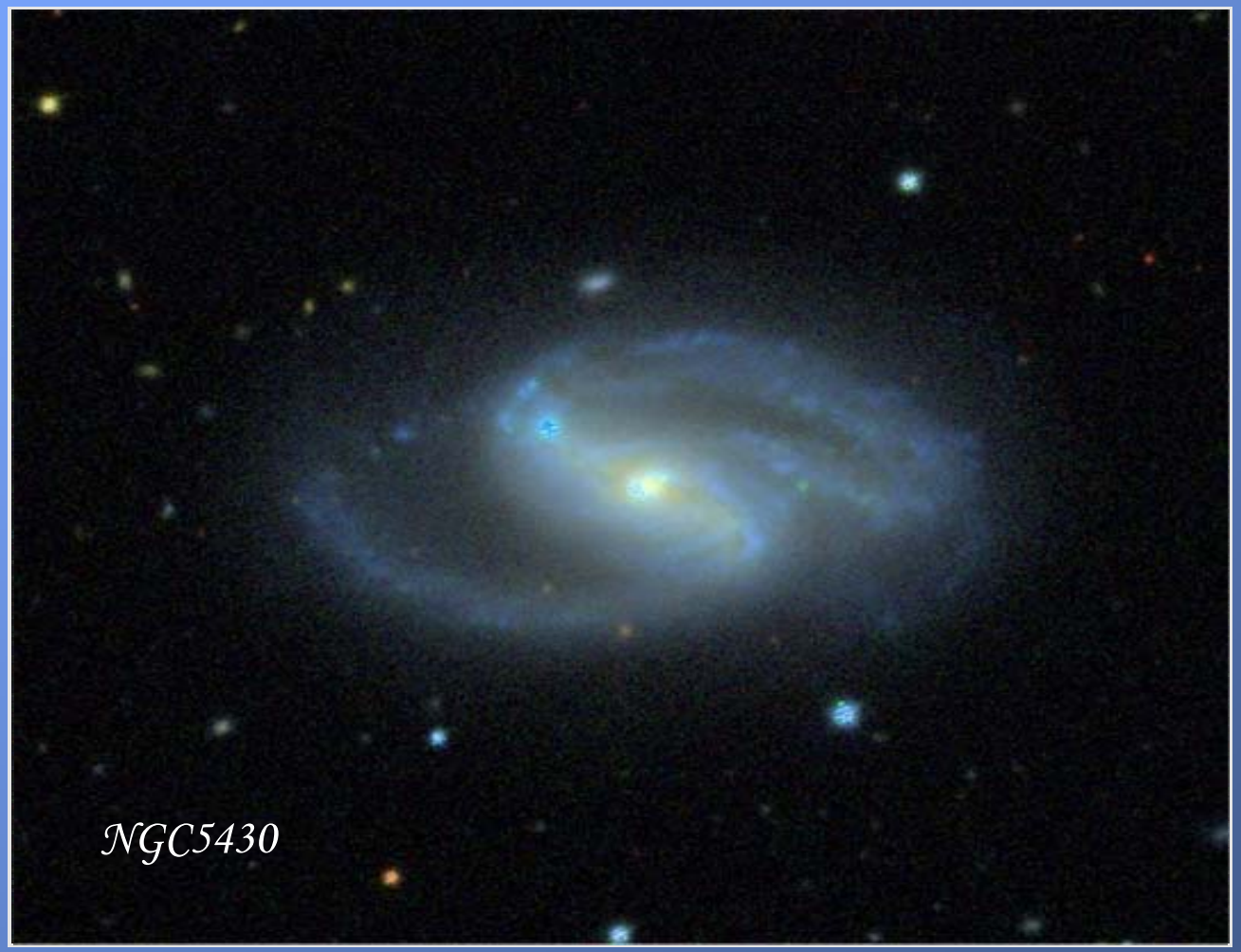
SpIOMM , OASIS
&
Star-forming Galaxies



Carmelle Robert

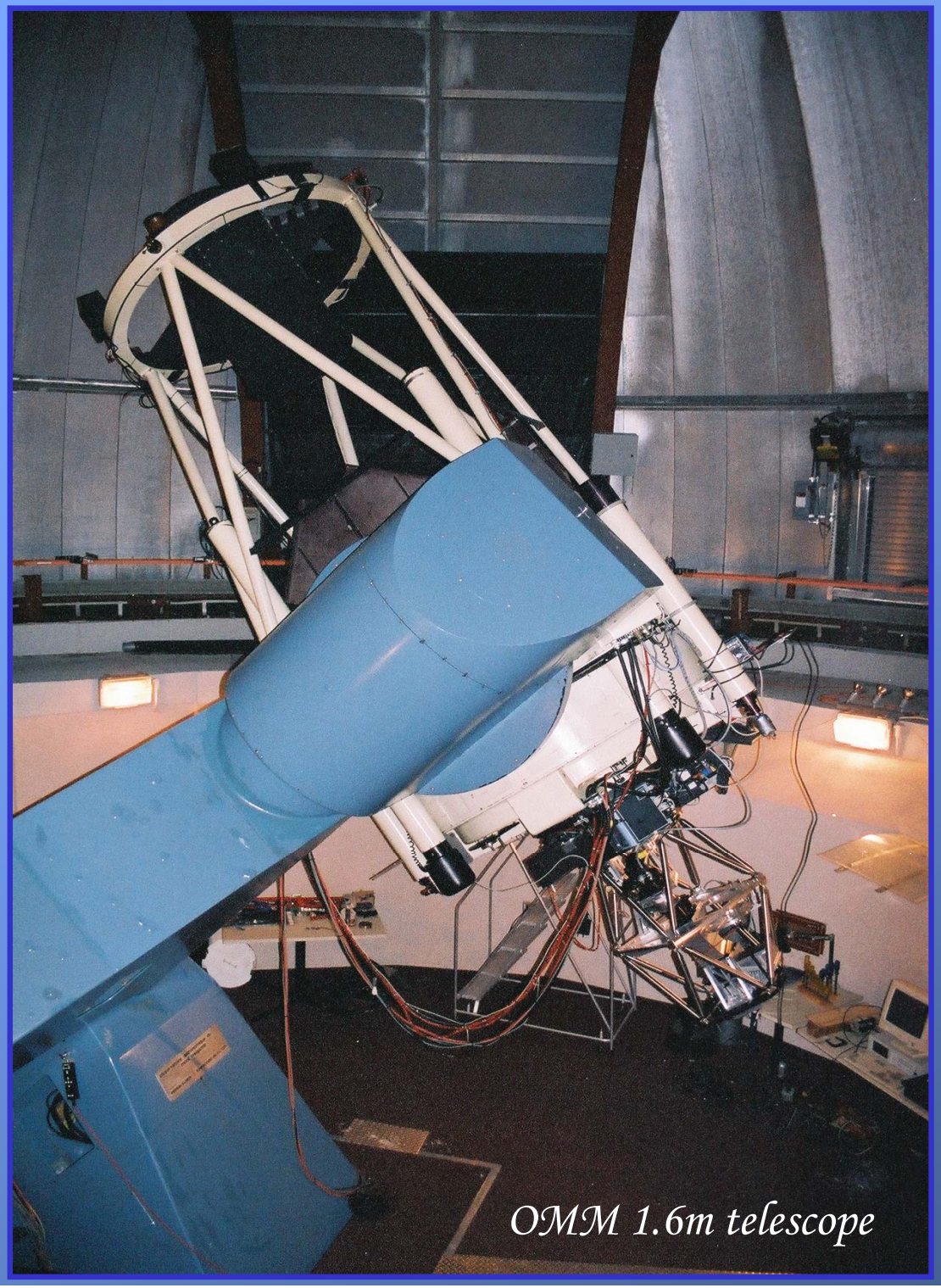
UNIVERSITÉ LAVAL

Canada

CRAQ

Centre de recherche en astrophysique du Québec

Granada-IAA 06/09



Spectromètre Imageur de l'Observatoire du Mont Mégantic

Imaging Fourier Transform Spectrometer

Laurent Drissen

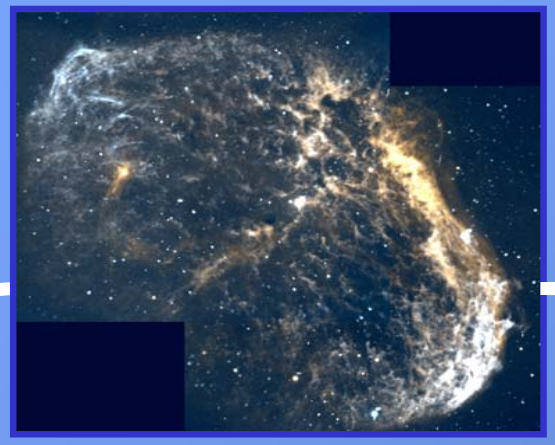
Frédéric Grandmont

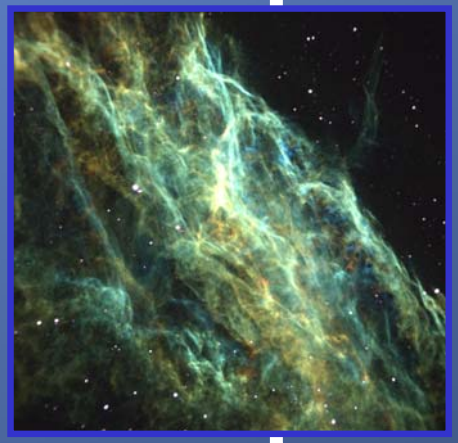
Anne-Pier Bernier

Maxime Charlebois

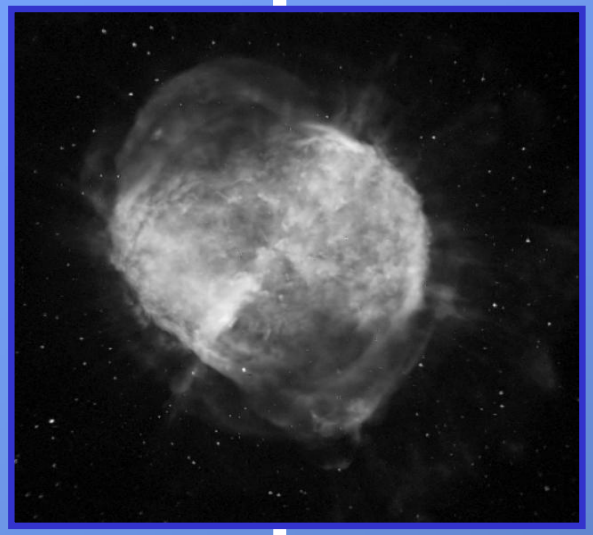
ABB

UNIVERSITÉ LAVAL





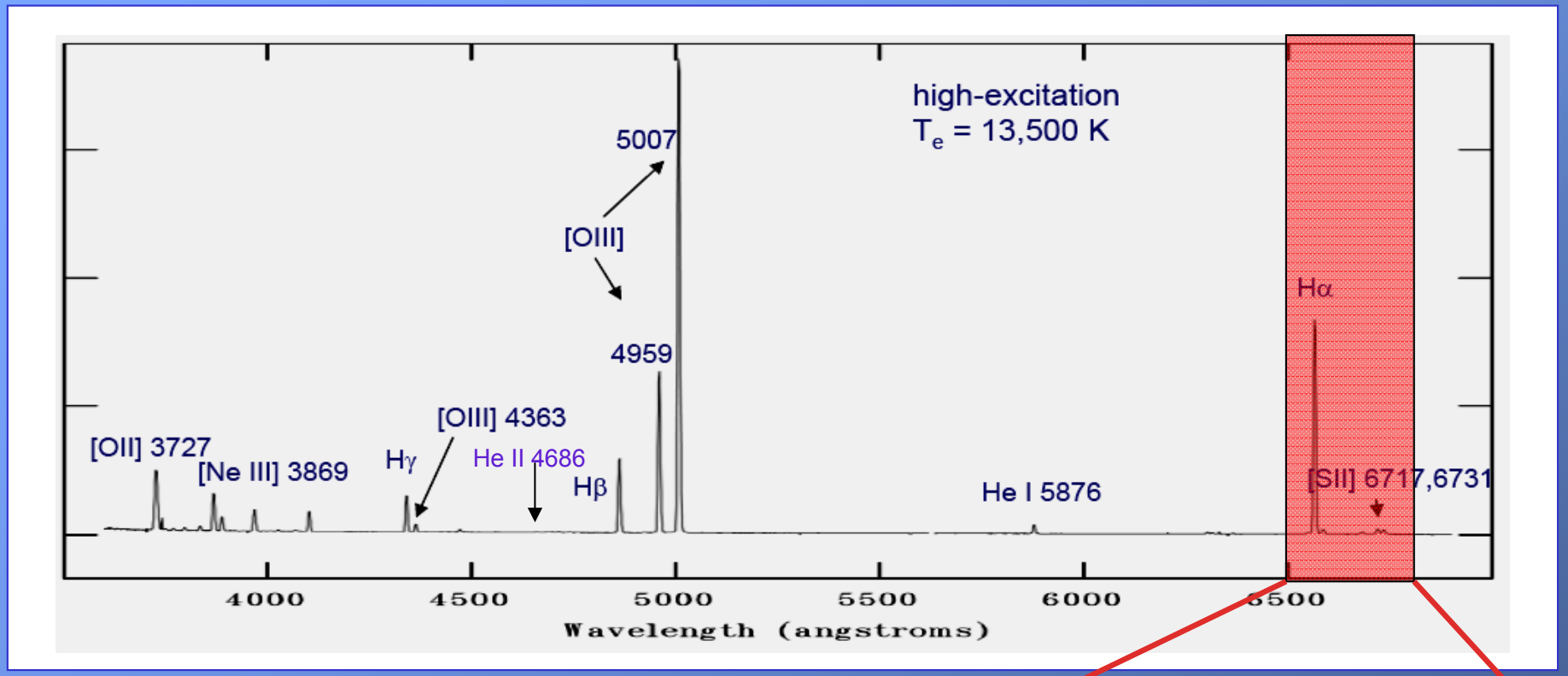




Integral field spectrograph

Wide field of view

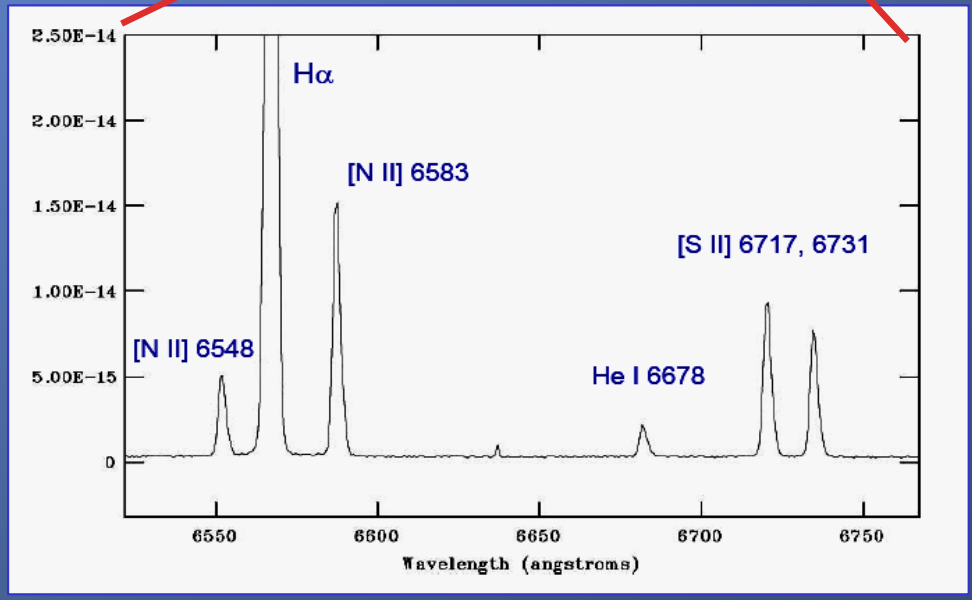
Good spectral resolution



We want to separate the

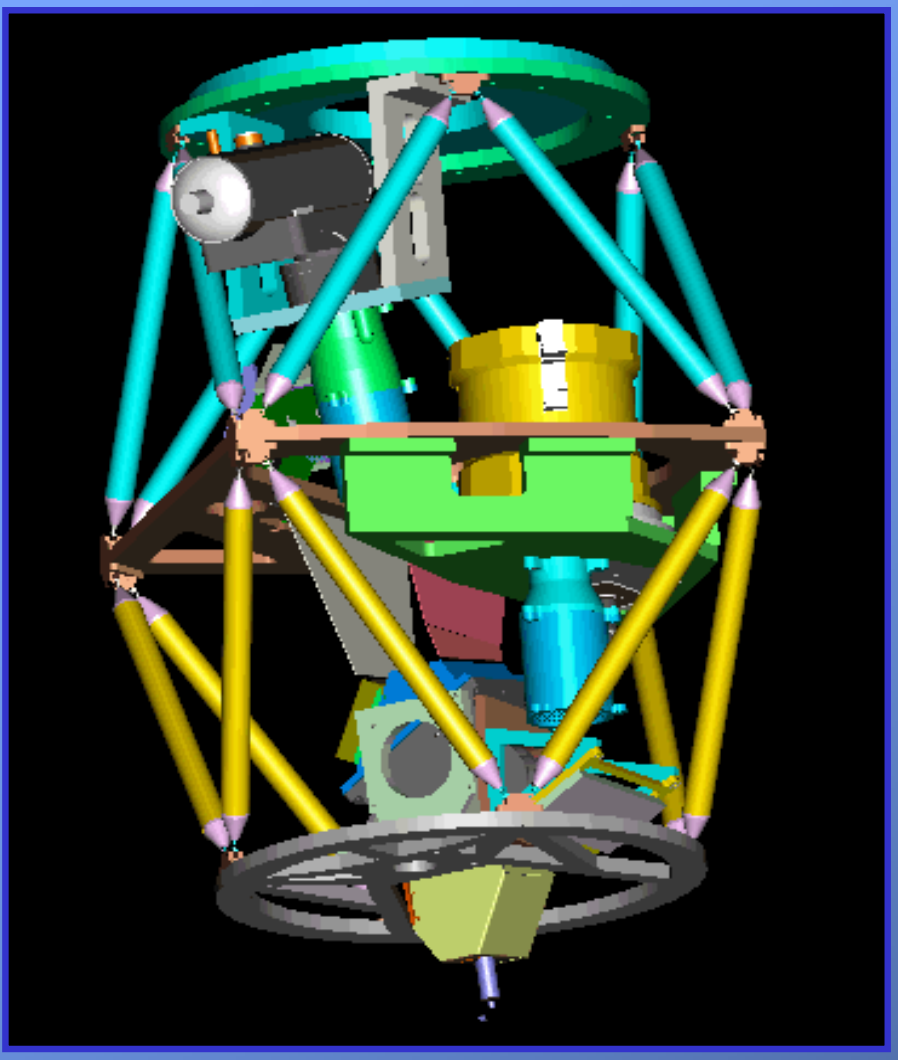
[SII] doublet at 6717 & 6731 Å

➔ R ~ 1200



SpIOMM : Michelson interferometer

= extract the information from the light beam by making it interfere with itself



1.33 m long
110 kg

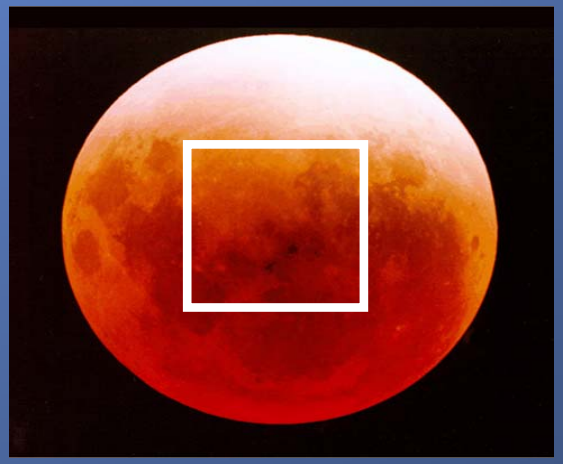
Field of view: 12’

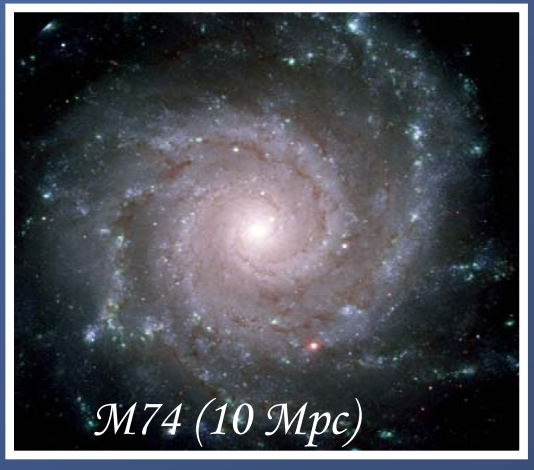
Detector: 1340 x 1300 EEV CCD

Spatial resolution: 0.55’’/pixel (seeing limited)

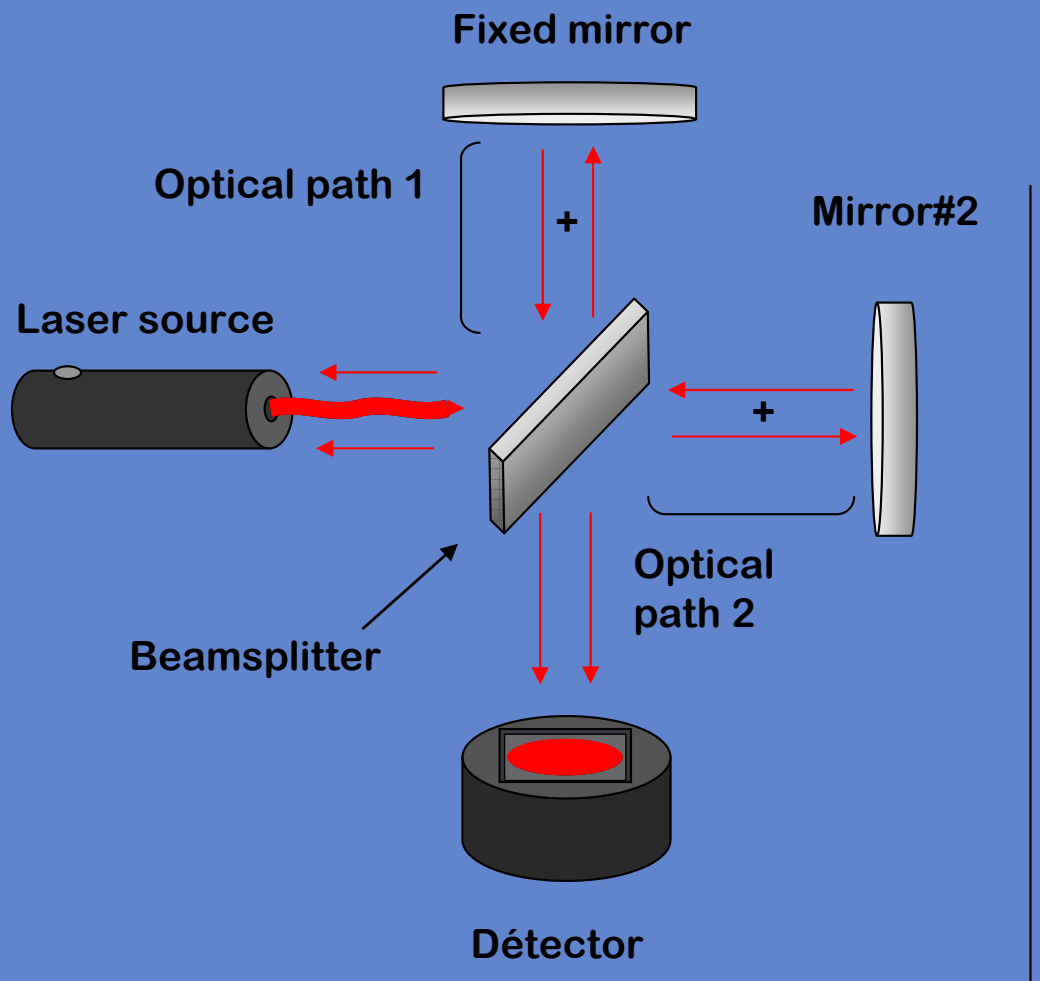
Wavelength range: 350 - 900 nm

Spectral resolution: $\lambda / \Delta \lambda$ = up to 25 000



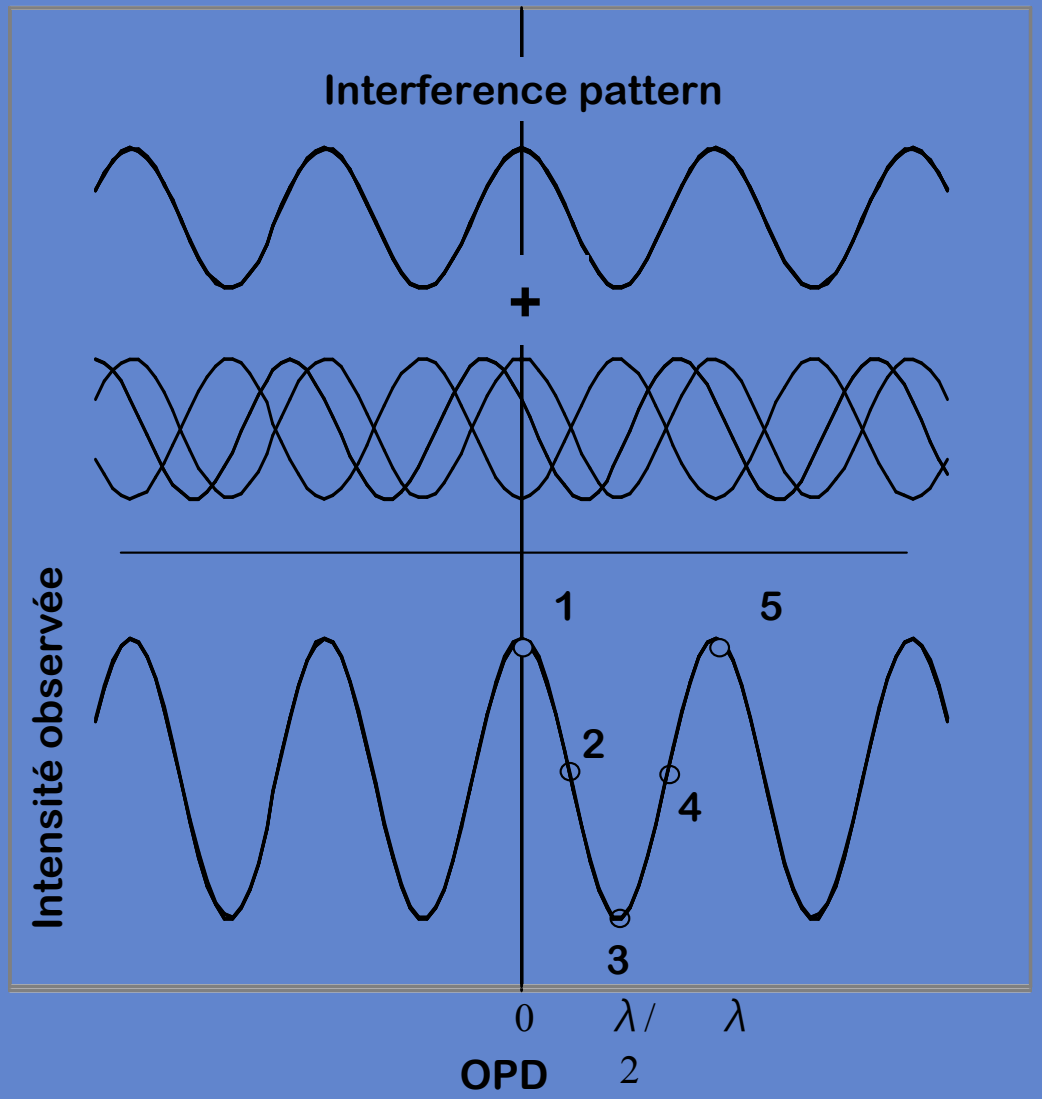


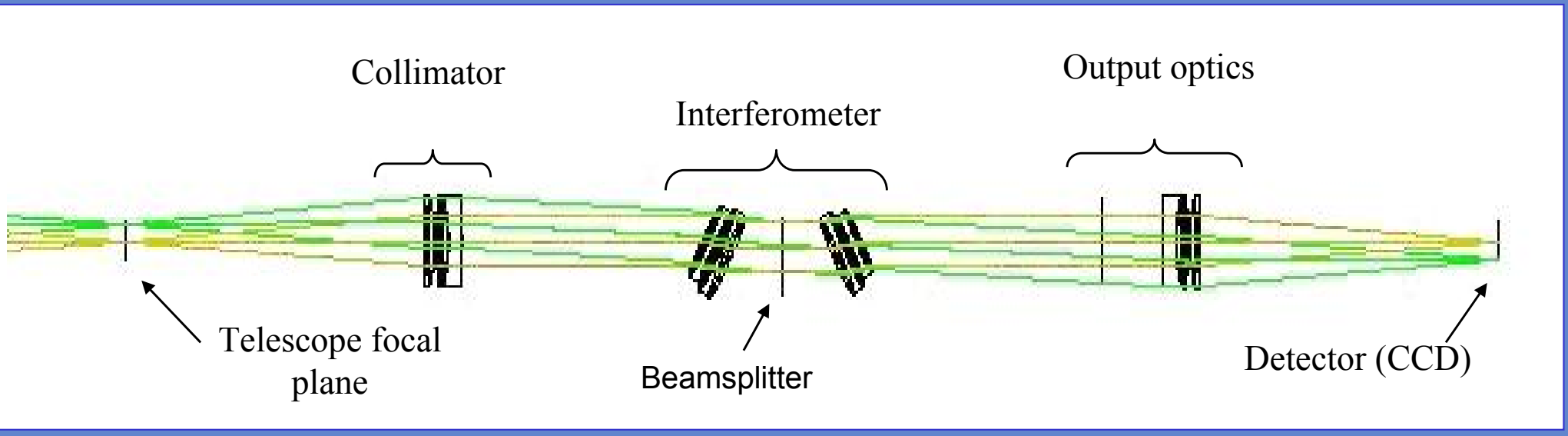
Michelson interferometer

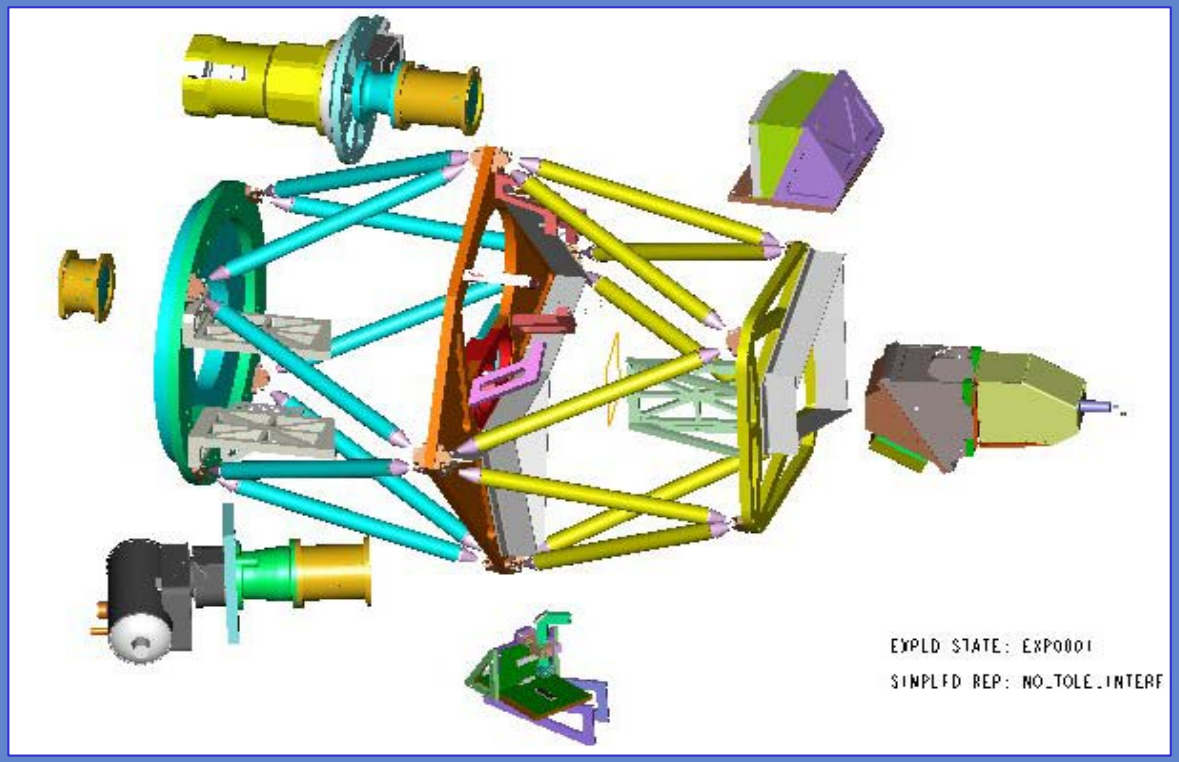


OPD = (λ

Optical path 2 – Optical path 1

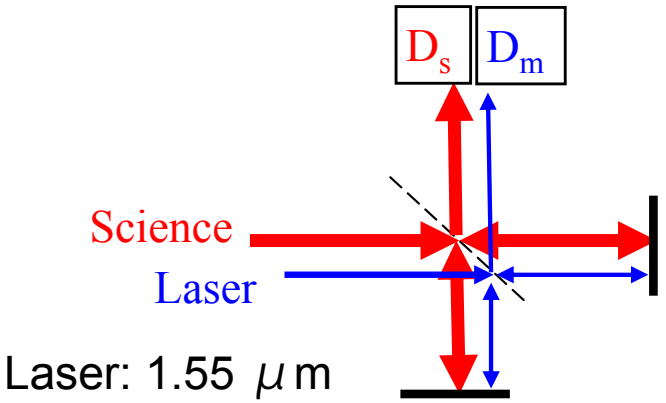



Collimator
Interferometer
Output optics
Telescope focal plane
Beamsplitter
Detector (CCD)

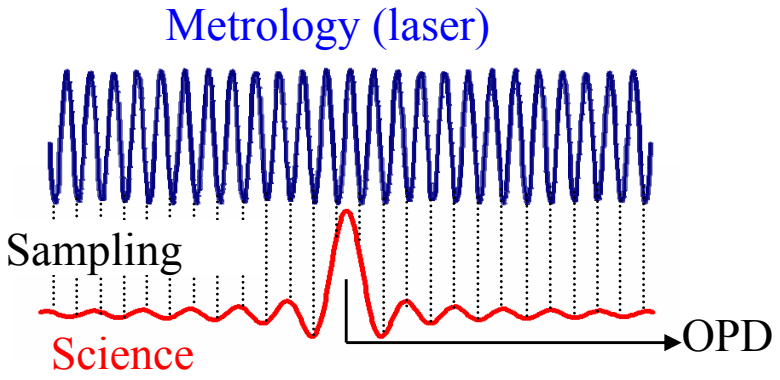

EXPLD STATE: EXP0001
SIMPLFD REP: NO_TOLE_INTERF

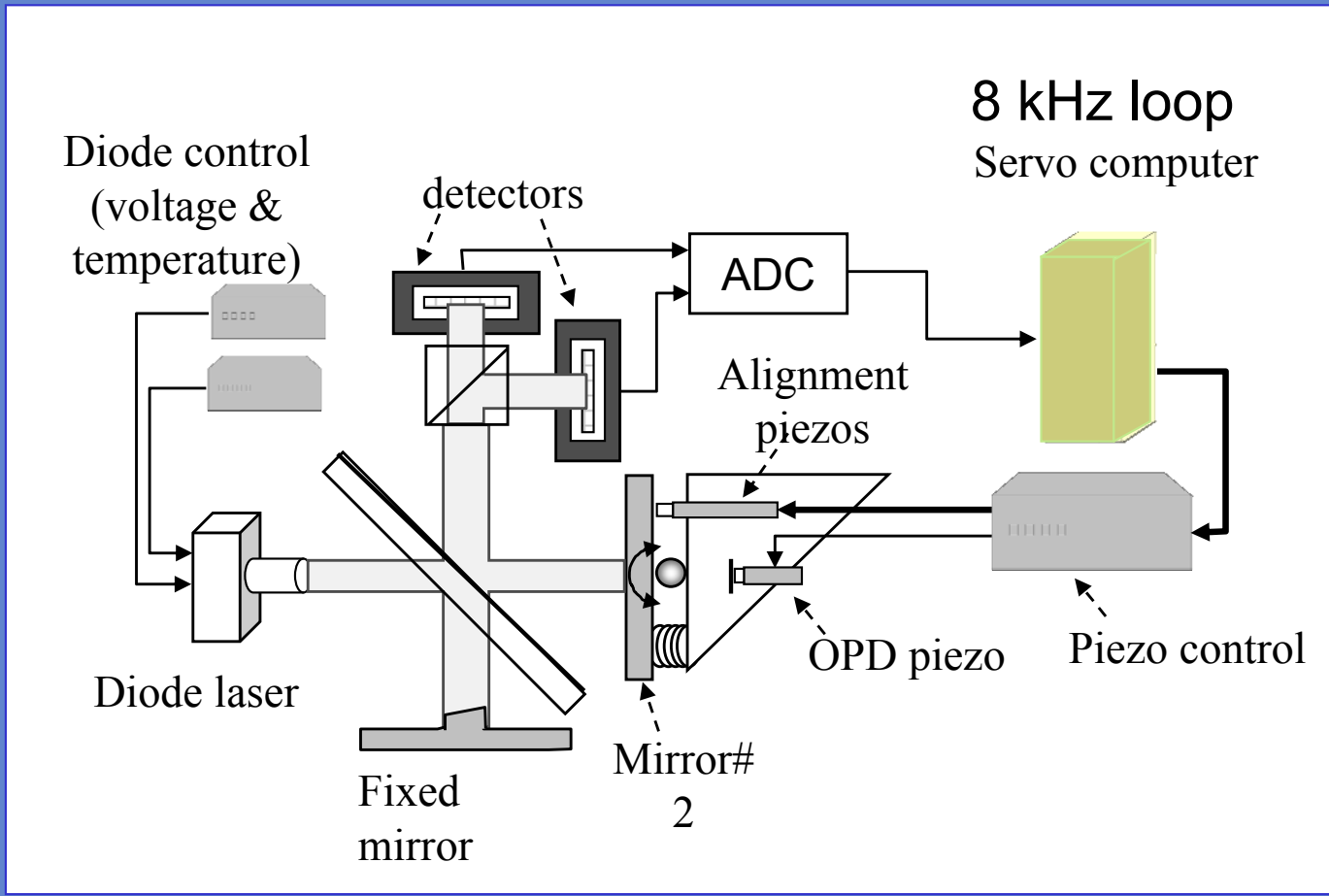
Efficiency : 65%

- mirror alignment (few nm)
- metrology (modulation efficiency ≈ 80% i.e. like grating's efficiency)
- optical parts (beamsplitter + 1 mirror + camera)

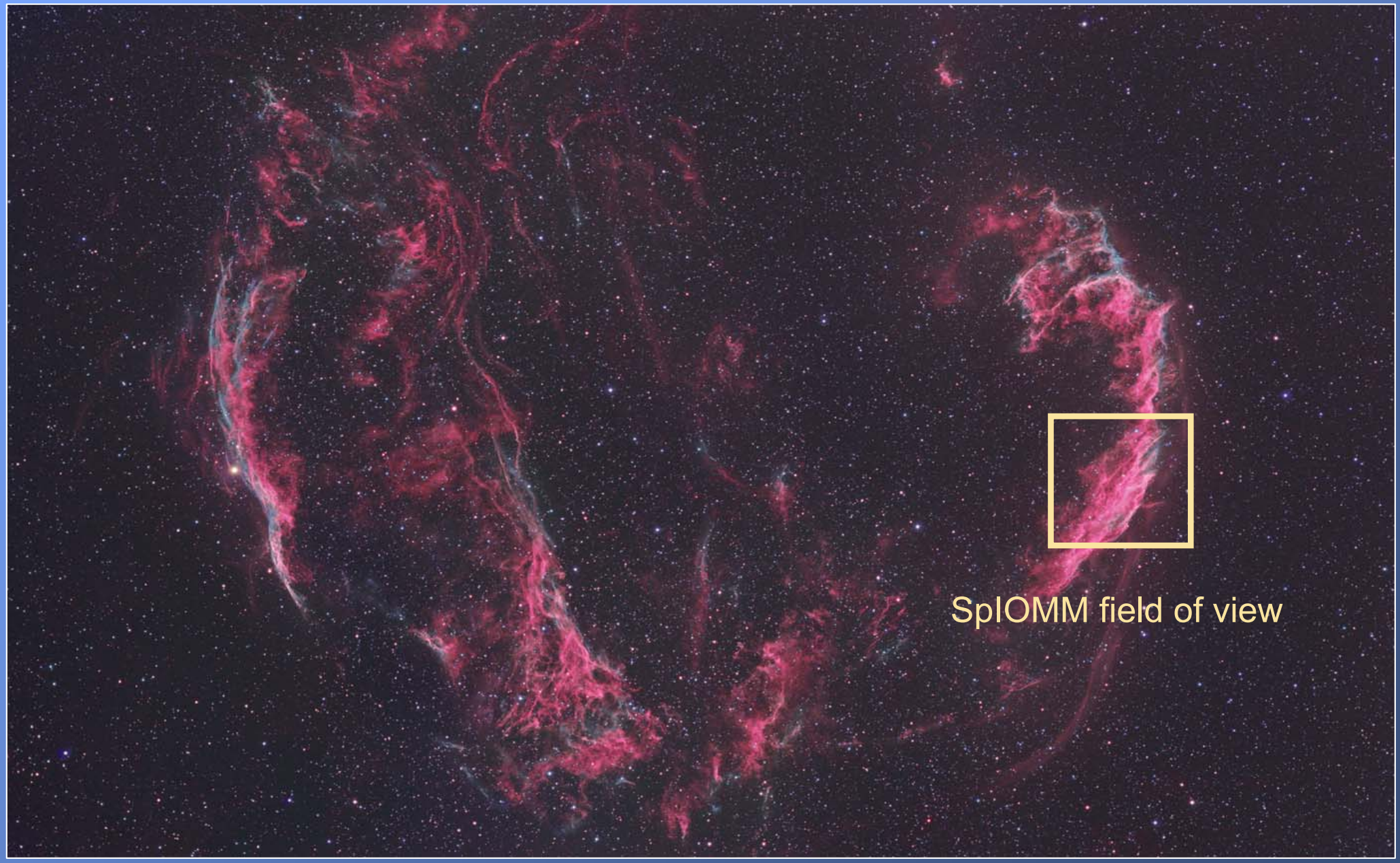


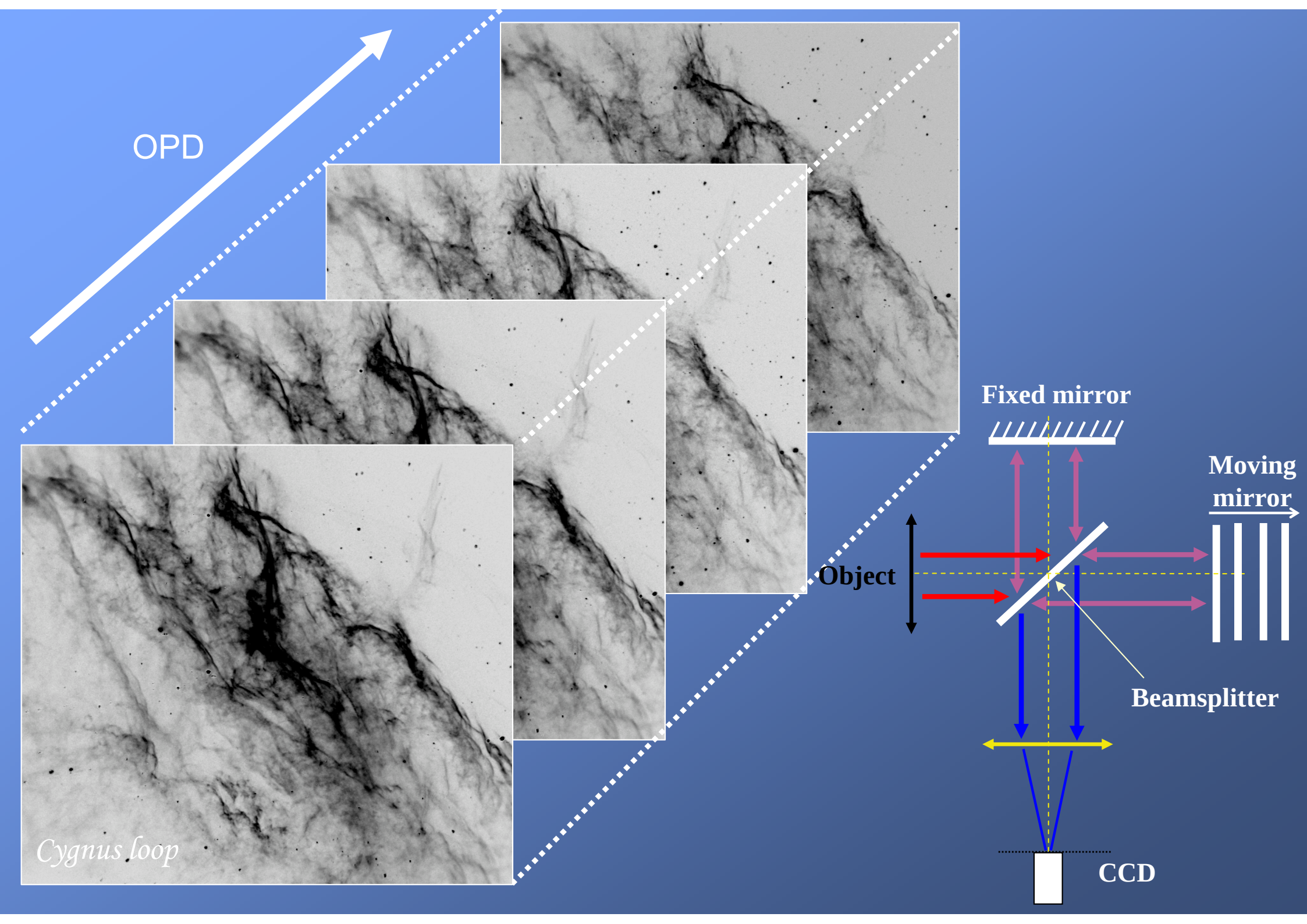
Interferogram





Cygnus loop - Old supernova remnant



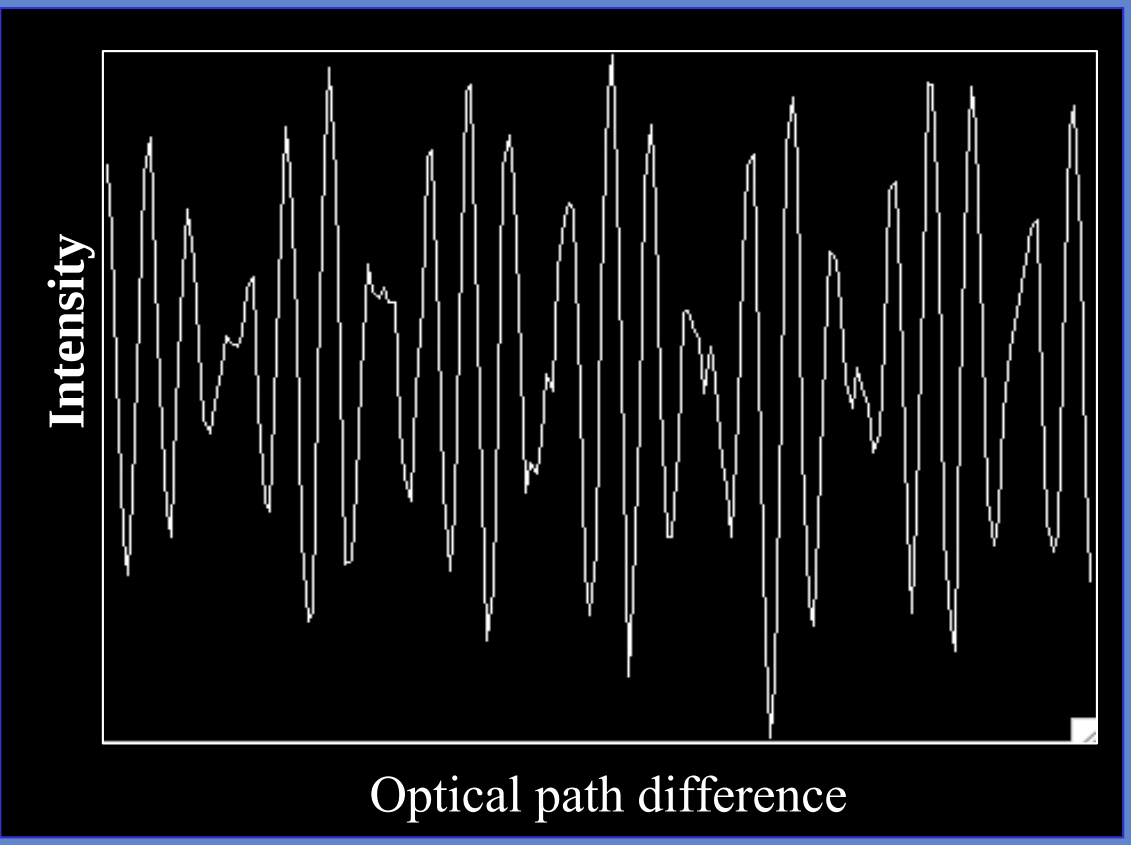

OPD
Fixed mirror
Moving mirror
Object
Beamsplitter
CCD
Cygnus loop

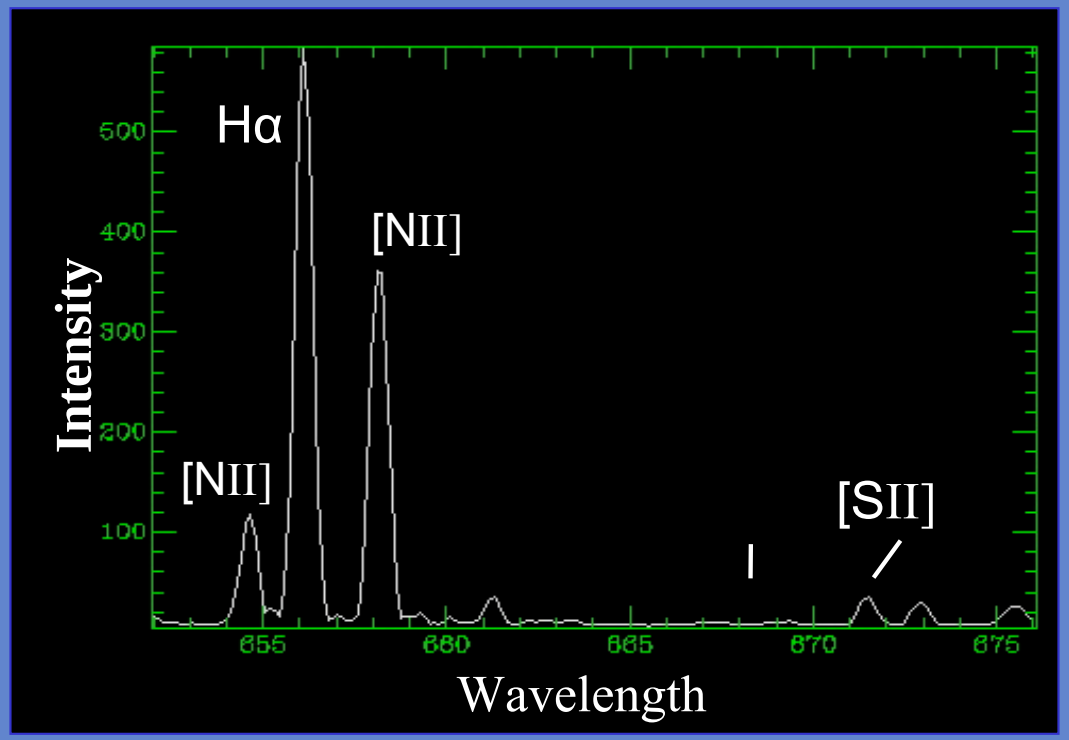
Data reduction (pixel by pixel)

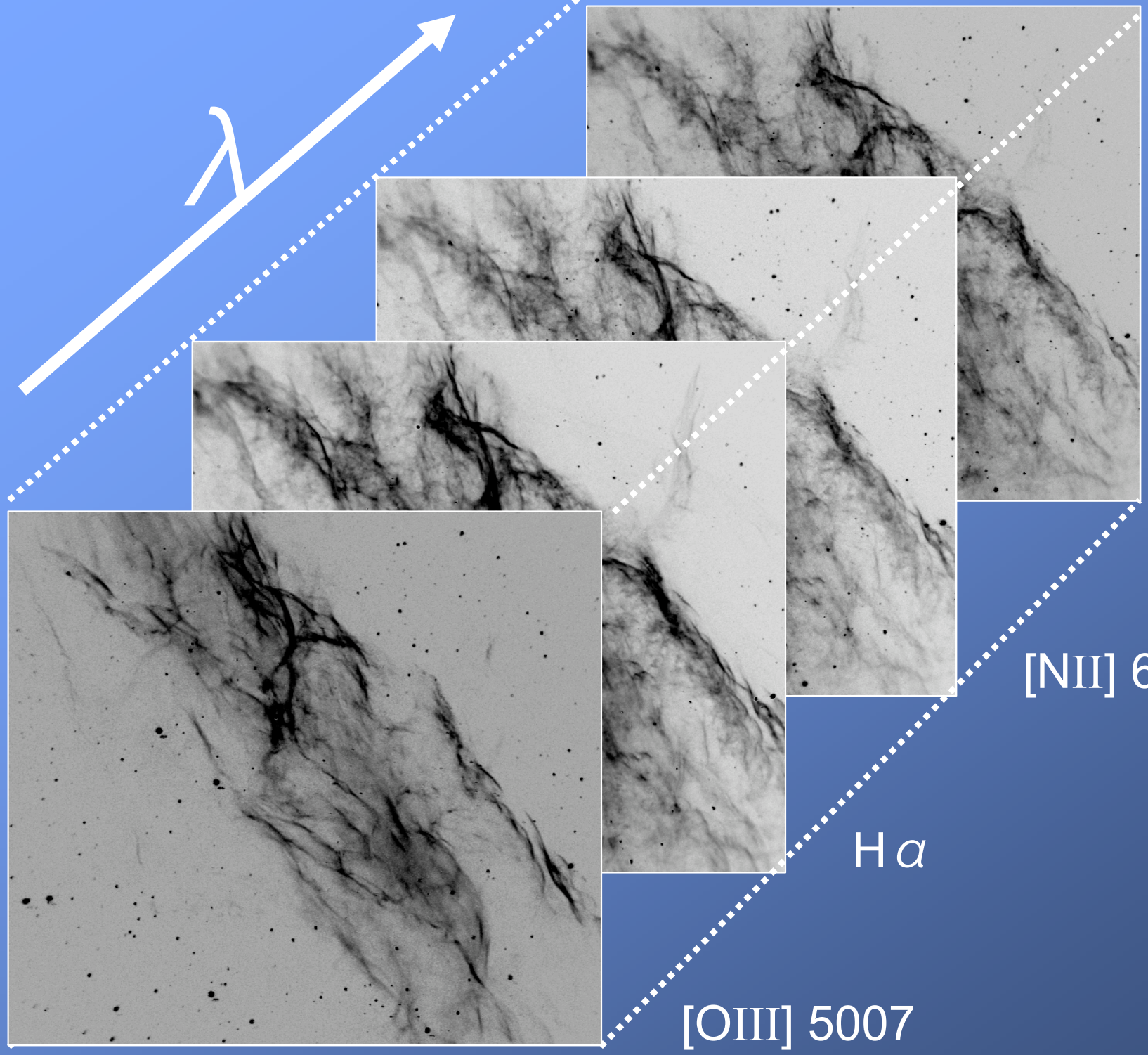
Bias, flat, image alignment,
sky background subtraction.
cosmis rays…

Fourier transform

$$F(k) = \int_{-\infty}^{\infty} f(x) e^{-ikx} dx$$






λ
[SII] 6717
[NII] 6583
H α
[OIII] 5007

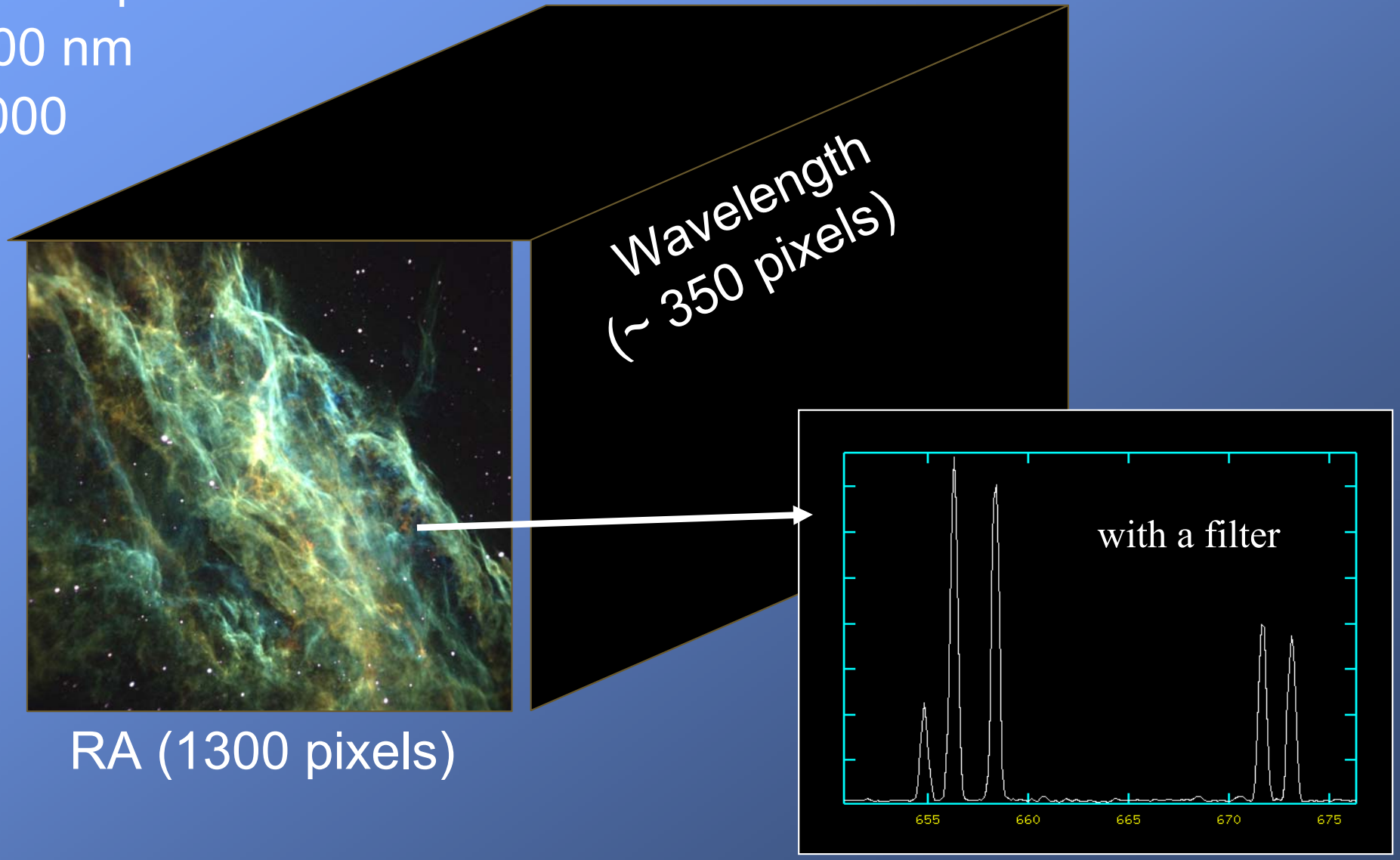
A standard data cube :

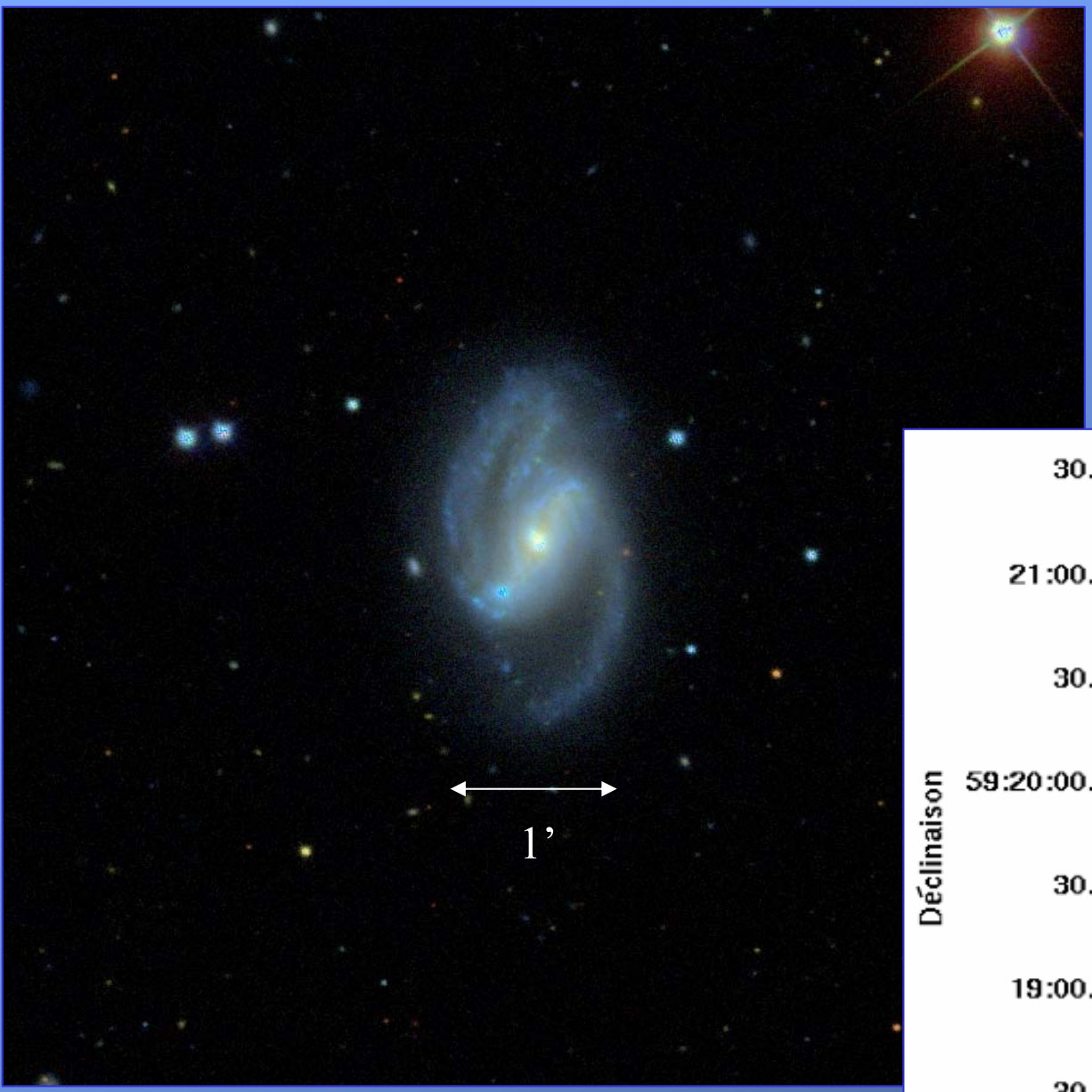
12’ x 12’

1.6 million spectra

350-900 nm

R ~ 2000



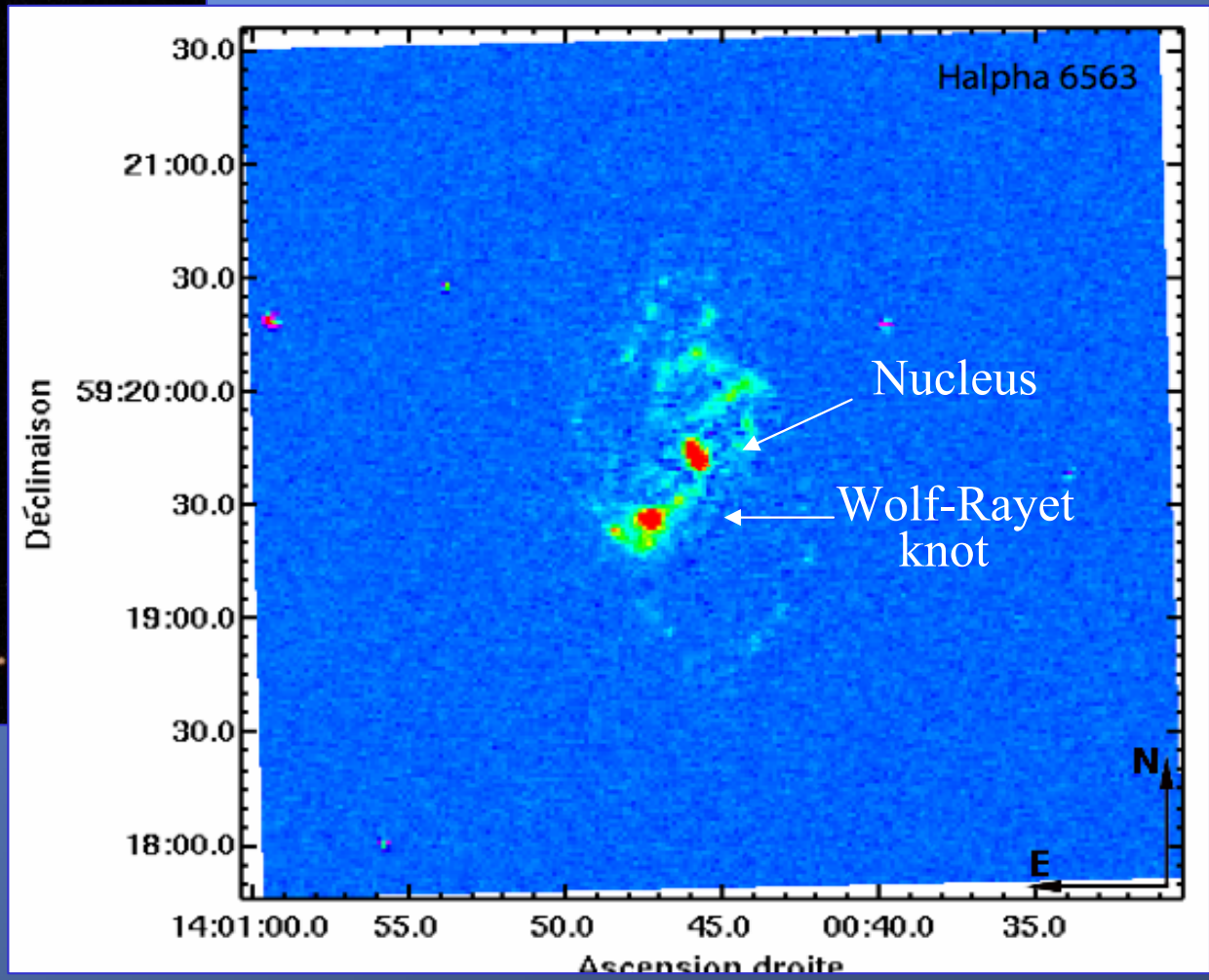


One test object for SpIOMM:

NGC 5430 at 42 Mpc

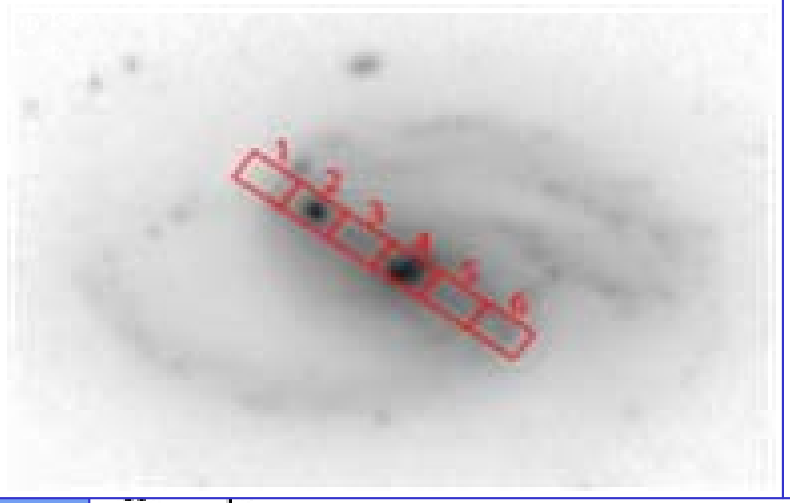
SB(s)b - Starburst 13 mag

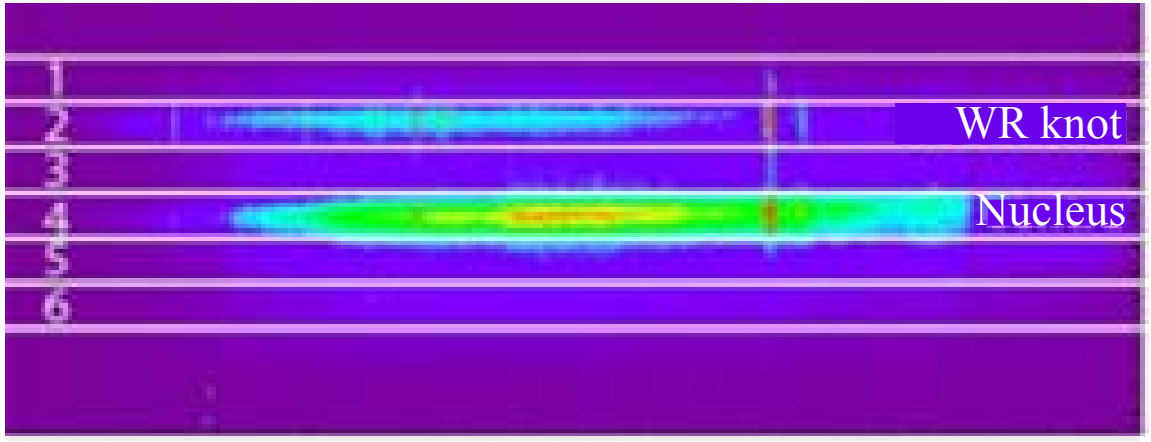
2 datacubes - 2h each

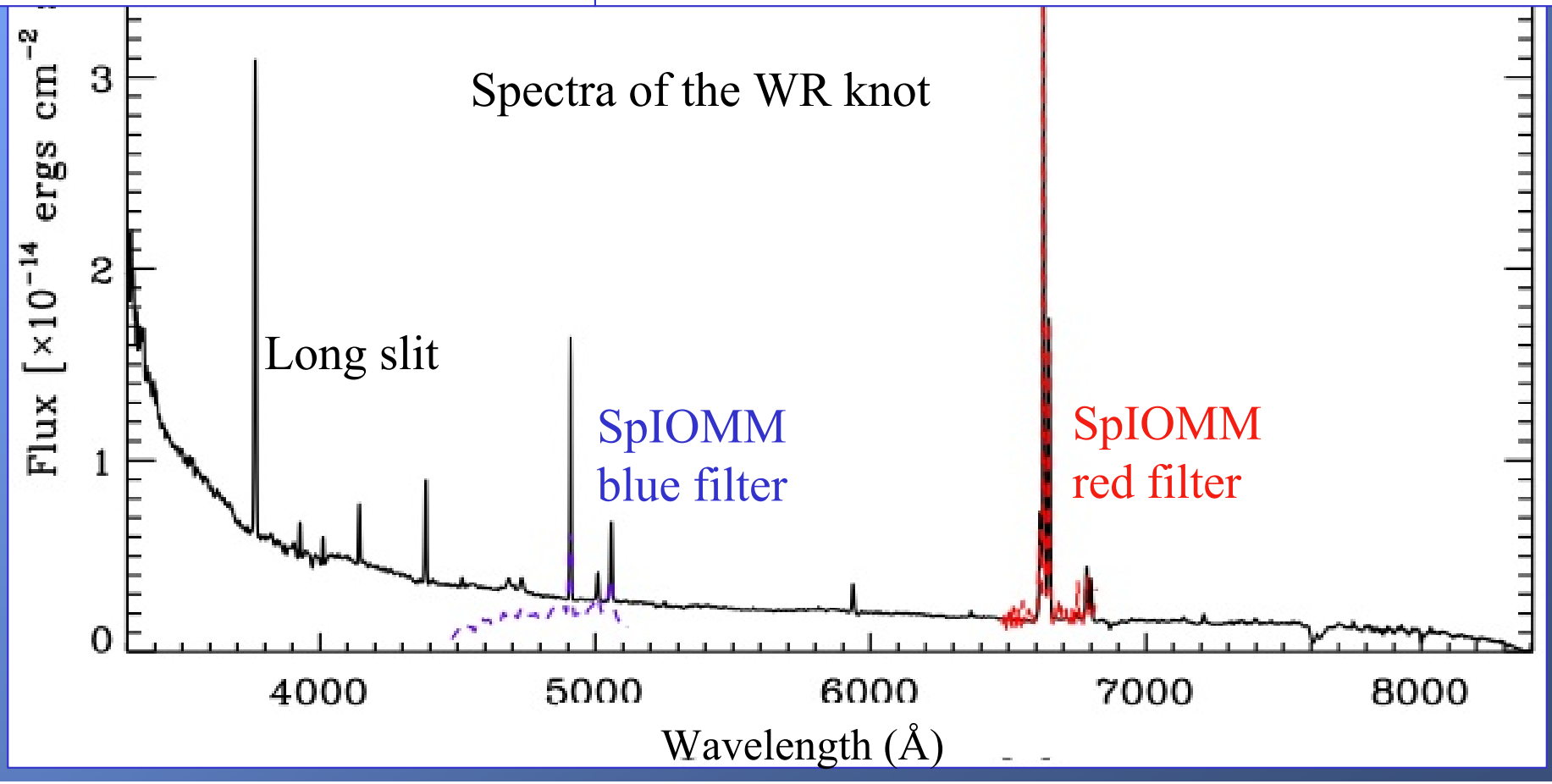


Élaine Brière
M.Sc. Thesis (U. Laval)

Long slit spectroscopy along the galaxy bar for comparison :

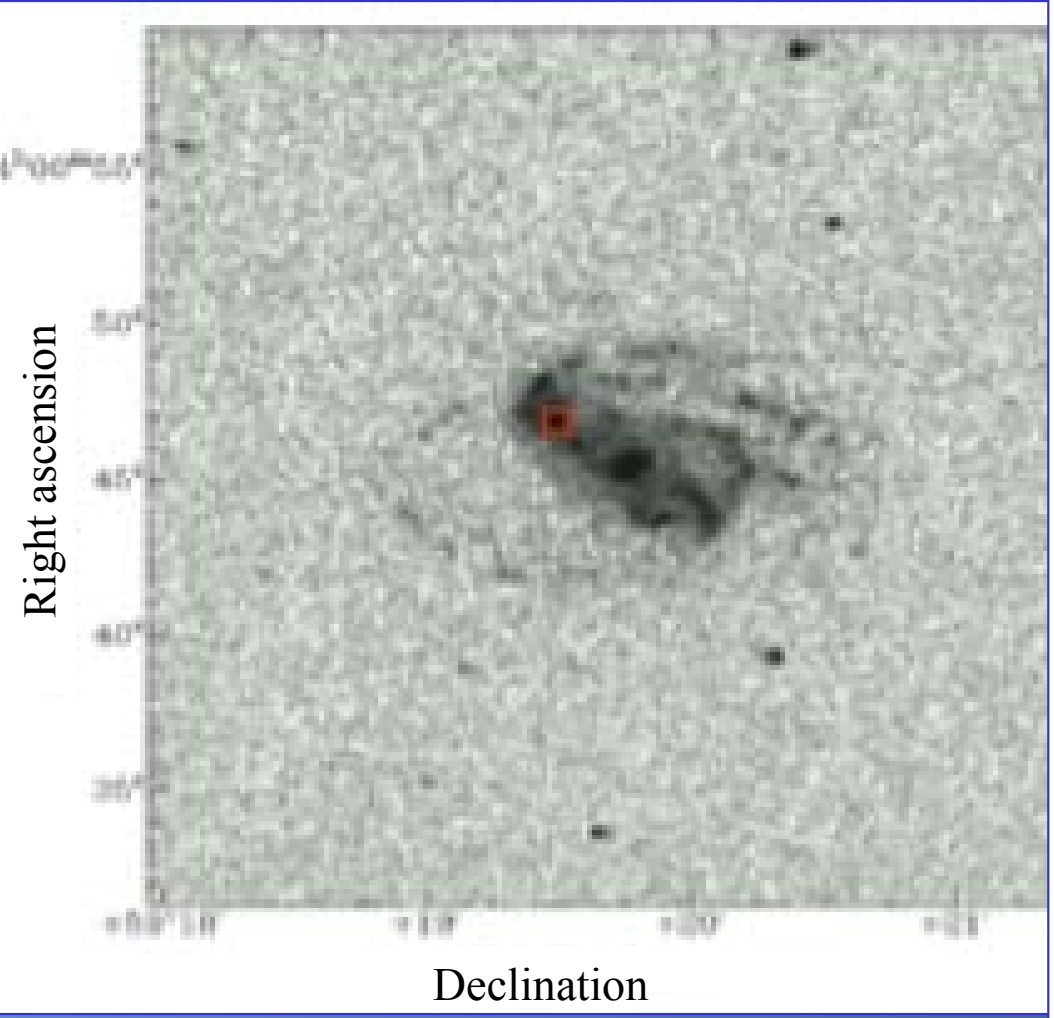


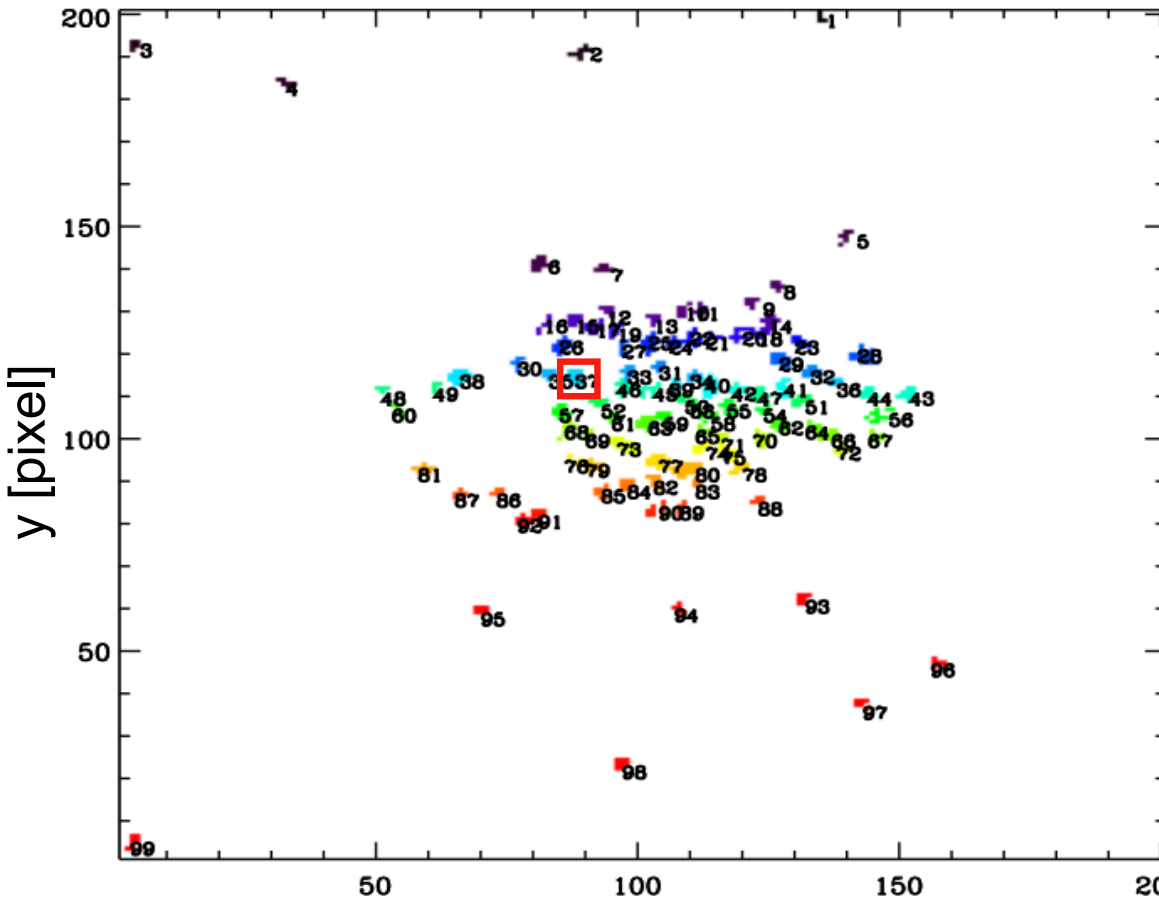




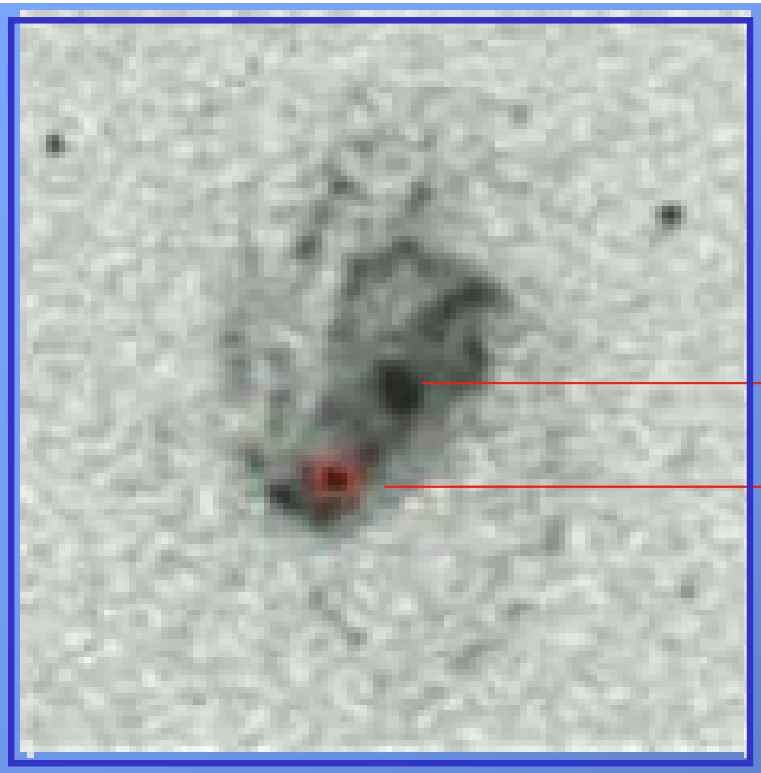
HII Region identification

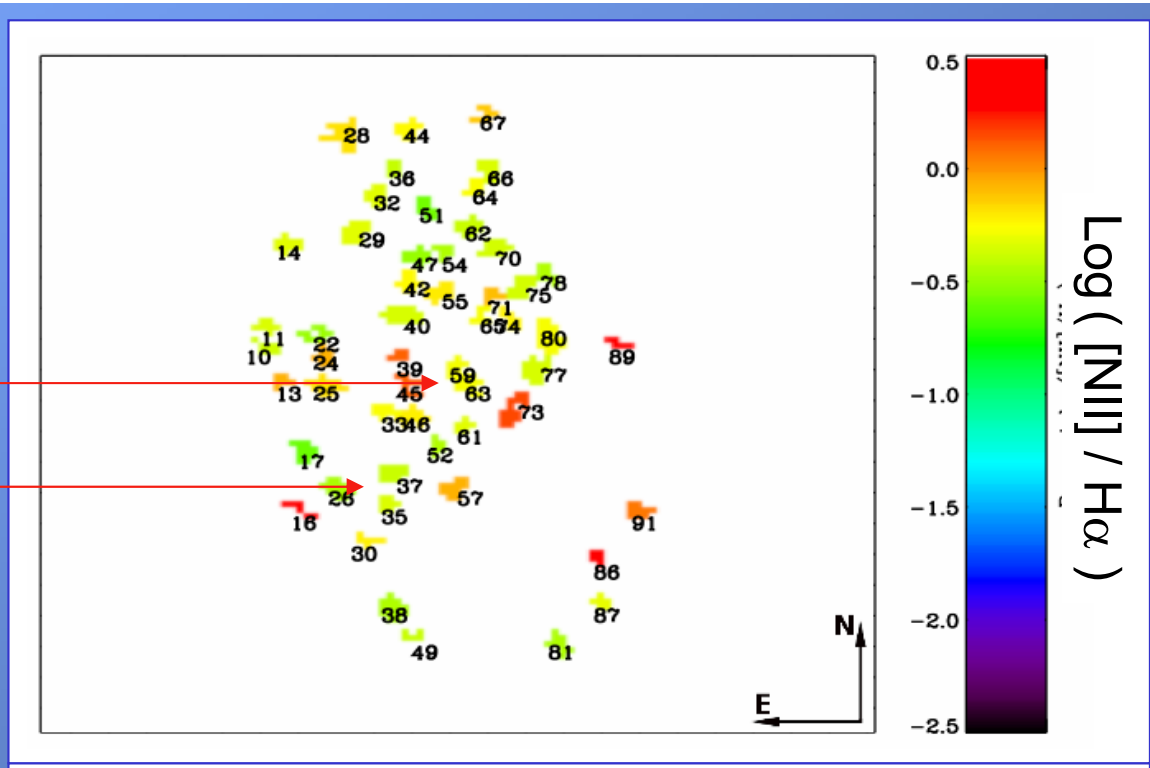
- Using the program HIIphot (NASA)
- to get size, nb, properties… versus radius, galaxy type

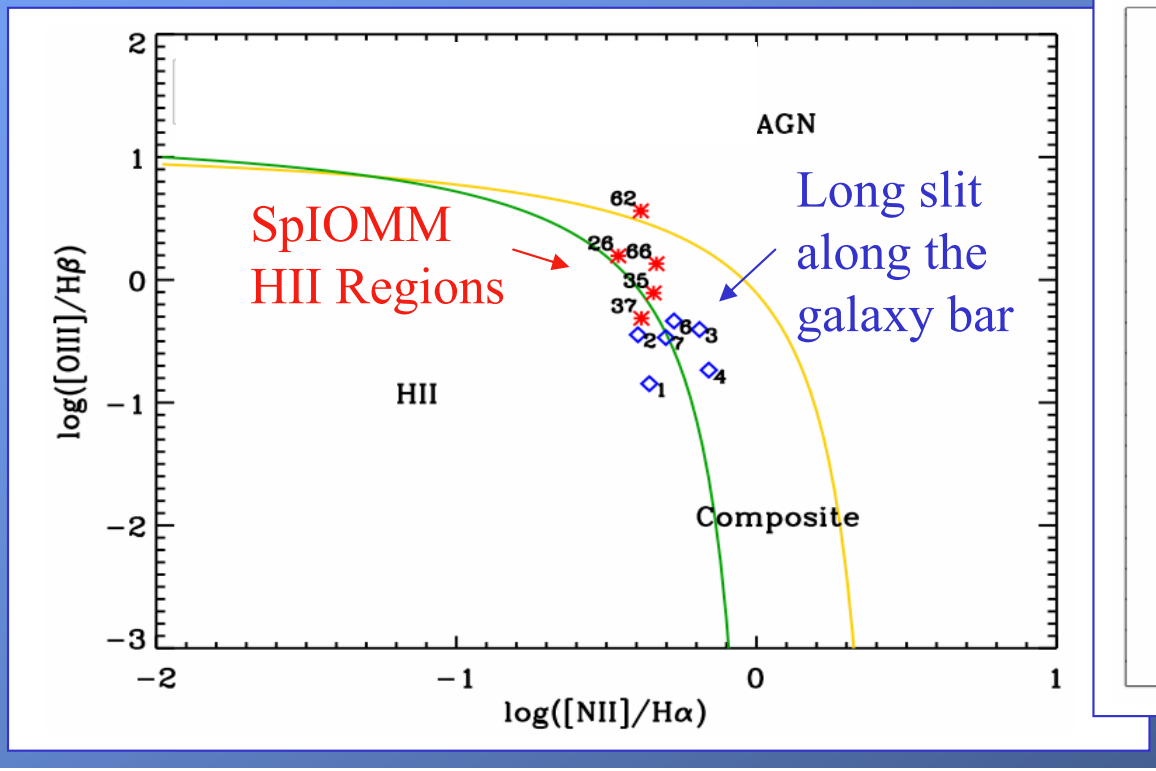


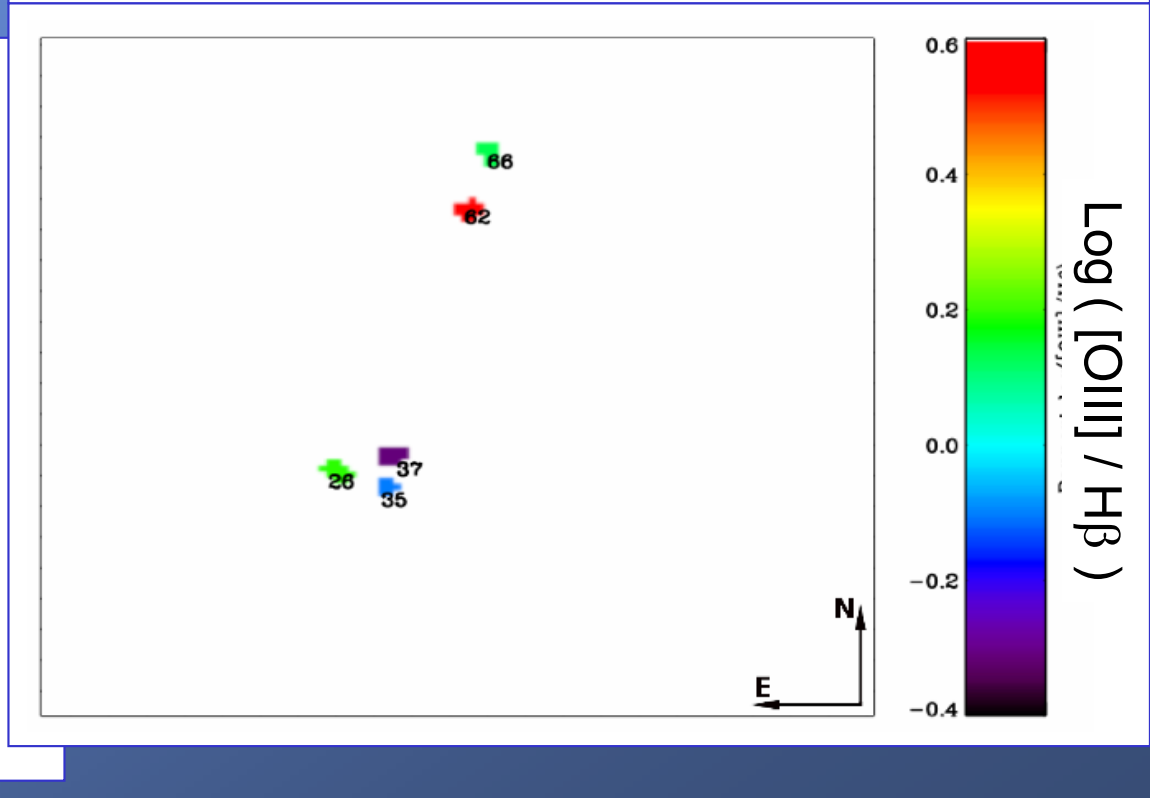


Emission line ratios = chocs in the bar & arms









Gas metallicity

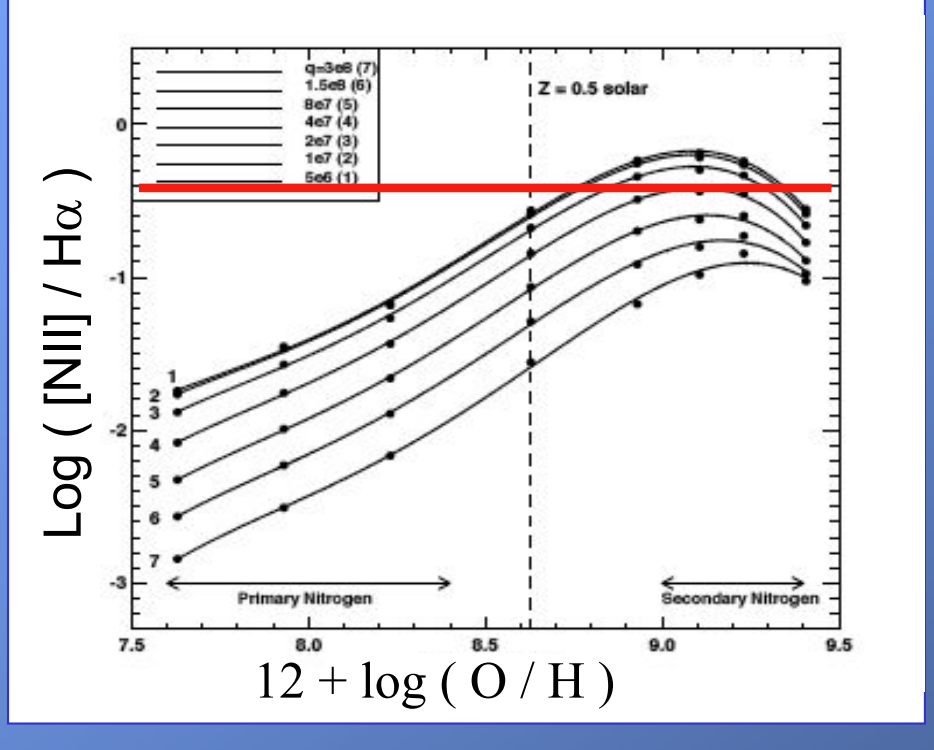
- using Kewley & Dopita (2002) :

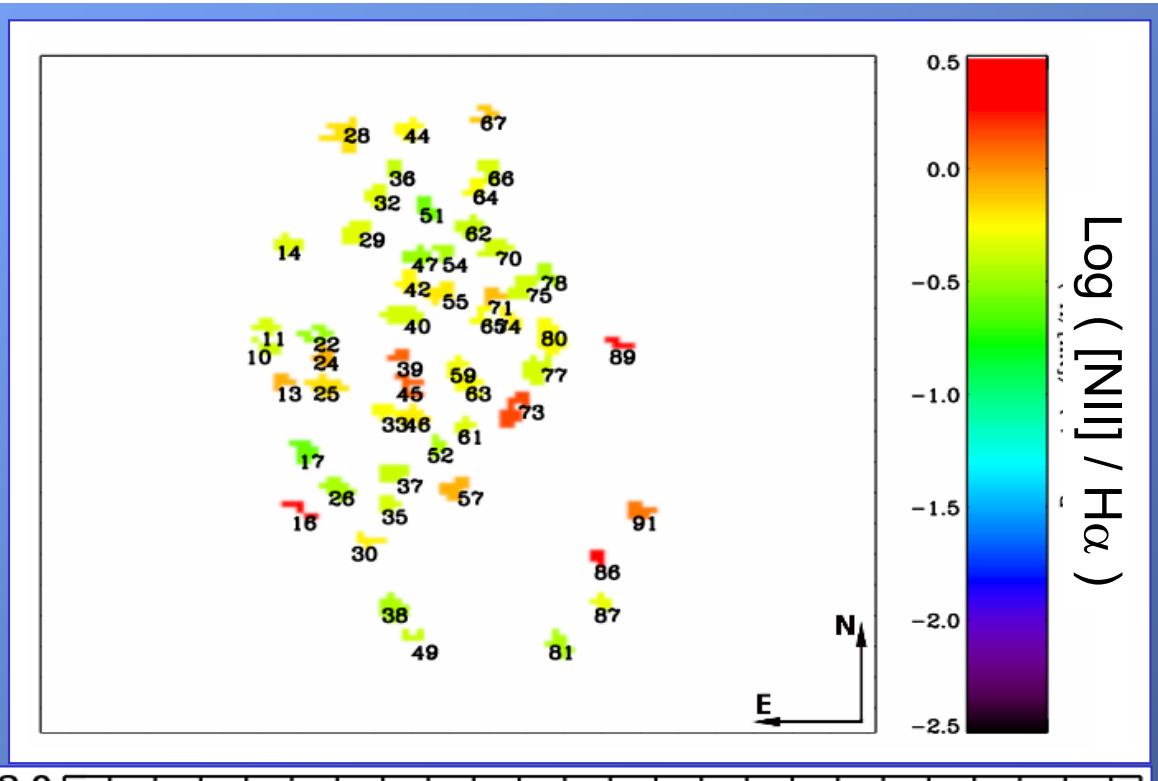
  NII / Hα vs

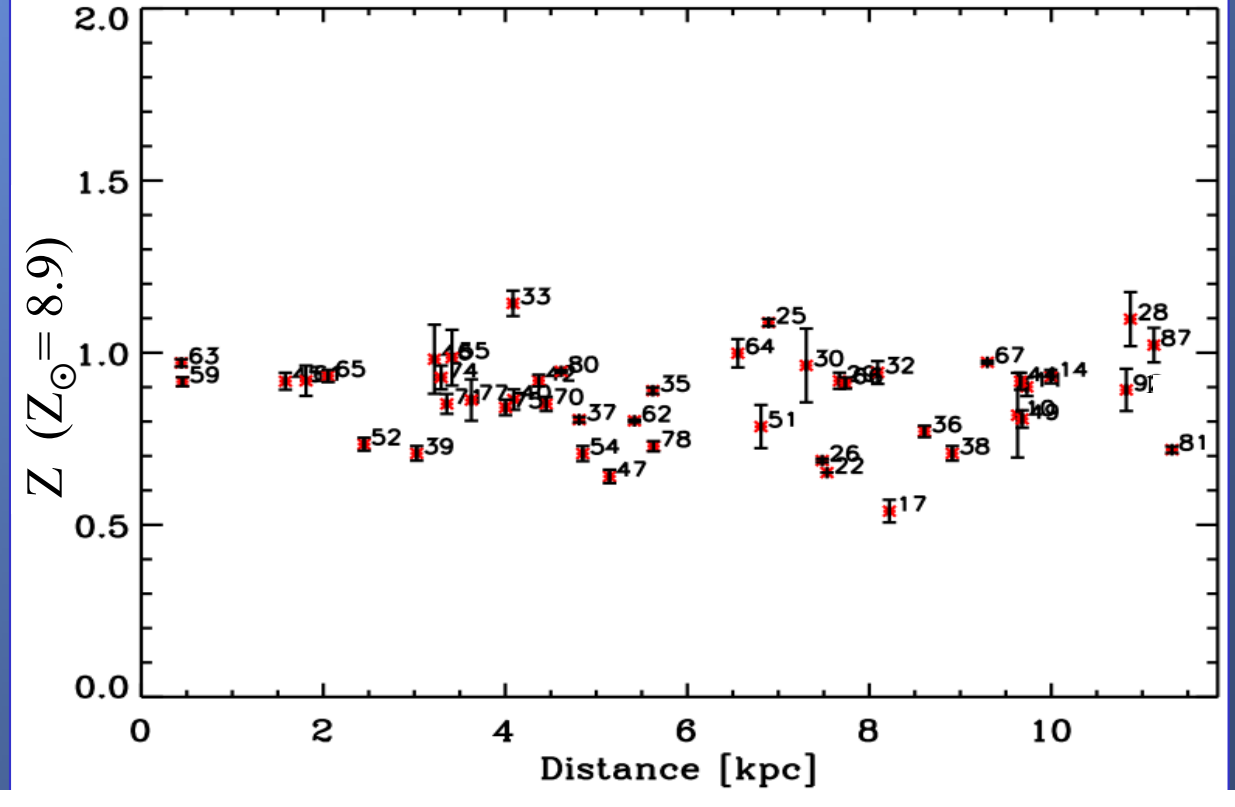
  - metallicity 12 + log(O/H)
  - ionization parameter $q=S_{ip}/n_H$

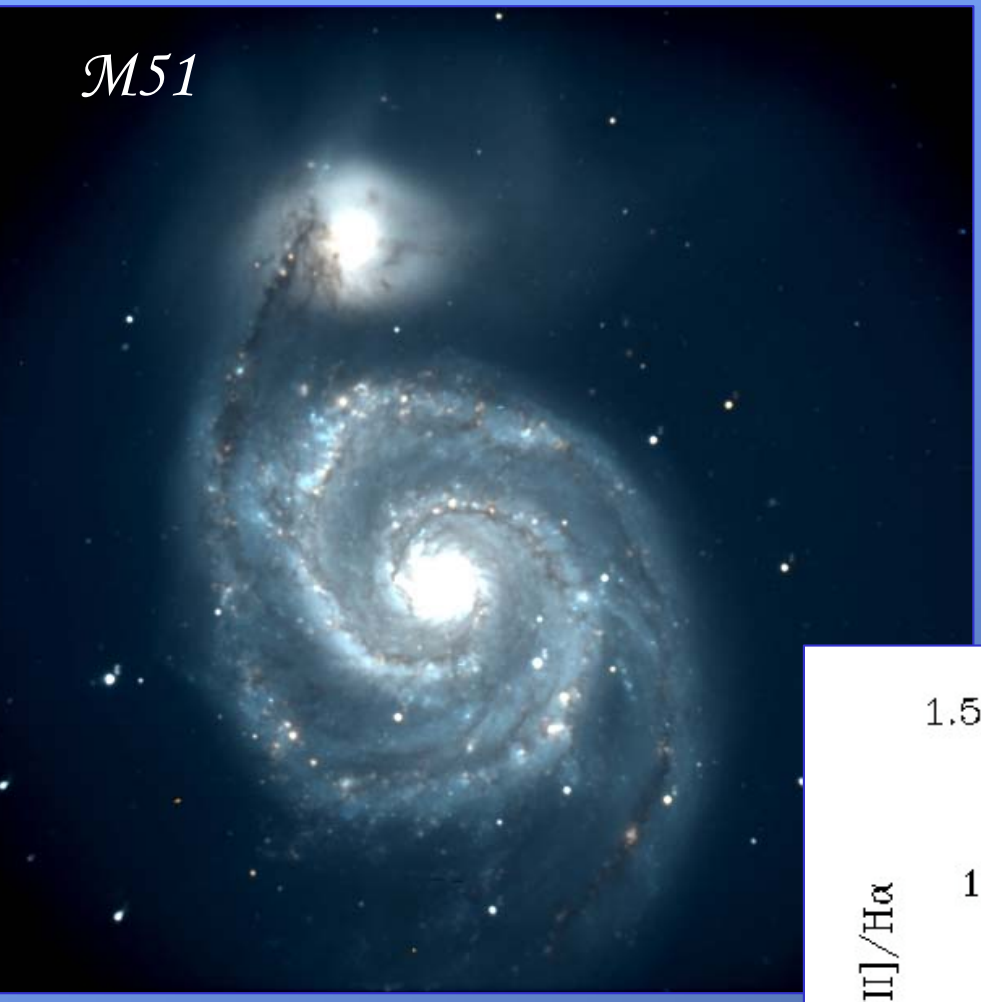
- Near $Z_\odot$ for most HII regions ?

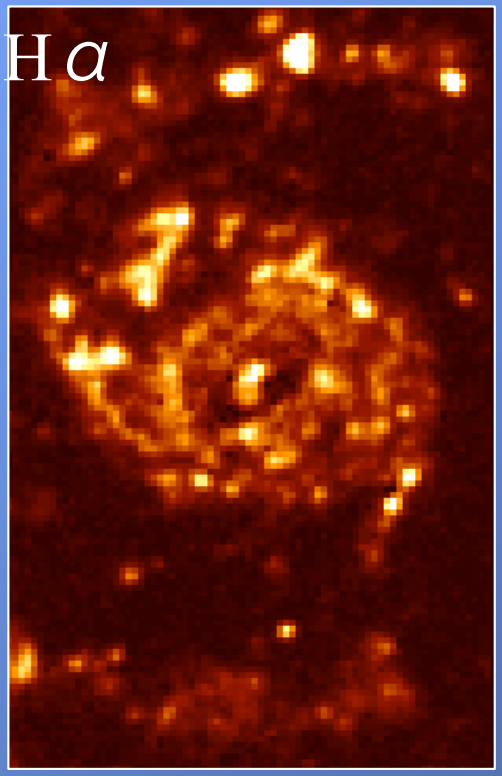
  No gradient in a barred S

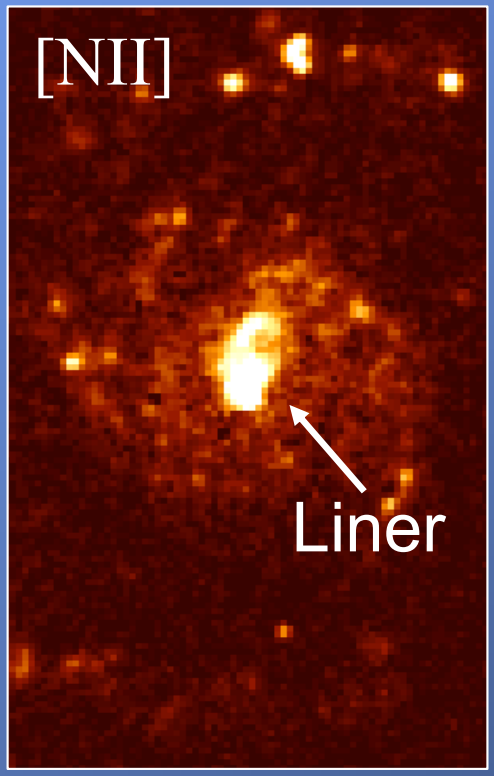


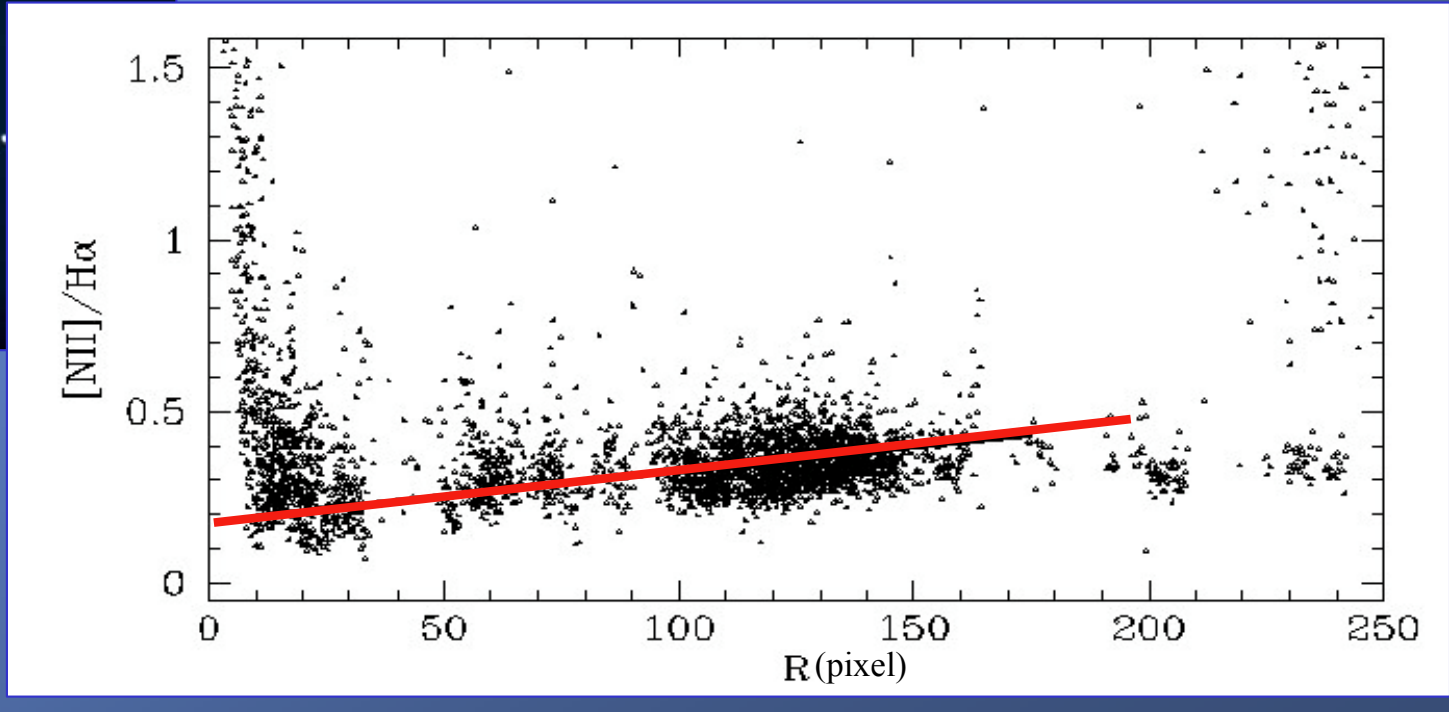










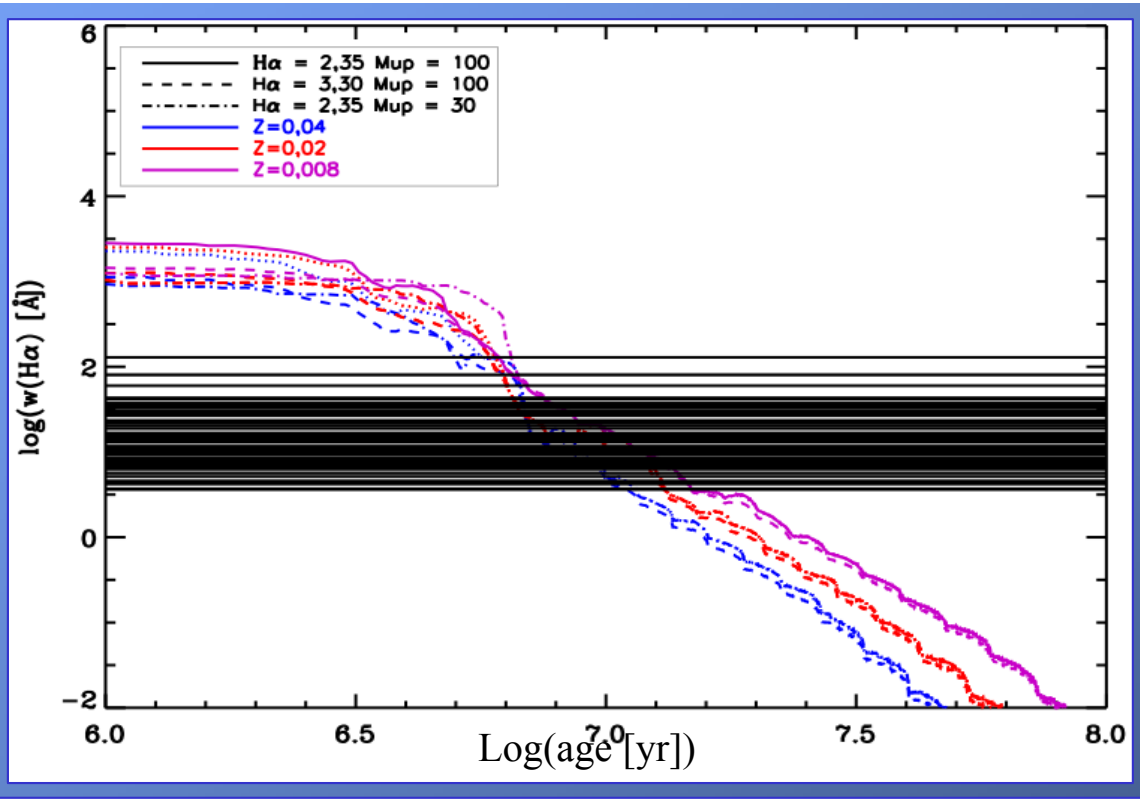


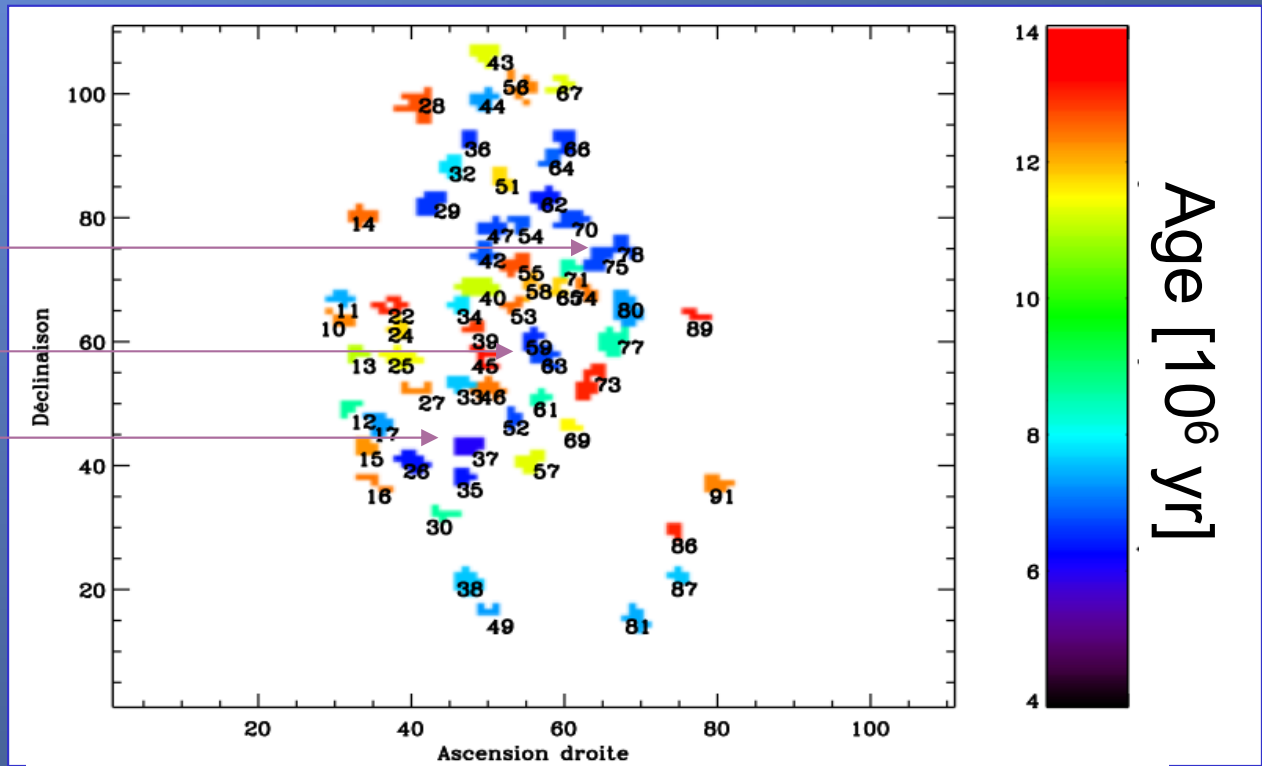
Anne-Pier Bernier
Ph. D. Thesis (U. Laval)

Age of the HII Region stellar populations

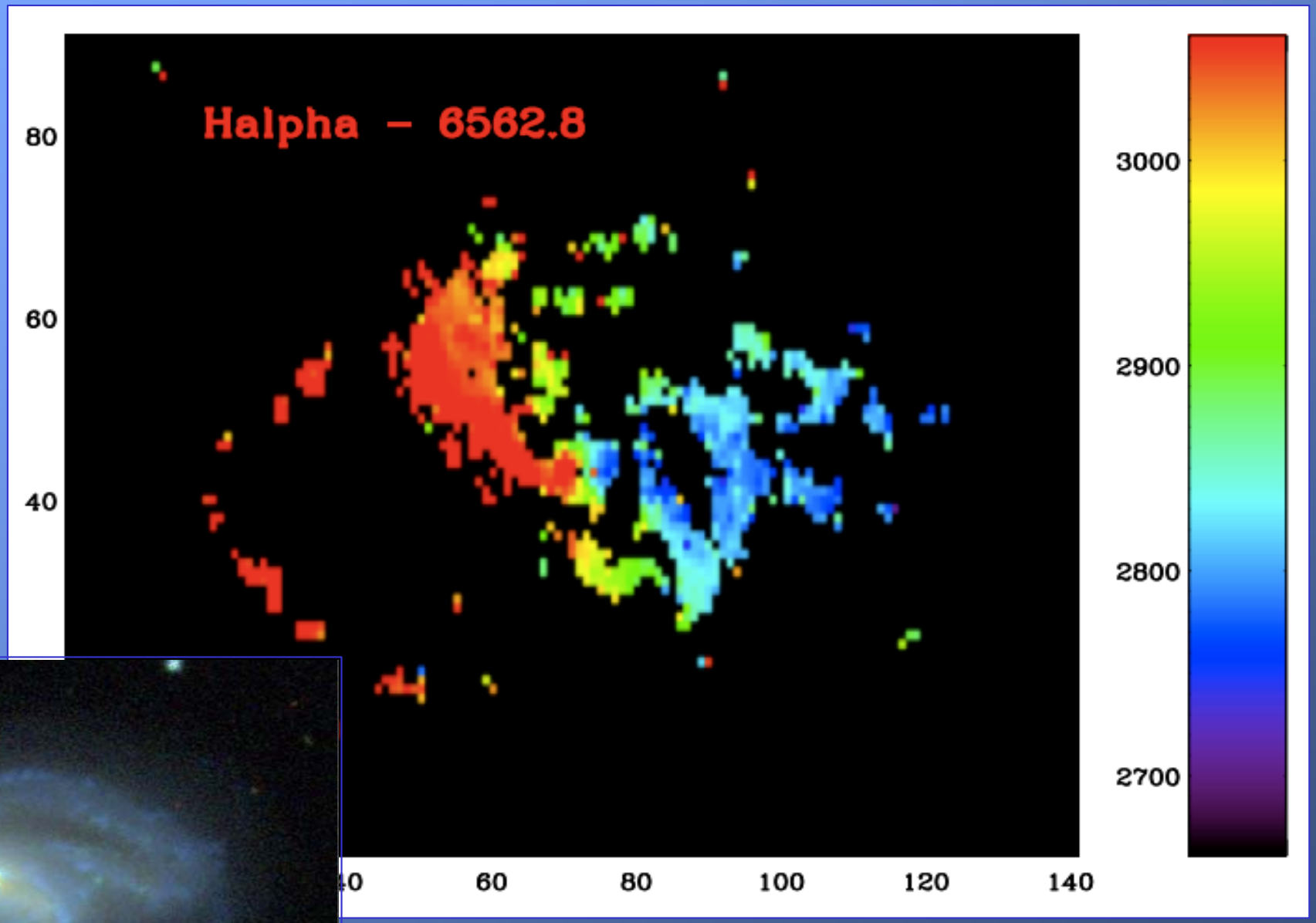
- Using Starburst99, based on the equivalent width of the emission lines Hα and Hβ

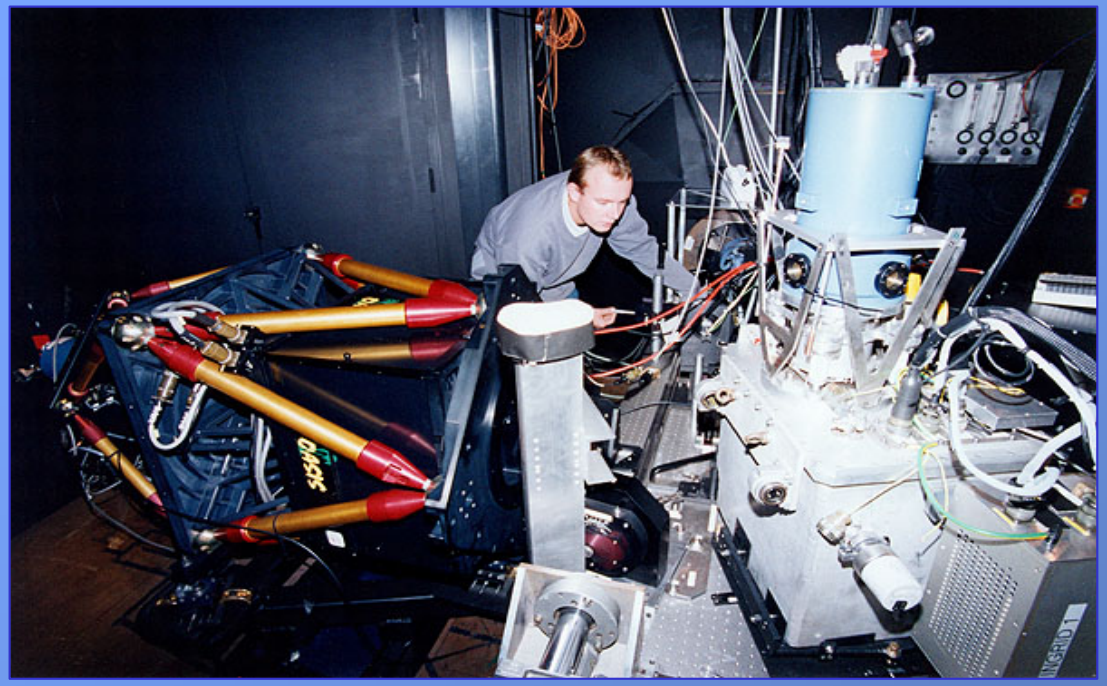
- from 6 to 14 Myr
  youngest = WR knot
  central region
  near 3rd arm





Velocity





Optically Adaptive System for Imaging Spectroscopy

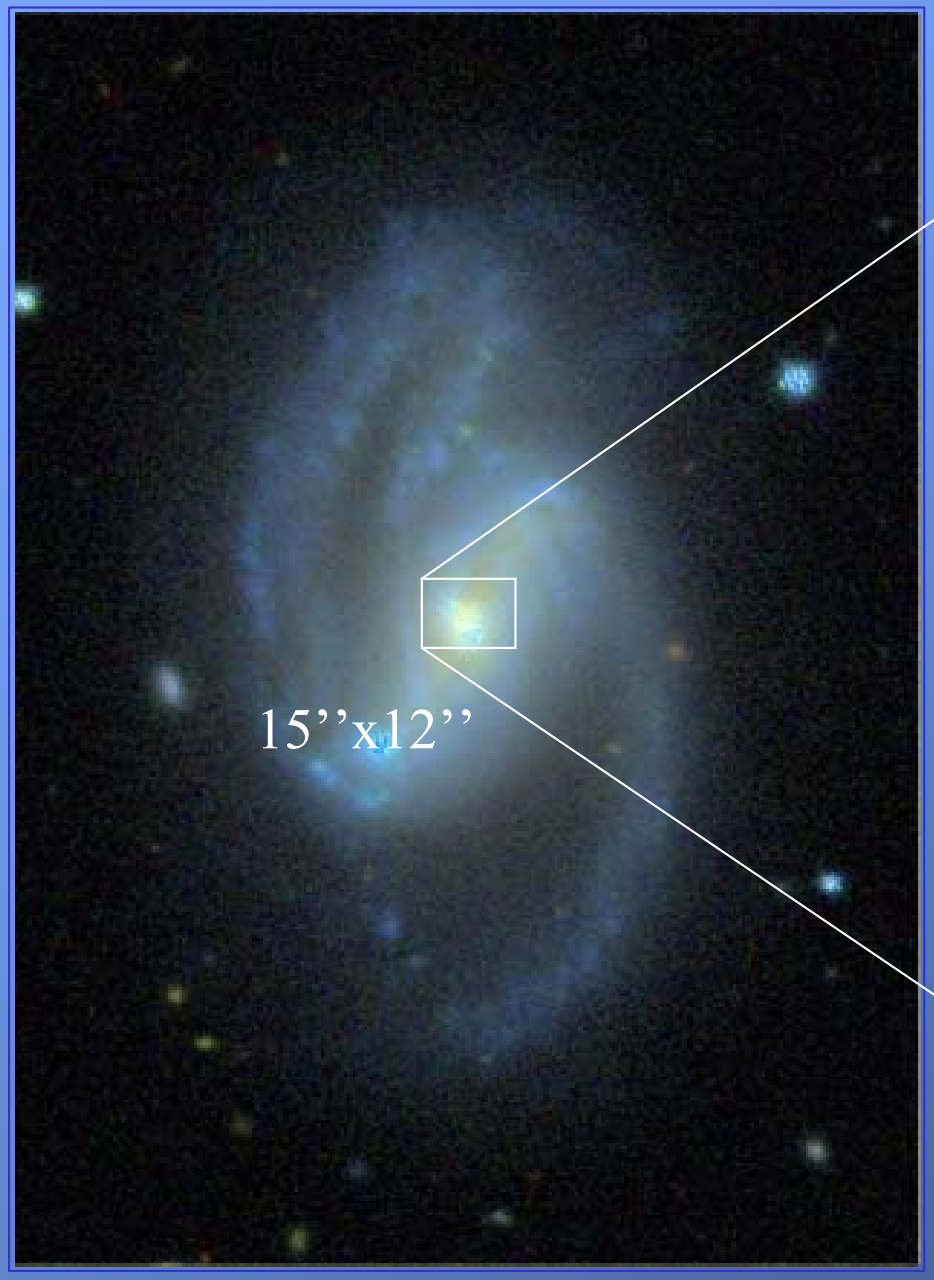
By R. Bacon for the CFHT in 1997
… now at the WHT

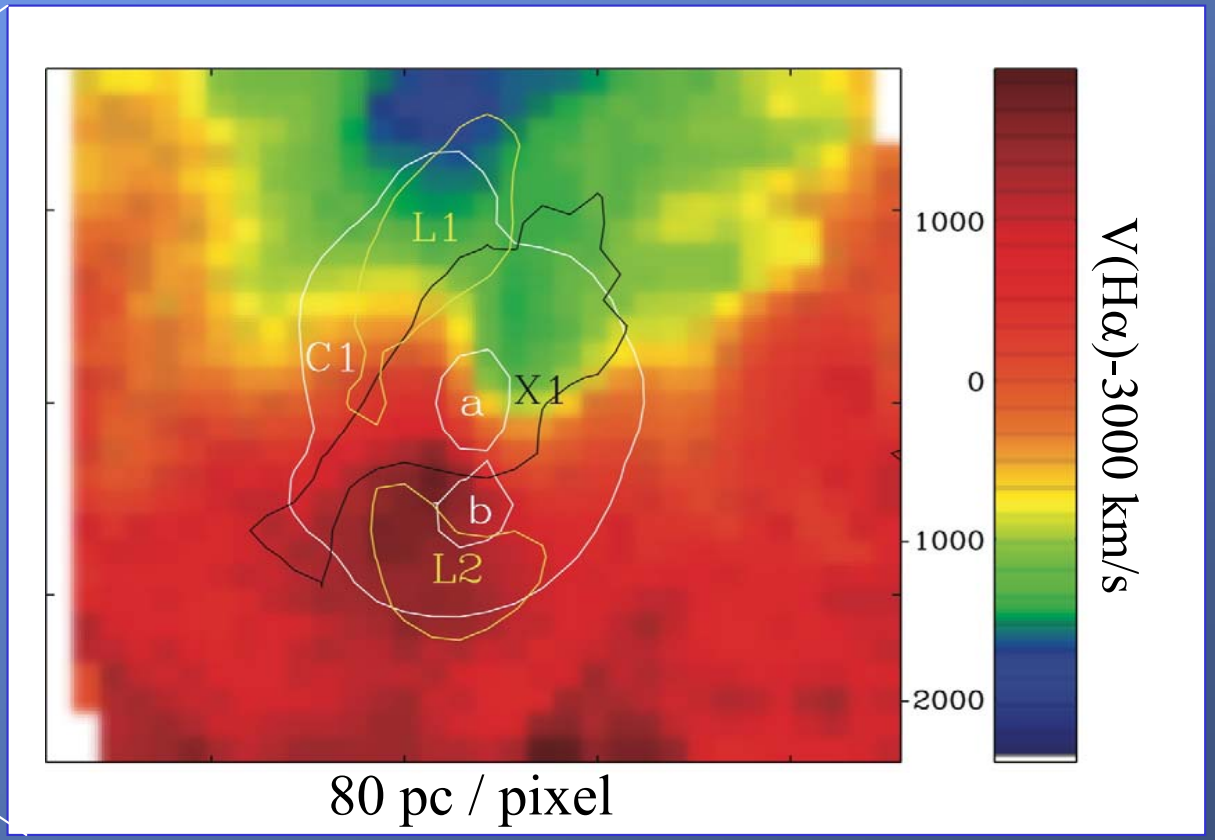
~1100 lenslets in a rectangular array
light is dispersed by a prism and imaged on CCD

Field of view : 2.7'' to 10.3'' (3 possibilities)
Spatial resolution : 0.09''/lenslet to 0.26''/lenslet

Wavelength coverage : 4200 to 10300 Å (many configurations)
Spectral resolution : 0.8 to 35 Å/pixel

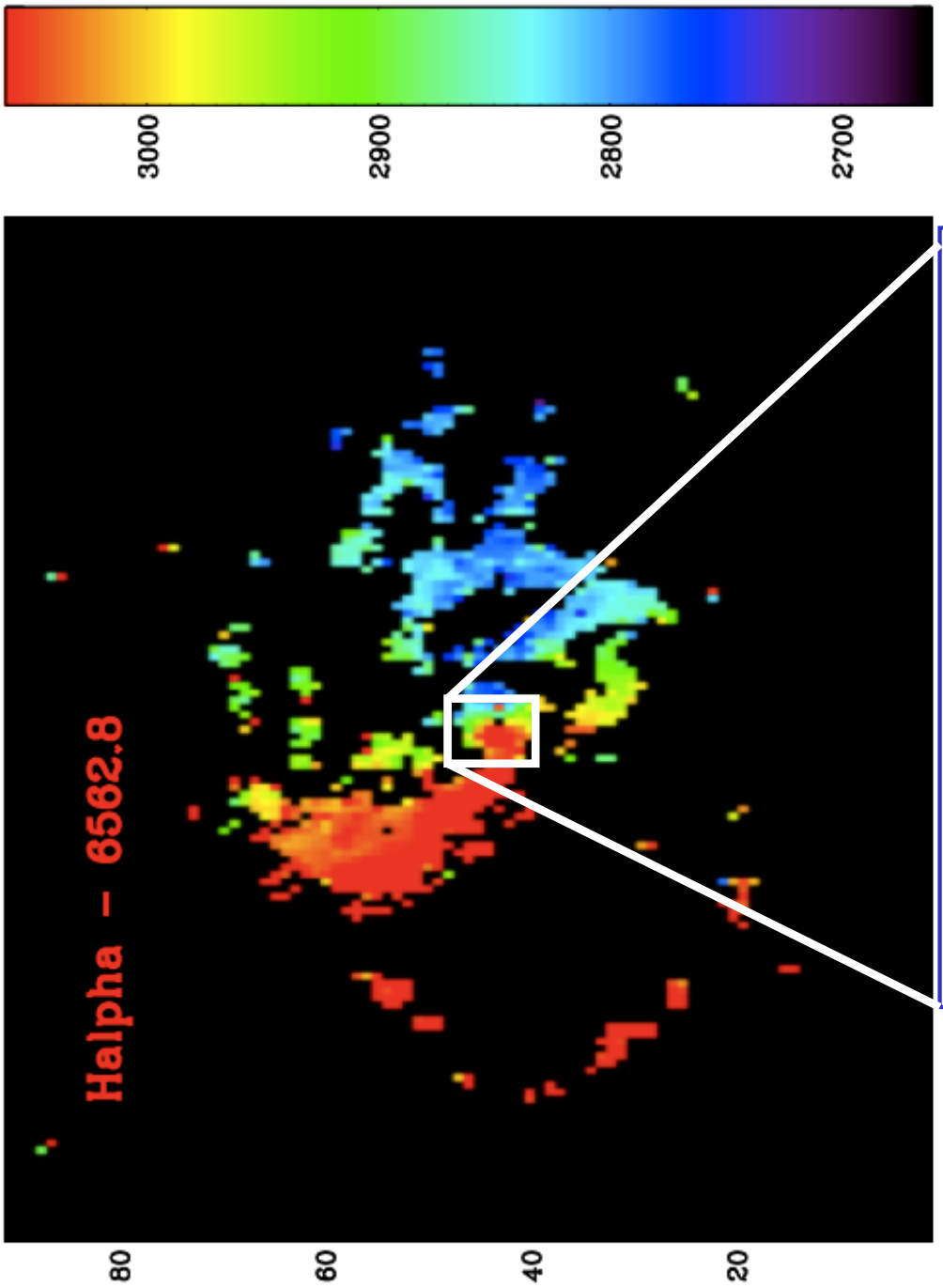
NGC5430 : with OASIS at the CFHT



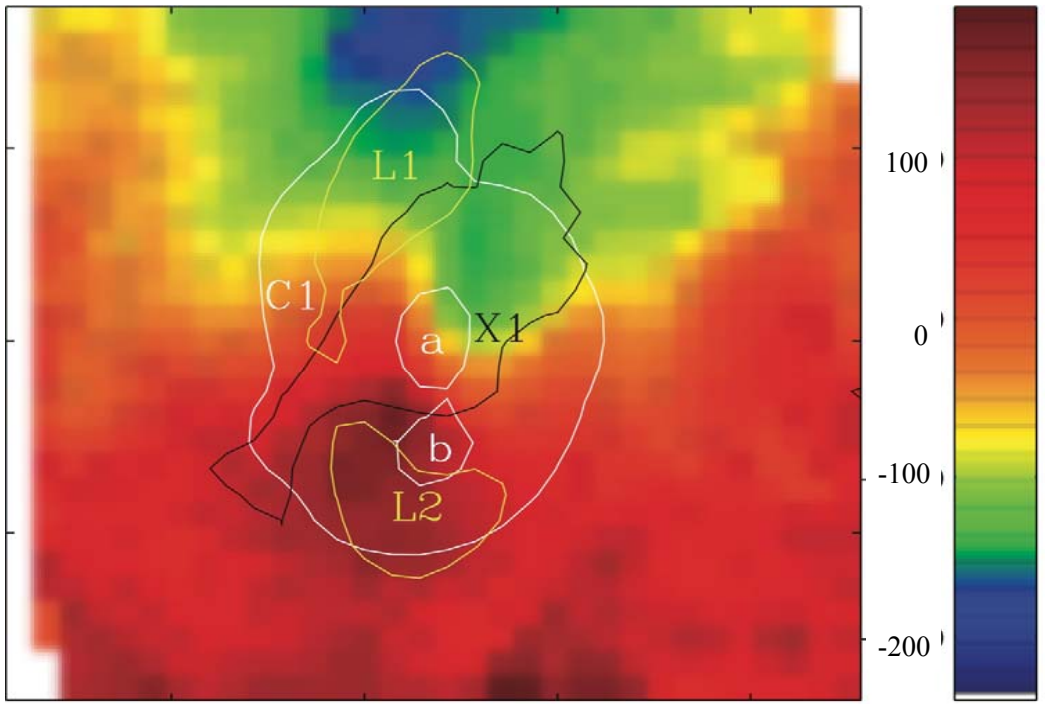


Simon Cantin
Pd. D. Thesis (U. Laval)

SpIOMM

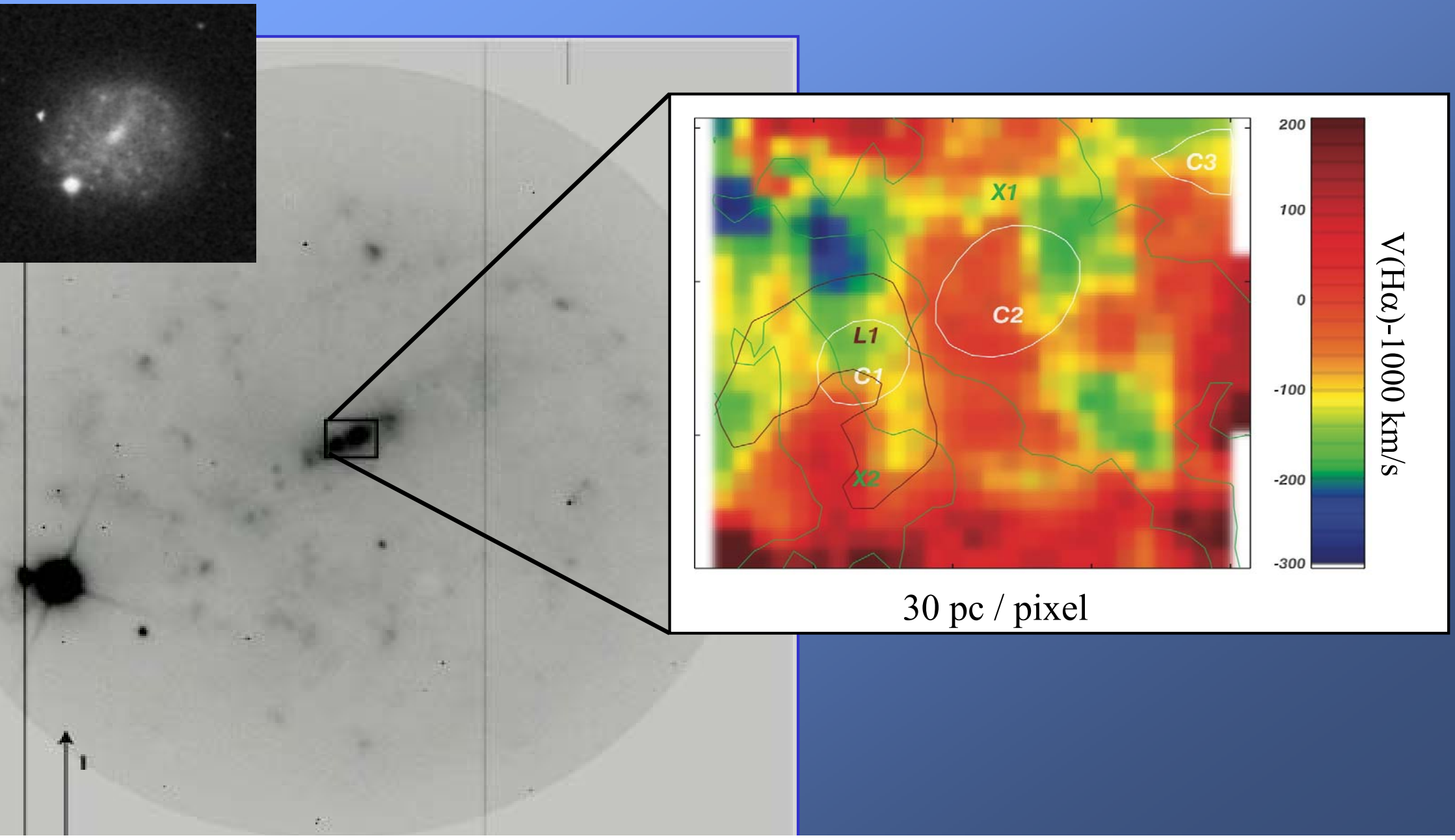


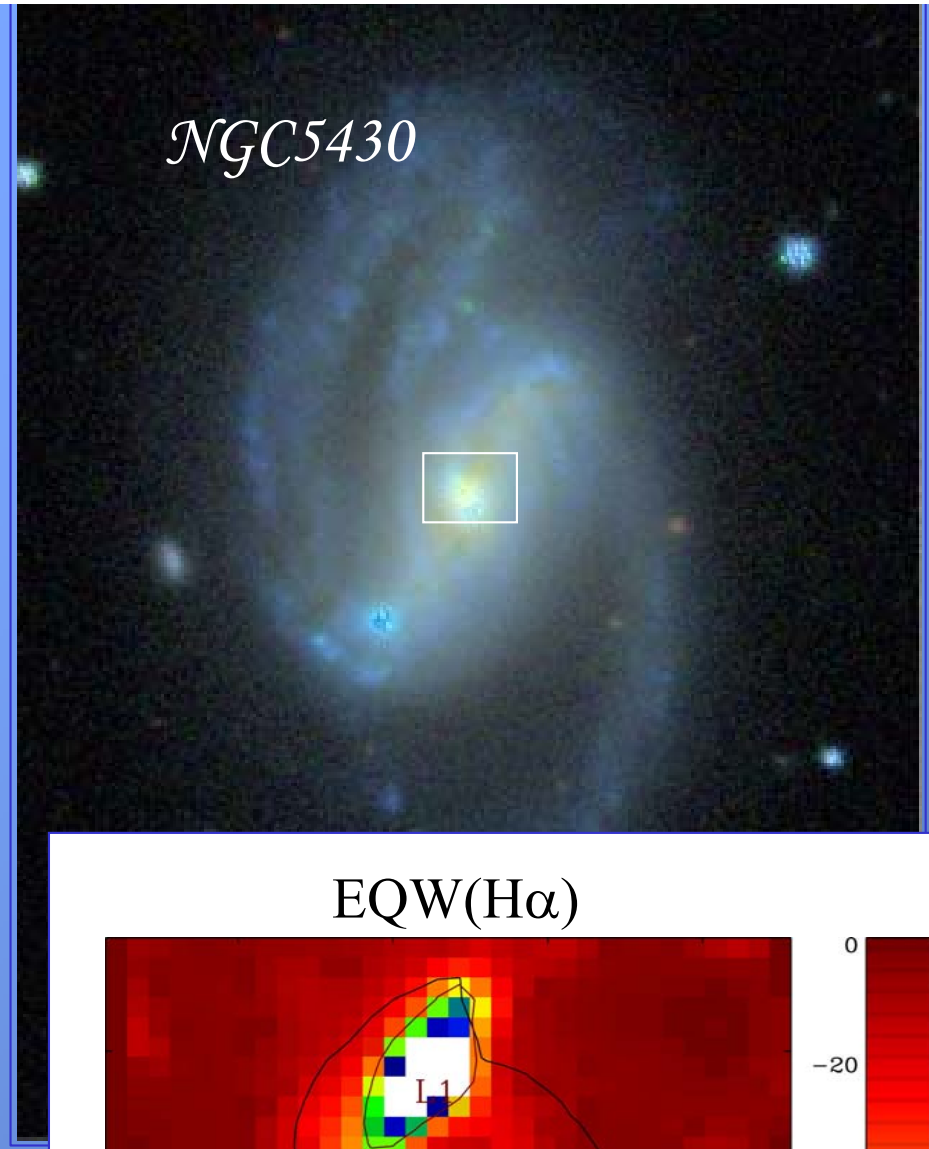
OASIS



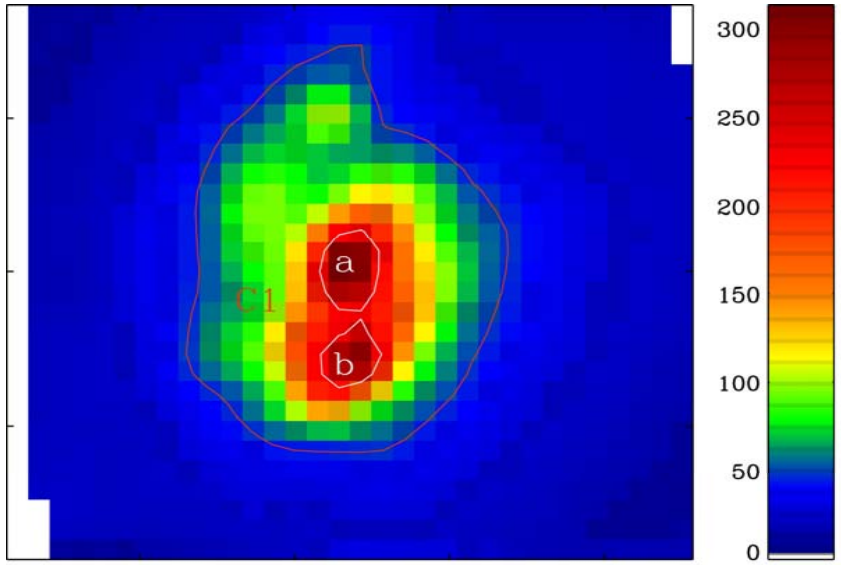
80 pc / pixel

NGC4900 - SB(rs)c HII at 13Mpc

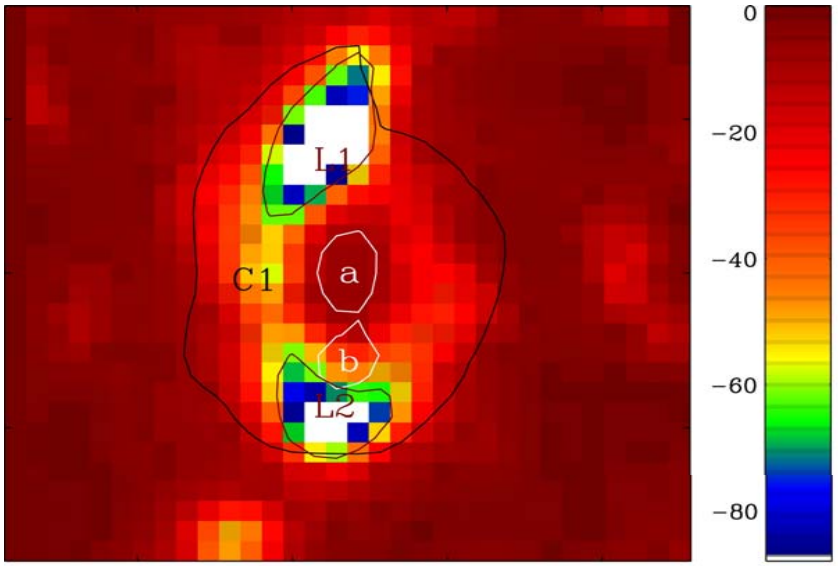




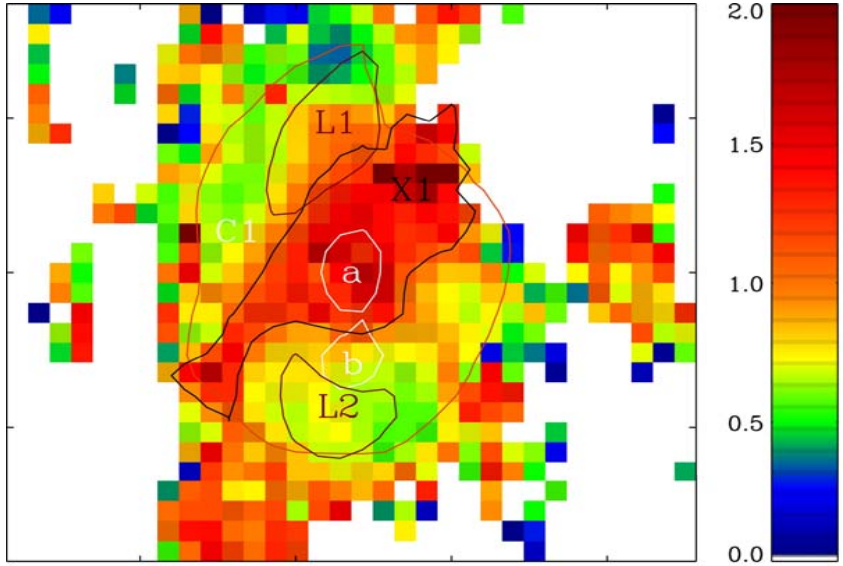
Red Continuum Flux



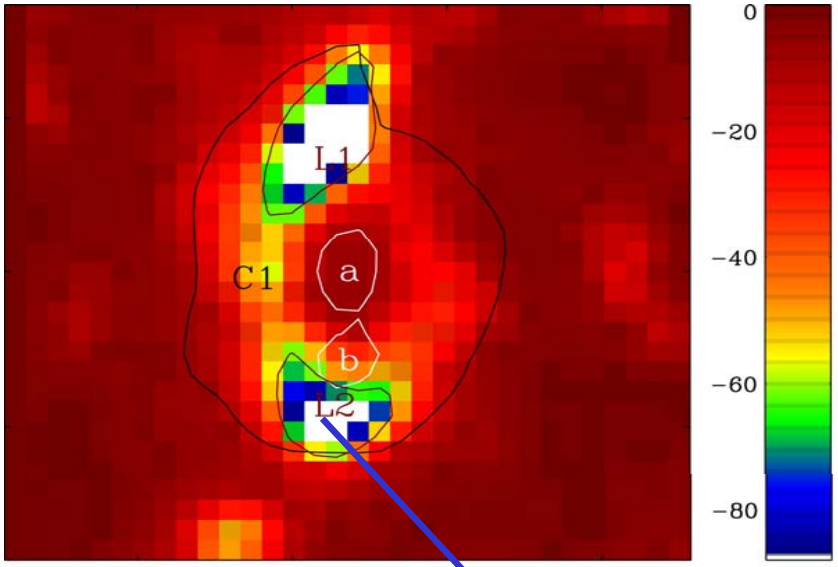
EQW(Hα)

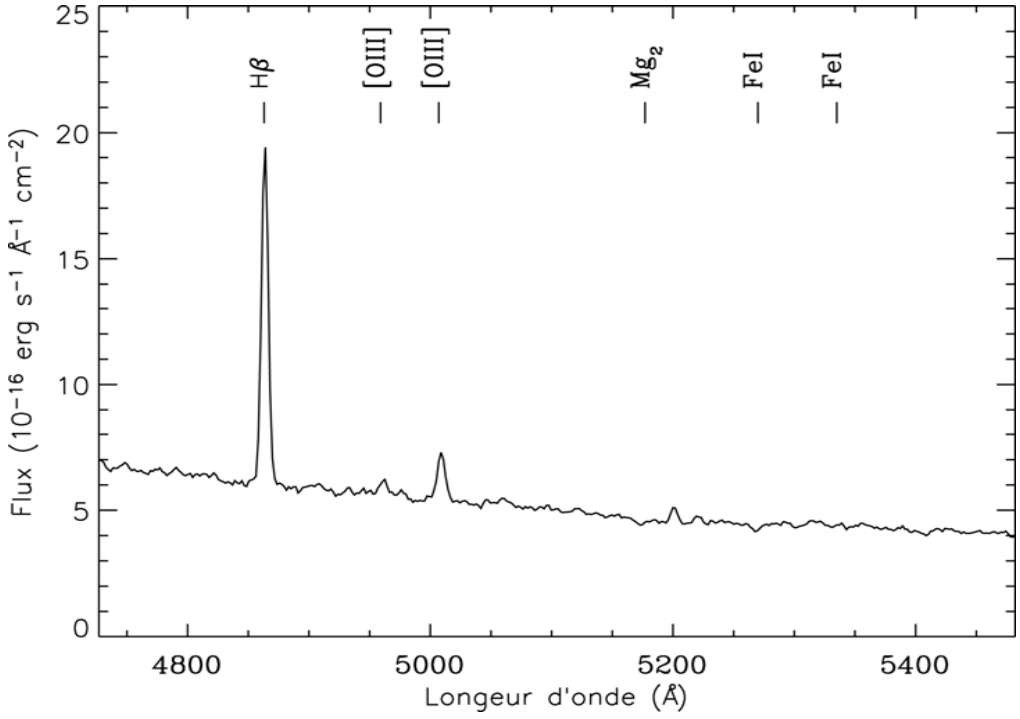


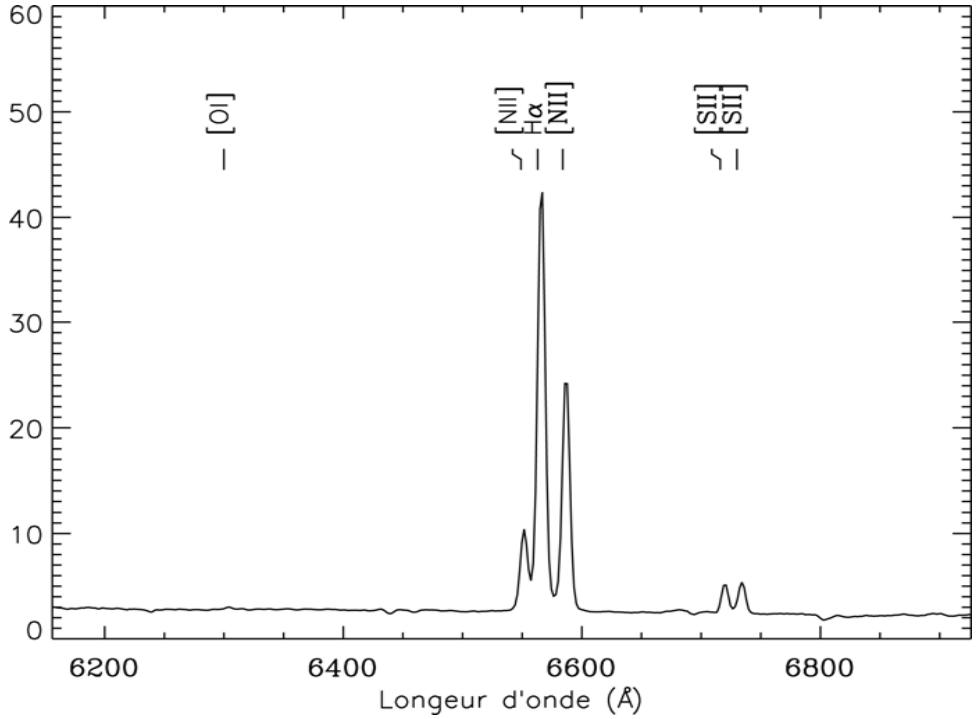
E(B-V)



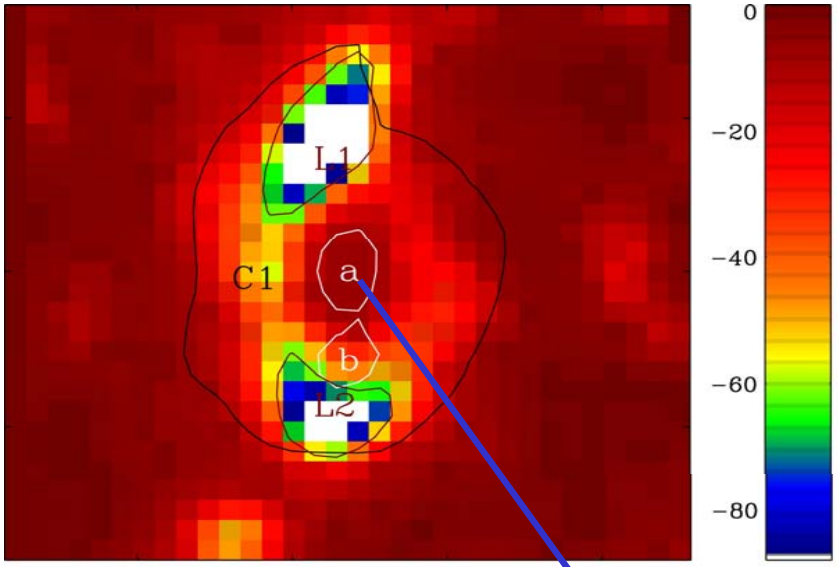
EQW(Hα)

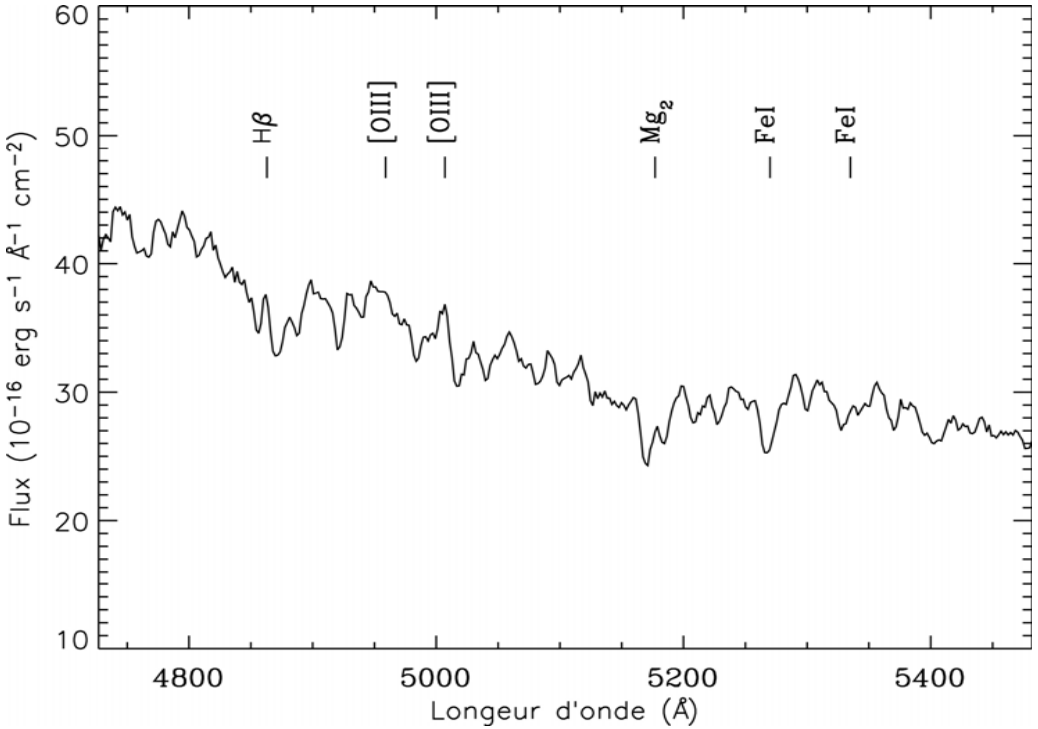

L1
C1
a
b
L2
0
−20
−40
−60
−80

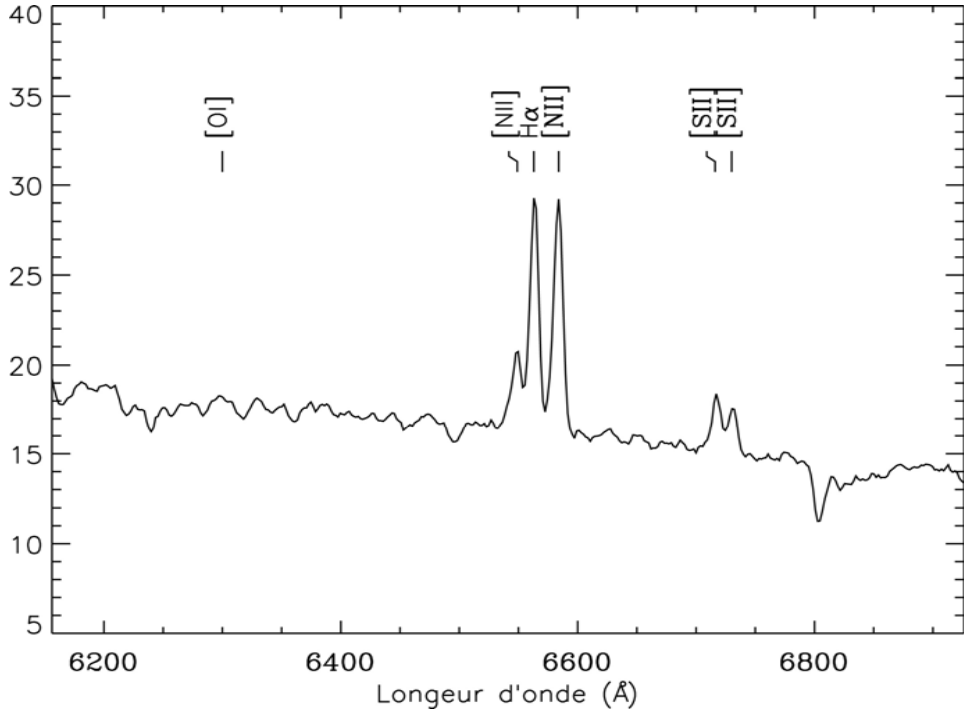

Hβ
[OIII]
[OIII]
Mg2
FeI
FeI
Flux (10−16 erg s−1 Å−1 cm−2)
Longeur d'onde (Å)


[OI]
[NII]
Hα
[NII]
[SII]
[SII]
Longeur d'onde (Å)

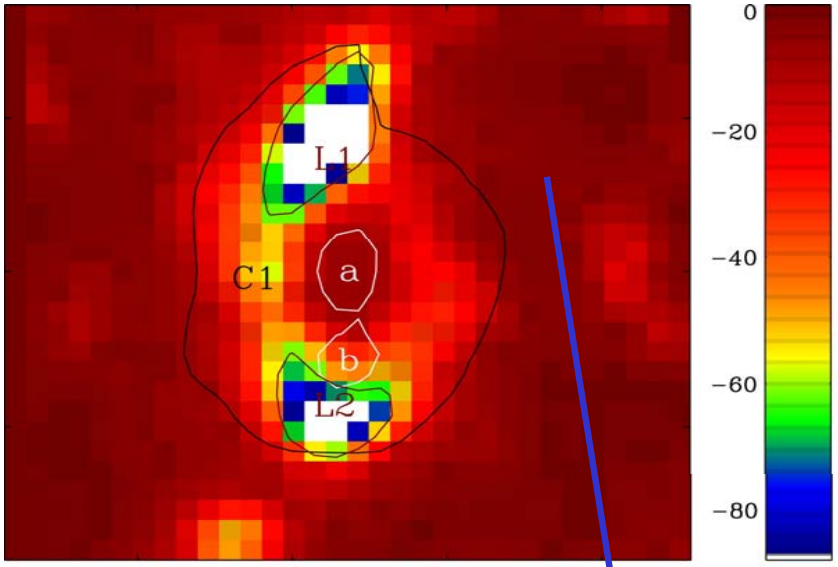
EQW(Hα)

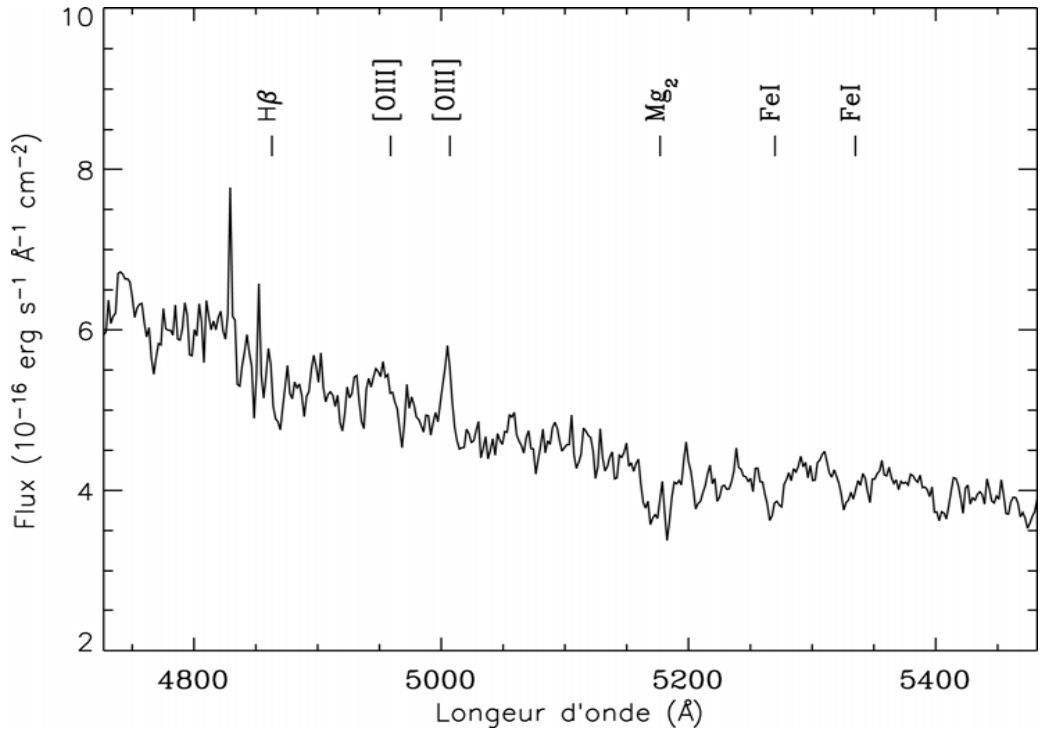

L1
C1
a
b
L2
0
−20
−40
−60
−80

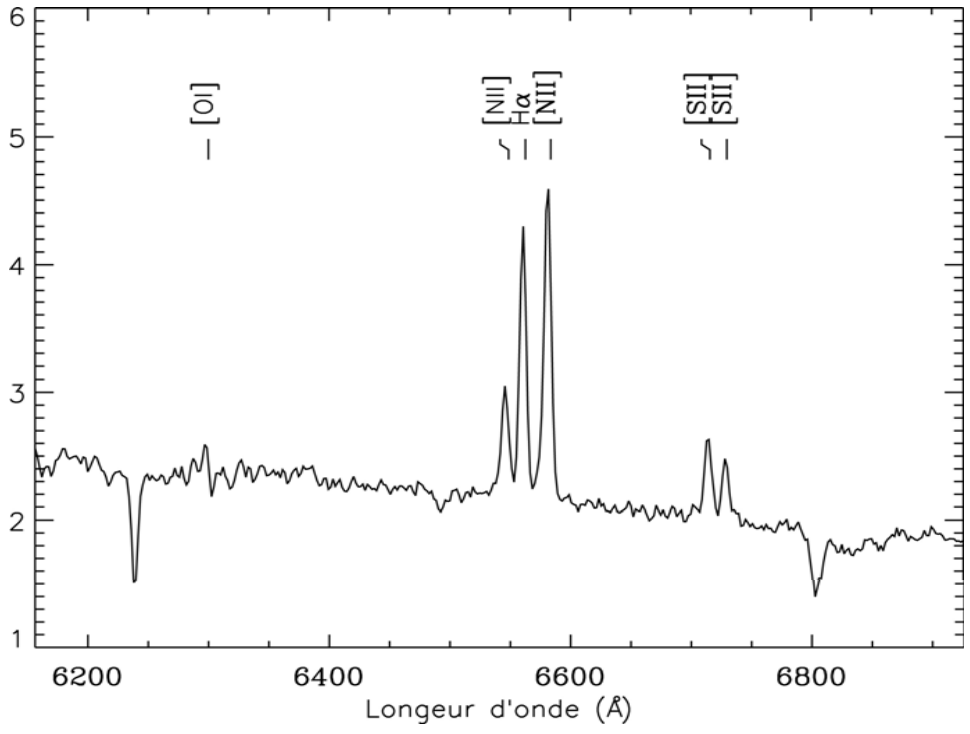

Hβ
[OIII]
[OIII]
Mg2
FeI
FeI
Flux (10−16 erg s−1 Å−1 cm−2)
Longeur d'onde (Å)


[OI]
[NII]
Hα
[NII]
[SII]
[SII]
Longeur d'onde (Å)

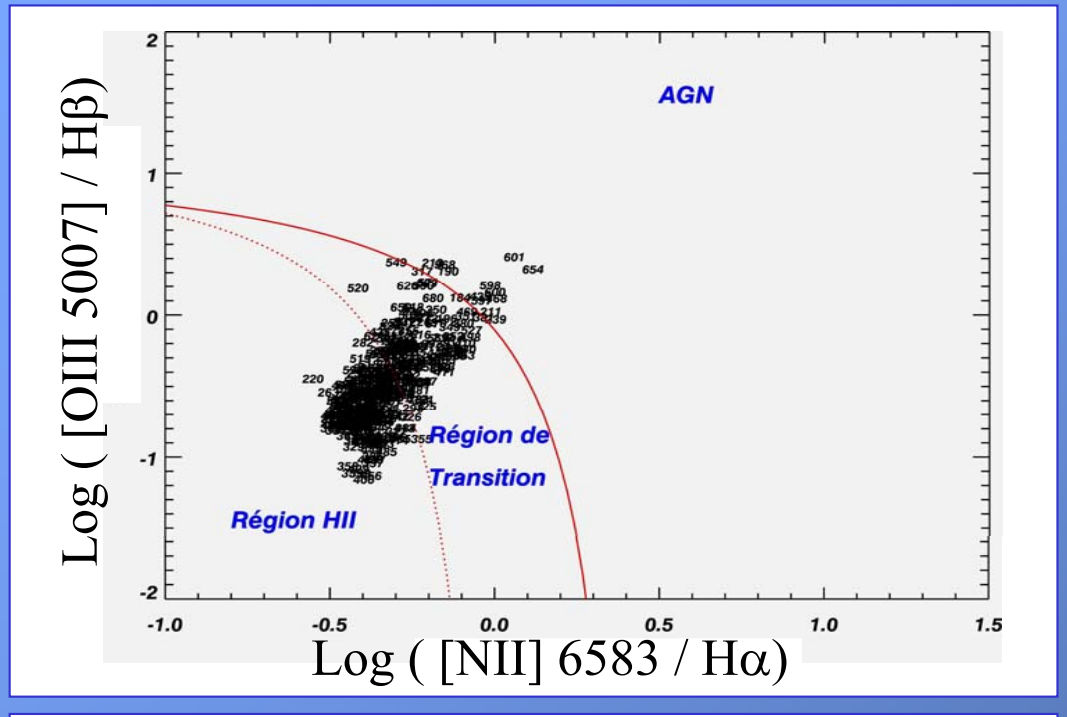
EQW(Hα)

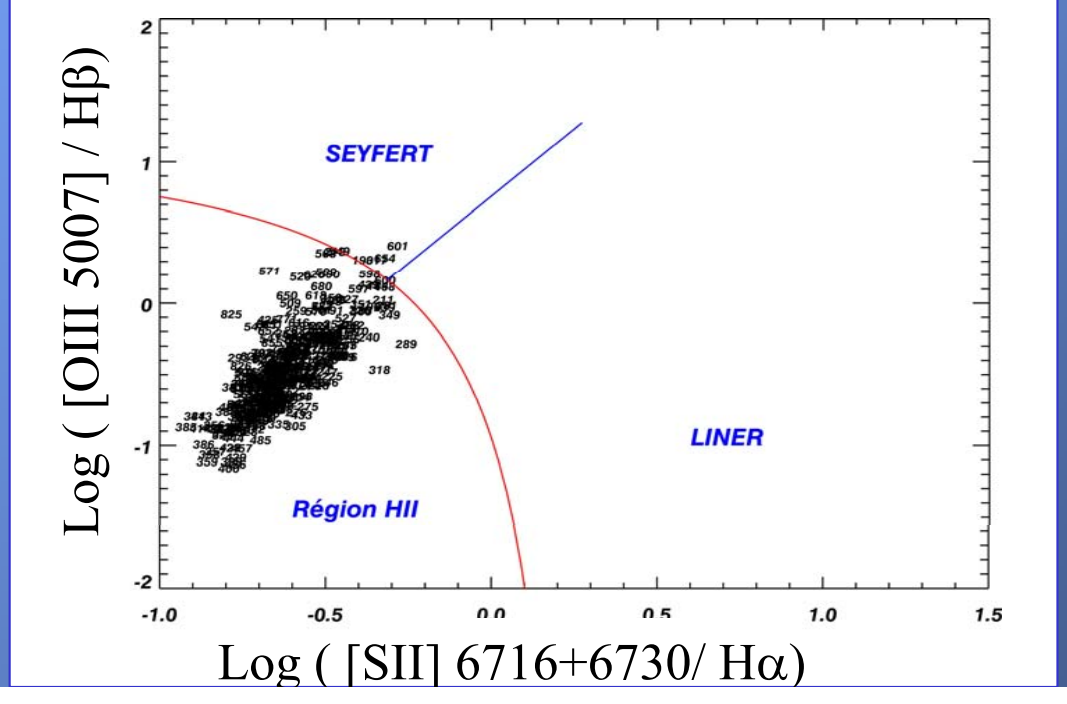

L1
C1
a
b
L2
0
−20
−40
−60
−80


Hβ
[OIII]
[OIII]
Mg2
FeI
FeI
Flux (10−16 erg s−1 Å−1 cm−2)
Longeur d'onde (Å)

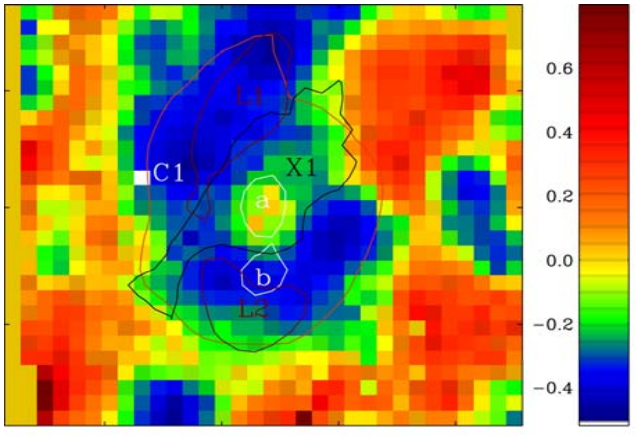

[OI]
[NII]
Hα
[NII]
[SII]
[SII]
Longeur d'onde (Å)

Weak nuclear activity & chocs

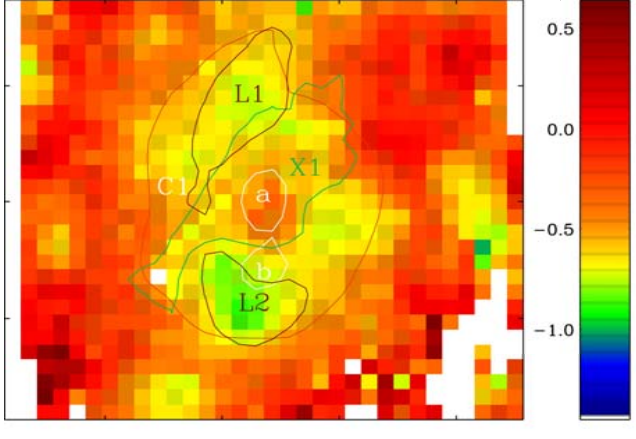




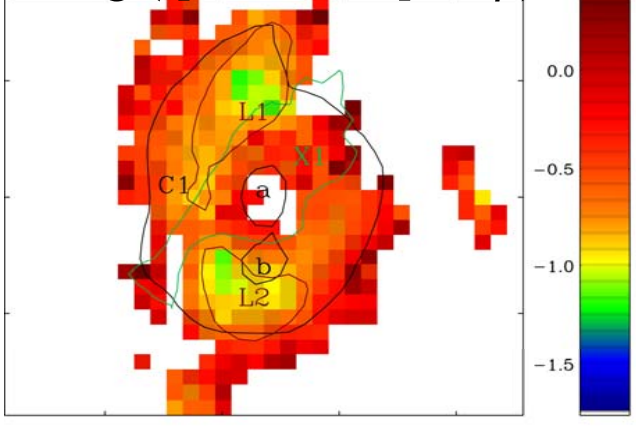
Log ([NII] 6583 / Hα)



Log ([SII] 6716+6730/ Hα)

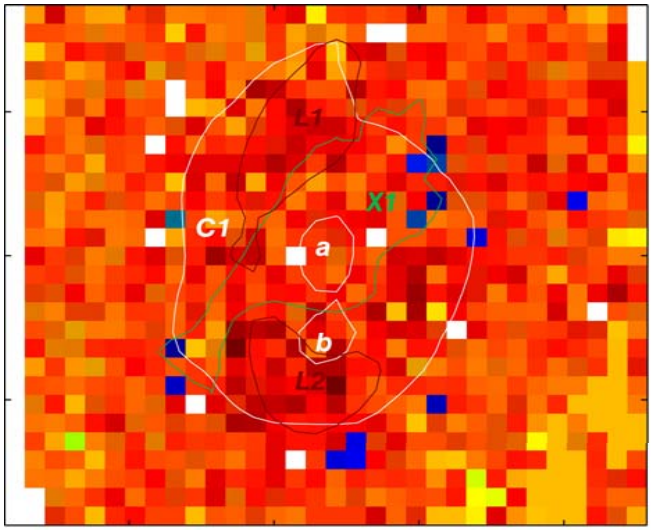


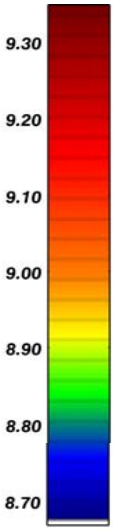
Log ([OIII 5007] / Hβ)



Stellar populations : iterative process for young pop + older pop…

Gas emission lines: 12+log(O/H)

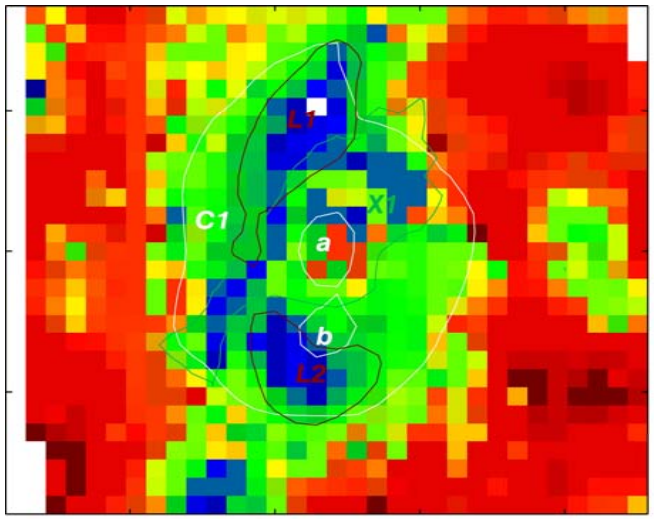




average: 9.1±0.1

L1, L2: 9.2±0.1

Hα & Hβ emis. : young pop. age.



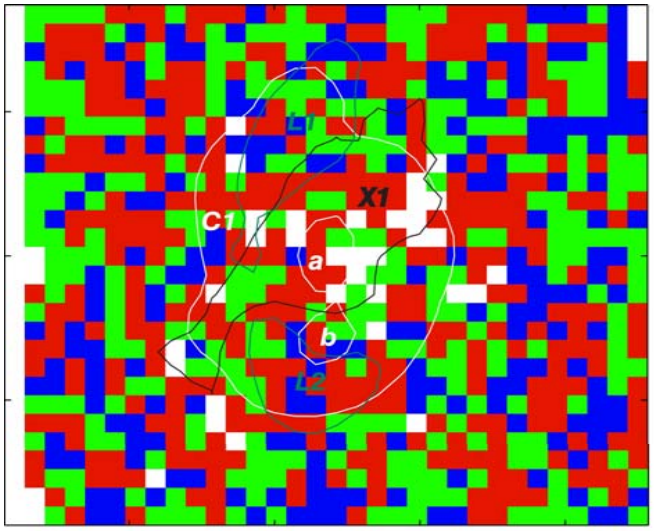
in Myr

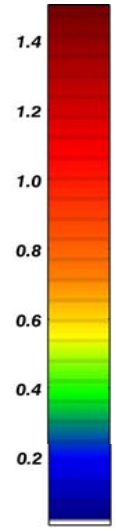
L1, L2: 6.2±0.8

C1a: 10.2±0.2

around: 9 to 13

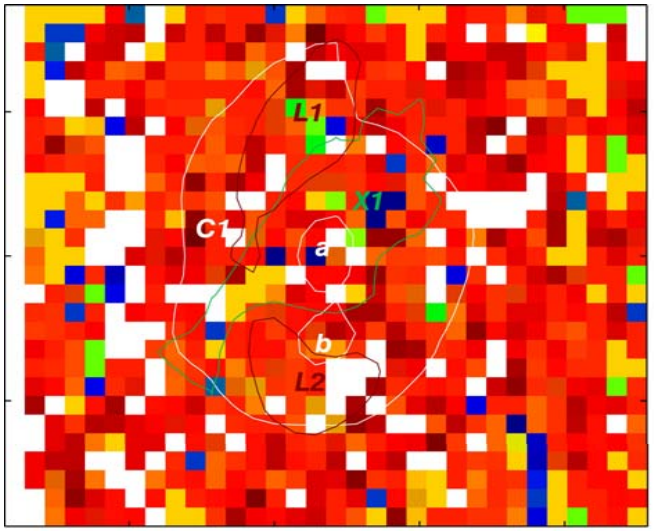
Hβ, Mg_2 & FeI abs. lines: [Fe/H]

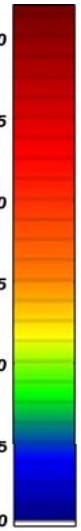




average: $0.4\pm0.2Z_{\odot}$

Hβ, Mg_2 & FeI abs. lines : old pop.age

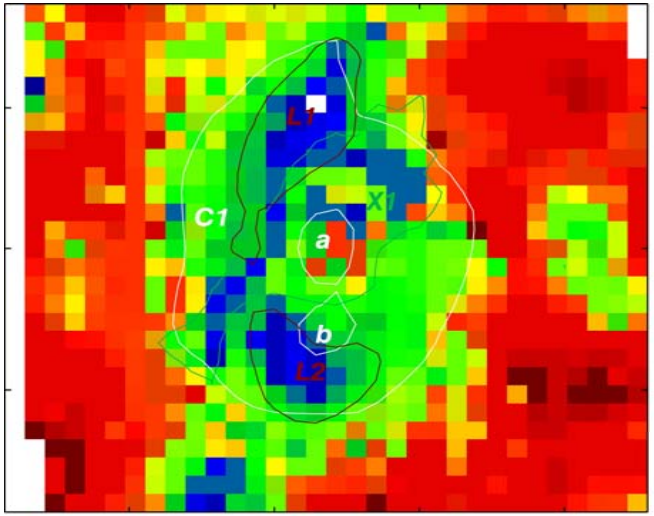


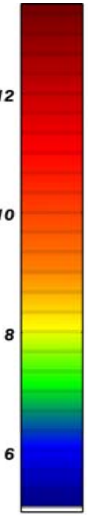


From : 700 Myr (near edge) to 4 Gyr (center)

average: 1.6 Gyr

Hα & Hβ emis. : young pop. age.





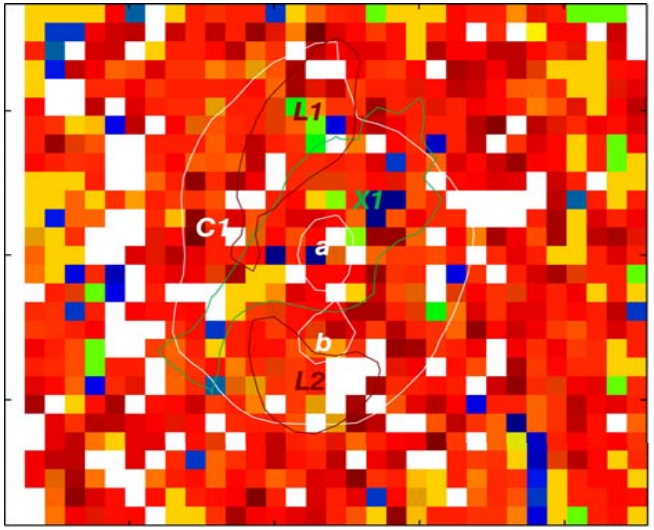
in Myr

L1, L2:
6.2±0.8

C1a:
10.2±0.2

around:
9 to 13

Hβ, Mg_2 & FeI abs. lines : old pop.age

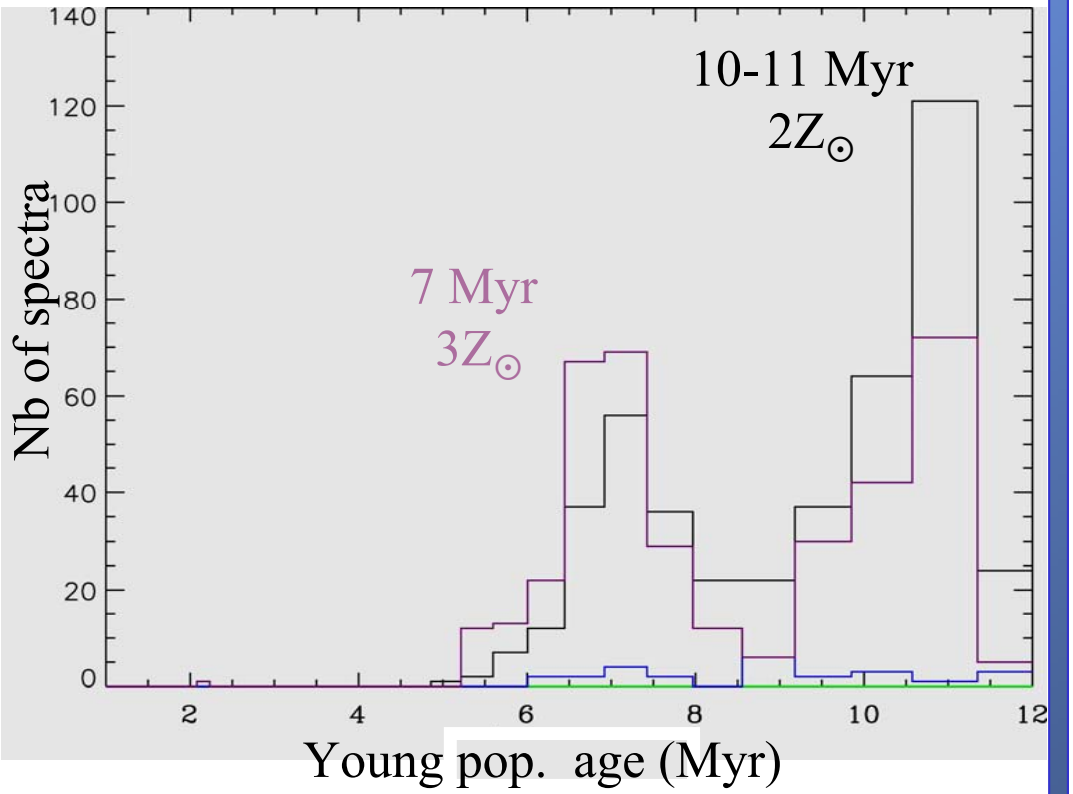


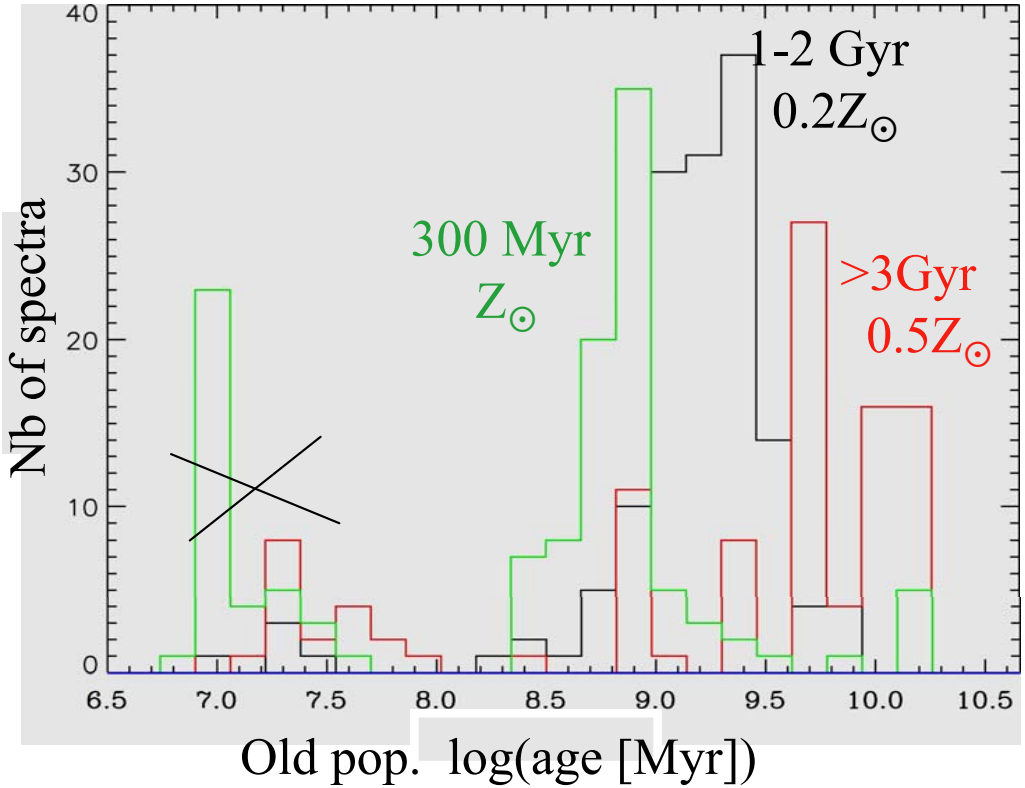
From :

700 Myr
(near edge)

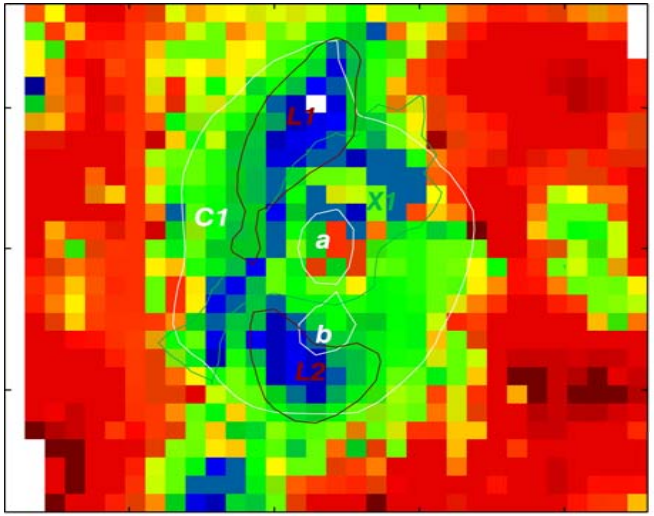
to 4 Gyr
(center)

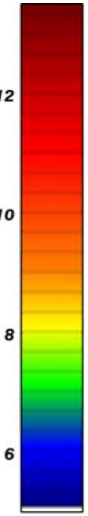
average:
1.6 Gyr





Hα & Hβ emis. : young pop. age.





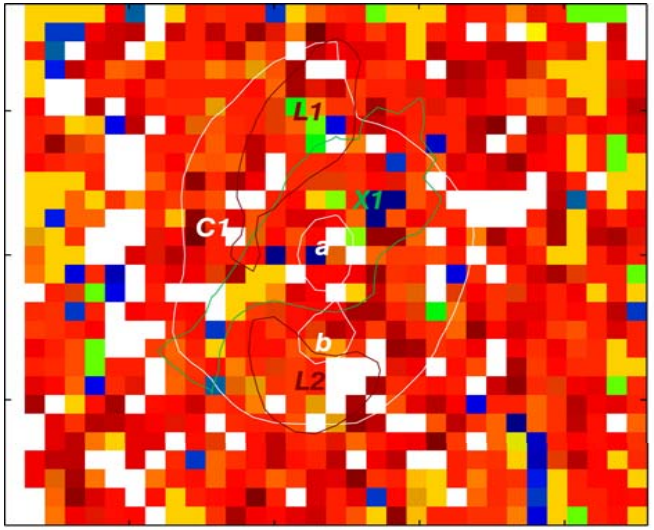
in Myr

L1, L2: 6.2±0.8

C1a: 10.2±0.2

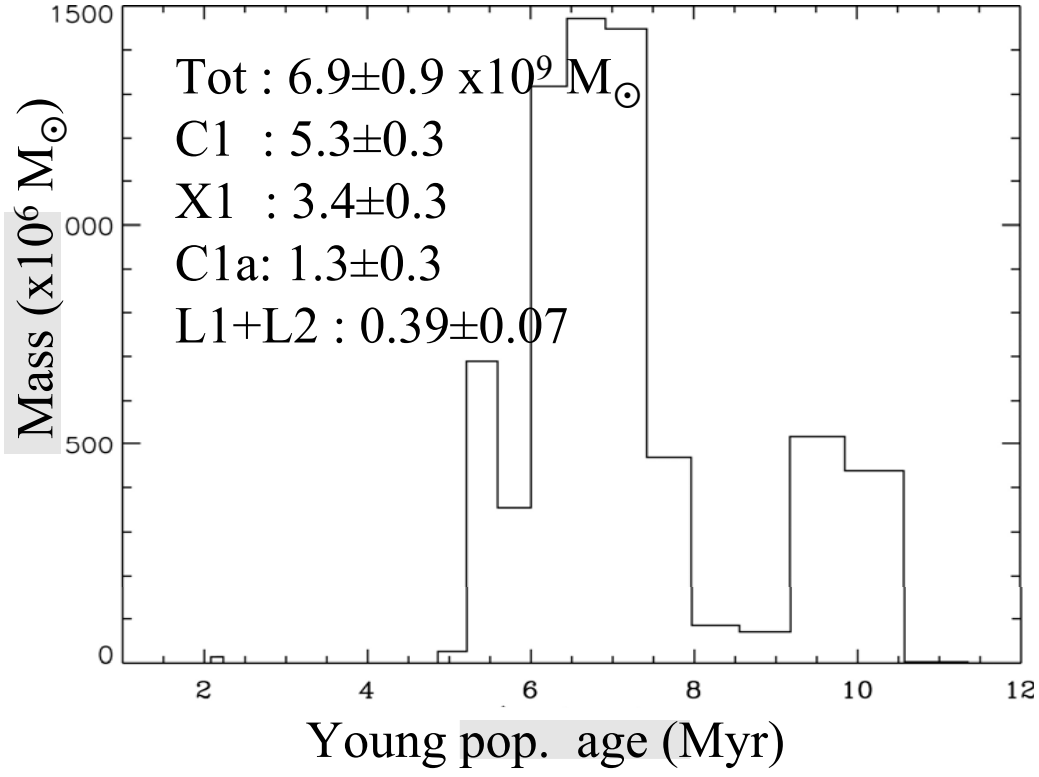
around: 9 to 13

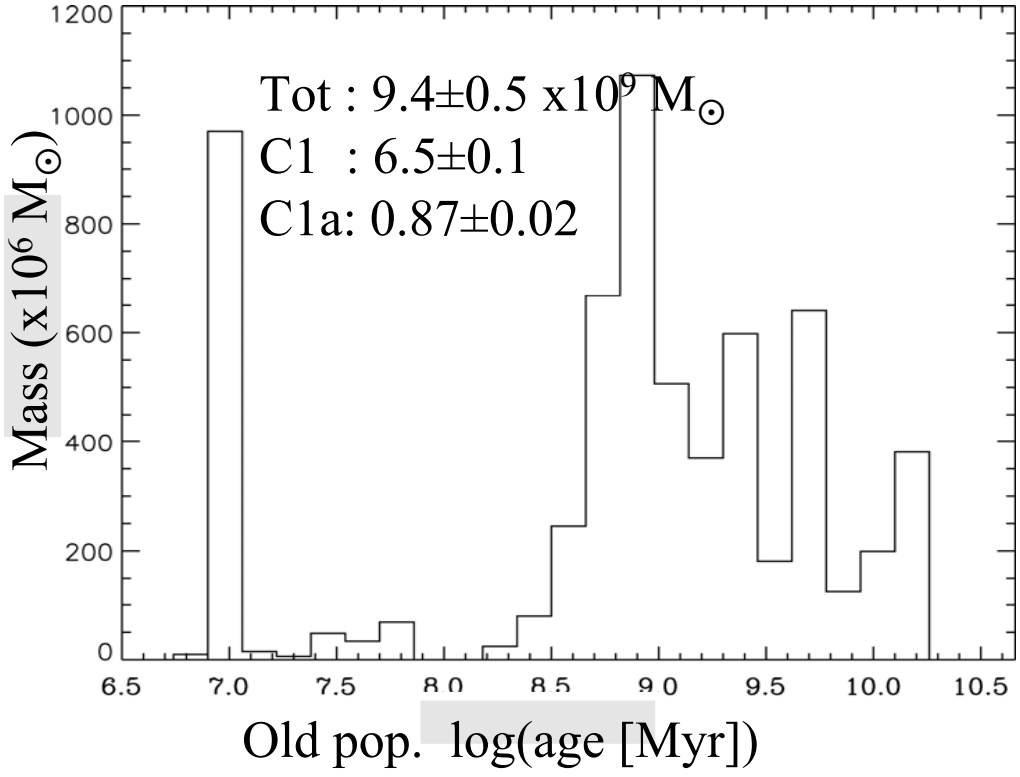
Hβ, Mg_2 & FeI abs. lines : old pop.age



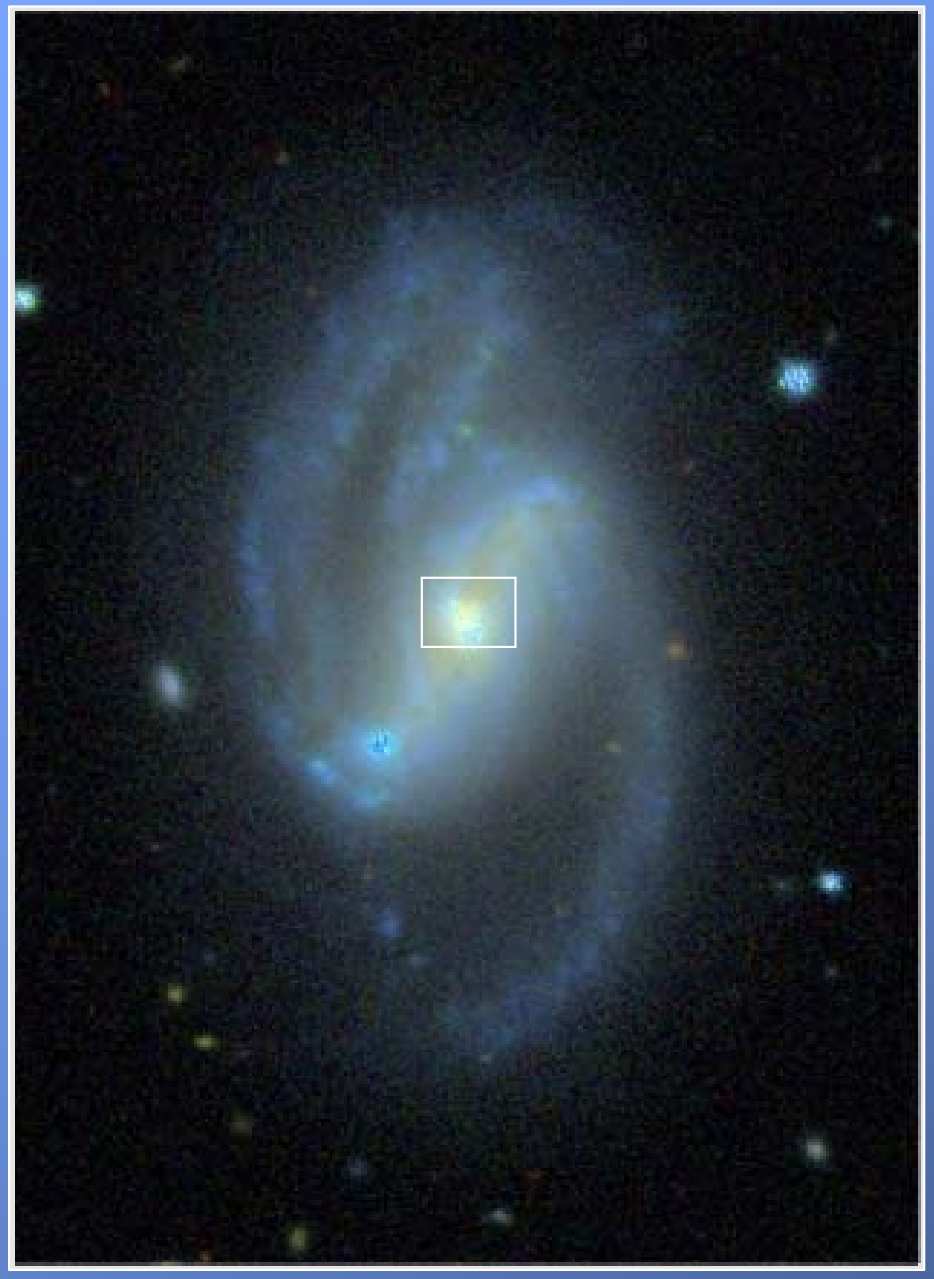
From : 700 Myr (near edge) to 4 Gyr (center)

average: 1.6 Gyr





NGC5430 with
OASIS & SpIOMM



- Nuclear ring or
  2 tight nuclear spirals extending into the bar
  with young populations of 6-7 Myr, 2 $Z_{\odot}$
  TFS = 3.51±0.2 $M_{\odot}$/yr
  dusty nuclear bar

- Weak nuclear activity & chocs

- Central region = underlying superposition of
  old bursts which took place
  300 Myr to 10 Gyr ago
  (max amplitude ~ 1Gyr)
  with variable low Z

- Galaxy bar is a mixing agent
  other HIIR at 6 Myr …

⇒ Secular evolution building up a pseudobulge
(Kormendy & Kennicutt 2004)
- slow & older phases used the internal gas
  and new gas (environment)
- recent phase indicates a clear role
  by the galaxy bar to bring gas
  into the central region

SpIOMM

- Imaging Fourier Transform Spectro.
  'True' Integral field spectrometer
  = a spectrum for every pixel
- Wide field 12'x12'
  10 000 times Gemini GMOS/IFU
  100 times VLT/MUSE
- High spatial resolution (seeing limited)
- Broad spectral range in the visible
  + filters
- R = 1 - 25 000

To do: Replace beamsplitter
+ Second CCD

Next: SITELLE for the CFHT

OASIS

- Lenslet array with a grism
  = need to work out the instrument optical path
- Small field 10''
- High spatial resolution +NAOMI
- Many wavelength configurations in the visible
- R = 200 - 4000

To do: blue CCD

Next… important to have didicated projects (like SAURON)