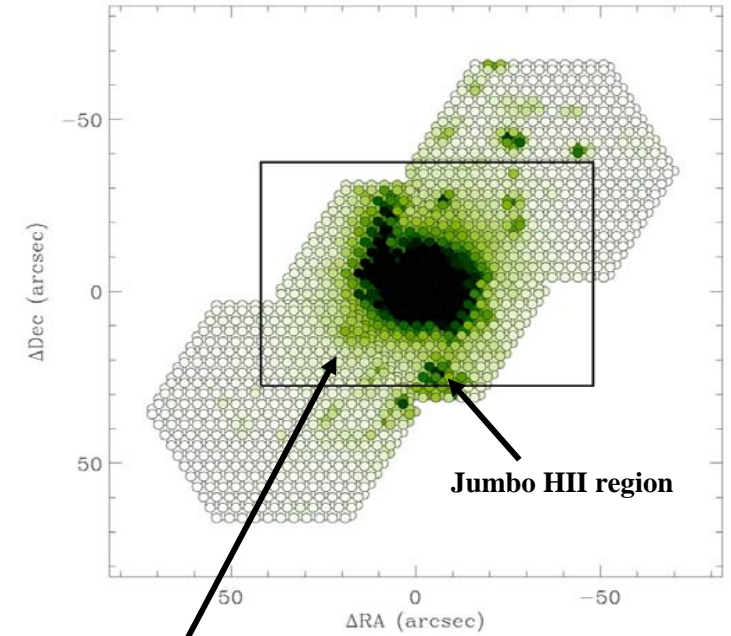
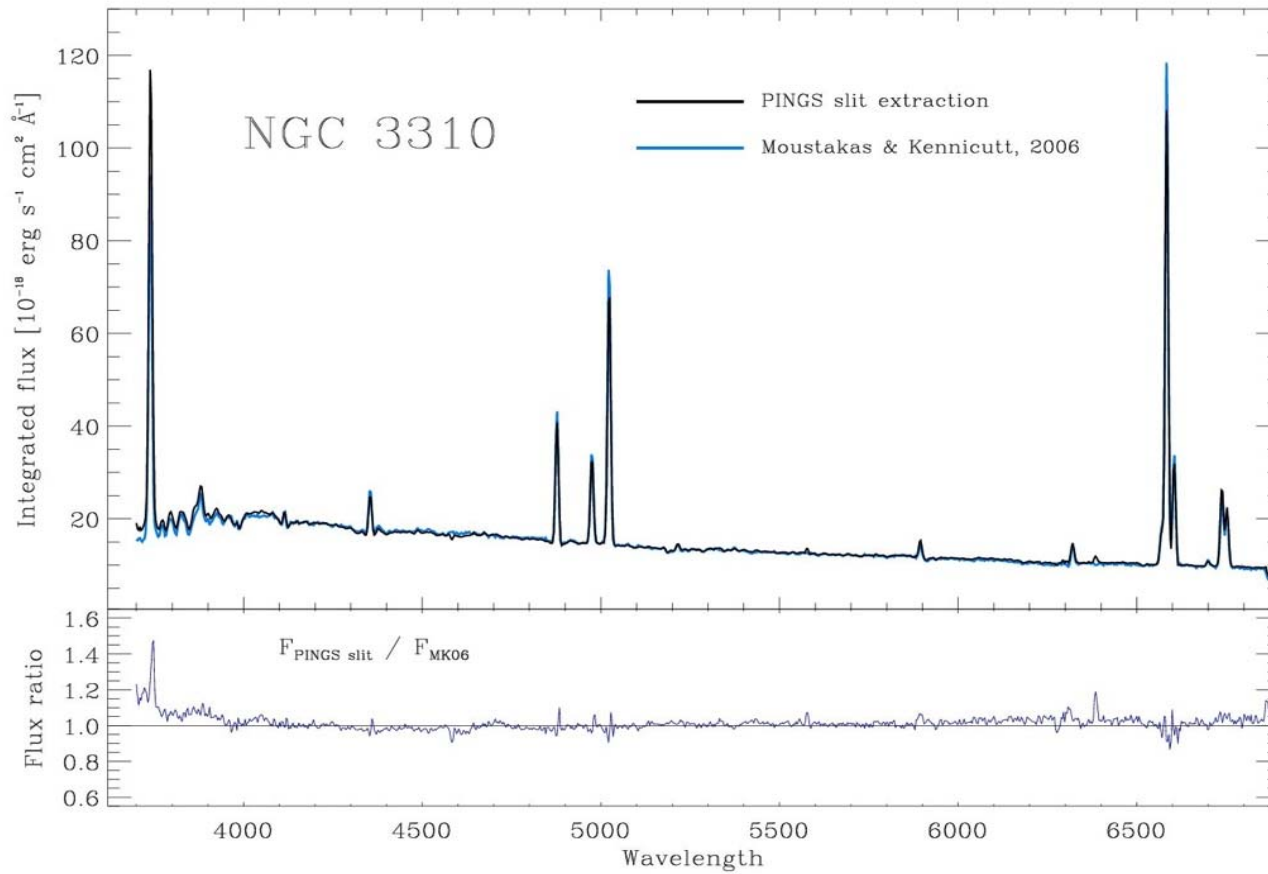
**2,979 spectra**



# Integrated spectrum

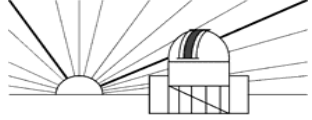


## NGC 3310



drift-scanning aperture  
*Moustakas & Kennicutt 2006*

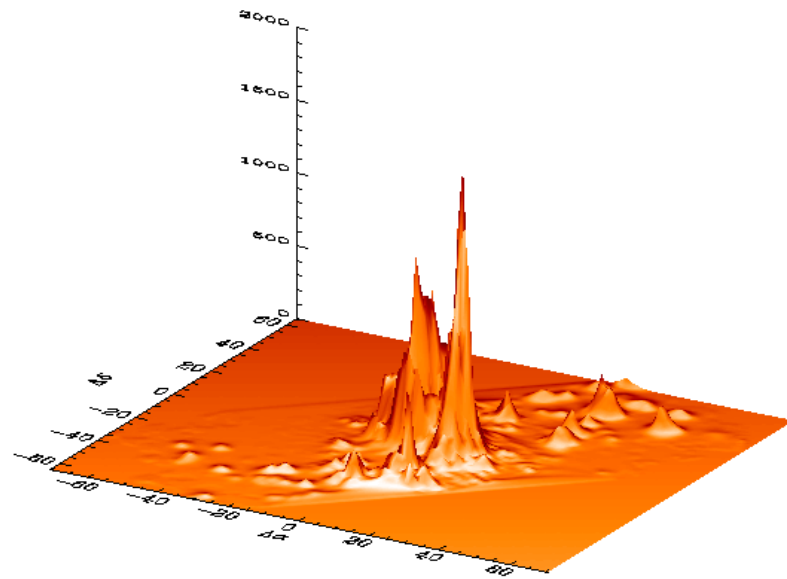




# 3D emission line distributions

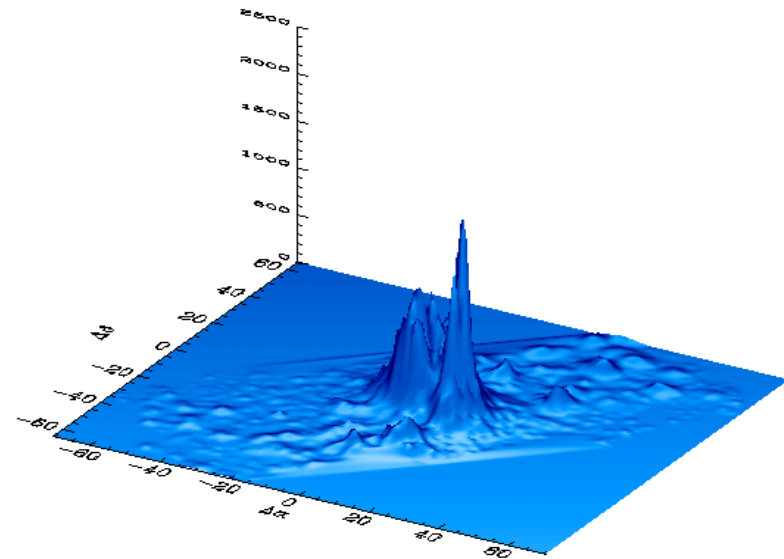


[OIII]  $\lambda 5007$  Intensity

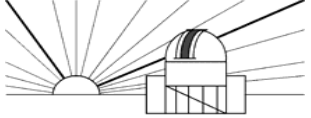


NGC 3310

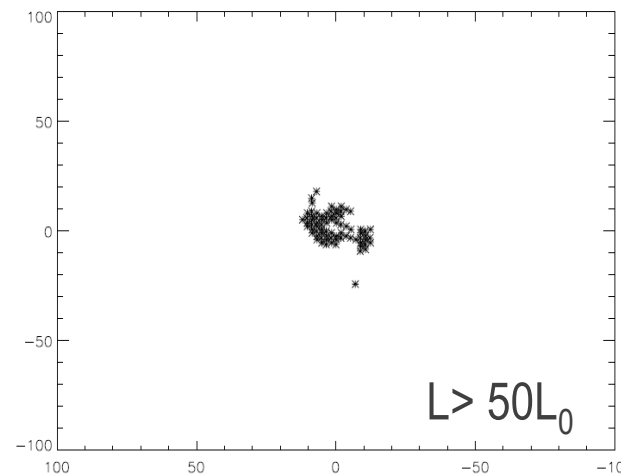
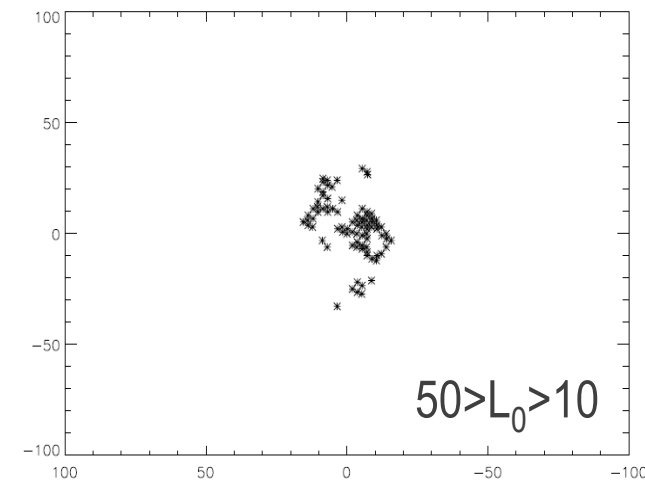
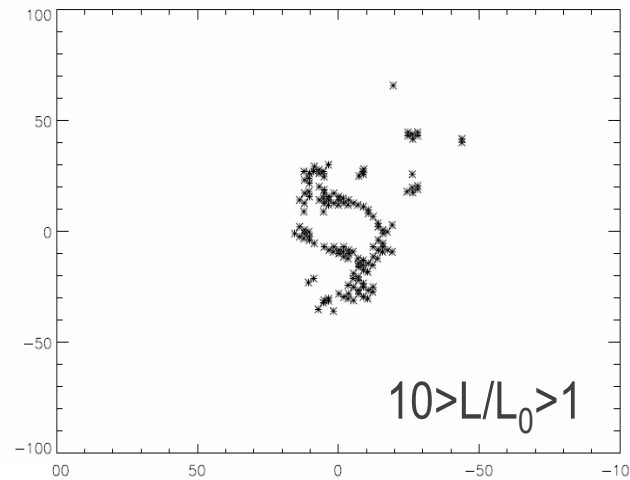
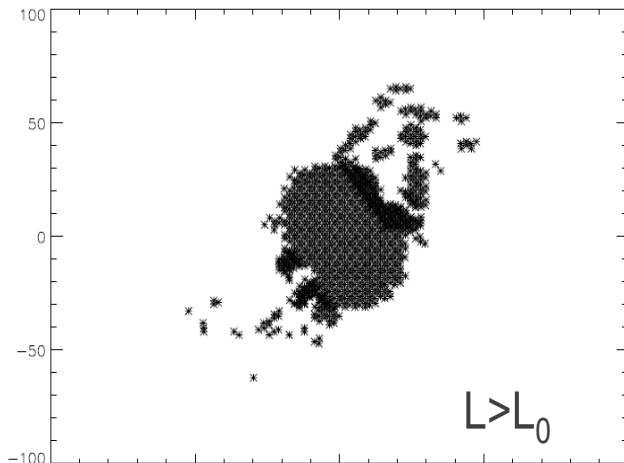
[OII]  $\lambda 3727$  Intensity



NGC 3310



# Luminosity bins in NGC 3310



$D = 17.5 \text{ Mpc}$

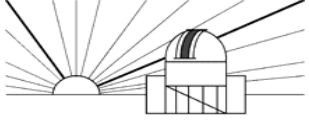
For a star cluster of  $M = 10^4 M_{\odot} \Rightarrow Q(\text{H}^0) = 2.5 \times 10^{50} \text{ s}^{-1}$

Which corresponds to

$L(\text{H}\alpha) = 3.44 \times 10^{38} \text{ erg s}^{-1}$

$$L(\text{H}\alpha)/F(\text{H}\alpha) = 3.68 \times 10^{52} \text{ erg s}^{-1}$$

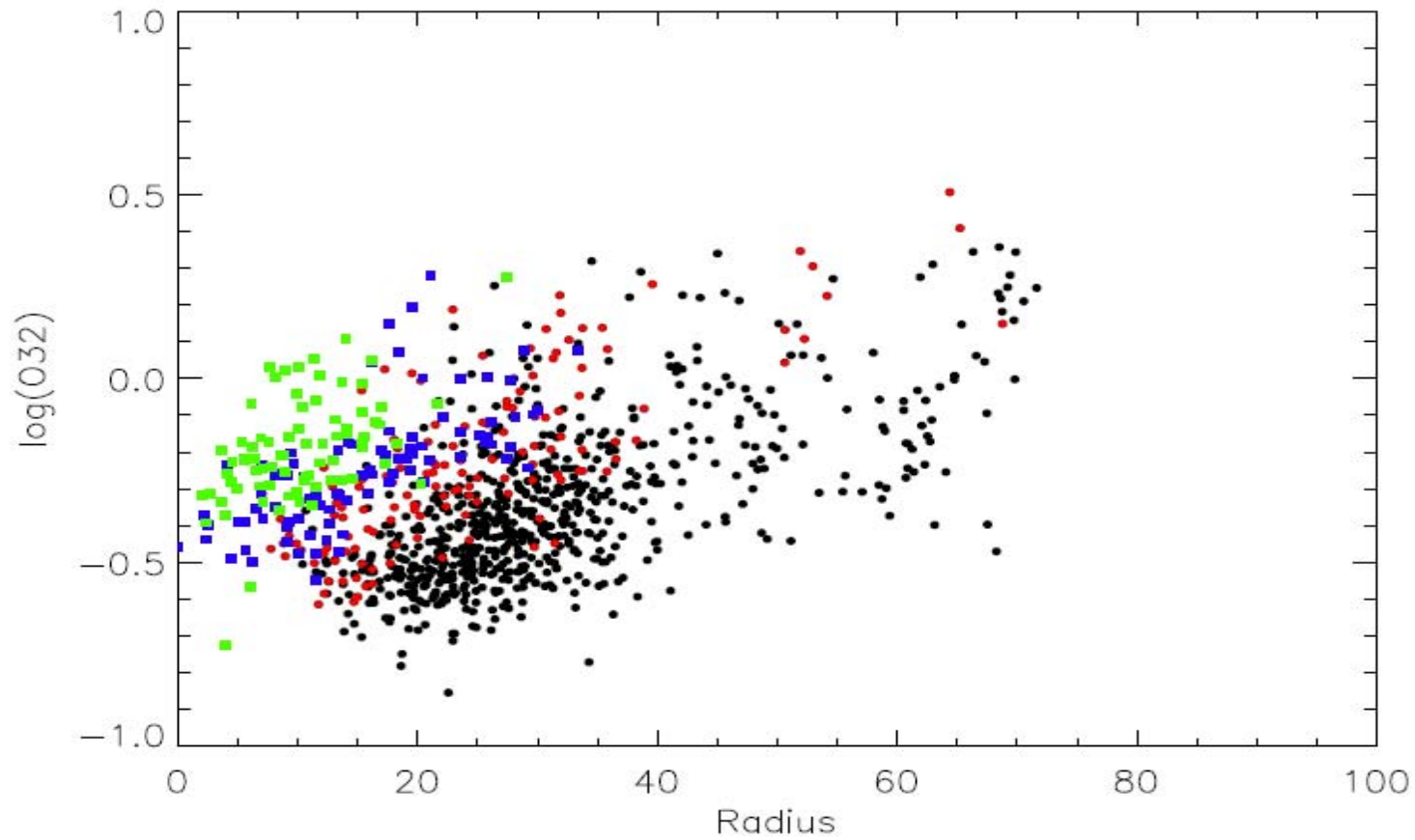
$$L_0(\text{H}\alpha) = 3.7 \times 10^{37} \text{ erg s}^{-1}$$

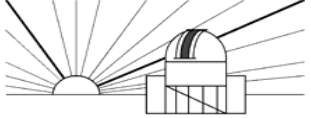


# Excitation vs radius



$$\log O32 = \log([\text{OIII}]/[\text{OII}])$$

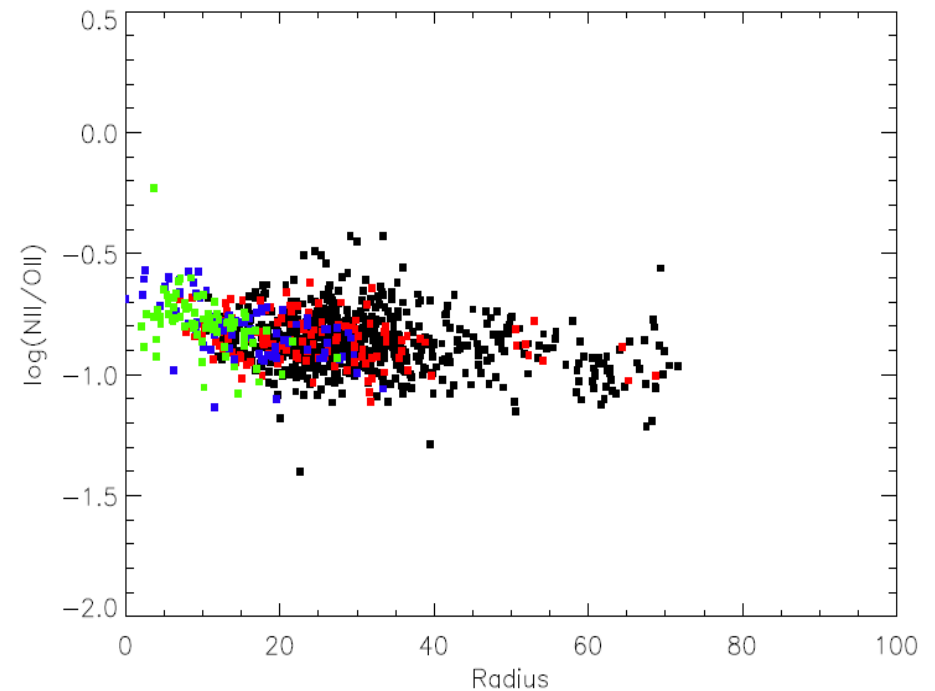
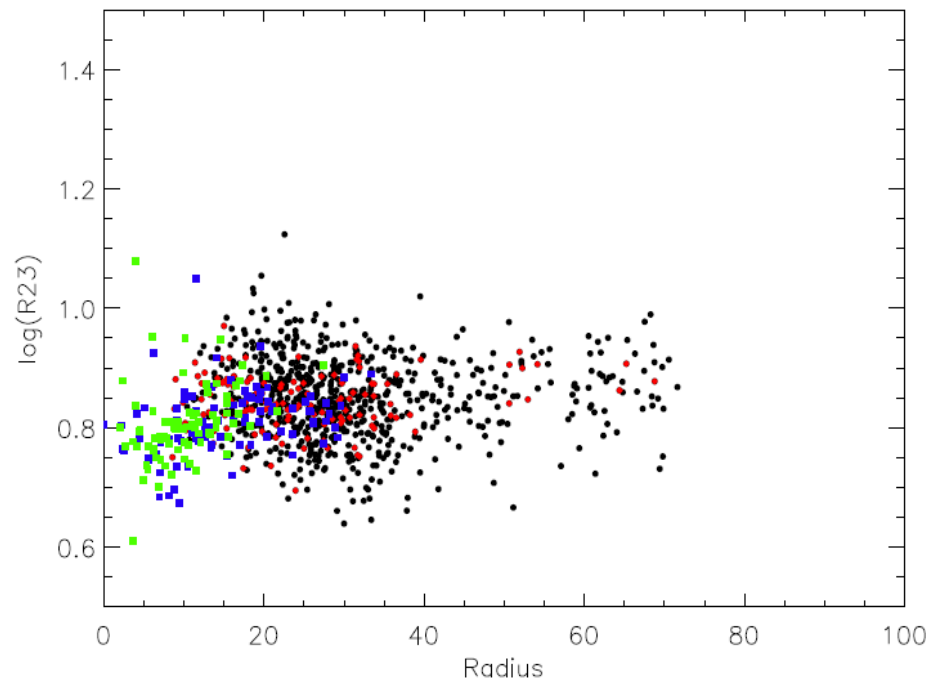


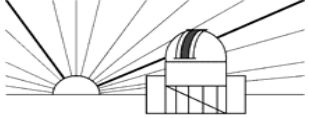


# Abundance indicators vs radius

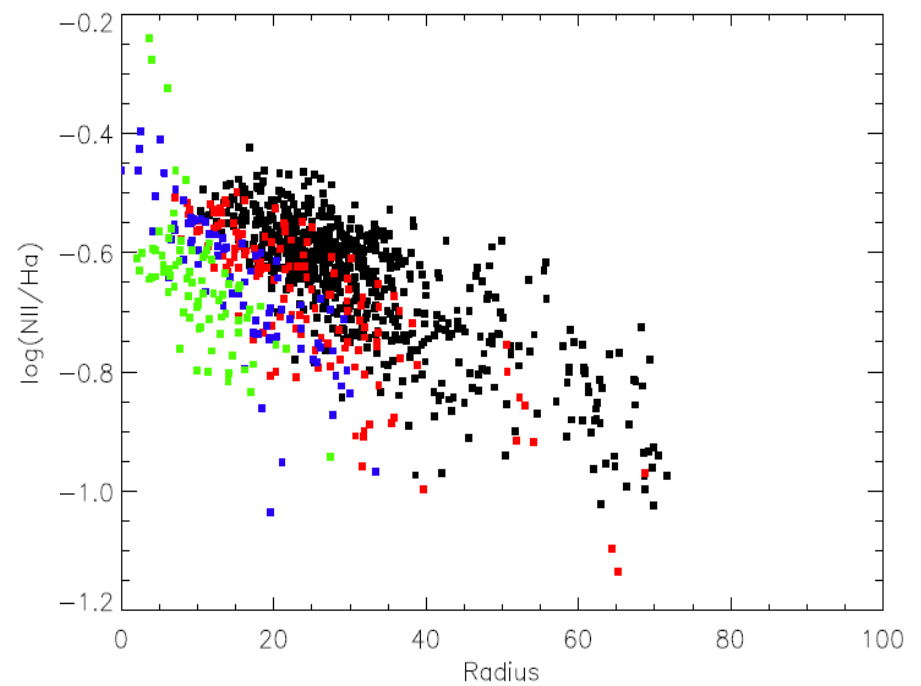
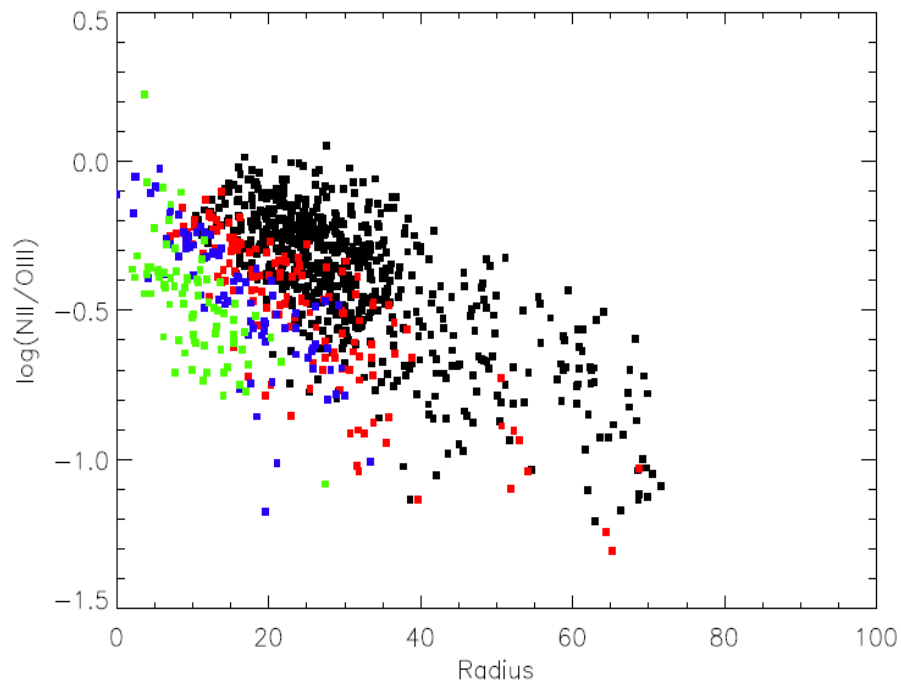


$$R_{23} = \log([\text{OII}] + [\text{OIII}]) / \text{H}\beta$$

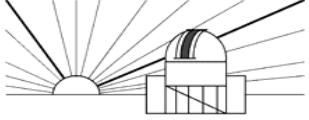




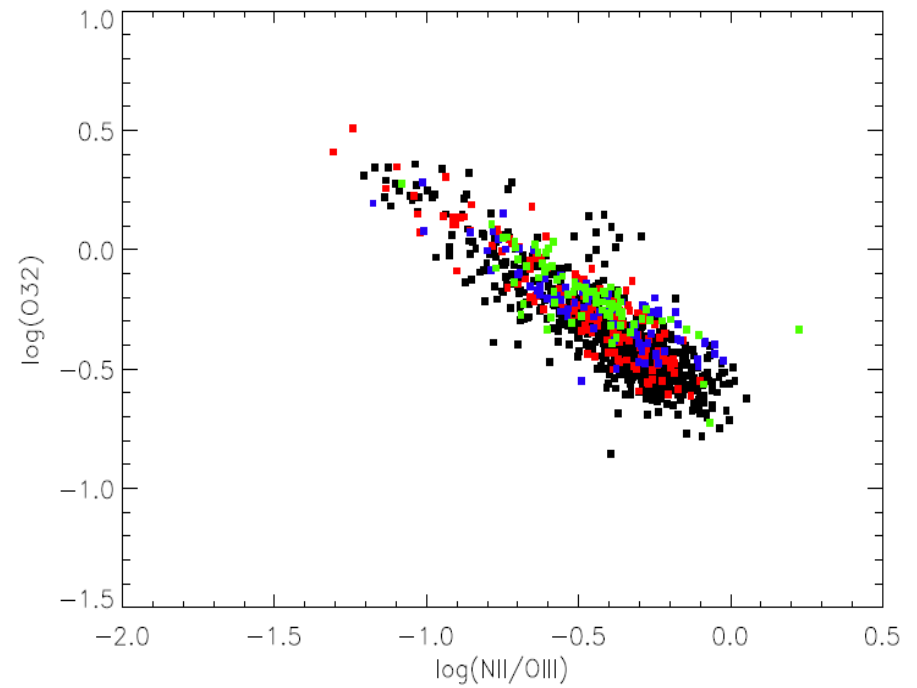
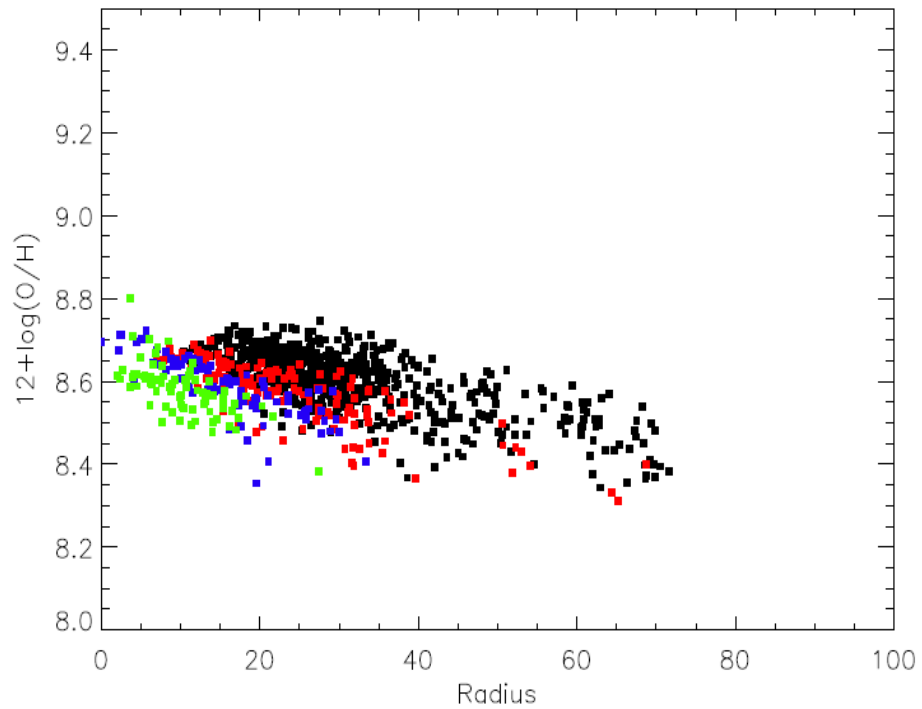
# Abundance indicators vs radius

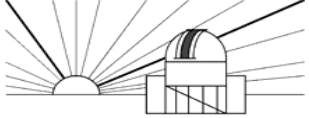




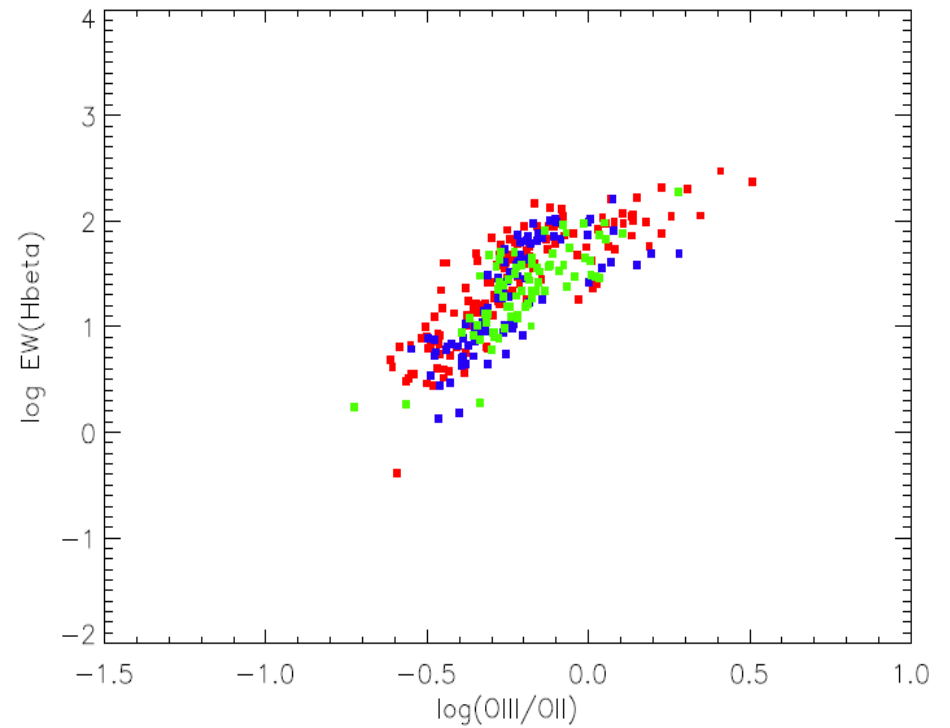
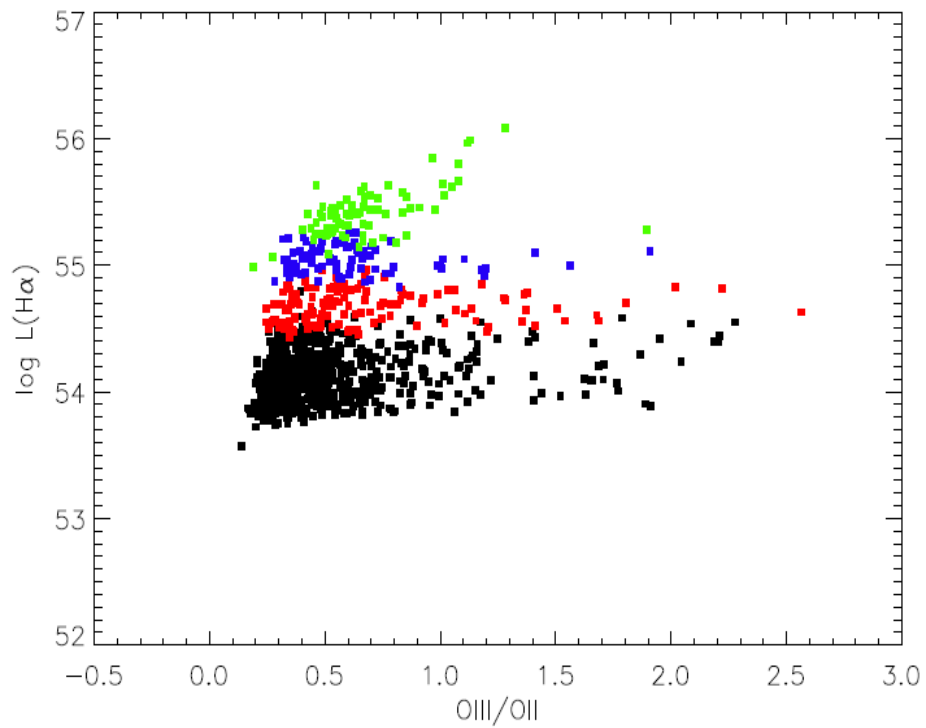


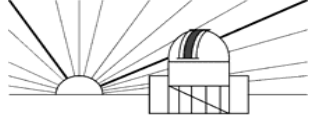
# Abundance vs excitation



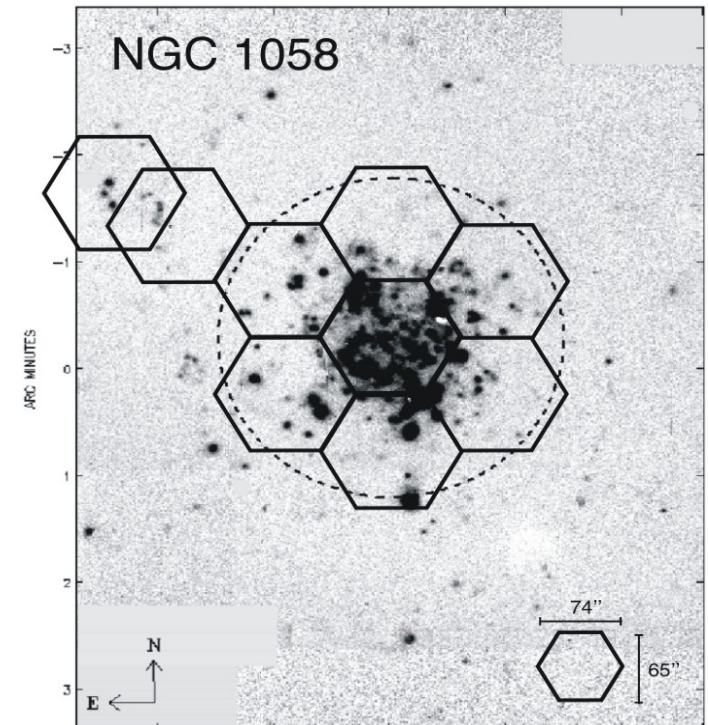


# Luminosity vs excitation





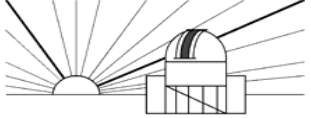
# NGC 1058



**complete**

all positions in  
dithering mode

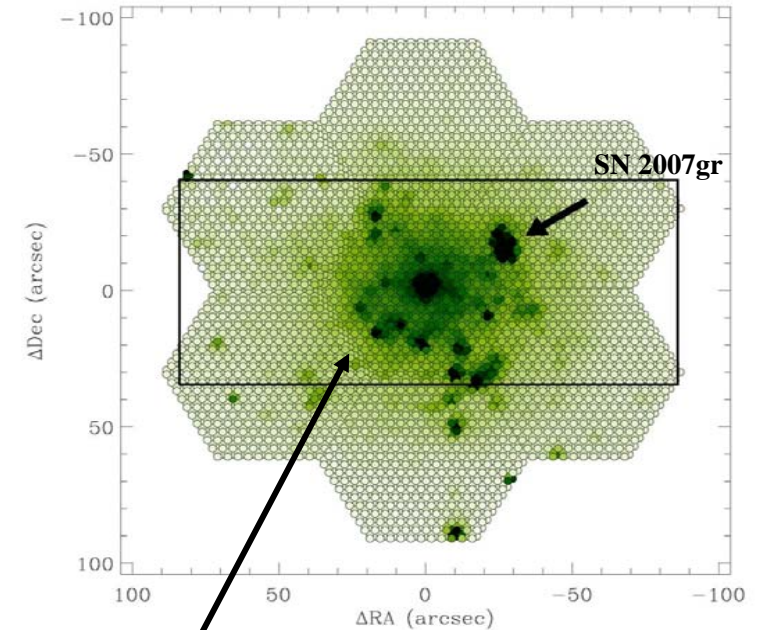
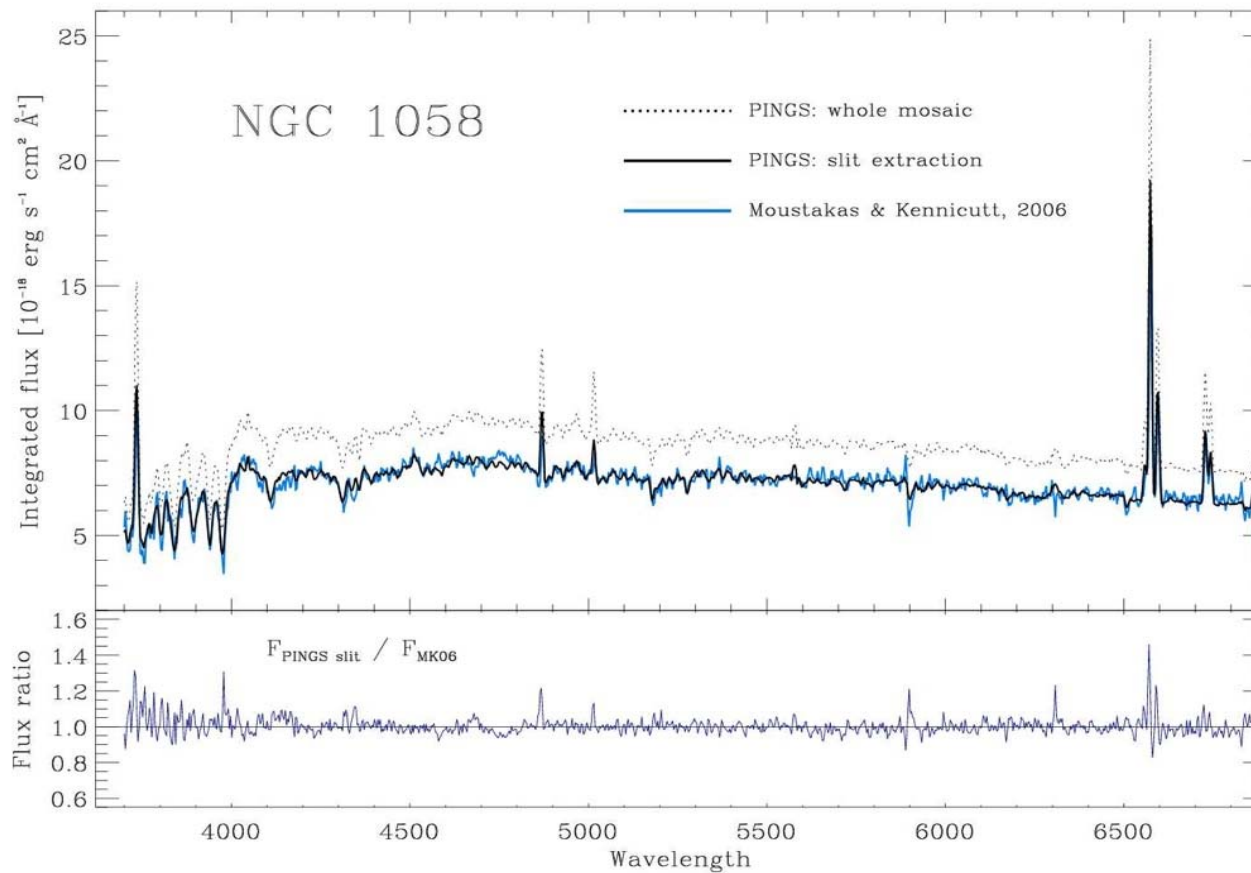
**8,275 spectra**



# Integrated spectrum



## NGC 1058



drift-scanning aperture  
*Moustakas & Kennicutt 2006*

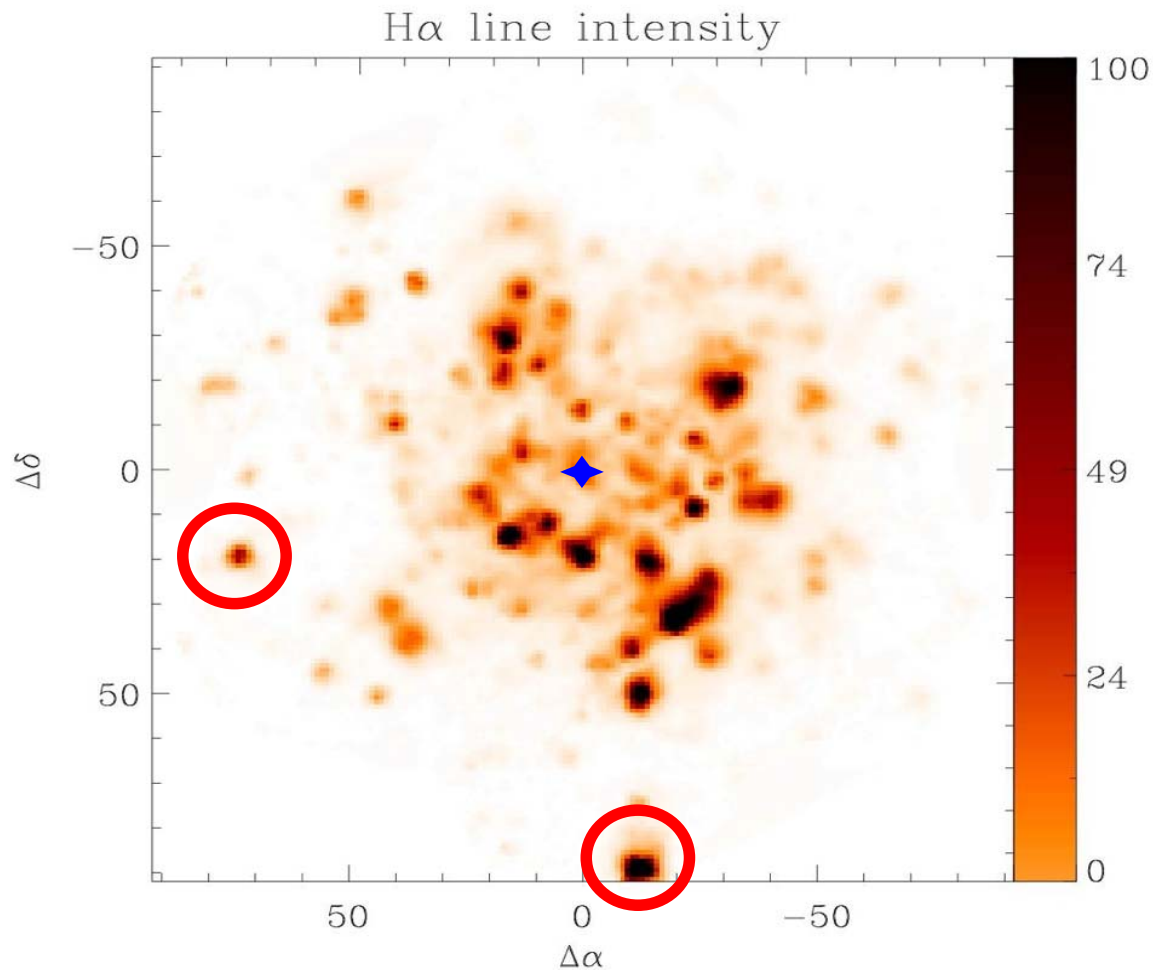


# NGC 1058: H $\alpha$ line intensity

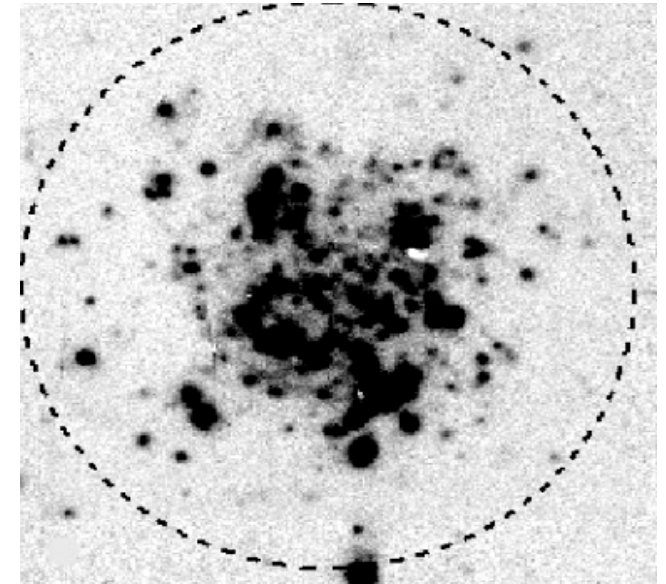
## Interpolated continuum-subtracted map

Units:  $10^{-16}$  erg s $^{-1}$  cm $^{-2}$  arcsec $^{-2}$

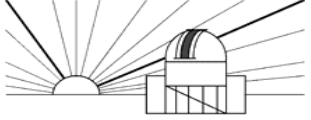
Low S/N masking applied



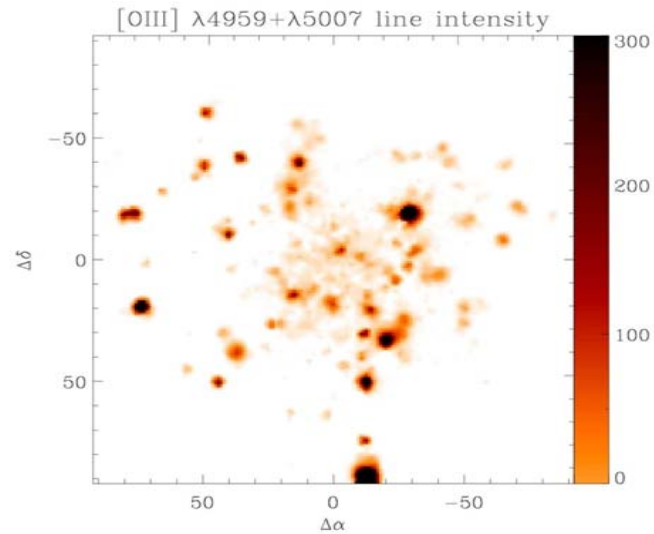
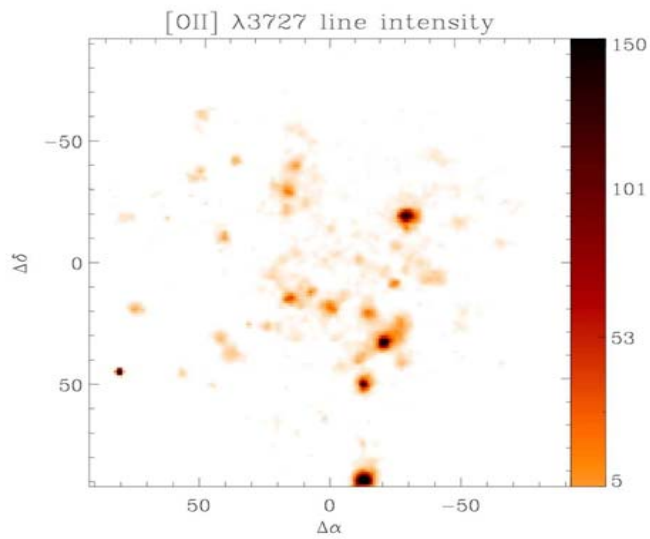
Ferguson et al 1998



- Many intense emission regions not associated with the spiral structure
- Asymmetric star-formation
- Diffuse emission clearly seen and traced in the inter-arm regions
- Outlying star-forming regions responsible for the difference between MK06 vs PINGS integrated spectrum

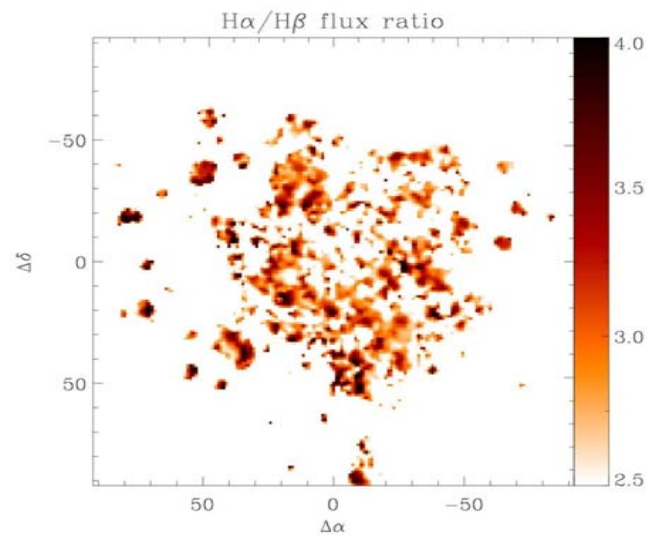
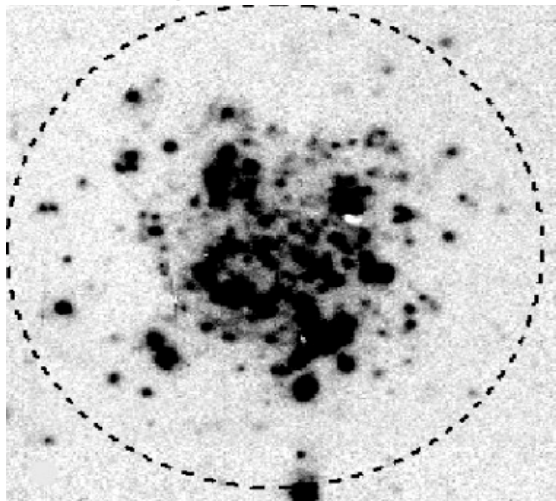


# Emission line maps: NGC 1058



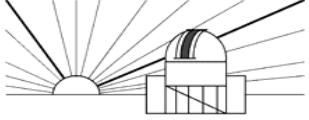
Oxygen emission  
distribution

Ferguson et al 1998

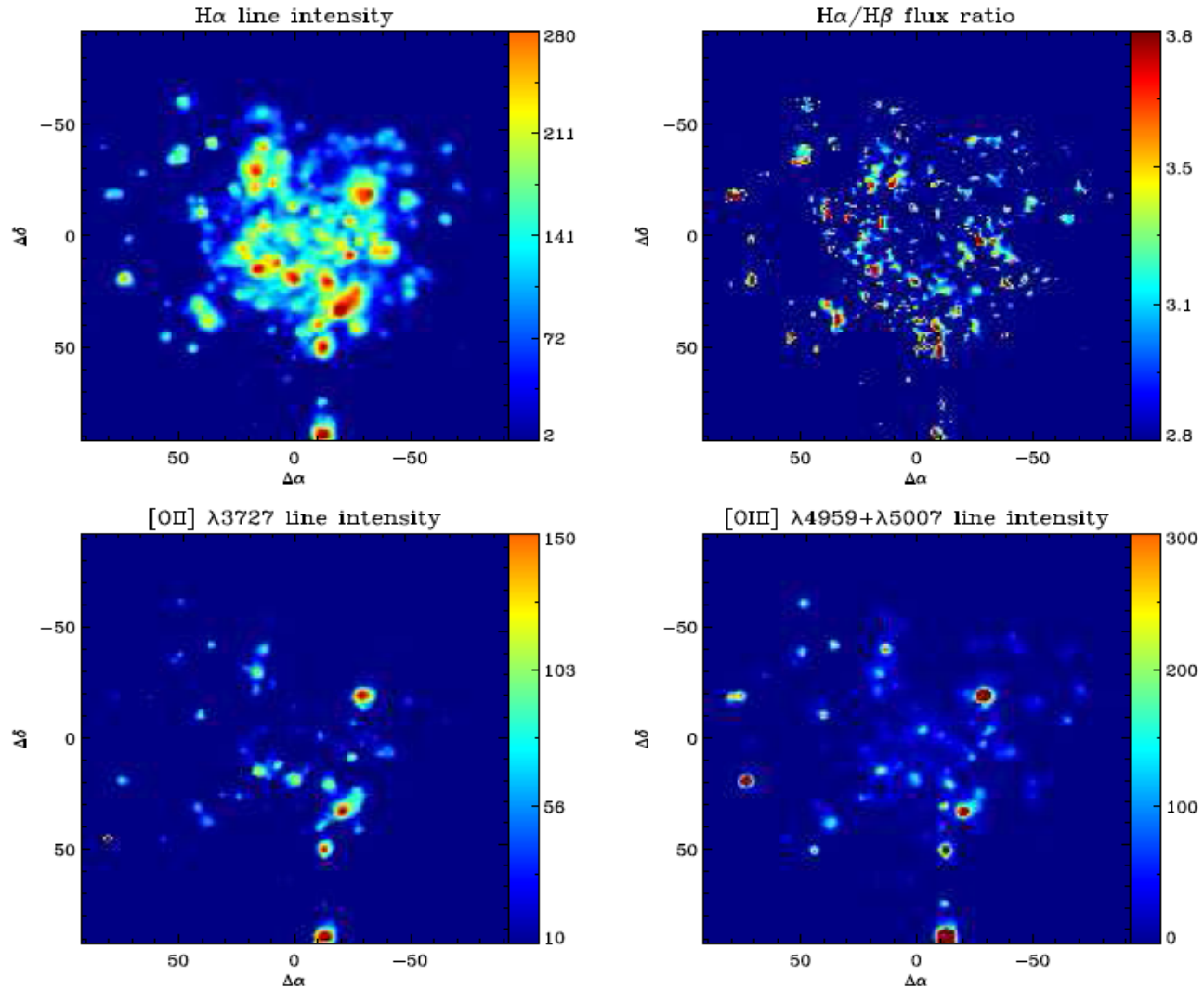


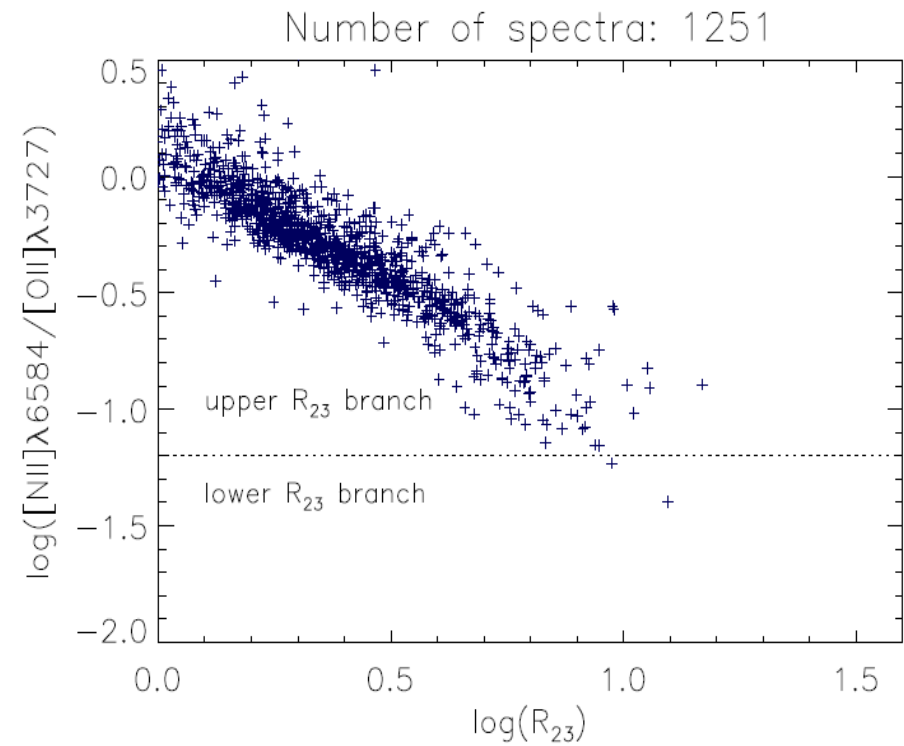
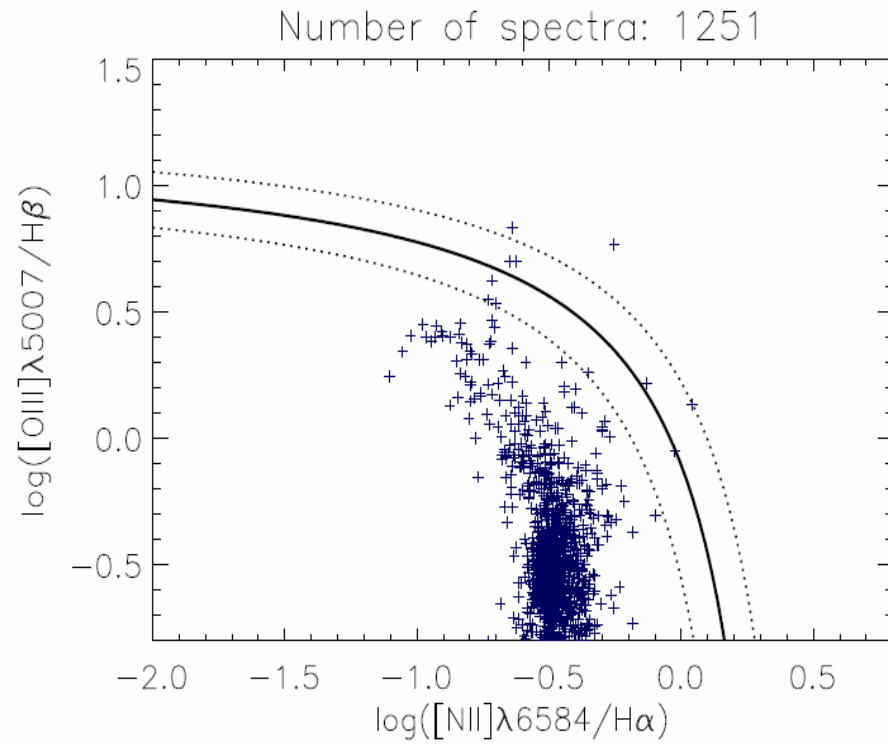
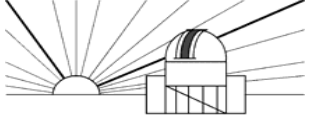
Dust extinction  
distribution

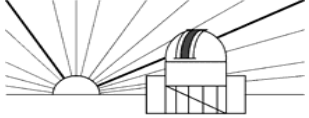




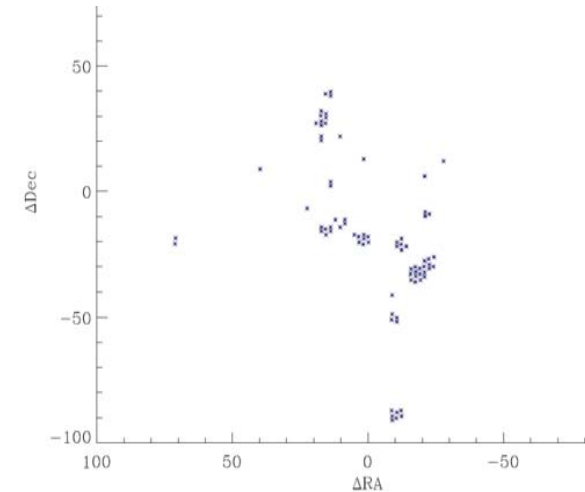
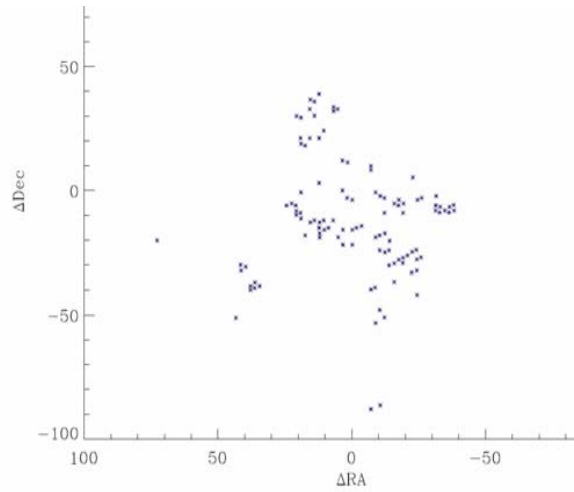
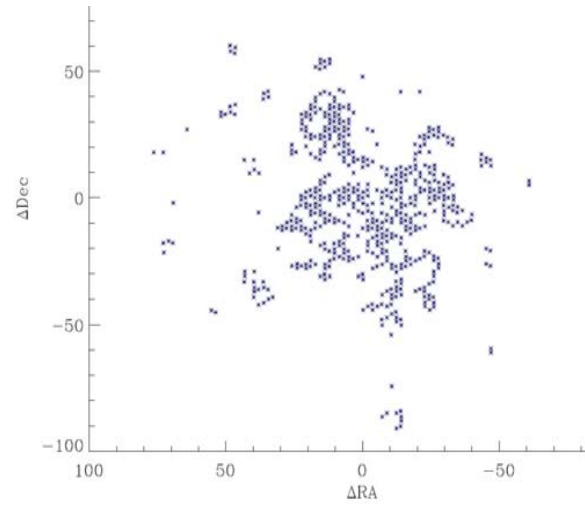
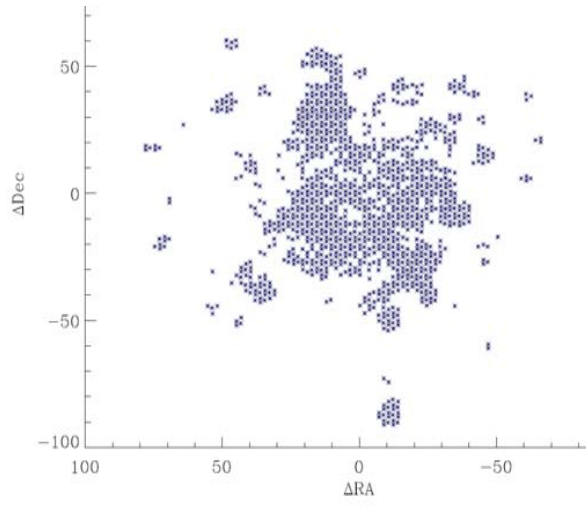
# Emission line maps

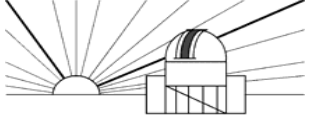




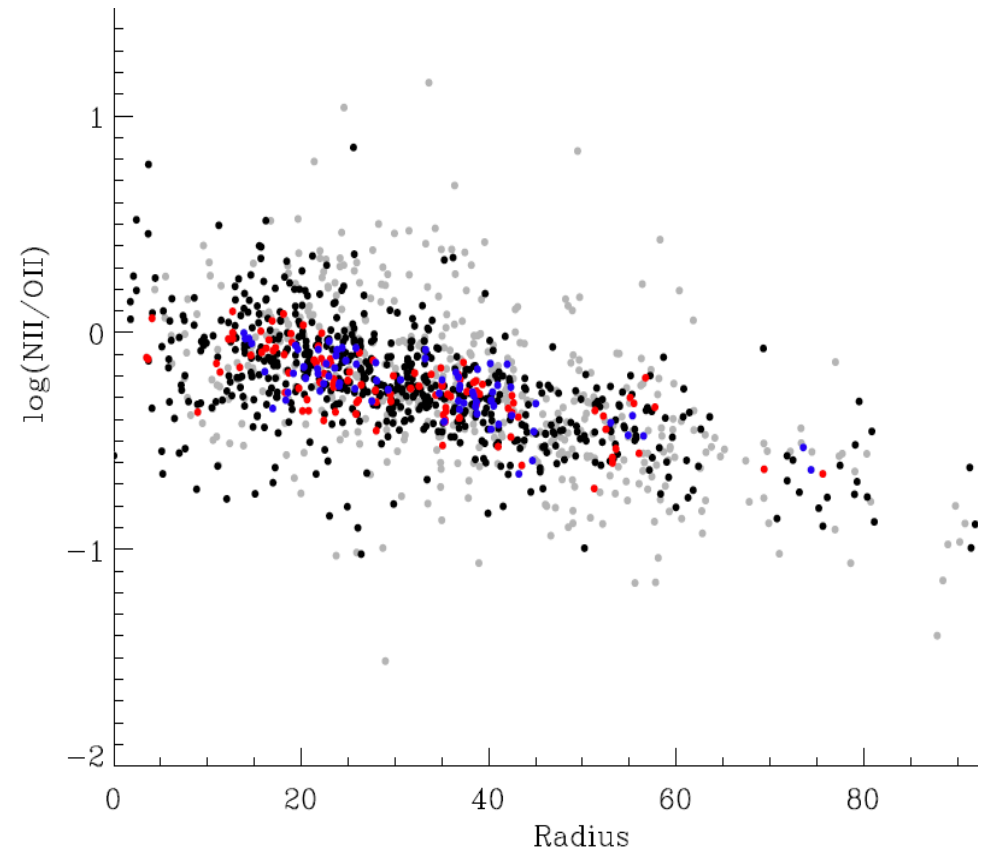
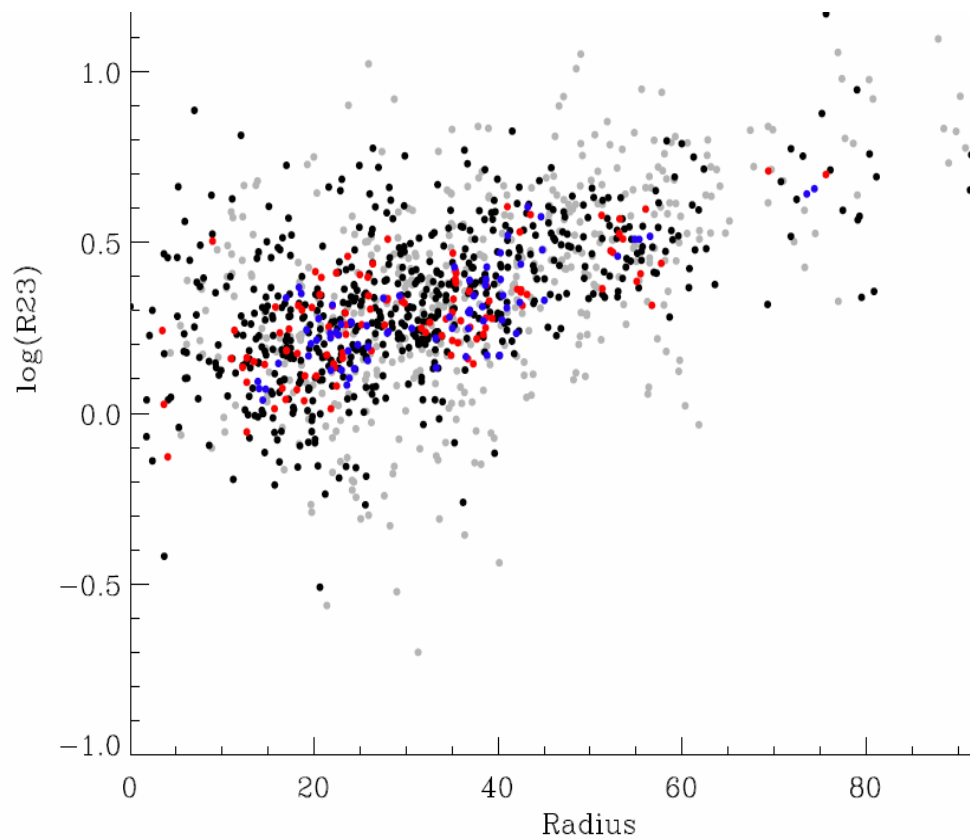


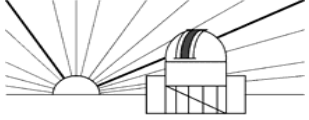
# NGC 1058: Luminosity bins



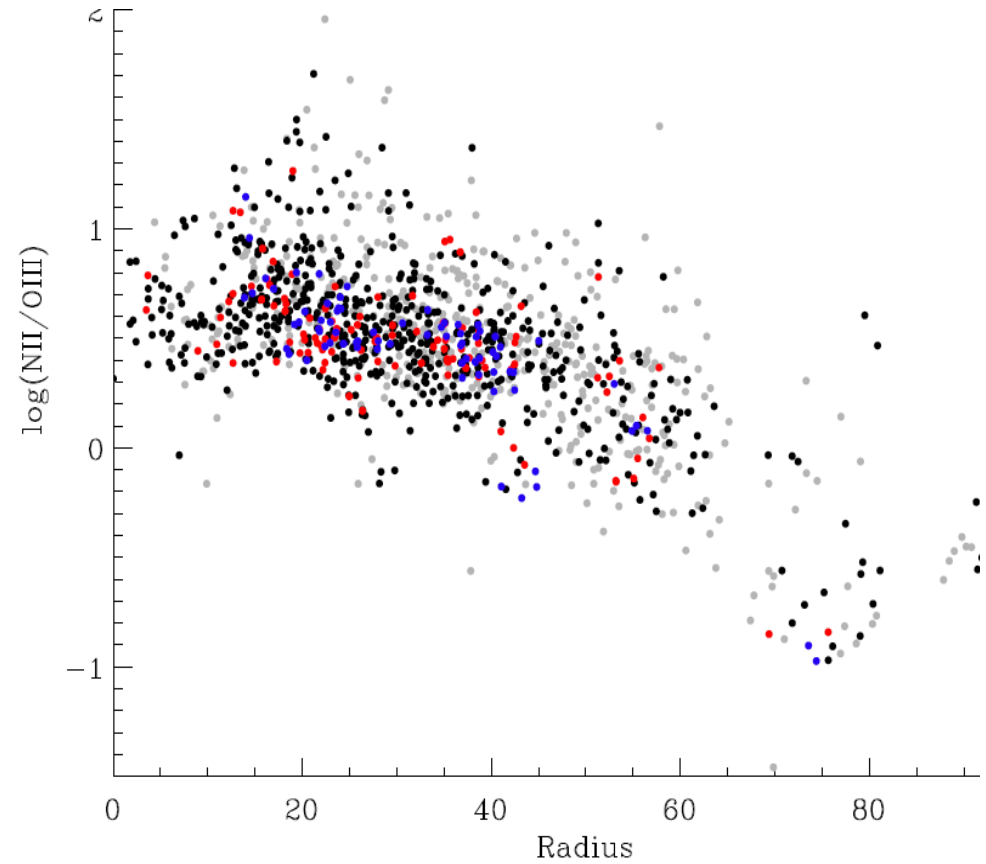
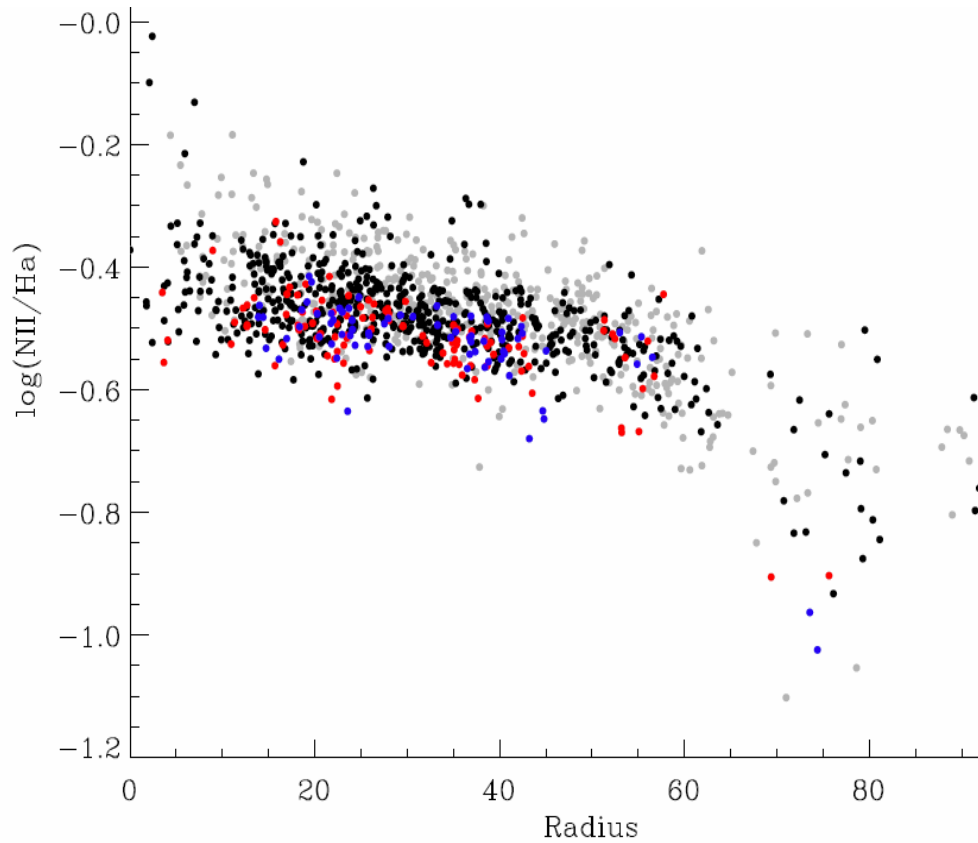


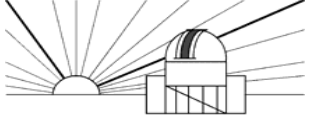
# Abundance indicators vs radius



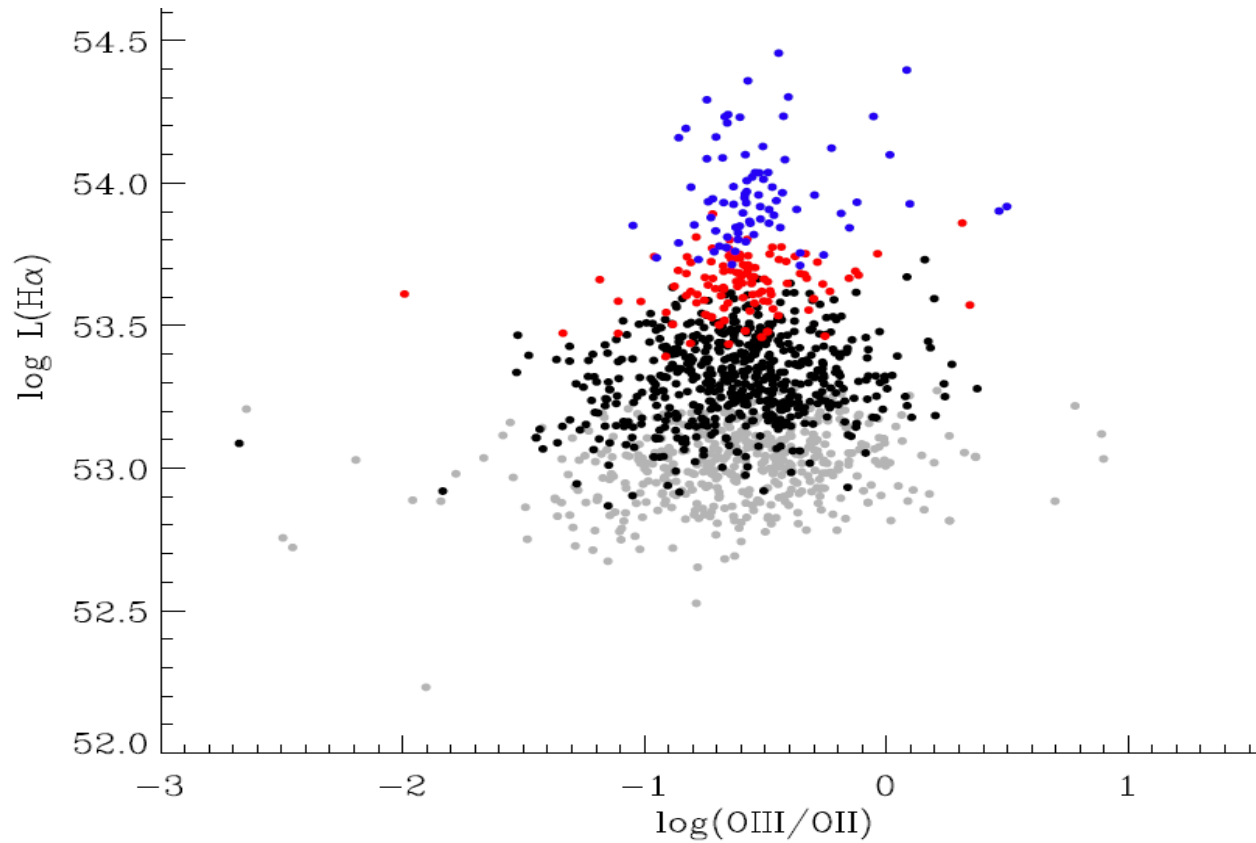


# Abundance indicators vs radius

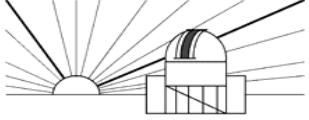




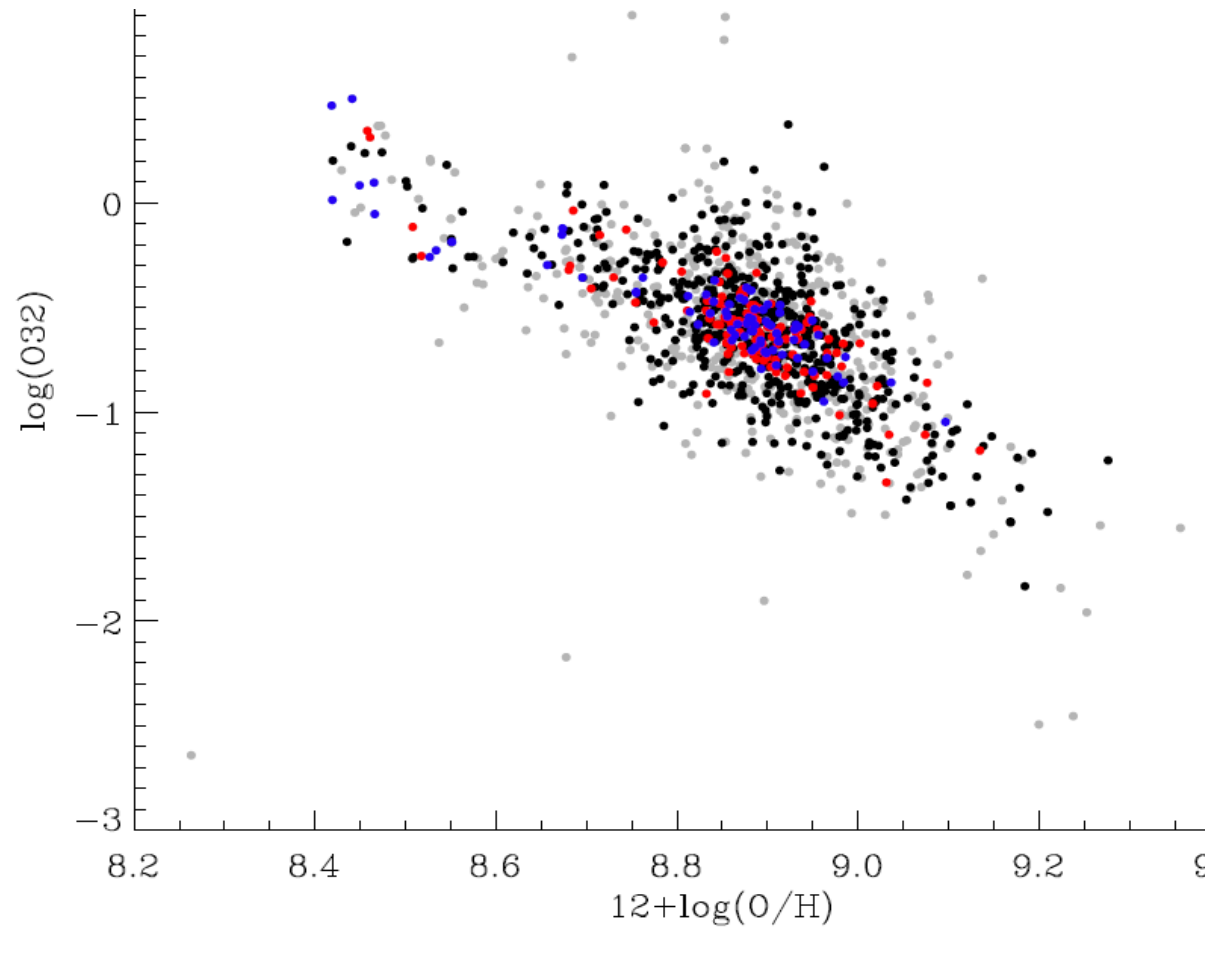
# Luminosity vs excitation

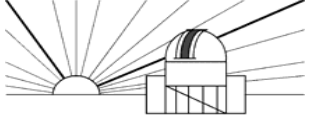




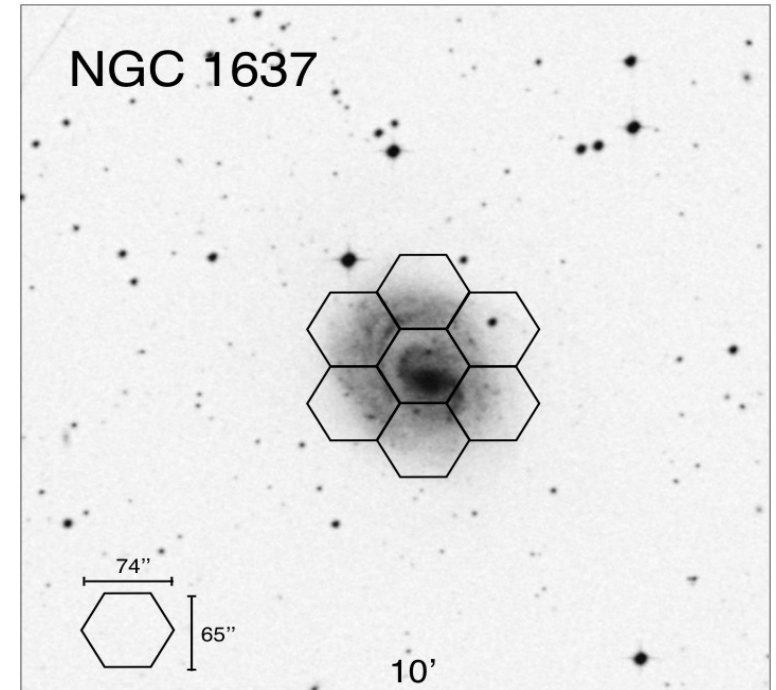


# Excitation vs abundance





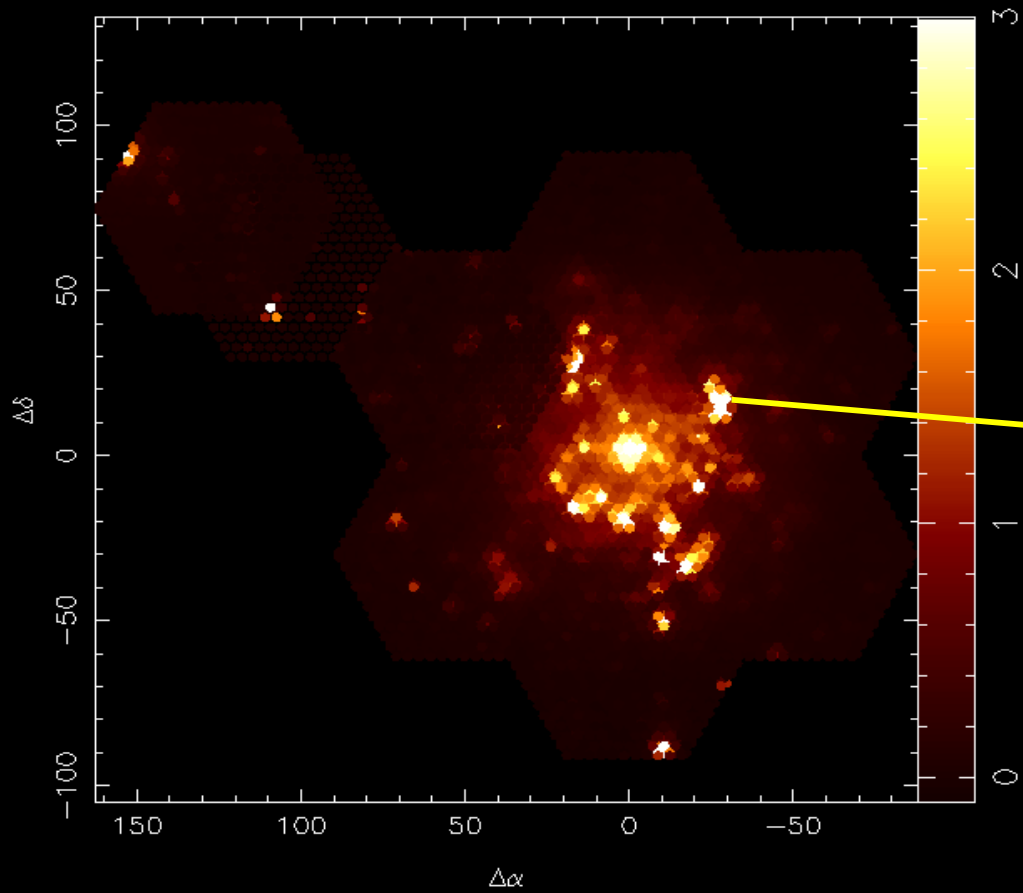
# NGC 1637



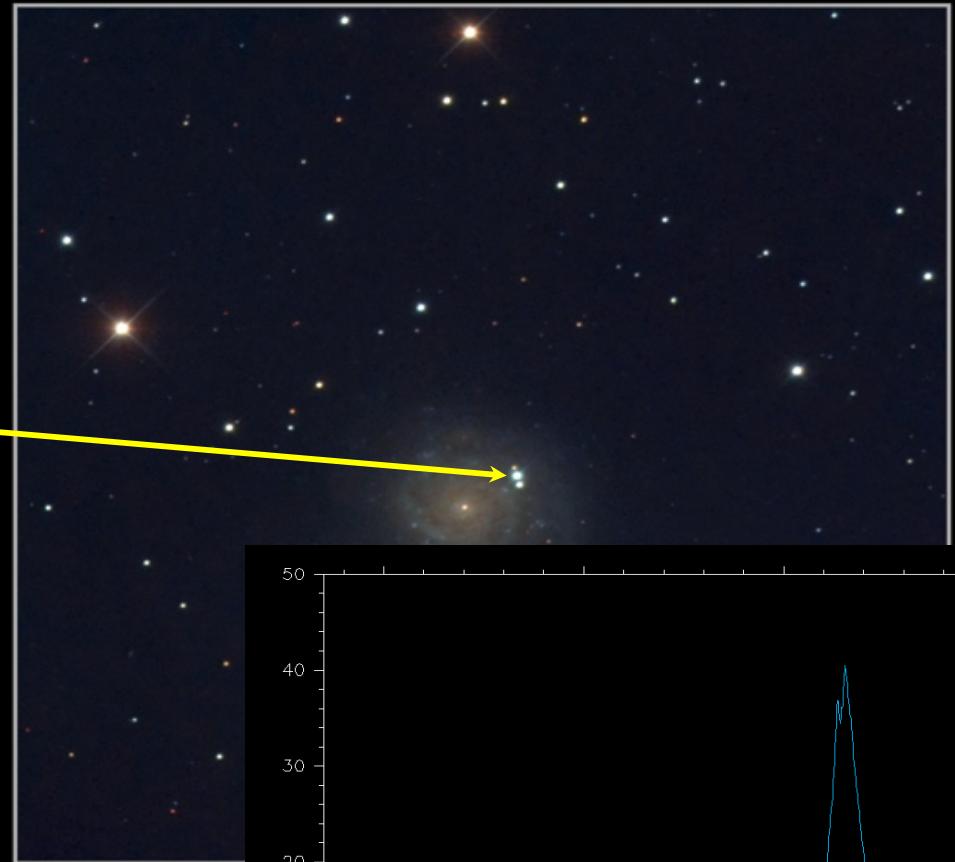
**complete**  
all positions in  
dithering mode  
6,951 spectra

# NGC 1058

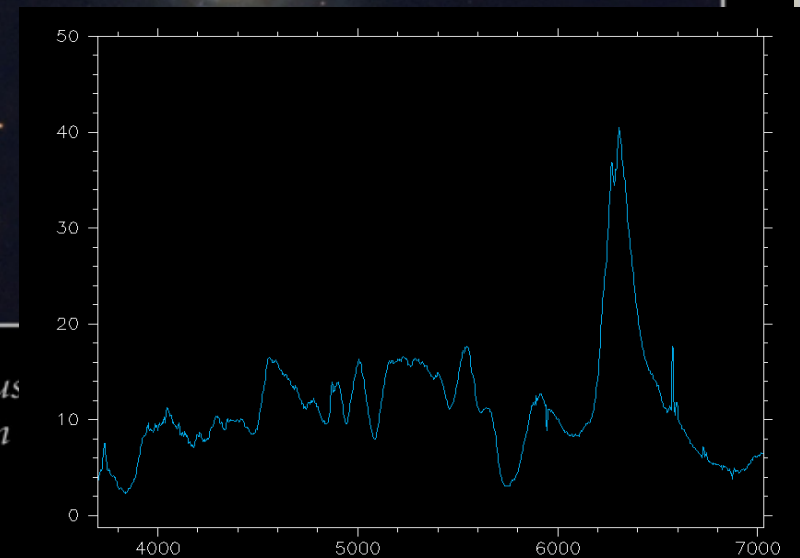
*NGC 1058*



*NGC 1058 with SN 2007gr*

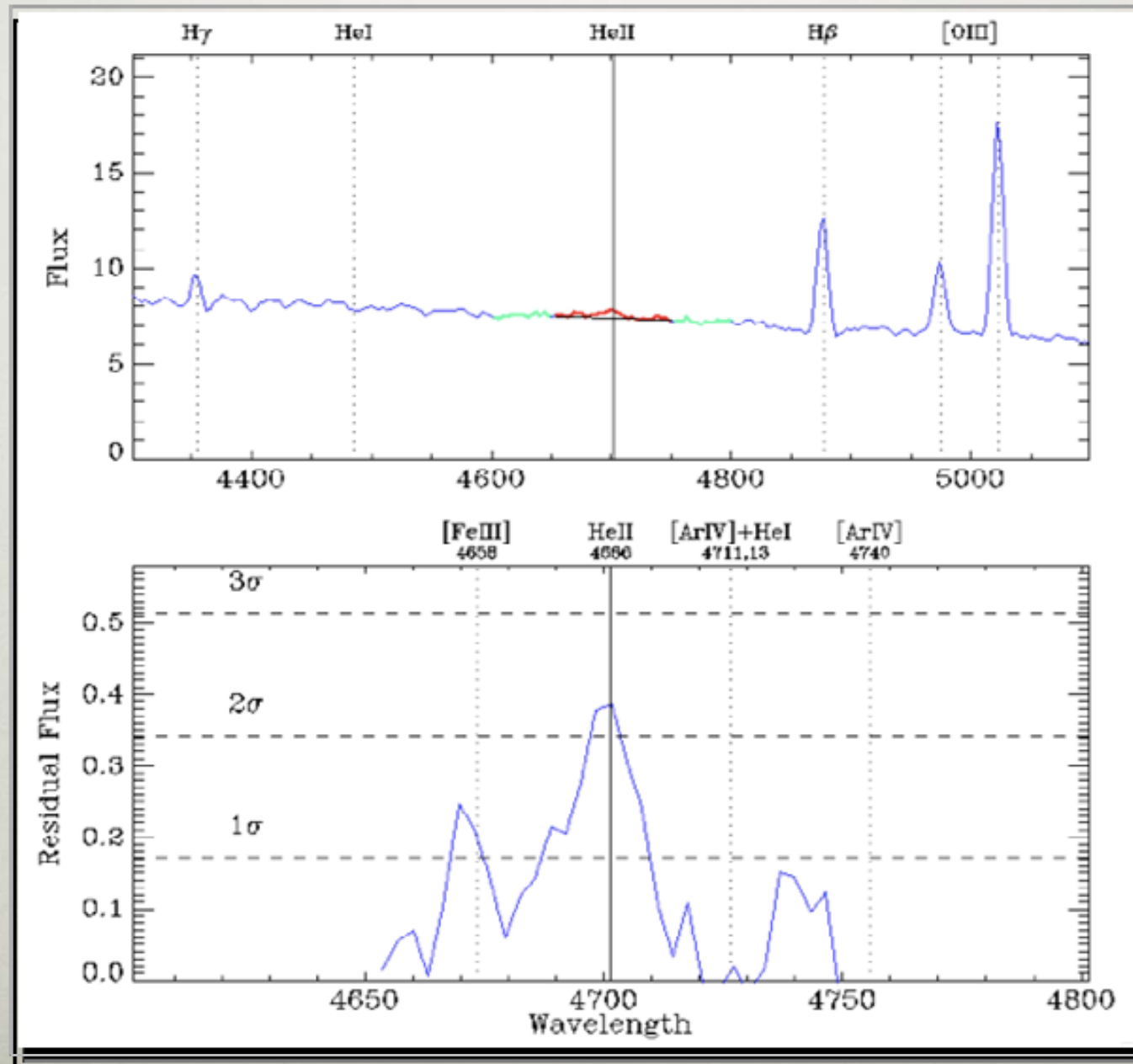


*on 2007 August  
with the 0.8m*



**1st SN observed by an IFU?**

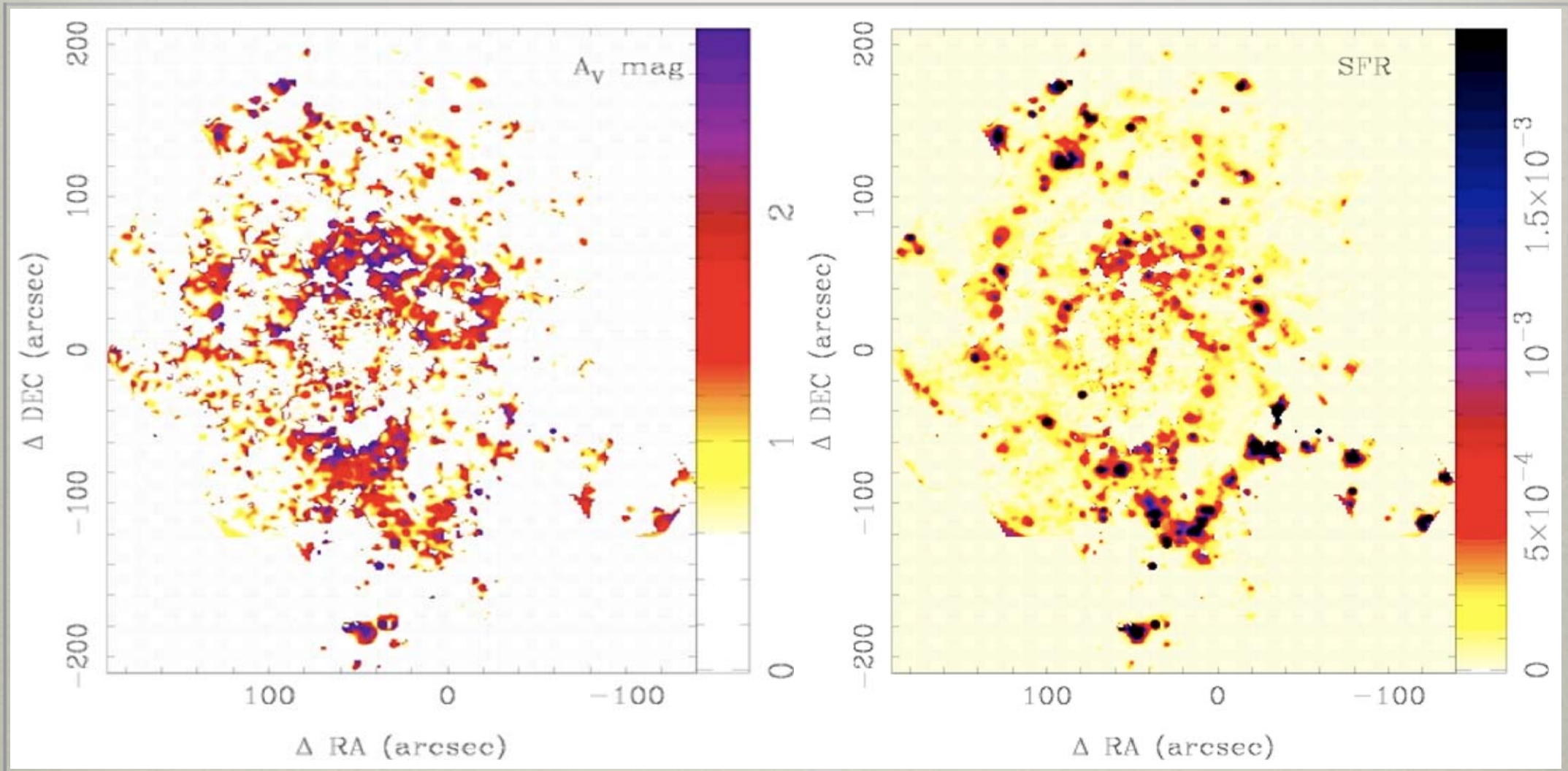
# NGC 3310: WR features





# Preliminary Results

## NGC 628



Extinction map

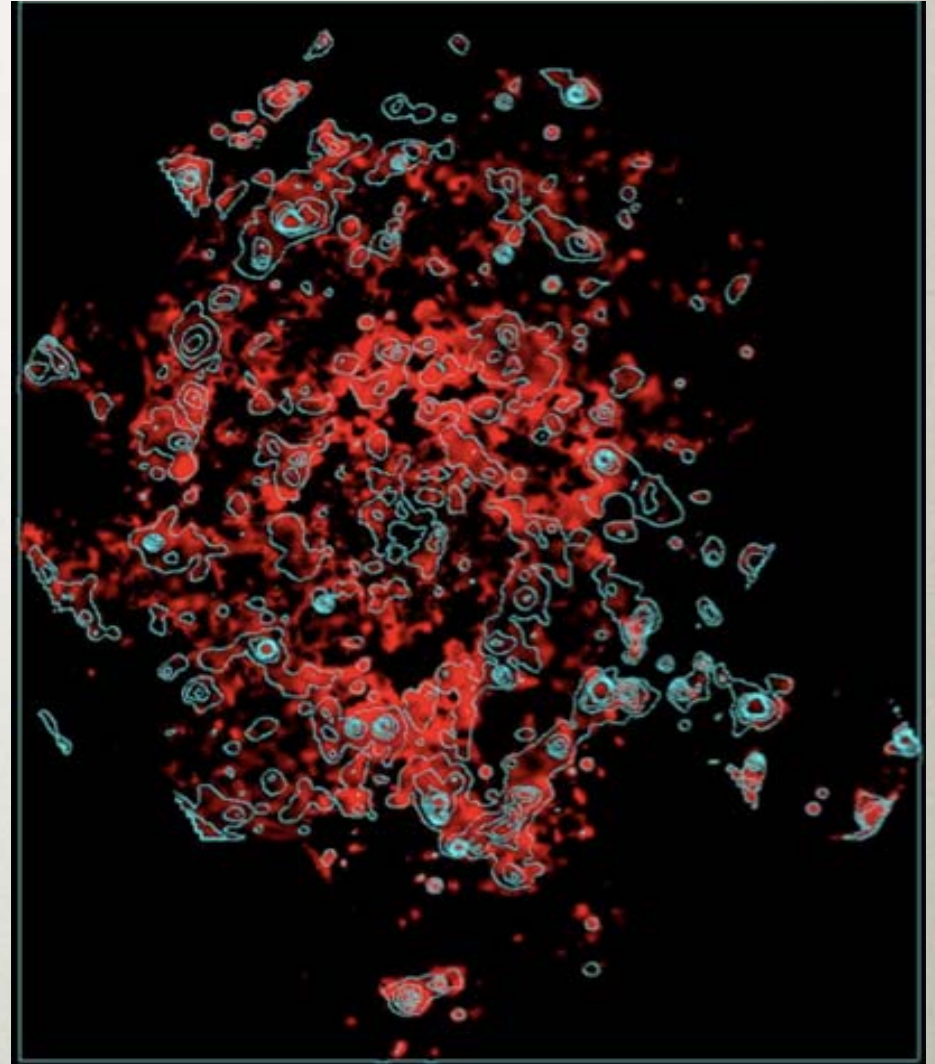
SFR from dust corrected H $\alpha$

# Preliminary Results

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- Gas ionization stages, e.g.  $[\text{NII}]/\text{H}\alpha$
- Measure of diffuse interstellar gas

Gas metallicity to be tested  
(HUGE!)



Residuals vs  $[\text{NII}]/\text{L}(\text{H}\alpha)$



# PINGS project

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- **PINGS: the PPAK IFS Nearby Galaxies Survey**  
Rosales-Ortega et al. (in preparation)
- **The PINGS galaxy NGC 628, the biggest field covered by an IFU**  
Sanchez et al. (in preparation)
  - Tentative last run: April 2009
  - First data release: Summer 2009

**More info:** <http://www.ast.cam.ac.uk/~frosales/pings>

Google: PINGS PPAK

**Gracias!**