

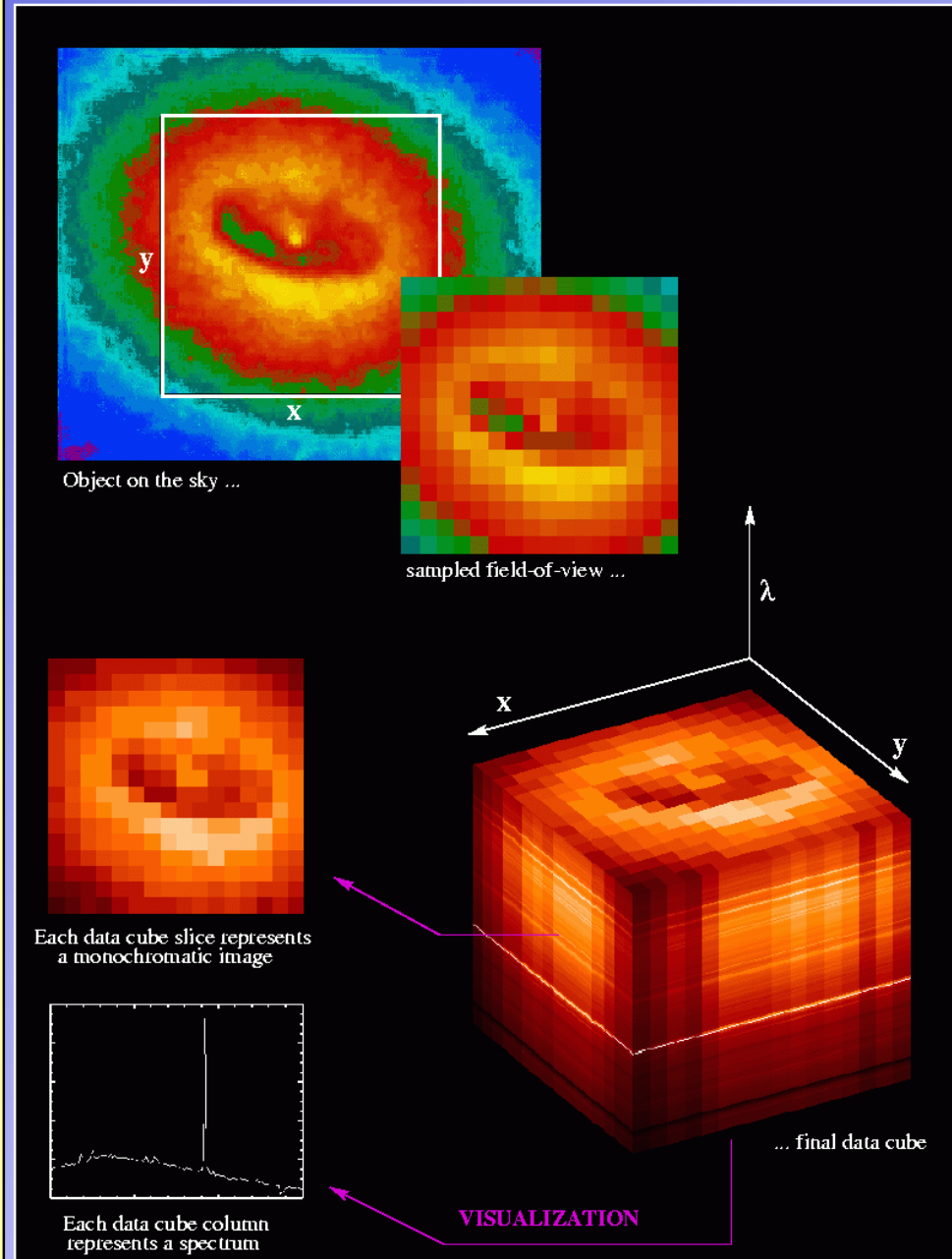
Espectroscopía de Campo Integral

Instrumentación Astronómica -Espectroscopía 3D-
África Castillo

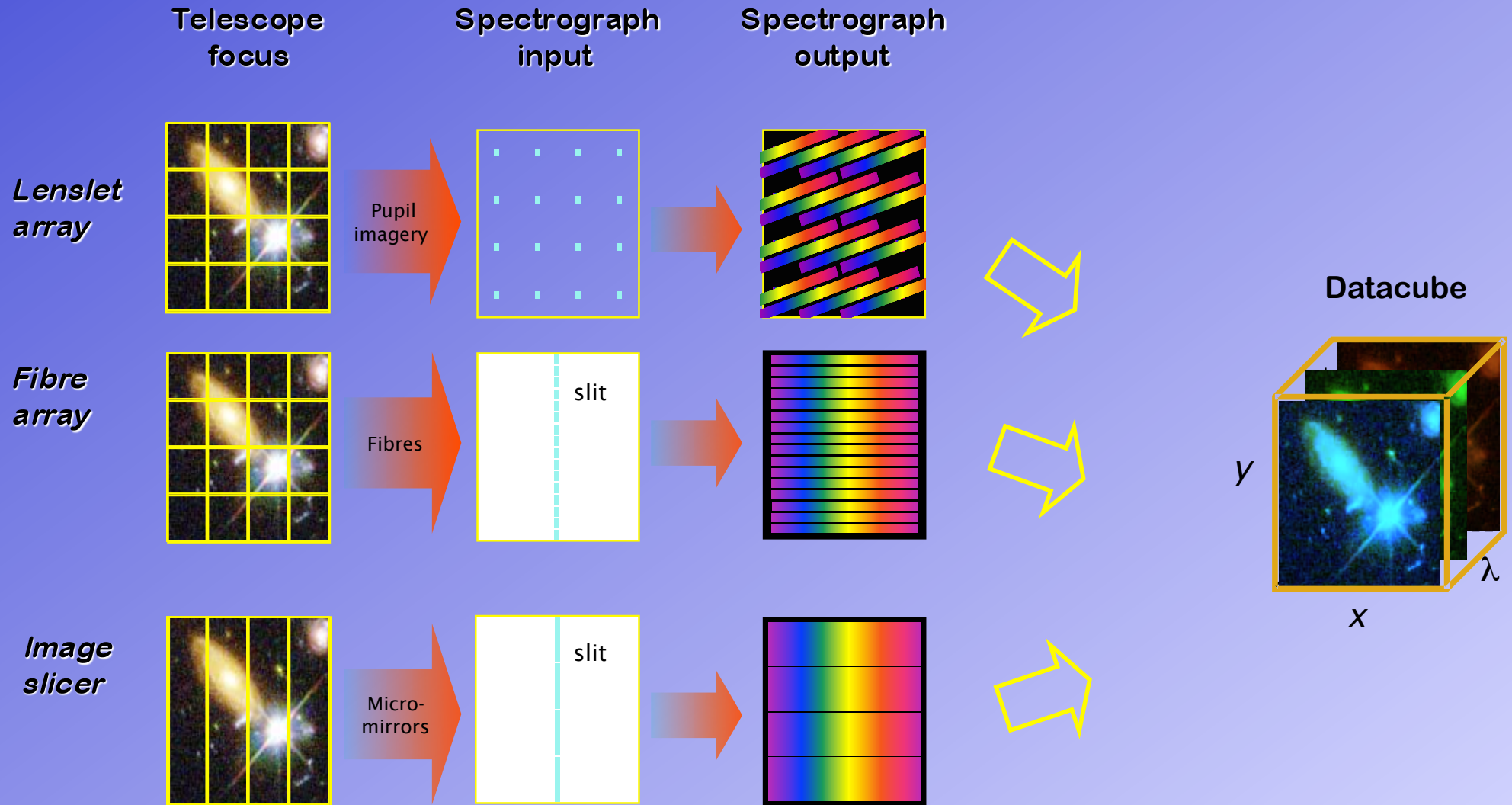
Espectrógrafos de campo integral

Espectrógrafos de haces de fibras:

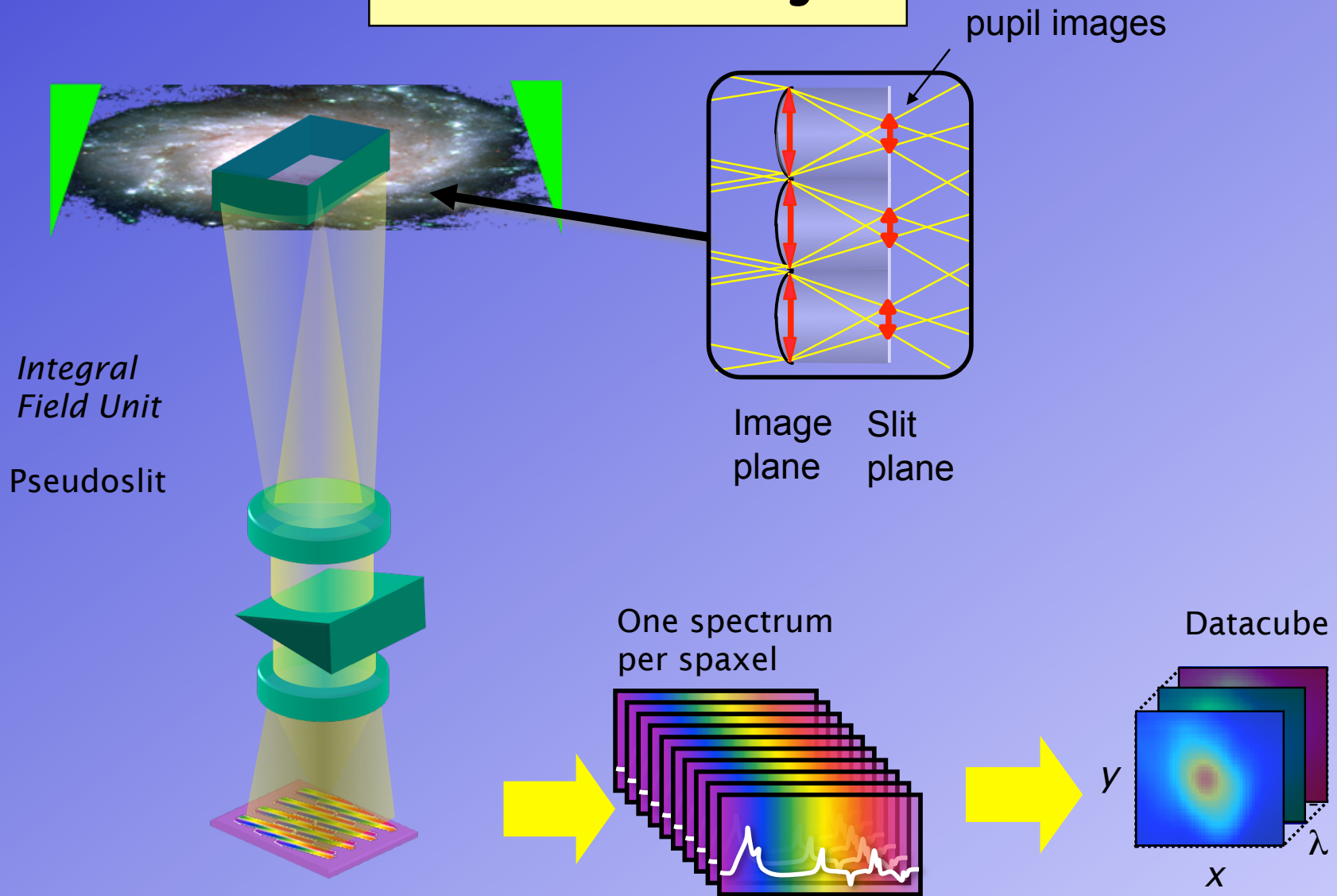
- Una zona bidimensional del cielo (blanco) es muestreado en elementos espaciales discretos (SPAXELS)
- Espectros individuales de cada SPAXEL simultáneamente en todo el FOV
- Tras la reducción, los espectros individuales se reorganizan para formar un cubo en 3 dimensiones (2 espaciales y 1 en longitud de onda; espectroscopía 3D)
- Alternativamente, es posible crear imágenes monocromáticas o en bandas fotométricas concretas a partir de rebanadas del cubo
- Debido a la refracción atmosférica, el cubo se deforma en un romboide debido al desplazamiento espacial en función de la longitud de onda.



Principales técnicas de espectroscopía integral



Lenslet arrays



Lenslet-coupled fibre arrays

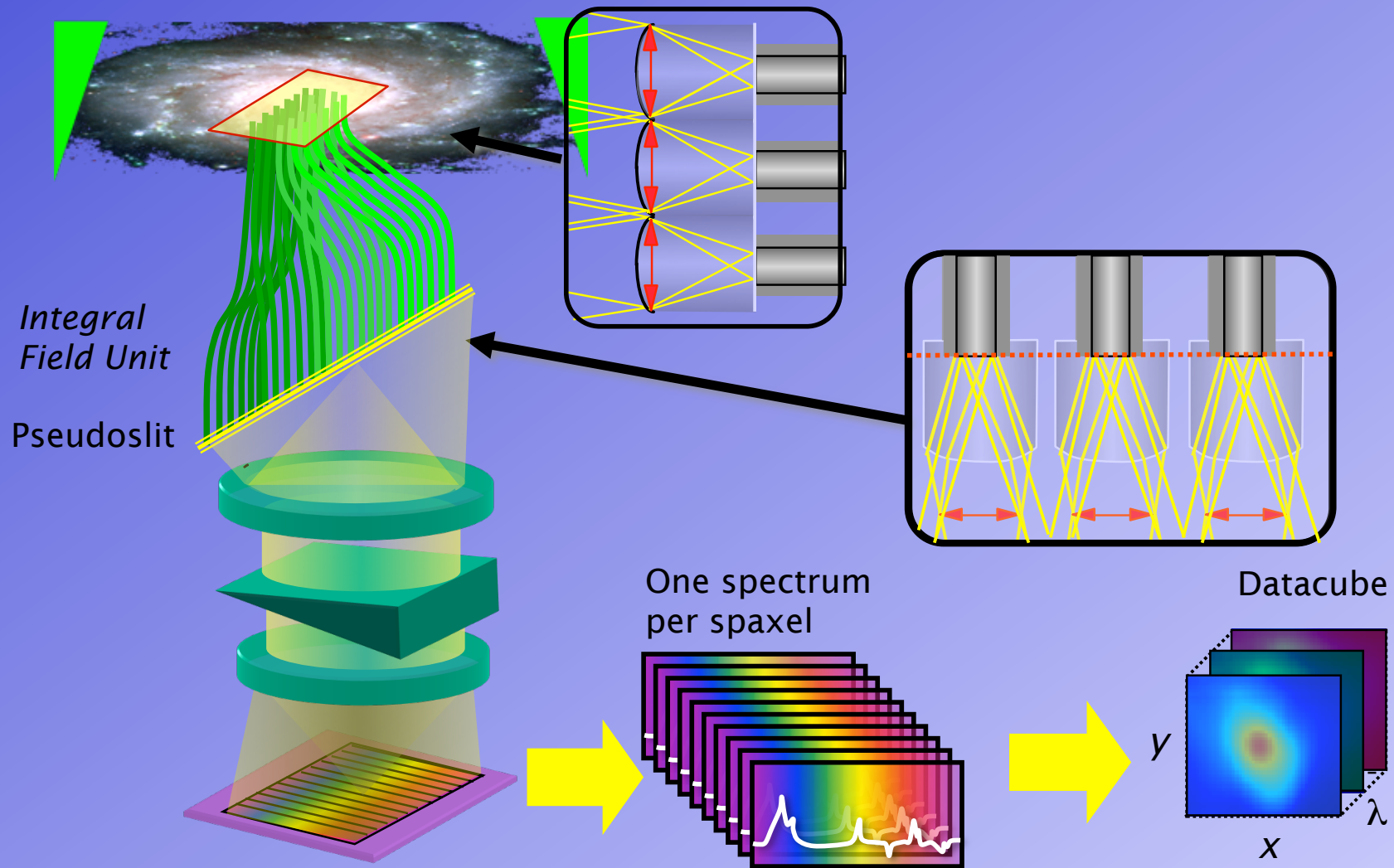
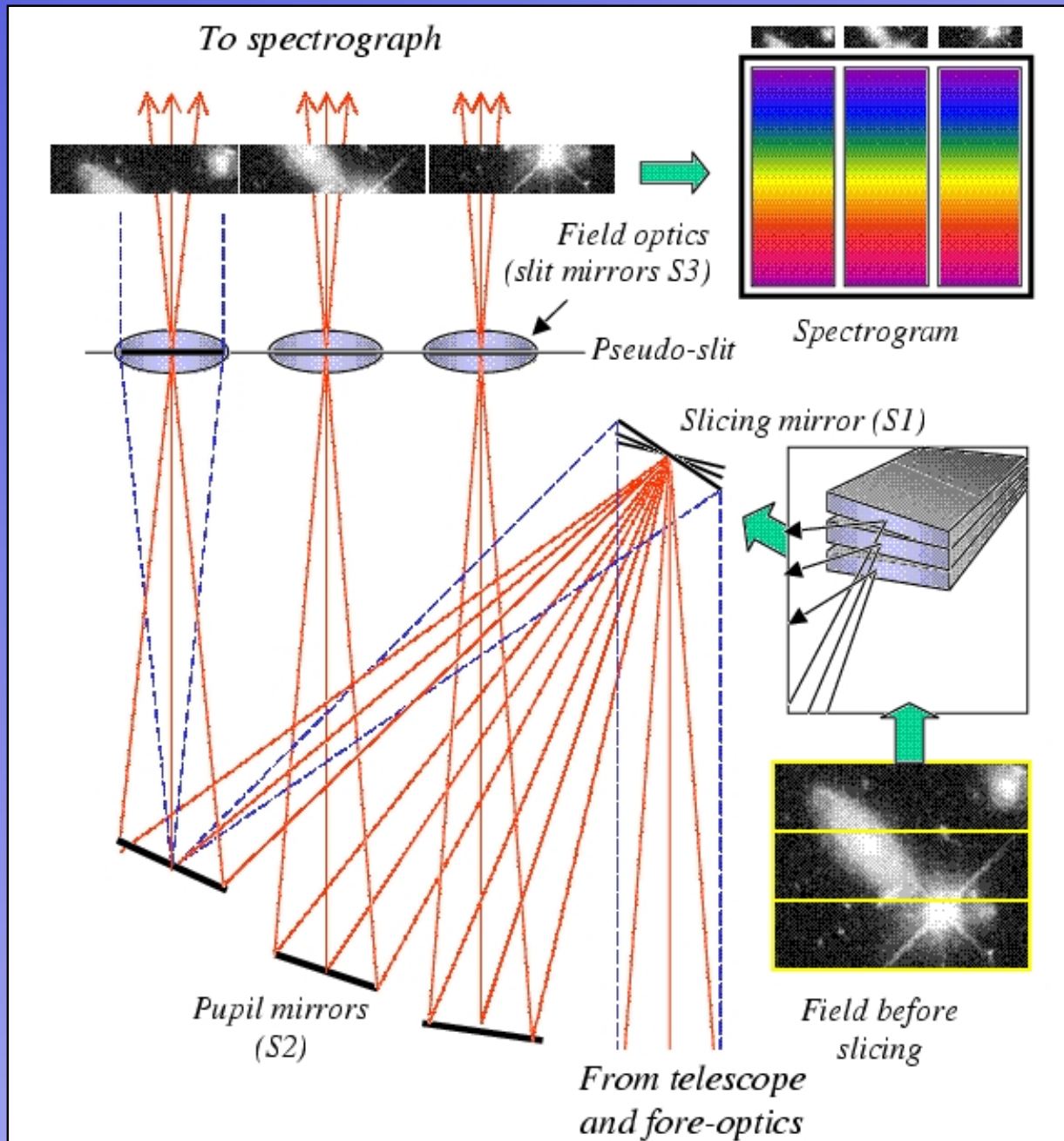


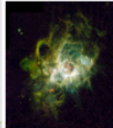

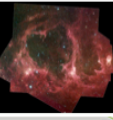
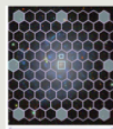

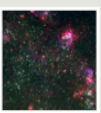



Image slicers



SUMMARY INSTRUMENT

MEGARA (Multi-Espectrógrafo en GTC de Alta Resolución para Astronomía) is an optical Integral-Field Unit (IFU) and Multi-Object Spectrograph (MOS) designed for the GTC 10.4m telescope in La Palma. The MEGARA IFU mode will offer two different bundles, one covering 14" x 12" with a spaxel size of 0.685" (Large Compact Bundle; LCB) and another one covering 10" x 8" with a spaxel size of 0.480" (Small Compact Bundle; SCB). The MEGARA MOS will allow observing up to 100 objects in a region of 3.5' x 3.5' around the two IFU bundles. Eight of these bundles will be devoted to the determination of the sky during the observation with the LCB IFU. Both the LCB IFU and MOS capabilities of MEGARA will provide intermediate-to-high spectral resolution ($R \sim 6000, 11000$ and 19000). When the SCB is used the resolving powers provided by MEGARA are $R = 8000, 14500$ and 25000 .

SCIENCE DRIVERS

Milky Way	HII REGIONS 	PLANETARY NEBULAE 	STELLAR CLUSTERS 
	STAR-FORMING GALAXIES 	NEARBY GALAXIES 	RESOLVED STELLAR POPULATIONS 
Local Universe	HIGH-Z GALAXIES 	HIGH-Z ISM 	

SCIENCE TEAM



...plus 35 researchers from Spain, Mexico & UF not in the photo.

PI Armando Gil de Paz

agil@fis.ucm.es

PM Marisa García Vargas

marisa.garcia@fractal-es.com

INSTRUMENT TEAM



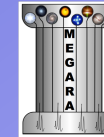
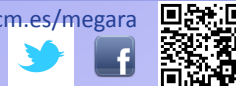
CONSORTIUM led by the UCM, with the collaboration of INAOE, IAA & UPM



PARTICIPATING COMPANIES

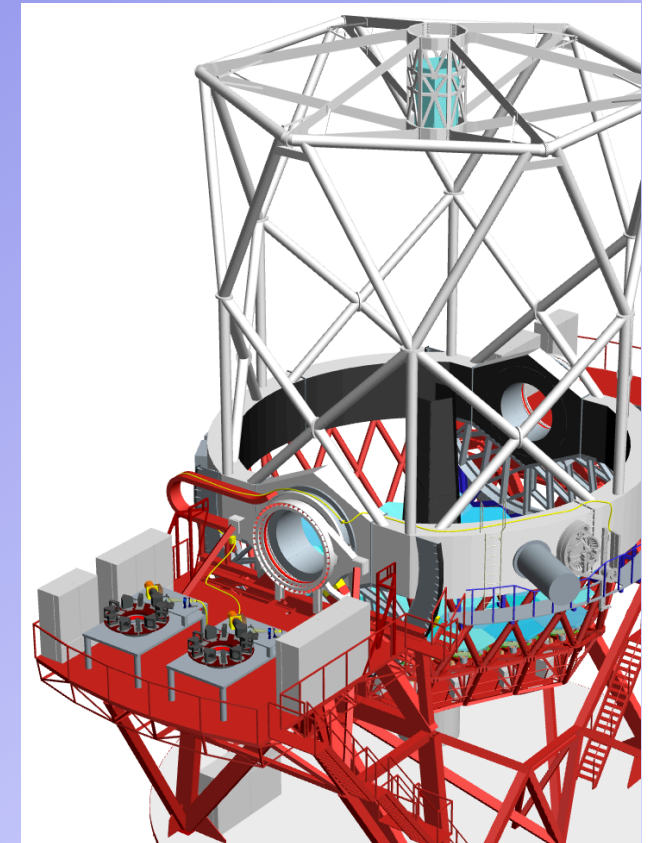


For more info visit <http://guaix.fis.ucm.es/megara>
You can follow us at [megara_project](#)



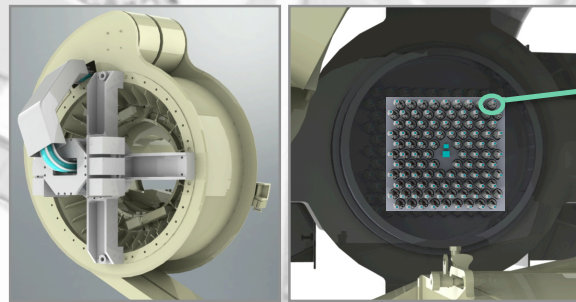
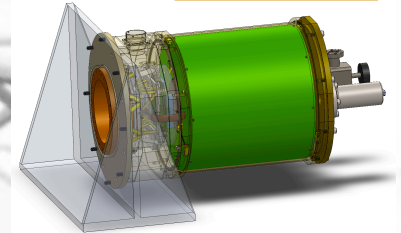
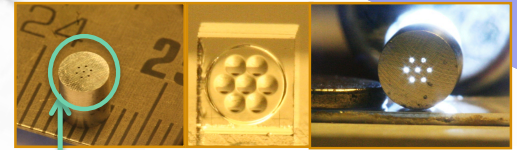
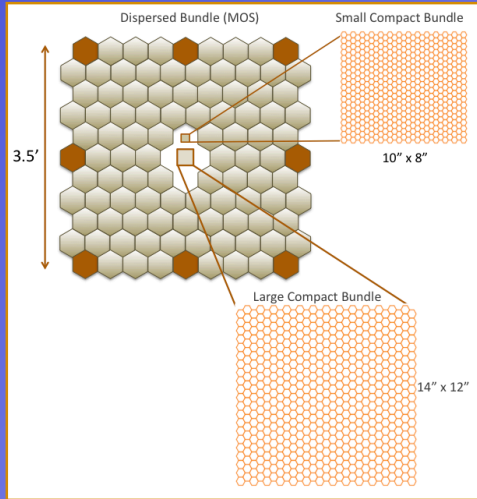
MEGARA

The future optical IFU & MOS for the 10.4m GTC

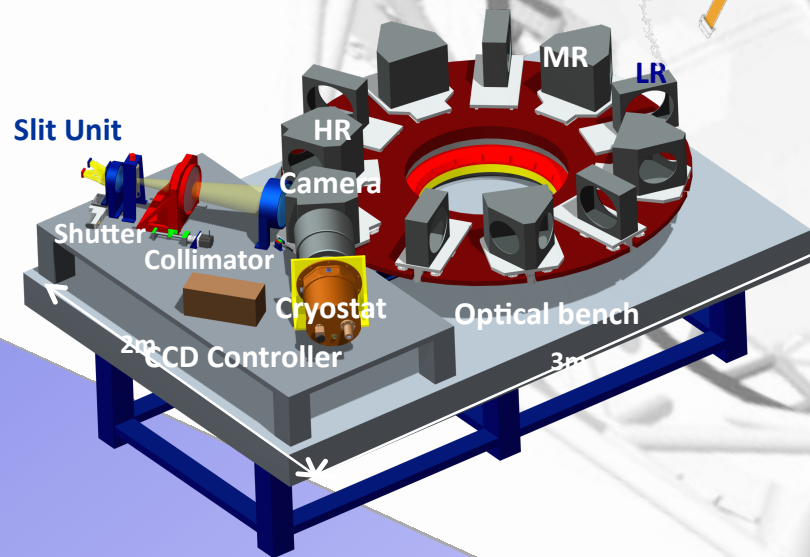
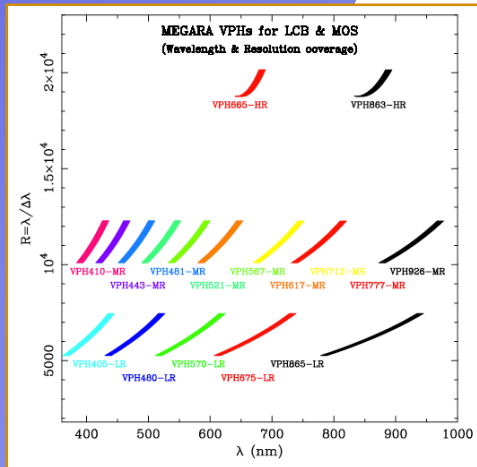


MEGARA

Multi Espectrógrafo en GTC de Alta Resolución para Astronomía



		LCB	SCB	MOS
Spaxel size		0.685 arcsec	0.480 arcsec	0.685 arcsec
Field of View		14 x 12 arcsec ²	10 x 8 arcsec ²	3.5 x 3.5 arcmin ²
$\Delta\lambda$ (1D)		3.5 pix	2.7 pix	3.5 pix
R ($\lambda/\Delta\lambda$)	LR	R _{ID} ~6,250 R _{FEED80} ~5,500	R _{ID} ~8,100 R _{FEED80} ~7,000	R _{ID} ~6,250 R _{FEED80} ~5,500
		R _{ID} ~11,000 R _{FEED80} ~10,000	R _{ID} ~14,400 R _{FEED80} ~13,000	R _{ID} ~11,000 R _{FEED80} ~10,000
	MR	R _{ID} ~19,100 R _{FEED80} ~17,000	R _{ID} ~24,700 R _{FEED80} ~22,000	R _{ID} ~19,100 R _{FEED80} ~17,000
		HR		



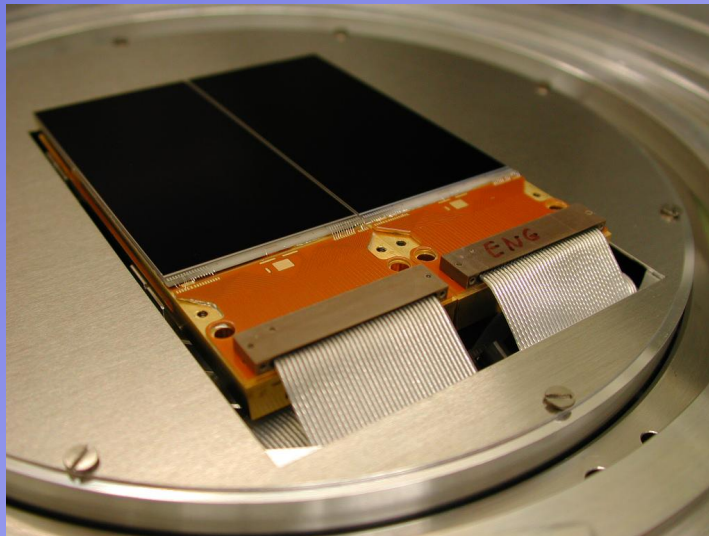
VPH Name	Setup	R _{ID}	$\lambda_1 - \lambda_2$ (Å)	λ_c (Å)	$\Delta\lambda$ @ λ_c	km/s	Å/pix
VPH405-LR	LR-U	6,251	3,670-4,402	4,051	0.648@4,051	48	0.185
VPH480-LR	LR-B	6,251	4,348-5,216	4,800	0.768@4,800	48	0.219
VPH570-LR	LR-V	6,250	5,164-6,194	5,700	0.912@5,700	48	0.261
VPH675-LR	LR-R	6,249	6,115-7,334	6,749	1.080@6,749	48	0.309
VPH865-LR	LR-I	6,248	7,836-9,399	8,650	1.384@8,650	48	0.396
VPH410-MR	MR-U	11,069	3,890-4,309	4,104	0.370@4,104	27	0.106
VPH443-MR	MR-UB	11,067	4,200-4,652	4,431	0.400@4,431	27	0.114
VPH481-MR	MR-B	11,067	4,562-5,054	4,814	0.435@4,814	27	0.124
VPH521-MR	MR-G	11,065	4,941-5,472	5,213	0.471@5,213	27	0.135
VPH567-MR	MR-V	11,065	5,371-5,950	5,667	0.512@5,667	27	0.146
VPH617-MR	MR-VR	11,064	5,847-6,477	6,170	0.558@6,170	27	0.159
VPH712-MR	MR-R	11,064	6,744-7,470	7,115	0.643@7,115	27	0.184
VPH777-MR	MR-I	11,063	7,362-8,154	7,767	0.702@7,767	27	0.201
VPH926-MR	MR-Z	11,062	8,778-9,723	9,262	0.837@9,262	27	0.239
VPH665-HR	HR-R	19,079	6,450-6,841	6,646	0.348@6,646	16	0.099
VPH863-HR	HR-I	19,079	8,379-8,887	8,634	0.452@8,634	16	0.129

MEGARA Quik facts:
 IFUs: 14"x12" & 10"x8"
 MOS: x100 in 3.5'x3.5'
 R=6000-25000
 First Light: 2015

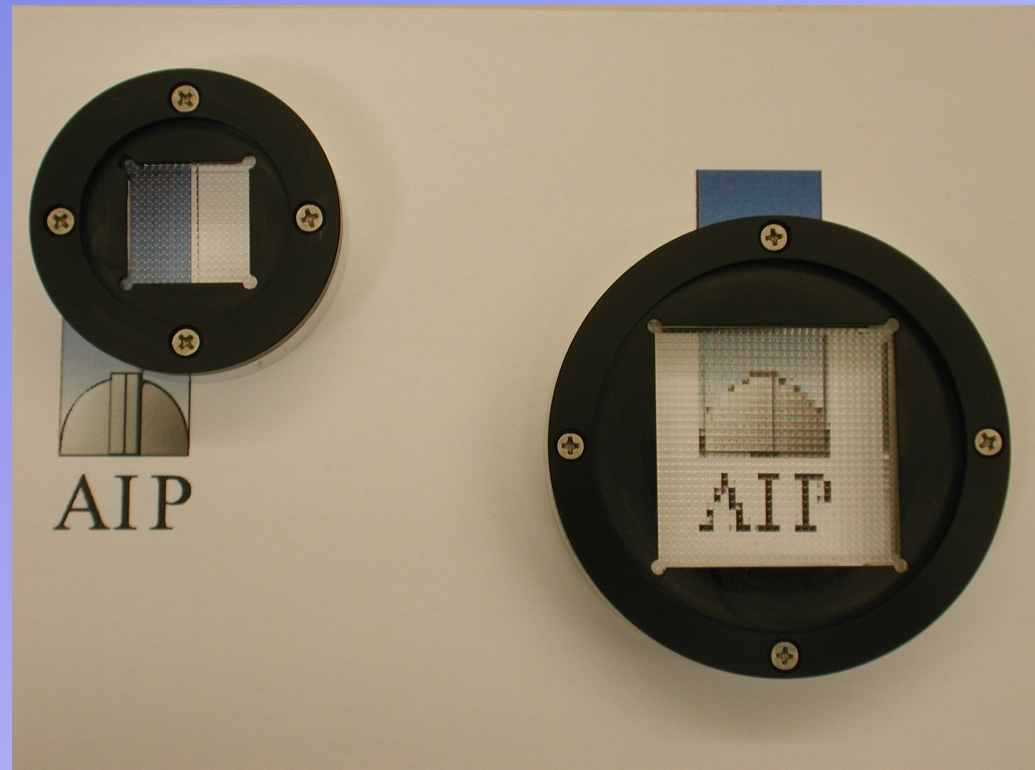
Espectrógrafo de campo integral PMAS @ 3.5-m telescopio CAHA Lentes+fibras

- FOV pequeño
- Alta resolución espacial

- 16x16 lentes (elementos)
- Escalas de 0"5, 0"75 y 1"0
- FOV de 8x8, 12x12 y 16x16 arcsec
- Diferentes redes de difracción para varias resoluciones espectrales
- 2 CCDs de 2kx4k, píxel 15 μ m



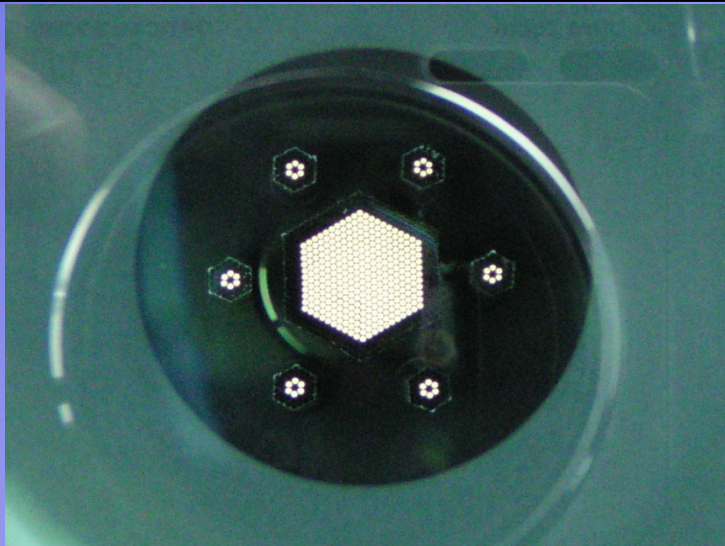
PMAS (CAHA 3.5m)
<http://www.caha.es/pmas/>



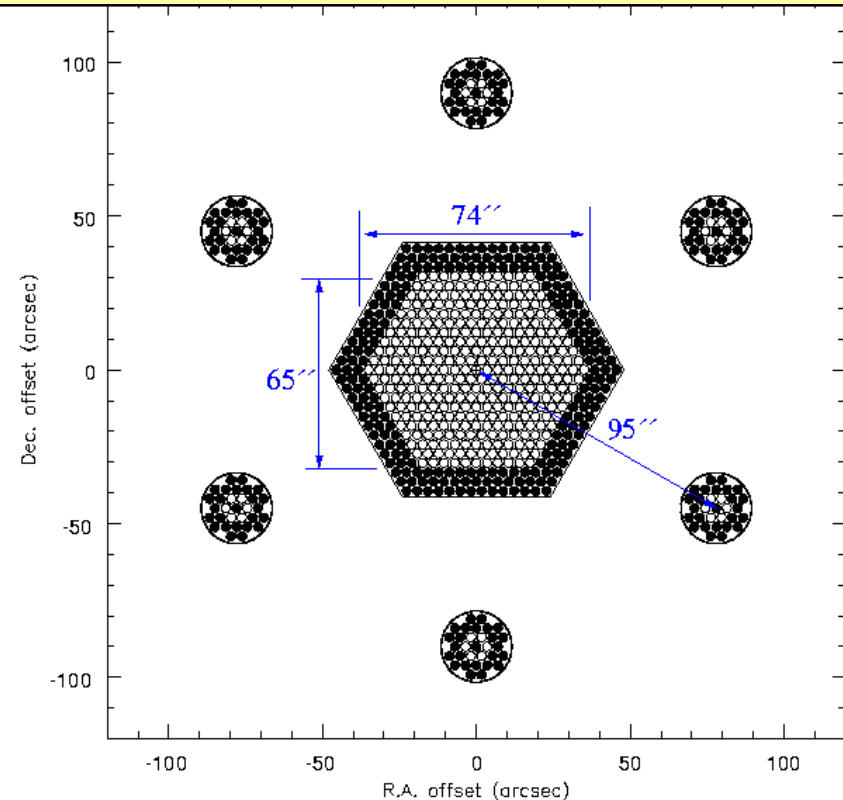
Espectrógrafo de campo integral PPAK @ 3.5-m telescopio CAHA Fibras

- FOV grande
- Baja resolución espacial

- Reductor de focal
- 2.7 '' / fibra
- Mazo hexagonal
- 331 fibras de 150 μ m y 2m largo
- Diferentes redes de difracción para varias resoluciones espectrales
- 18 Mb por fichero



PMAS (CAHA 3.5m)
<http://www.caha.es/sanchez/pmas/pmas.html>

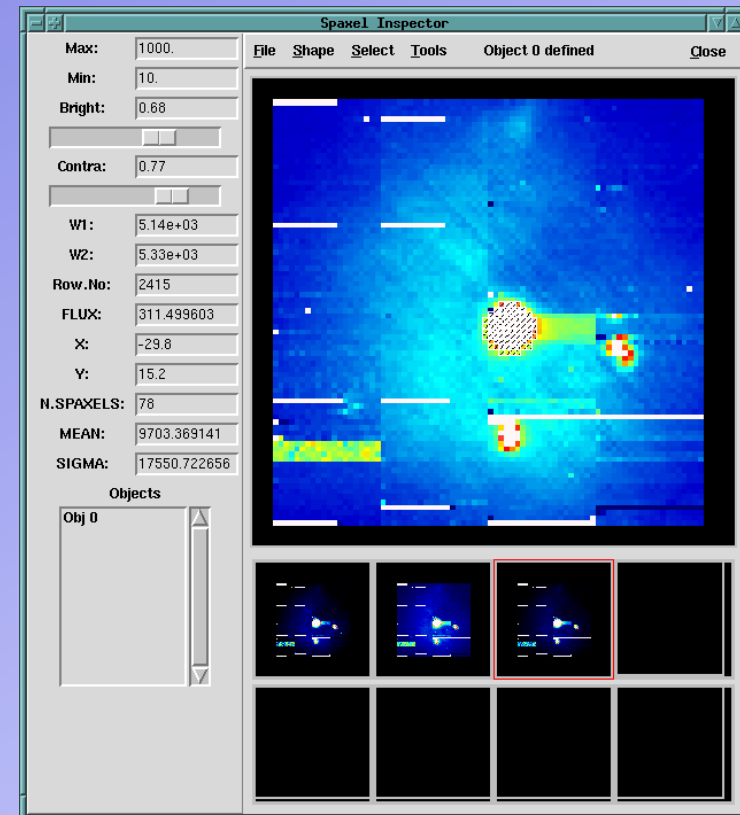
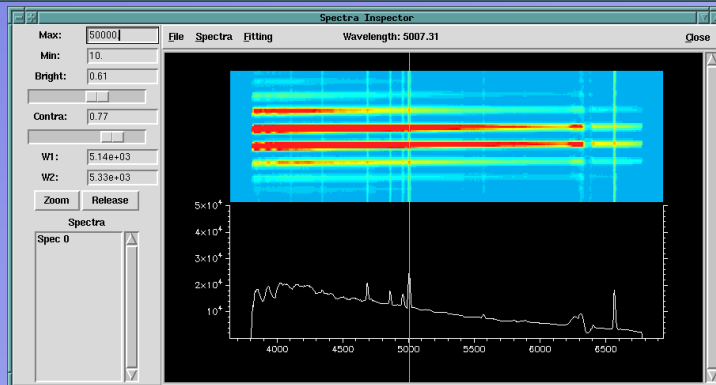
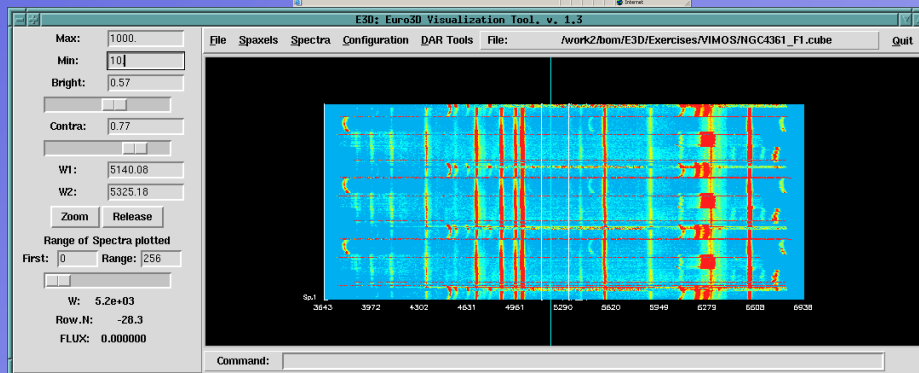
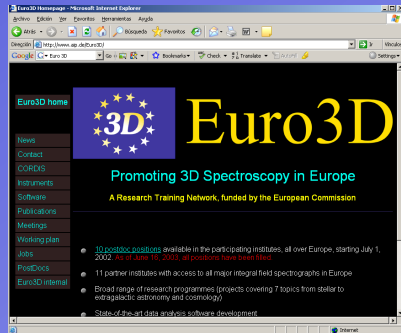


- Reducción y tratamiento de datos complicado:

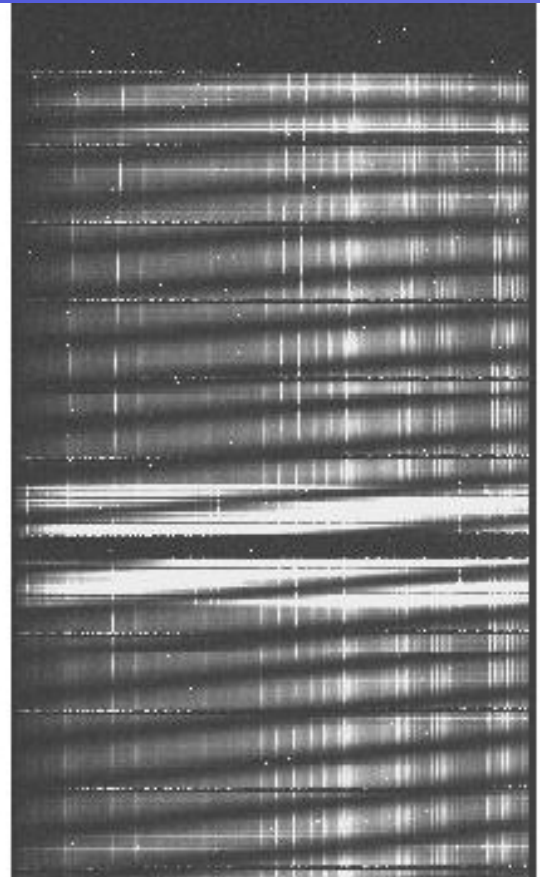
- Euro3D
- Estándar de NOAO
- UK 3D

RTN Euro3D

- nuevo formato
- librerías en C
- Herramienta de visualización
 - Spaxels inspector
 - Spectra inspector



Espectroscopía 3D en el visible



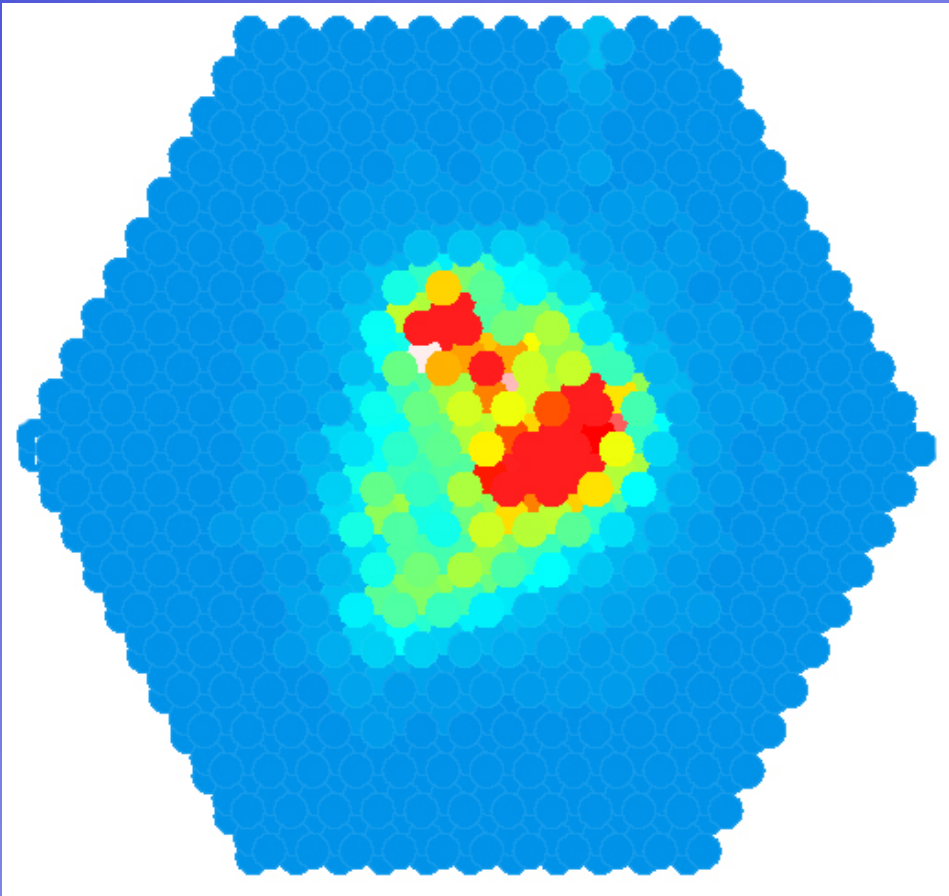
Pipeline reduction

R3D (Sánchez, S.F. astroph-0606263)

E3D (Sánchez, S.F, AN, 325, 167 2004)

- * Bias subtraction
- * Cosmic rays elimination
- * Distortion correction
- * Wavelength calibration
- * Sky subtraction
- * Flux calibration
- * Differential atmospheric refraction correction
- * Image reconstruction through dithering

Espectroscopía 3D en el visible



Pipeline reduction

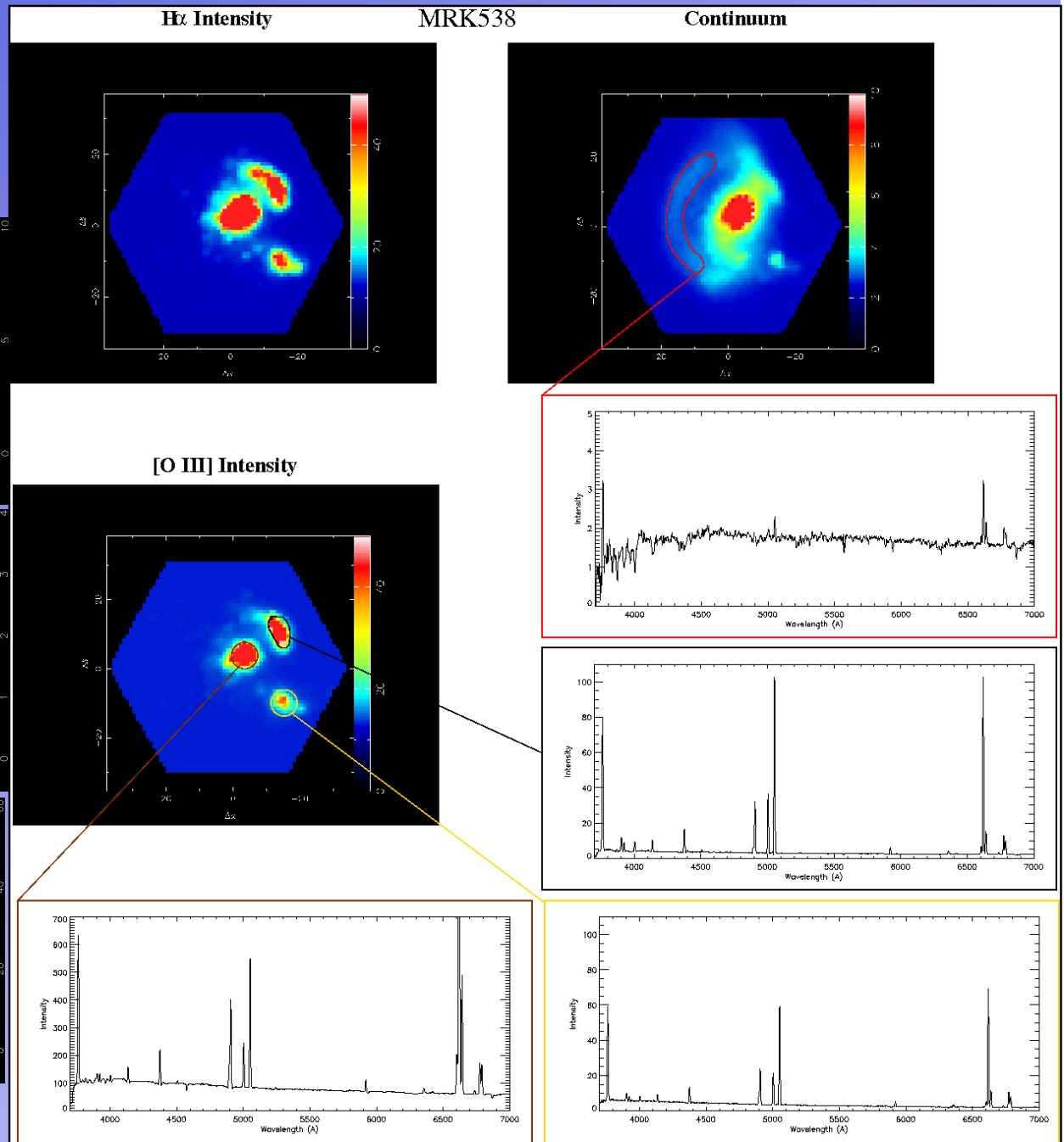
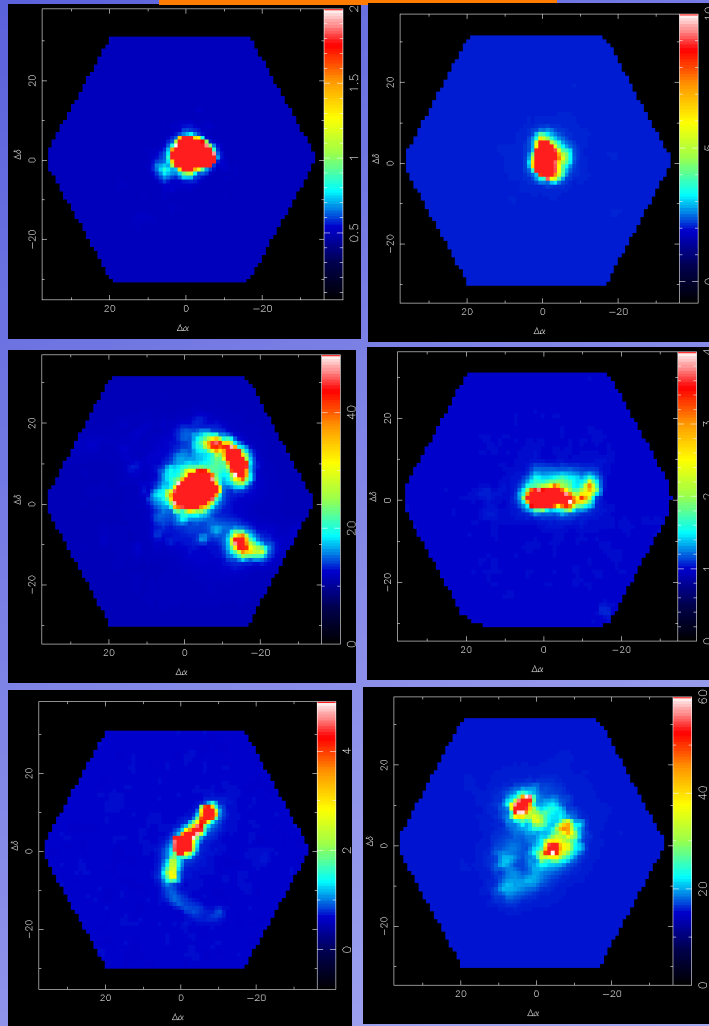
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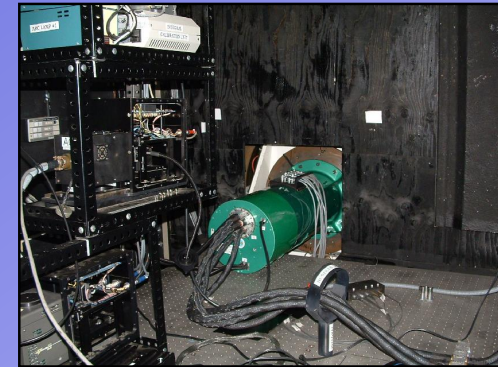
Espectroscopía 3D en el visible

H α intensity maps



Espectrógrafo de campo integral INTEGRAL @ 4.2-m telescopio WHT Fibras

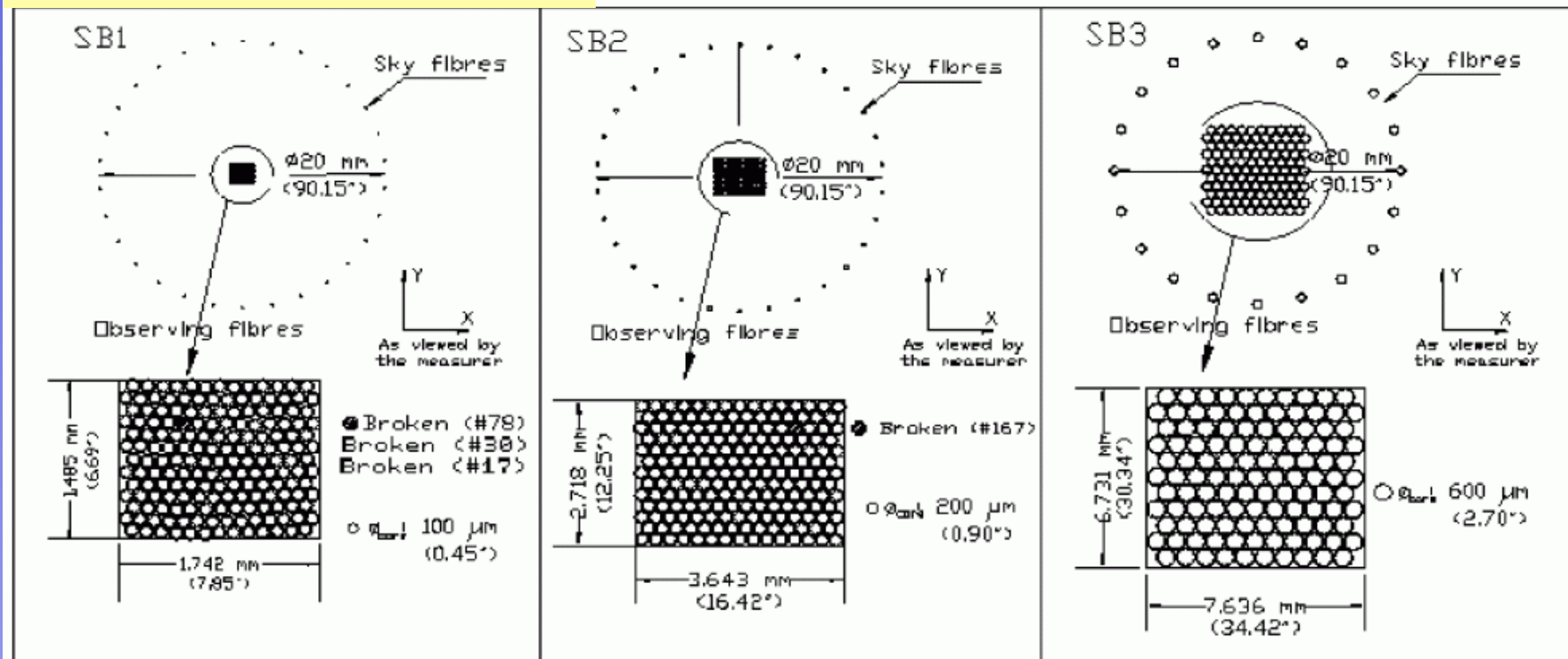
- Campo rectangular central + anillo fibras de cielo
- Fibras no contiguas (~40% pérdida)
- 3 mazos 0"45, 0"9 y 2"7 / fibra
- ~200 fibras de 5.5m largo



INTEGRAL (WHT 4.2m)

<http://www.iac.es/proyect/integral/>

Haces de fibras de INTEGRAL

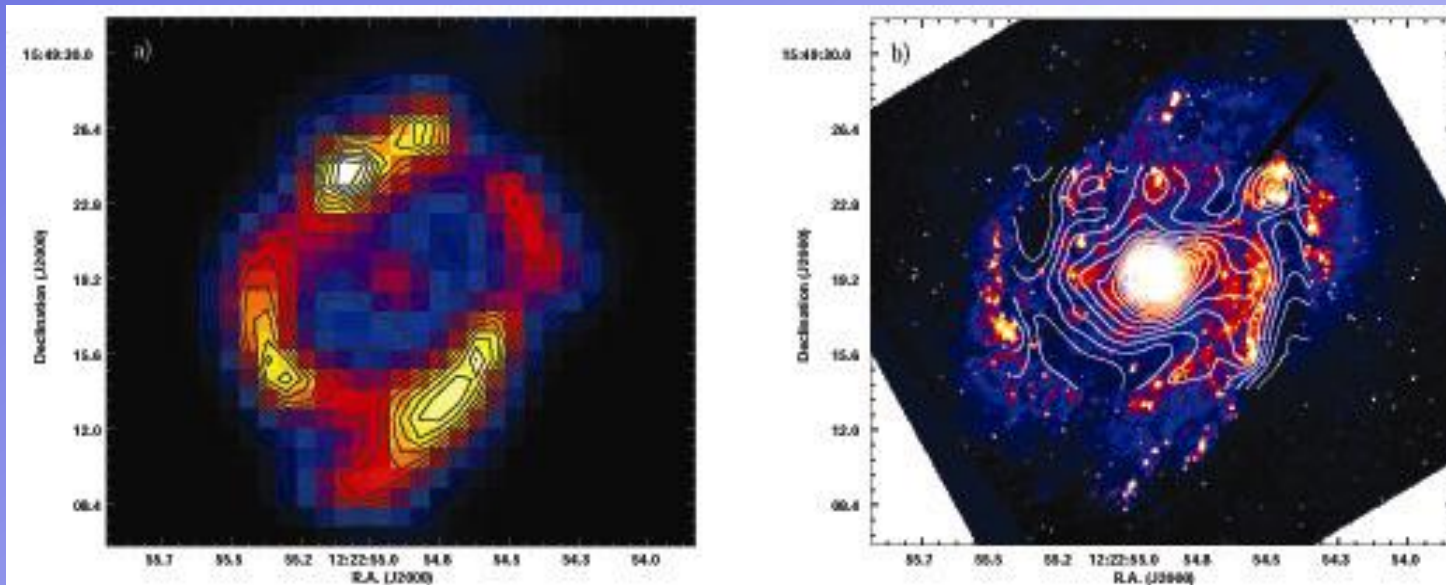


Espectroscopía 3D en el visible

Espectrógrafos de Campo Integral:

Con ellos se pueden hacer mapas de intensidad, de velocidad, de índices espectrales ...

Mapa de Intensidad $H\alpha$ para galaxia M100 (INTEGRAL)



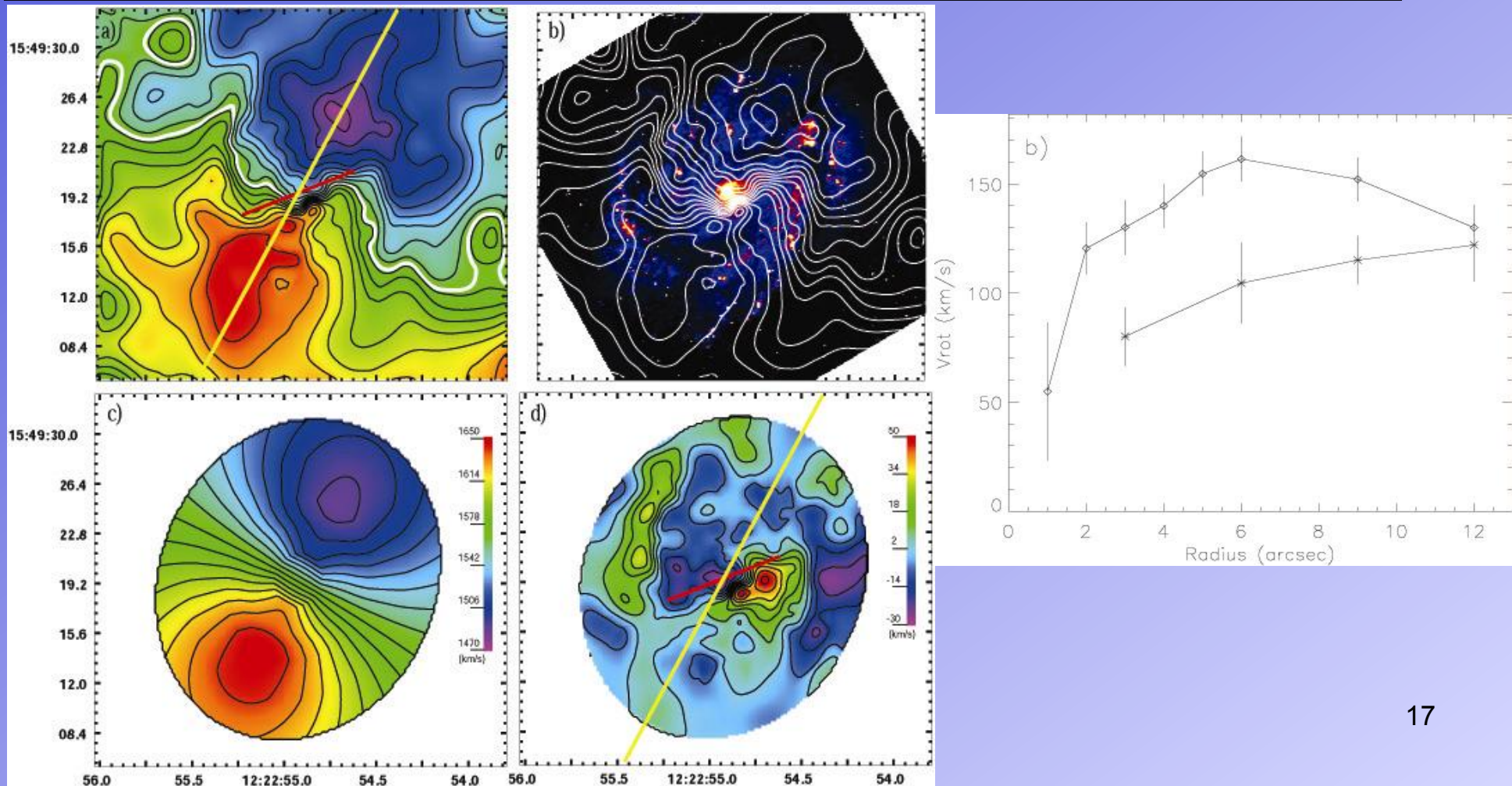
Mapa de continuo para galaxia M100 (INTEGRAL)

Espectroscopía 3D en el visible

También podemos estudiar la cinemática del gas y obtener curvas de rotación

Non-circular motion evidences in the circumnuclear region of M100 (NGC 4321)

(Castillo-Morales et al 2007)



Espectrógrafo de campo integral SINFONI @ 8-m telescopio VLT Rebanador de imagen



Características:

.Consiste en un módulo de **AO** y un espectrógrafo de campo integral **SPIFFI** (32 rebanadas).

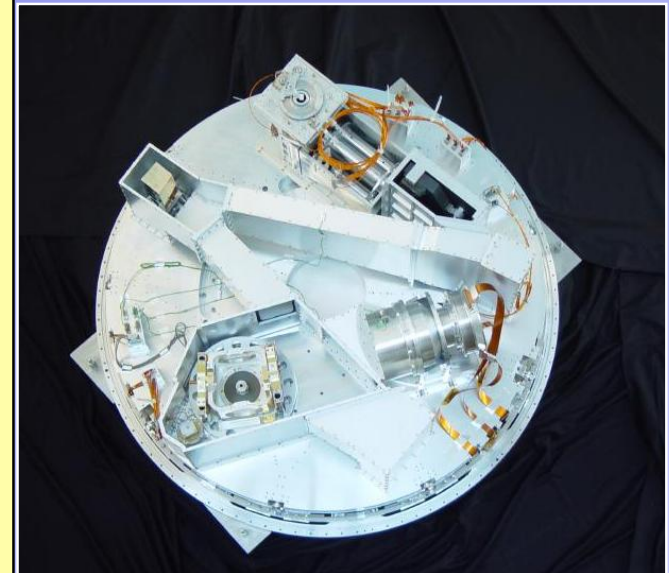
.(S**P**ectrometer for Infrared Faint Field Imaging)

* SPIFFI: NIR (1.1 - 2.45 μm) , instalado en el foco Cassegrain de UT4.

* 4 gratings (J, H, K, H+K) que proporcionan resoluciones de 2000, 3000, 4000 en J, H, K, respectivamente, y 1500 en H+K.

* Detector Hawaii 2RG (2kx2k)

* Resolución espacial 0.25", 0.1" y 0.025" por rebanada, se corresponde con un FOV de 8"x8", 3"x3", y 0.8"x0.8" respectivamente

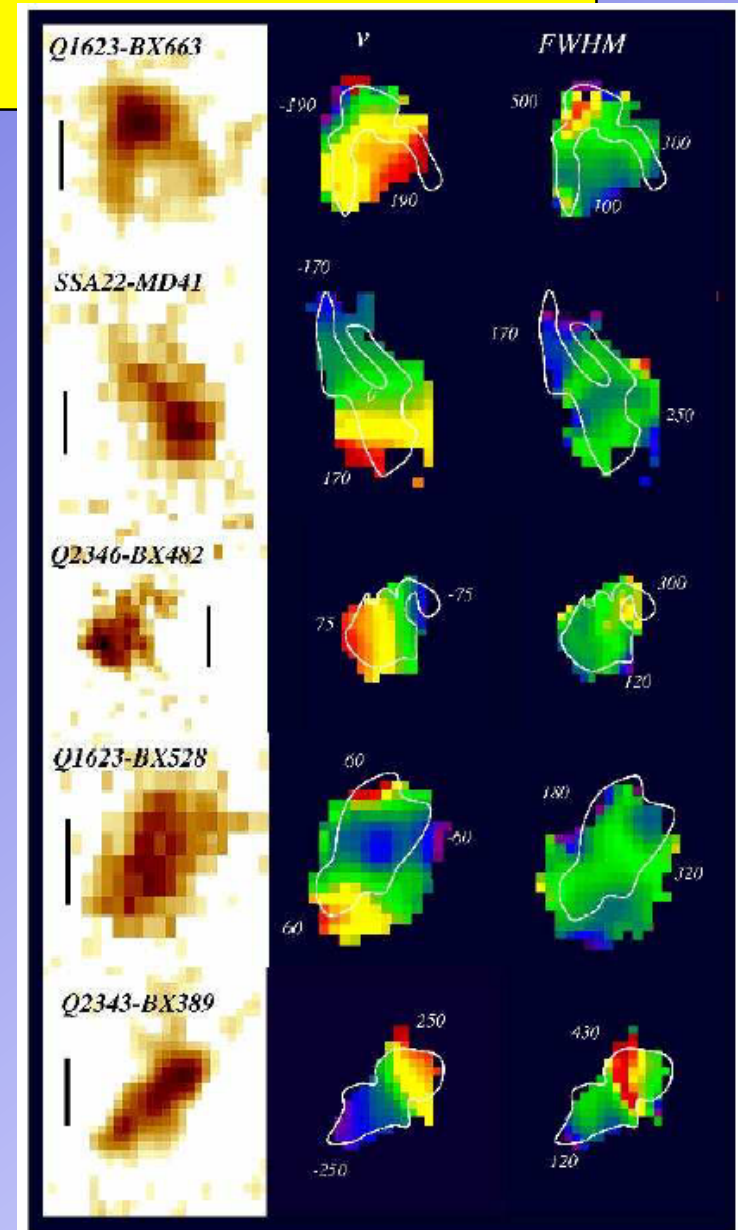
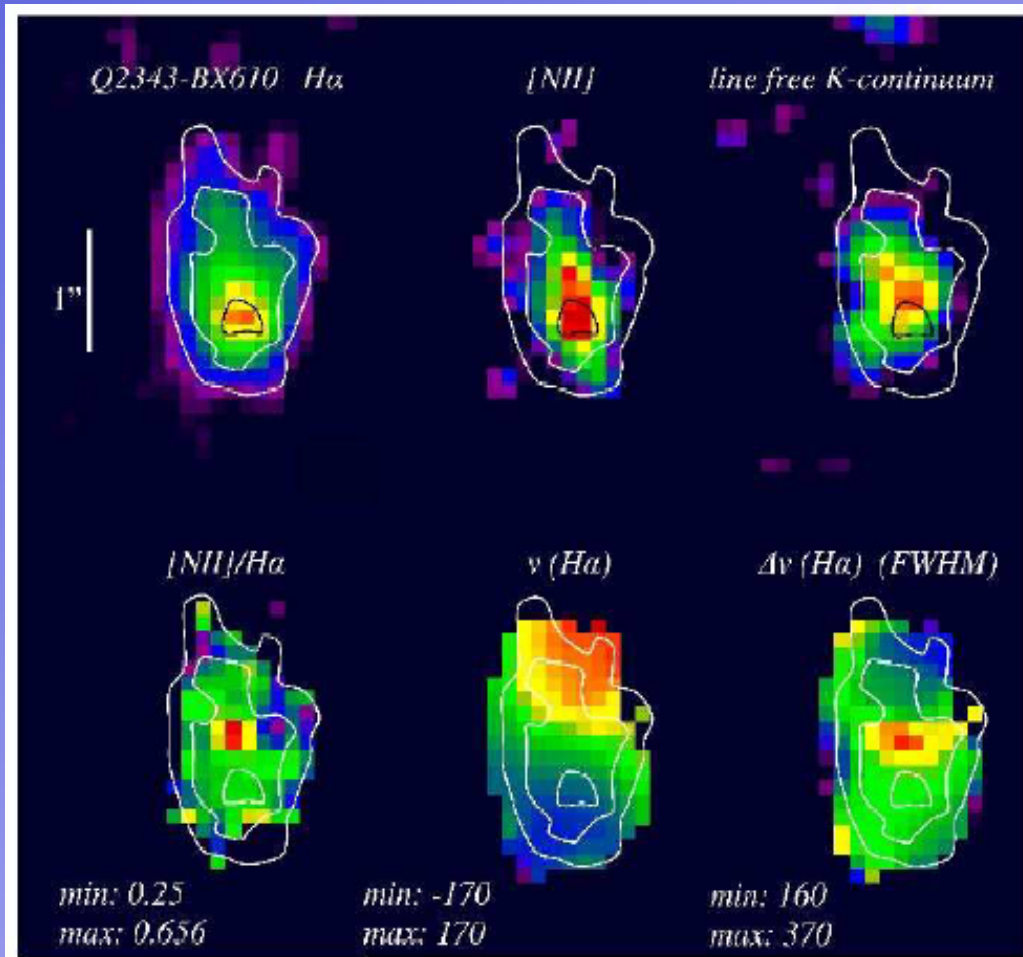


Espectroscopía 3D en NIR

SINFONI INTEGRAL FIELD SPECTROSCOPY OF $Z \sim 2$ UV-SELECTED GALAXIES: ROTATION CURVES AND DYNAMICAL EVOLUTION

(Föster Schreiber et al. 2006)

Mapas de Intensidad, velocidad y dispersión con SINFONI



Práctica de Espectroscopía 3D: Galaxia UCM2325+2318 (NGC7673) Análisis con E3D

Integral field spectroscopy of local LCBGs: NGC 7673, a case study. Physical properties of star-forming regions

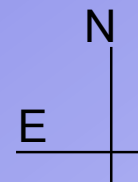
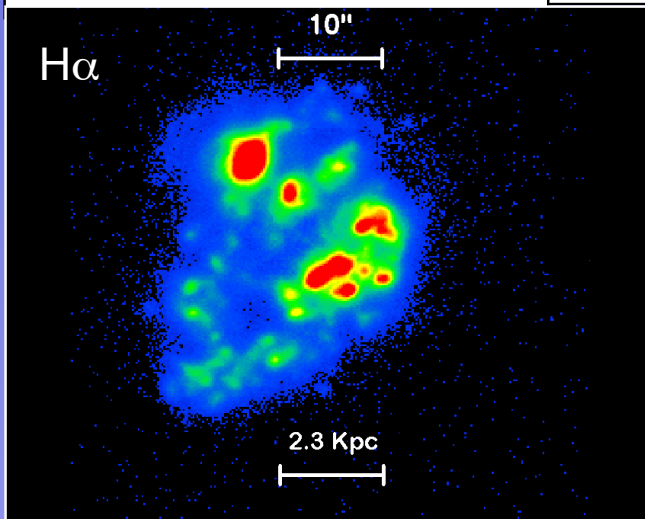
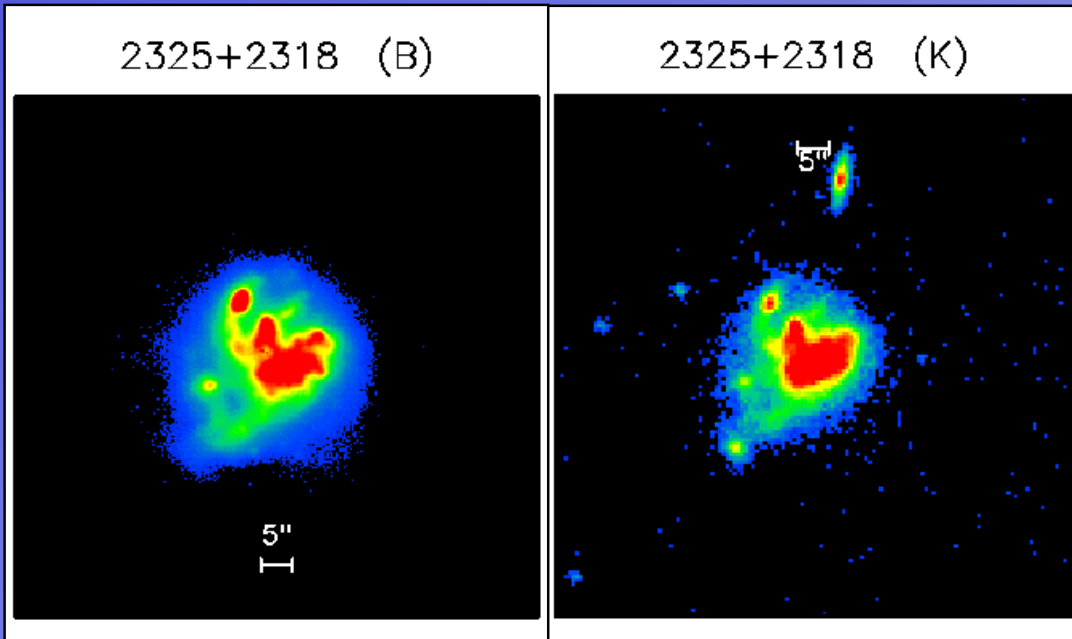
Castillo-Morales, A.; Gallego, J.; Pérez-Gallego, J.; Guzmán, R.; Muñoz-Mateos, J. C.; Zamorano, J.; Sánchez, S. F.
MNRAS, Volume 411, Issue 3, pp. 1819-1832, 2011

3D spectroscopy of local luminous compact blue galaxies: kinematics of NGC 7673

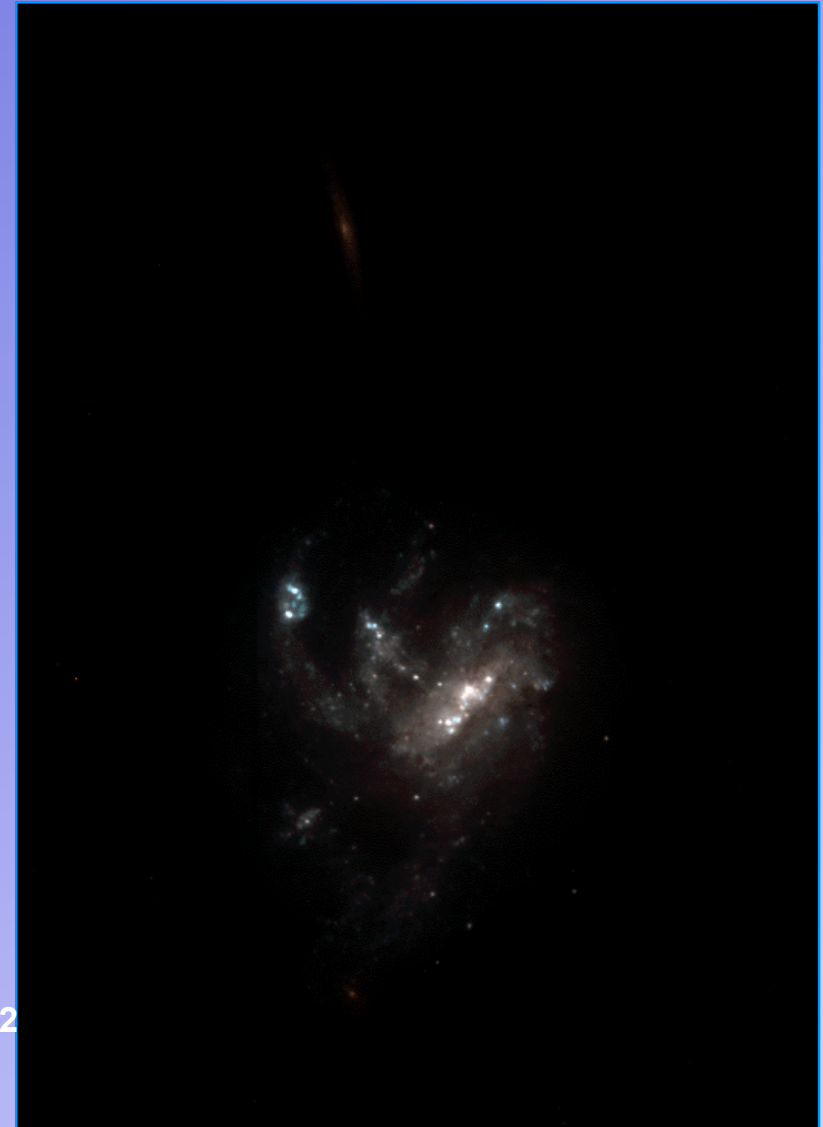
Pérez-Gallego, J.; Guzmán, R.; Castillo-Morales, A.; Castander, F. J.; Gallego, J.; Garland, C. A.; Gruel, N.; Pisano, D. J.; Sánchez, S. F.; Zamorano, J.
MNRAS, Volume 402, Issue 2, pp. 1397-1406, 2010

UCM2325+2318 (NGC 7673)

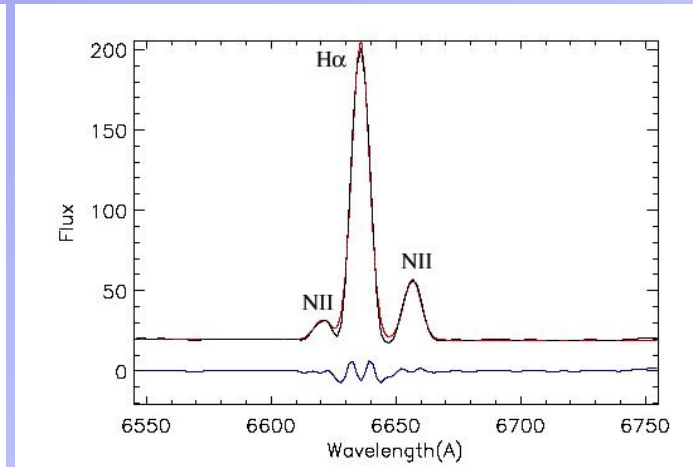
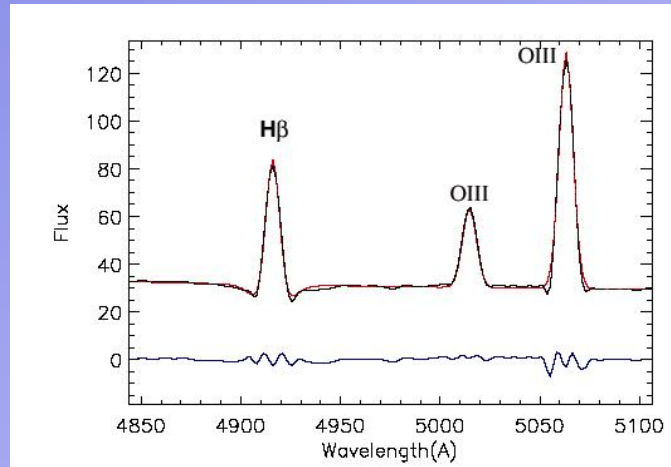
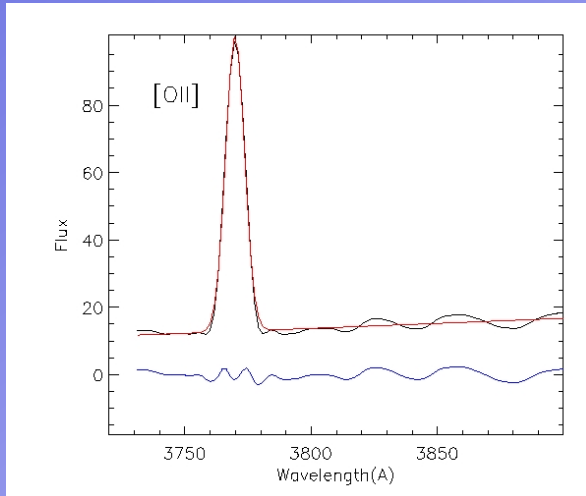
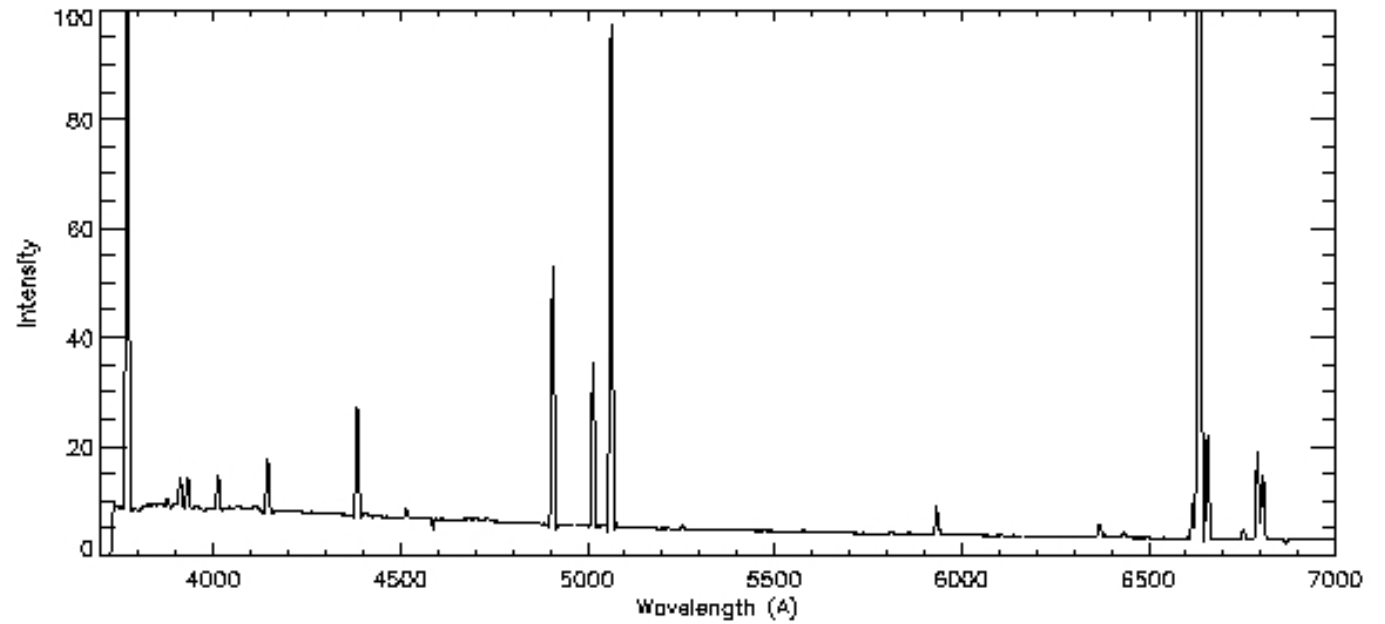
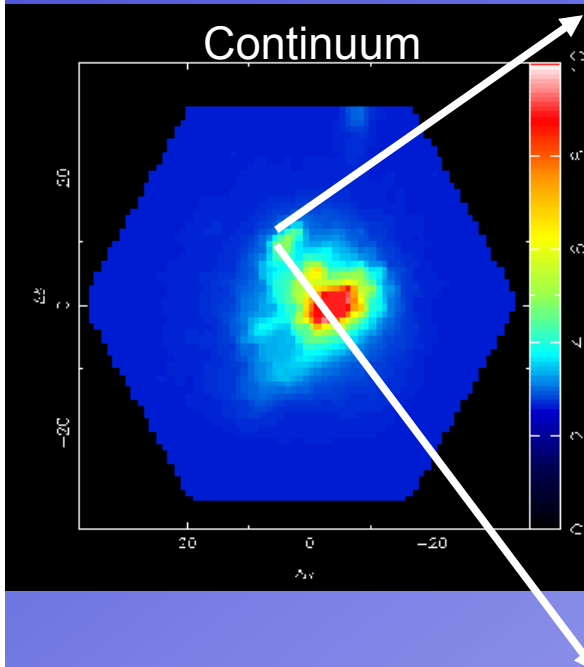
WFPC2 @ HST



$z = 0.011368$
 $M_B = -20.4$
 $SB_e = 19.6 \text{ mag/arcsec}^2$
 $B-V = 0.34$



UCM2325+2318 con PPAK

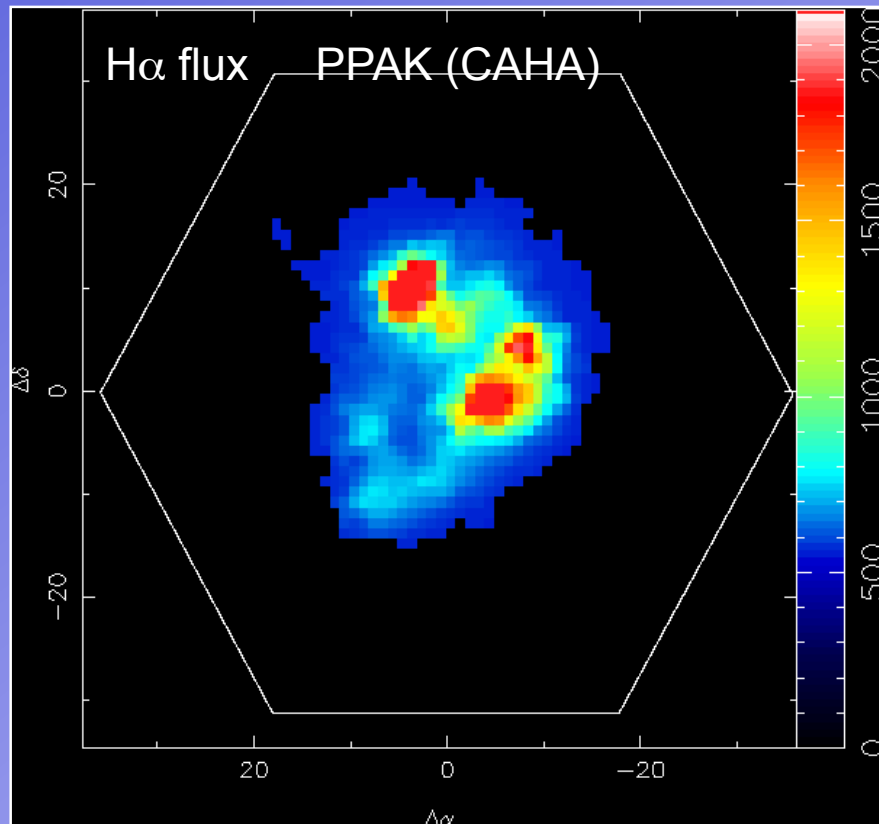
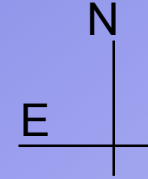


UCM2325+2318 con PPAK

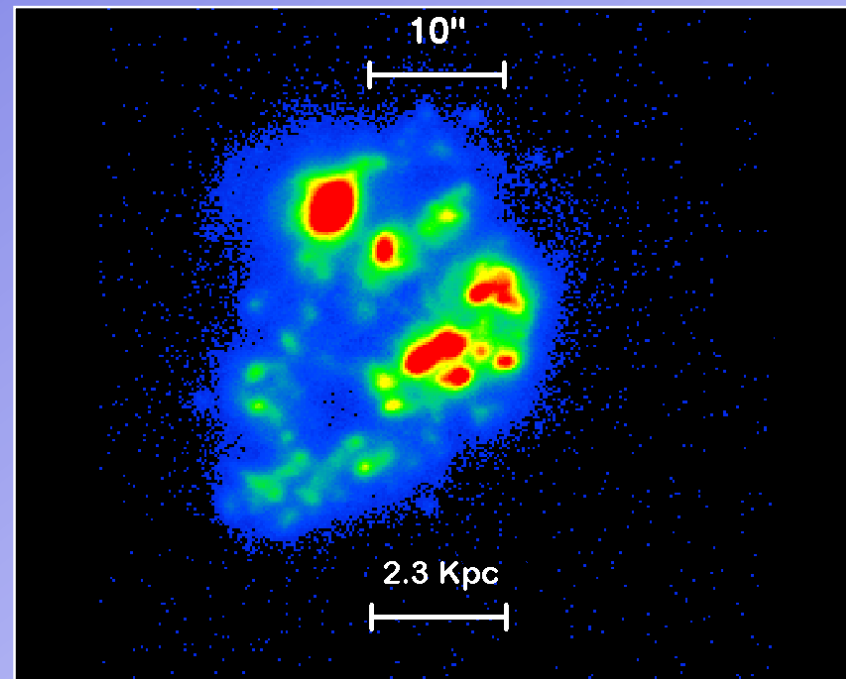
A partir del Flujo $H\alpha$ obtenemos una estimación de la SFR

$$\text{SFR} = \frac{L(H\alpha) \text{ (erg/s)}}{1.22 \cdot 10^{41}} (M_{\odot}/\text{yr})$$

Kennicutt et al. 1998

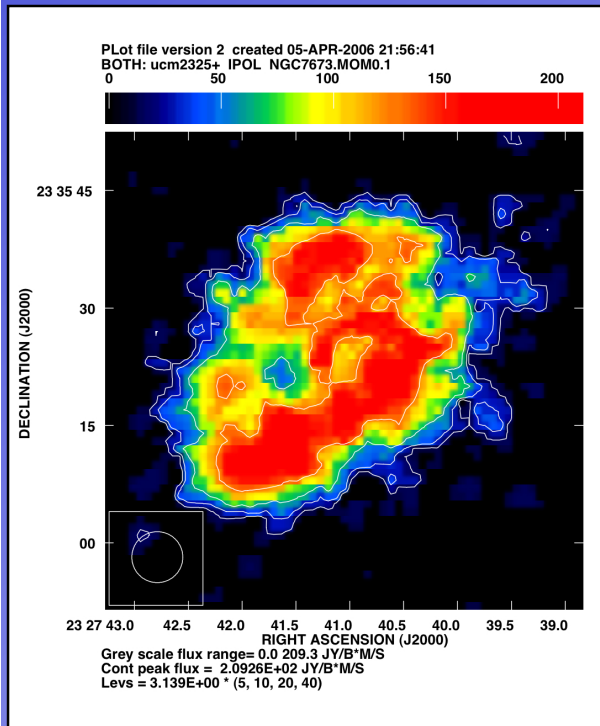


$H\alpha$ image from ALFOSC+FASU (NOT)

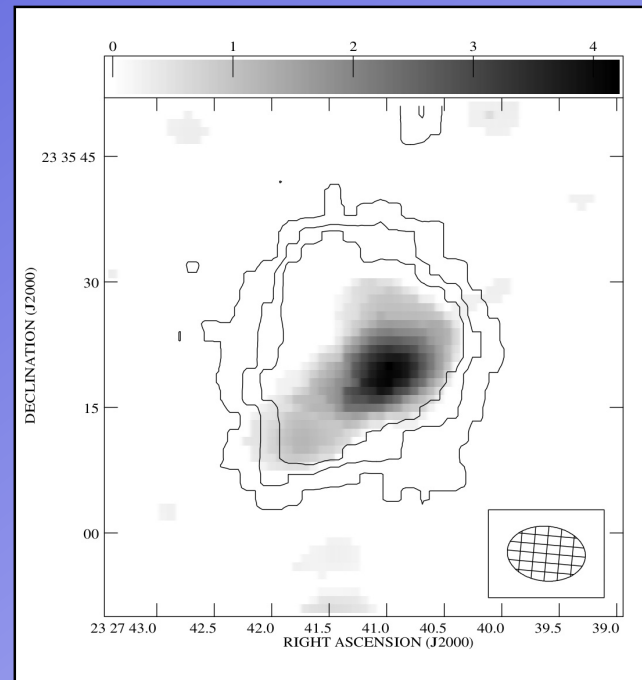


HI & H₂ & HII UCM2325+2318

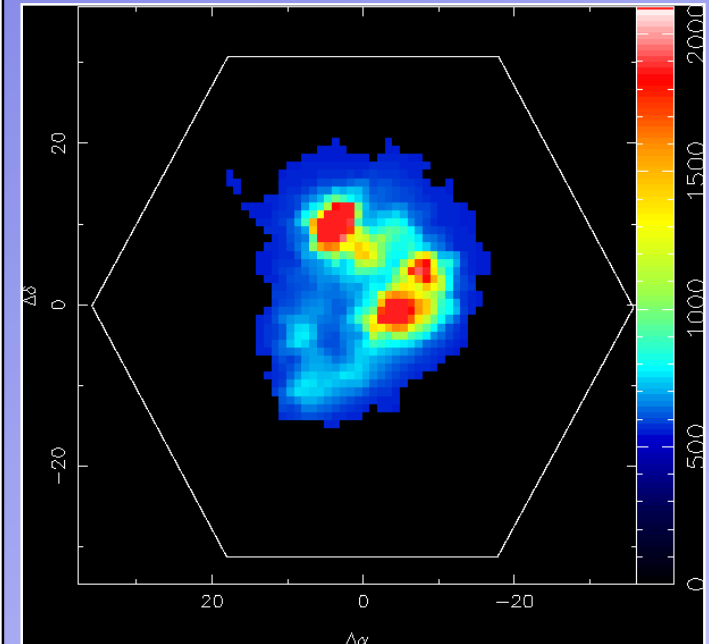
HI flux (VLA)



H₂ flux (OVRO)

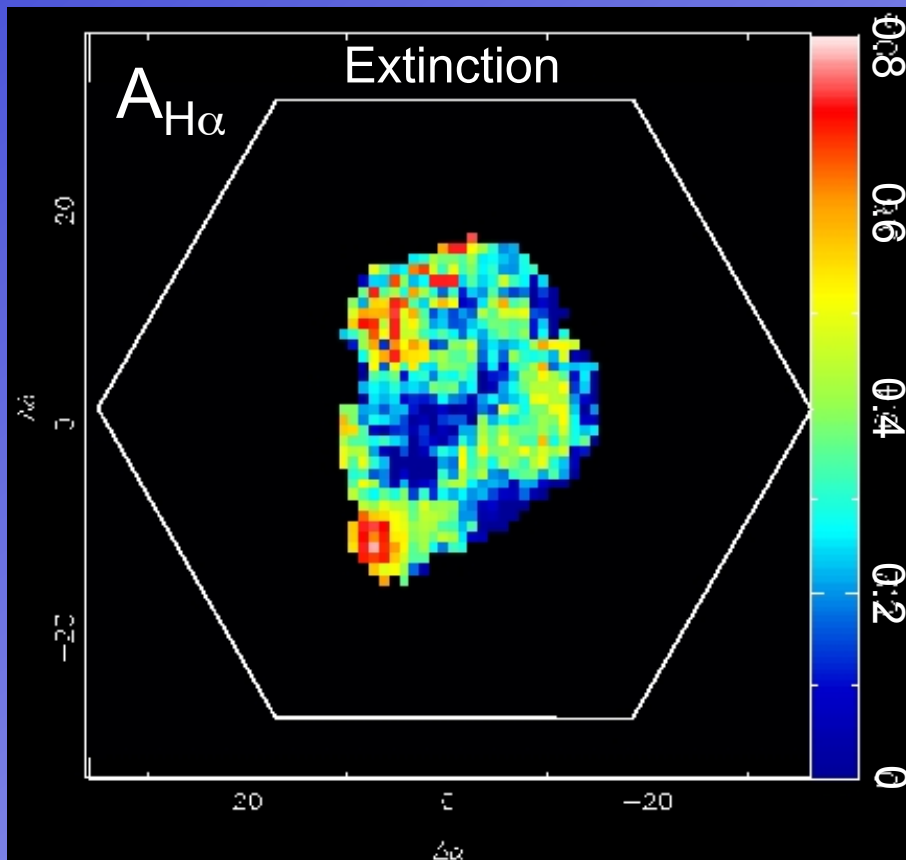


HII flux (PPAK)



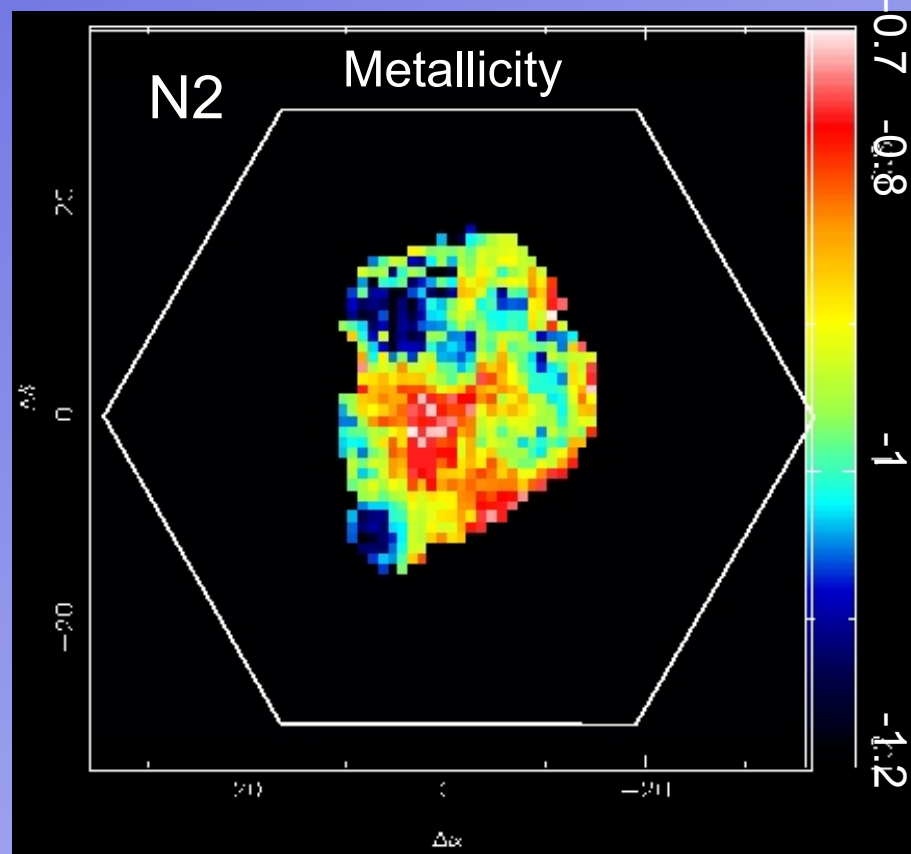
- * Distribución de HI y HII parecida
- * La emisión de H₂ concentrada cerca del brote principal

UCM2325+2318 con PPAK



$$A_{H\alpha} \text{ (Balmer)} = 5.25 \times \log \left[\frac{H\alpha/H\beta}{2.859 t_e^{-0.07}} \right]$$

Extinción máxima: $A_{H\alpha} < 1$ mag



$$N2 = \log \left[\frac{[NII]\lambda 6584}{H\alpha} \right]$$

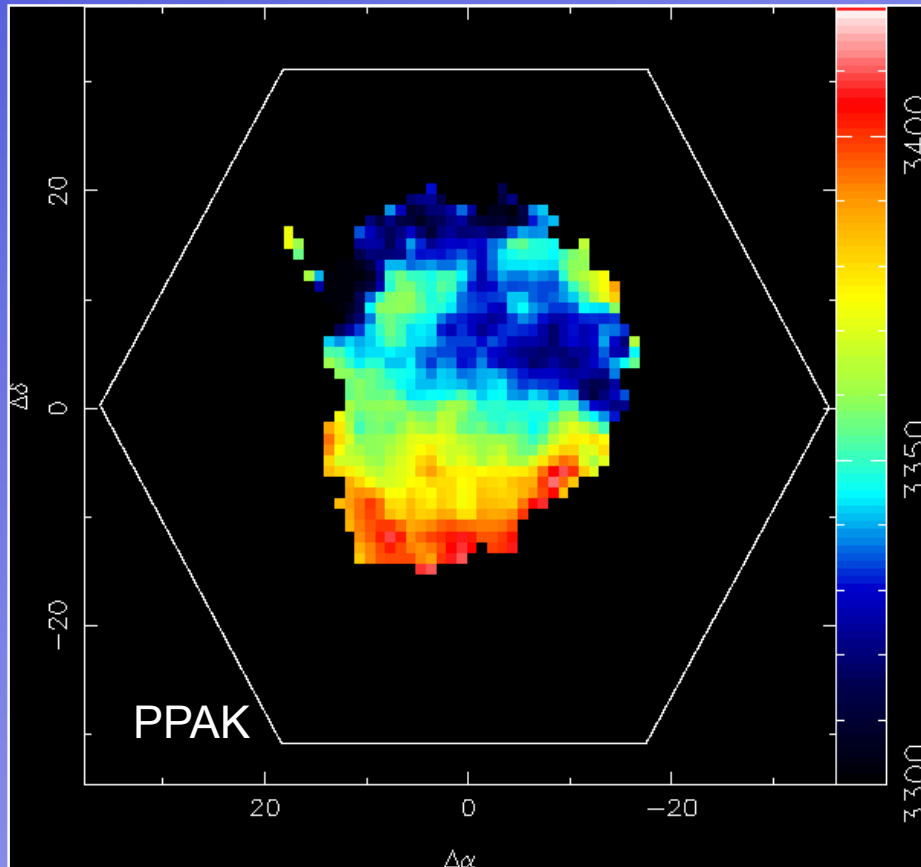
$$12 + \log(O/H) = 9.12 + 0.73 N2$$

(Denicoló et al. 2002)

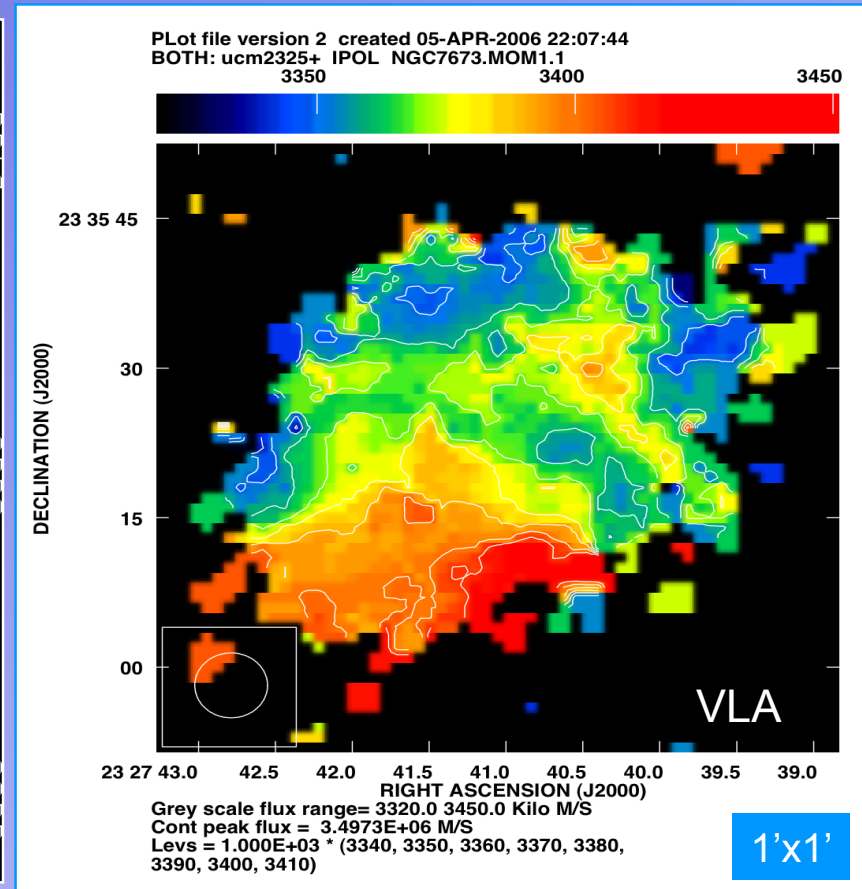
Metalicidad: 0.3-0.7 (solar)

HII & HI UCM2325+2318

Campo de velocidad H α



Campo de velocidad HI



Disco rotando+distorsiones
Campo de velocidad de HI con velocidades comparables