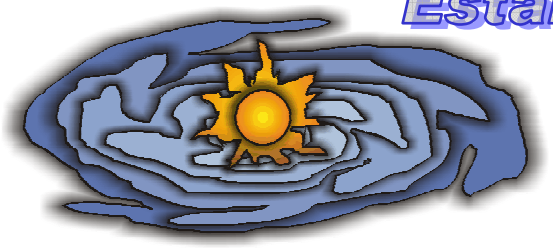


ESTALLIDOS VI
Estructura de la población estelar
Trazadores de formación estelar

J. Miguel Mas Hesse
CAB (CSIC-INTA)
LAEFF-INTA
12-14 diciembre 2007

MEC PNAYA 2004-08260



Introducción

- Componentes básicos
  - Estrellas O en la Galaxia
  - Estructura de la población estelar en starbursts cercanos
- Avances en modelos de síntesis evolutiva
- El problema de la emisión Lyman α en starbursts
- Objetos individuales
- Trazadores de formación estelar
  - Luminosidad a 24 μm
  - Luminosidad en rayos X blandos (0.2-2.4 keV)
- Lista de publicaciones

Catálogo de estrellas O

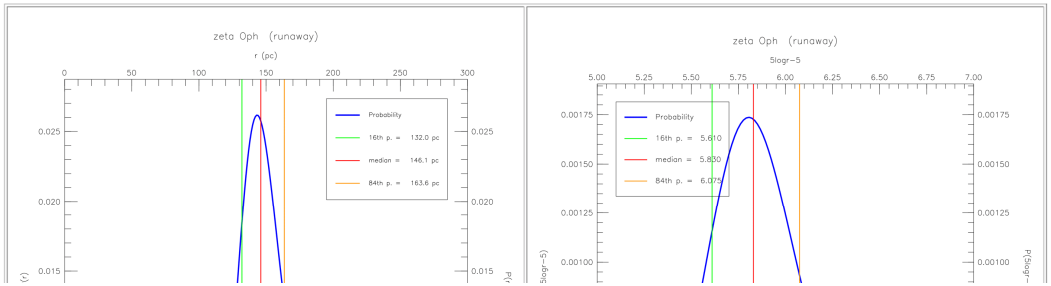
- V2.0 contiene más de 700 estrellas O en la Galaxia
- Incluye toda la información disponible sobre las mismas.
- Completo hasta B<14

G006.28+23.59_01

Links	Alternate IDs
DSS	HD 149757
2MASS	TYC 5632-01042-1
Imag	zeta Oph
Spec	

Spectral Classification				
SC	LC	qual	sec	ref
O9.5	V	nn		L68a
O9.5	V			H56a
O9.5	V	n		H99
O9				C71a
O9	V	(e)		C74c
O9.5	V			M55a
O9.5	V			B69
O9.5	V			W55
O9.5	V	nk		B60
O9.5	V	nn		M98a

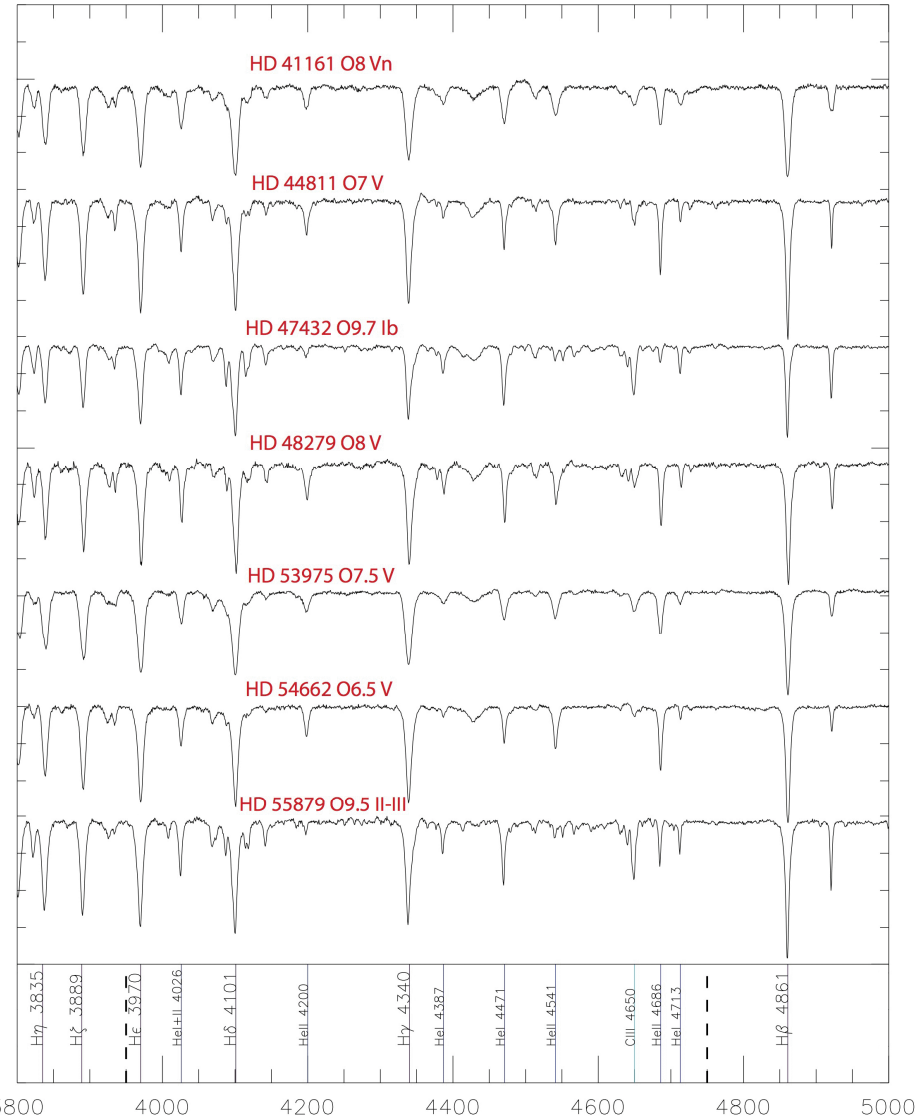
Astrometry		Photometry		Multiplicity Membership	
RA:	16:37:09.530	BT:	2.575± 0.014	pr1:	>100
dec:	-10:34:01.75	VT:	2.546± 0.009	pr2:	>100
ty:	TB	J:		SB:	C
long:	6.281152	H:		mult:	1
lat:	23.587730	K:		dmin:	
pi:	7.12	V:	2.565± 0.008	dmax:	
sigpi:	0.71	B-V:	0.019± 0.010	group:	Sco OB2
mod:	r	U-B:	-0.860± 0.014	runaw:	yes
d:	146	V-R:	0.049± 0.020	ref:	H01
sigd-:	14	R-I:	0.048± 0.020		
sigd+:	17	b-y:	0.085± 0.007		
DM:	5.83	m1:	0.014± 0.008		
sigDM-:	0.22	c1:	-0.065± 0.010		
sigDM+:	0.24	D:	N		

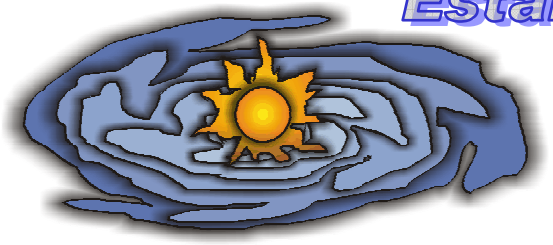


LINKS					IDENTIFICATIONS						SPECTRAL CLASSIFICATIONS				
#	DSS	2MASS	Imag	Spec	GOS	HD	com	TYC	WDS	other	name	SC	LC	qual	se
001	DSS	2MASS	Imag	Spec	G001.91-02.62_01	164019		6854-01467-1			HD 164019	O9.5	III		
002	DSS	2MASS	Imag	Spec	G004.54+00.30_01	162978		6845-00692-1			HD 162978	O7.5	II	((f))	
003	DSS	2MASS	Imag	Spec	G005.82-06.31_01	168941		6852-05110-1			HD 168941	O9.5	II-III		
004	DSS	2MASS	Imag	Spec	G005.97-01.17_01	164740				Herschel 36	Herschel 36	O7.5	V	(n)	
005	DSS	2MASS	Imag	Spec	G006.01-01.20_01	164794		6842-01702-1		9 Sgr	9 Sgr	O4	V	((f))	
006	DSS	2MASS	Imag	Spec	G006.06-01.20_01	164816		6842-01472-1			HD 164816	O9.5	III-IV	(n)	
007	DSS	2MASS	Imag	Spec	G006.12-01.48_01	165052		6846-01128-1			HD 165052	O6.5	V	(n)((f))	
008	DSS	2MASS	Imag	Spec	G006.28+23.59_01	149757		5632-01042-1		zeta Oph	zeta Oph	O9.5	V	nn	
009	DSS	2MASS	Imag	Spec	G006.40-01.56_01	165246		6842-01179-1	18061-2412		HD 165246	O8	V	(n)	
010	DSS	2MASS	Imag	Spec	G006.94-02.10_01	165921		6843-00543-1			HD 165921	O7	V		O9 V
#	DSS	2MASS	Imag	Spec	GOS	HD	com	TYC	WDS	other	name	SC	LC	qual	se

Catálogo de estrellas O

- Se está completando el survey espectroscópico.
- Identificadas más de 13 nuevas binarias masivas.





Evolutionary Models

Mercedes Mollá & Marisa García-Vargas

- **Initial Mass Function**

Single Stellar Populations have been computed for the following IMF parameters:

IMF-1: Salpeter (1955), $\Phi(m) = m^{-\alpha}$, $\alpha = 2.35$ mlow = 0.85 M⊙, mup = 120 M⊙
IMF-2: Salpeter (1955), $\Phi(m) = m^{-\alpha}$, $\alpha = 2.35$ mlow = 0.15 M⊙, mup = 100 M⊙
IMF-3: Ferrini, Penco & Palla (1990), mlow = 0.15 M⊙, mup = 100 M⊙
IMF-4: Kroupa (2002), mlow = 0.15 M⊙, mup = 100 M⊙
IMF-5: Chabrier (2003), mlow = 0.15 M⊙, mup = 100 M⊙

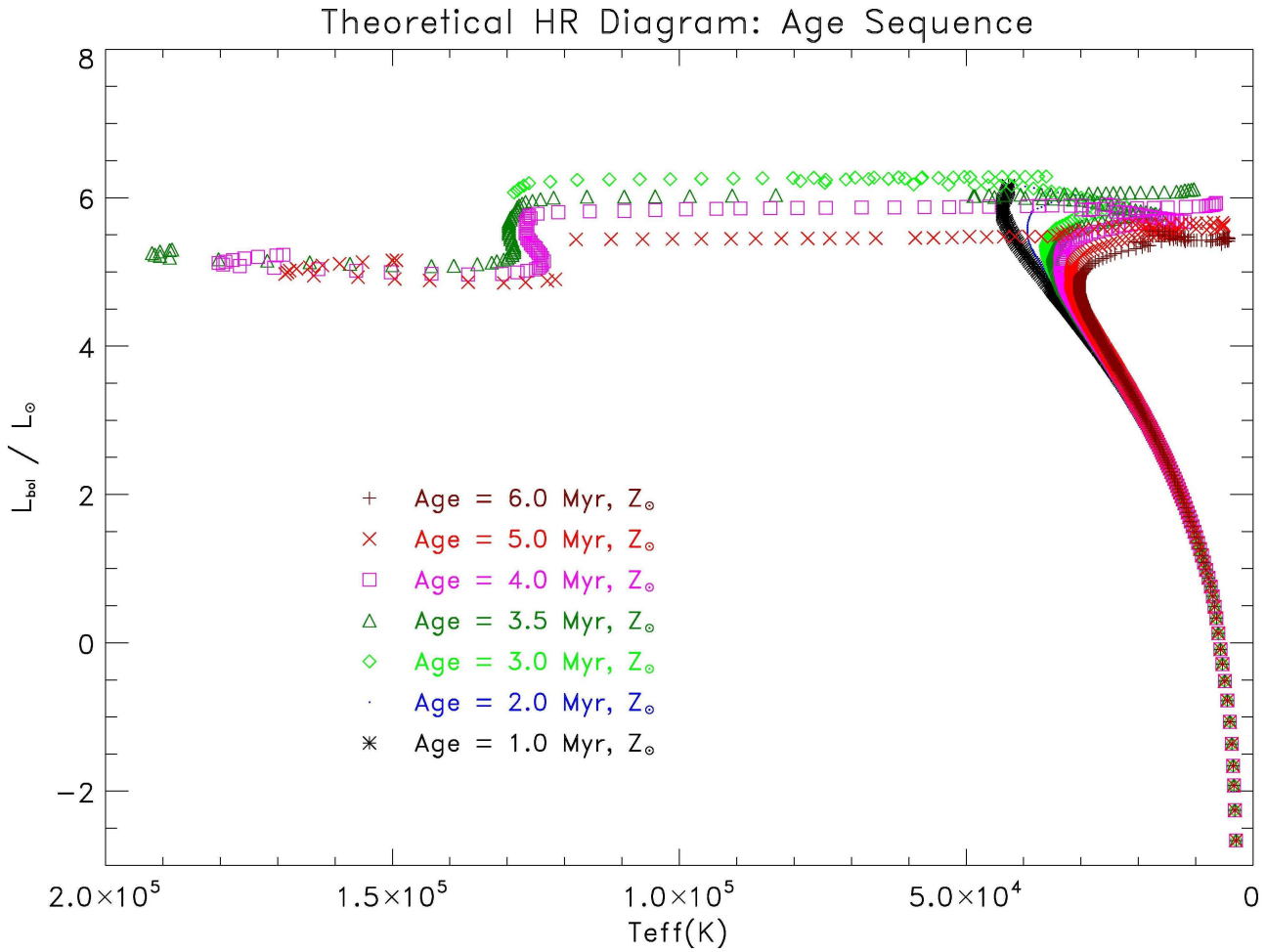
The models do not include binaries, either mass segregation. All the models have been computed for a Total Initial Cluster Mass (in stars) of 1 $M_\odot$ to ease comparison at the VO.

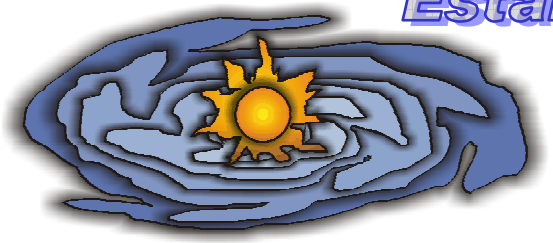
- **Synthesis Code**

We have used the synthesis code by García-Vargas, Mollá & Bressan (1998), updated by Mollá & García-Vargas (2000) and now updated (2007) with new isochrones and atmosphere models.

- Model description and download available at: http://www.fractal-es.com/SEDmod.htm

Isochrones

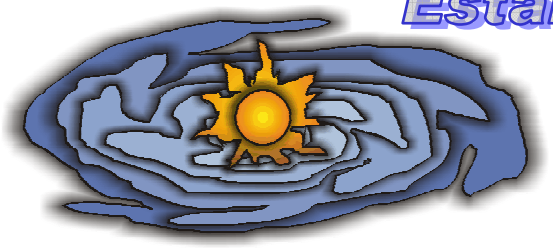

Theoretical HR Diagram: Age Sequence
8
6
4
2
0
−2
L_{bol} / $L_\odot$
2.0×10^5
1.5×10^5
1.0×10^5
5.0×10^4
0
Teff(K)
Age = 6.0 Myr, Z⊙
Age = 5.0 Myr, Z⊙
Age = 4.0 Myr, Z⊙
Age = 3.5 Myr, Z⊙
Age = 3.0 Myr, Z⊙
Age = 2.0 Myr, Z⊙
Age = 1.0 Myr, Z⊙



Model Products

The columns in the table give the following information (all the numbers are for 1 Mo).

- logage = Logarithm of the age (in yr)
- Ntot = Total number of stars at the time of cluster formation
- N20 = Total number of stars with initial mass higher than 20 Mo
- NOB = Total number of O, B stars present at the current age
- NWN = Total number of WN stars present at the current age
- NWC = Total number of WC stars present at the current age
- NRSG = Total number of RSG stars present at the current age
- NSN = Total number of SNs Ib+II since the cluster formation until the current age
- NPN = Total number of PN present at the current age
- Ewinds = Total Mechanical Energy deposited by winds at the current age
- ESN = Total Mechanical Energy deposited by SNs since the cluster formation until the current age
- Rc = Cluster radius at the current age (from mechanical energy deposition due to winds+SNs)
- QH = Total number of HI ionizing photons, Q(H), $\lambda < 912.4$ Ă, in s^{-1}
- QHe = Total number of HeI ionizing photons, Q(He), $\lambda < 504.6$ Ă, in s^{-1}
- QO = Total number of OI ionizing photons, Q(O), $\lambda < 353.3$ Ă, in s^{-1}
- QHe+ = Total number of HeII ionizing photons, Q(He+), $\lambda < 228.0$ Ă, in s^{-1}
- QHe/QH = Ratio between the number of HeI and HI ionizing photons, Q(He)/Q(H)
- QO/QH = Ratio between the number of OI and HI ionizing photons, Q(O)/Q(H)
- QHe+/QH = Ratio between the number of HeII and HI ionizing photons, Q(He+)/Q(H)



Model Products

We provide the spectra (SEDs) for and for 1 $M_{\odot}$cluster. Each file has four columns:

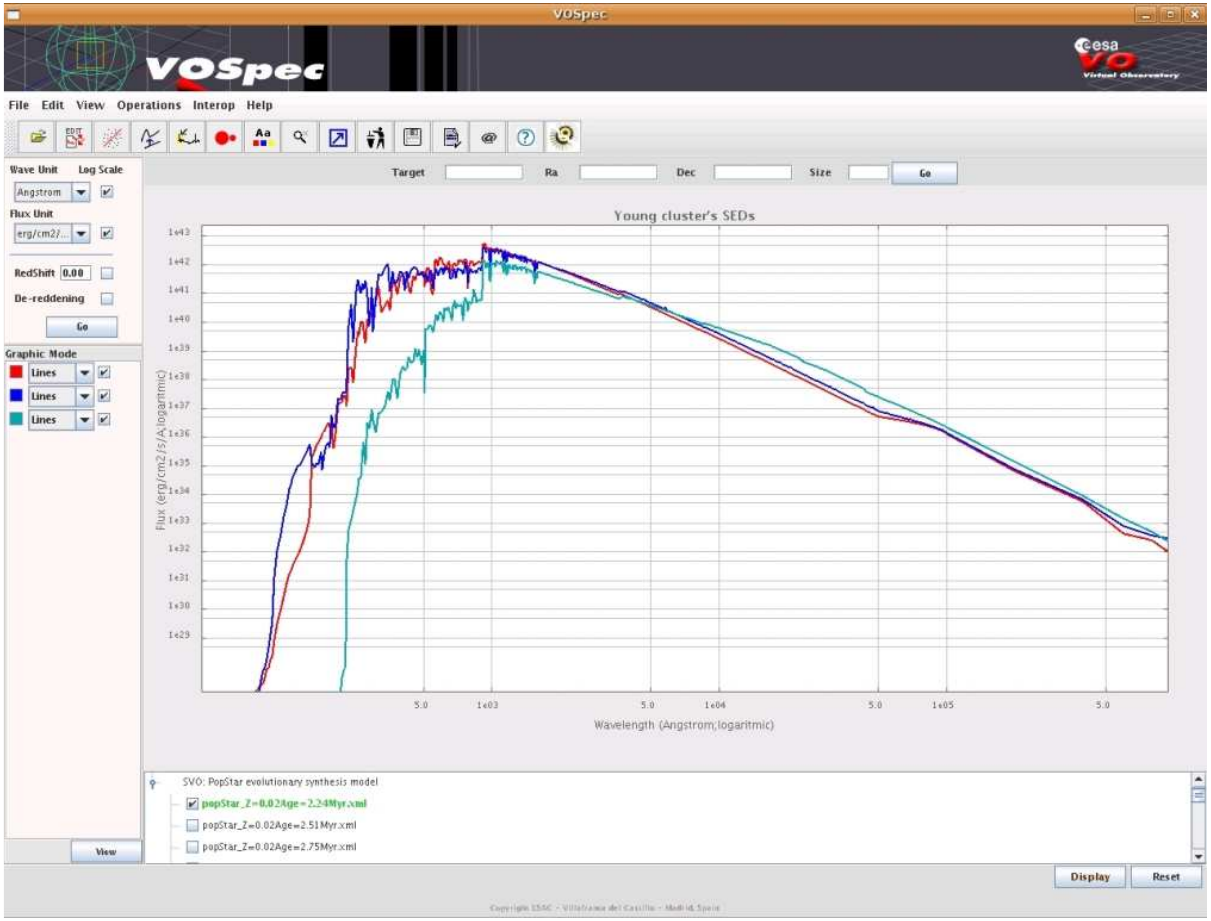
- λ (Å) = Wavelength
- $Lstar_{\lambda}$/ Lo ($Å^{-1}$) = Star continuum
- $Lneb_{\lambda}$/ Lo ($Å^{-1}$) = Nebular continuum
- $Ltot_{\lambda}$ / Lo ($Å^{-1}$) = Total (star+nebular) continuum

✓ Spectra can be chosen by IMF type, age and metallicity.

✓ To convert the luminosities in $ergs^{-1}$ you need to multiply by the solar luminosity, $L_{\odot} = 3.82 \times 10^{33}$ $ergs^{-1}$. Spectra can be managed with VOSpec

✓ All the spectra have been computed for a total mass of 1 $M_{\odot}$

Spectra at Virtual Observatory

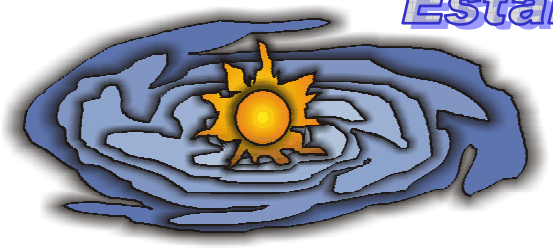


SVO: PopStar evolutionary synthesis model

Spectra can be chosen by IMF-type, age and Z and can be managed with VOSpec http://esavo.esa.int/vospec/

At VOSpec

- Enter a Galaxy (any e.g. M31)
- Select Theoretical Spectral Services
- Select PopStar



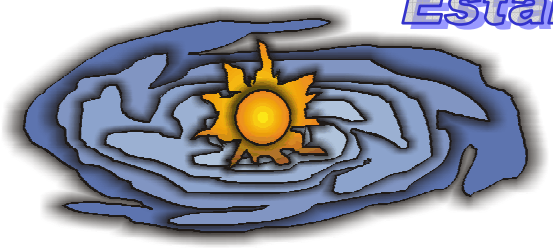
Products available soon

- Emission line spectra resulting from the synthesis + photoionization models

- **New SEDs**
  - Continuous Star Formation Models with different values of SFR and taking into account the chemical evolution (Mollá & Díaz, 2005)
  - Models with Dust (GRASSIL code, Padova)
  - SEDs with higher spectral resolution in the optical and near-IR ranges (with observed stellar libraries)

- **Indices**
  - Stellar Blue Spectral indices (Mg_b, Mg_2, Fe_{52}, Fe_{53}, NaD and H_β)
  - Stellar Near-IR Spectral indices (CaT, Na I and Mg I)

- **GTC Tools**
  - SDSS Colors to be used with images taken with Elmer at the GTC
  - Optical spectra for each of the spectroscopic configurations of Elmer

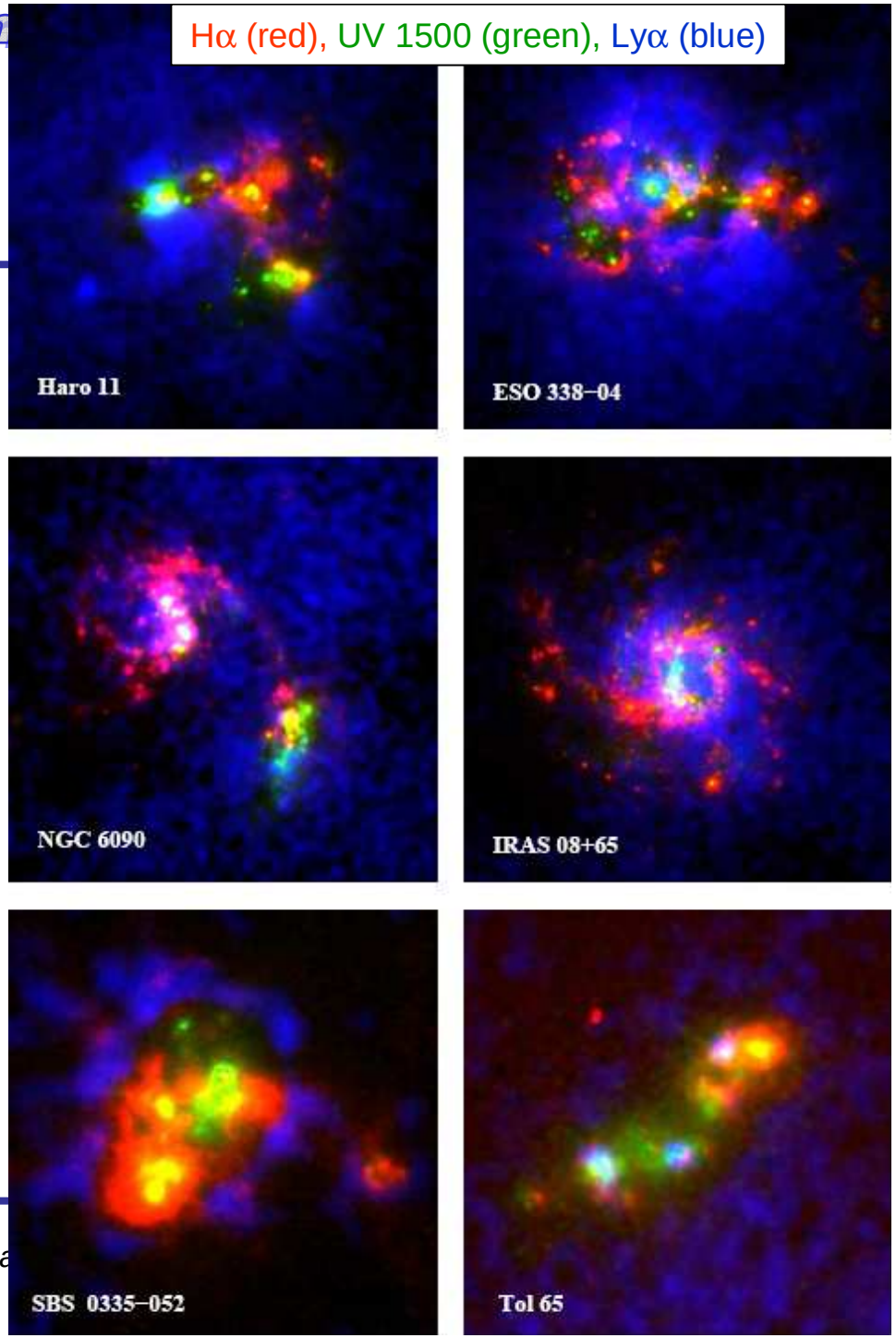


Emisión Lyman α

- Objetivo: Estudiar las propiedades de la emisión Lyman α en starbursts del Universo Local para poder interpretar correctamente las galaxias emisoras a alto redshift.
- Programa piloto basado en imágenes HST/ACS+WFPCII, espectroscopía HST/STIS e imágenes en Tierra.
- Los resultados del proyecto están prácticamente completados.

Emisión Lyman α

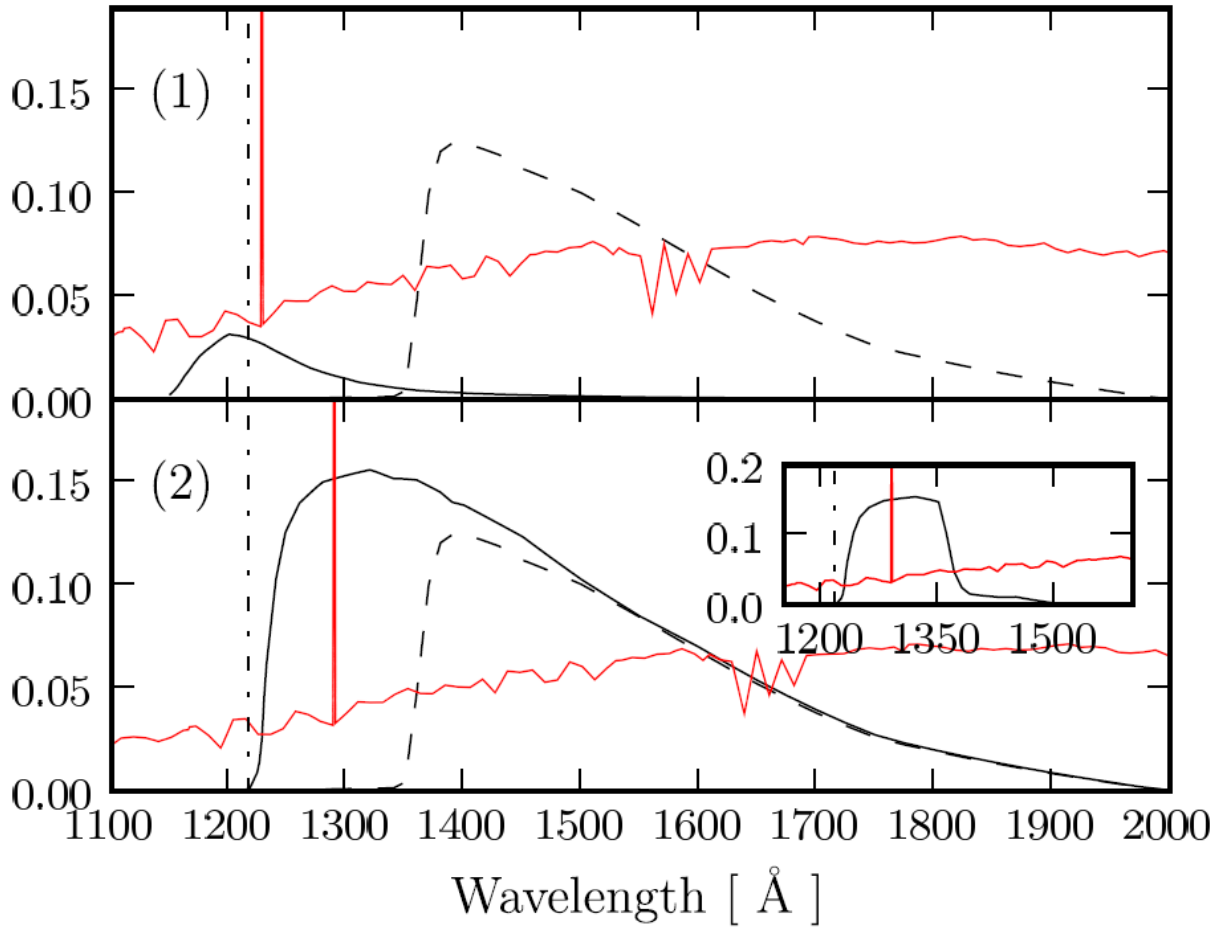
- Catálogo de galaxias starburst locales con emisión Lyman α.
- Basado en observaciones ACS/WFPCII en UV y óptico, líneas y continuo.
- Constituyen la muestra de referencia para estudiar objetos a alto redshift.
- Muestra la complejidad de la física de la emisión Lyman α.



Östlin...Mas-Hesse et al., 2008, ApJ, listo para enviar

Emisión Lyman α

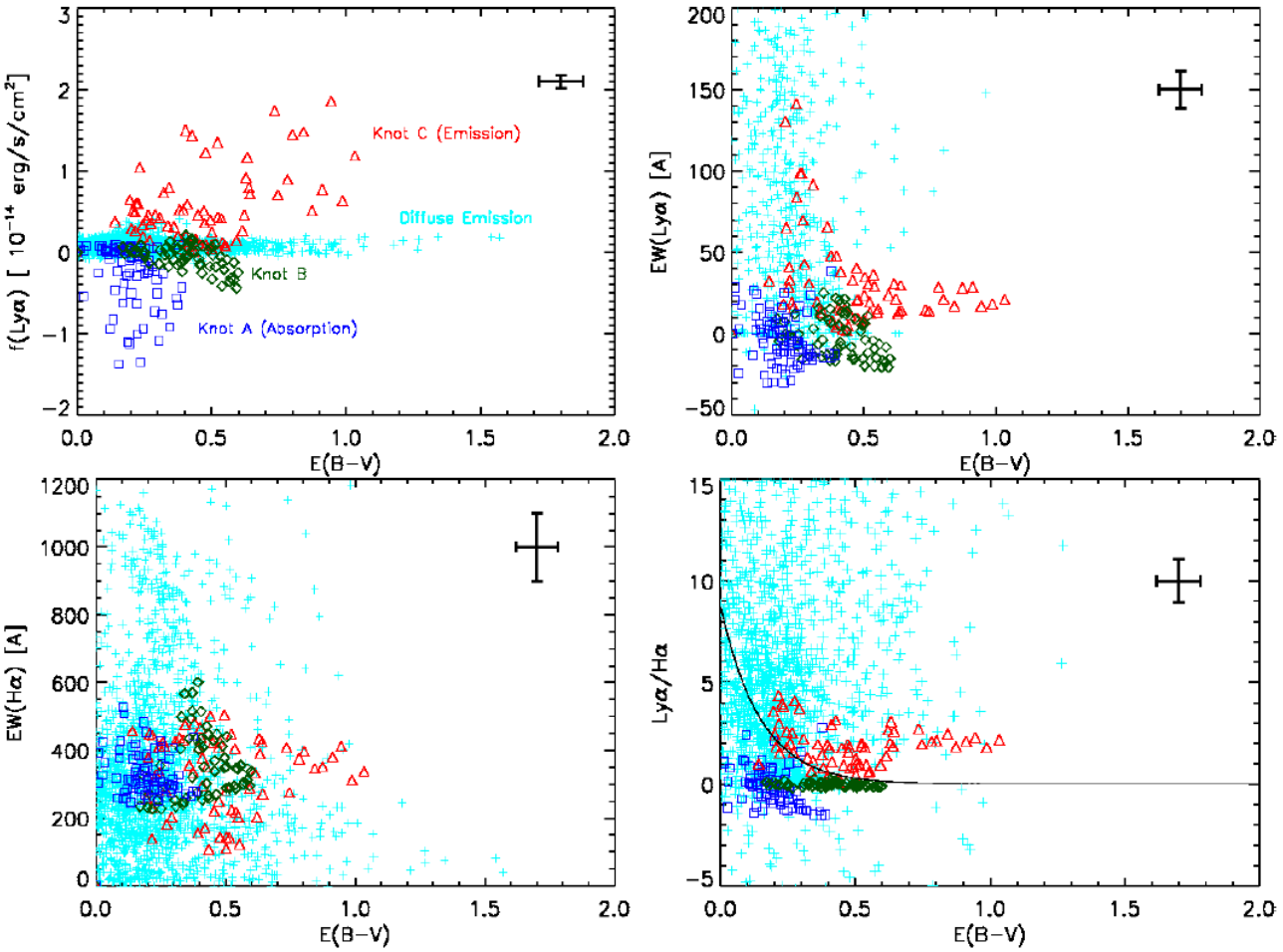
- Análisis muy detallado de las técnicas precisas para poder extraer las imágenes de Lyman α en emisión



Hayes...Mas-Hesse et al., 2007, ApJ, enviado

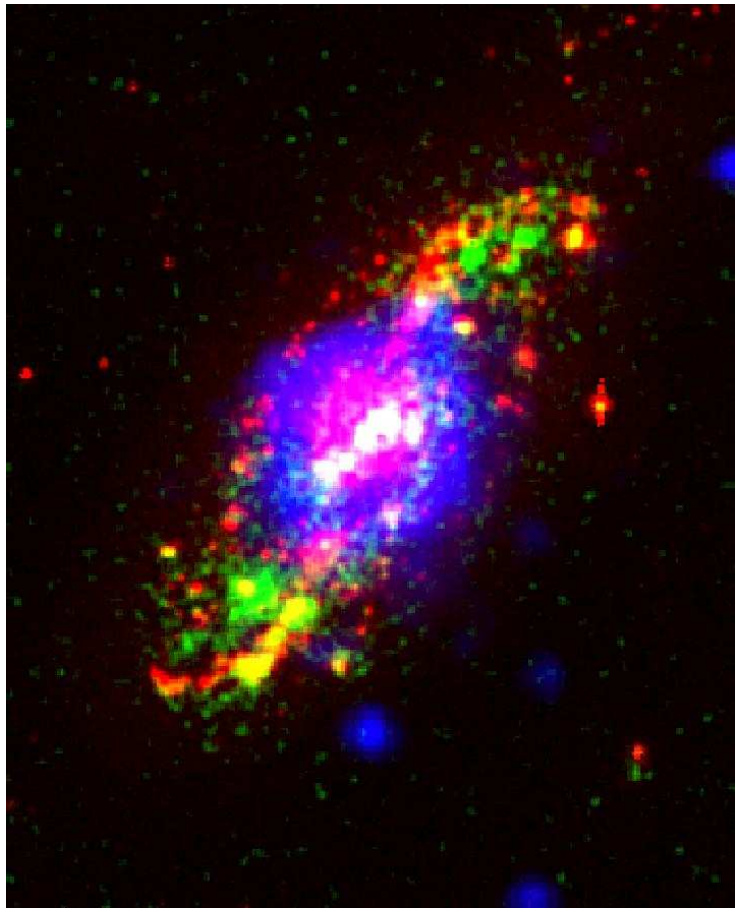
Emisión Lyman α

- Estudio de la relación entre la distribución del polvo y la emisión Lyman α.



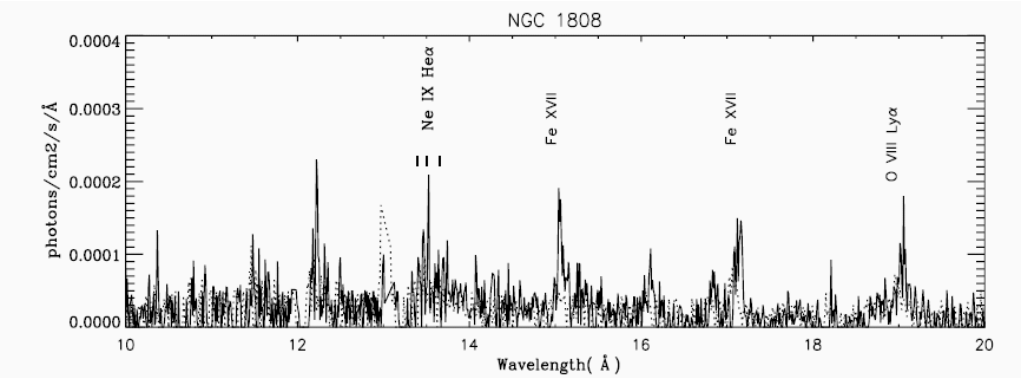
Atek...Mas-Hesse et al., 2008, A&A, próximo a enviar

Objetos individuales: NGC1808



Hα (red), UVW2 (green), EPIC X-rays (blue)

- XMM-Newton and Chandra observations prove the co-existence of a powerful starburst with a Low Luminosity Active Nucleus.
- The X-ray emission lines indicate metallicities in the range 0.7 to 2.2 $Z_{\odot}$.
- The hard X-ray emission of the nucleus is $L_{2\text{-}10\ keV} = 1.61 \times 10^{40}$ erg/s.

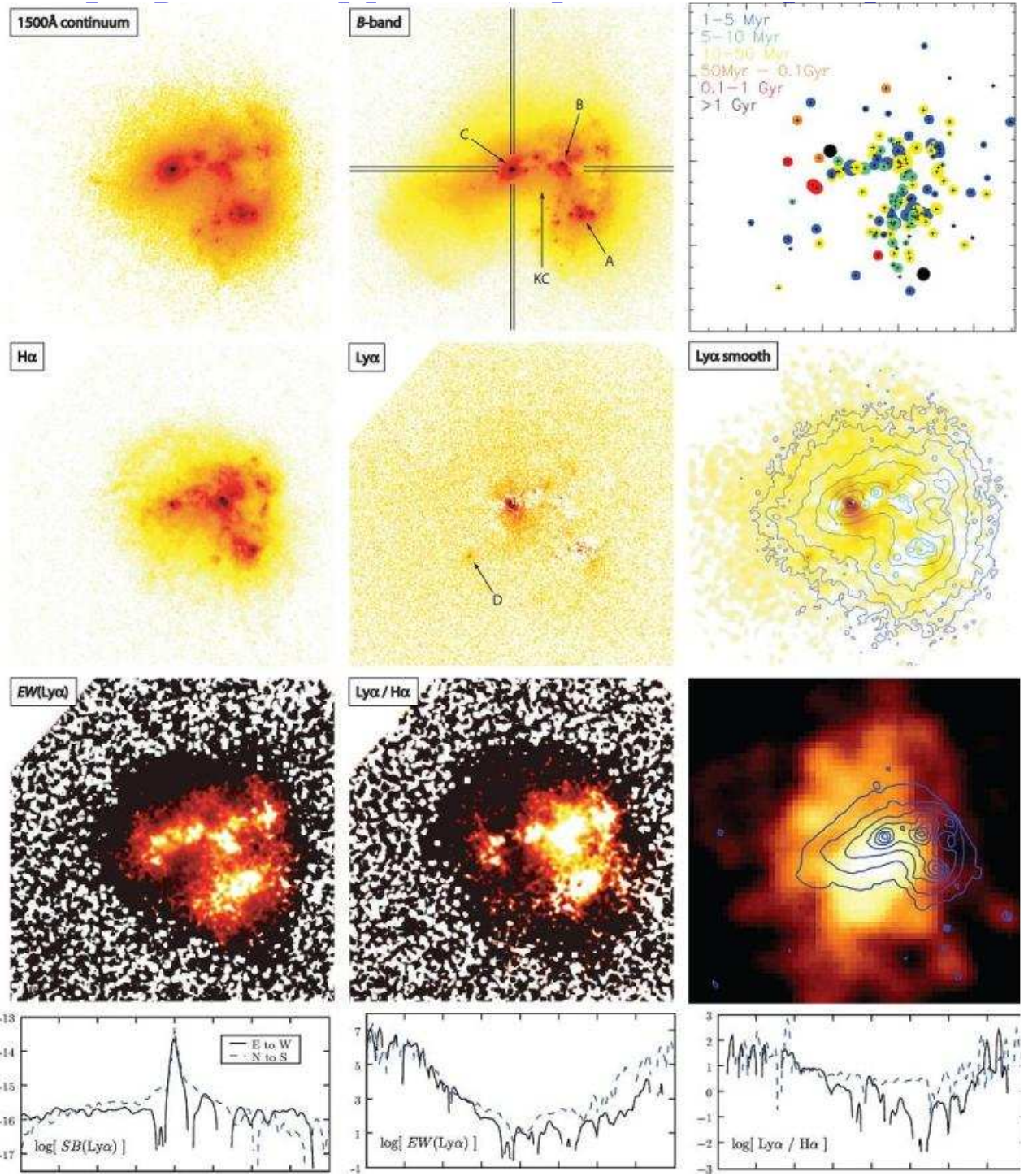


Jiménez-Bailón et al., 2005, A&A, 442, 861

C

- Estudio de las propi
  Haro 11a partir de u
  - Imágenes ACS/WI
  - Distribución de la e
  - Observaciones en
- Análisis detallado de
- Detección de emisió
  importante compone
- Prototipo del escena
  elevada SFR = 20 M

Hayes...Mas-Hesse…Jiménez-Bailón et al., 2007, MNRAS, 382, 1465



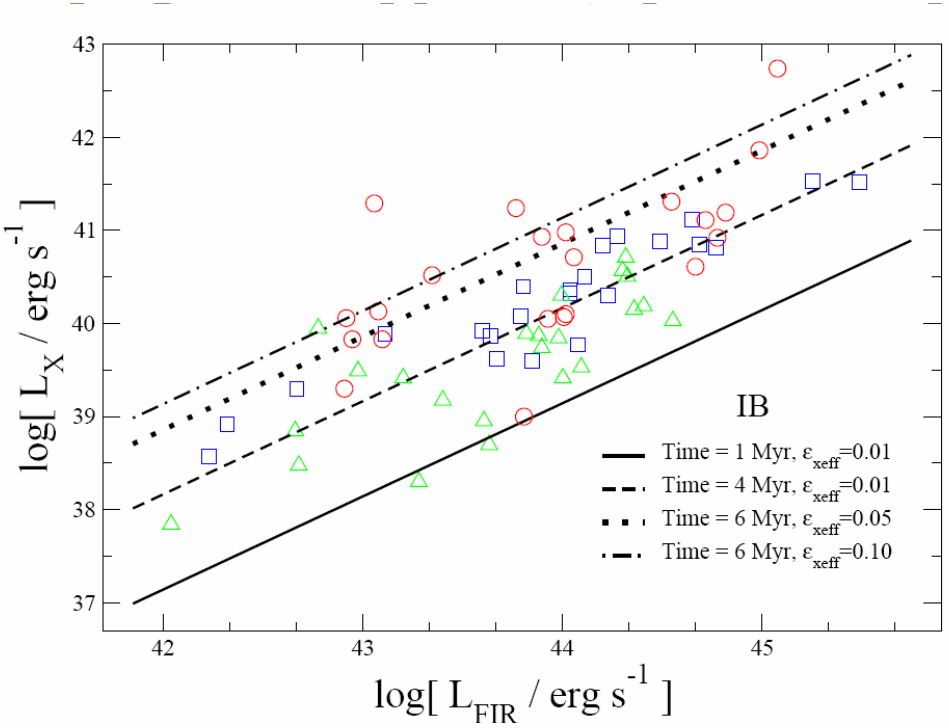
Objetos individuales: NGC 4214

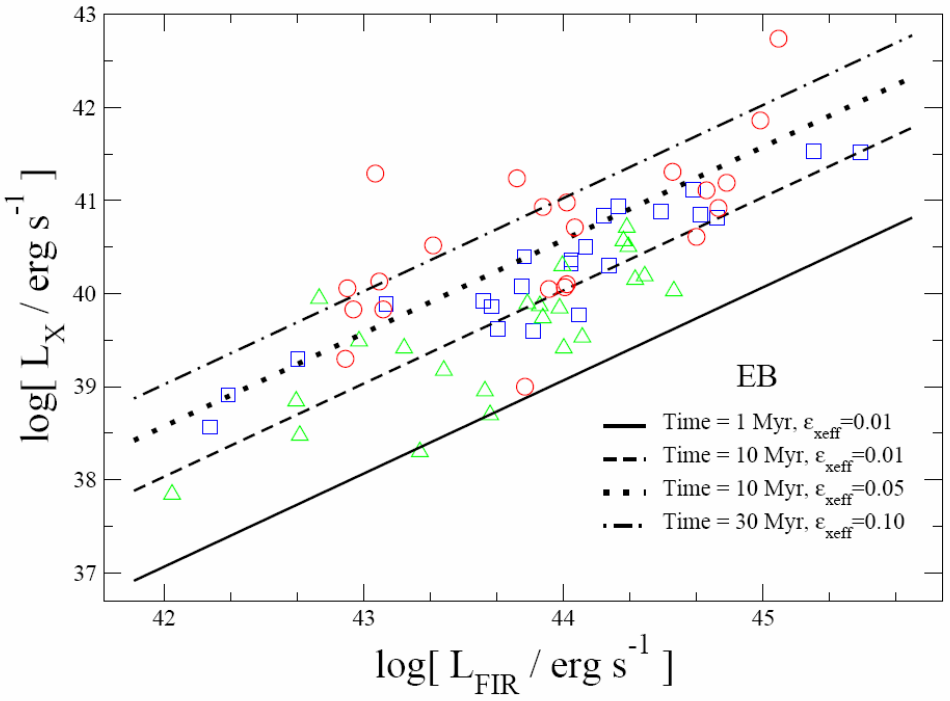
- The Young Stellar Population of NGC 4214 as Observed with the Hubble Space Telescope. II. Results
  Úbeda, Leonardo, Maíz-Apellániz, Jesús, & MacKenty, John W.
  2007, Astronomical Journal, vol 133, pg. 932-951



- Estudio del cociente L_{softx}/L_{FIR}, con el objetivo de testear la validez de L_{softx} como trazador de la SFR.
- Calibración de L_{softx} en base a la predicción de los modelos
- Estudio de su dependencia con metalicidad, ritmo de formación estelar….

Mas-Hesse, Otí-Floranes, Cerviño A&A, 2007, enviado





Trazadores SFR: $\mathcal{L}_{24\mu m}$

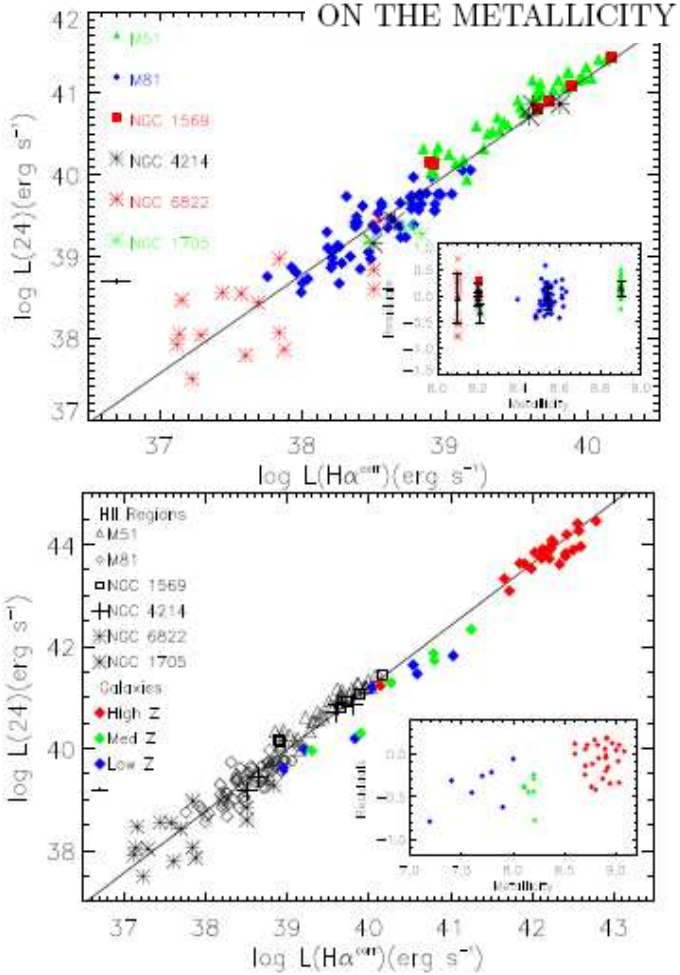
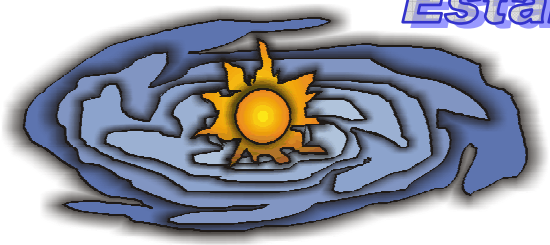


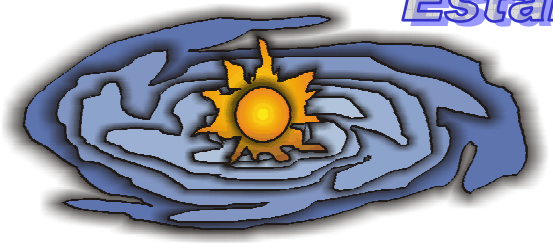
FIG. 1.— *Top:* 24μm luminosity as a function of the extinction corrected Hα luminosity for a sample of H II regions in M51, M81, NGC 1569, NGC 4214, NGC 6822 and NGC 1705. The solid line shows the linear fit to the H II regions of M51, M81 and the ULIRGs from Alonso-Herrero et al. (2006) (see Eq. 1). Typical error bars are shown in the lower left corner of the plot: they account for uncertainties in the calibration (4% for 24μm flux (Engelbracht et al. 2007), ~15% for Hα flux and ~0.2mag for the extinctions (Gil de Paz et al. 2003; Relaño et al. 2006)). In the inner panel we show the residuals of the 24μm luminosity (see text) *versus* the metallicity. The black triangles represent the mean value of the residuals for each galaxy. *Bottom:* The same plot as above but including the integrated luminosities of the galaxies in Table 1. The solid line is the linear fit shown in Eq. 1. We use different colors for galaxies with different metallicities: $Z \leq 8.0$ (blue), $8.0 < Z < 8.5$ (green) and $Z \geq 8.5$ (red). In the inner panel we show the residuals of the 24μm luminosity with respect to linear fit (Eq. 1) *versus* the metallicity.

Relaño, Lisenfeld, Perez-Glez, Vilchez, Battaner
ApJ Let 667, L141. (2007)



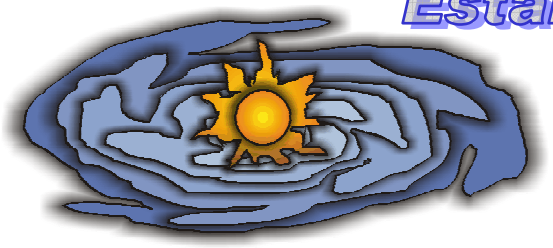
Publicaciones 2005-2007

- The escape of Lyman photons from a young starburst: the case of Haro 11
  Hayes M., Östlin, Atek H., Kunth D., Mas-Hesse J.M., Leitherer C., Jiménez-Bailón E., Adamo A.
  2007, MNRAS, 382, 1465
- On the Metallicity Dependence of the 24 μm Luminosity as a Star Formation Tracer
  Relaño, M., Lisenfeld, U., Pérez-González, P. G., Vílchez, J. M., & Battaner, E.
  2007, Astrophysical Journal, vol 667, pg. L141-L144
- Testing the predicted mass-loss bi-stability jump at radio wavelengths
  Benaglia P., Vink J. S., Martí J., Maíz Apellániz J., Koribalski B., Crowther P. A.
  2007, Astronomy and Astrophysics, vol 467, pg. 1265-1274
- Pismis 24-1: The Stellar Upper Mass Limit Preserved
  Maíz Apellániz, J., Walborn, Nolan R., Morrell, N. I., Niemela, V. S., & Nelan, E. P.
  2007, Astrophysical Journal, vol 660, pg. 1480-1485



Publicaciones 2005-2007

- The Young Stellar Population of NGC 4214 as Observed with the Hubble Space Telescope. II. Results
  Úbeda, Leonardo, Maíz-Apellániz, Jesús, & MacKenty, John W.
  2007, Astronomical Journal, vol 133, pg. 932-951
- The Young Stellar Population of NGC 4214 as Observed with the Hubble Space Telescope. I. Data and Methods
  Úbeda, Leonardo, Maíz-Apellániz, Jesús, & MacKenty, John W.
  2007, Astronomical Journal, vol 133, pg. 917-931
- X-ray emission from NGC 1808: more than a complex starburst
  Jiménez-Bailón, E., Santos-Lleó, M., Dahlem, M., Ehle, M., Mas-Hesse, J. M., Guainazzi, M., Heckman, T. M., & Weaver, K. A.
  2005, Astronomy and Astrophysics, vol 442, pg. 861-877
- Numerical Biases on Initial Mass Function Determinations Created by Binning
  Maíz Apellániz, J. & Úbeda, L.
  2005, Astrophysical Journal, vol 629, pg. 873-880



Publicaciones 2005-2007

- HST/ACS Lyman α imaging of the nearby starburst ESO 338-IG04
  Hayes, M., Östlin, G., Mas-Hesse, J. M., Kunth, D., Leitherer, C., & Petrosian, A.
  2005, Astronomy and Astrophysics, vol 438, pg. 71-85

- Young Super Star Clusters in the Starburst of M82: The Catalog
  Melo, V. P., Muñoz-Tuñón, C., Maíz-Apellániz, J., & Tenorio-Tagle, G.
  2005, Astrophysical Journal, vol 619, pg. 270-290