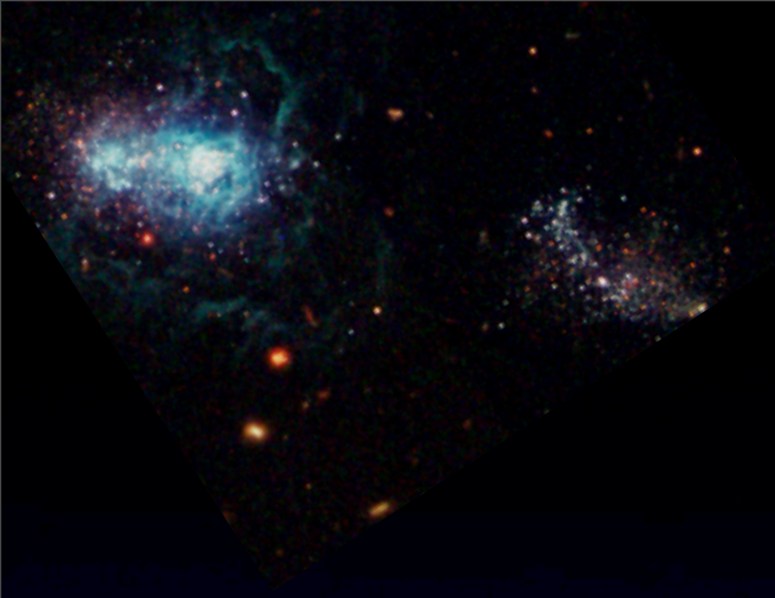

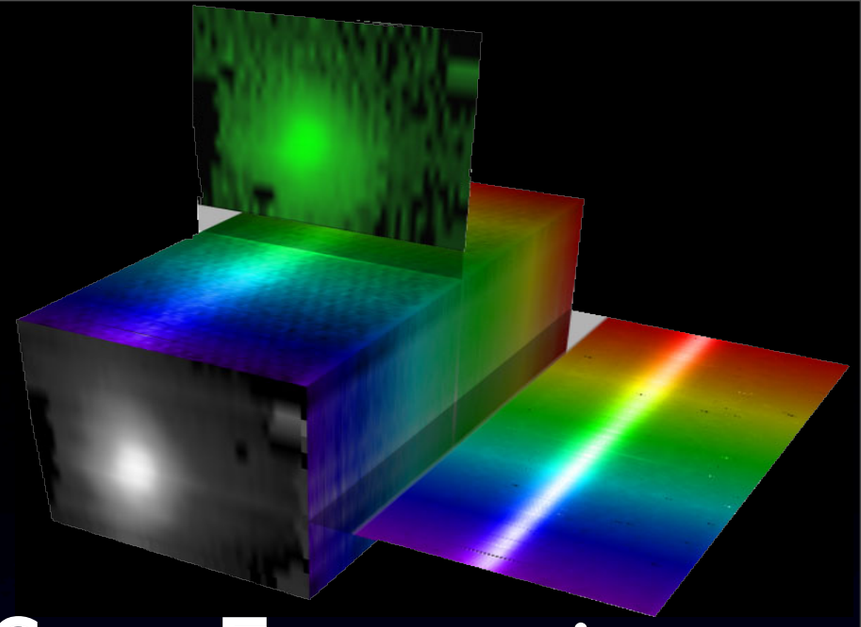

Exploring the Cause & Effect of Star-Formation in Blue Compact Dwarf Galaxies with IFU Observations

Bethan James

STScI

Yiannis Tsamis (ESO)
Mike Barlow (UCL)
Jeremy Walsh (ESO)
Mark Westmoquette (ESO)
Alessandra Aloisi (STScI)

Star Formation in Dwarf Galaxies
Lowell Observatory, June 2012

Talk Outline

- Intro to ‘high N/O’ blue compact dwarf galaxies
- UM420
- UM462
- Mrk996
- UM448
- Haro11

Kinematical maps
+
Stellar pop^{n} age + SFR+ type
+
Chemical abundance maps

- Future observations and Conclusions

BCDs: What's all the fuss about?

Low Metallicity
+
(often) starbursting
≈ High-z galaxies

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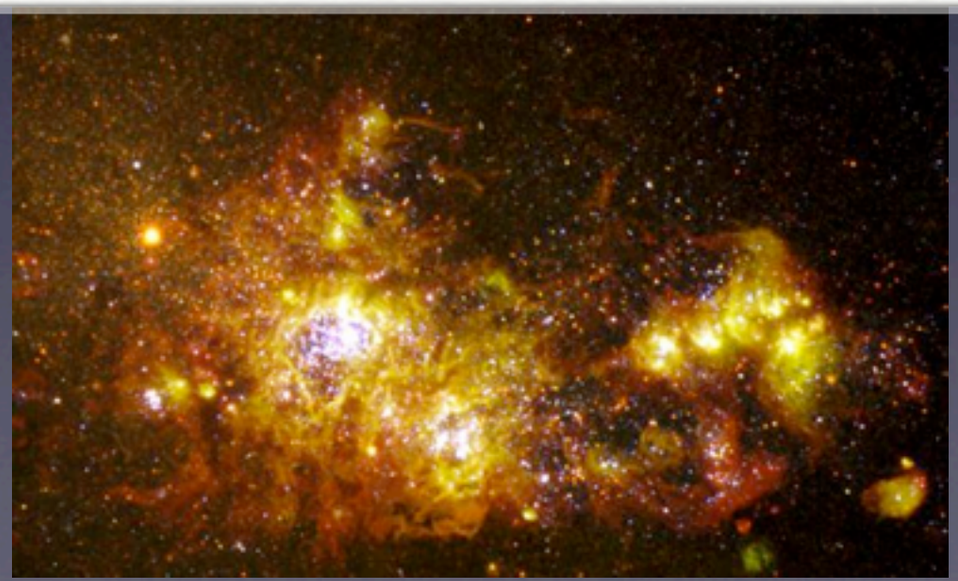
Lyman Break Galaxies



IZw18

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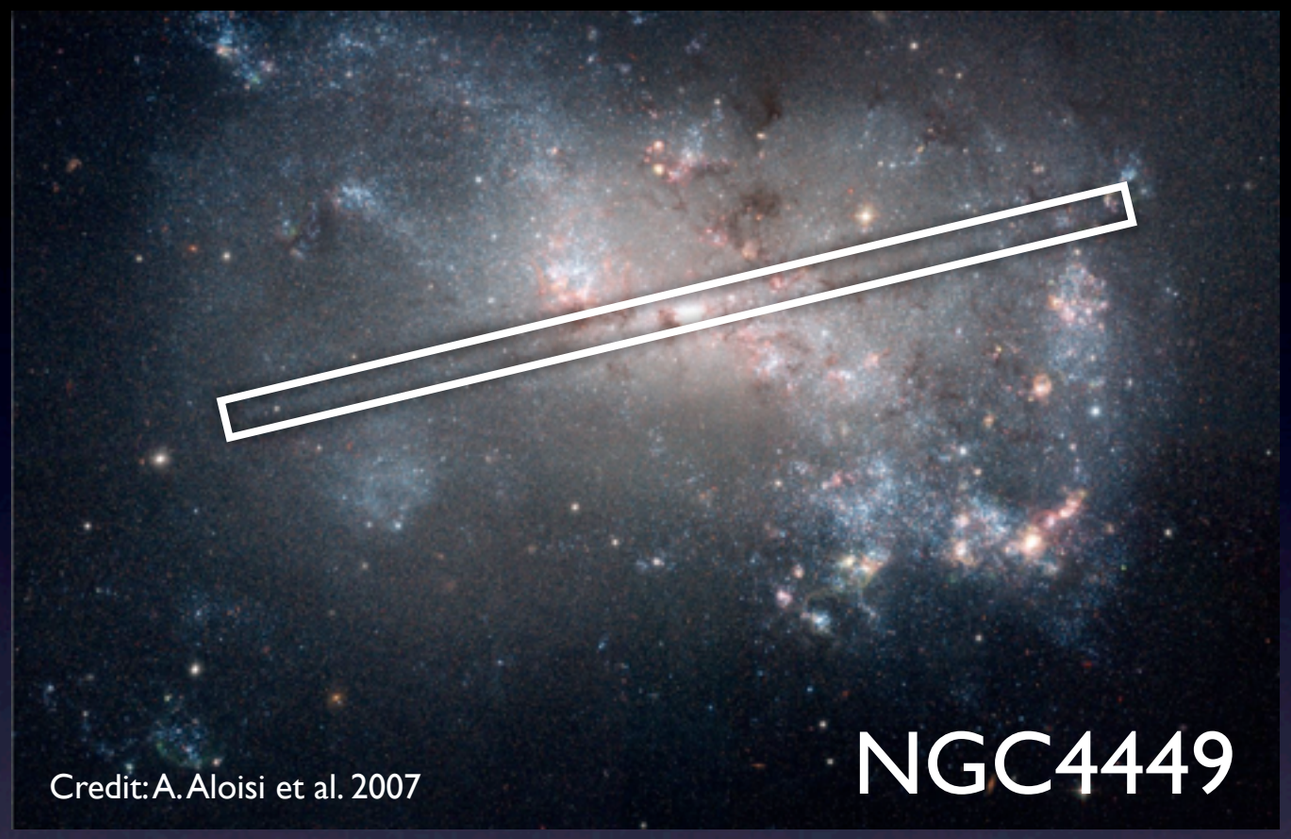

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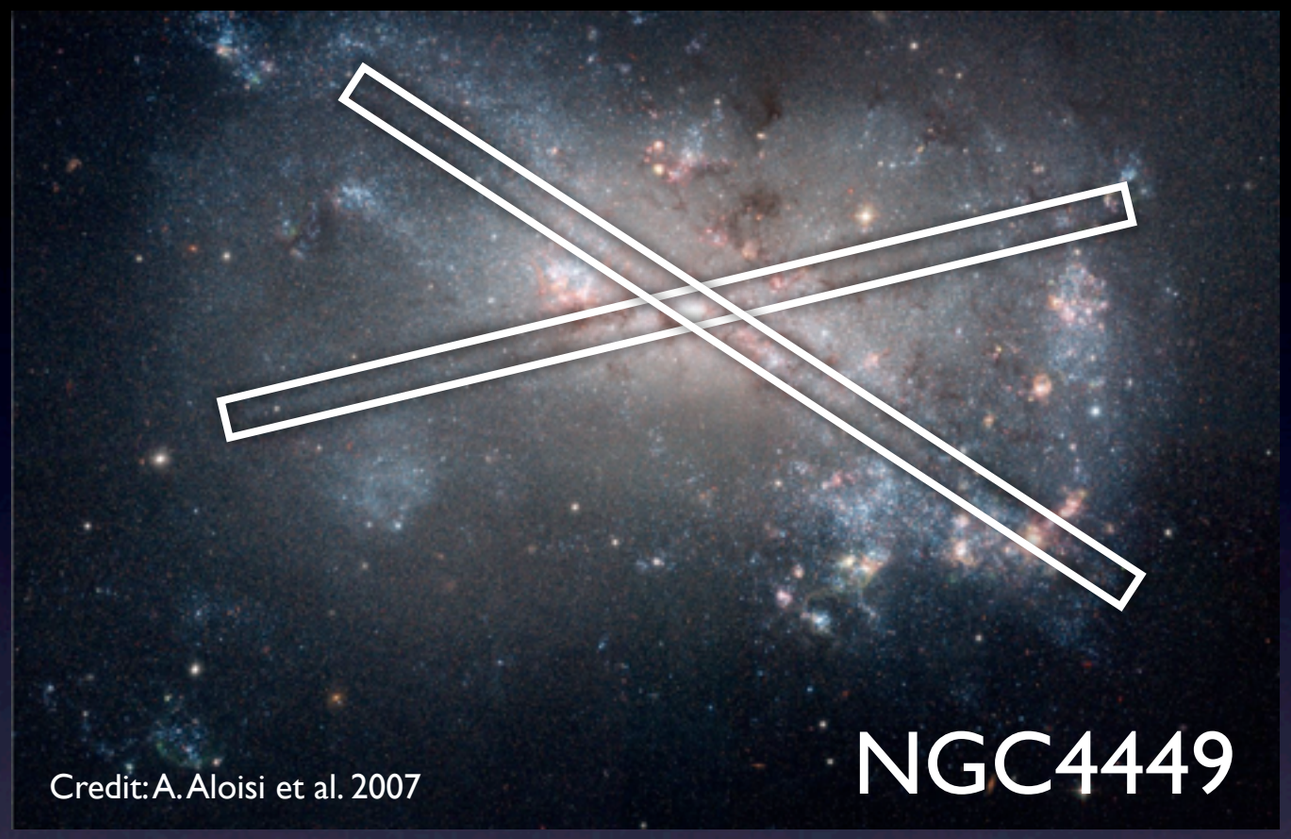

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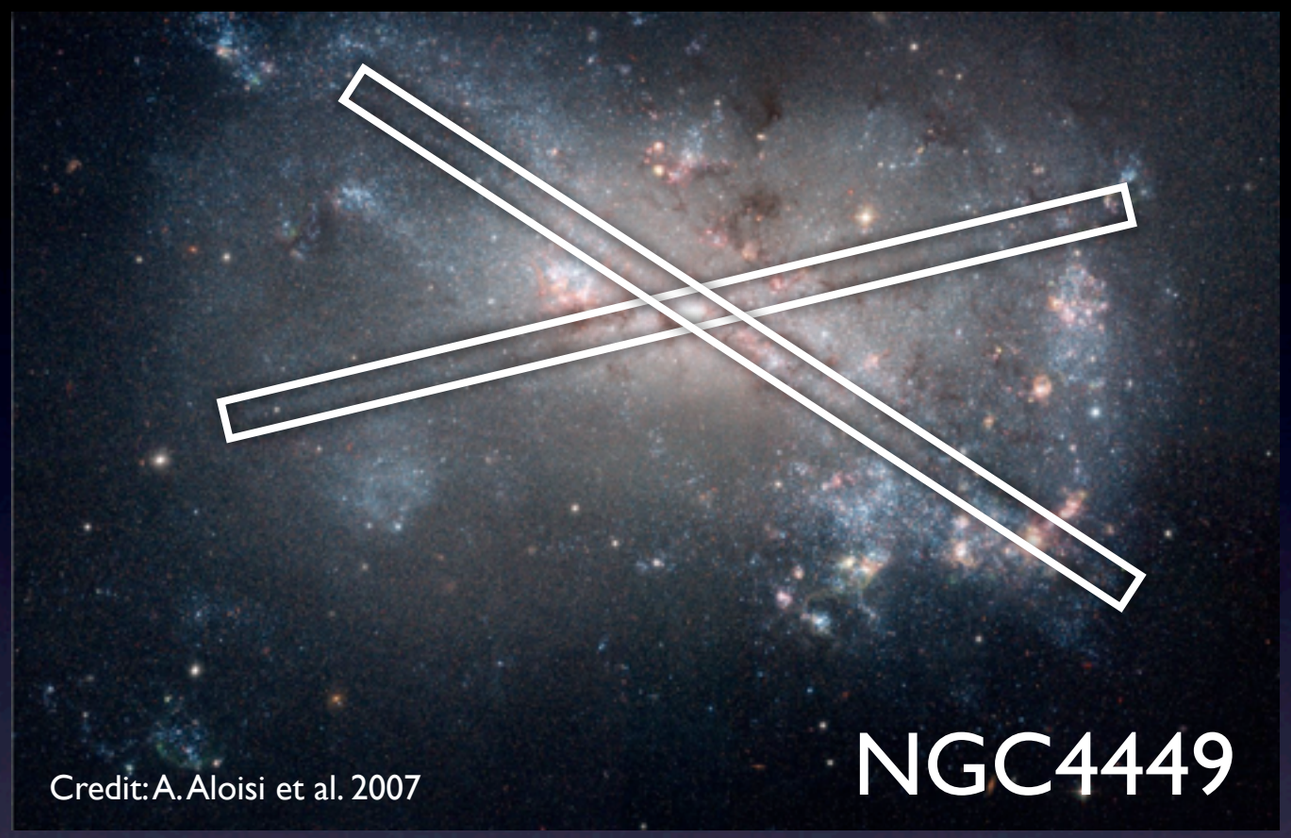

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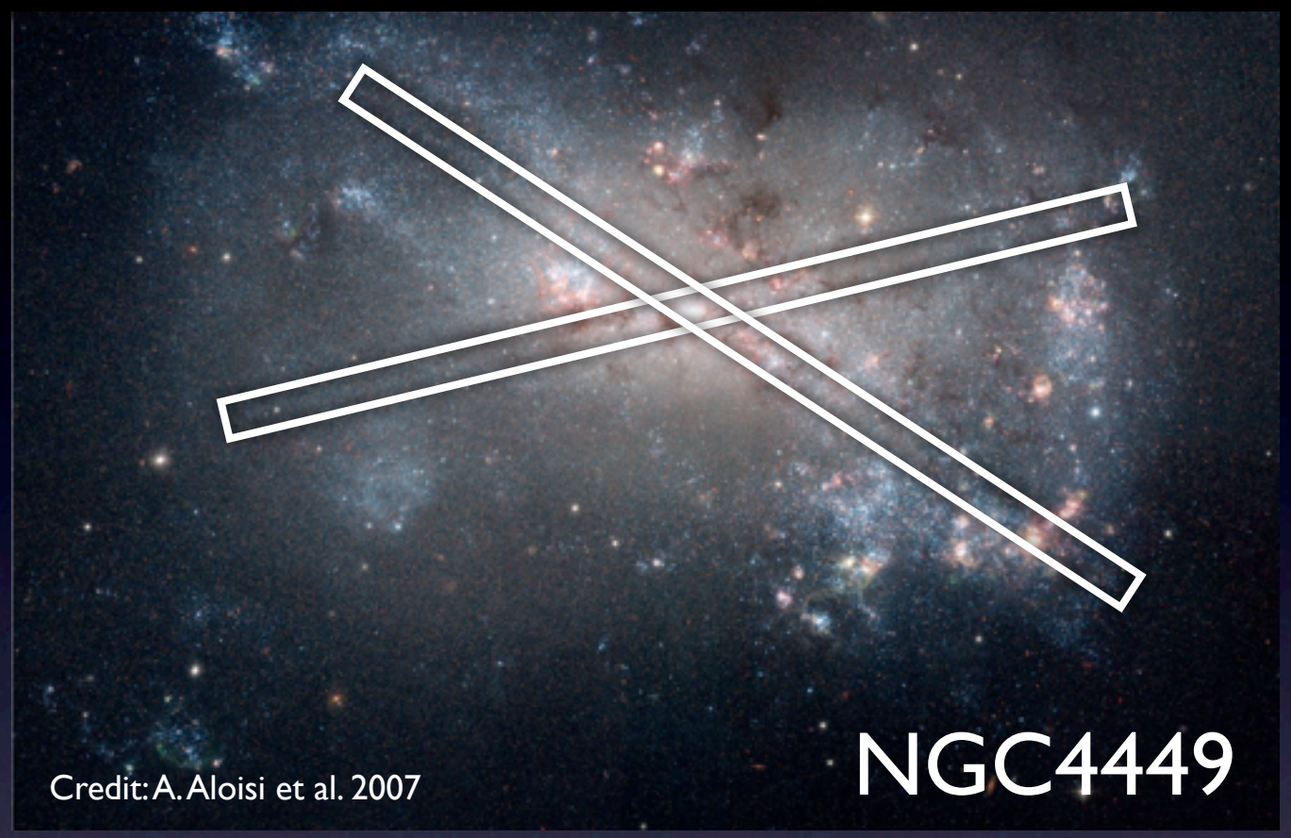

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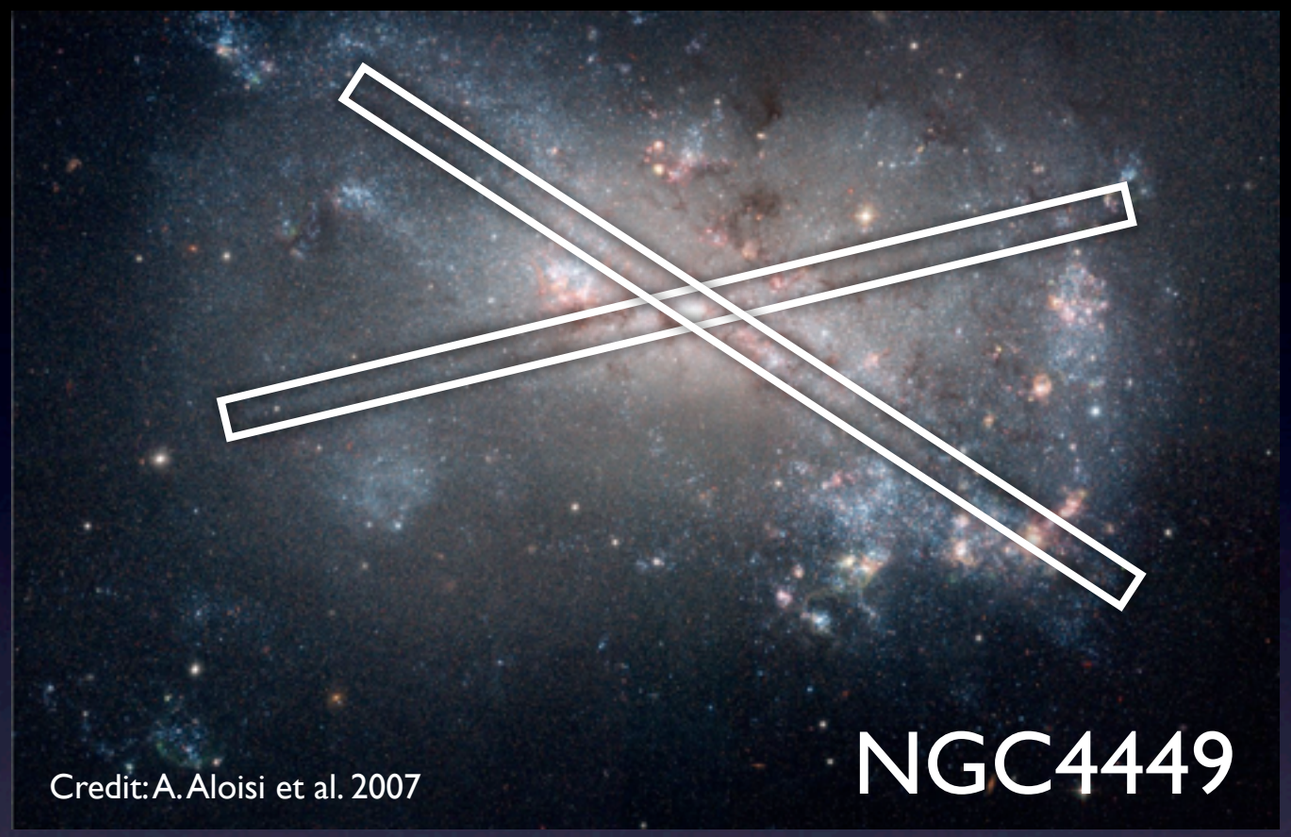

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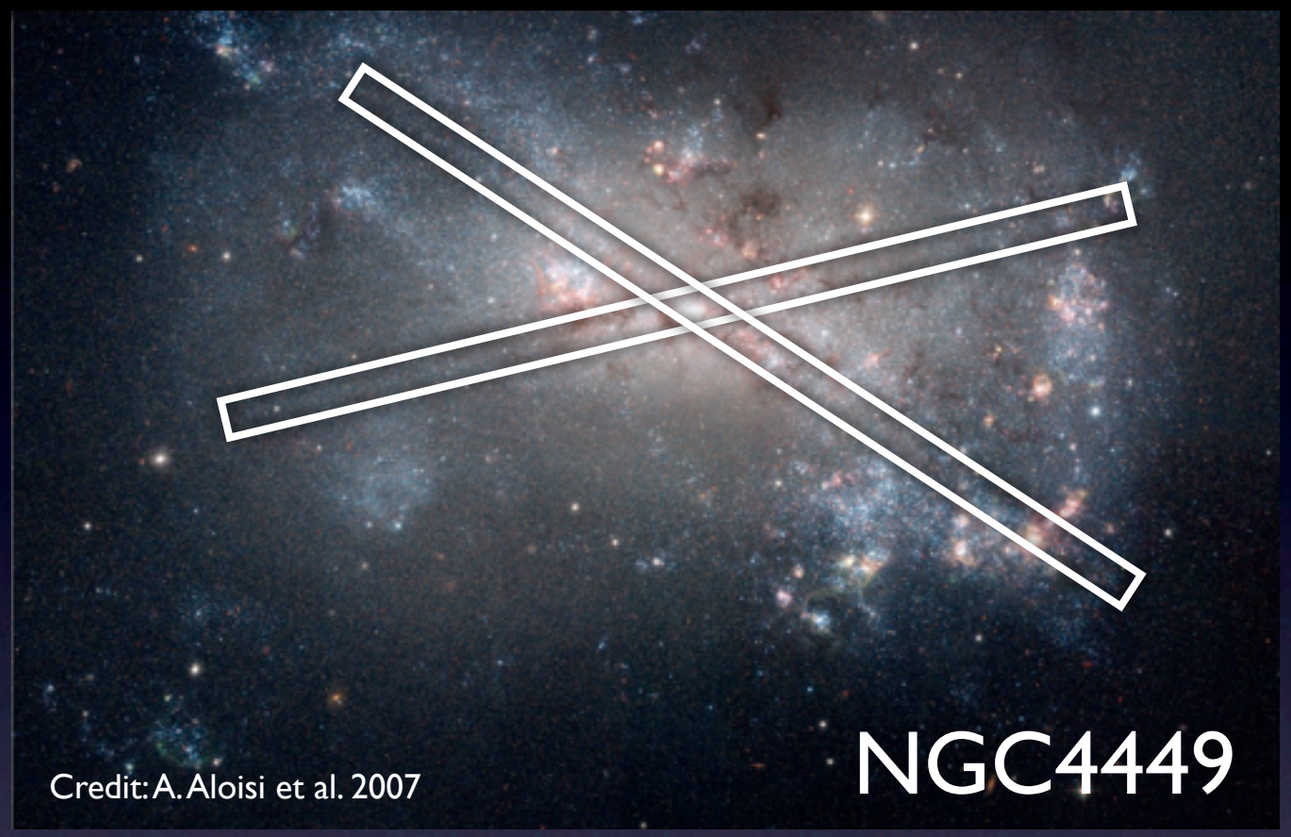

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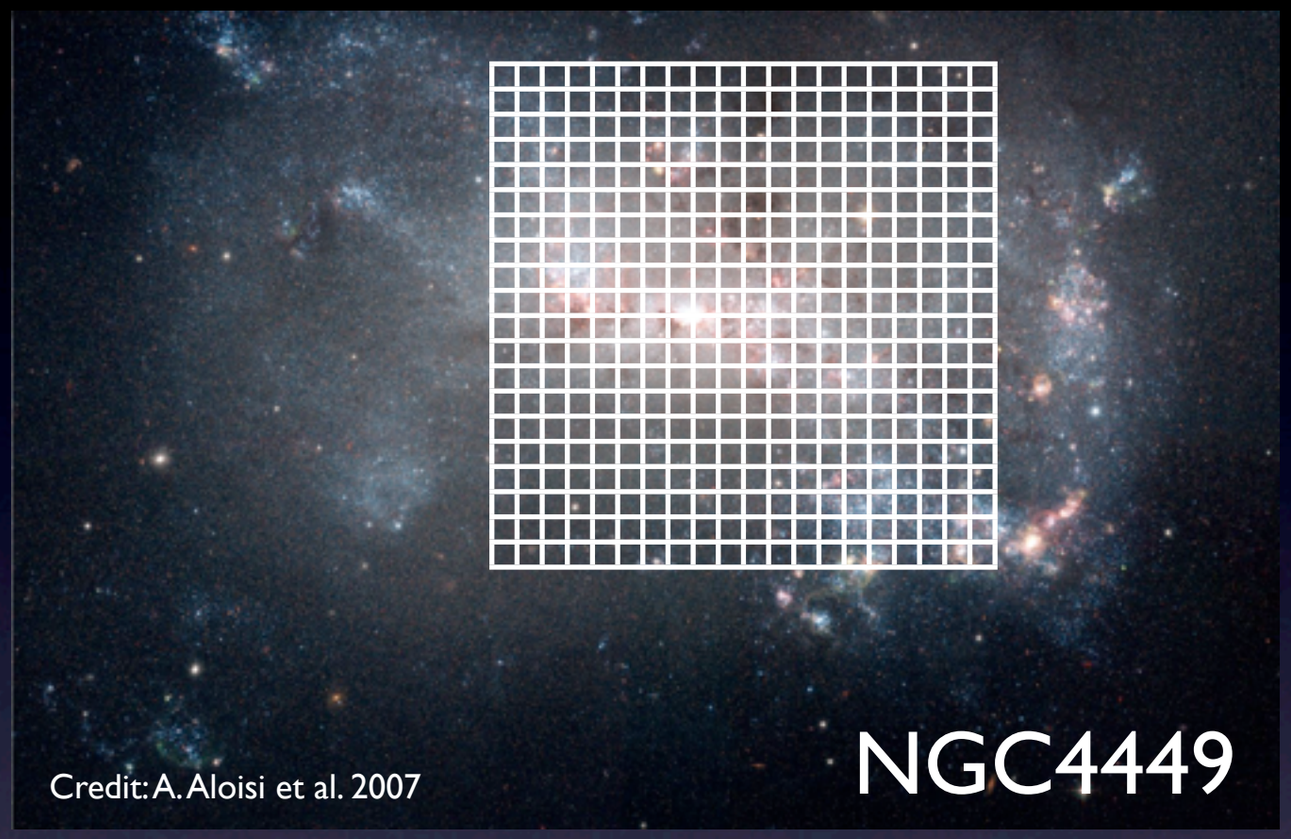

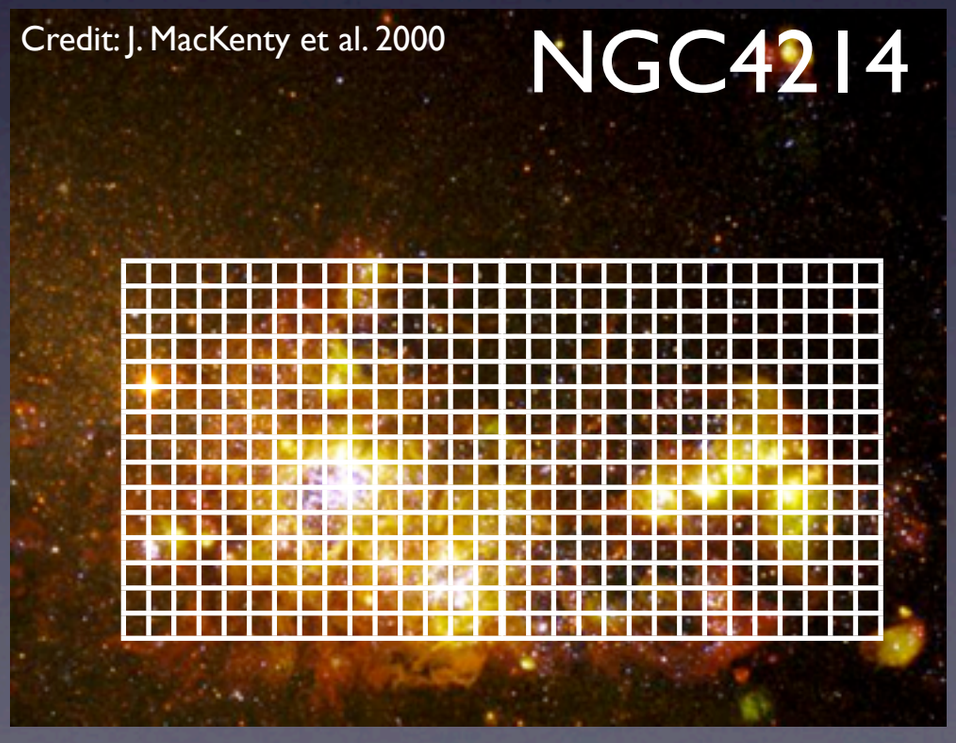

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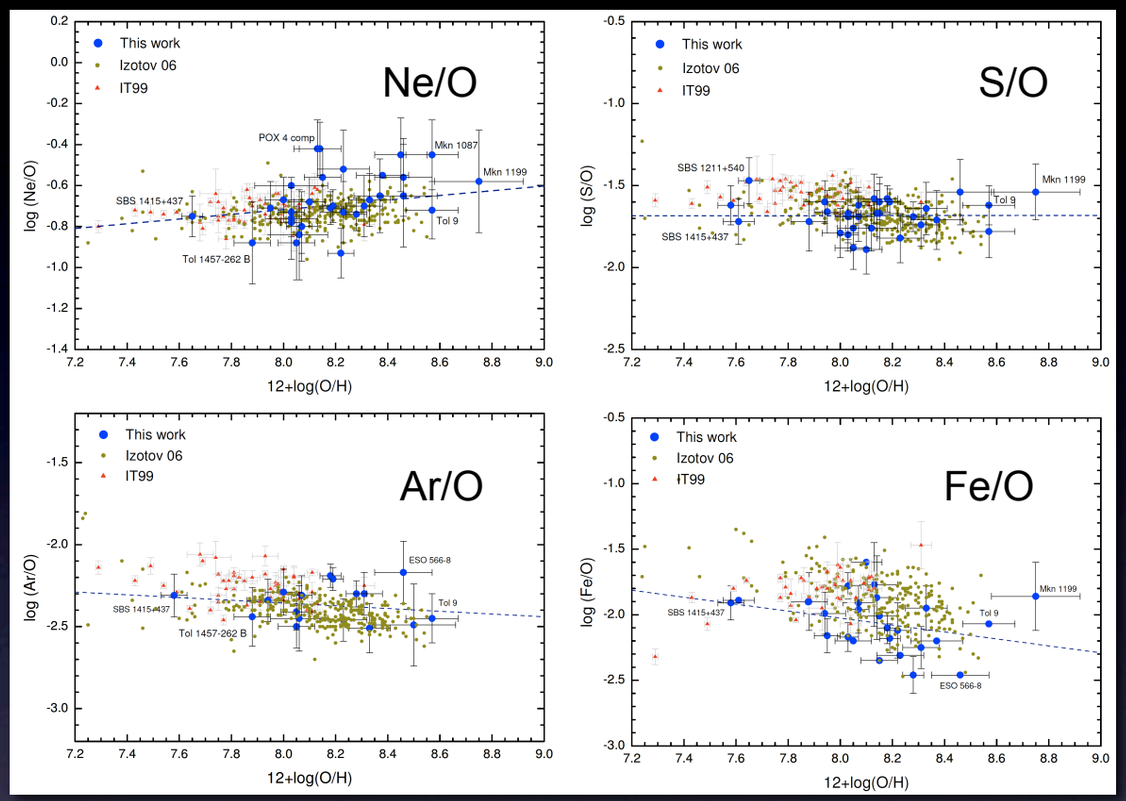
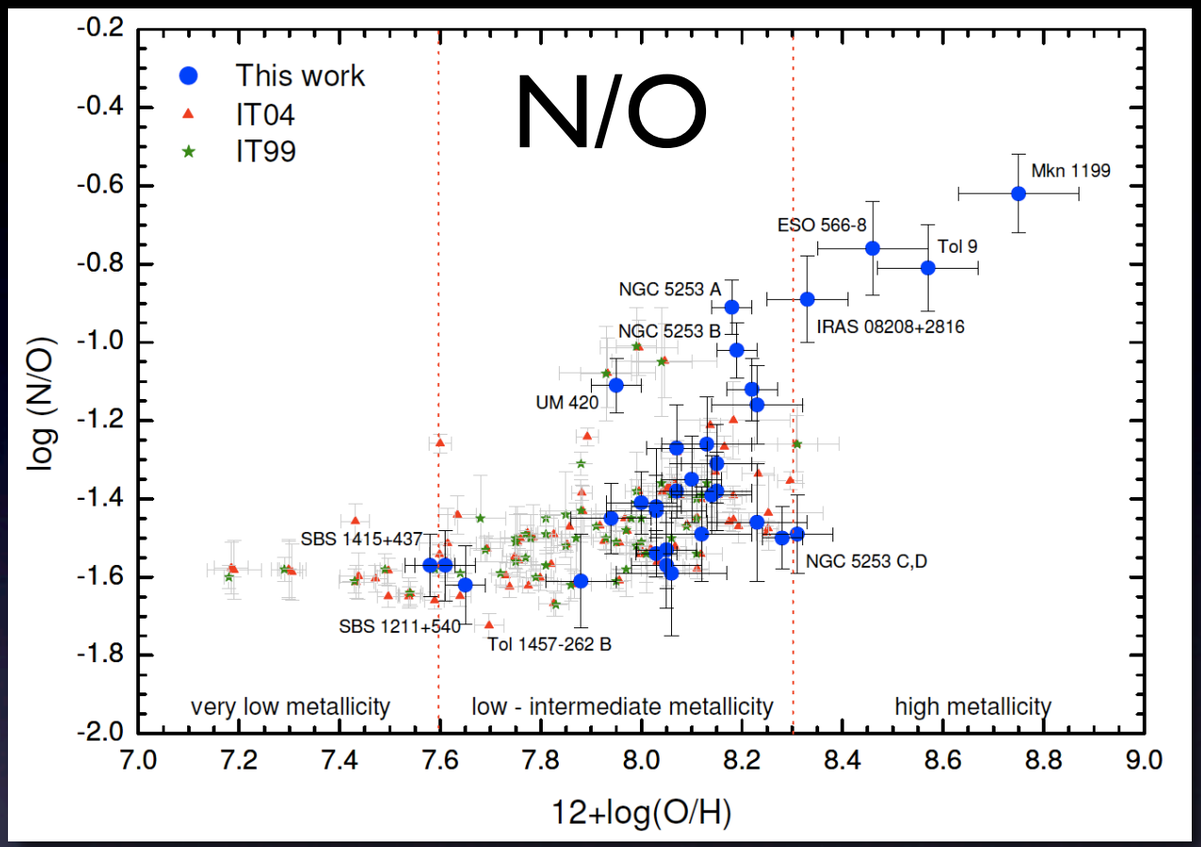
They need IFU Observations!

Chemical Abundances of BCDs



Lopez-Sanchez & Esteban, 2010



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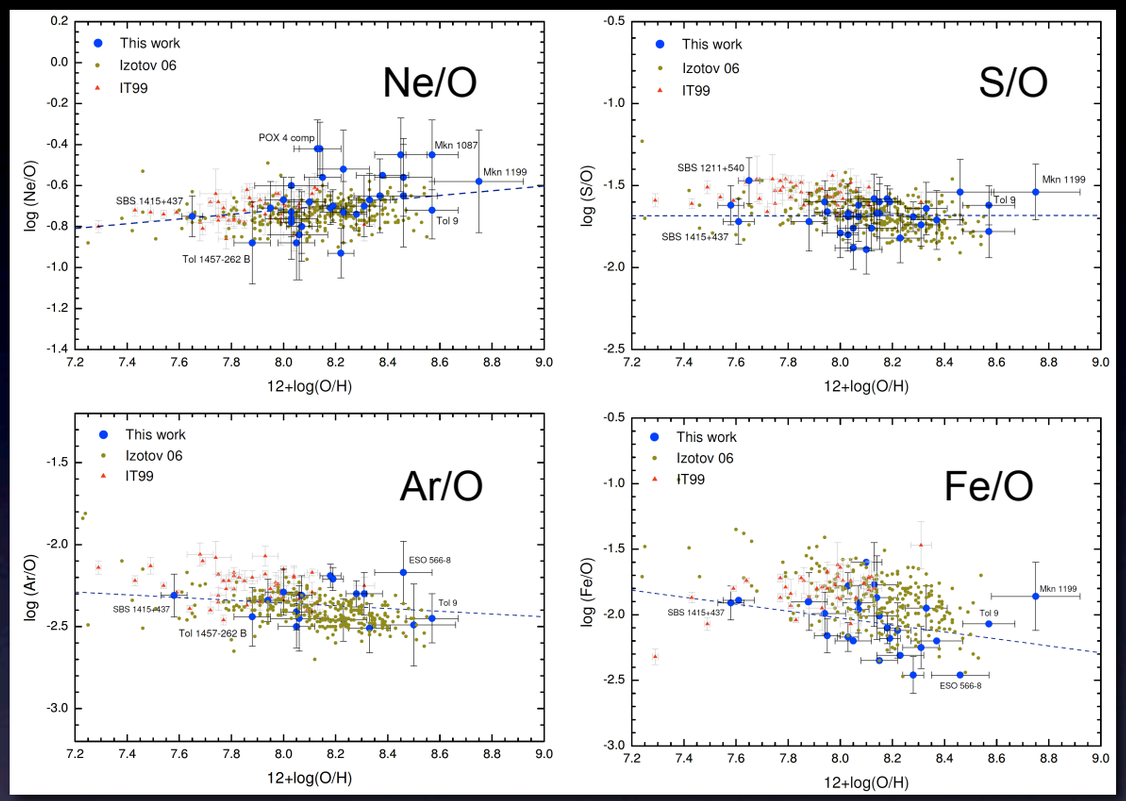

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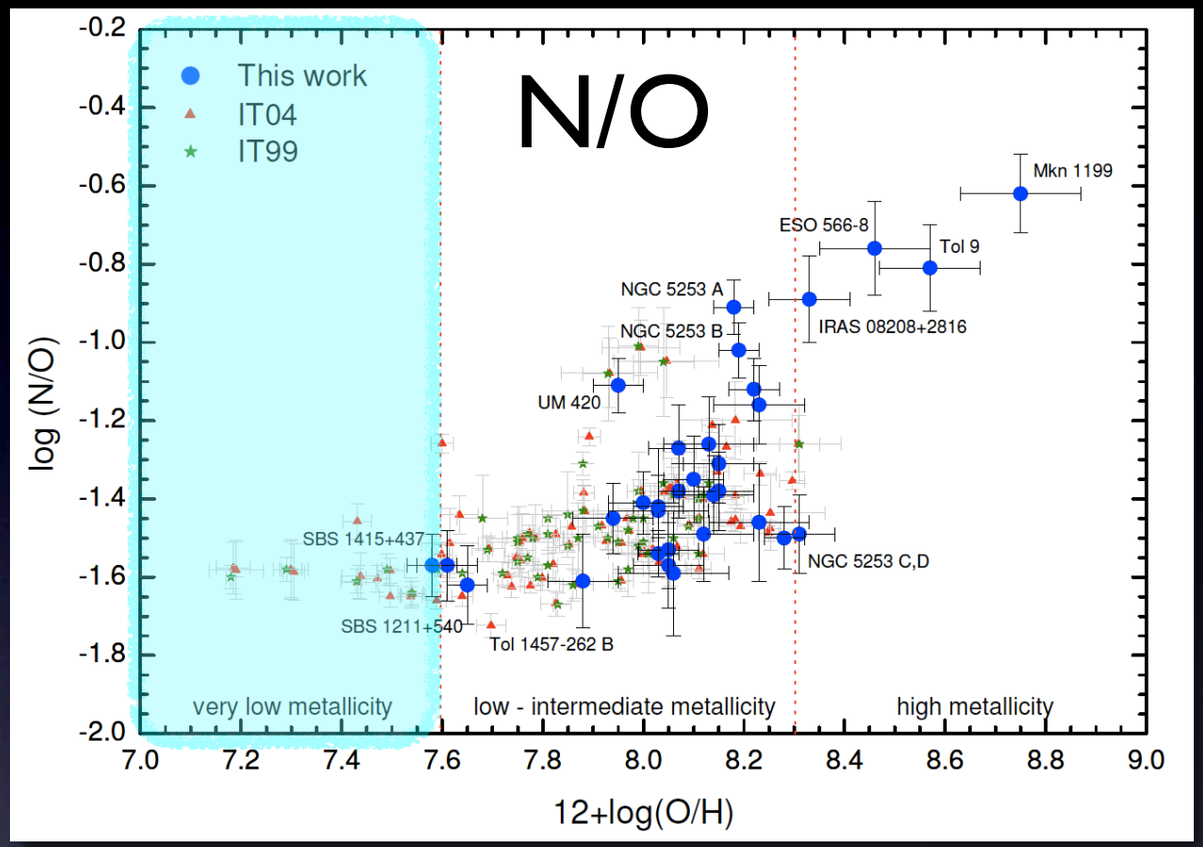

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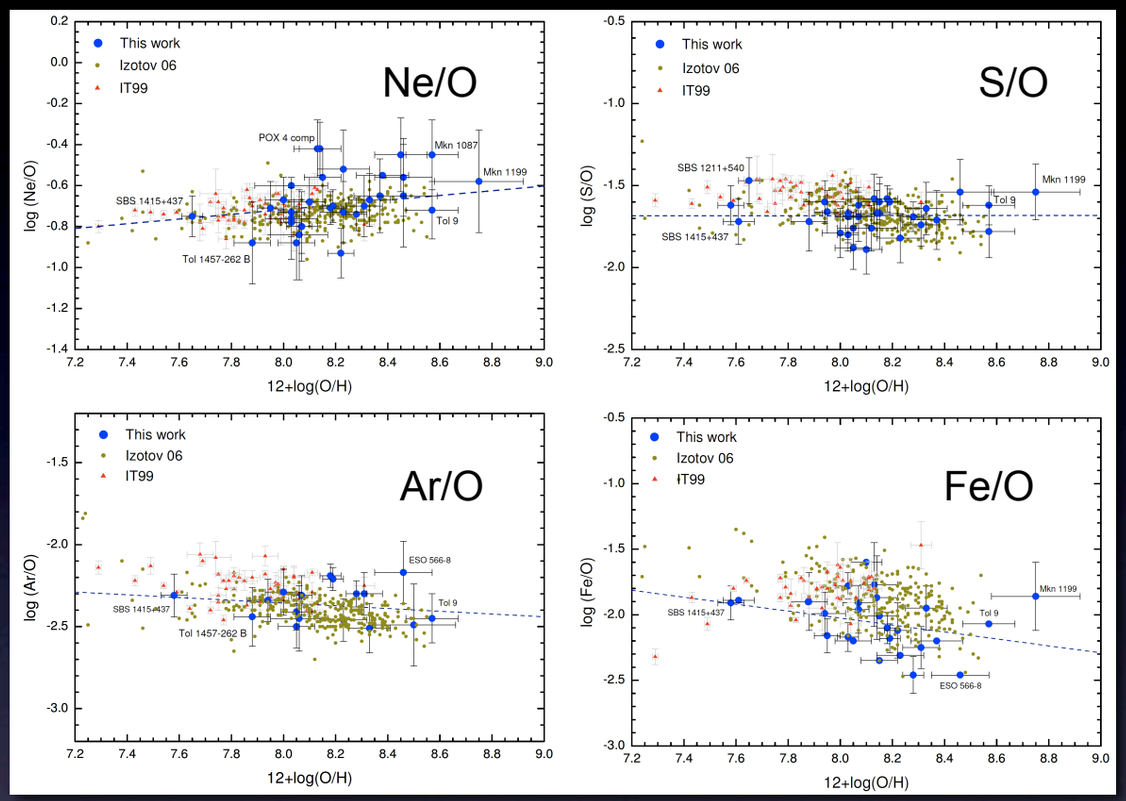

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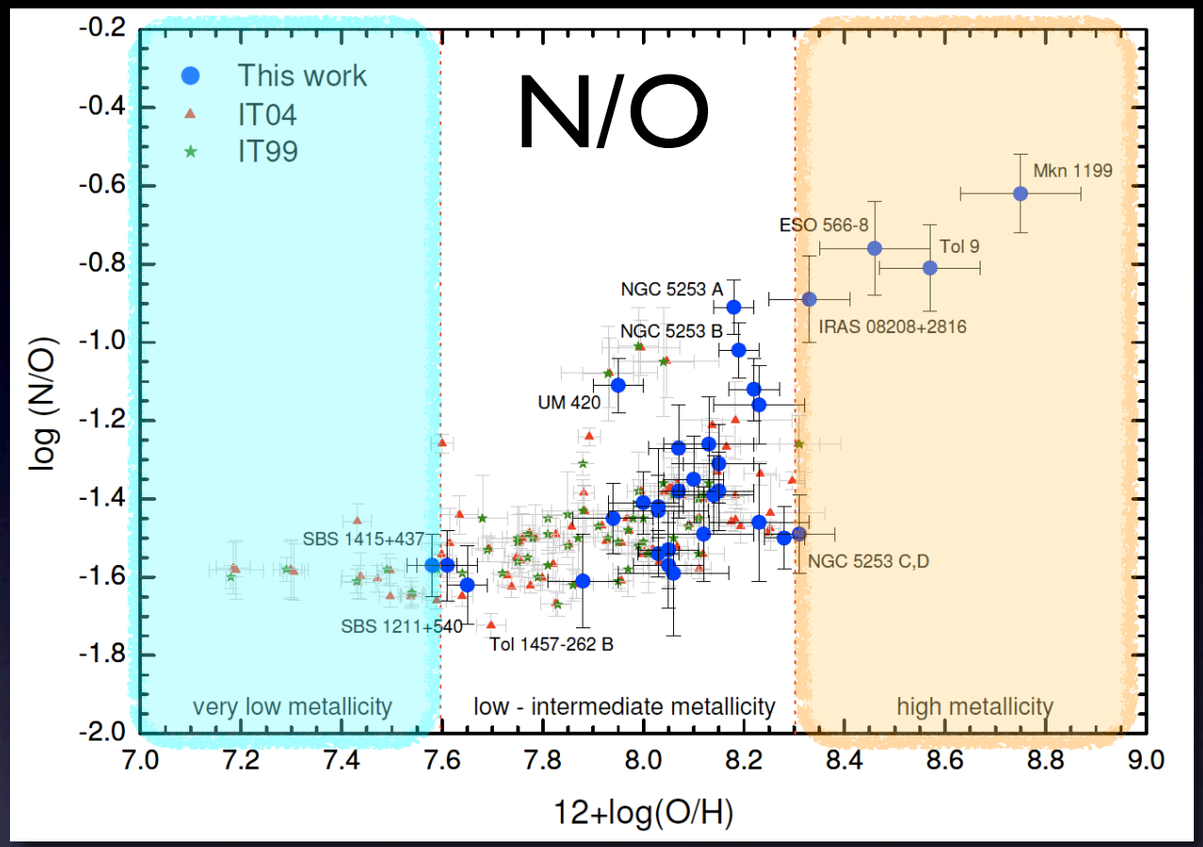

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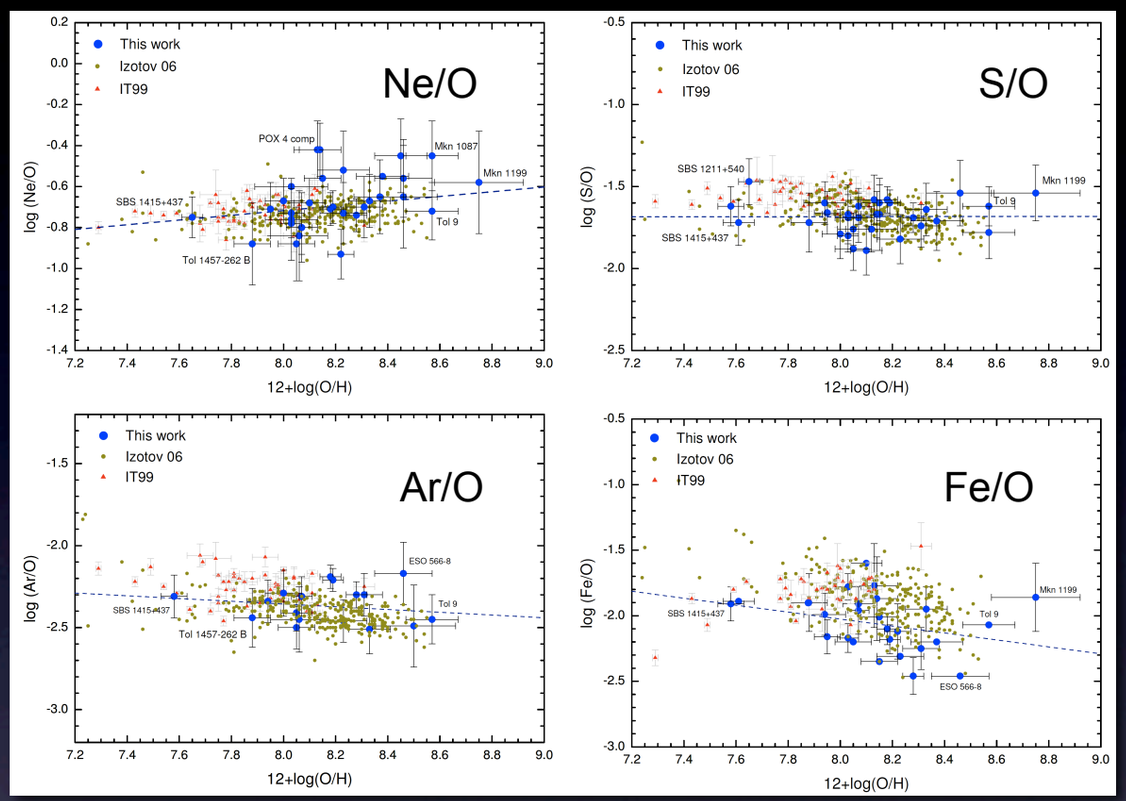

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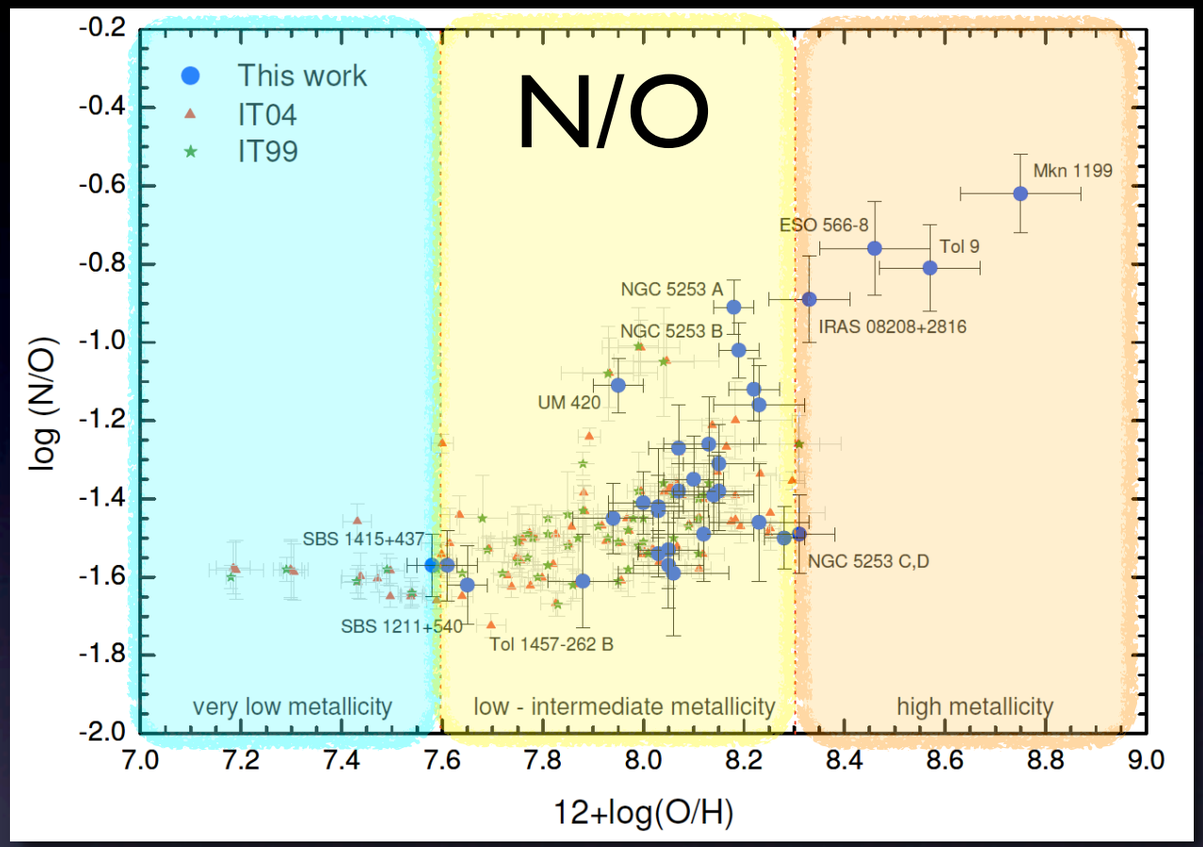

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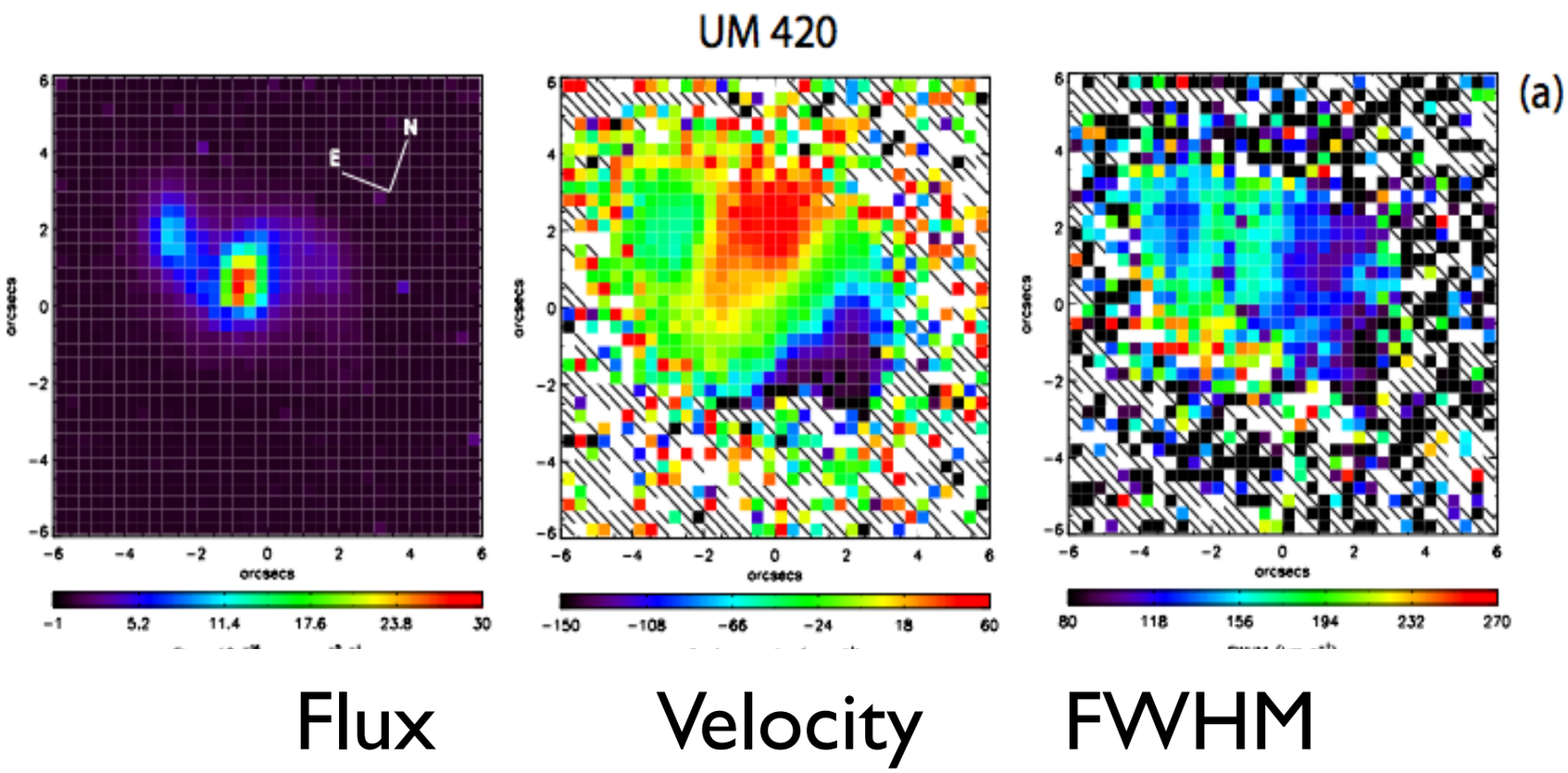

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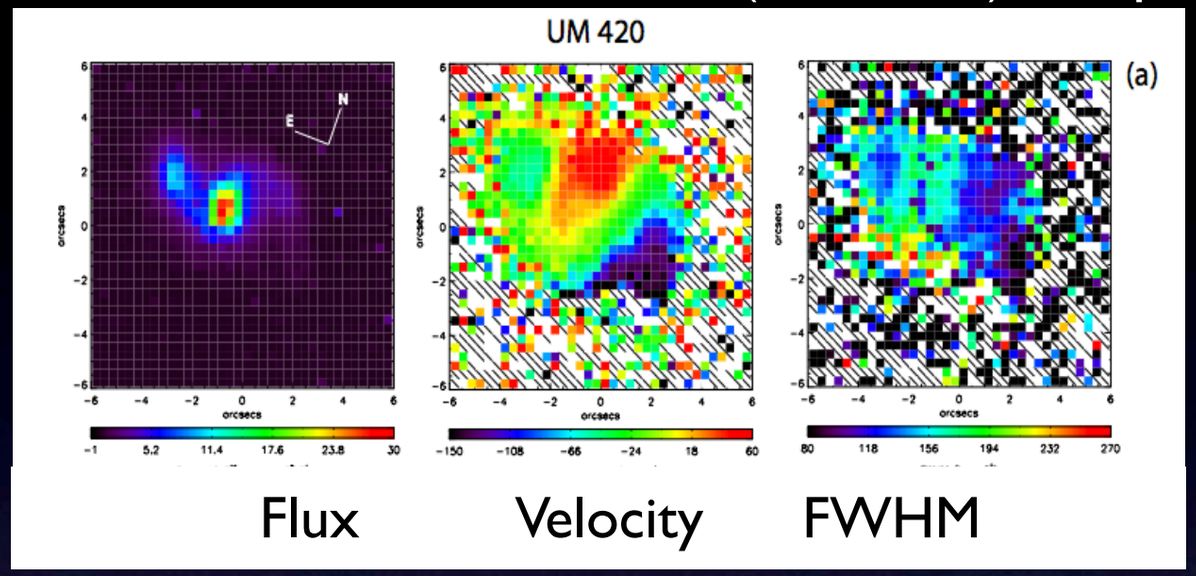

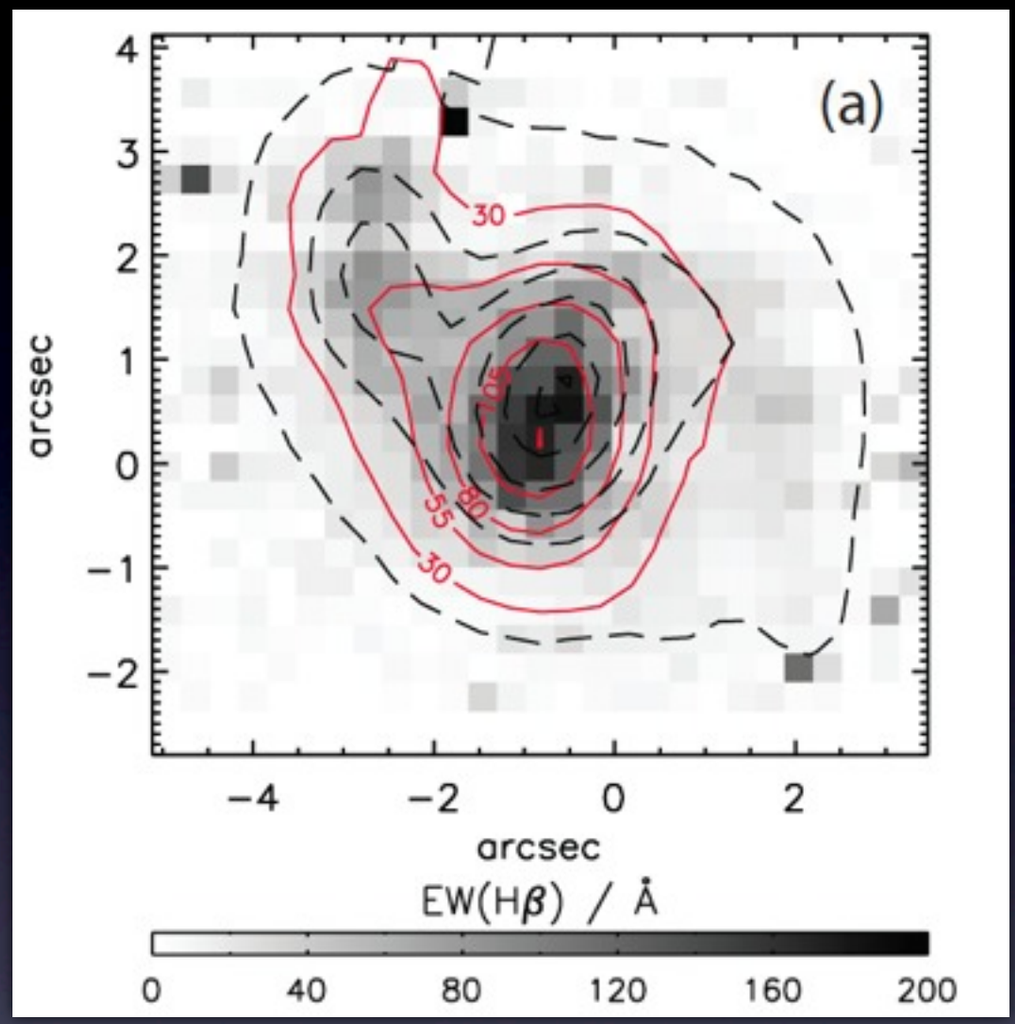

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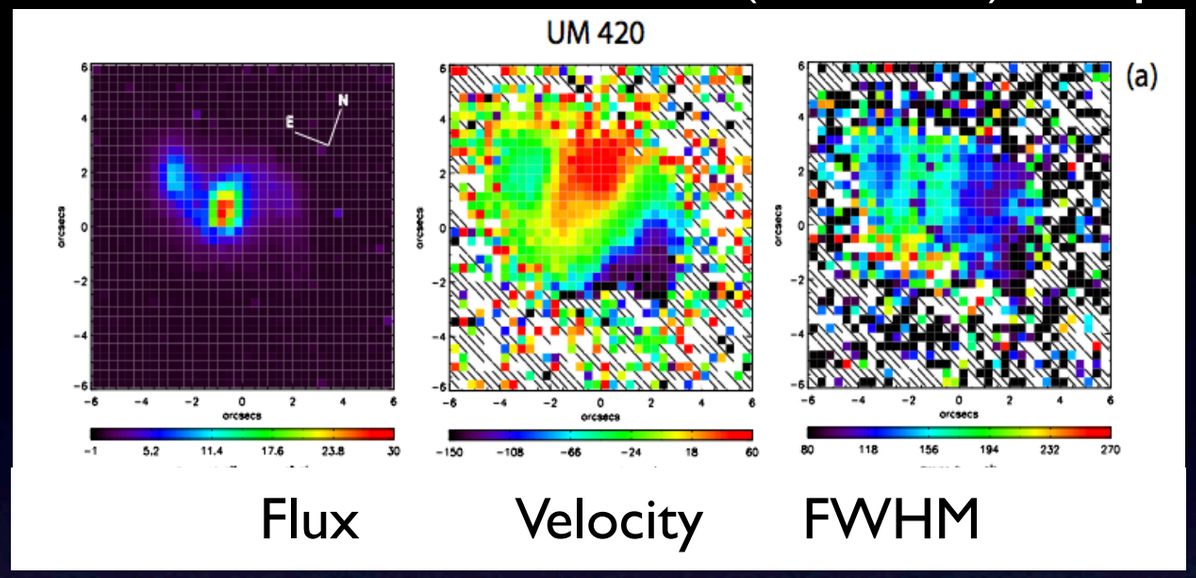

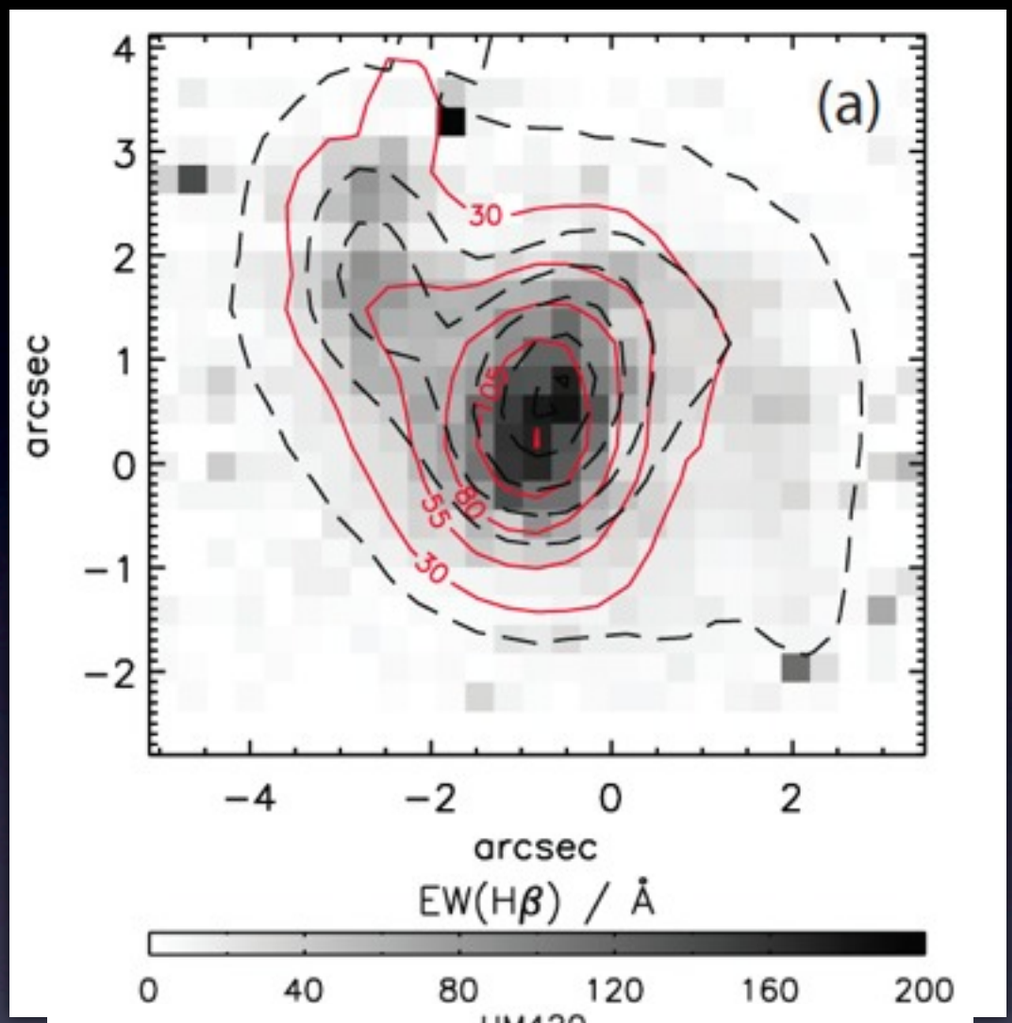

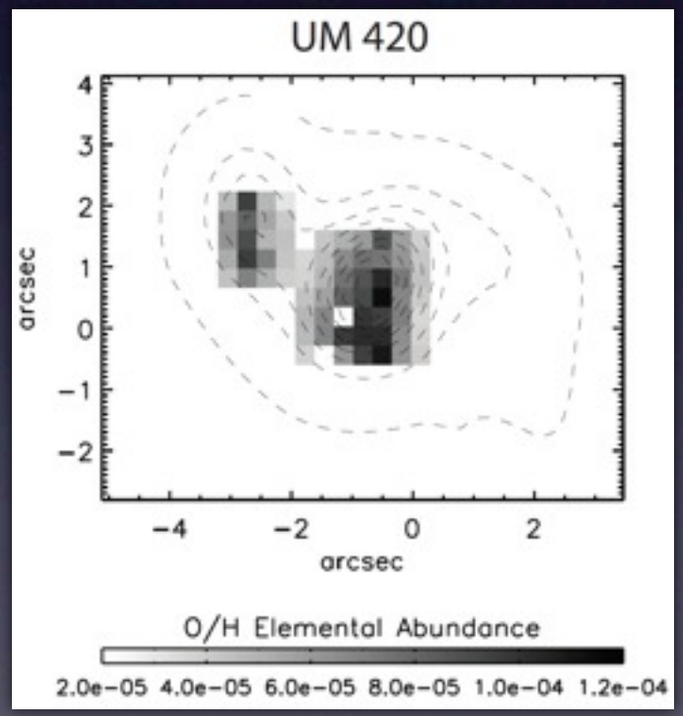

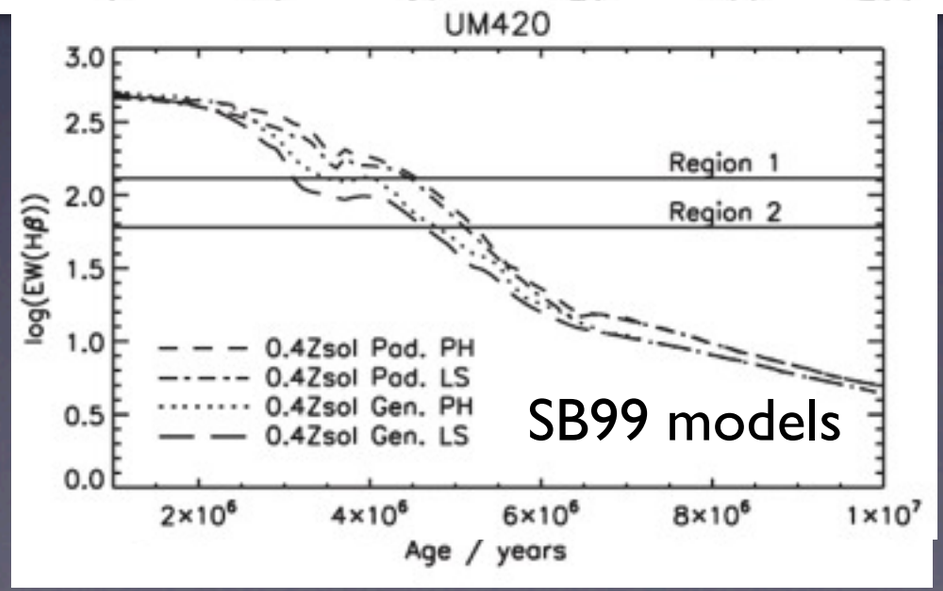

UM420

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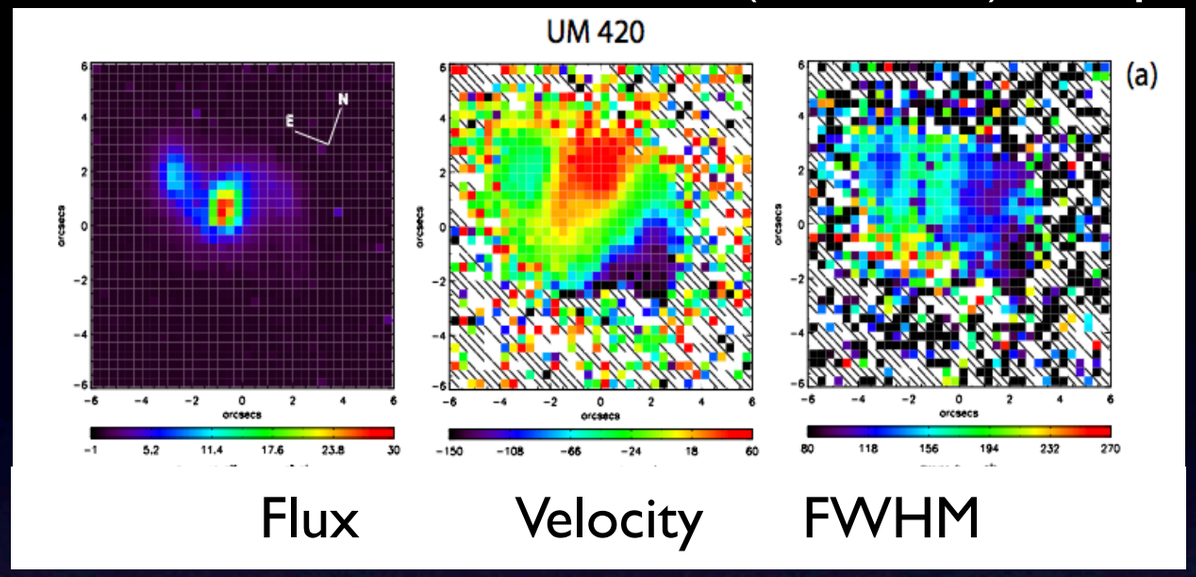
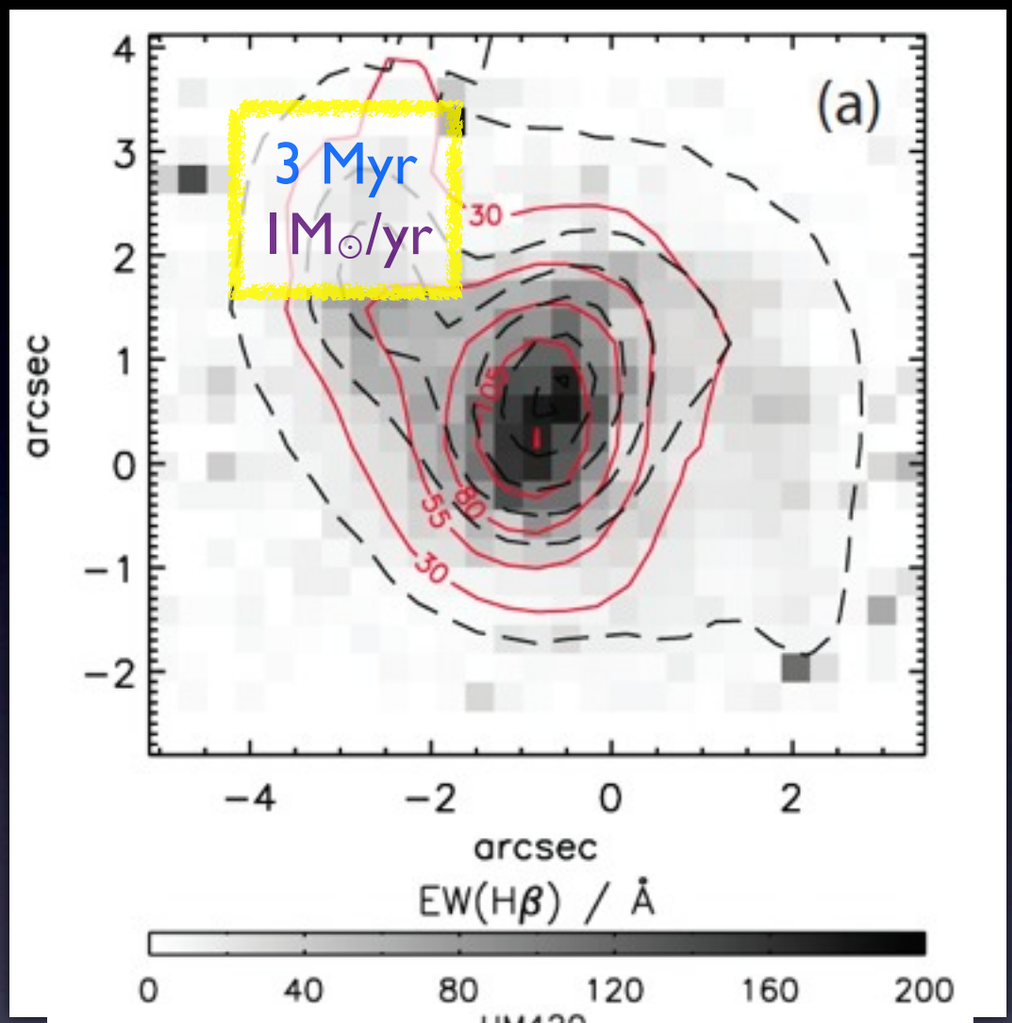
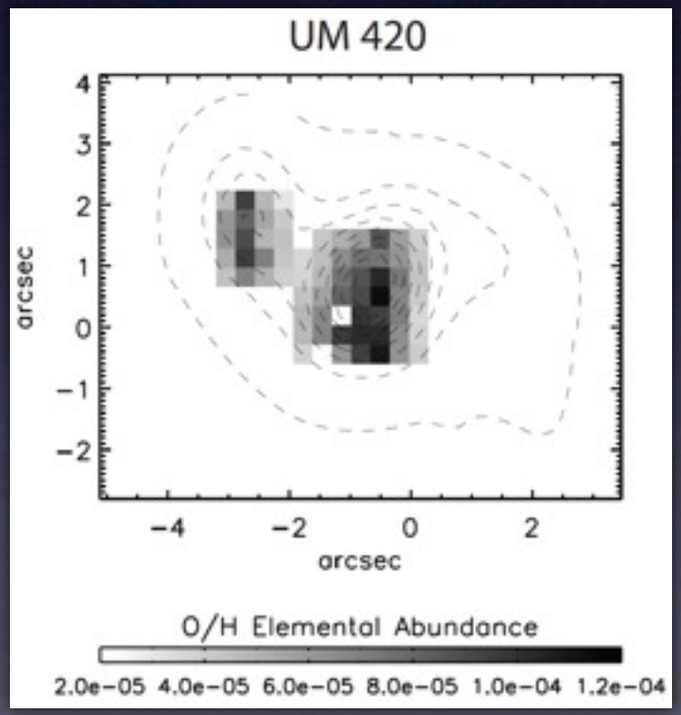
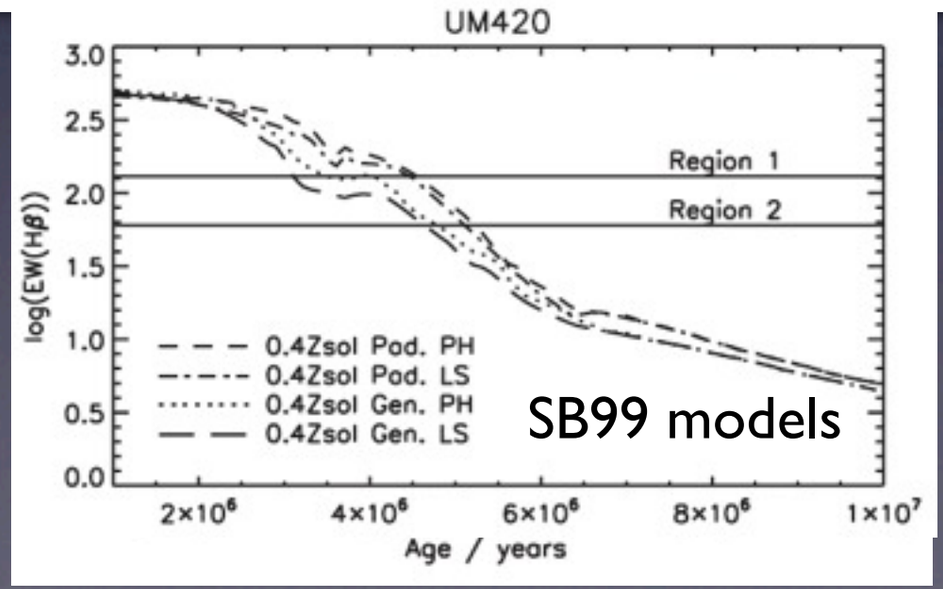
VLT/VIMOS IFU data (PI:Tsamis) - Maps in Hα, D~240Mpc









UM420

James et al. 2010

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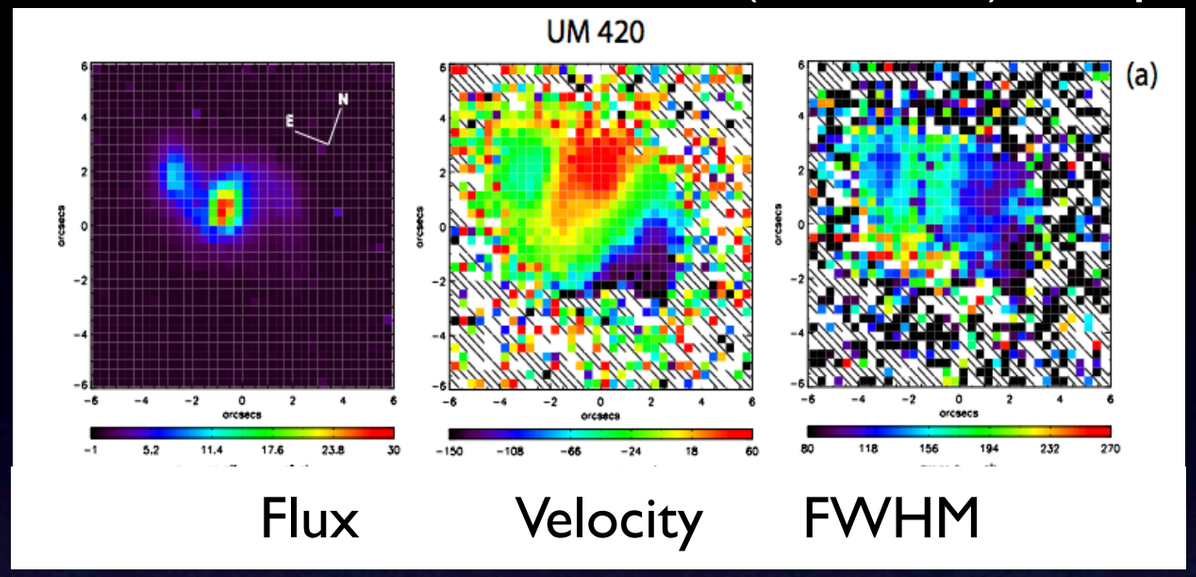

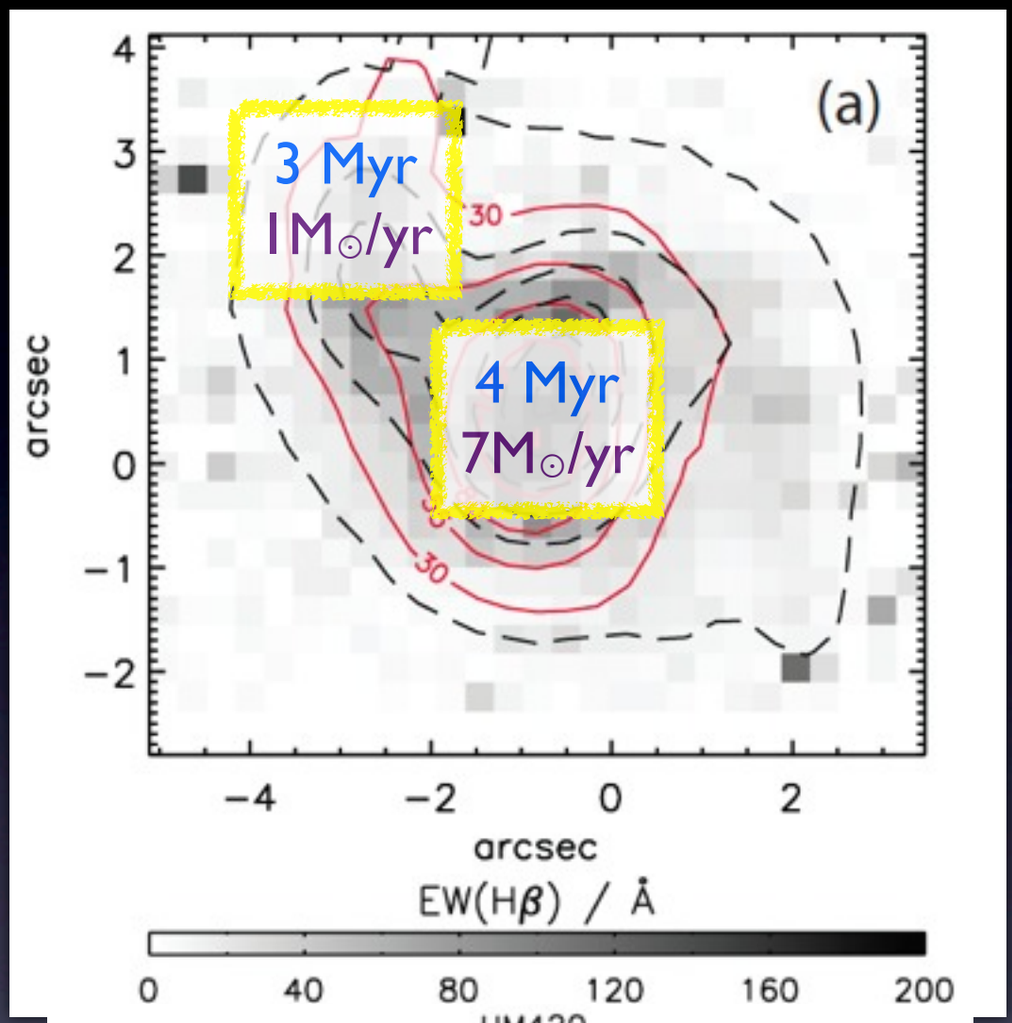

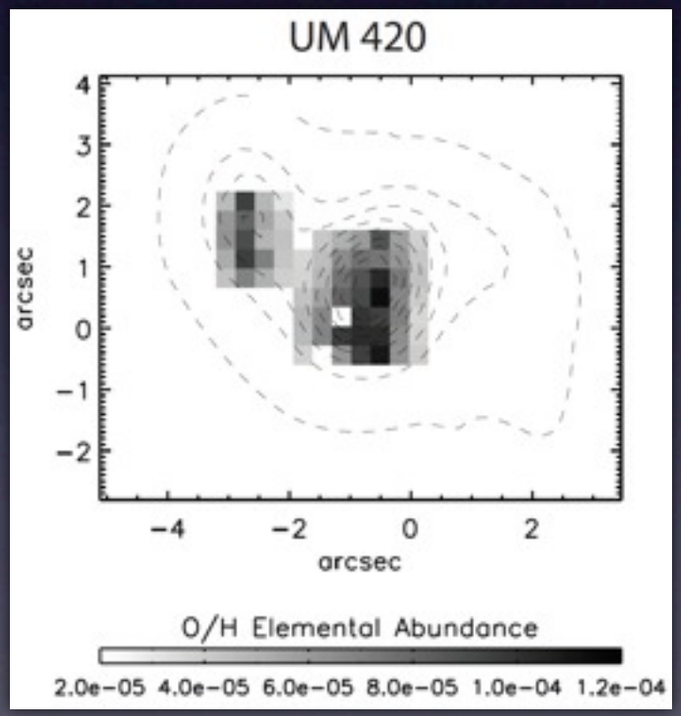

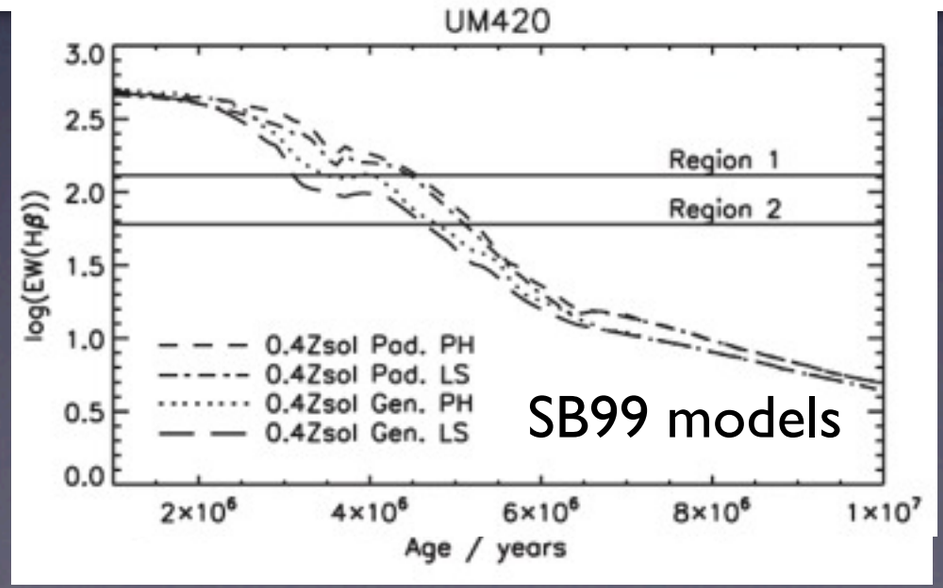

UM420

James et al. 2010

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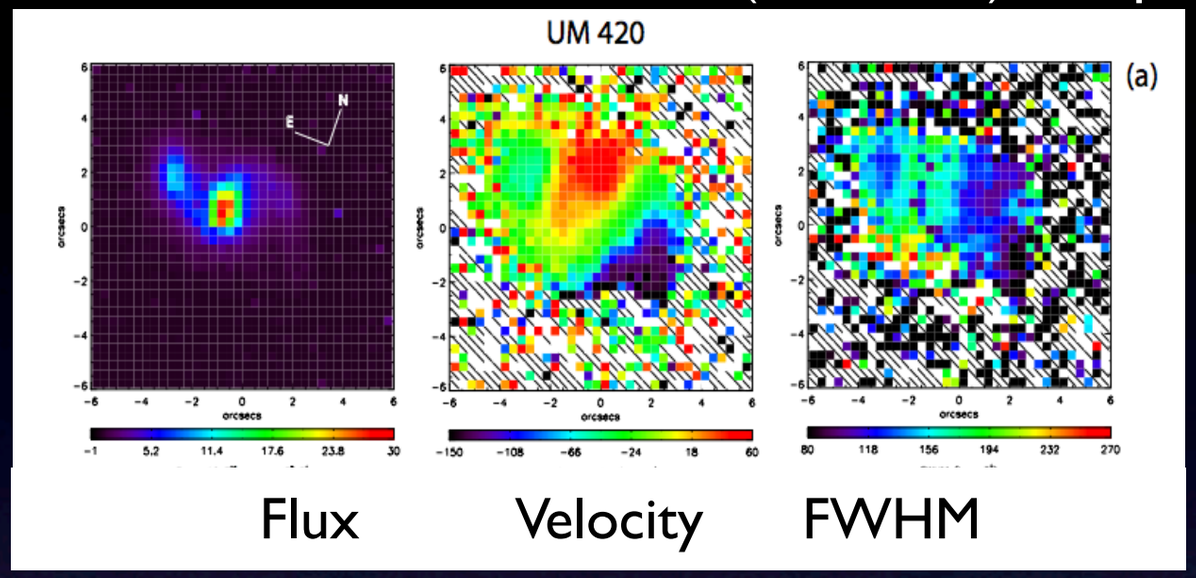

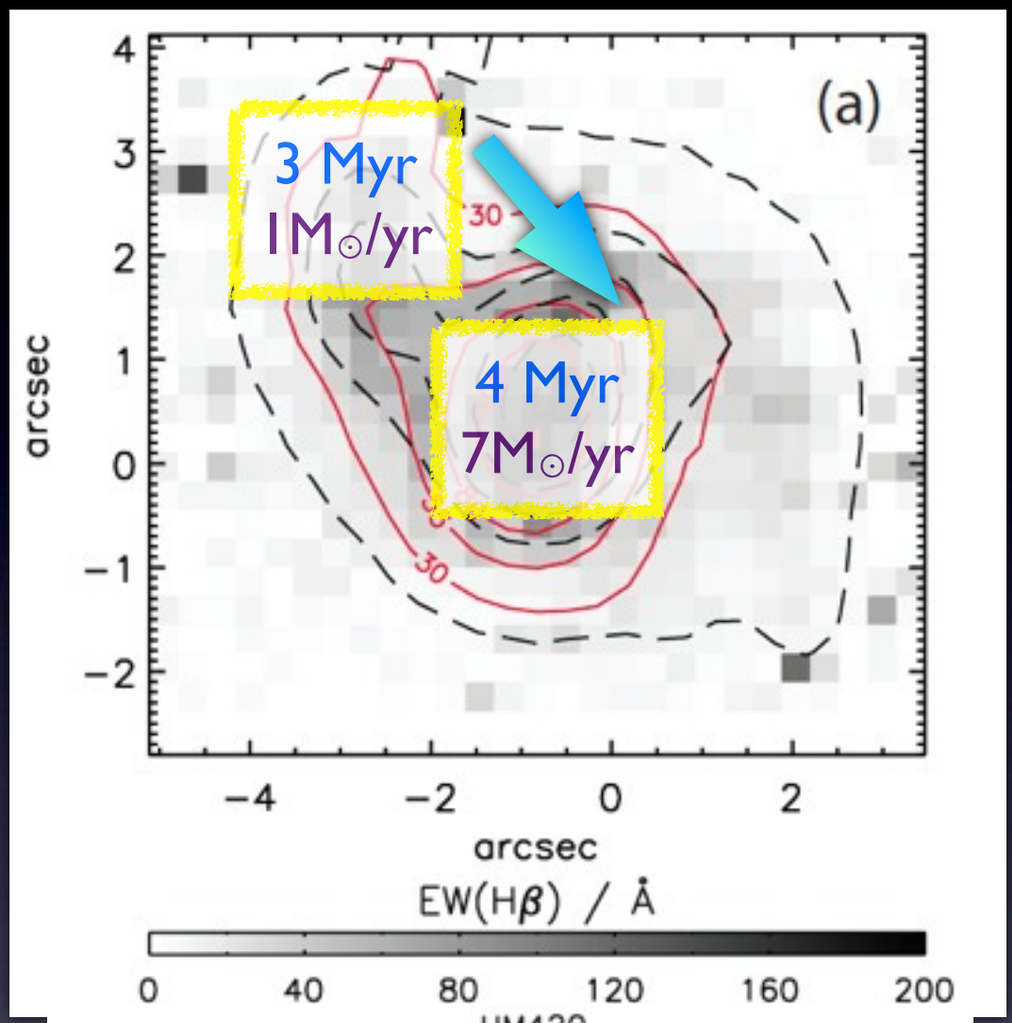

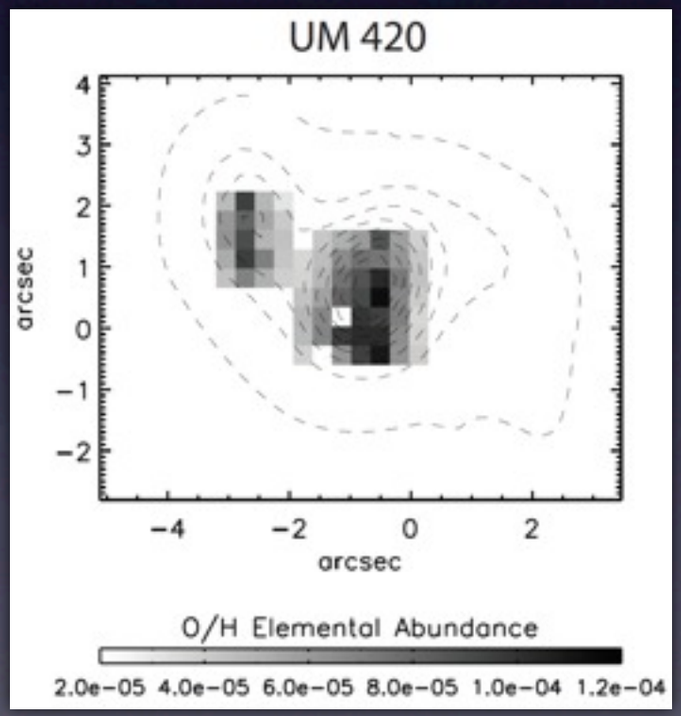

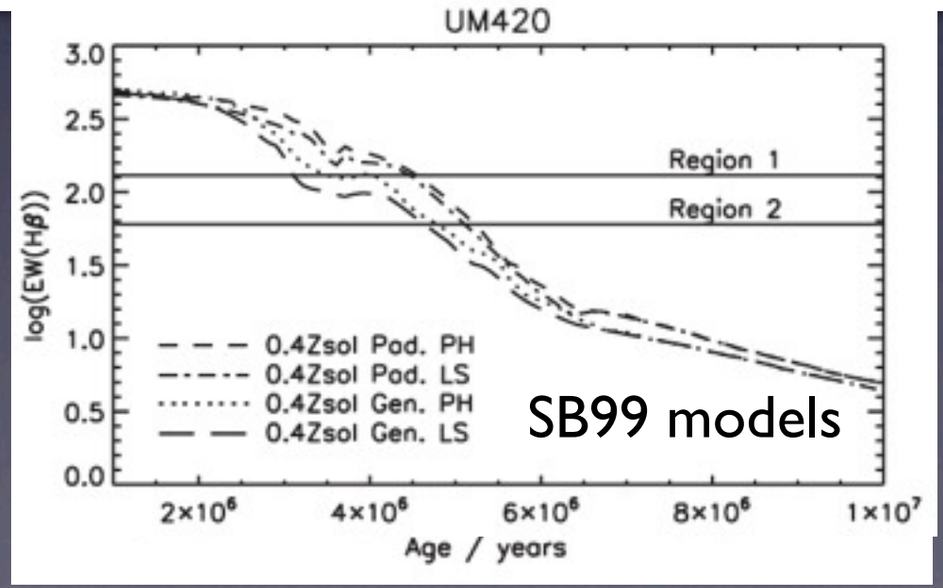

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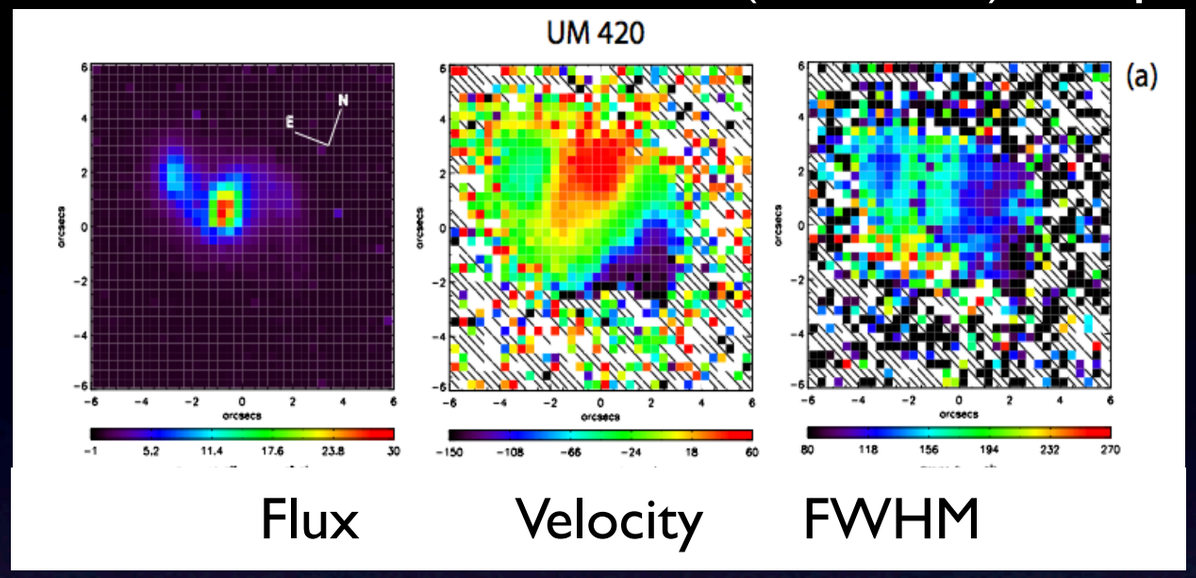
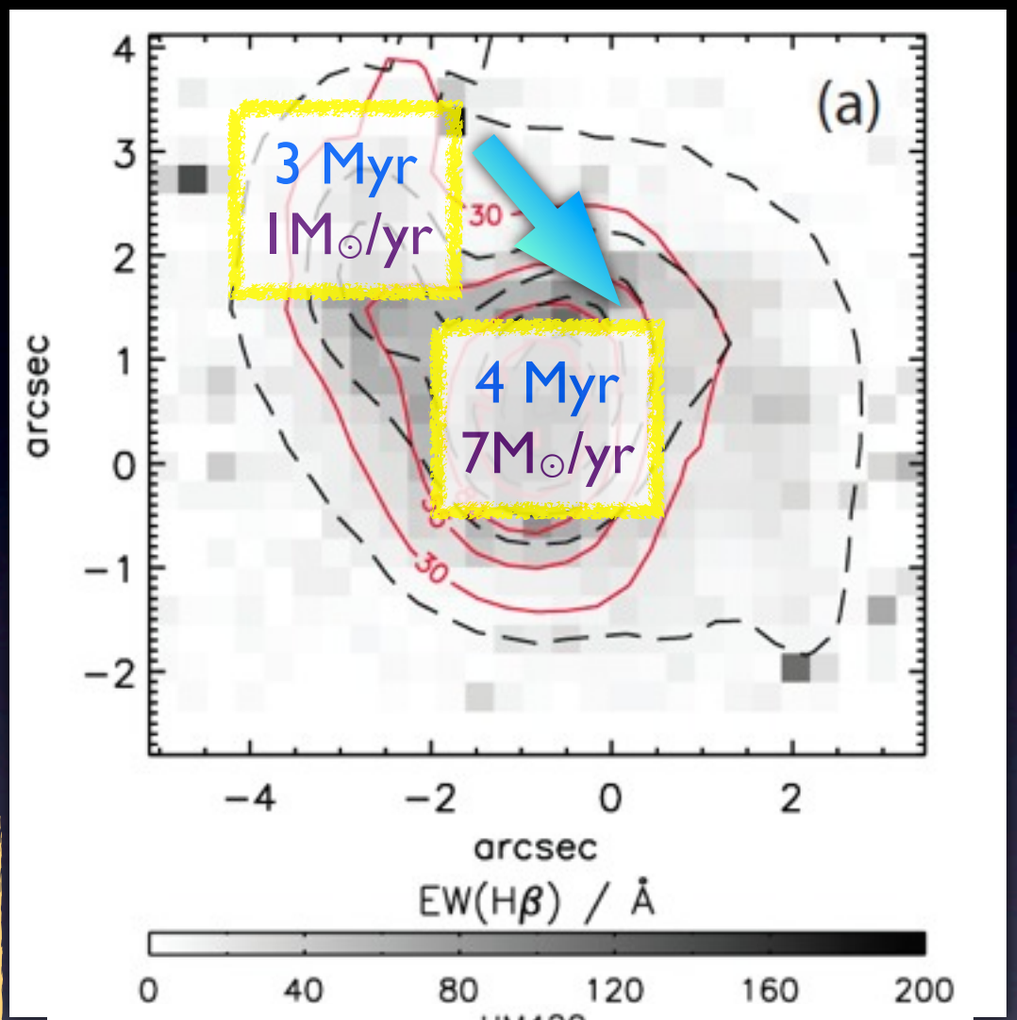
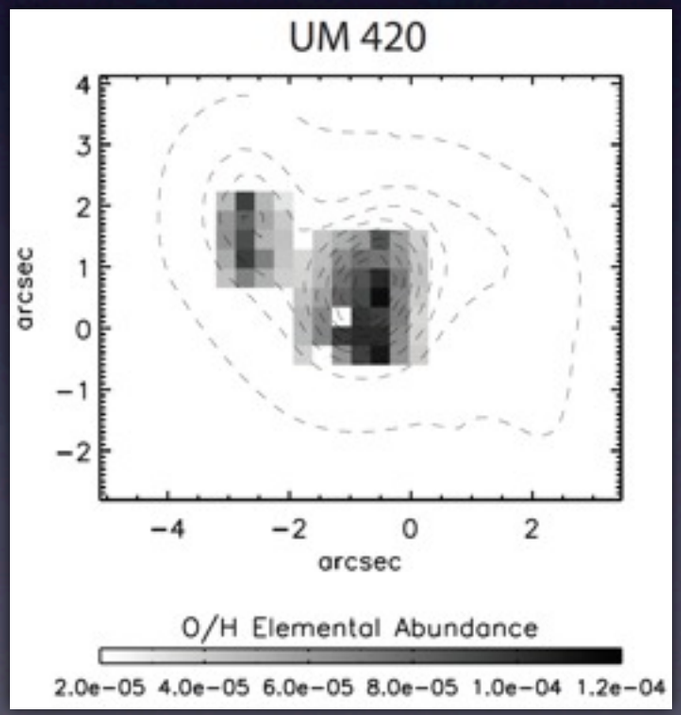


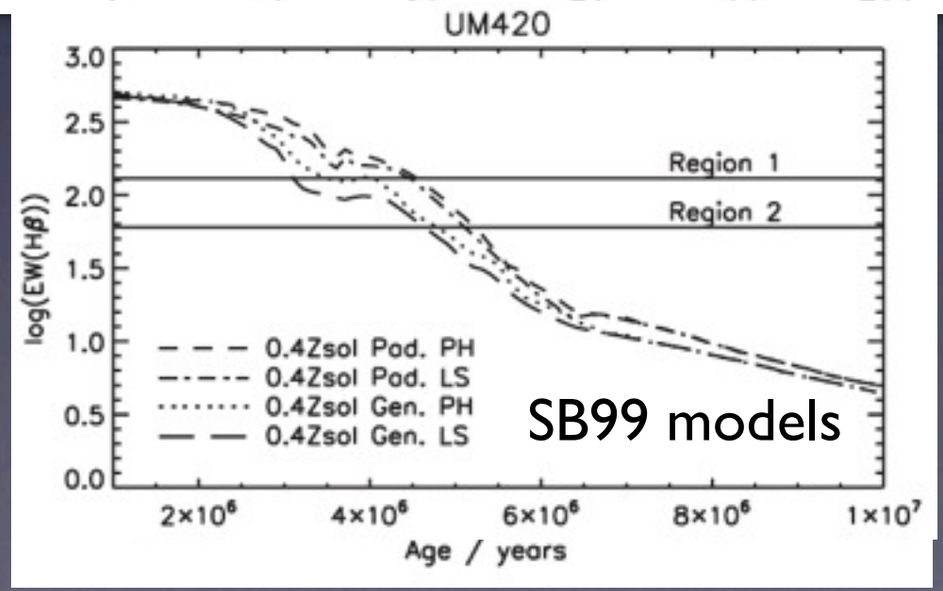




In-falling merger

↓

Triggered SF in main body?



UM420

James et al. 2010

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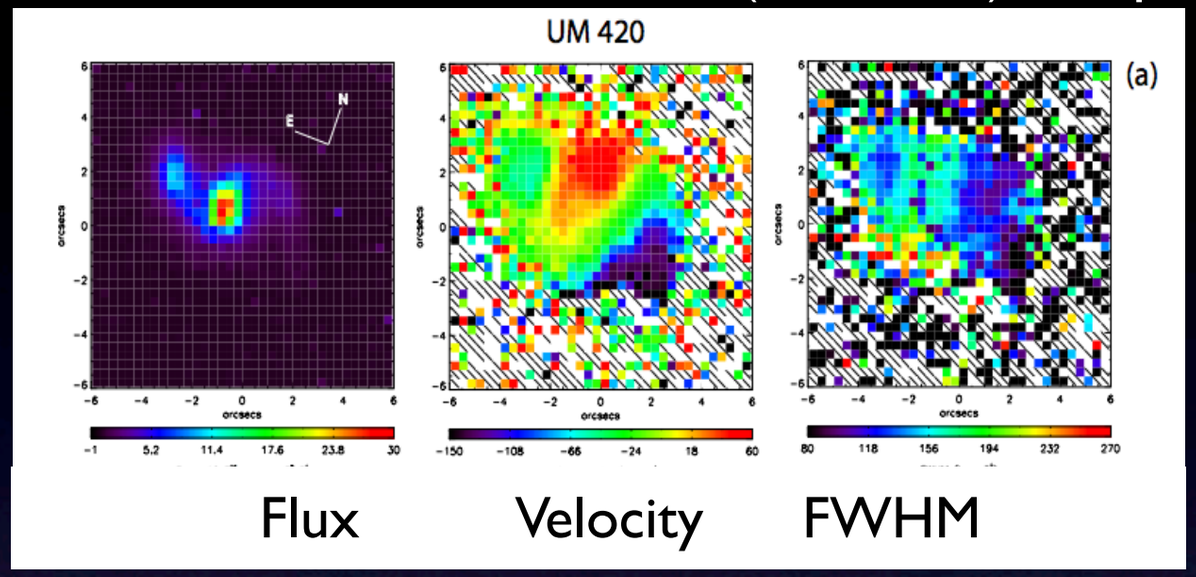

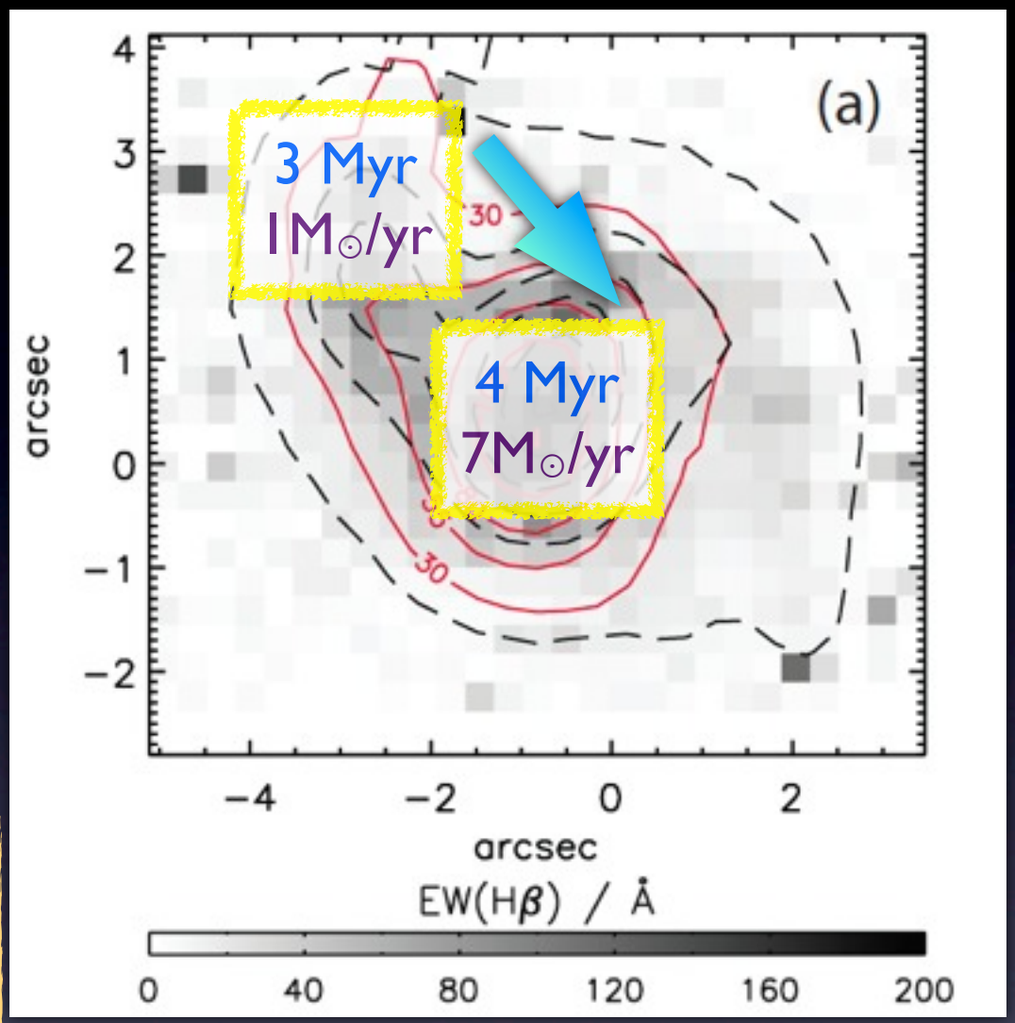

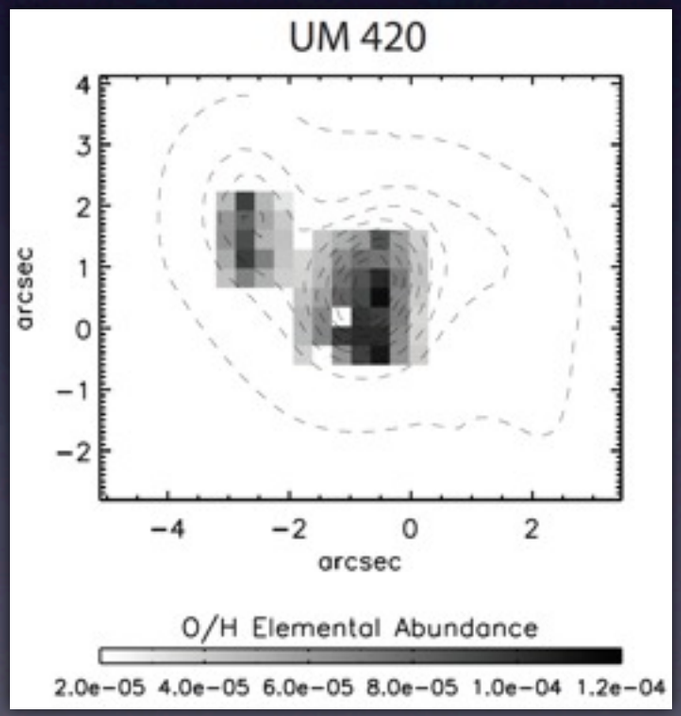

In-falling merger

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Triggered SF in main body?

Averaged results derived from spectra from each SF-region:

	Te	Ne	12+log(O/H)	12+log(N/H)	N/O
UM420	14000±1500	170±80	8.03±0.13	6.58±0.45	-1.45±0.6

Previous results from Izotov & Thuan 1998:

12+log(O/H)	log(N/O)
7.93±0.05	-1.08±0.05

UM420

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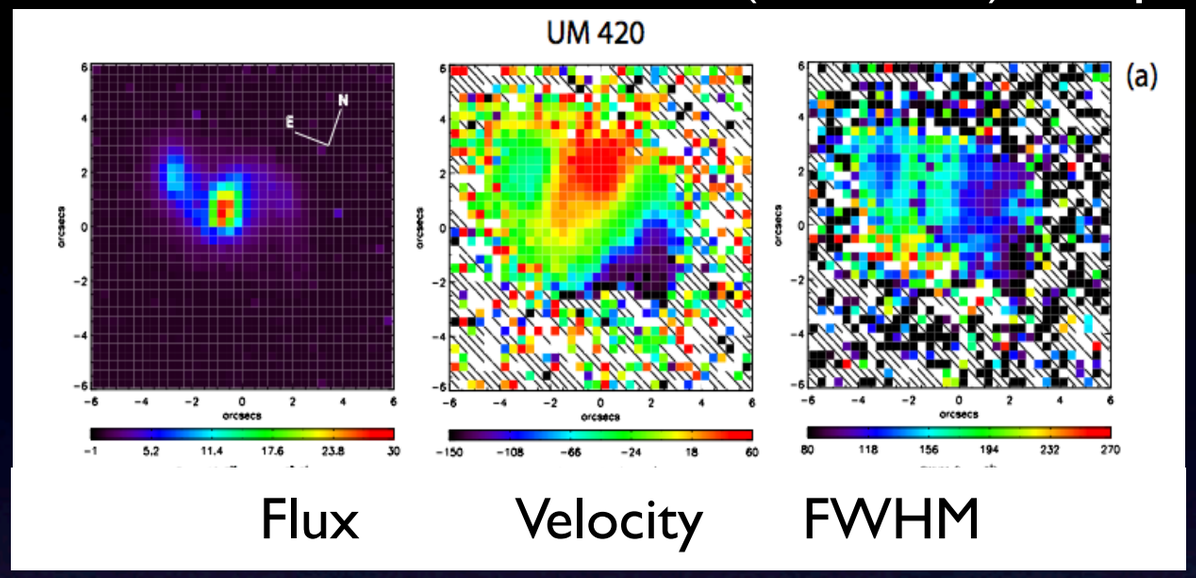
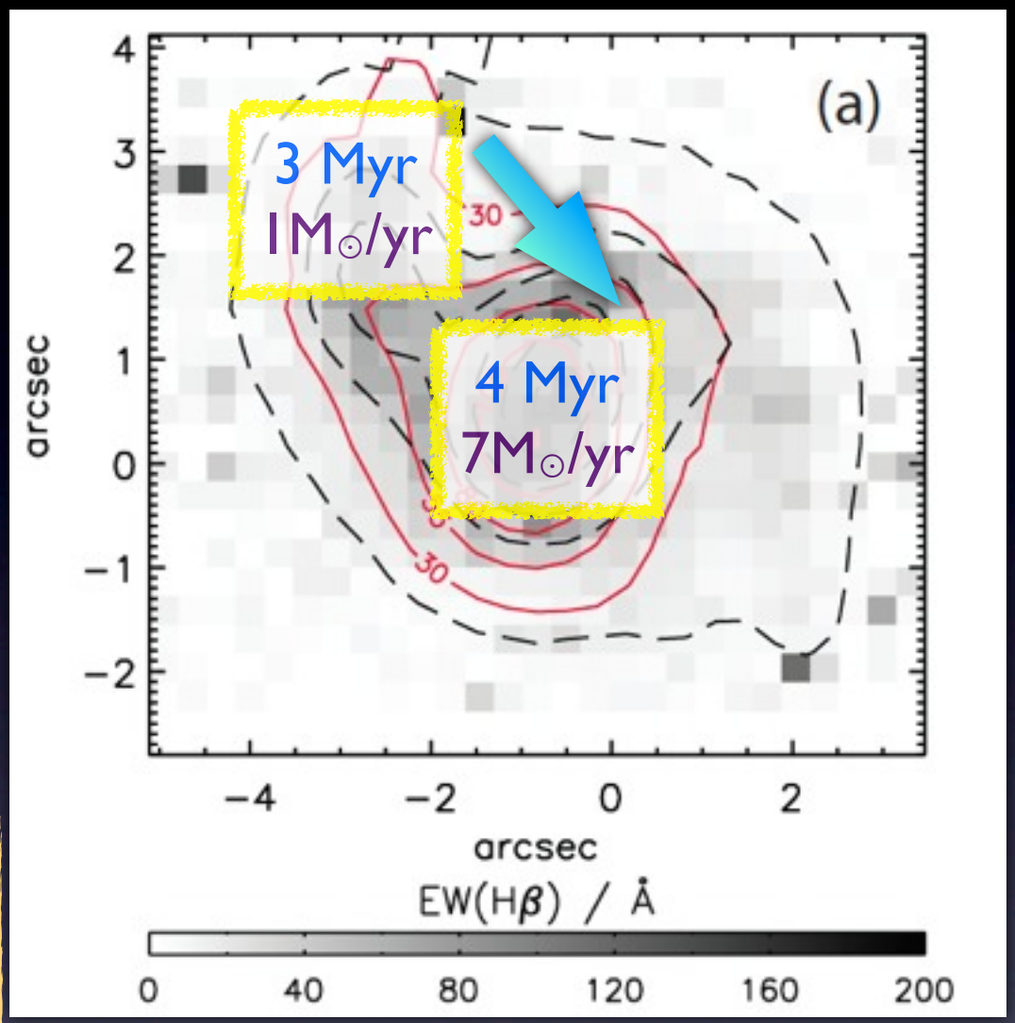
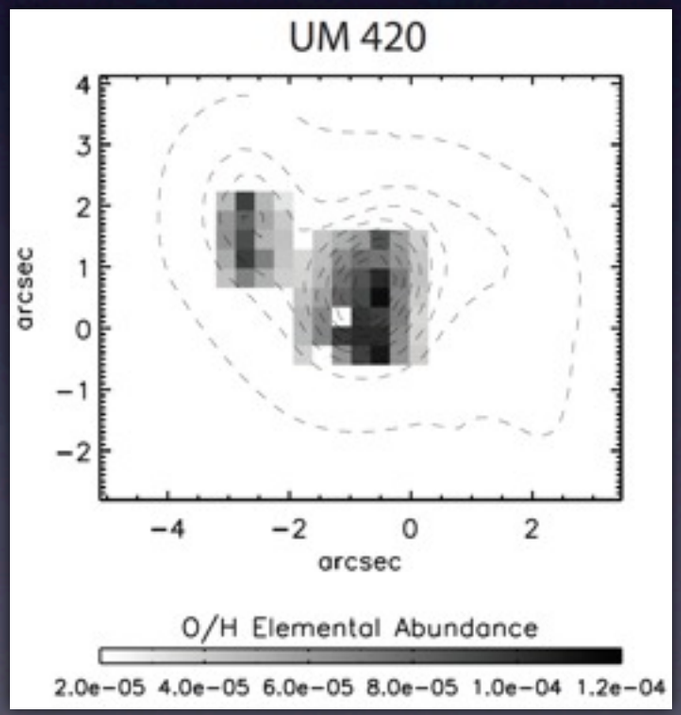
VLT/VIMOS IFU data (PI:Tsamis) - Maps in Hα, D~240Mpc







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UM462

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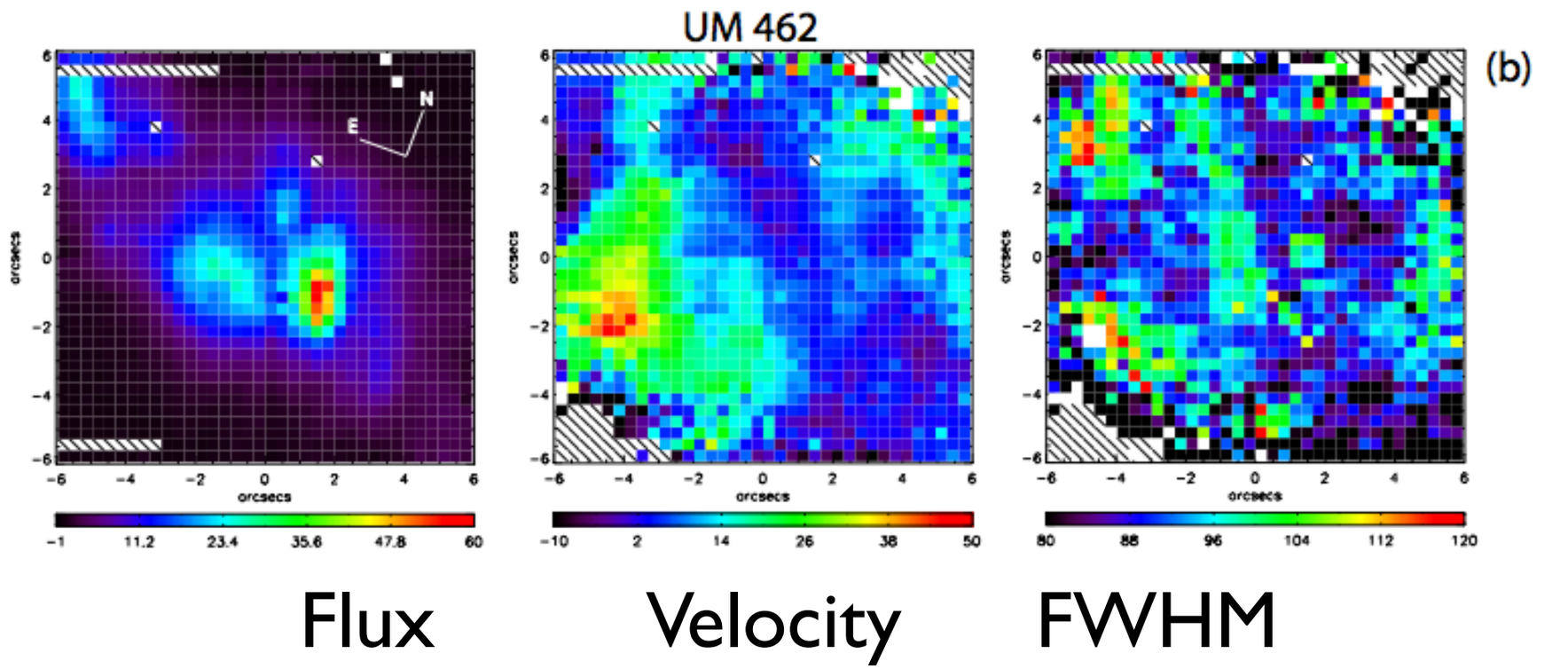
VLT/VIMOS IFU - Maps in Hα, D~14.4Mpc



Flux Velocity FWHM

UM462

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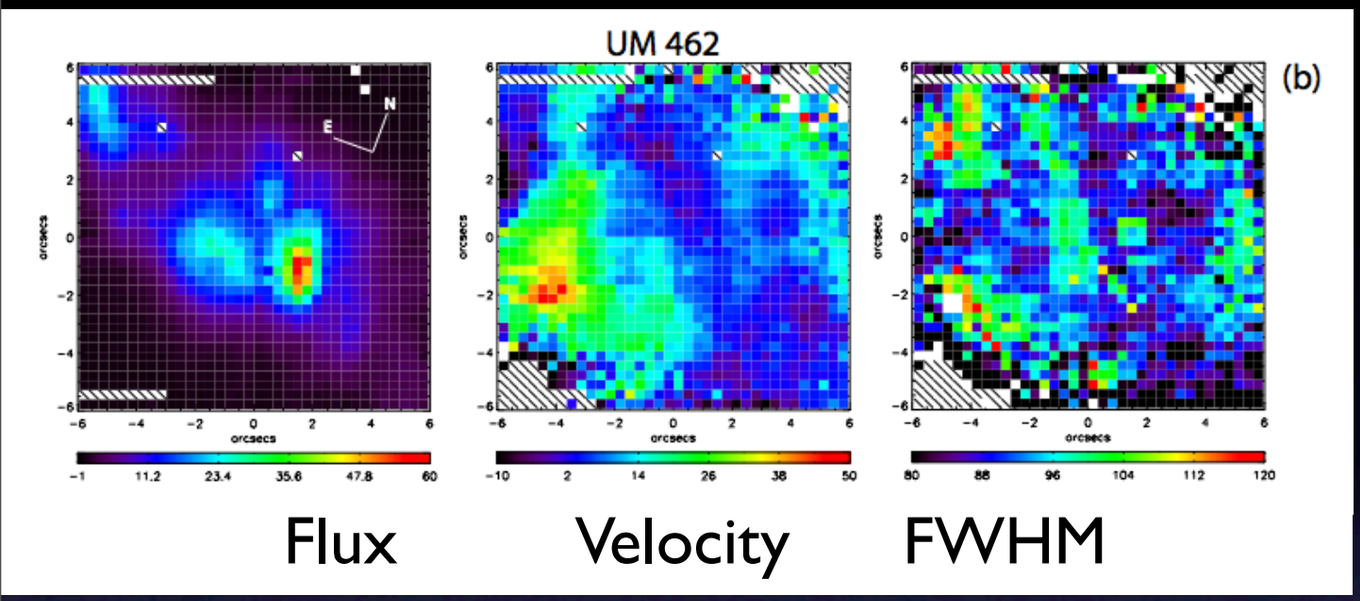

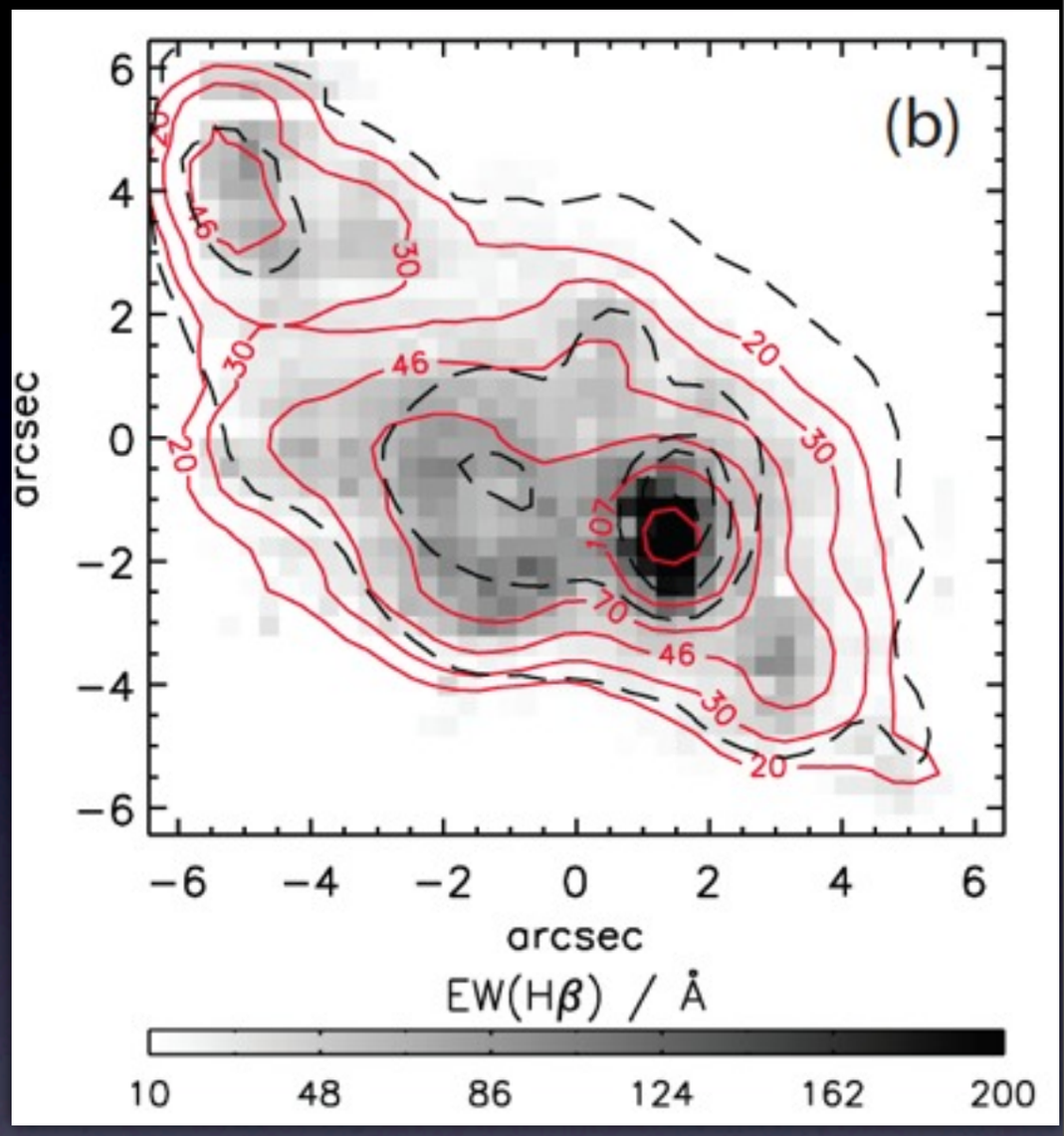

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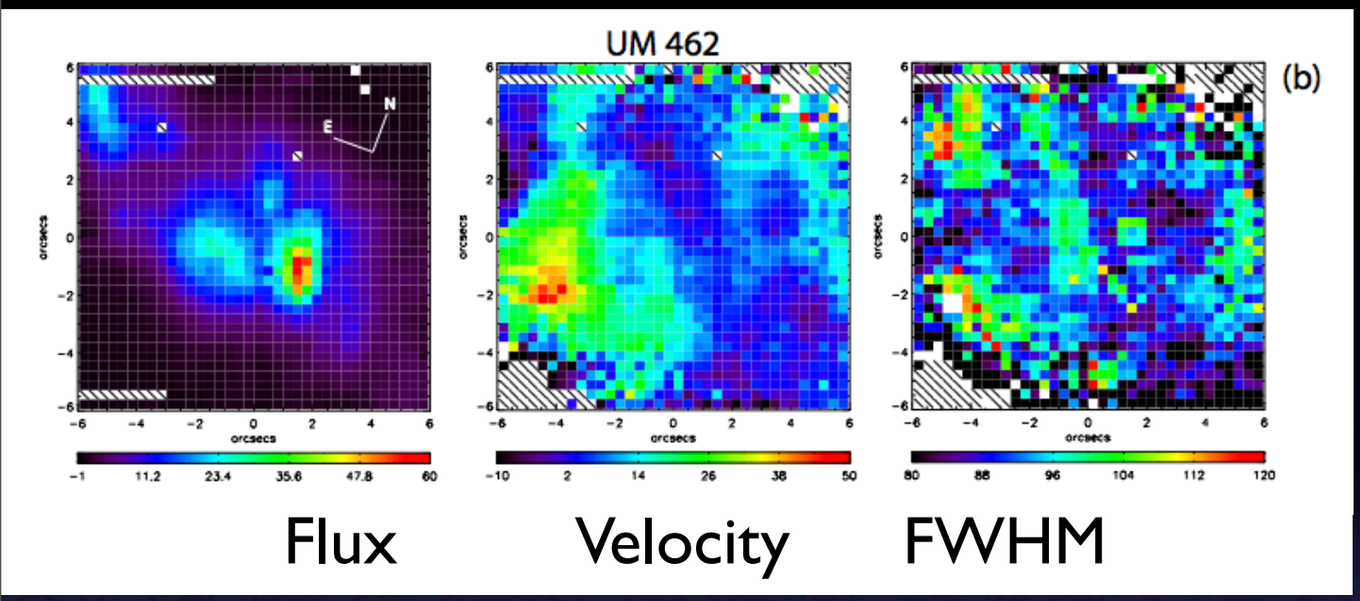

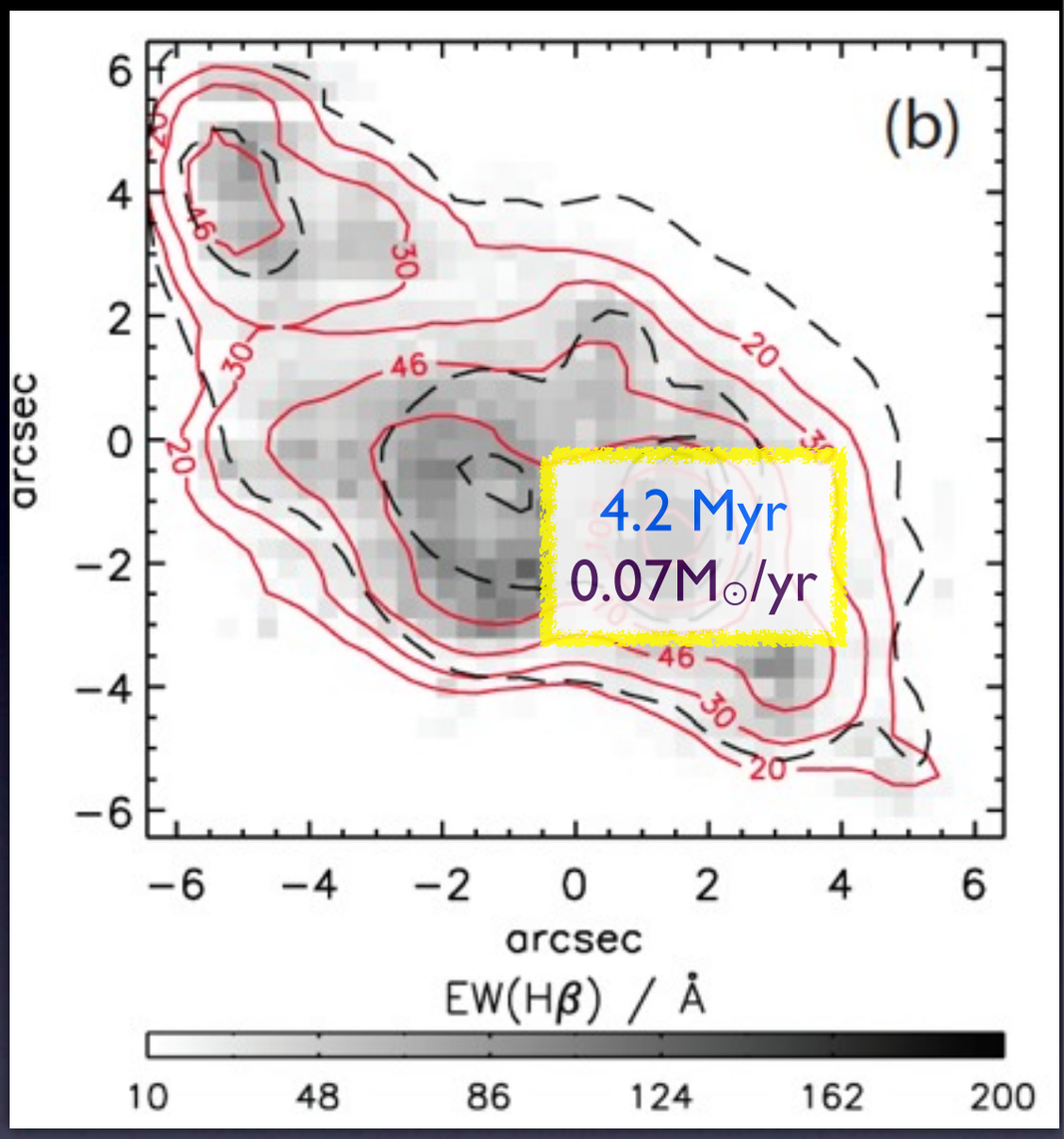

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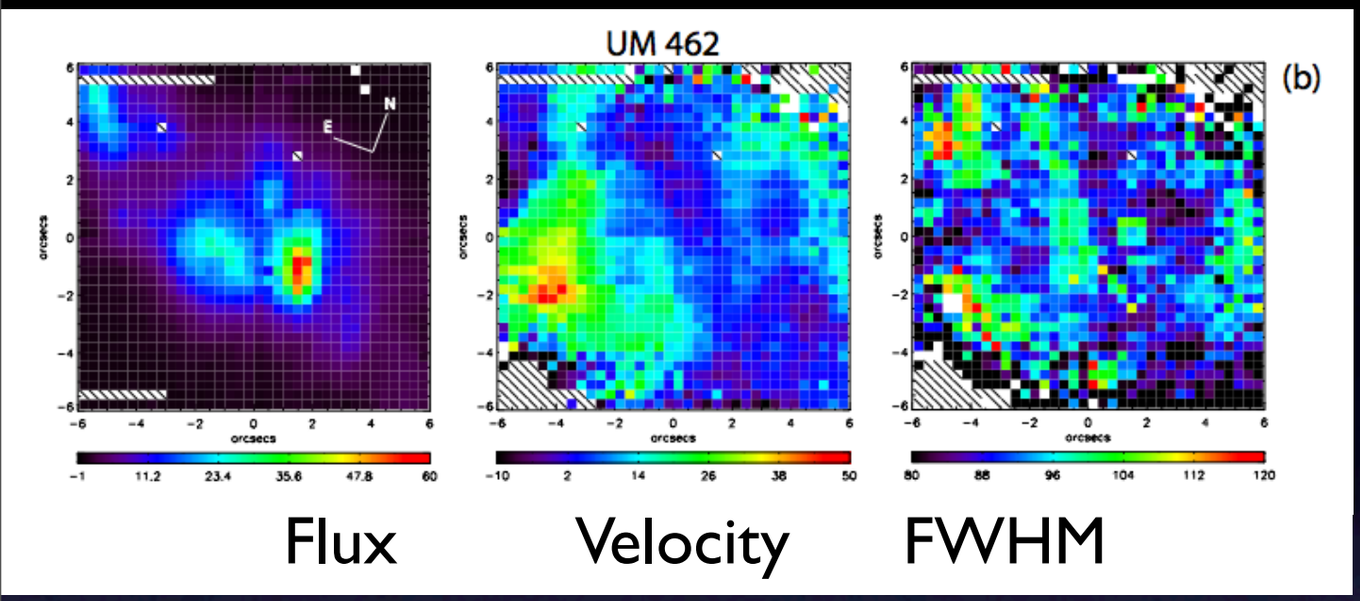

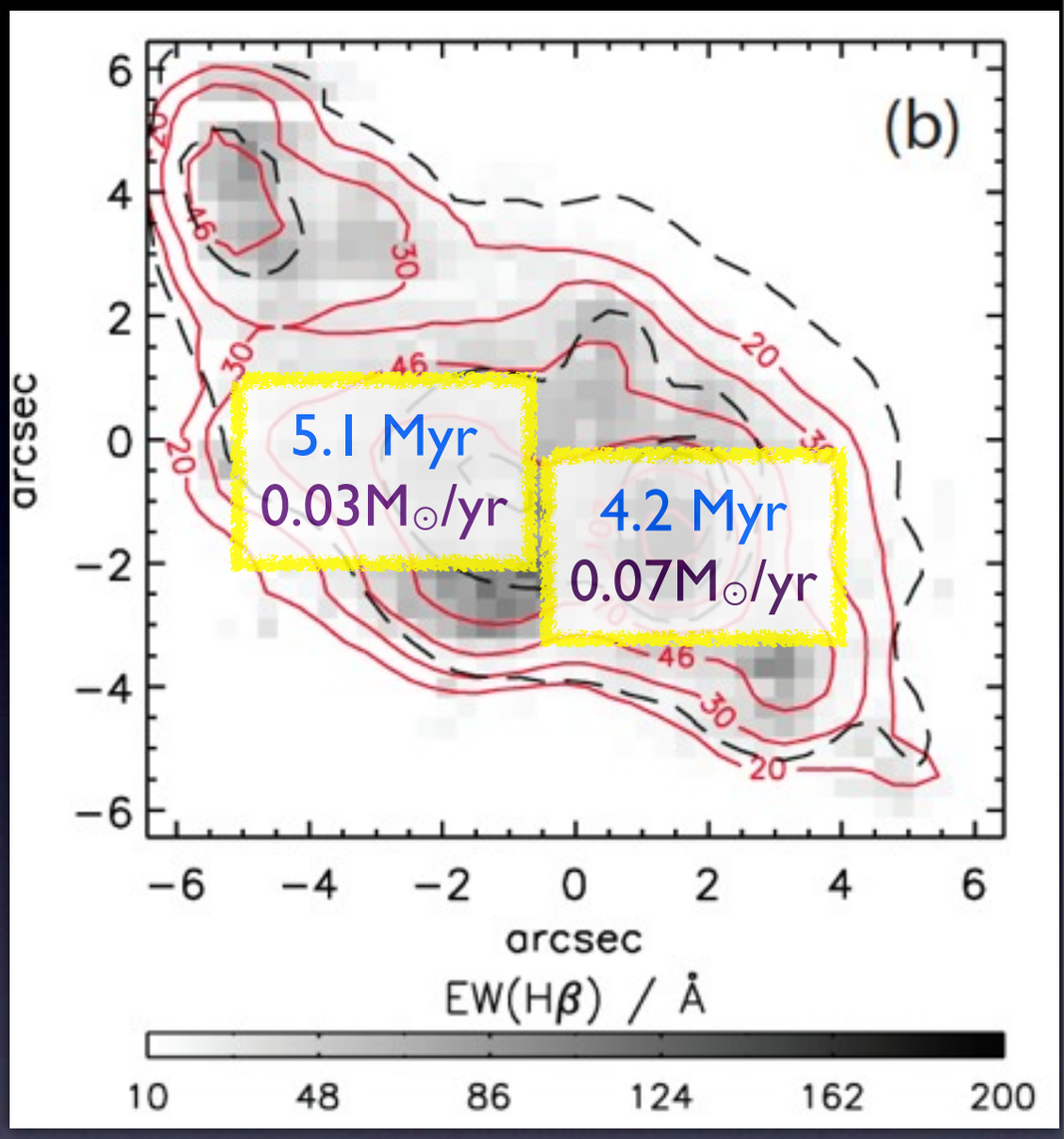

UM462

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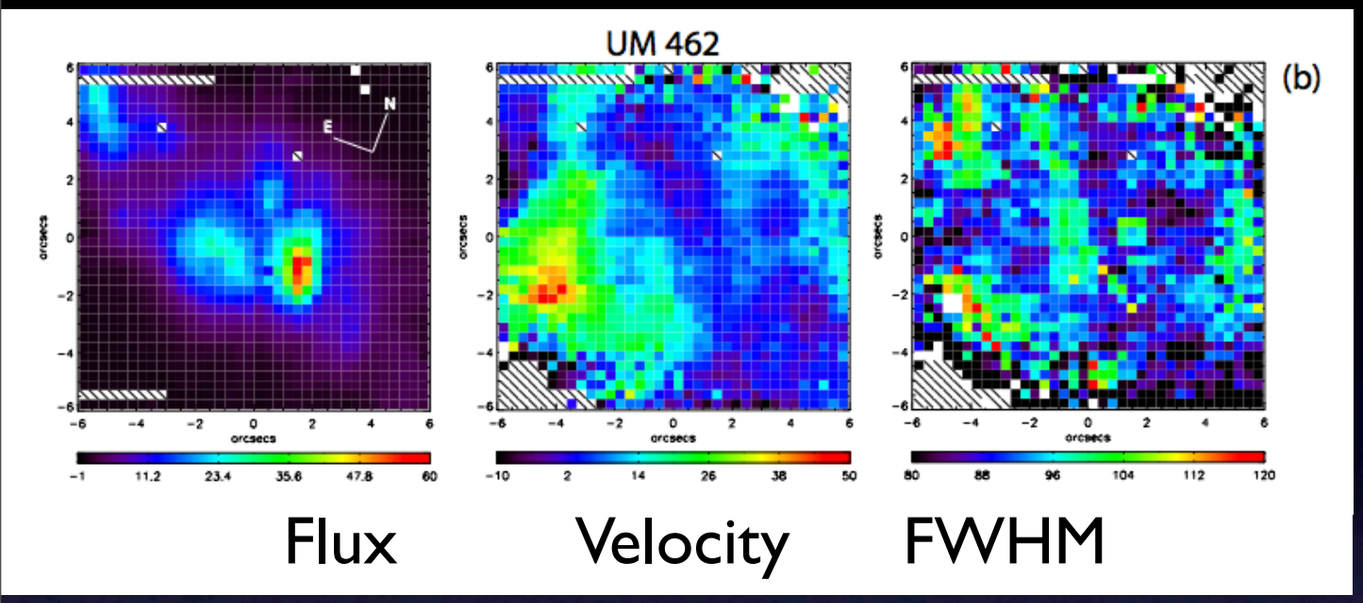

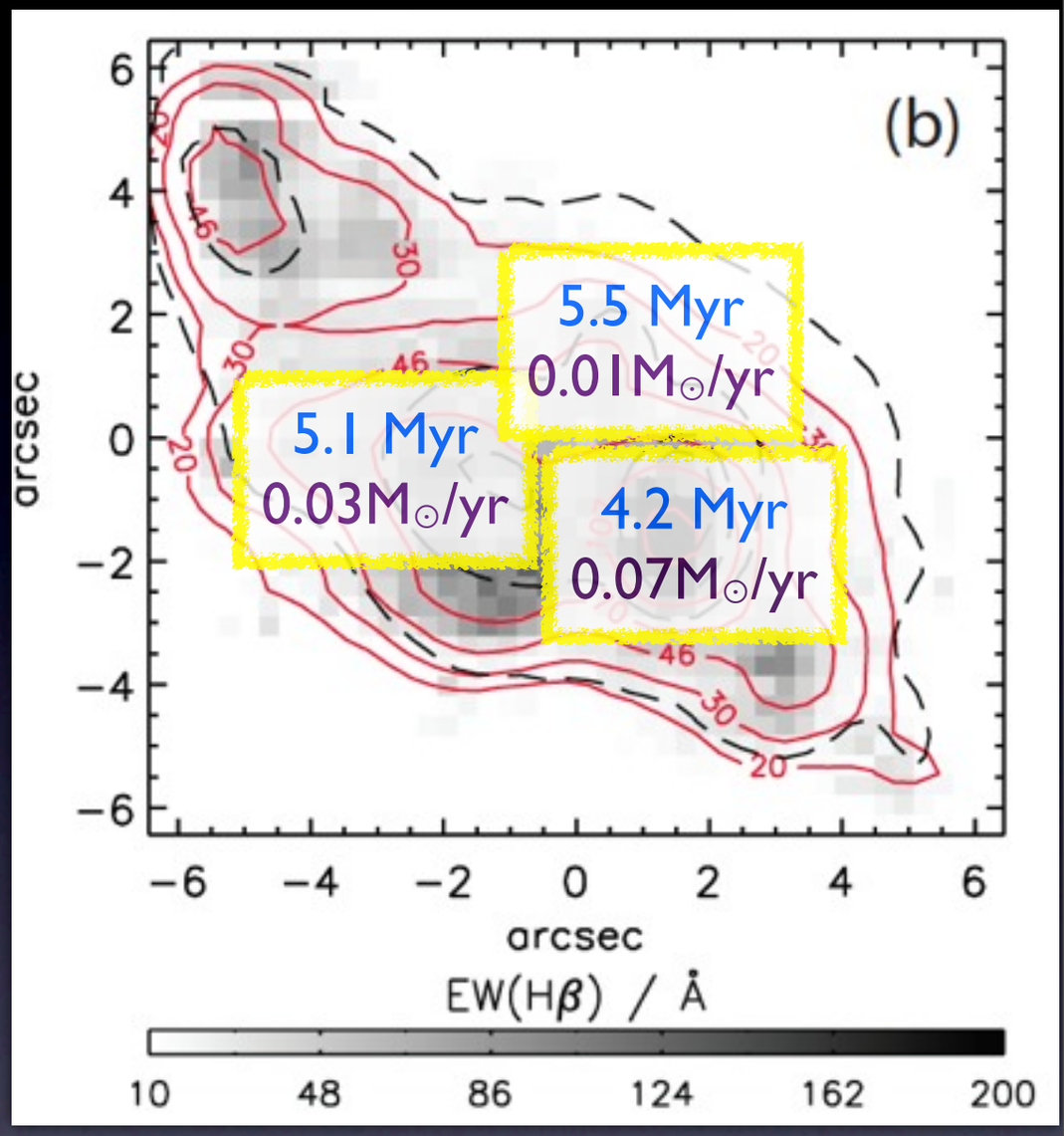

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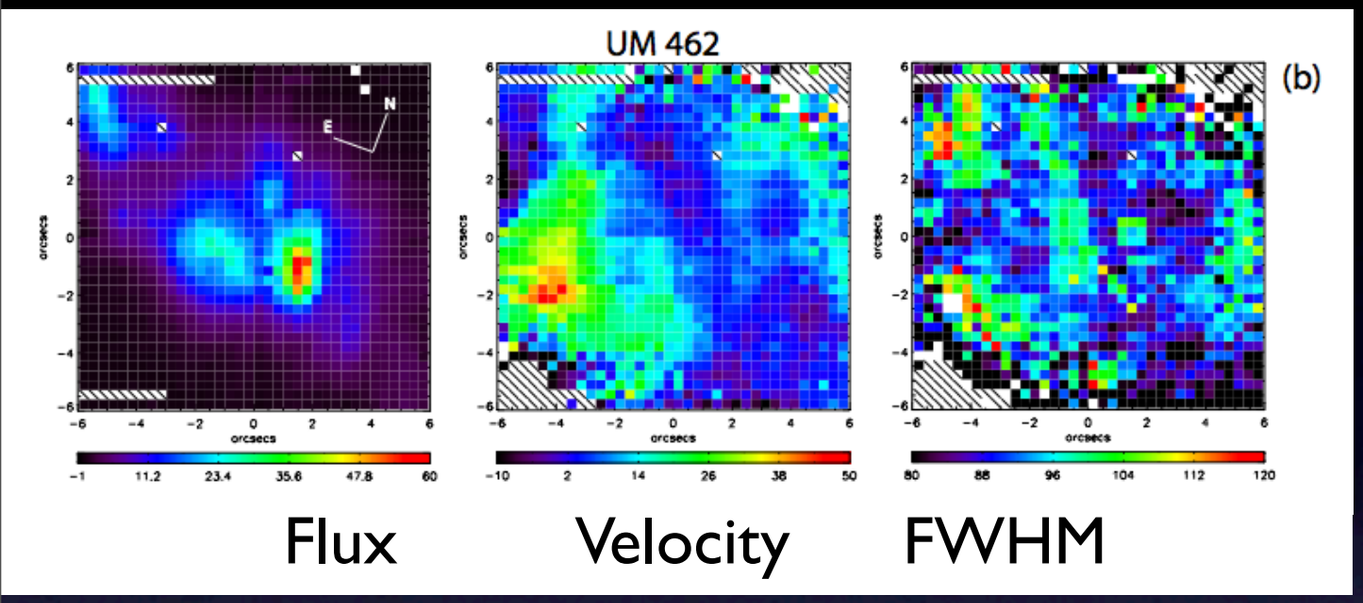

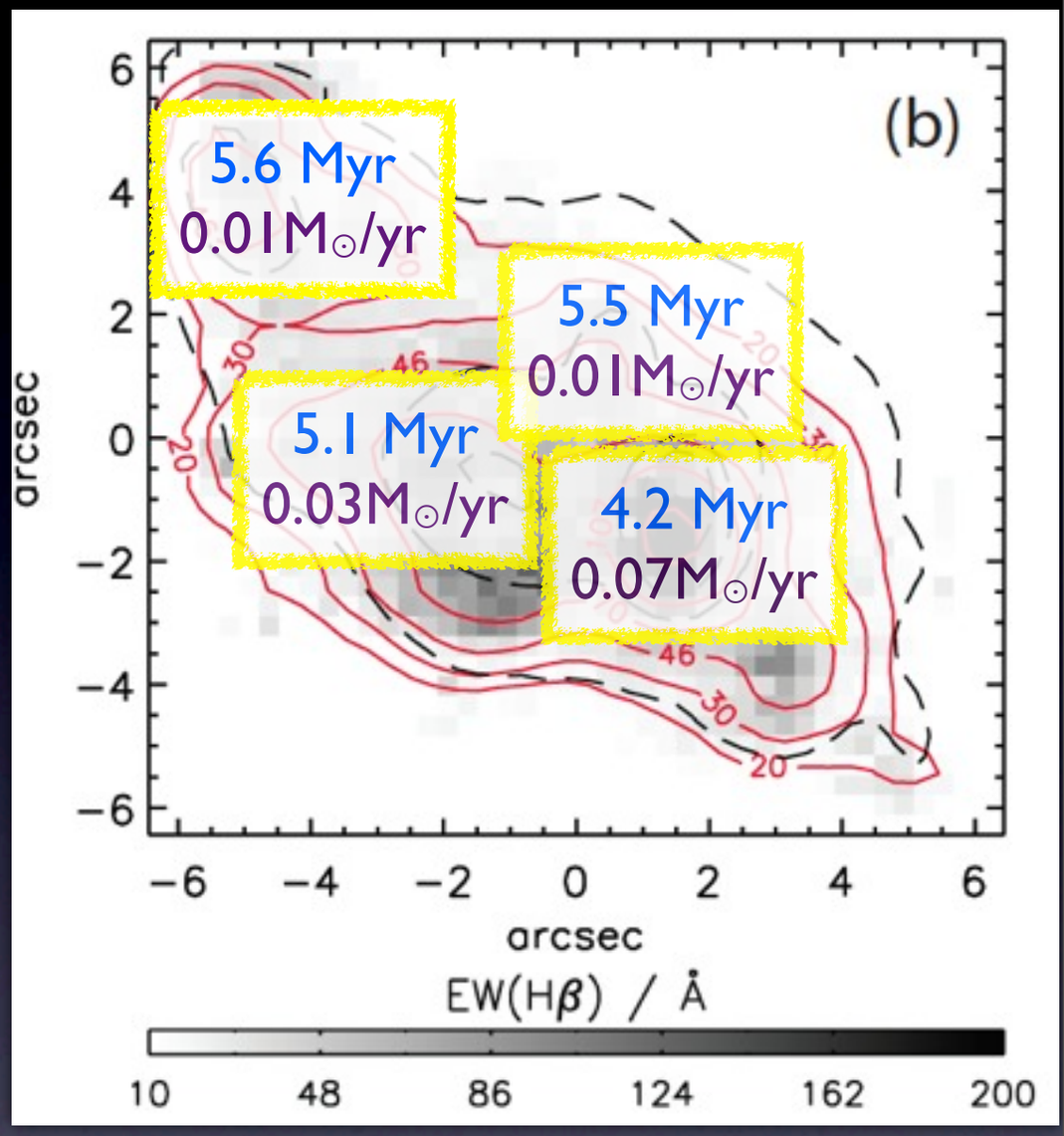

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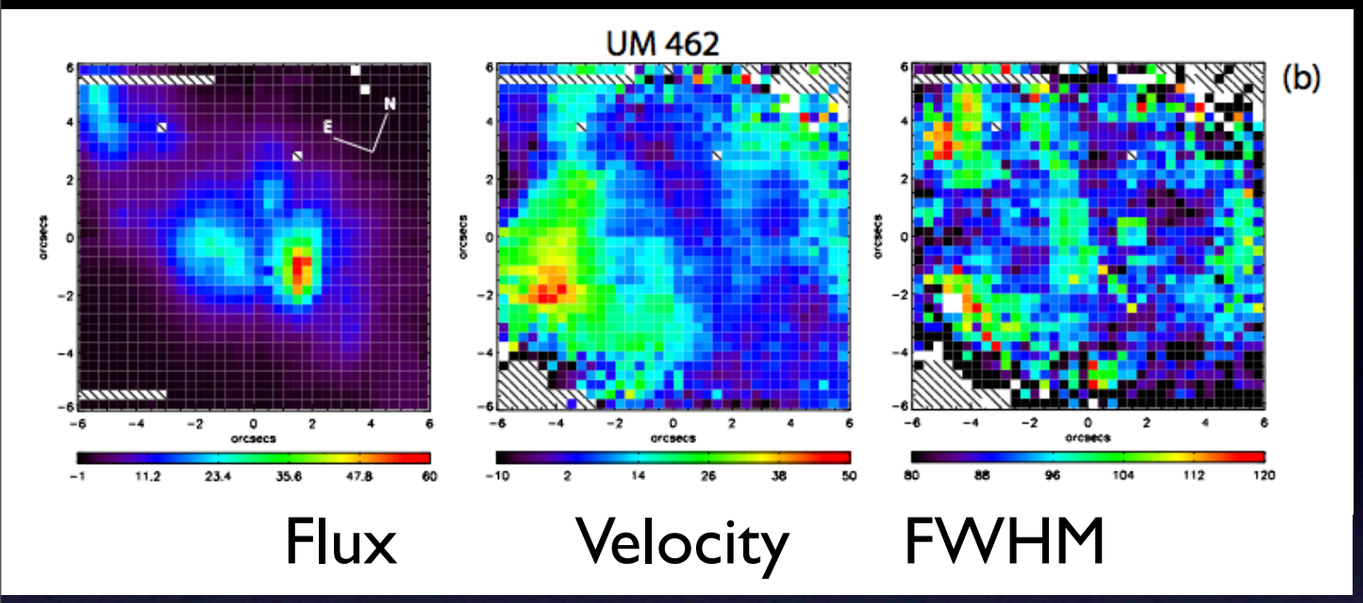

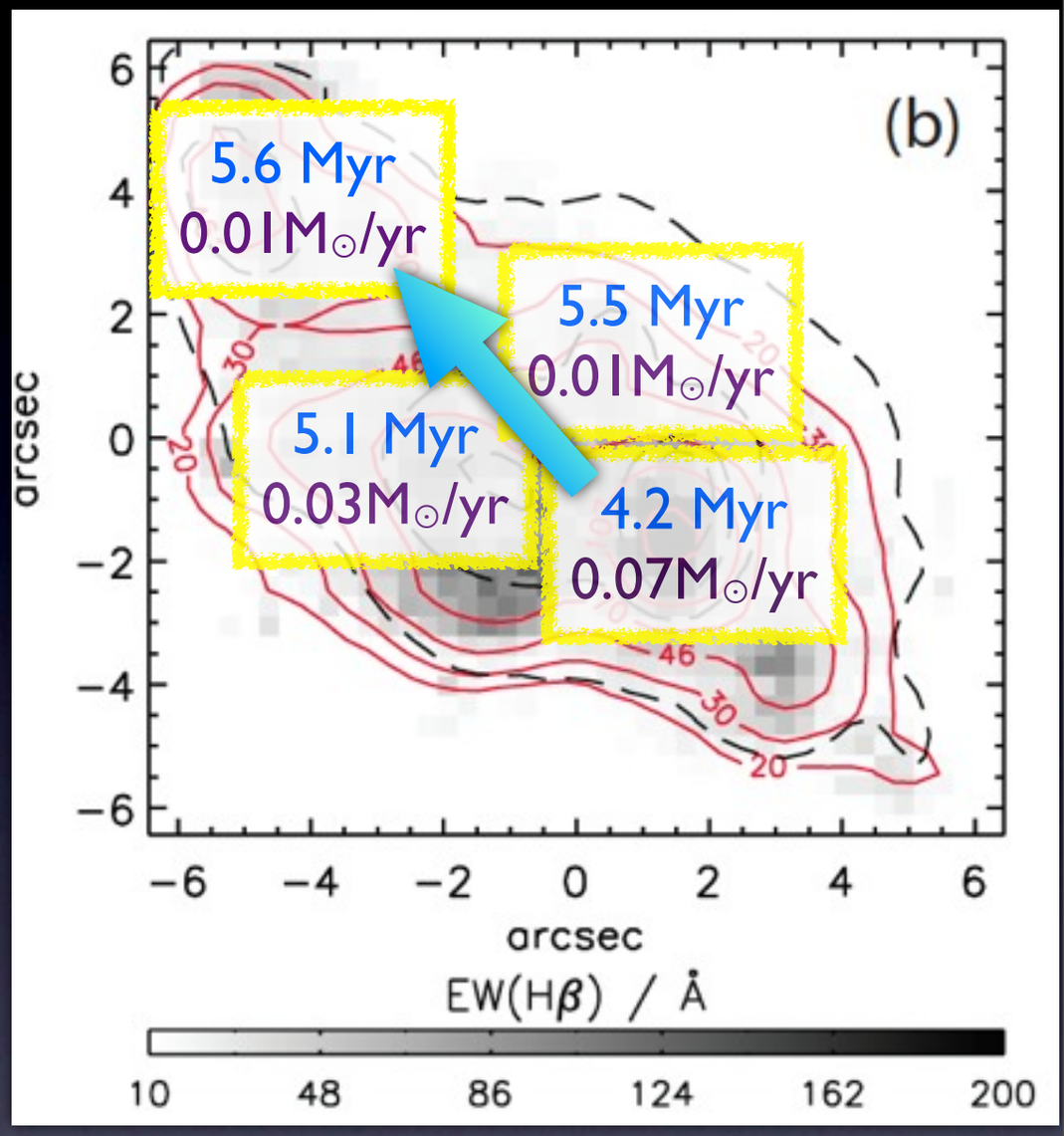

UM462

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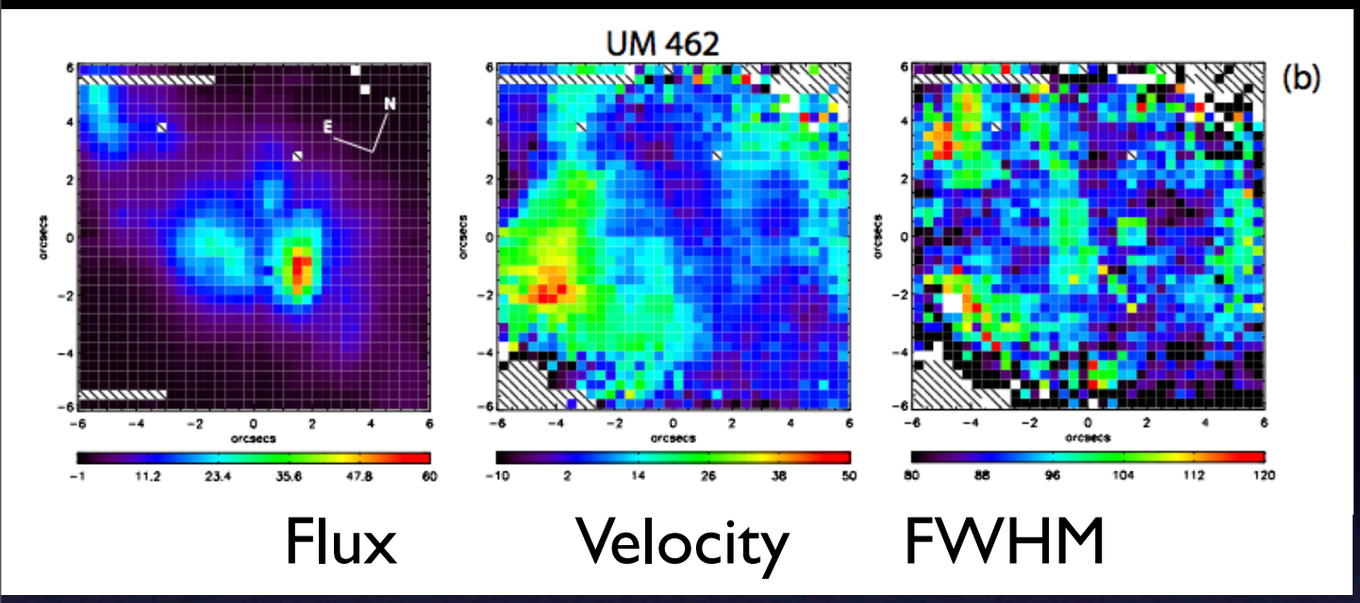
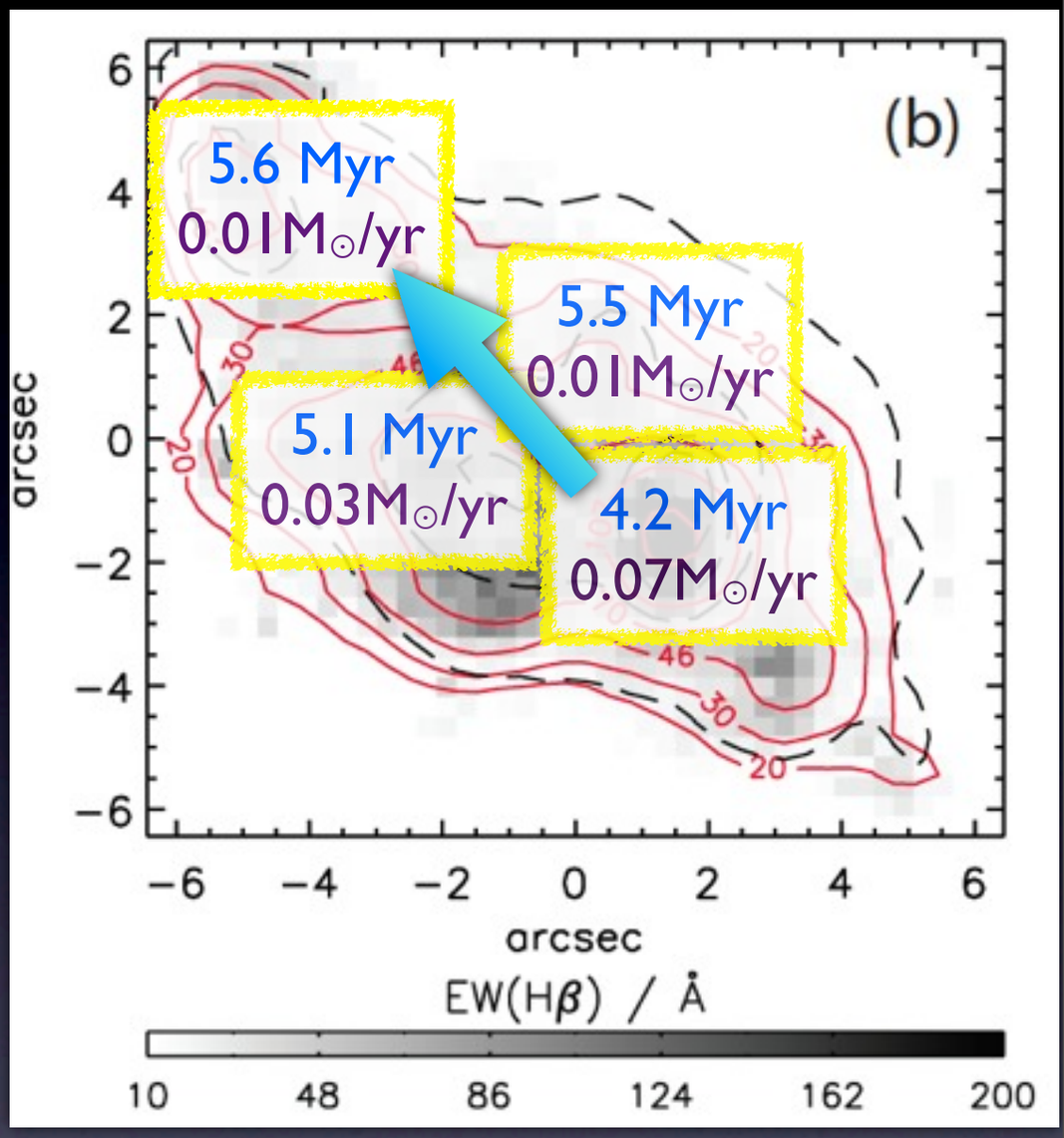
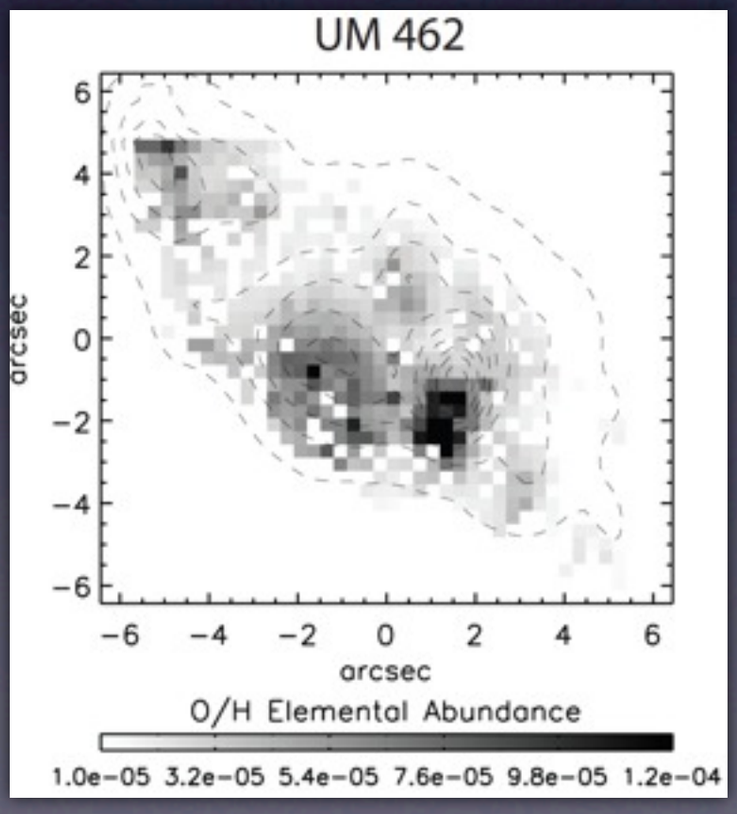




O/H abundance Map



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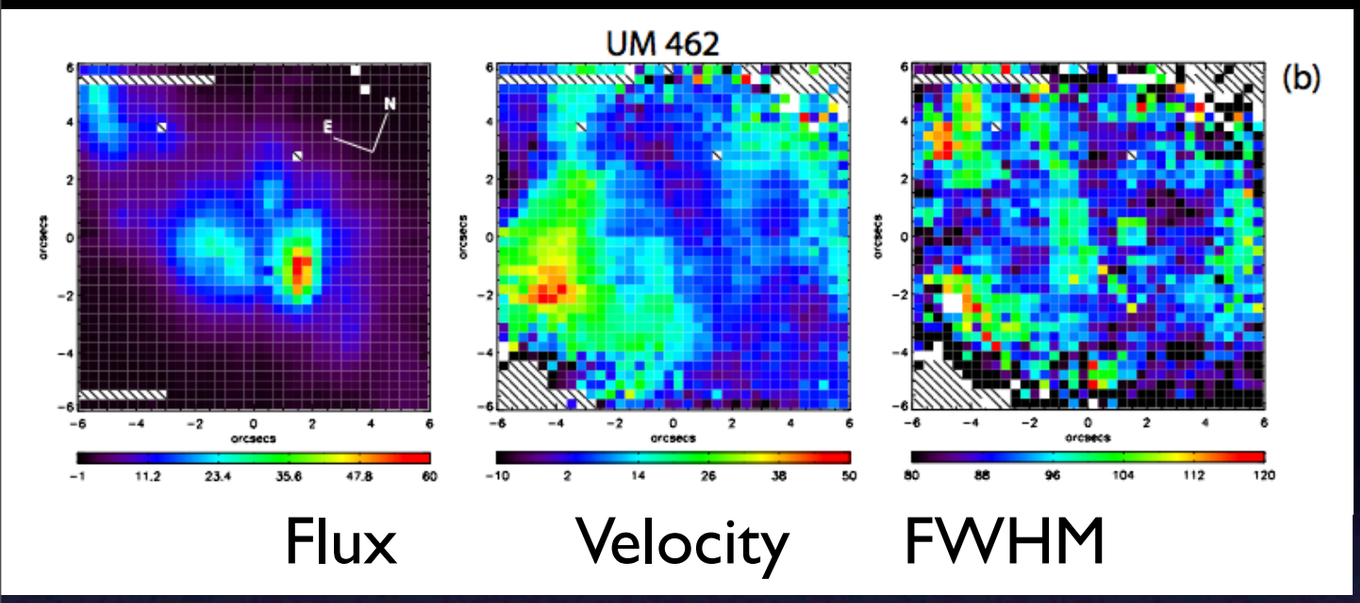
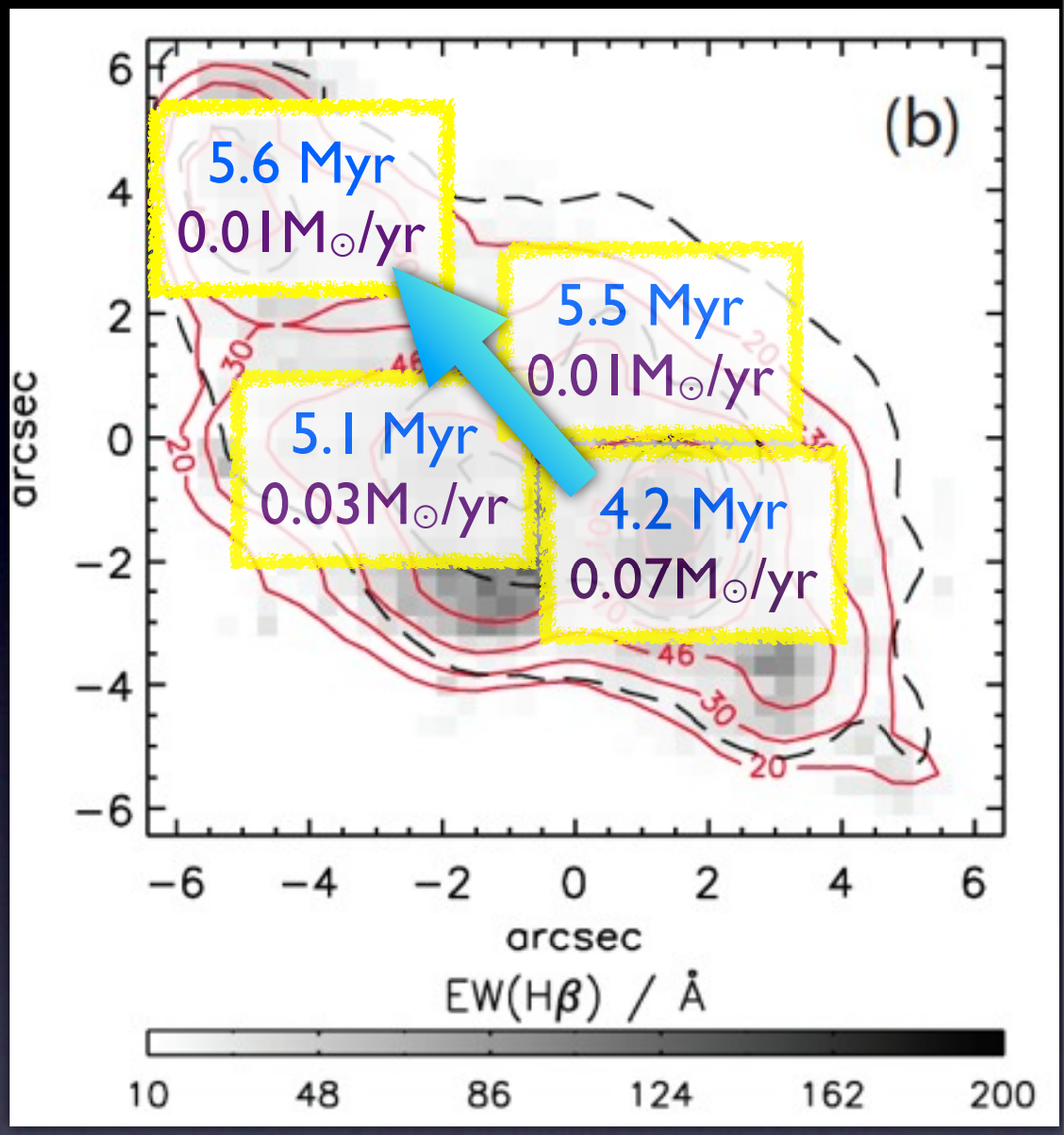
VLT/VIMOS IFU - Maps in Hα, D~14.4Mpc





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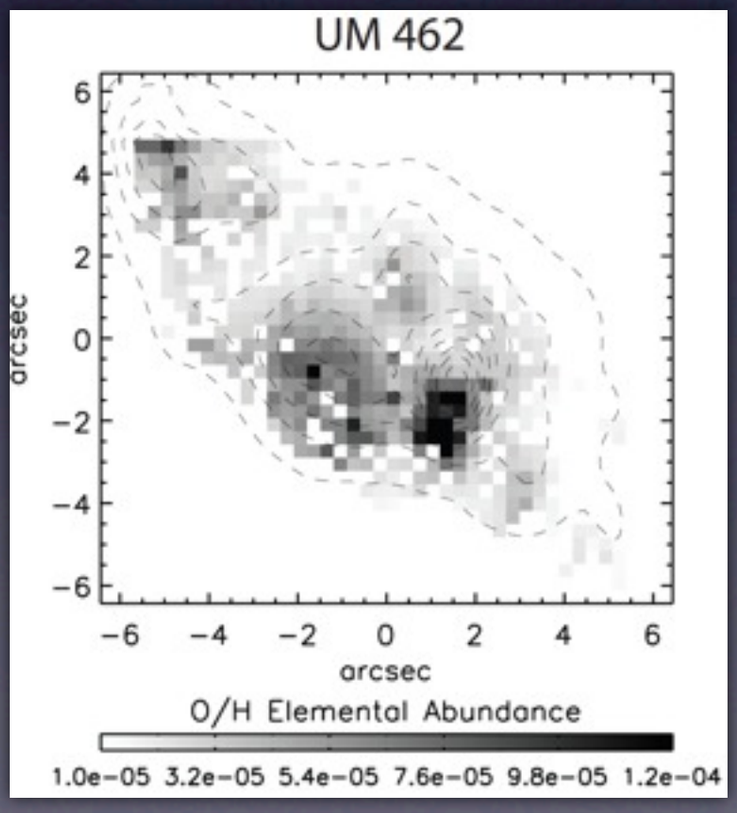

- Decreasing SFR

UM462

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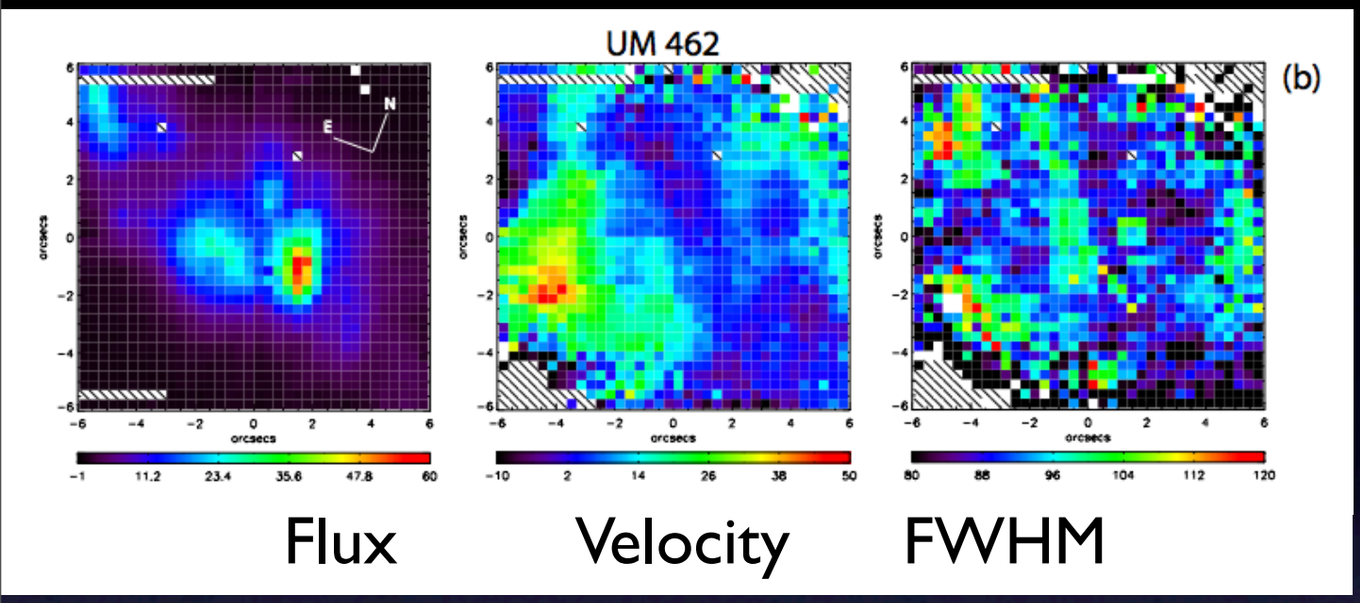
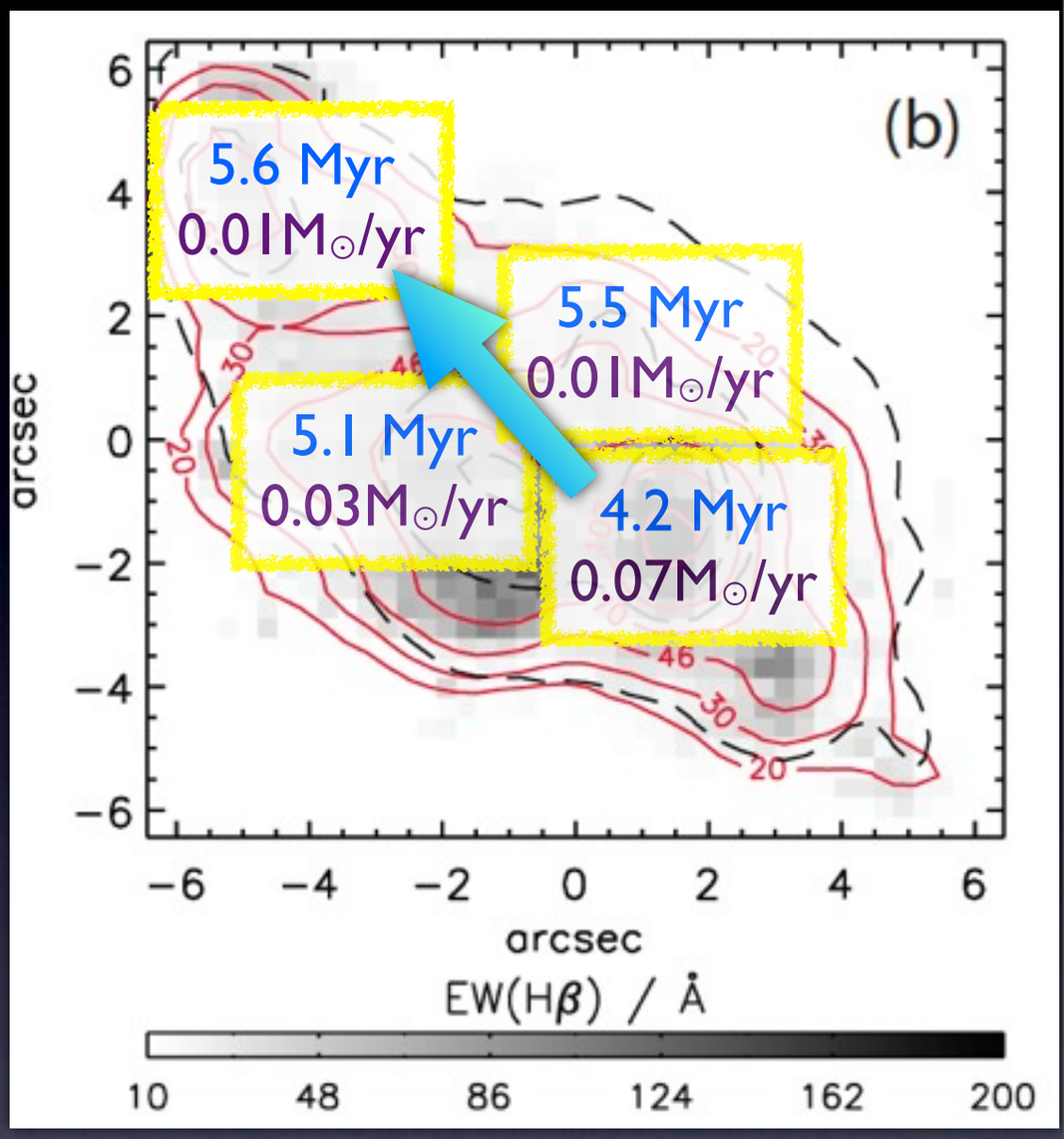
VLT/VIMOS IFU - Maps in Hα, D~14.4Mpc





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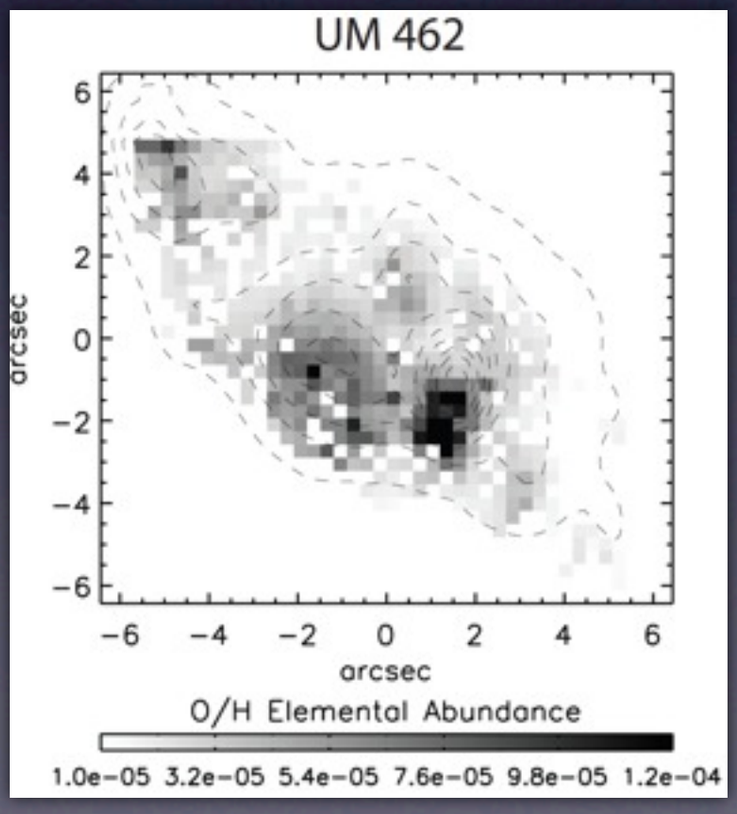

- Decreasing SFR
- Increasing stellar population age

UM462

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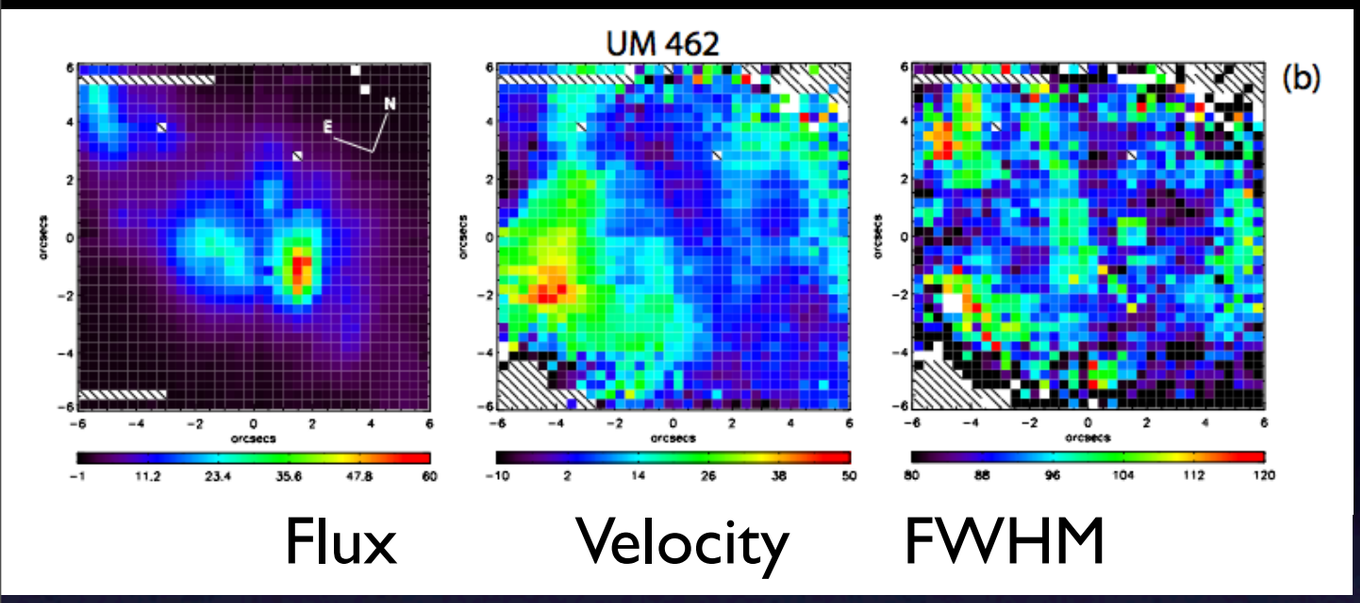
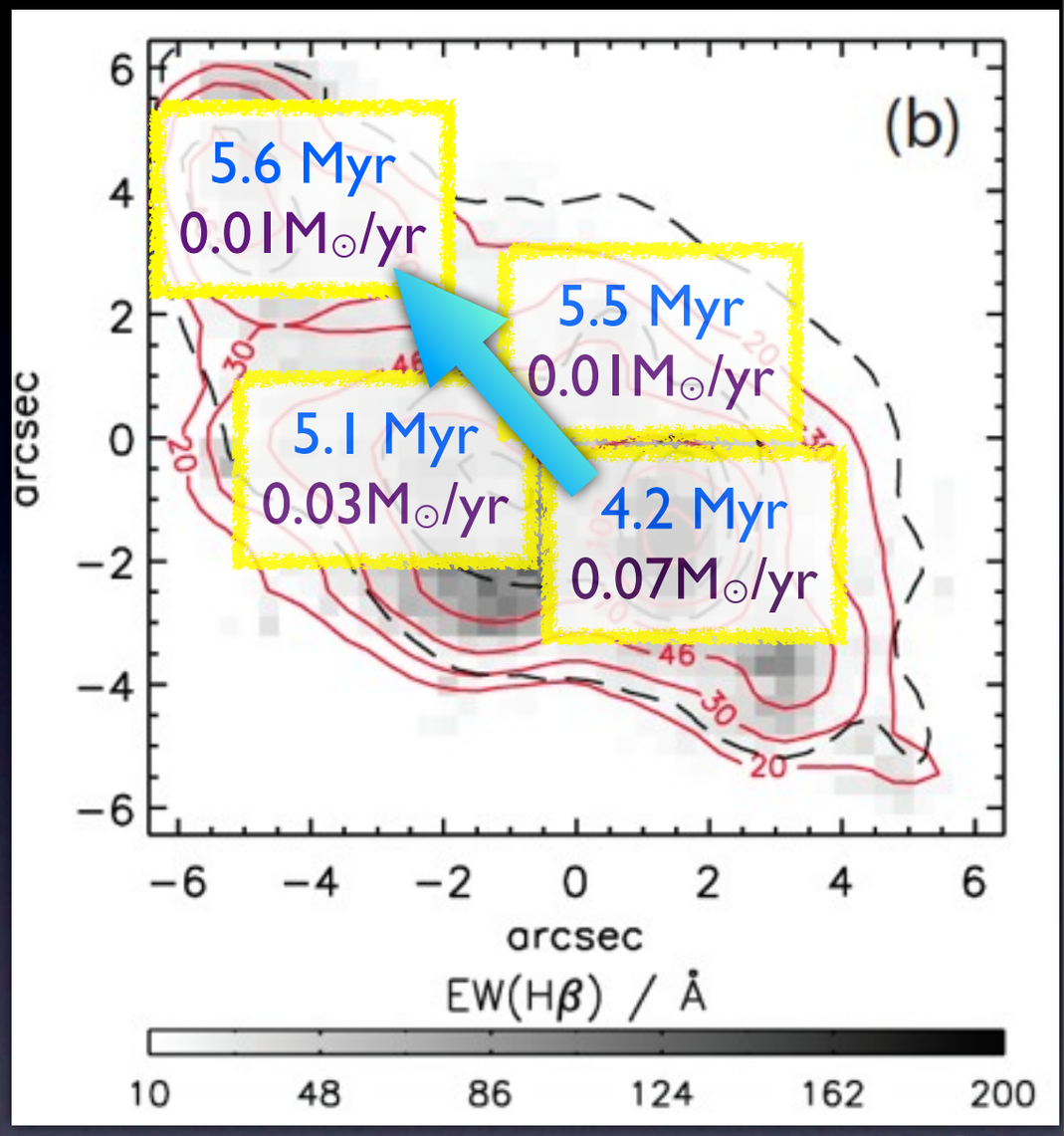
VLT/VIMOS IFU - Maps in Hα, D~14.4Mpc





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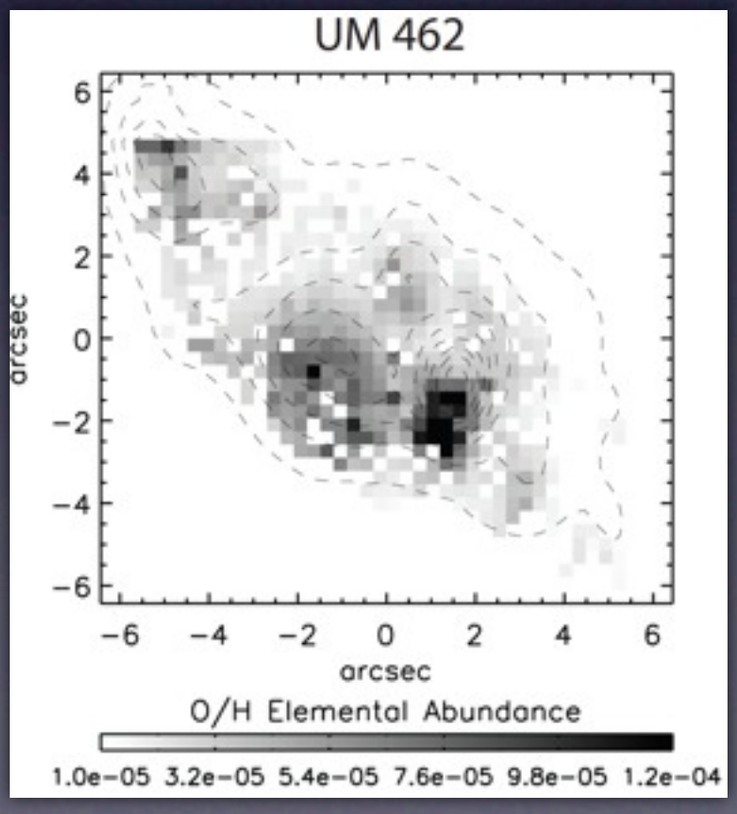

- Decreasing SFR
- Increasing stellar population age
- **Cause**: propagating/triggered SF from merger (disturbed Hα flux & kinematics)

UM462

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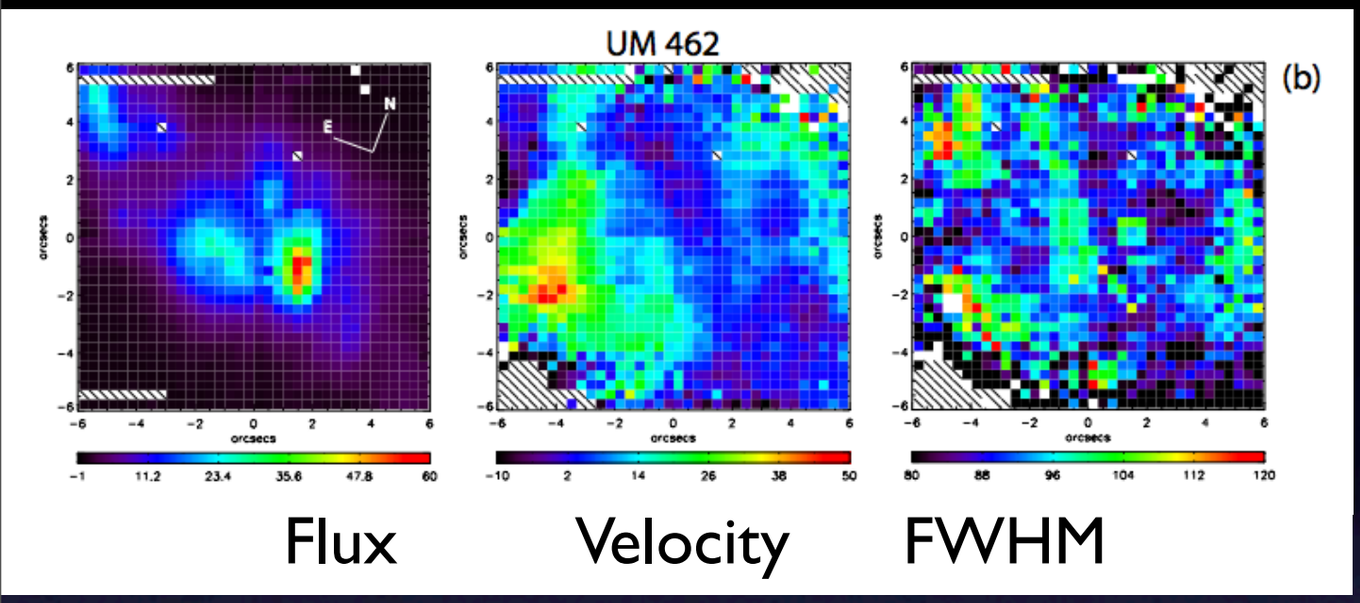
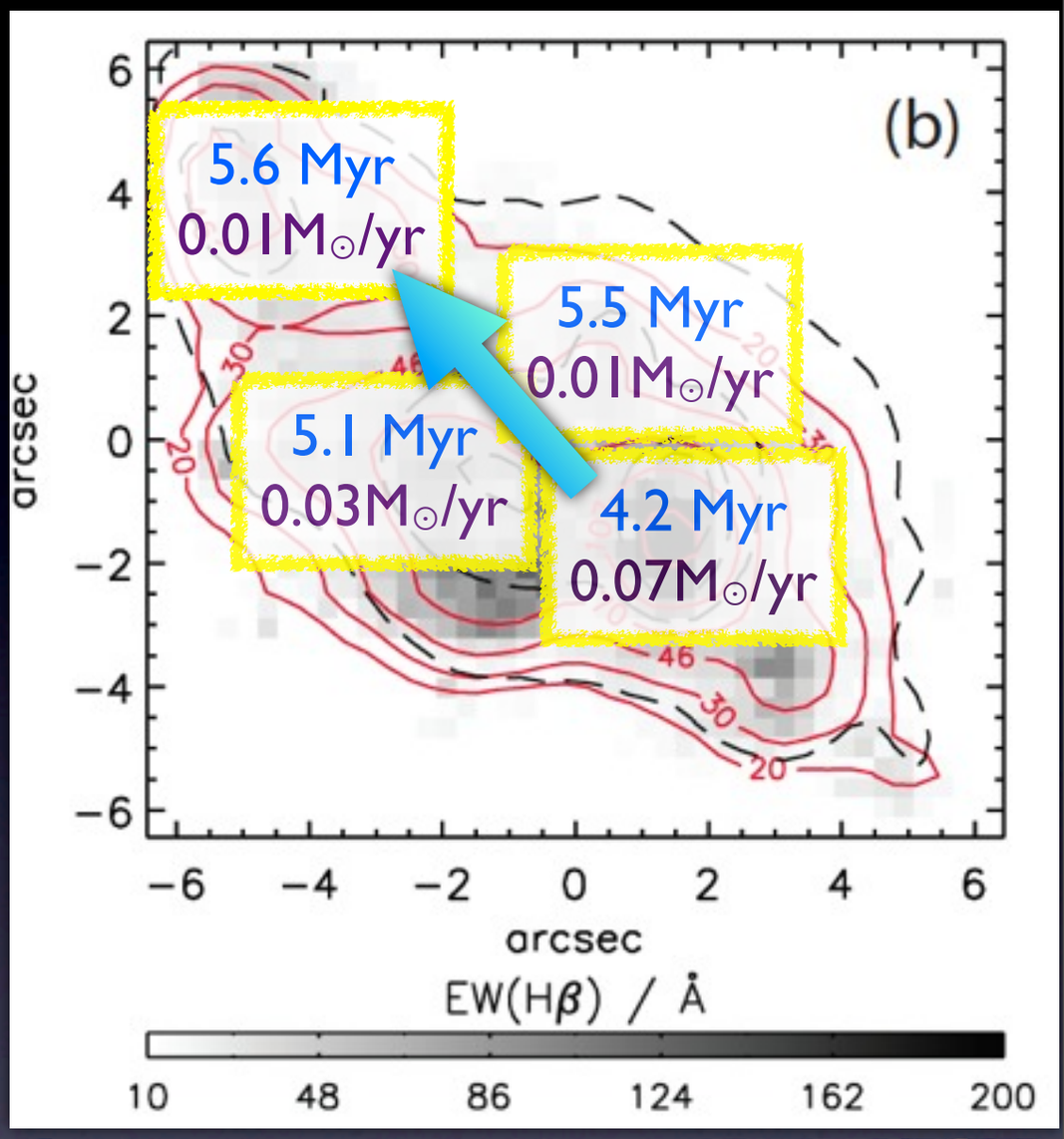
VLT/VIMOS IFU - Maps in Hα, D~14.4Mpc





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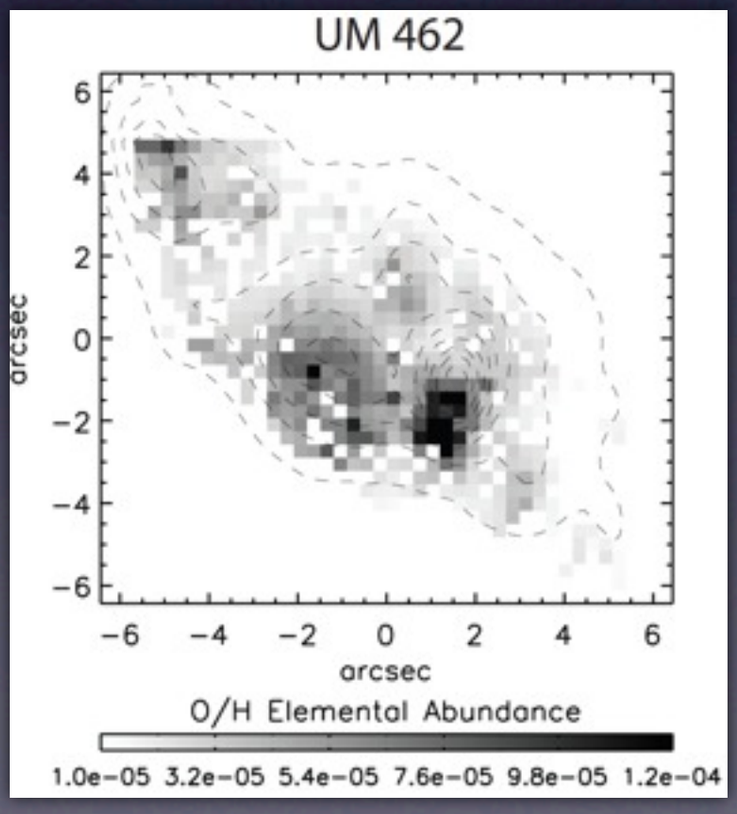
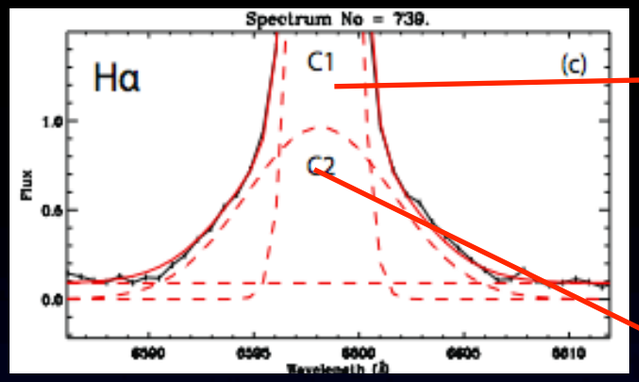
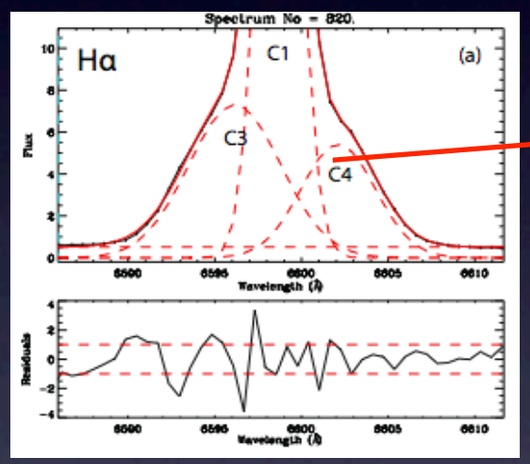


- Decreasing SFR
- Increasing stellar population age
- **Cause**: propagating/triggered SF from merger (disturbed Hα flux & kinematics)
- **Effect**: Decreasing metallicity

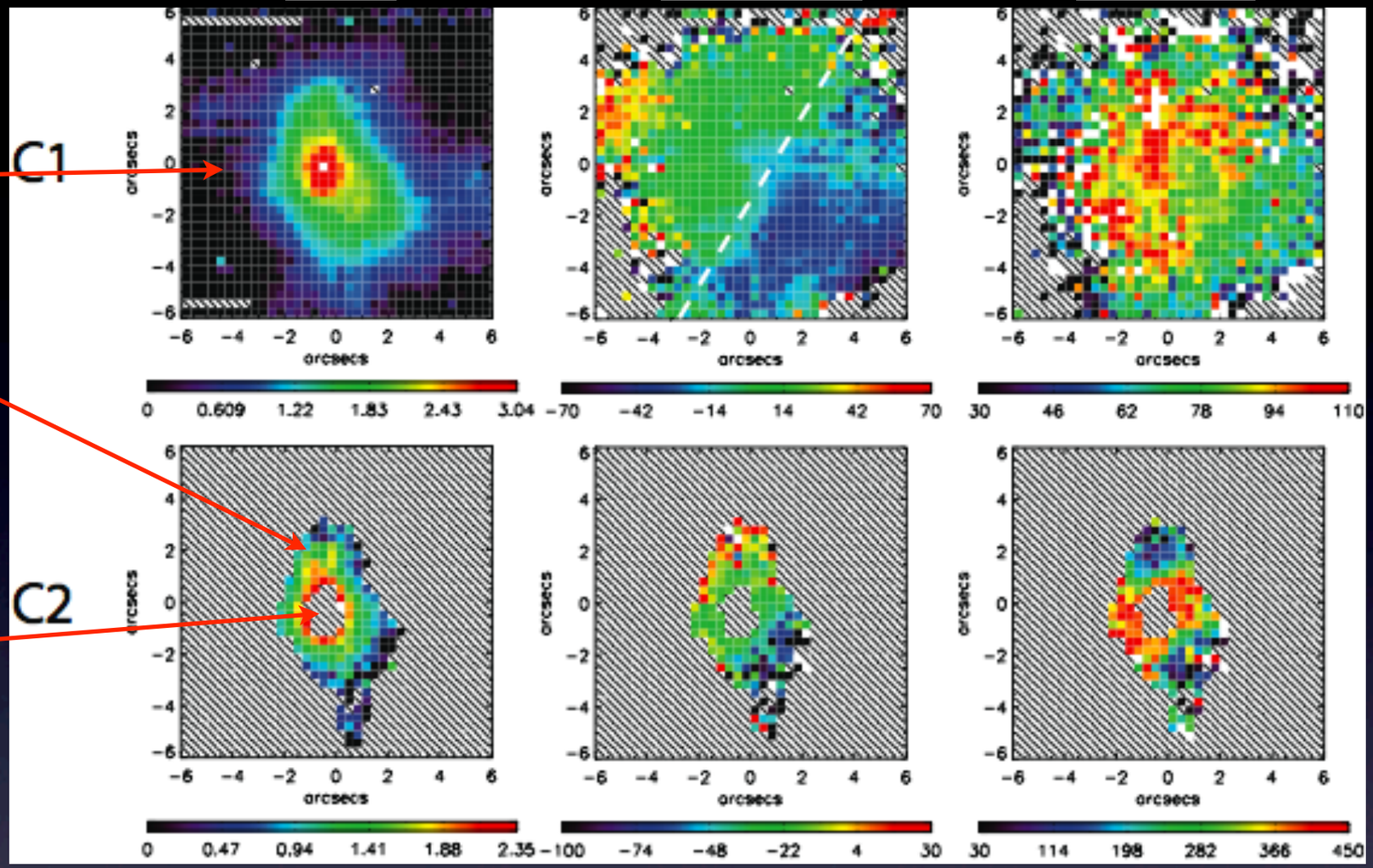
Mrk 996

James et al. 2009





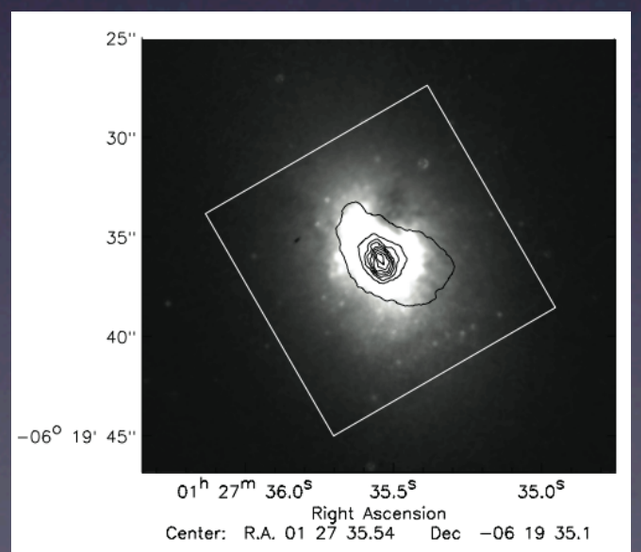
VLT/VIMOS IFU - Maps in Hα, D~22Mpc



Studied by Thuan et al. 1996 (WFPC2, FOS), 2008 (Spitzer):

✳Line widths increased with degree of ionisation e.g. [OIII] FHWM~900 km/s

✳Unphysically high Te unless you assume Ne~10^6 cm^{-3}

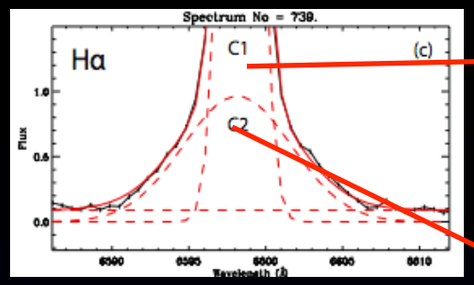


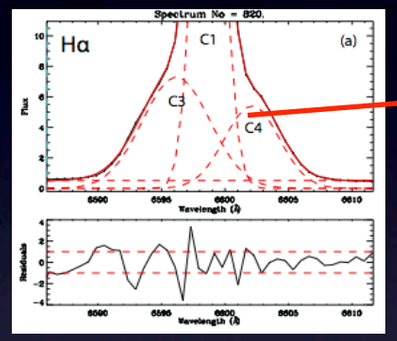
VIMOS IFU overlaid on WFPC2 V-band Image + Hα contours

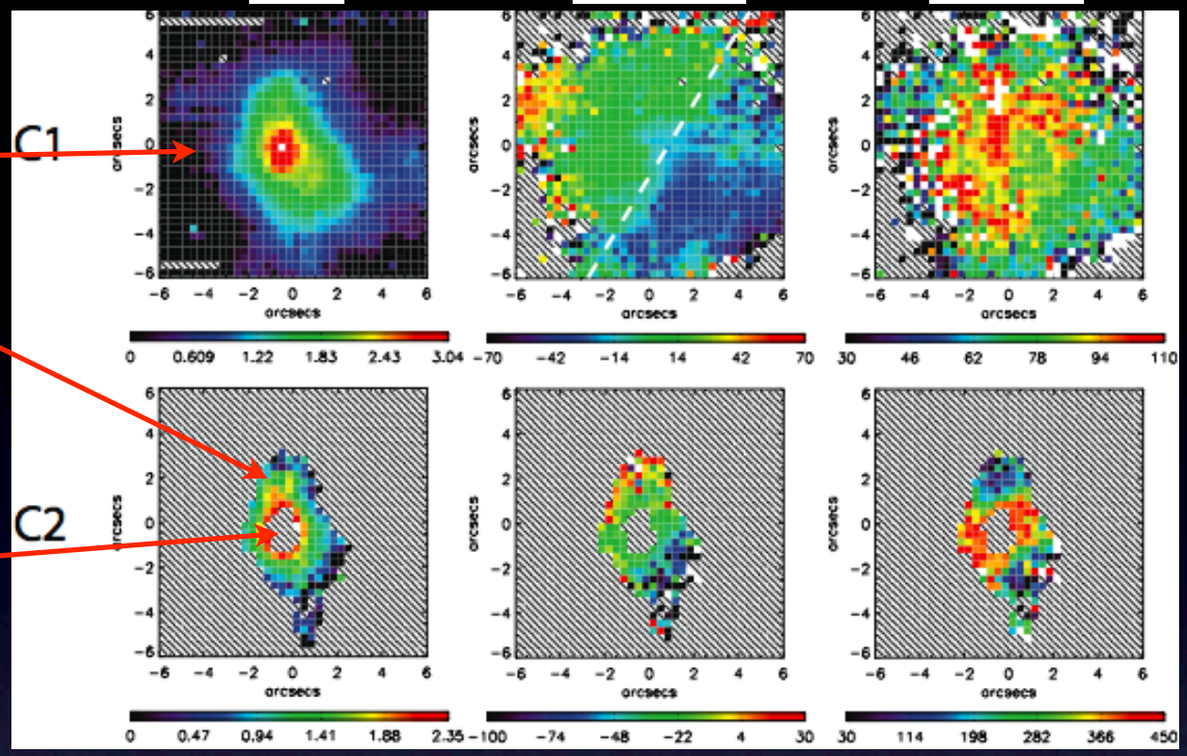
Mrk 996

James et al. 2009

VLT/VIMOS IFU - Maps in Hα, D~22Mpc







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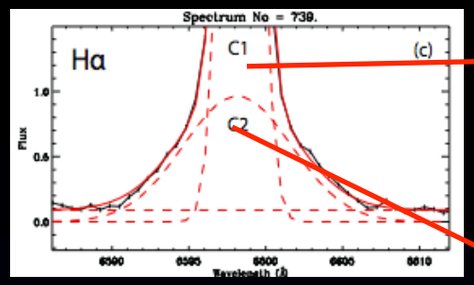
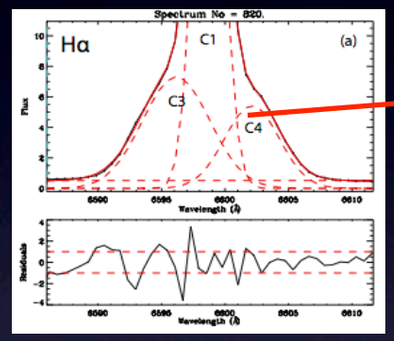
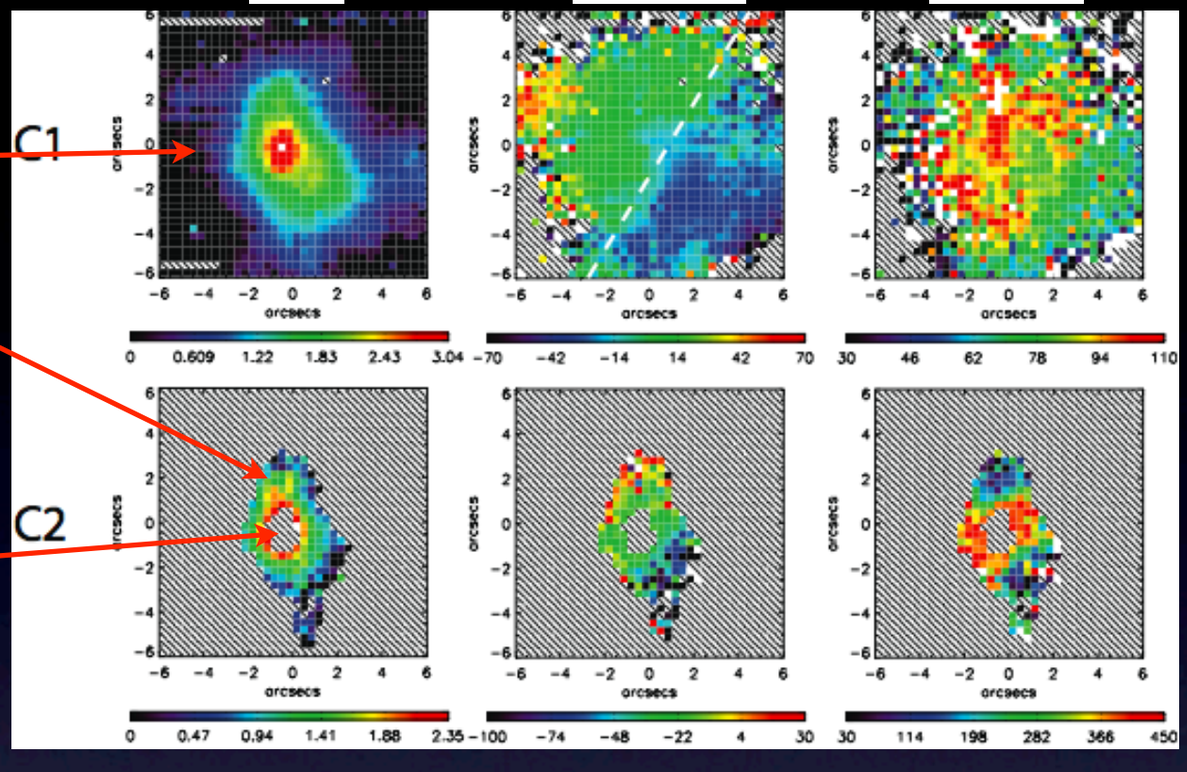
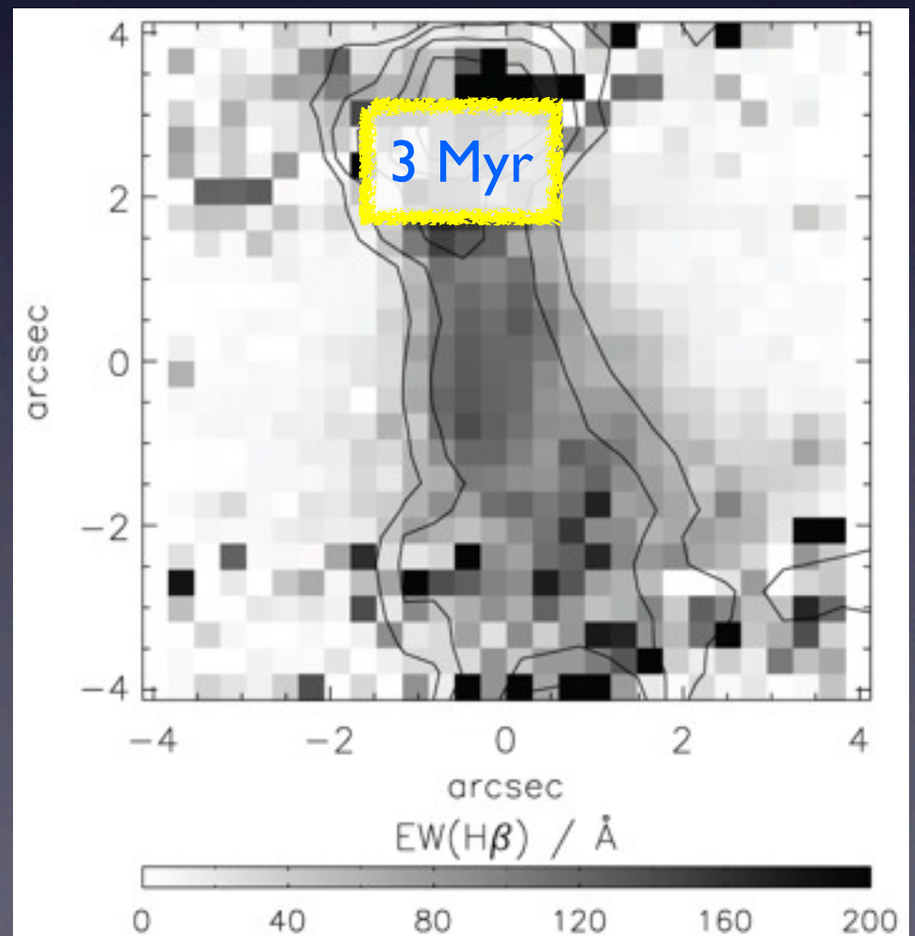
James et al. 2009

VLT/VIMOS IFU - Maps in Hα, D~22Mpc









Mrk 996

James et al. 2009

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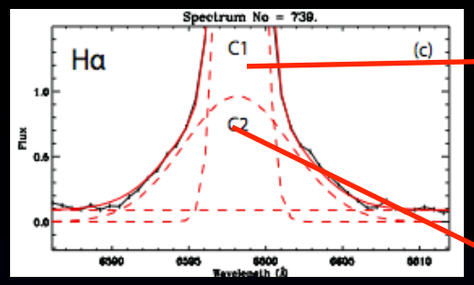

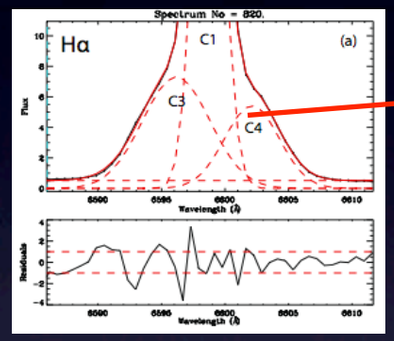

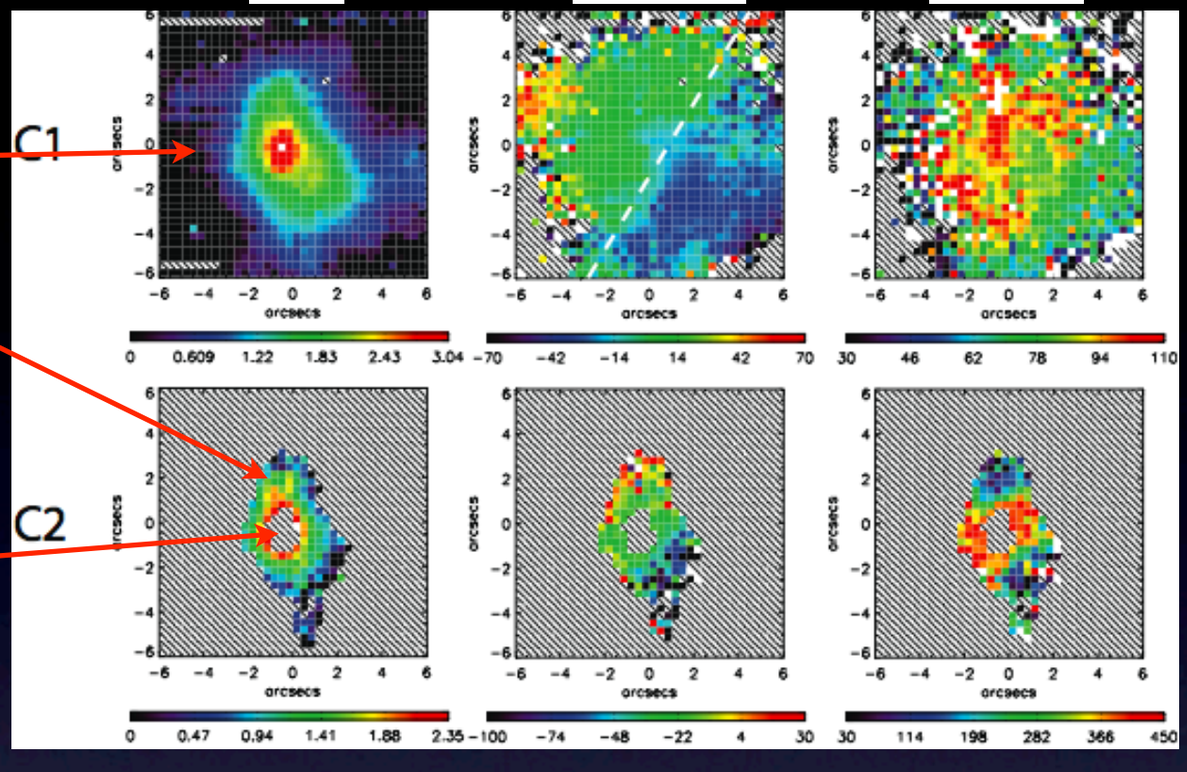

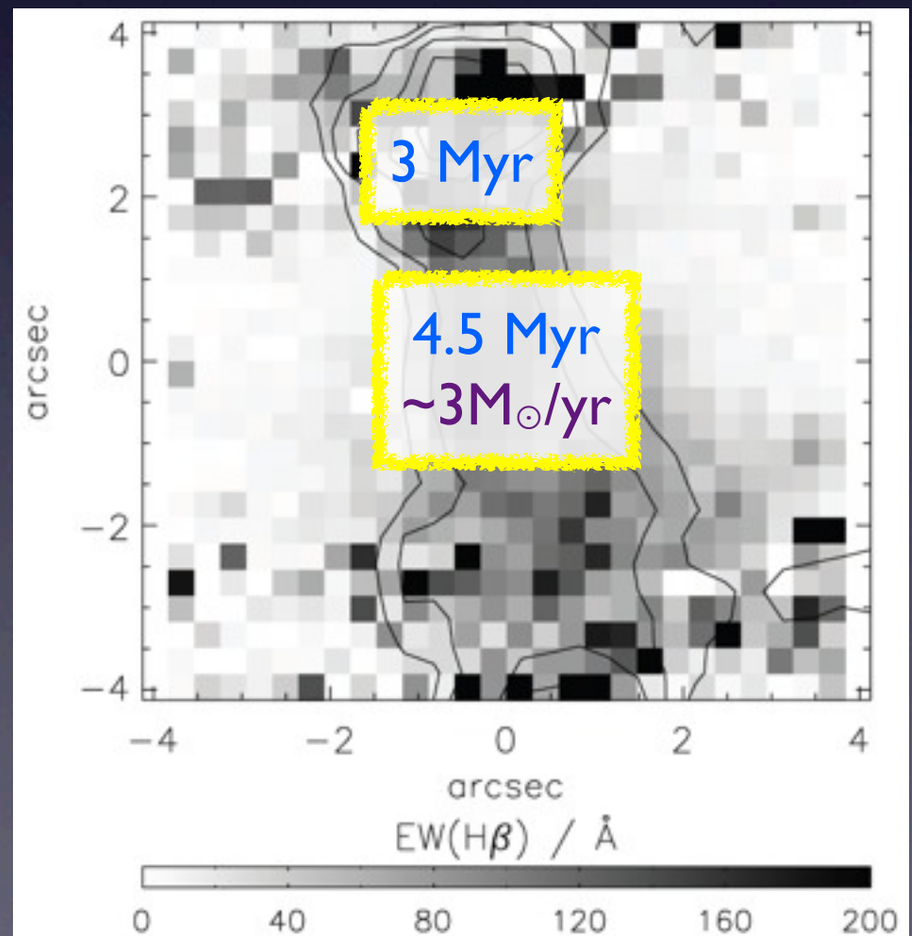

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James et al. 2009

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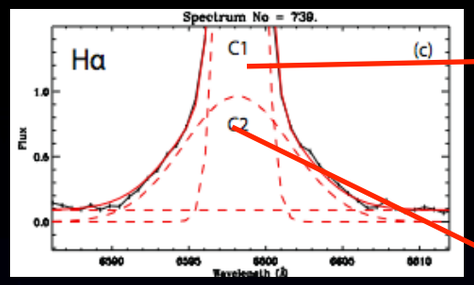

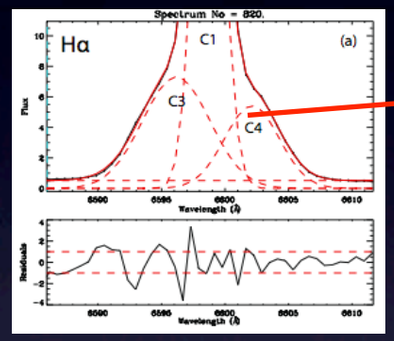

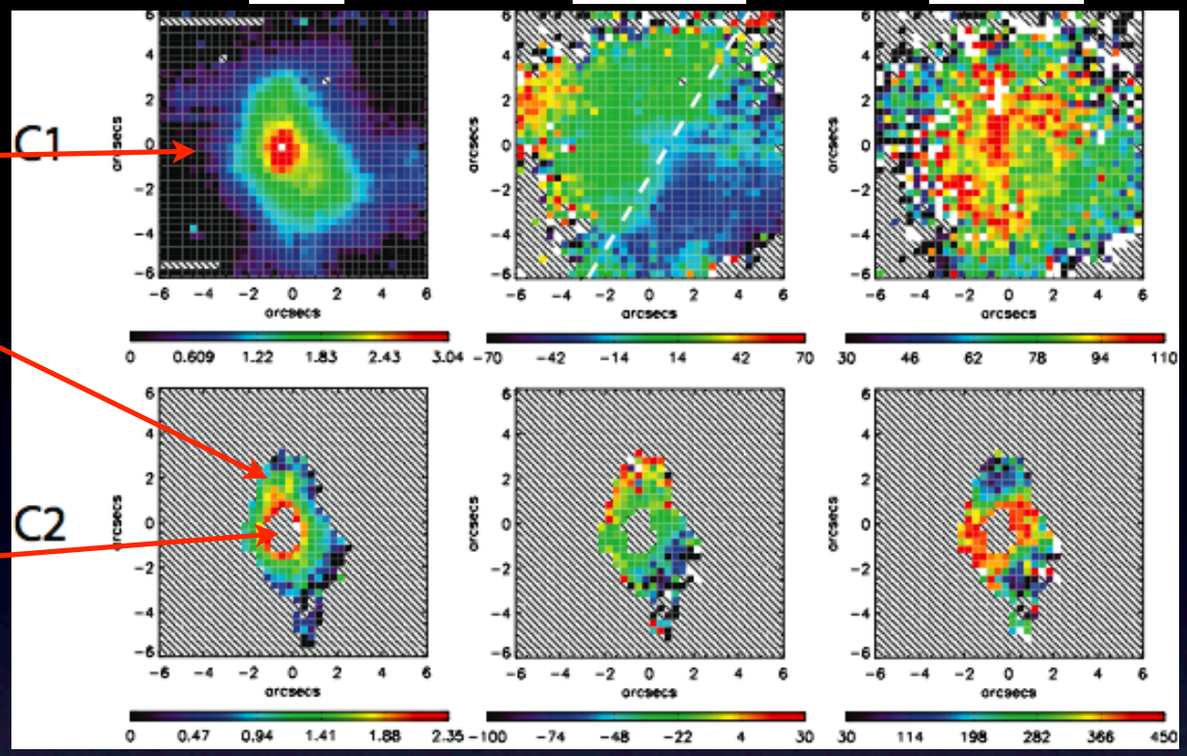

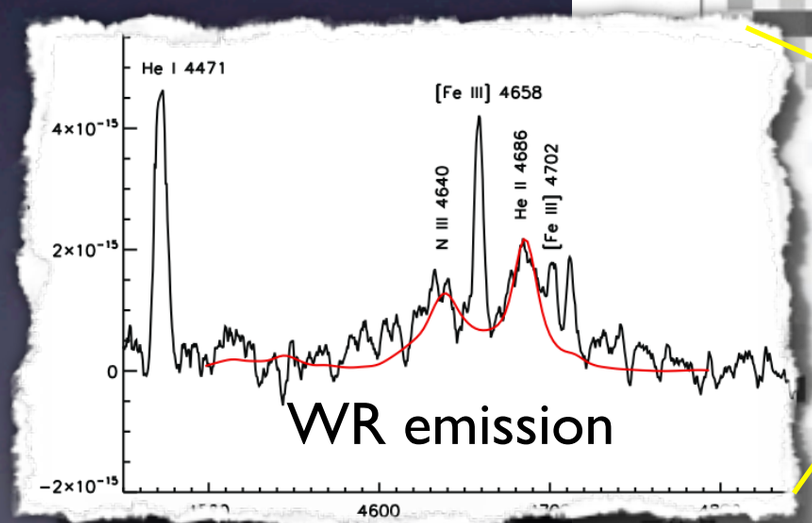

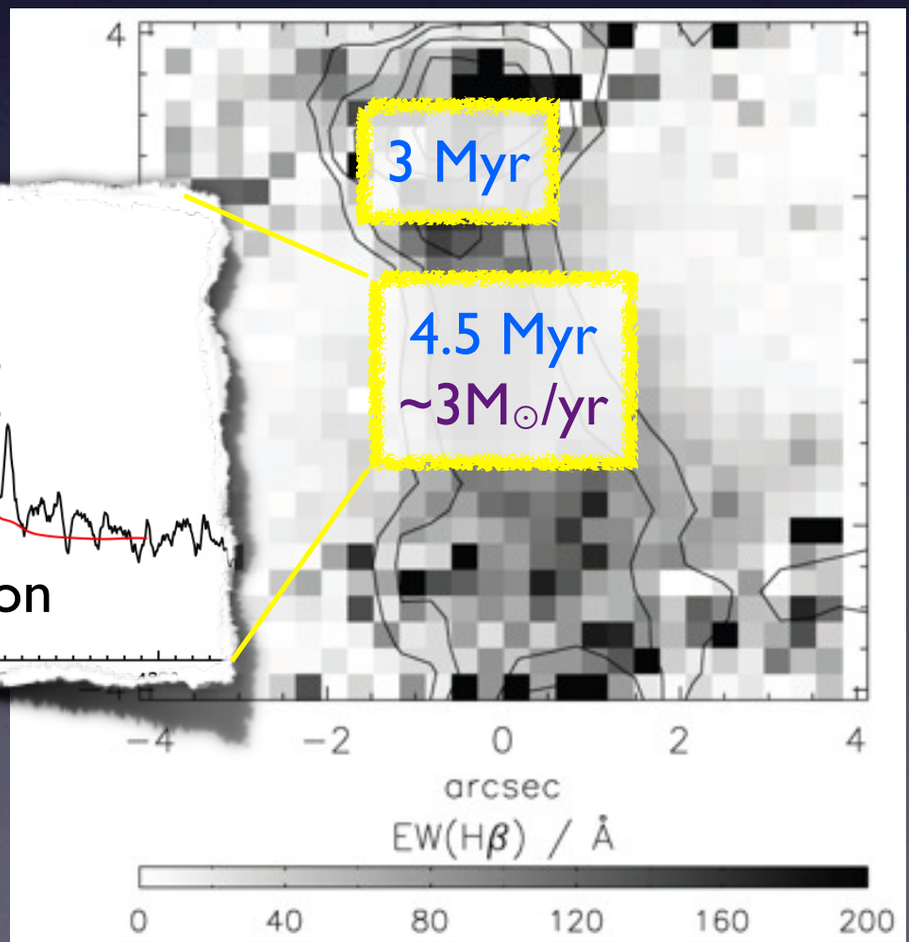

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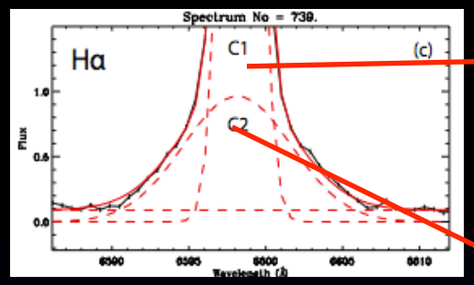
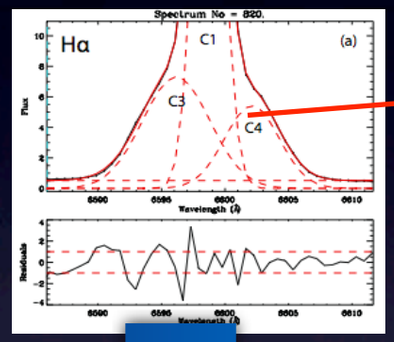
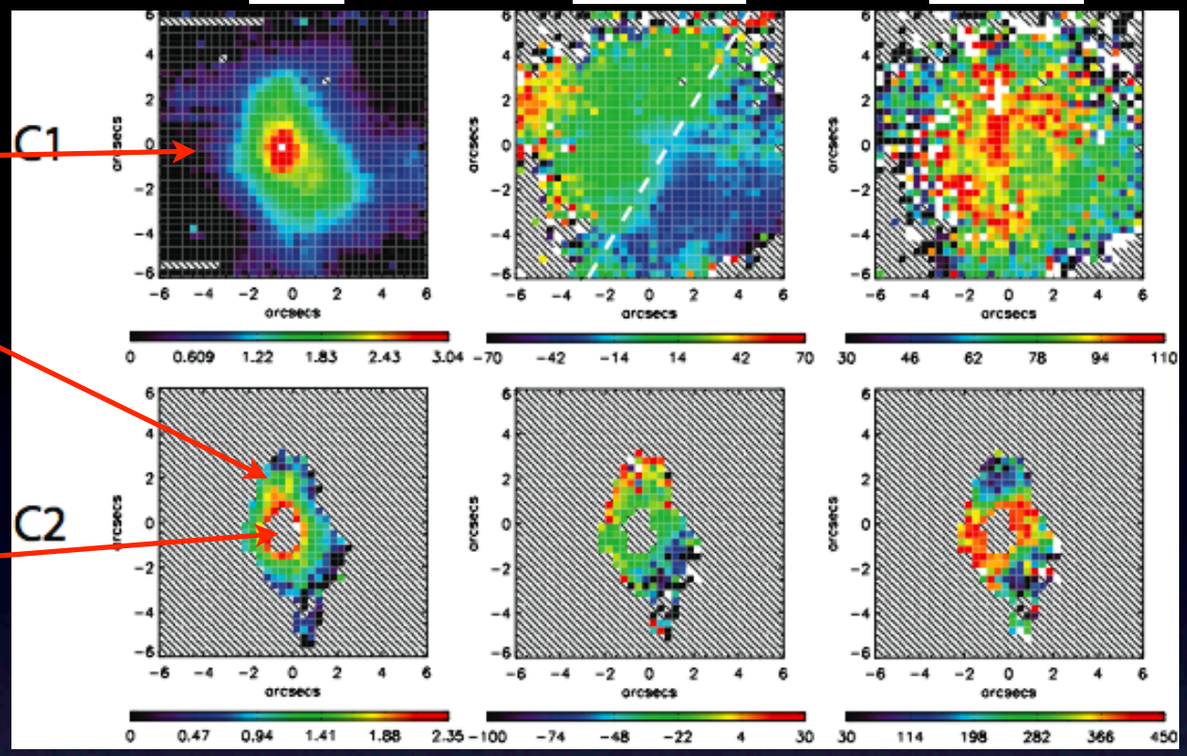
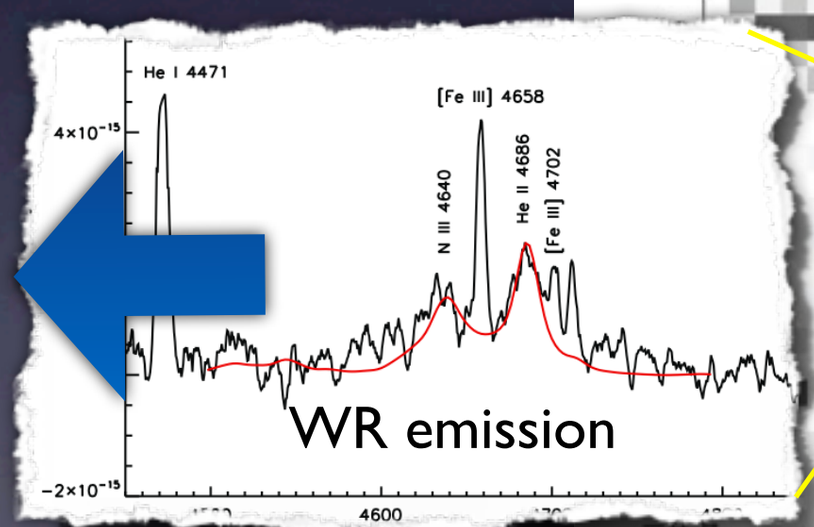
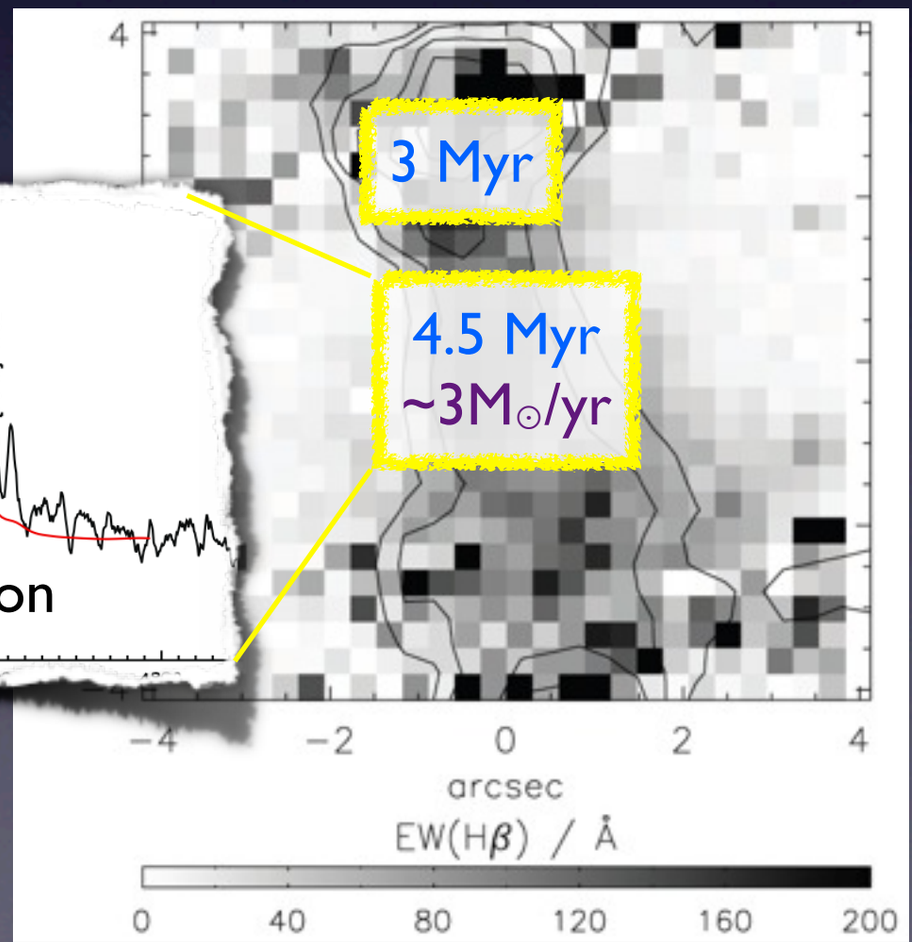






Multicomponent Te, Ne & Abundance analysis

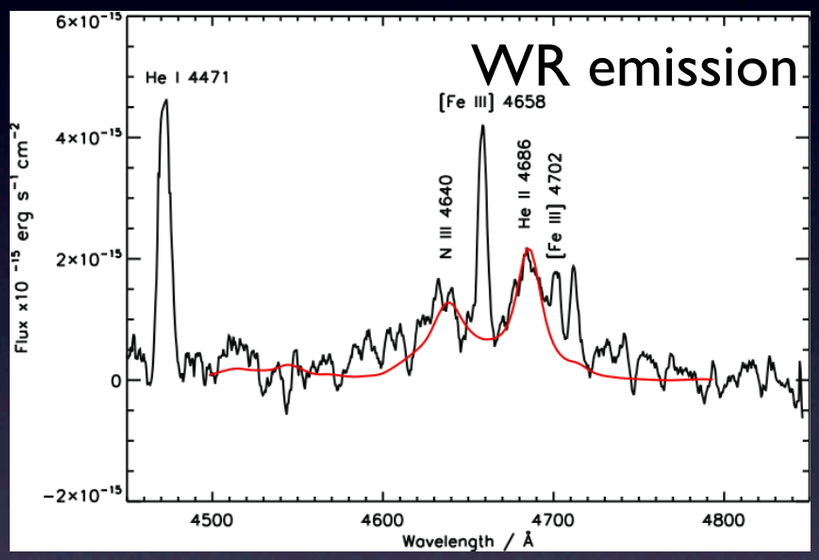




Mrk996: N-enrichment

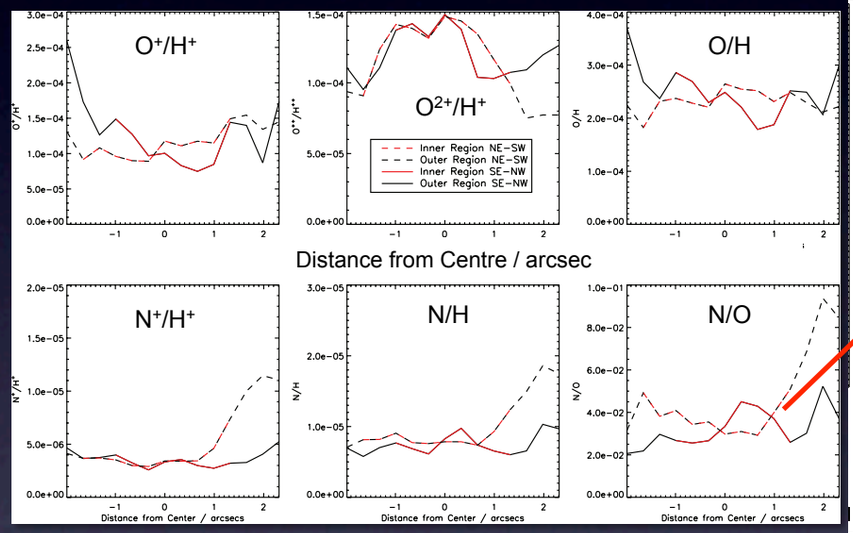
Broad Component

- Te:11,000 K Ne: 10^7 cm^{-3}
- O/H ~ 0.5 Z⊙ (0.2 Z⊙)
- log(N/O)=**-0.13** (-0.11)

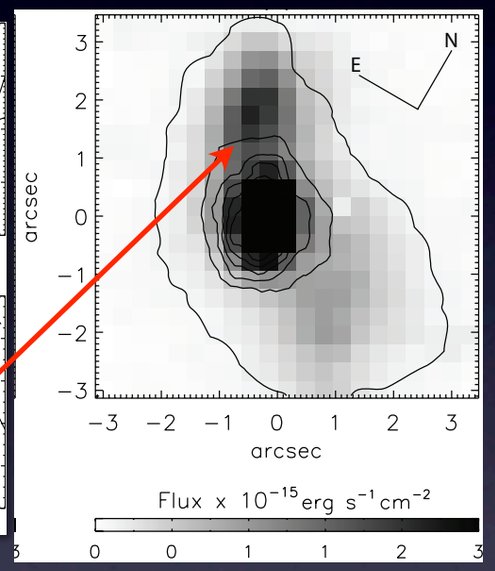


Narrow Component

- Te:10,000 K Ne: 170 cm^{-3}
- O/H ~ 0.5 Z⊙ (0.2 Z⊙)
- log(N/O)=-1.43 (-0.11)



[NII] λ6584 Map



N enrichment from N-rich WR winds

also seen in NGC5253 (Lopez-Sanchez+, 2010)

Stellar outflow of N from core? Localised N-enrichment from younger stars?

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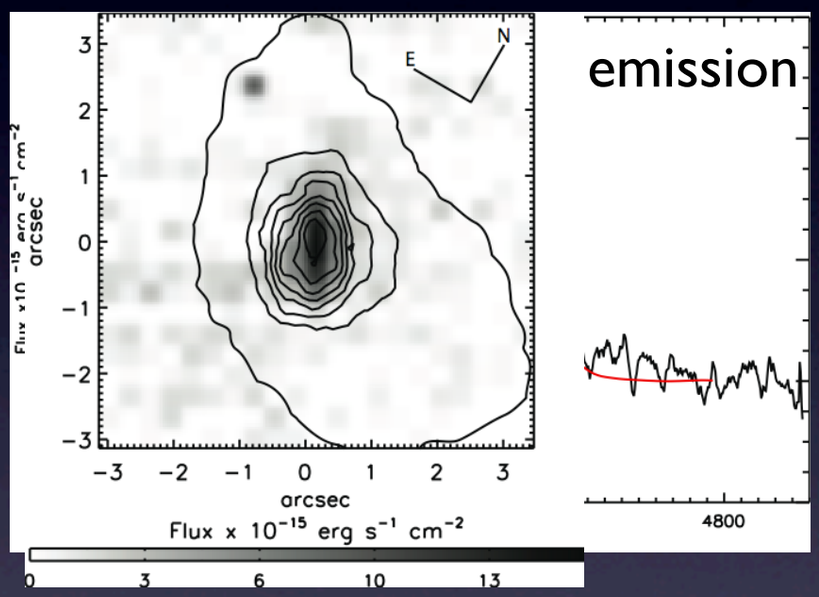

WR map

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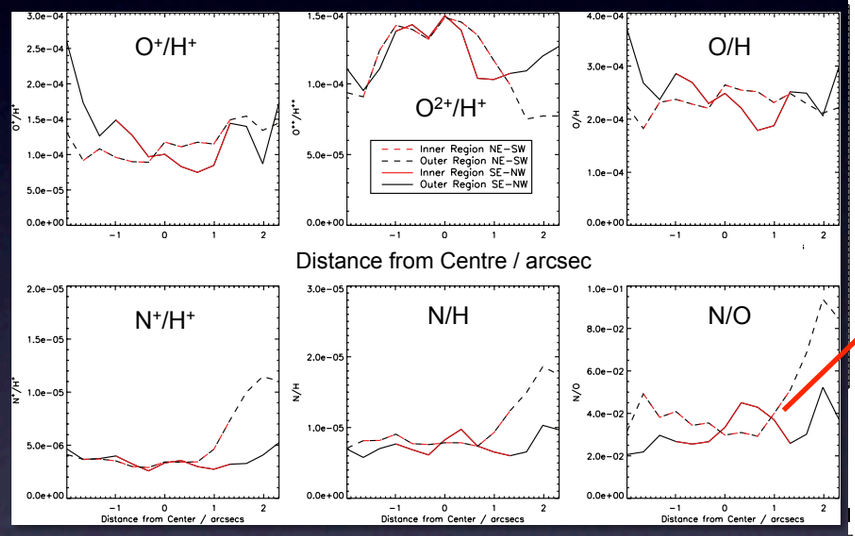

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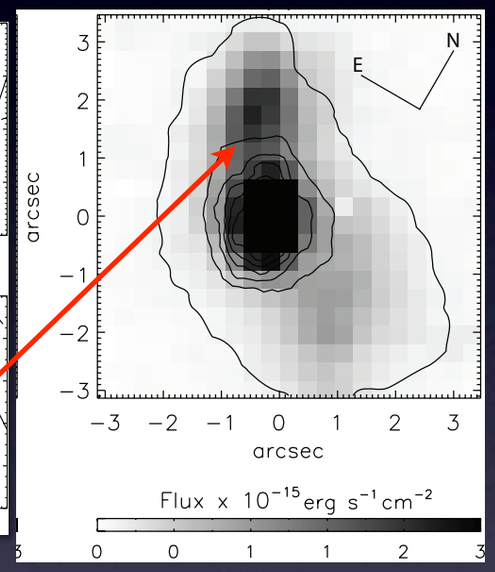

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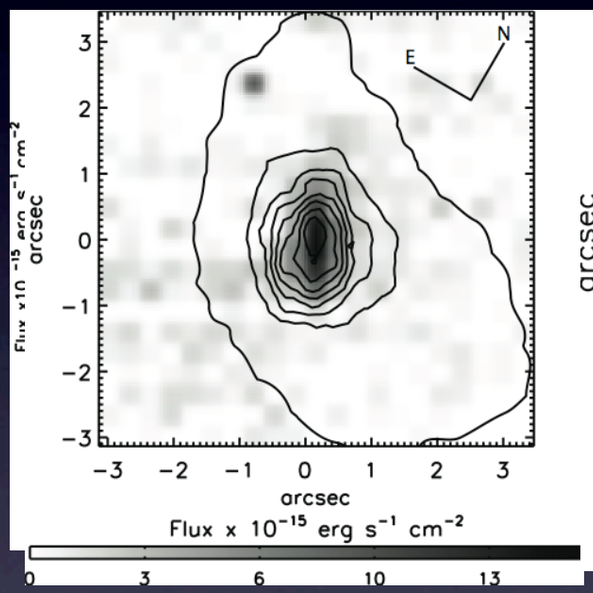

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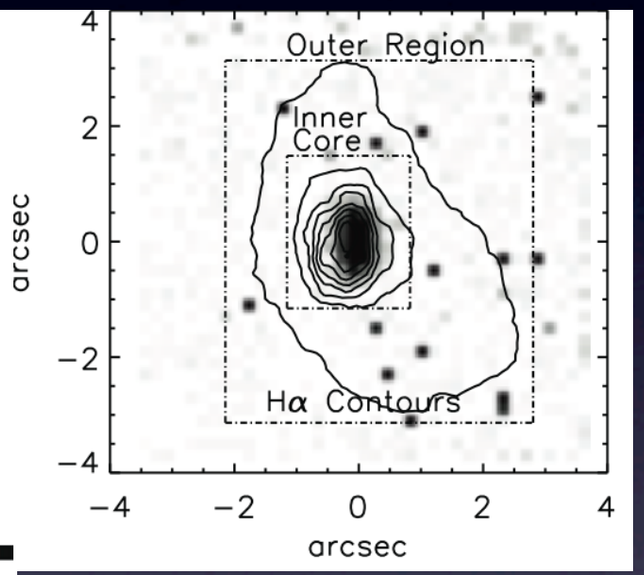
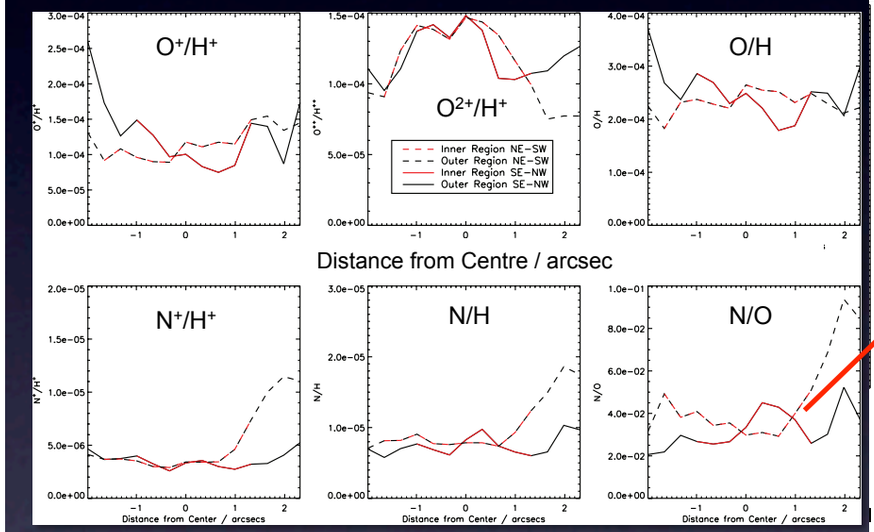


Broad emission



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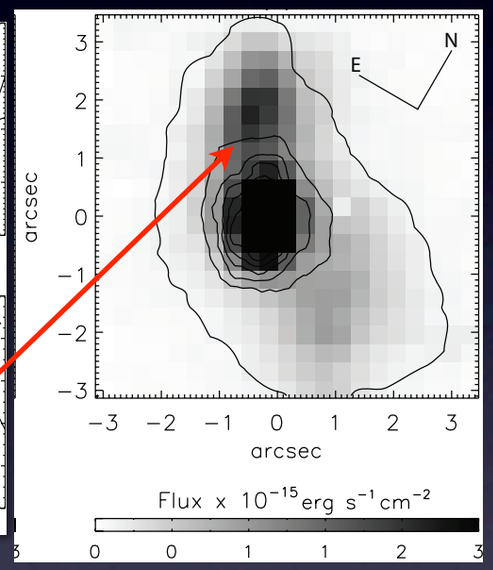

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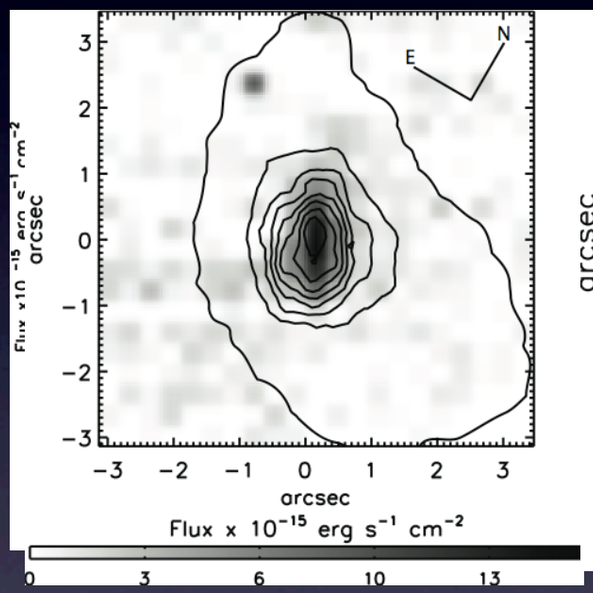
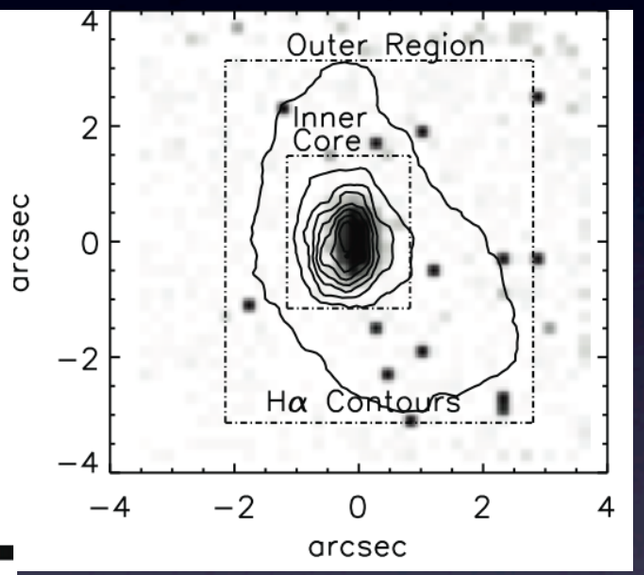


WR map



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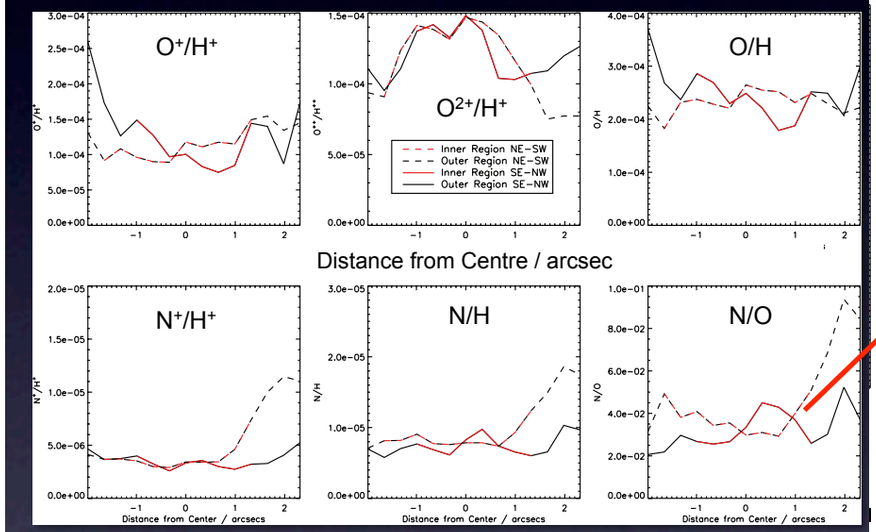

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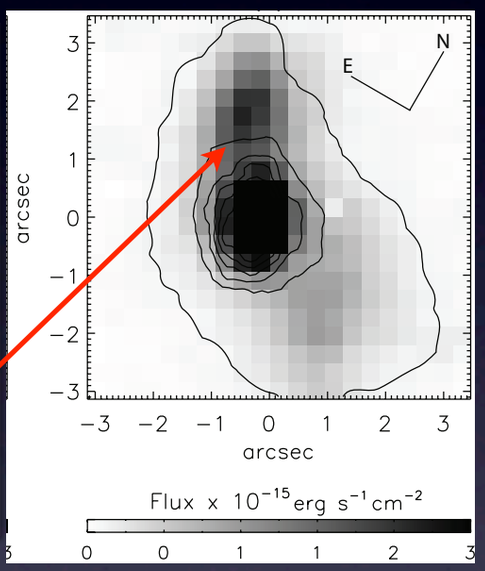

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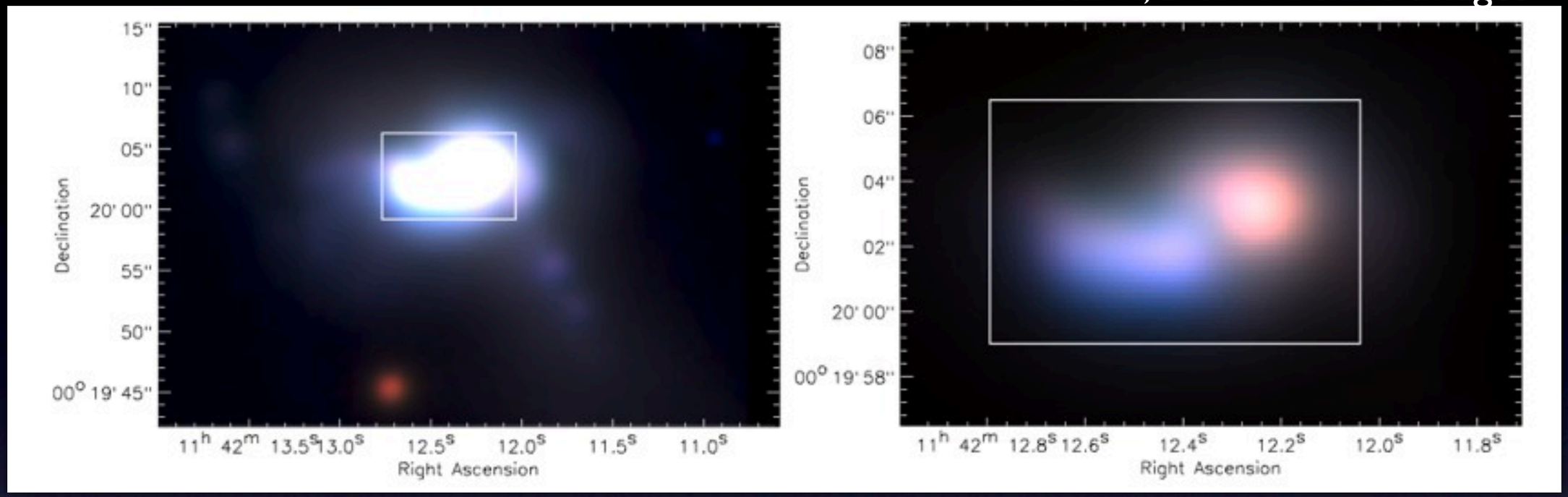
Stellar outflow of N from core?
Localised N-enrichment from younger stars?

A spatially resolved, multi-component spectroscopic analysis +mapped SF properties → isolated enrichment & its origin

UM448

James et al. 2012a (submitted)

SuSI2 R, B & V Archive Images



UM448

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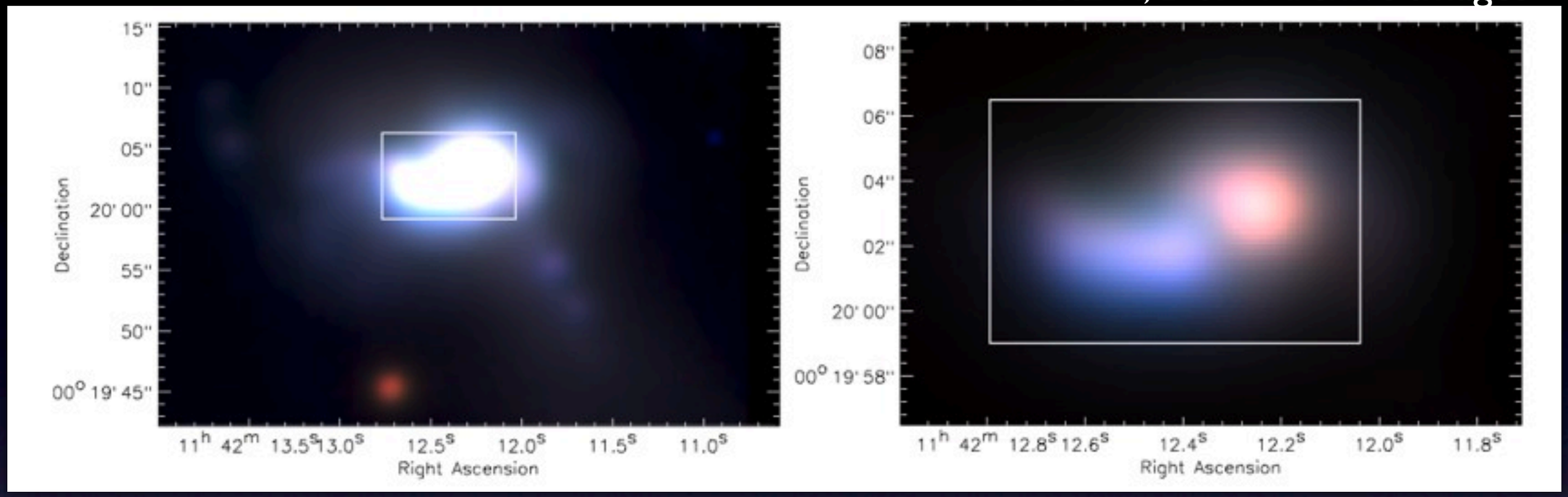
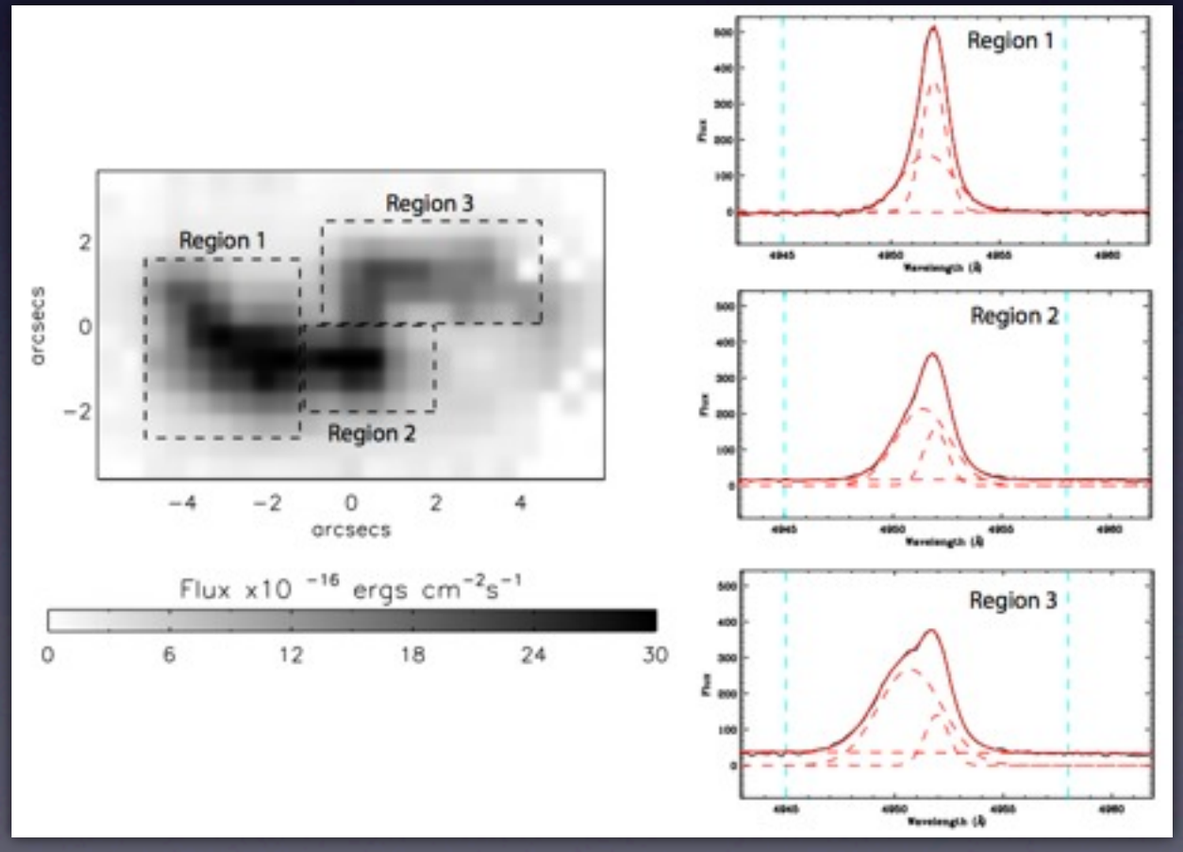
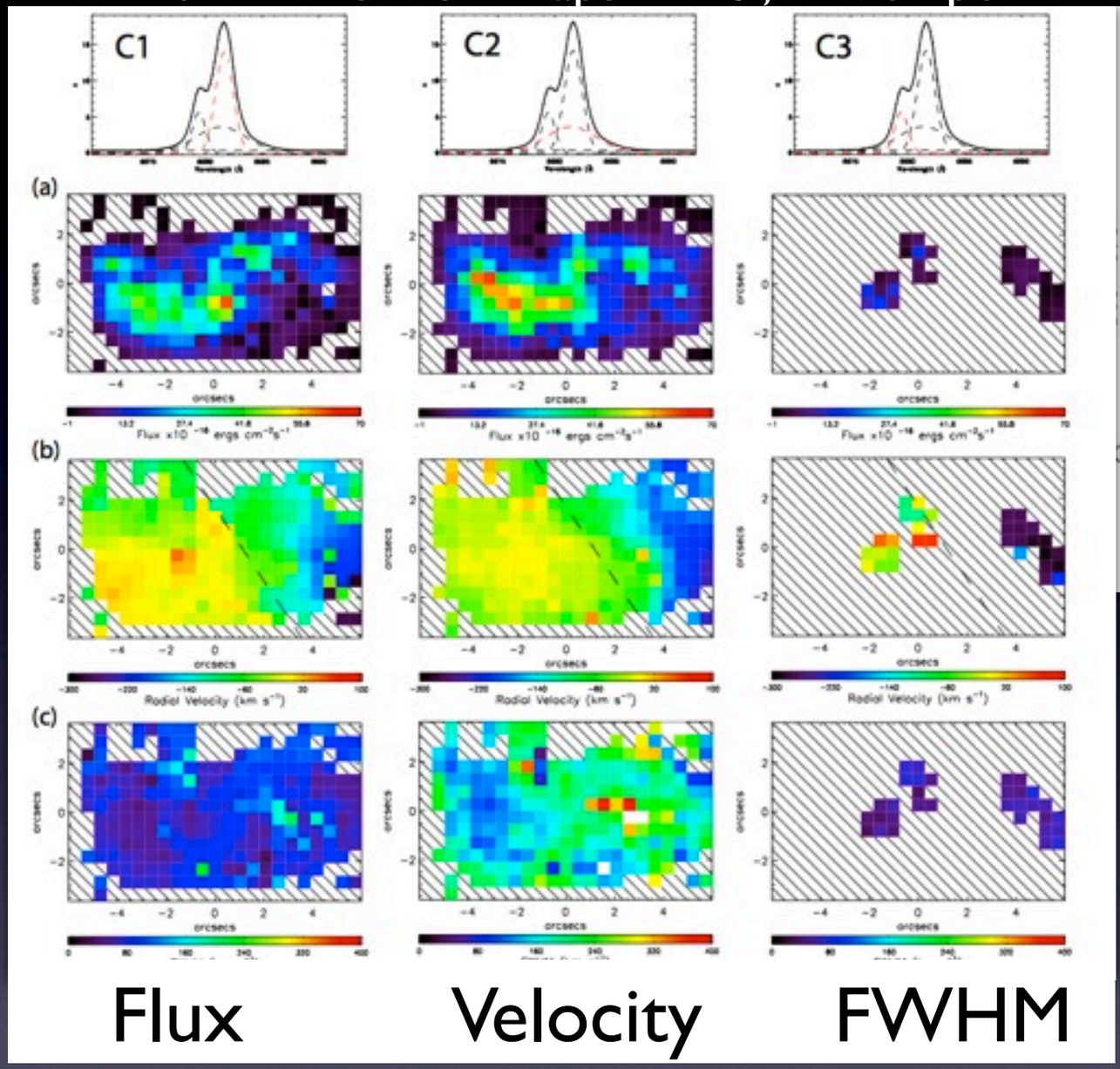




UM448

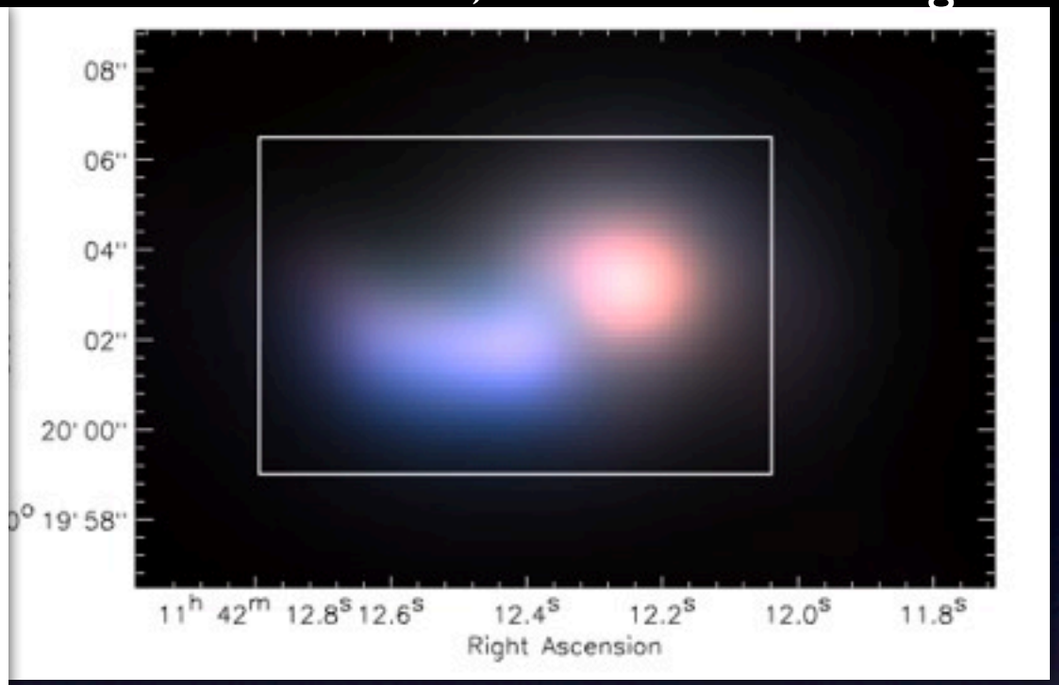
James et al. 2012a (submitted)

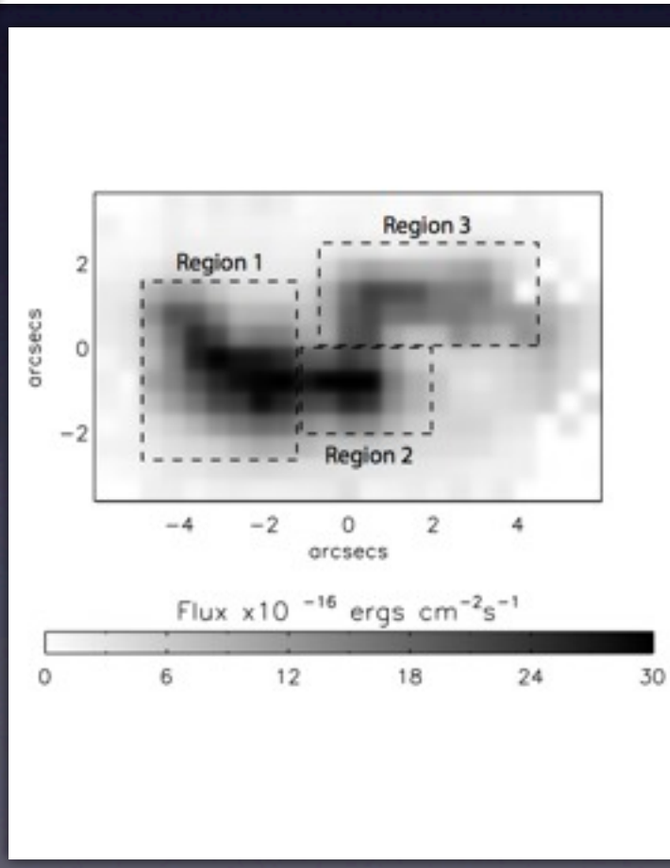
VLT/FLAMES IFU - Maps in Hα, D~76Mpc

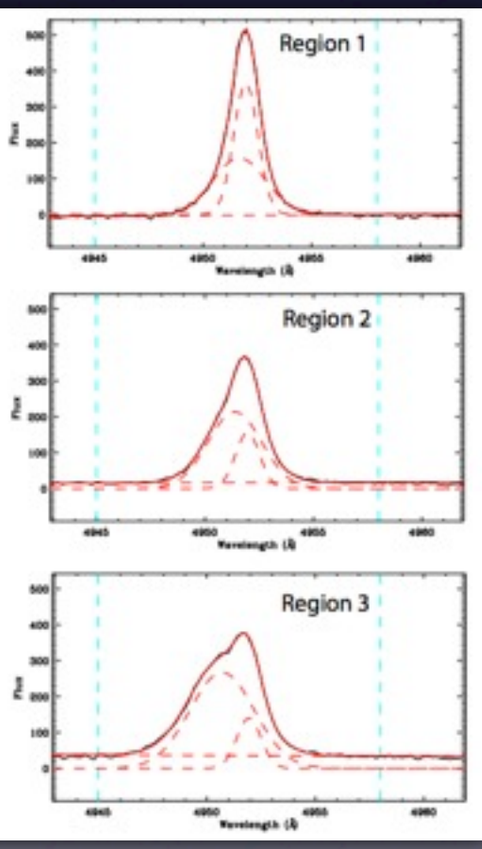


Flux Velocity FWHM

SuSI2 R, B & V Archive Images







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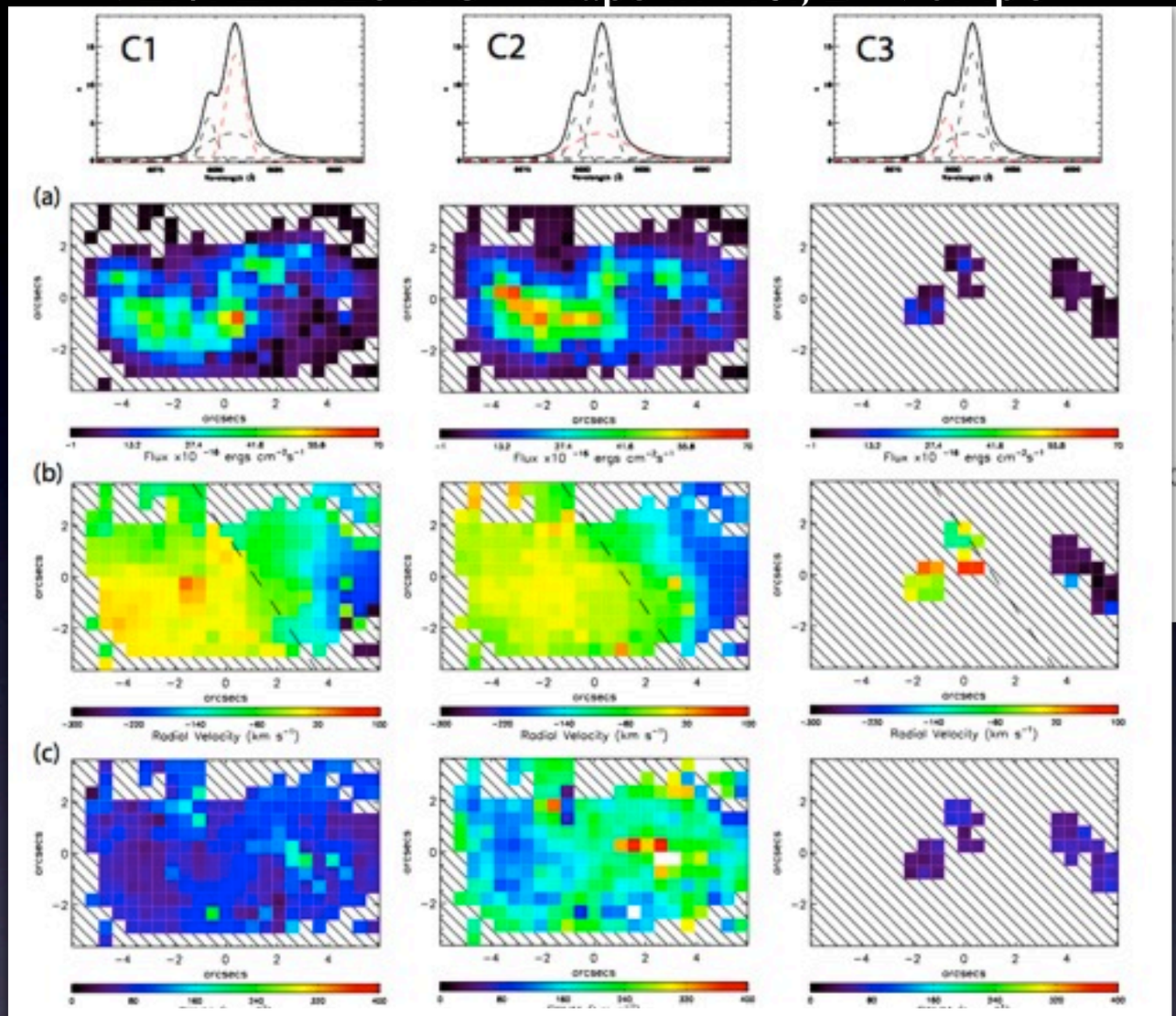

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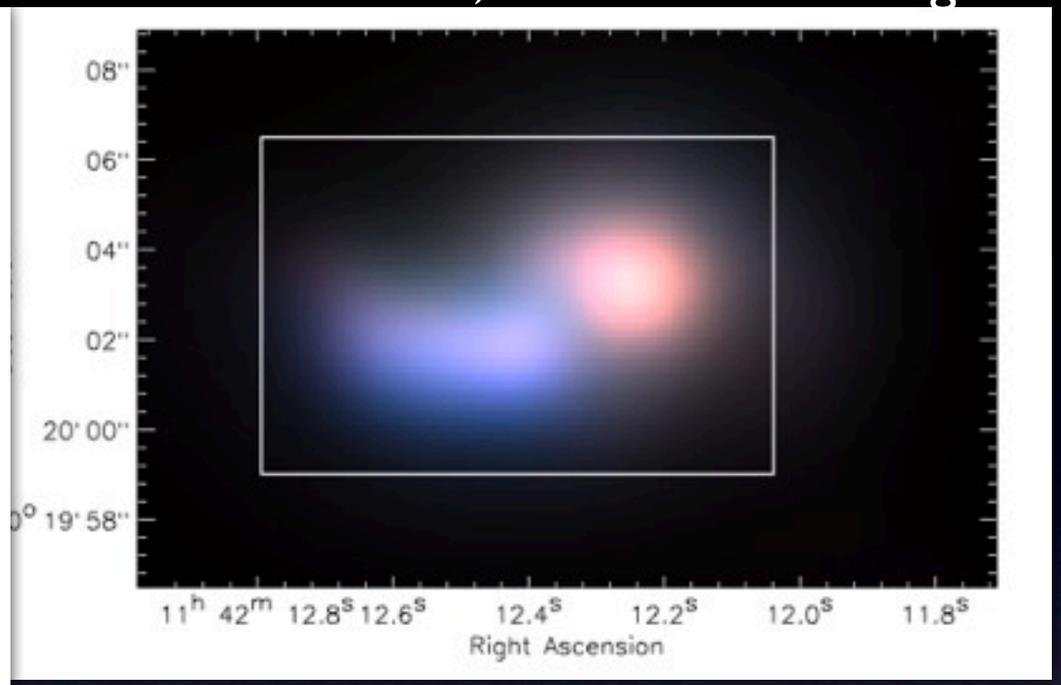
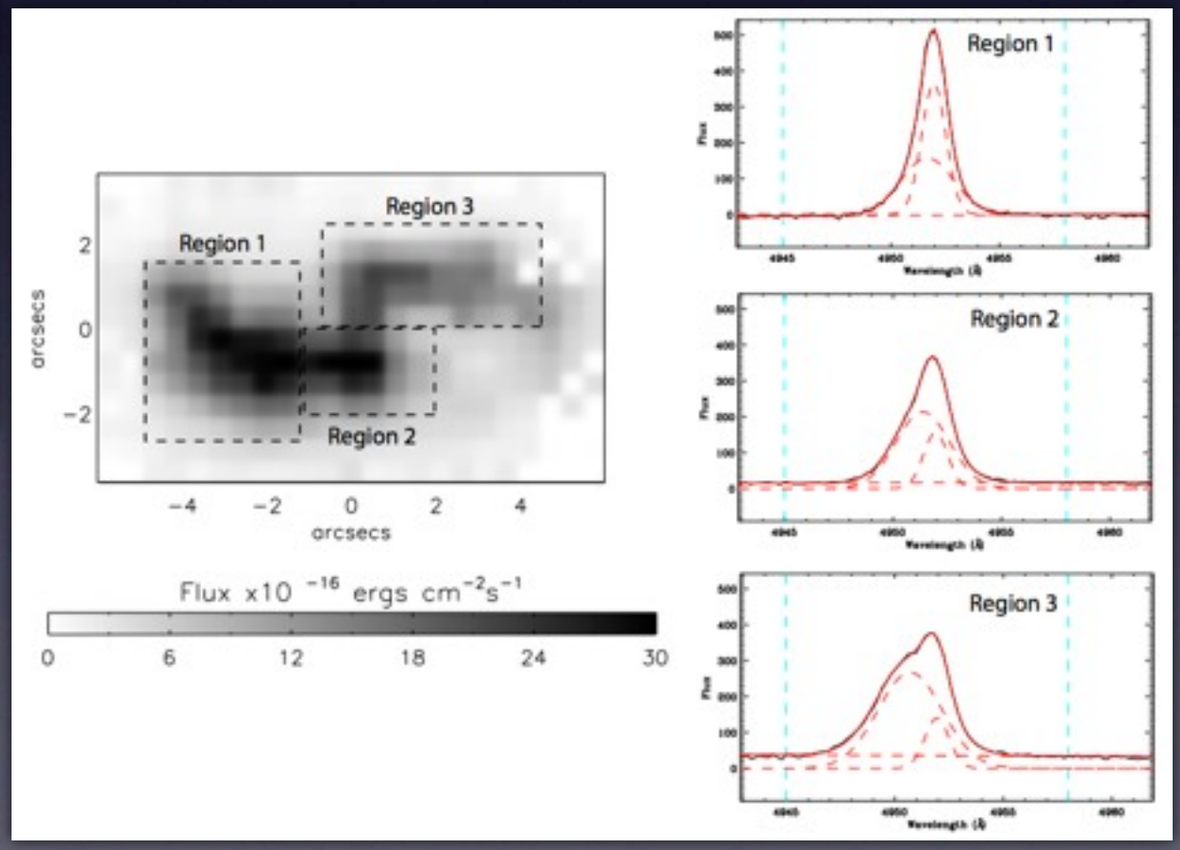
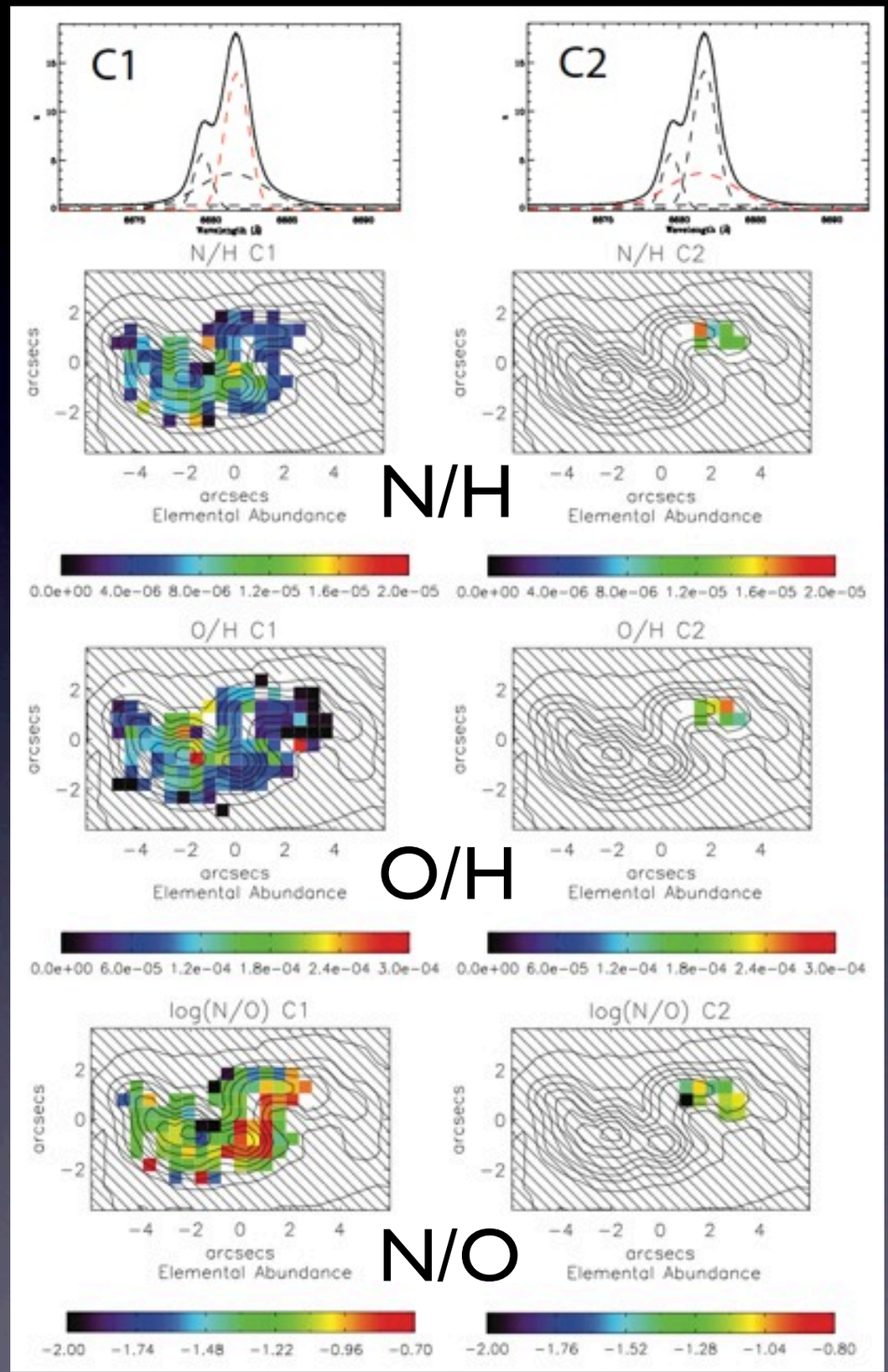




Multicomponent Te, Ne & Abundance analysis

UM448: stellar properties & origin of high N/O



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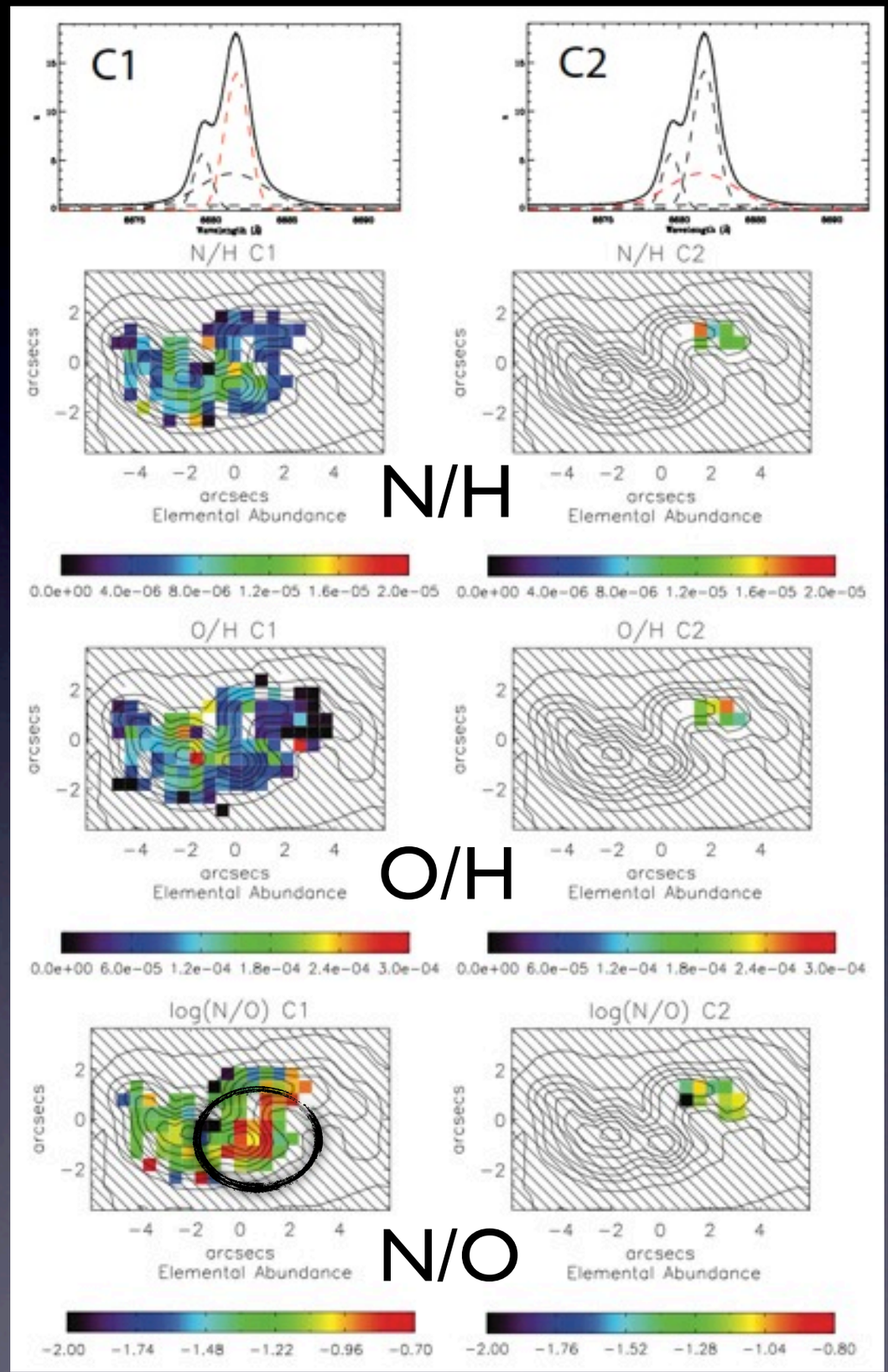

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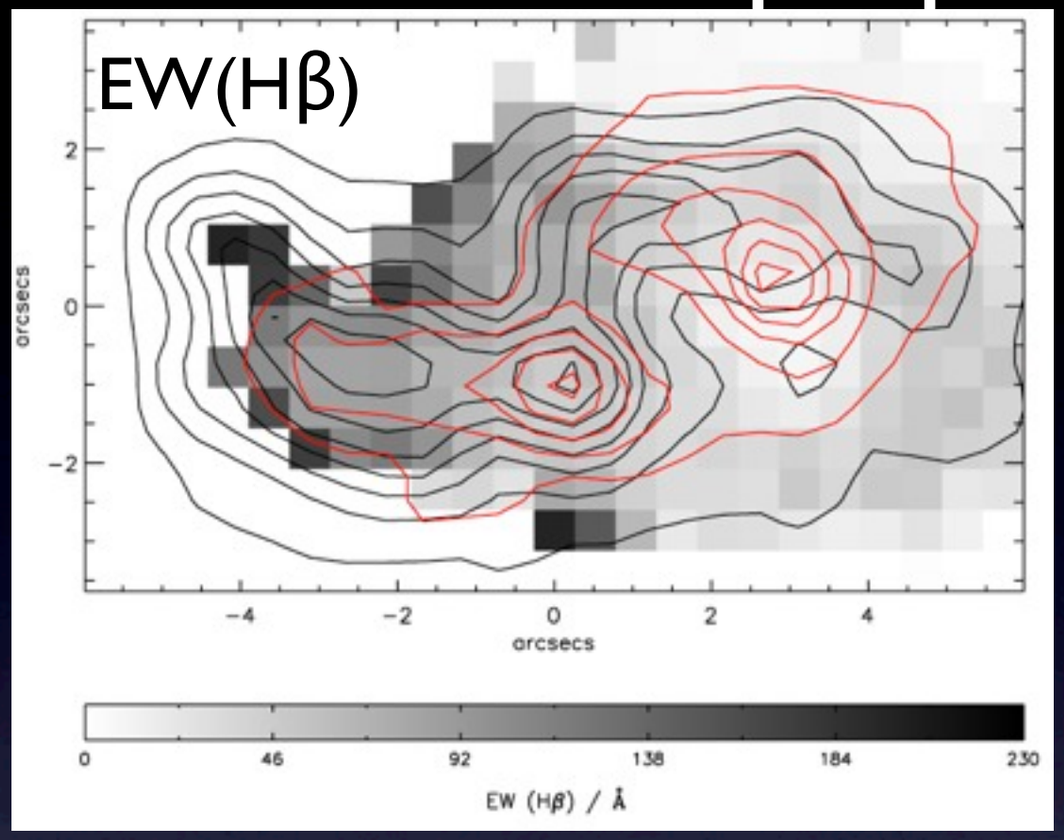
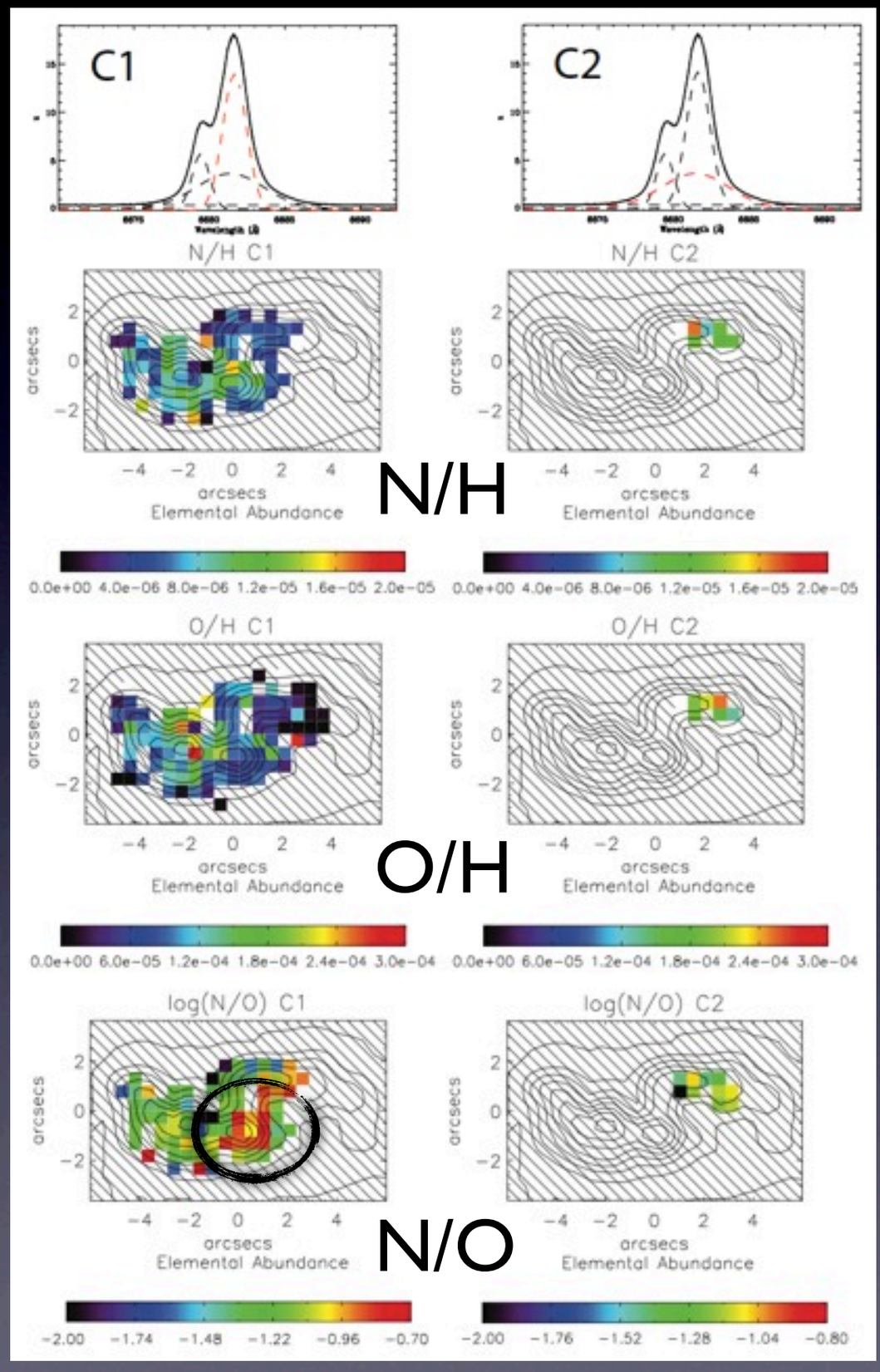
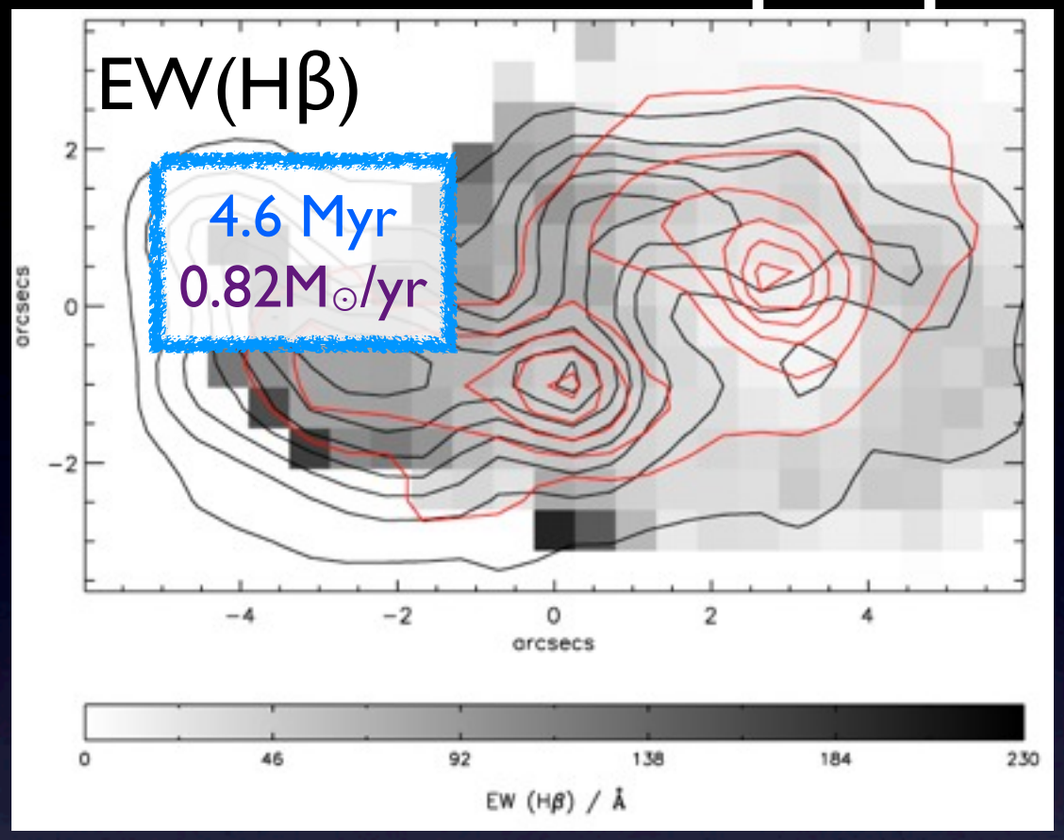
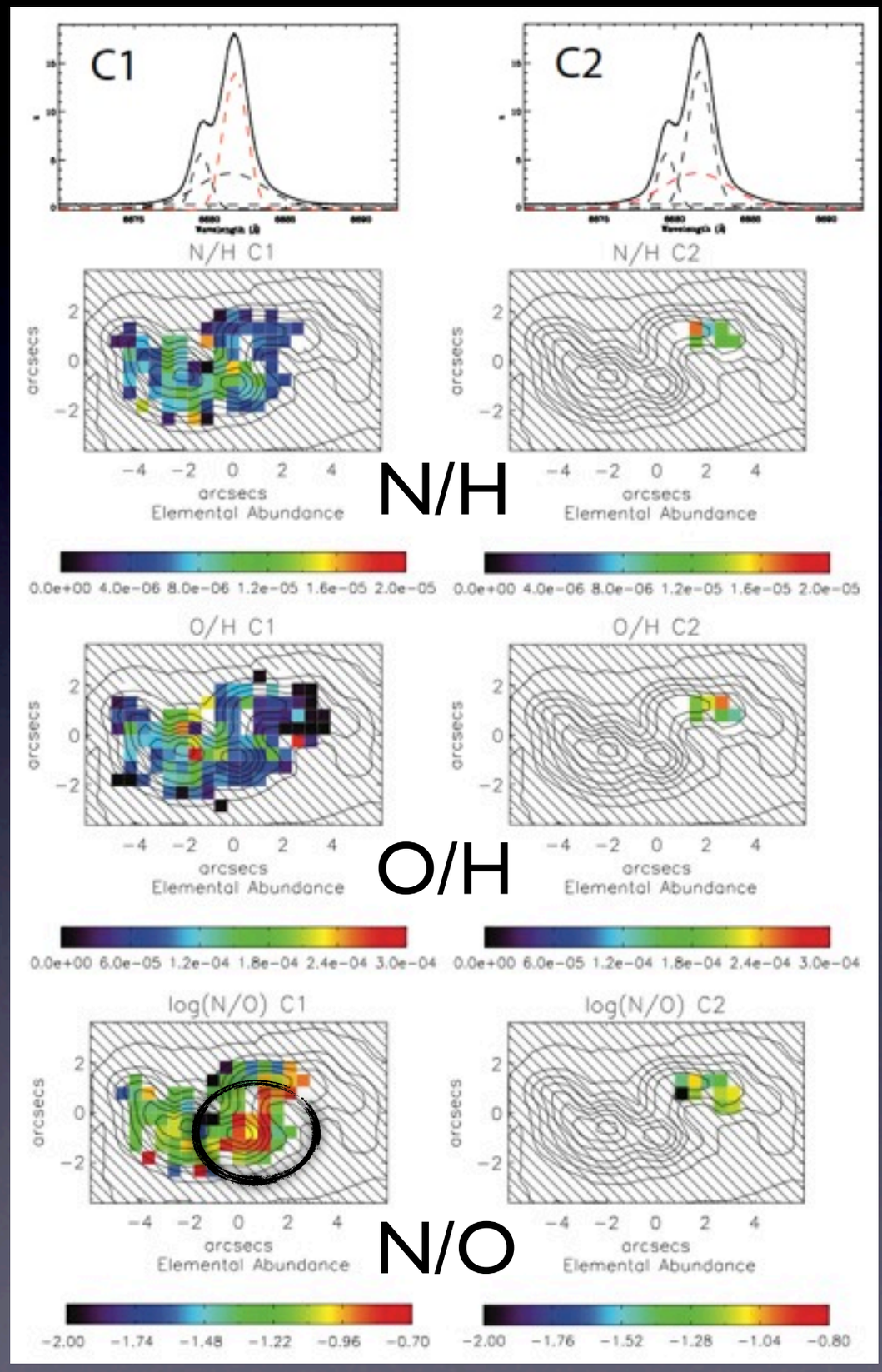




UM448: stellar properties & origin of high N/O





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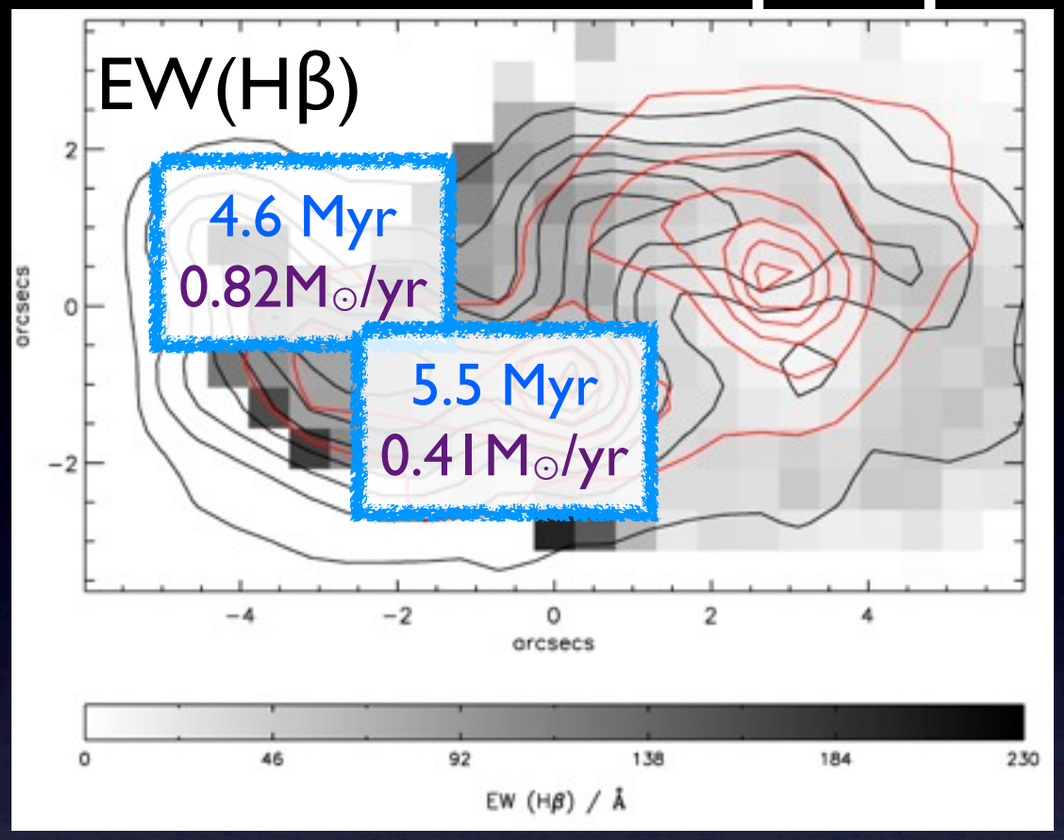

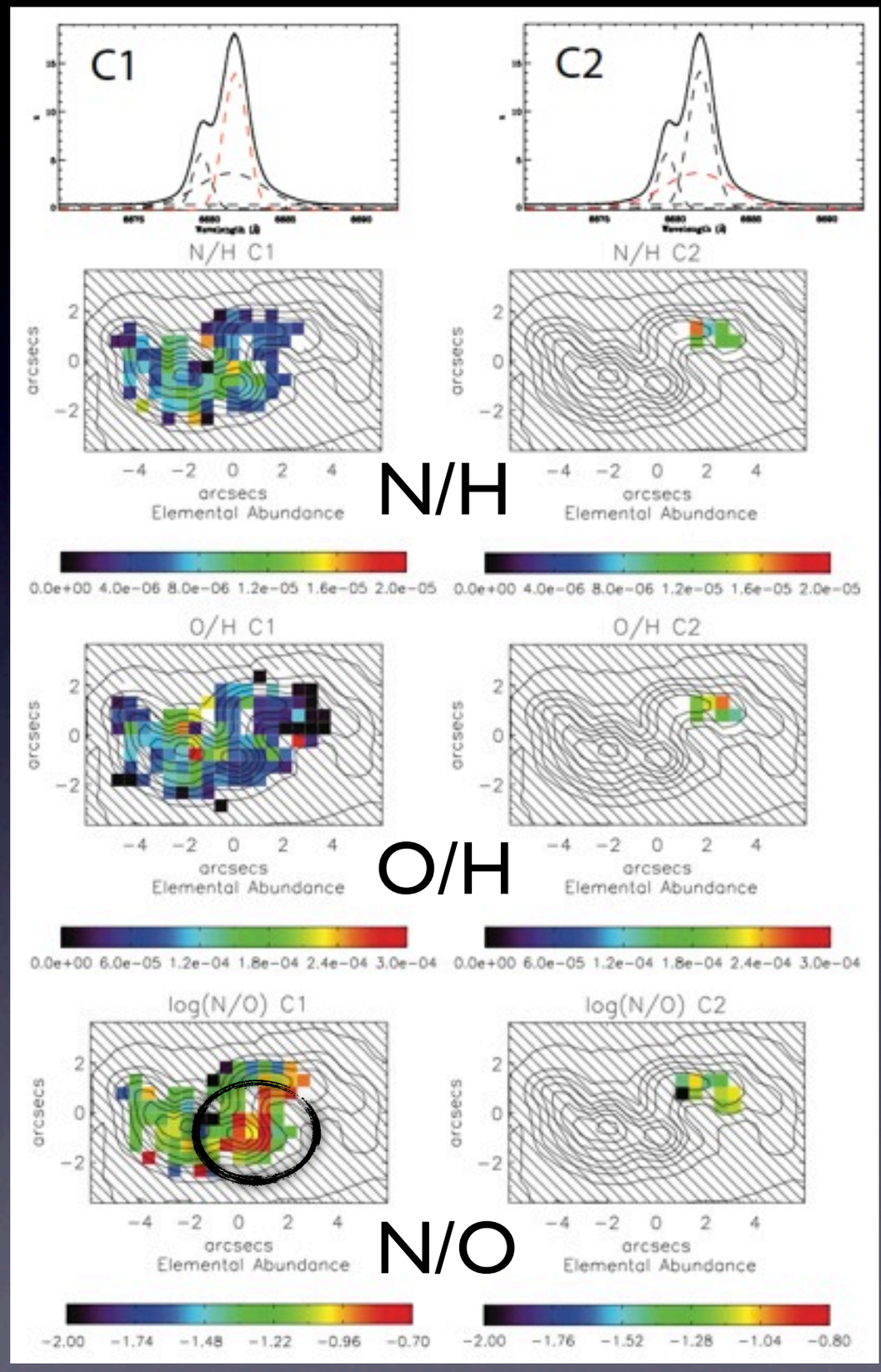

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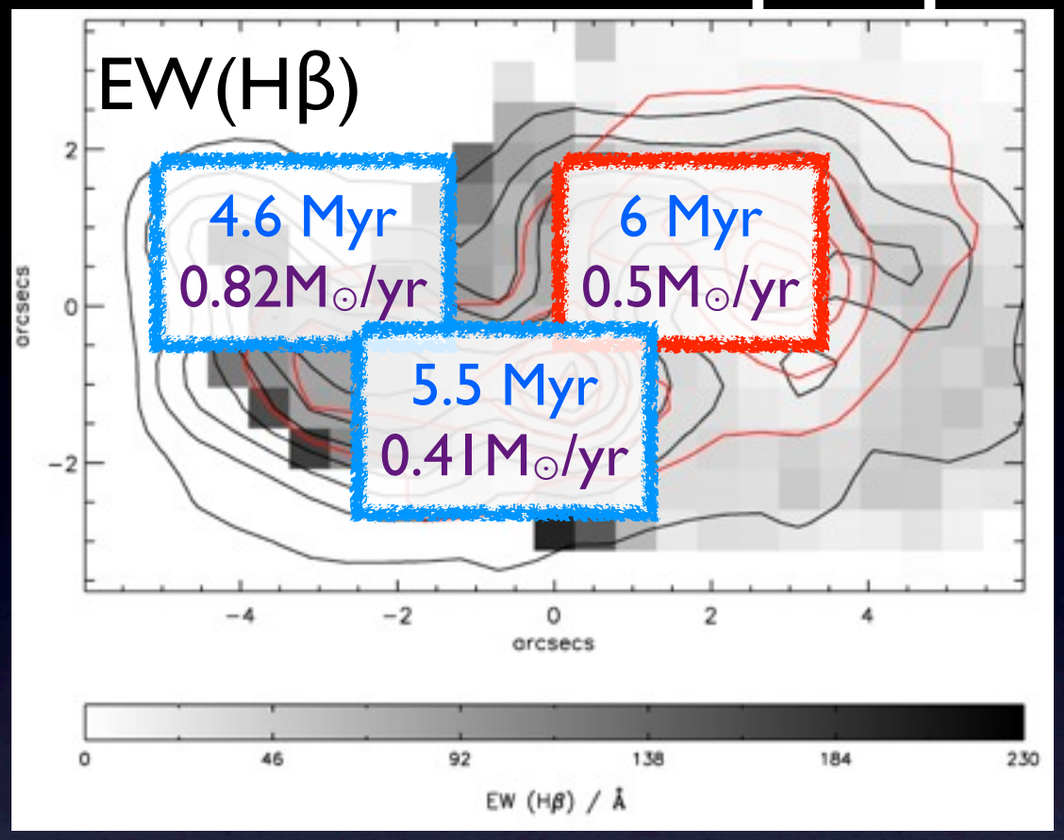

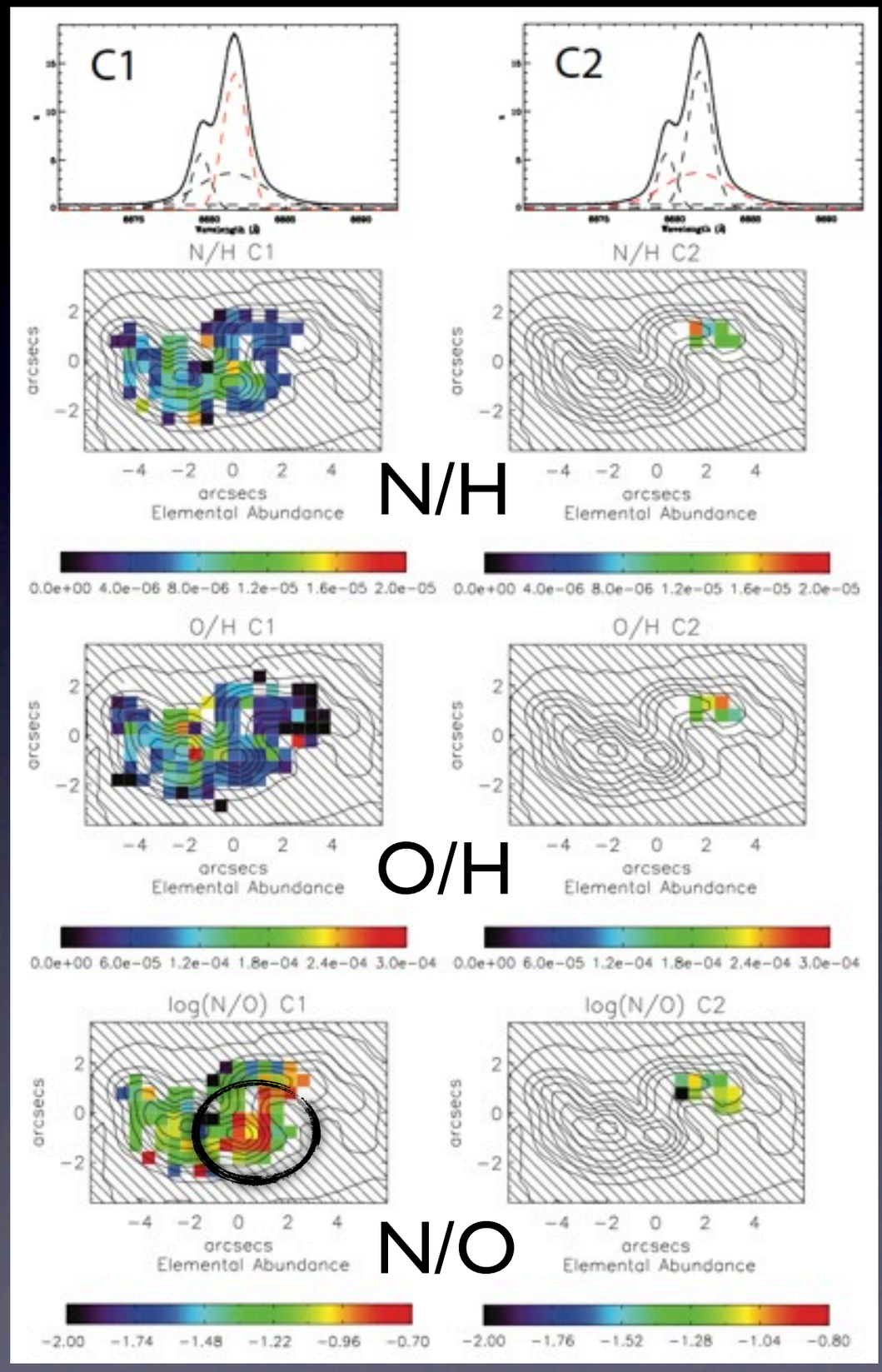

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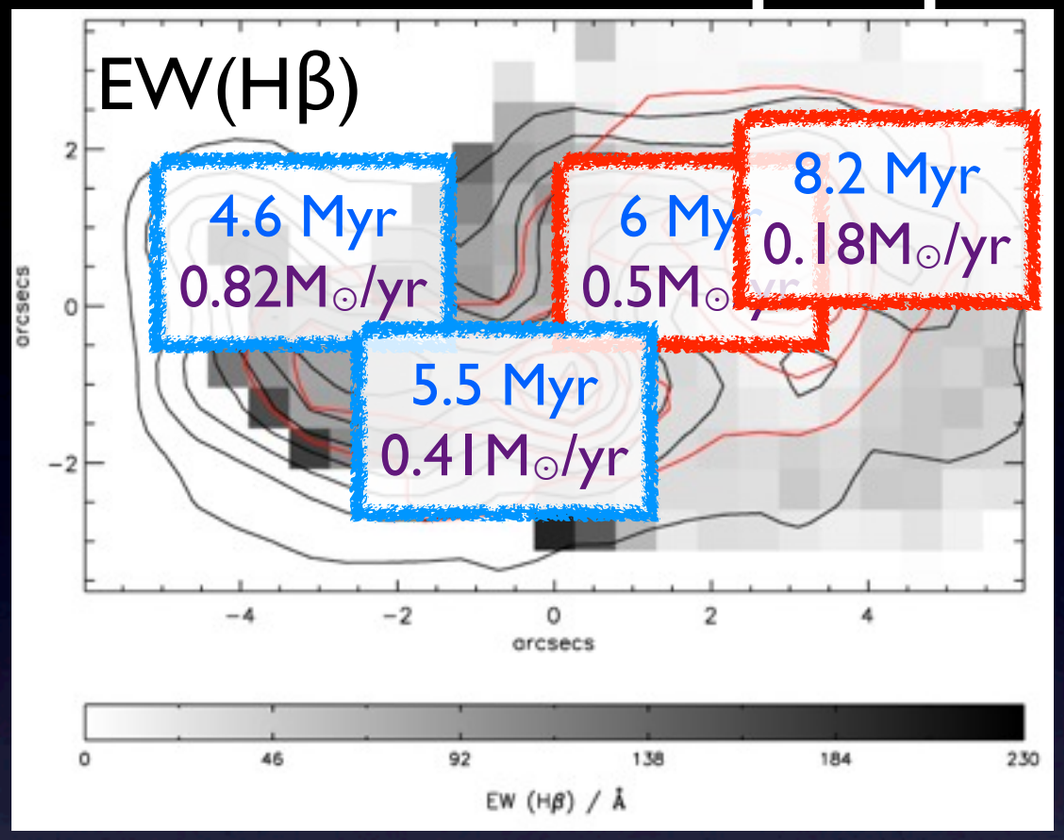

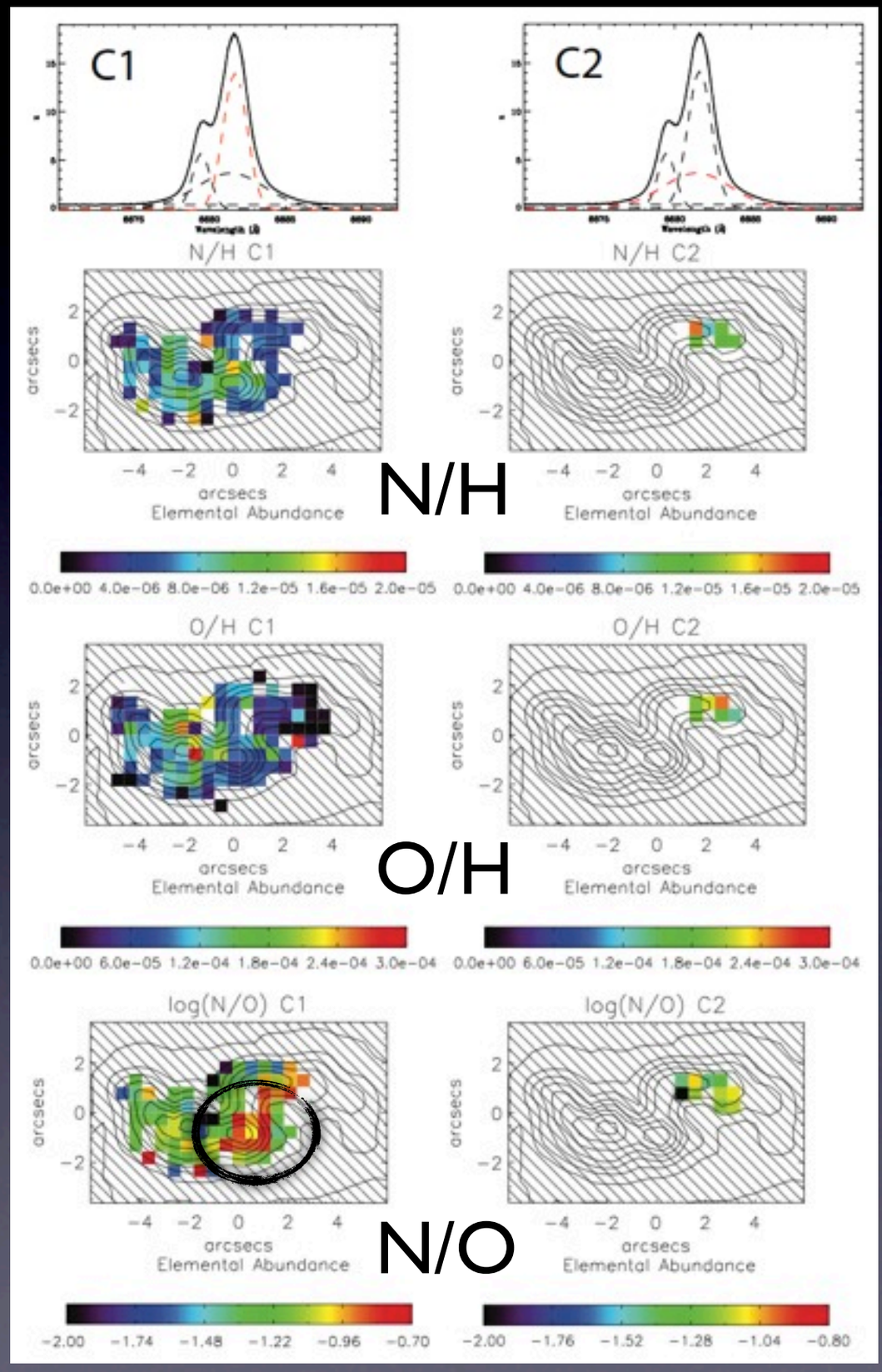

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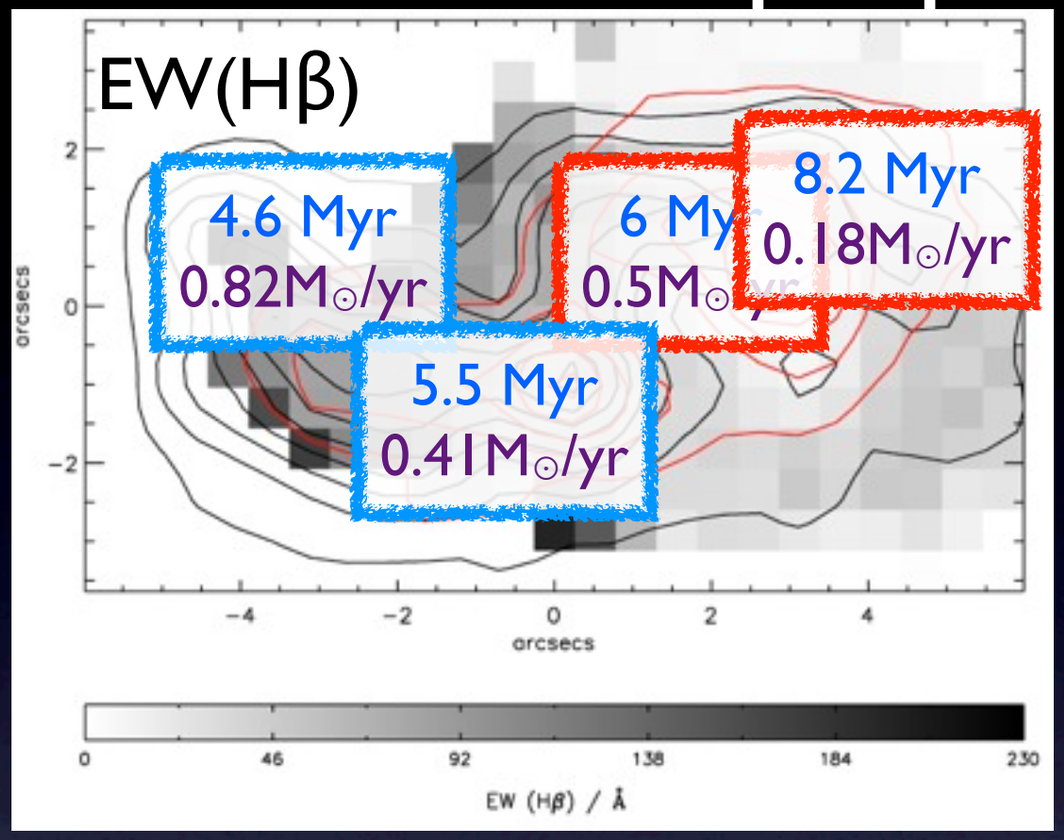
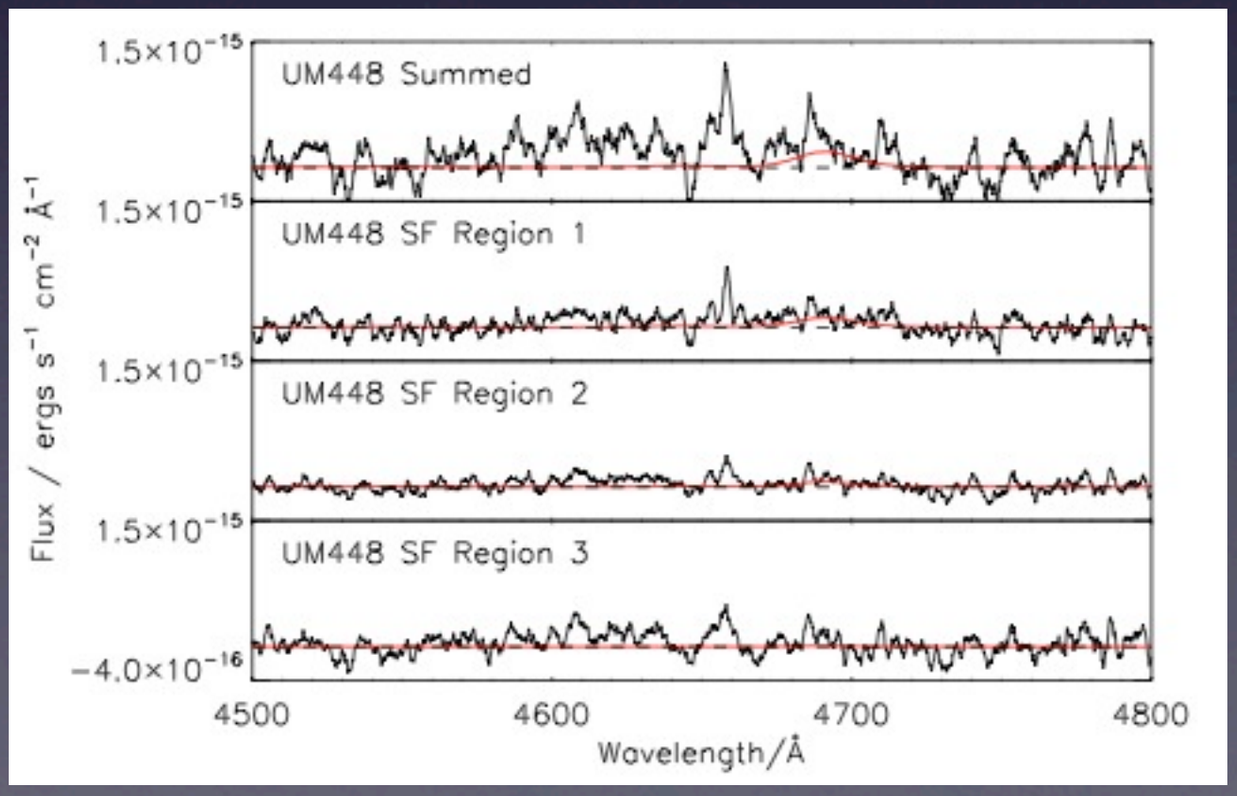
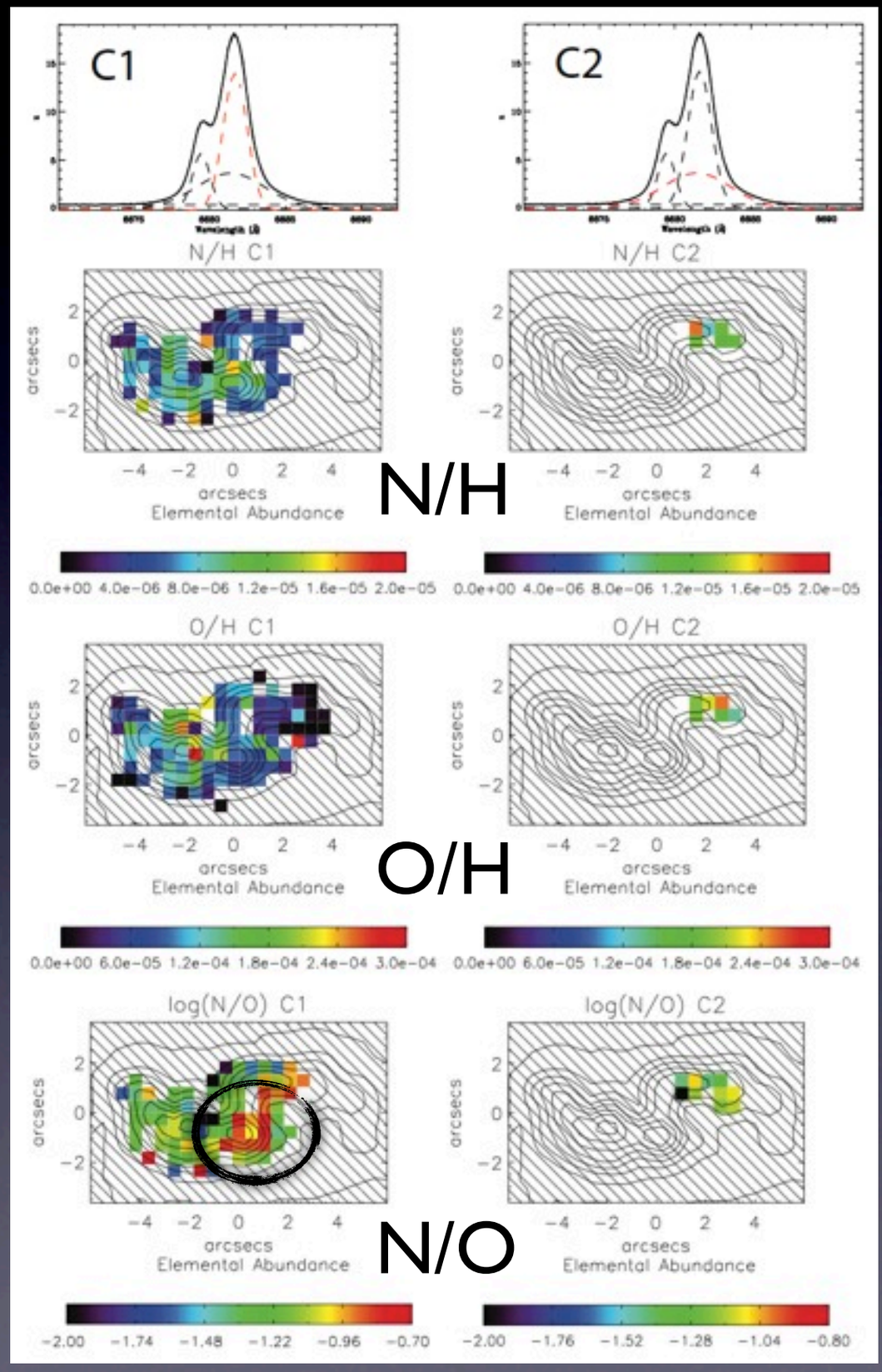


WR emission?





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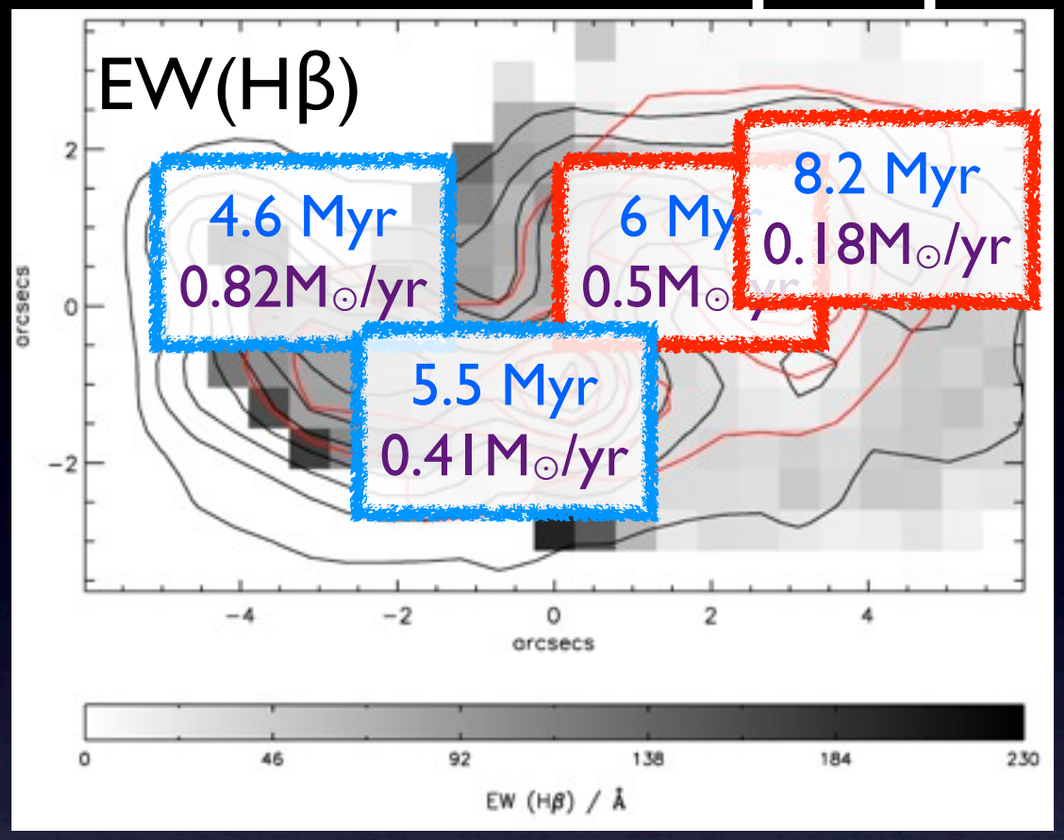
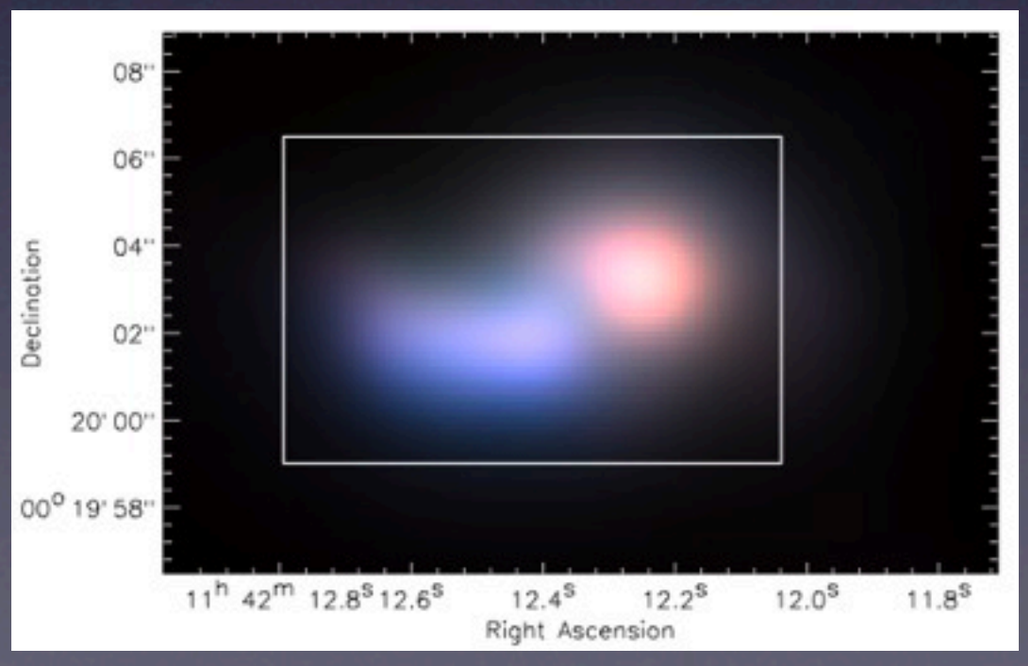
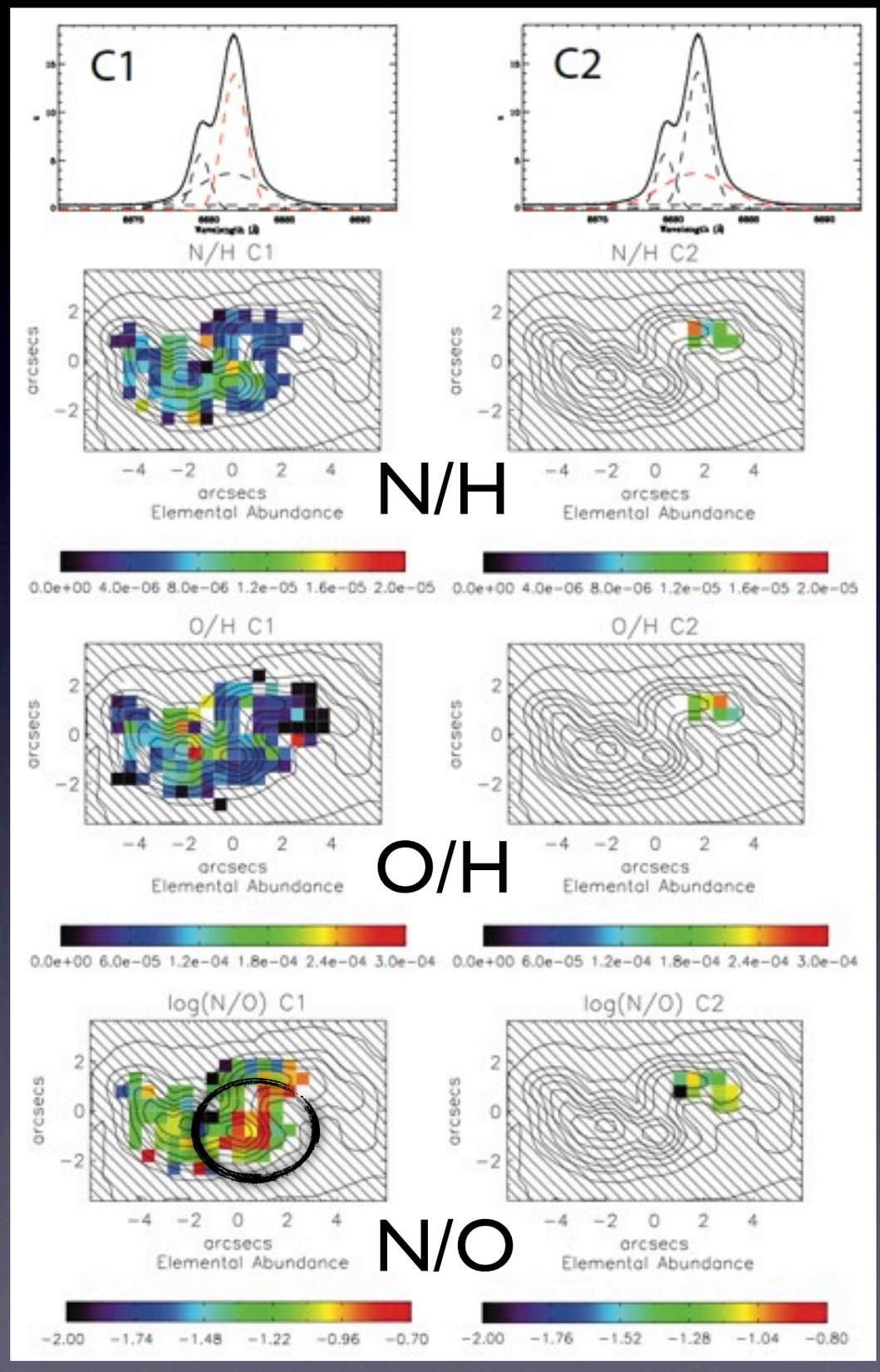


Metal poor/rich in/outflows?

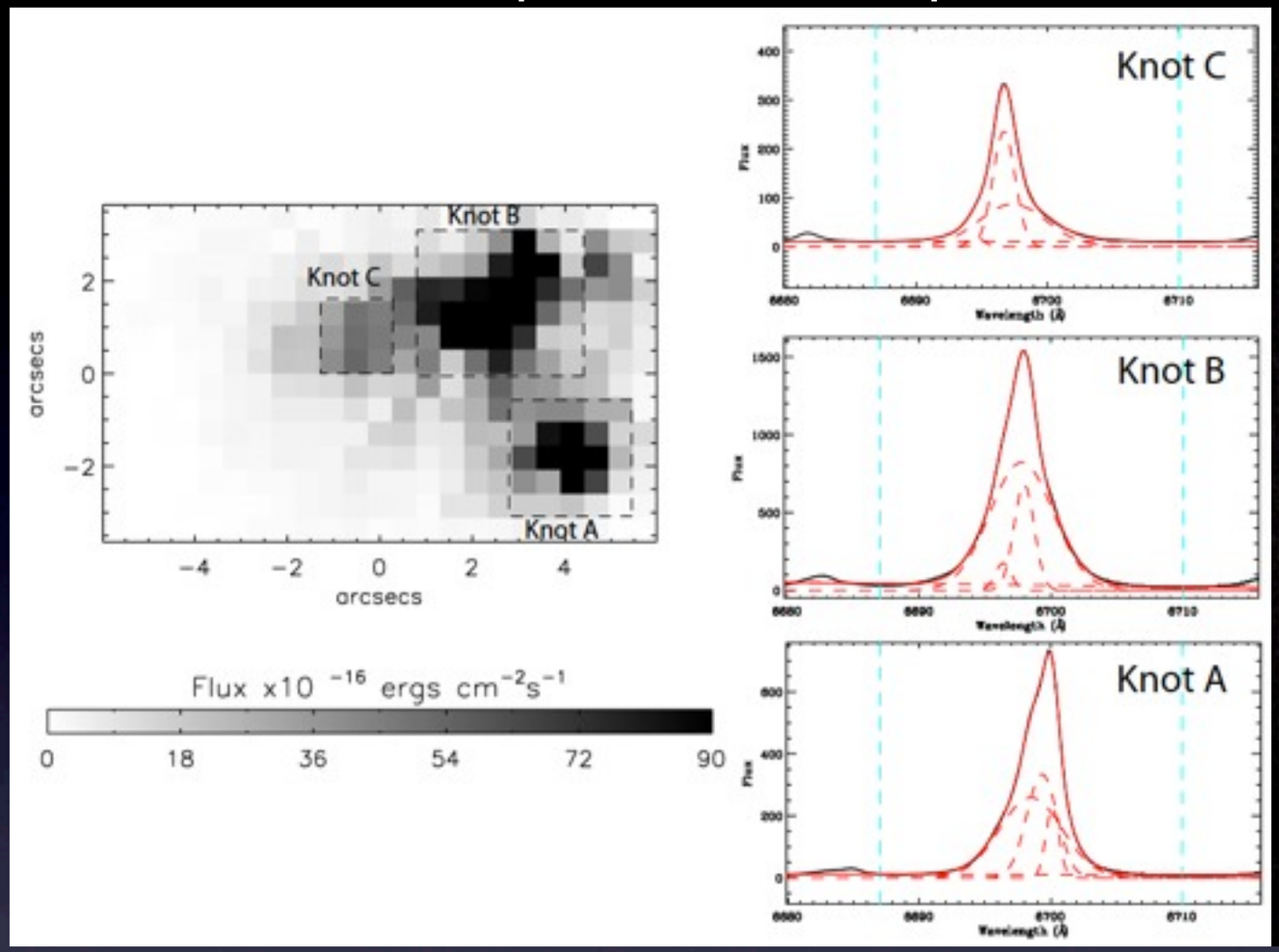




Haro 11

VLT/FLAMES IFU - Maps in Hα, D~85Mpc

James et al. 2012b (submitted)



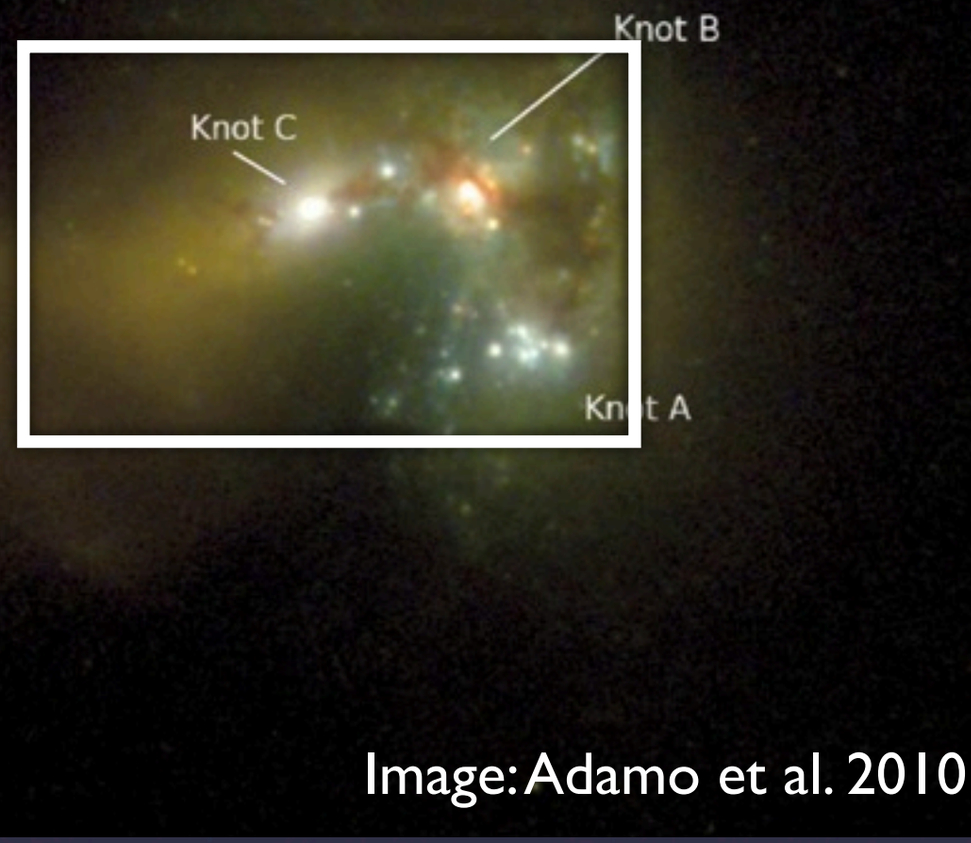


Image: Adamo et al. 2010

- Very efficient in producing young star clusters; present SFR ~22$M_{\odot}$/yr (Adamo+, 2010)
- Merger between low-mass evolved system and gas-rich component (Ostlin+, 2002)
- Lyα emitter in Knot C →Analogous to Lyman-break galaxy (Hayes+, 2007)
- Only galaxy in nearby Universe where LyC photons have been detected (Leitet+, 2011)

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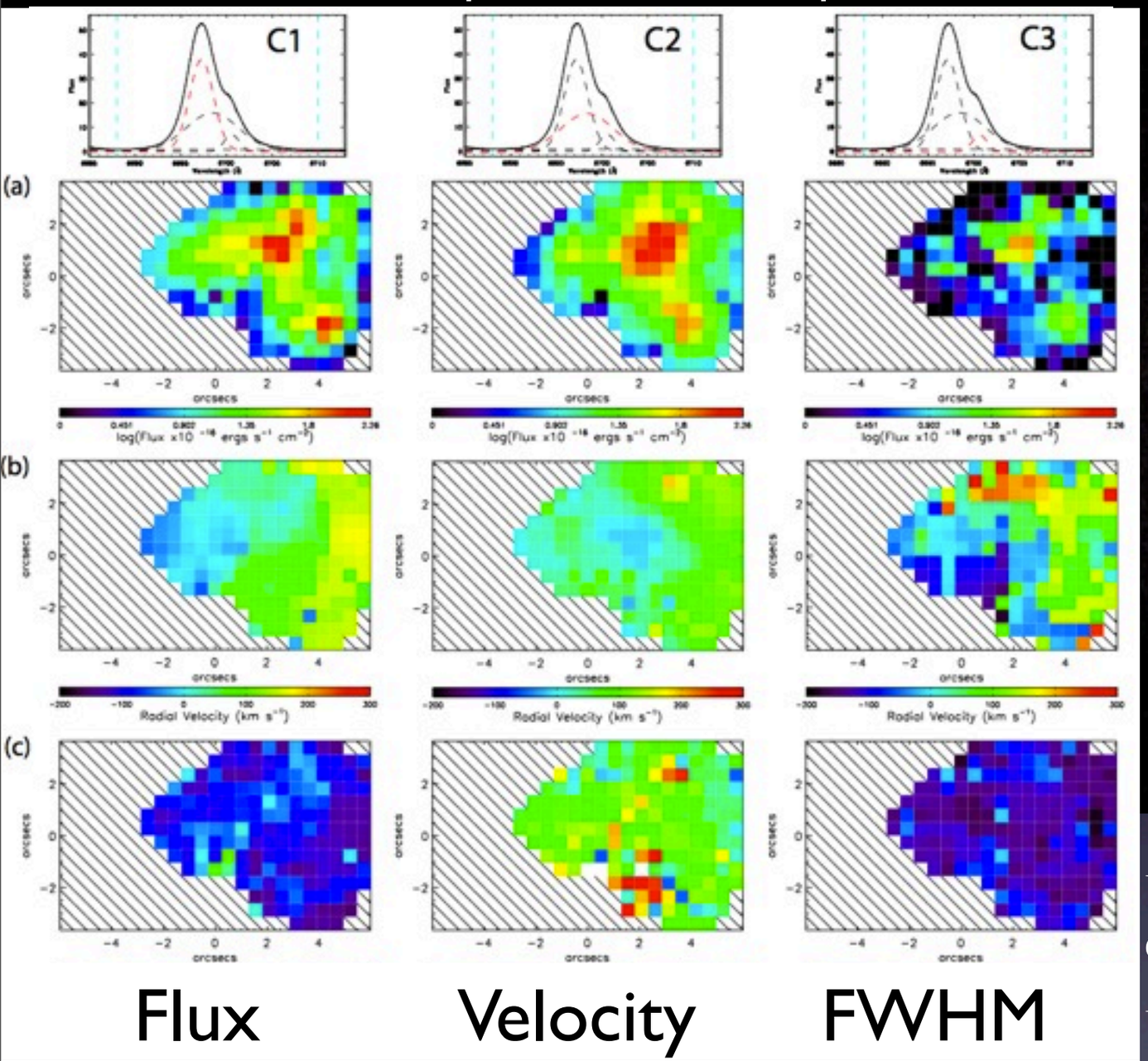
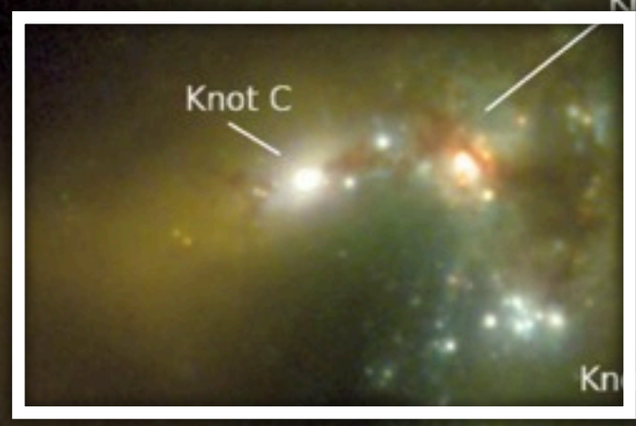


Flux Velocity FWHM



1"
360 pc

Image: Adamo et al. 2010

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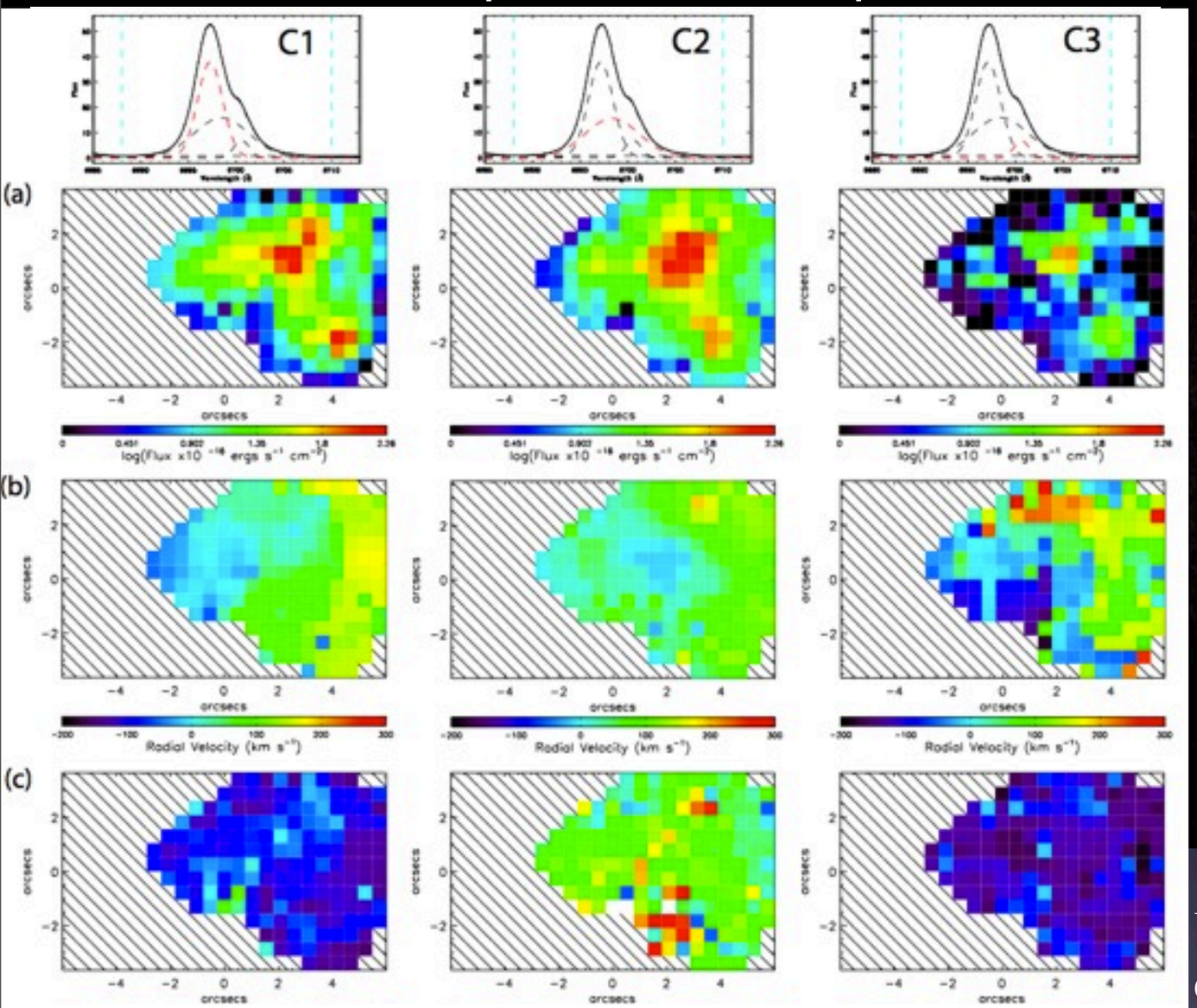
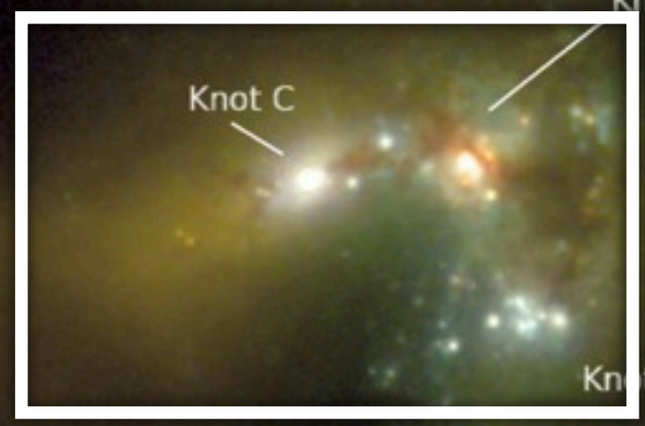


Flux Velocity FWHM



1"
360 pc

Image: Adamo et al. 2010

Multicomponent Te, Ne & Abundance analysis

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Haro11: SF properties & origin of high N/O...

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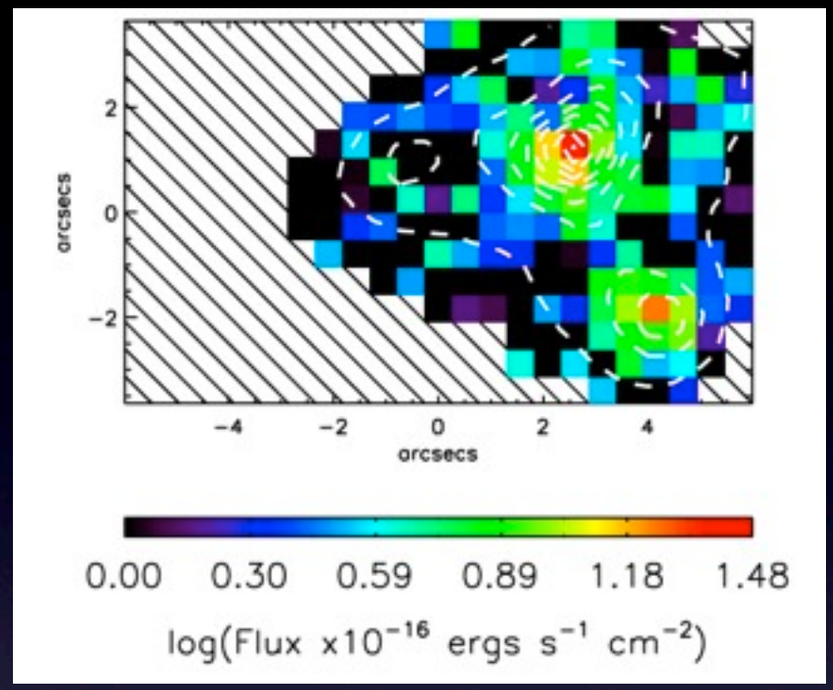
WR emission



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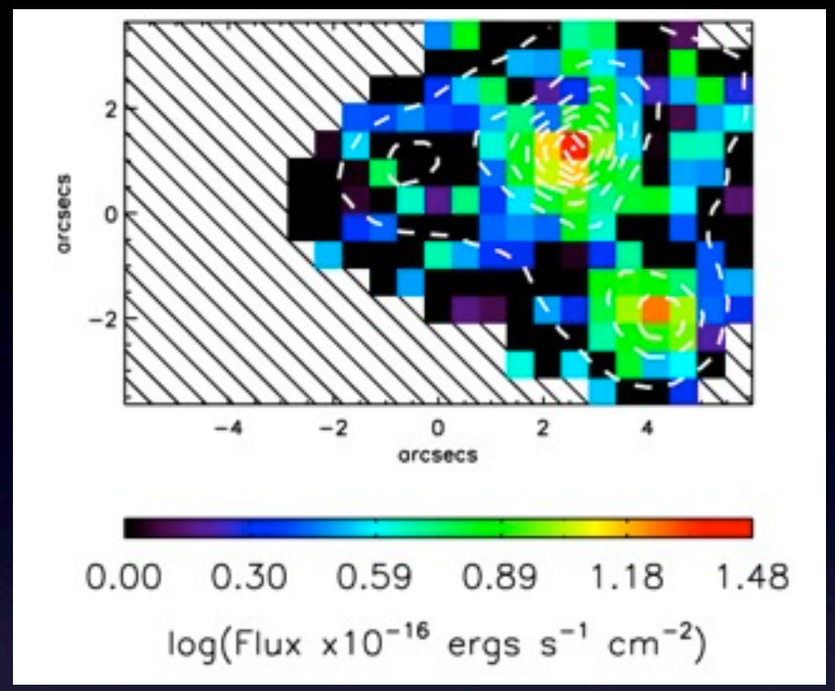
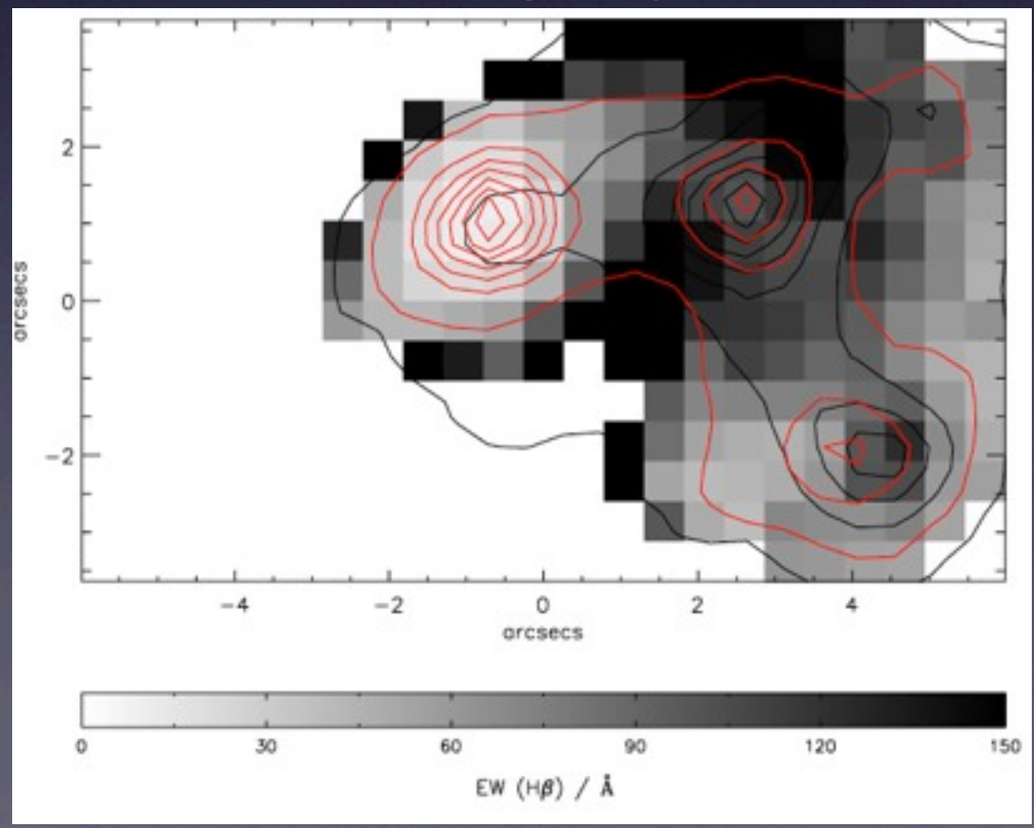


EW(Hβ)



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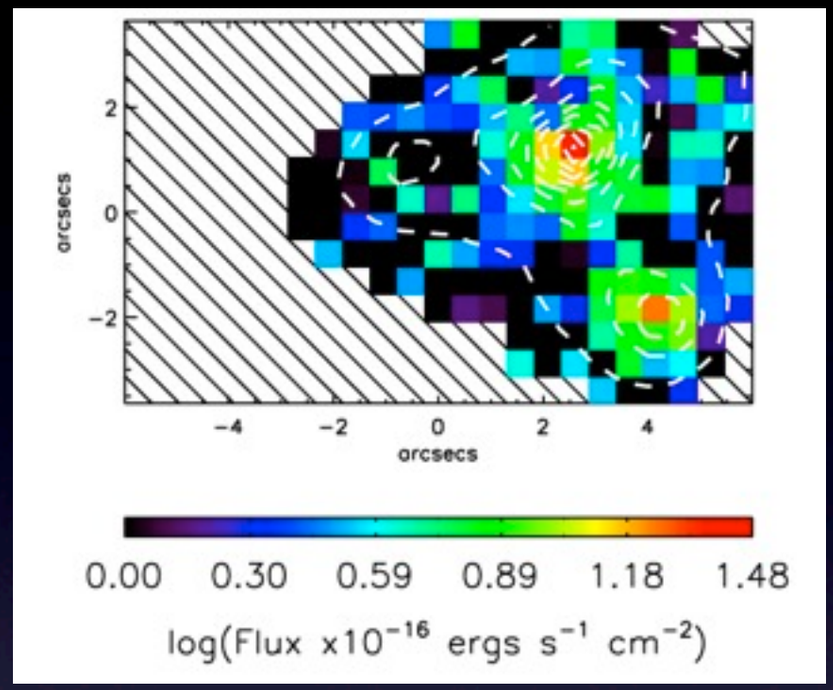
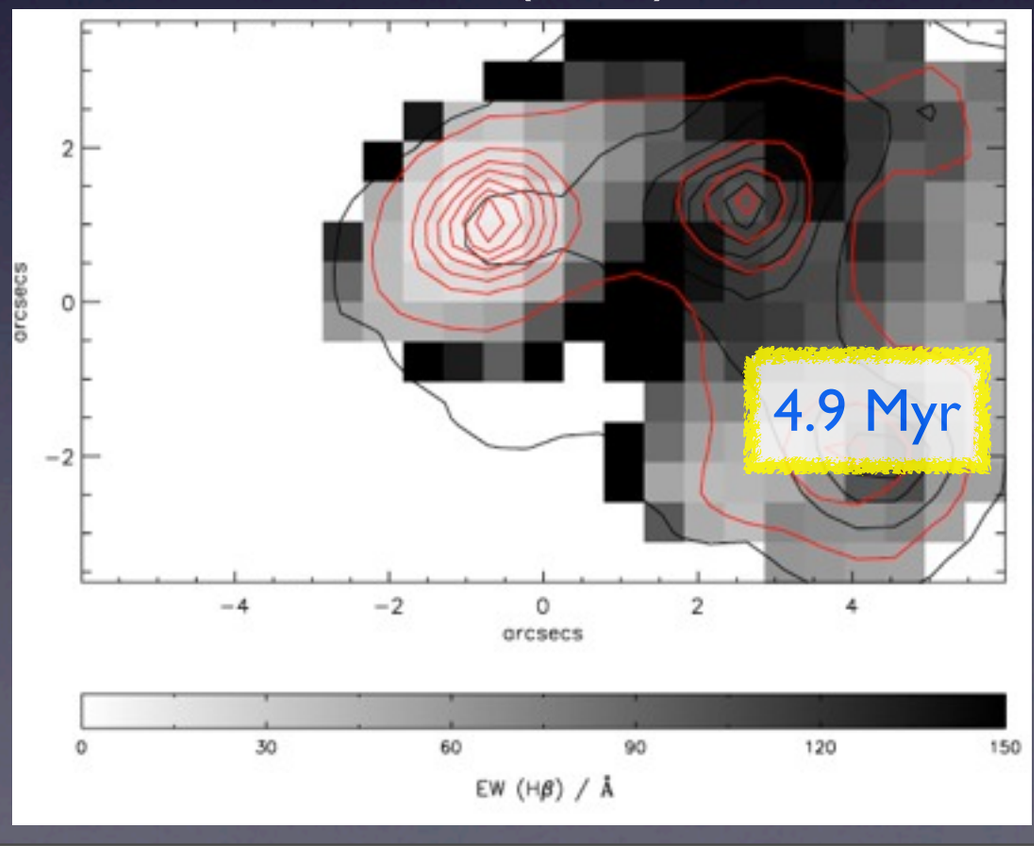


EW(Hβ)



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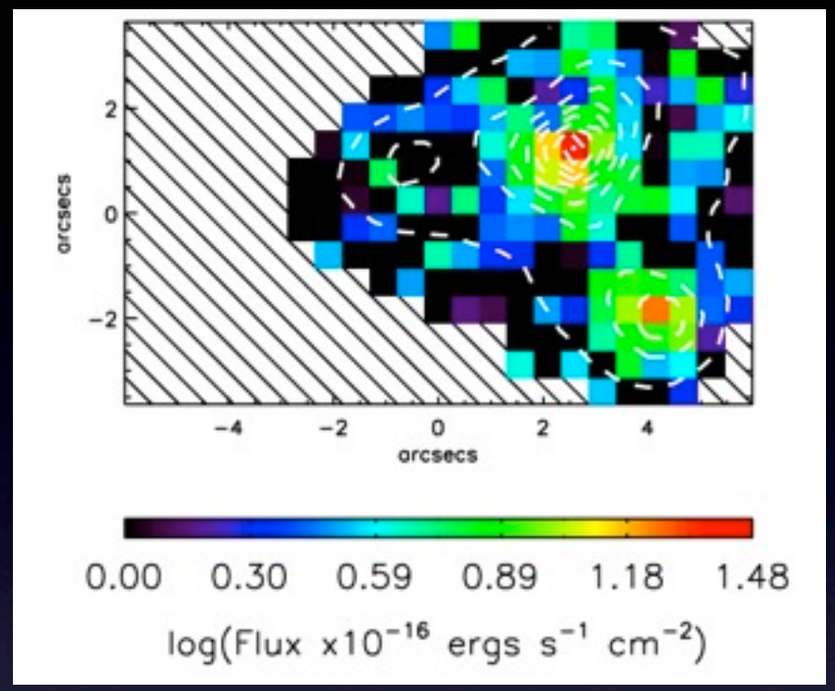

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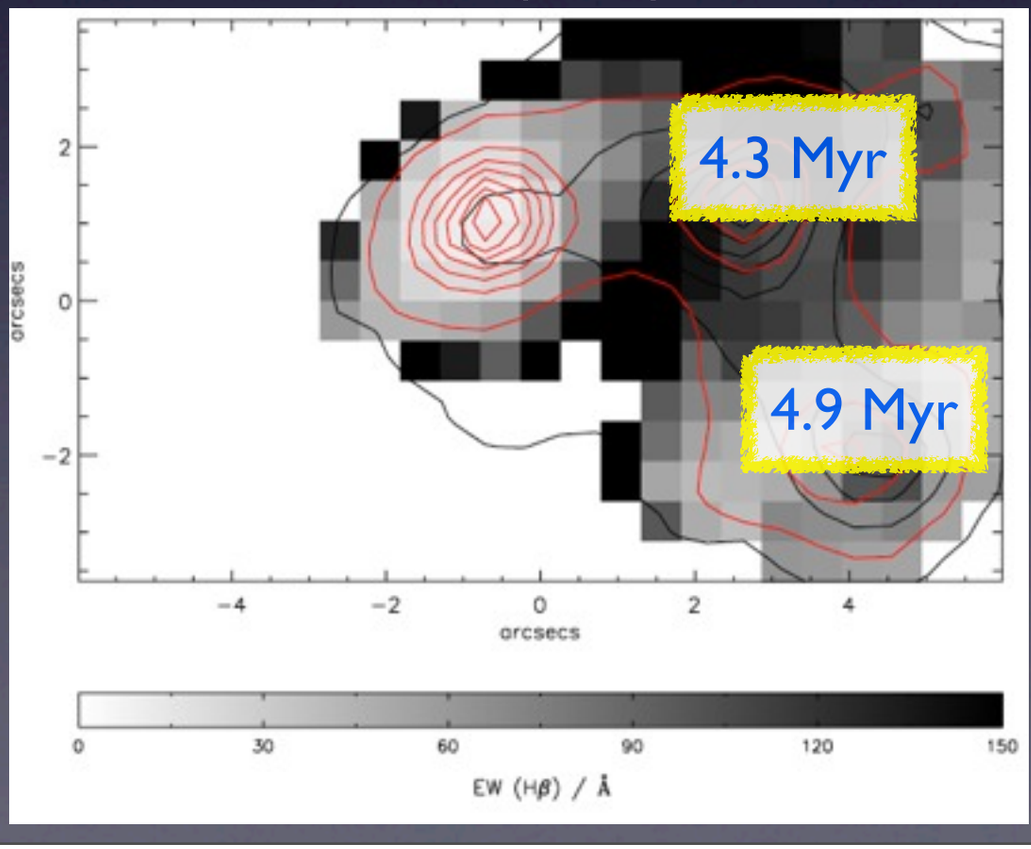

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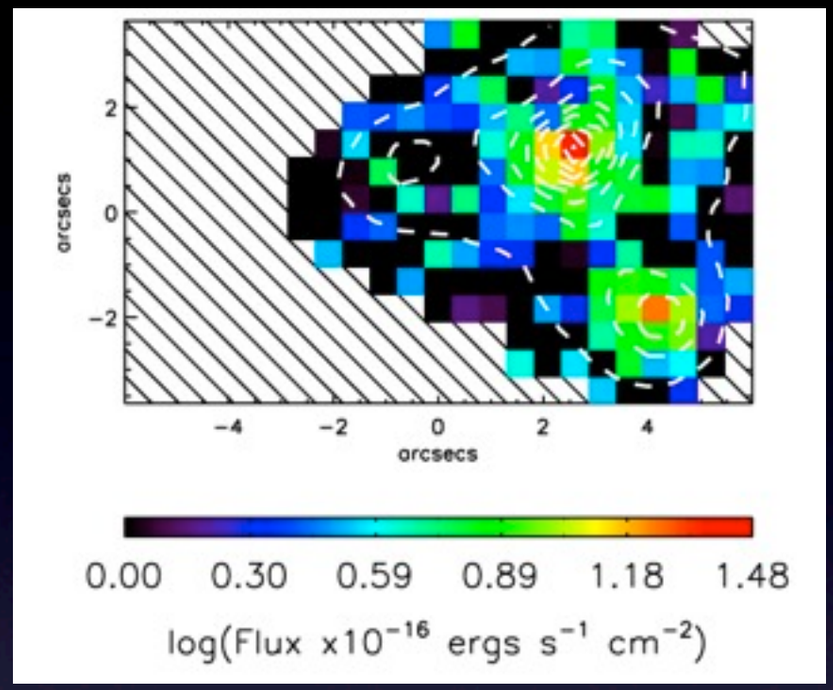

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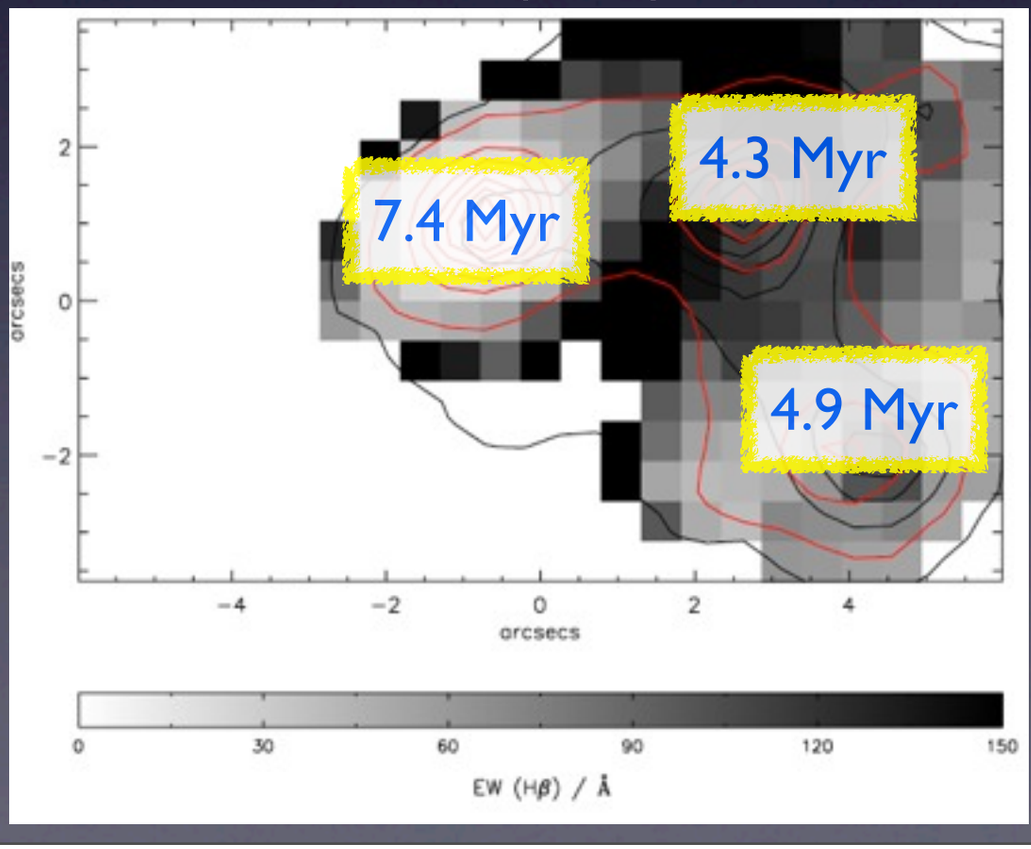

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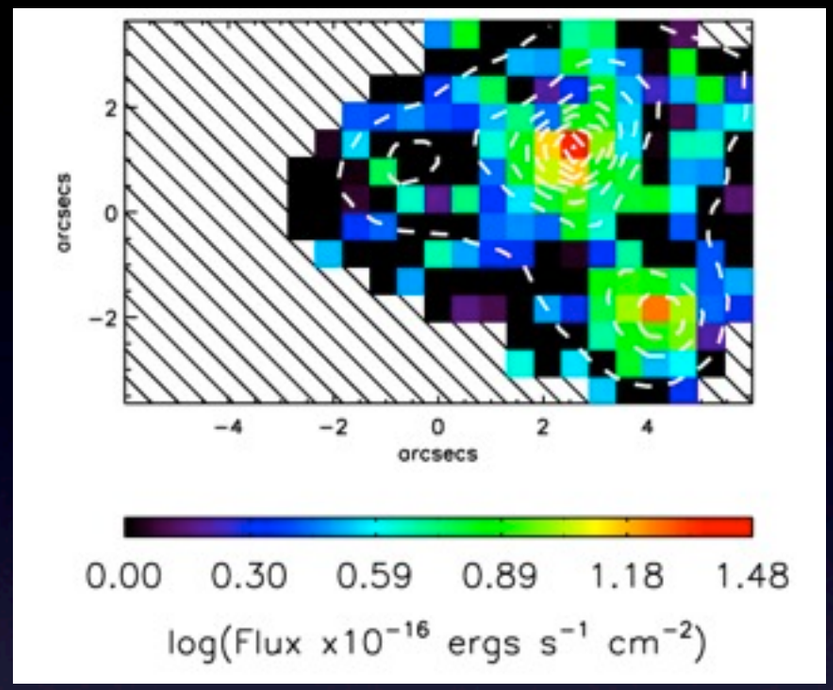

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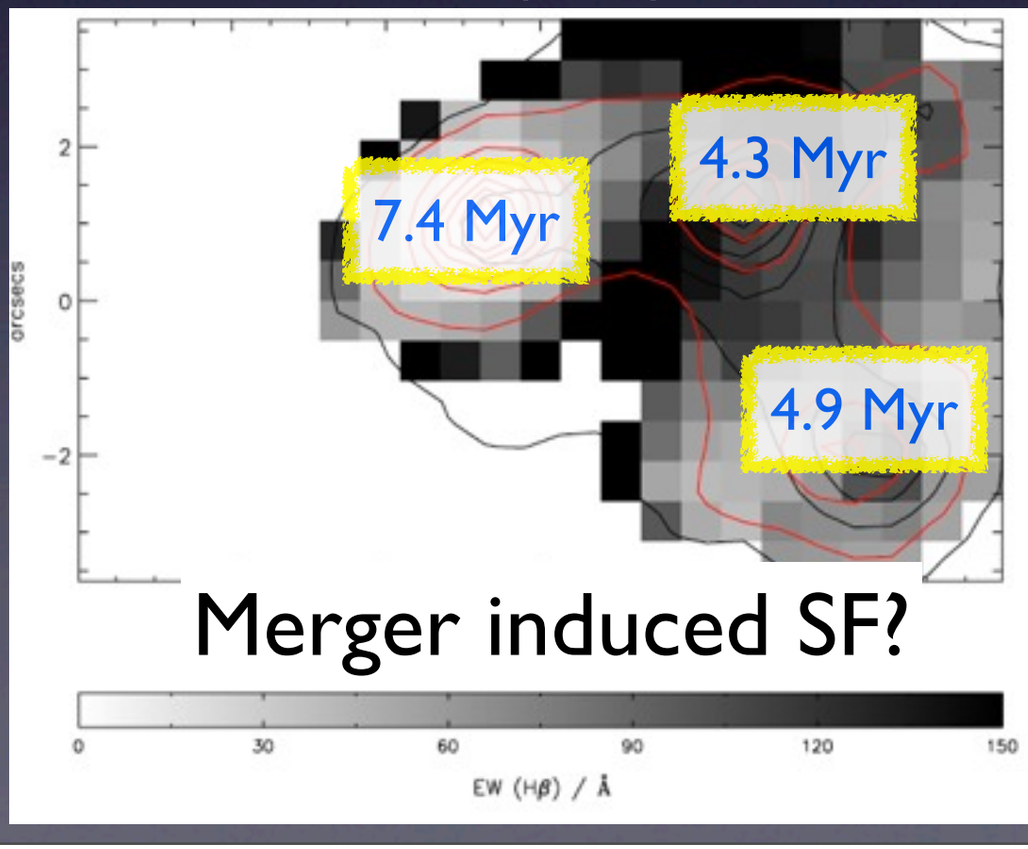

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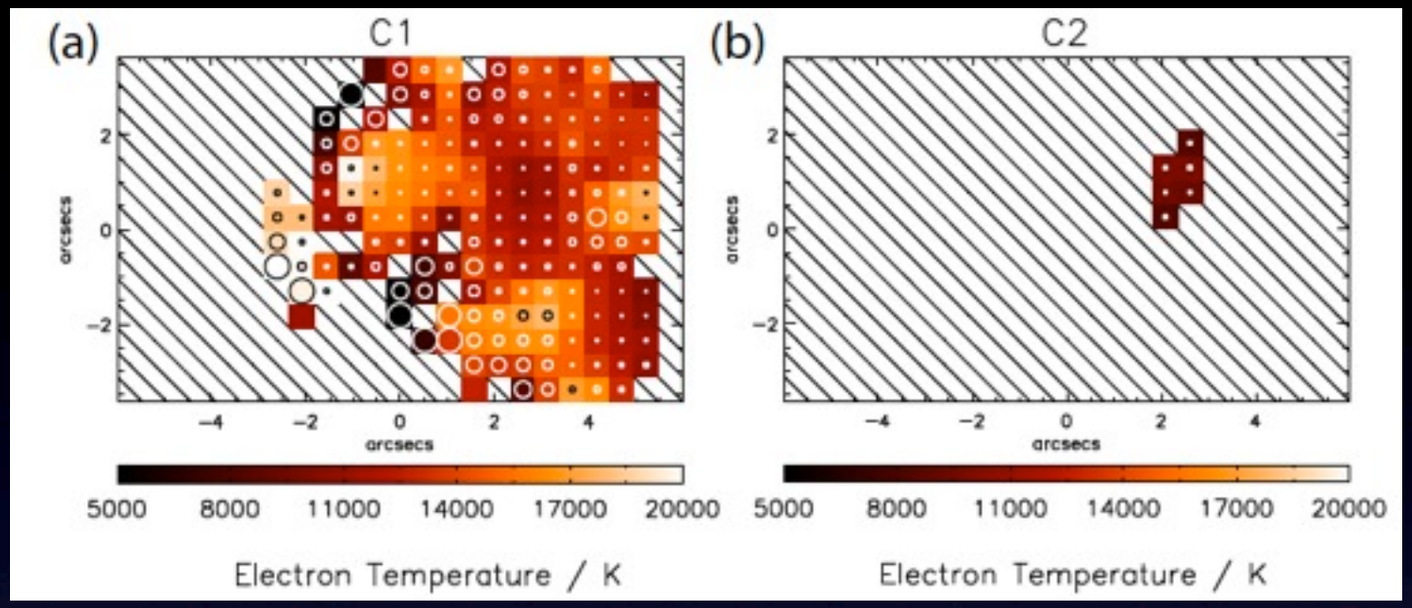

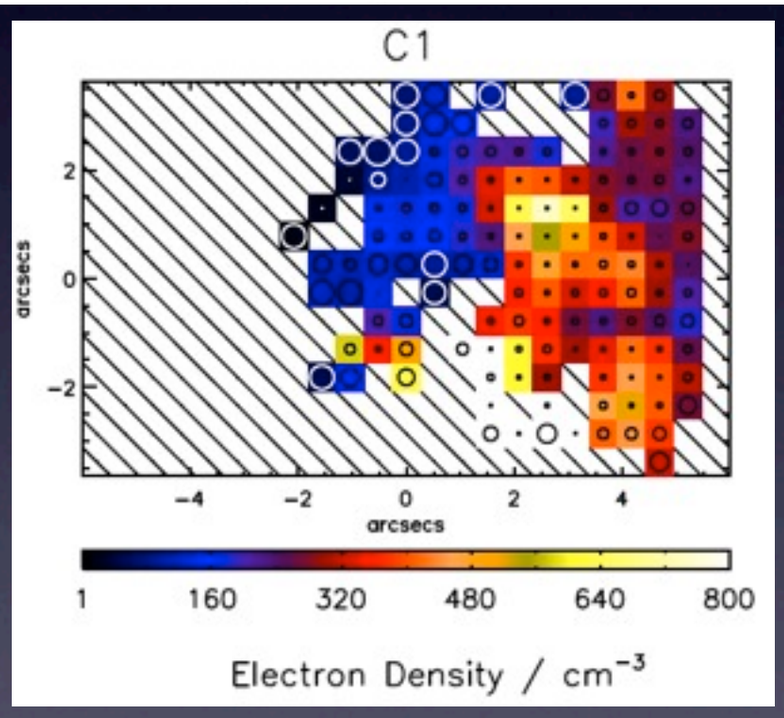

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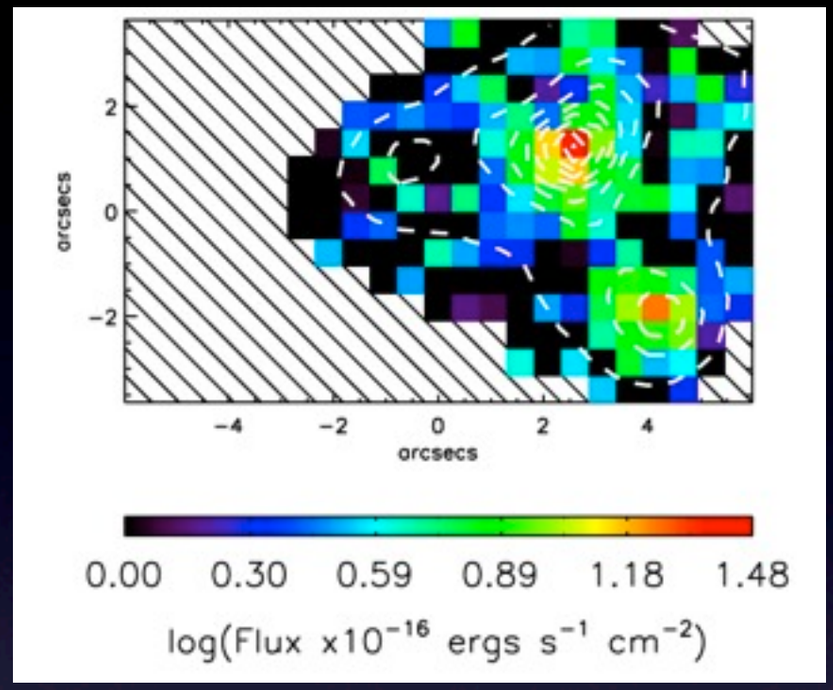

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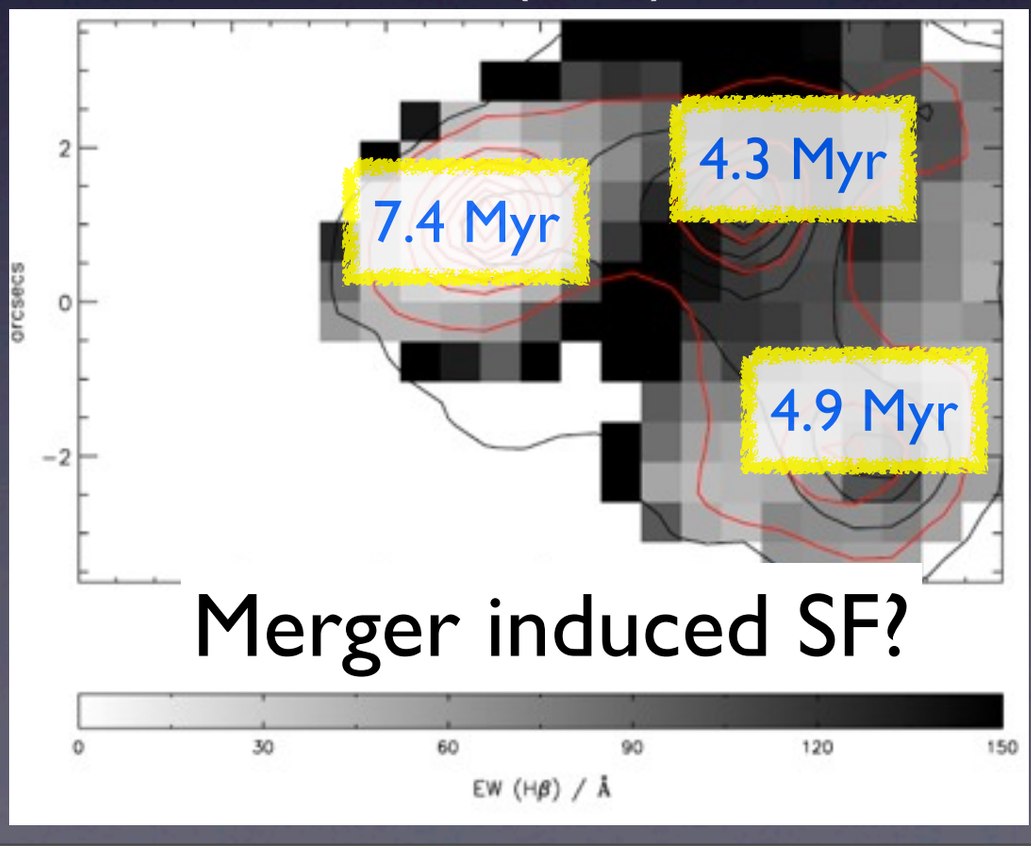

Merger induced SF?

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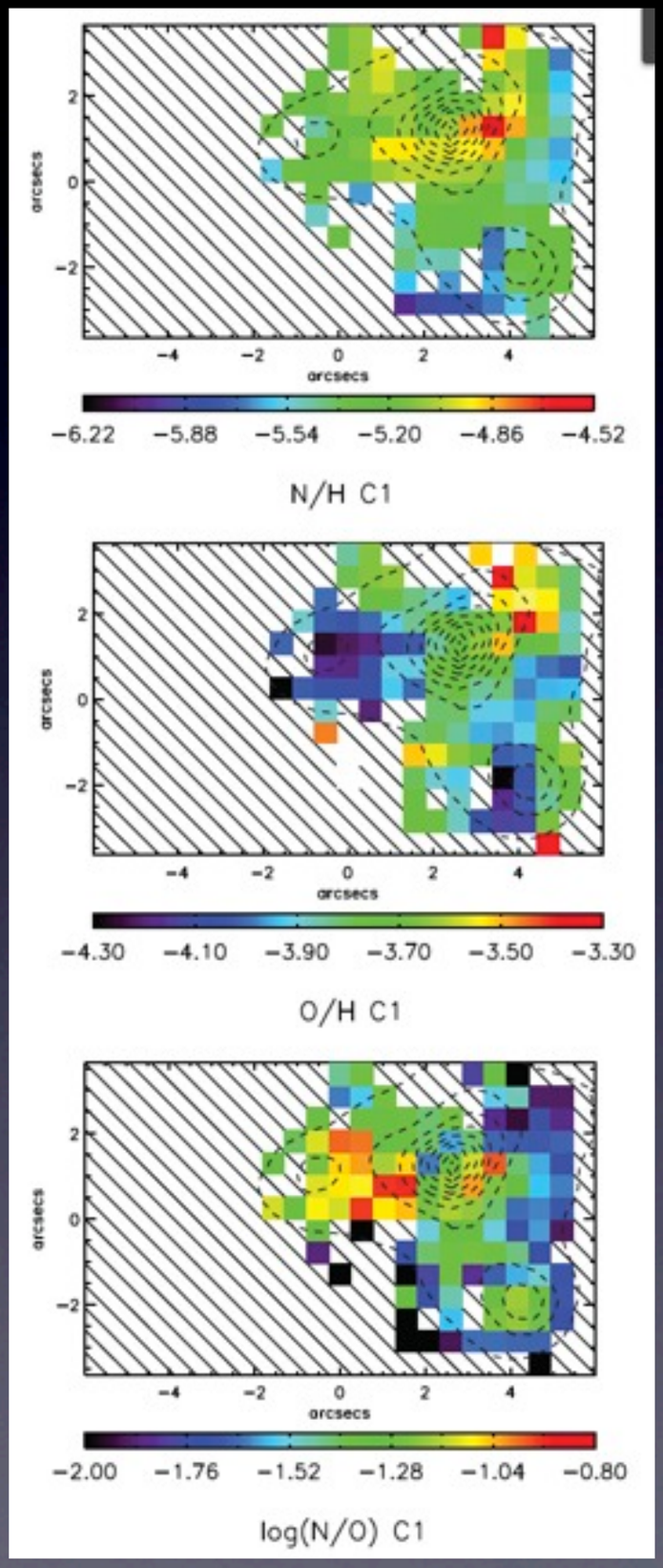

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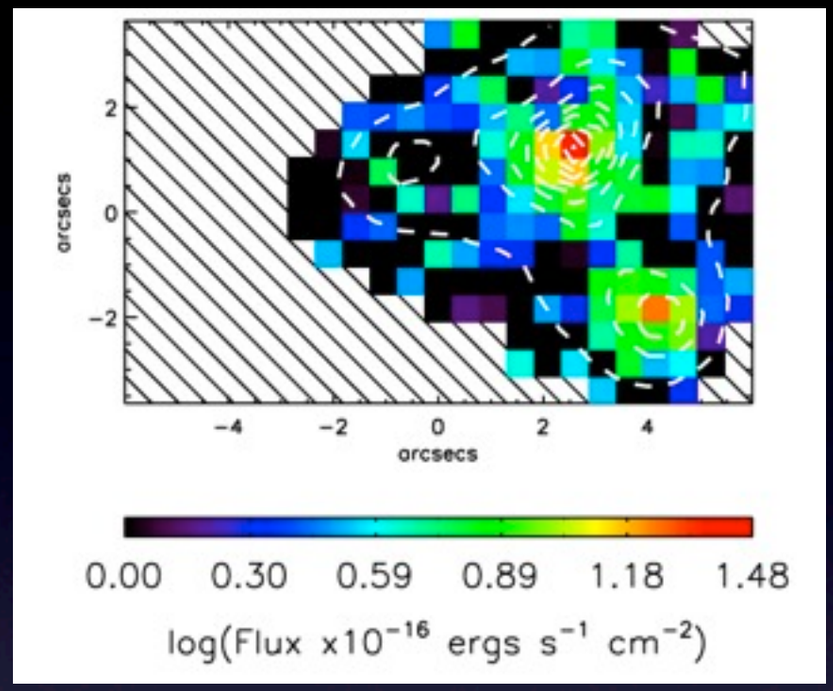
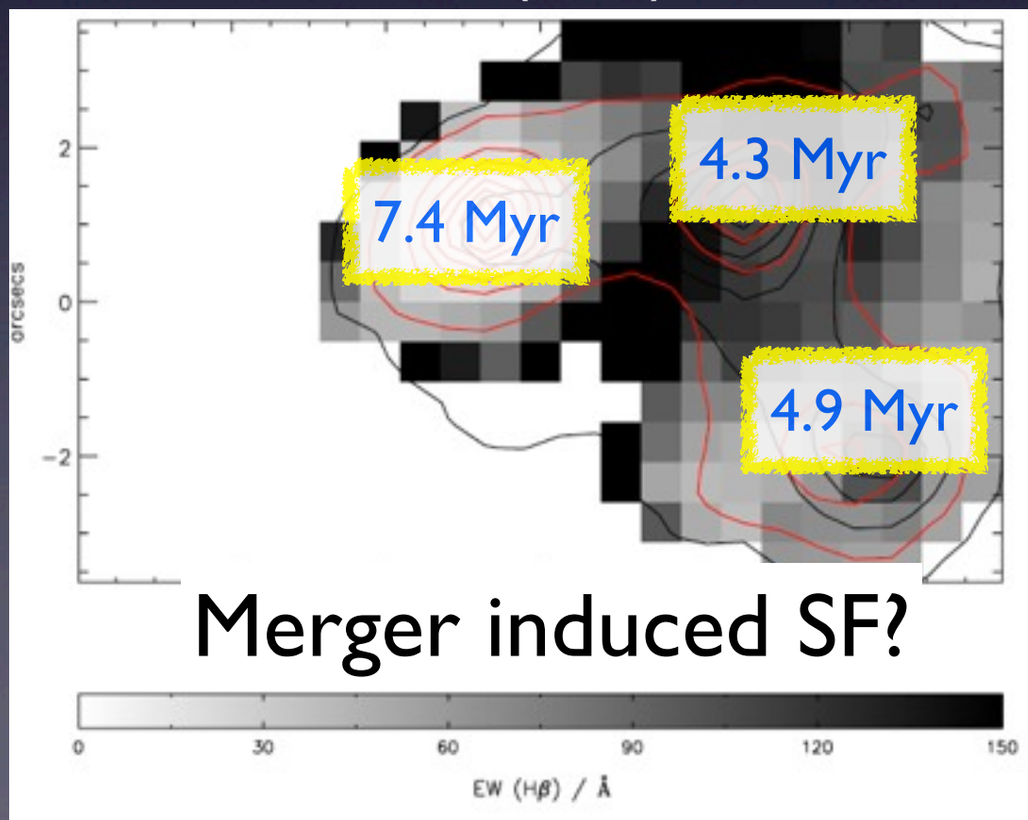


EW(Hβ)



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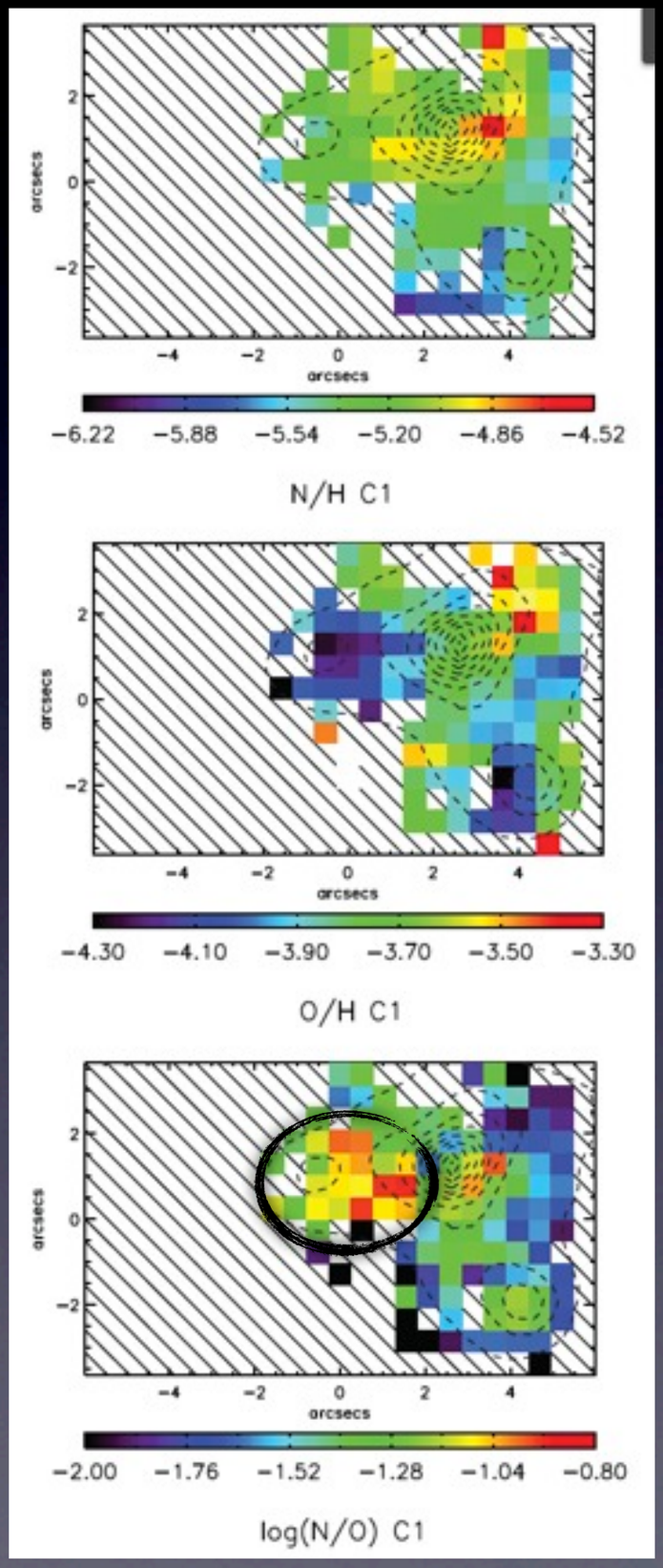

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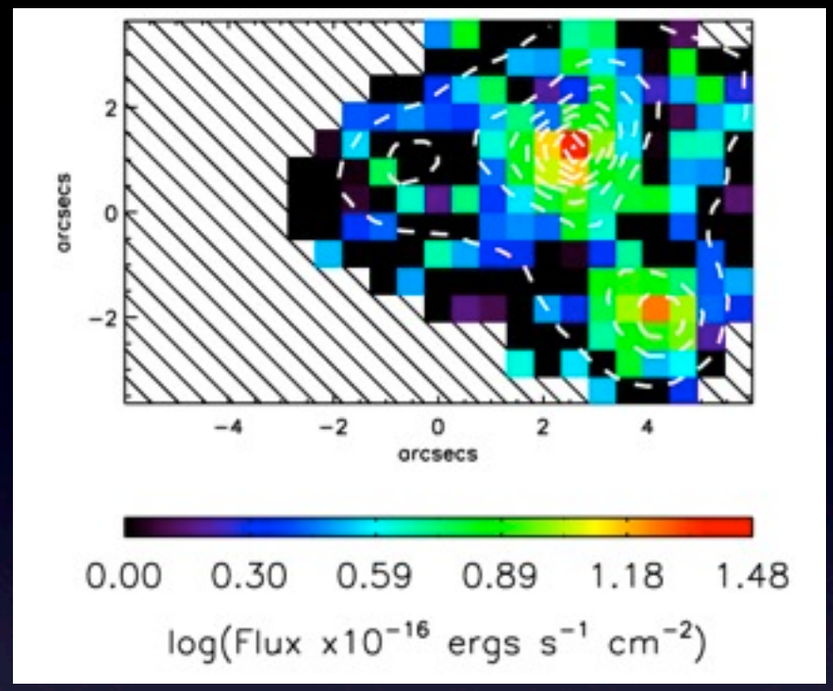

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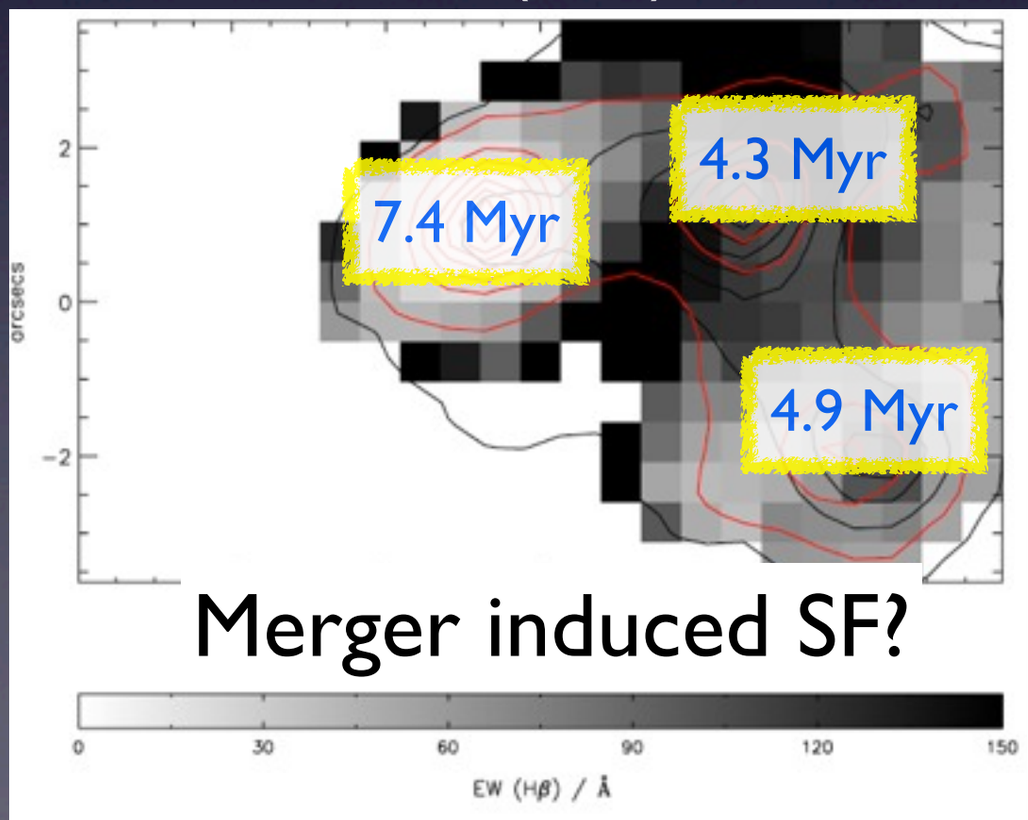

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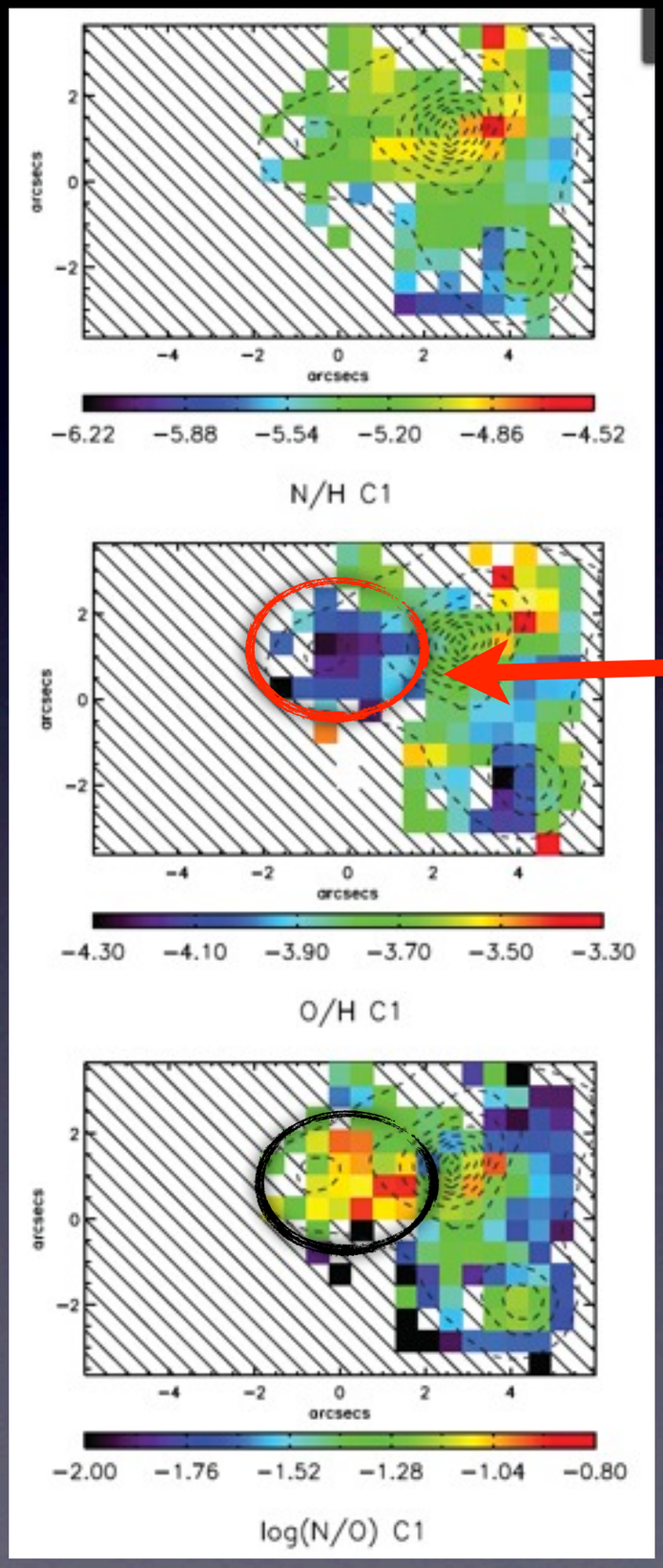
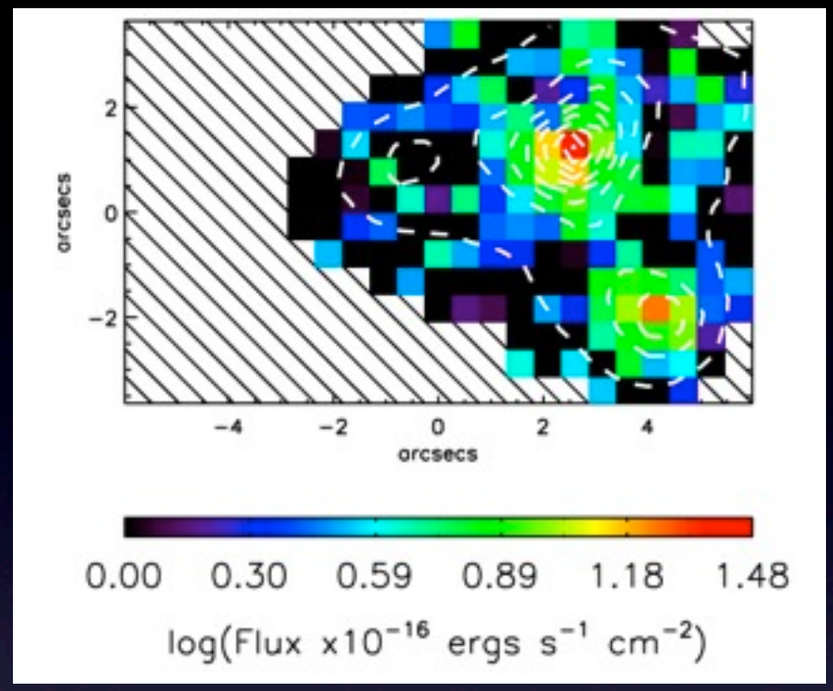


Accretion of metal-poor gas?
Outflow due to starburst winds?
$\Sigma_{SFR} \sim 1 M_\odot/yr/kpc^2$

WR emission



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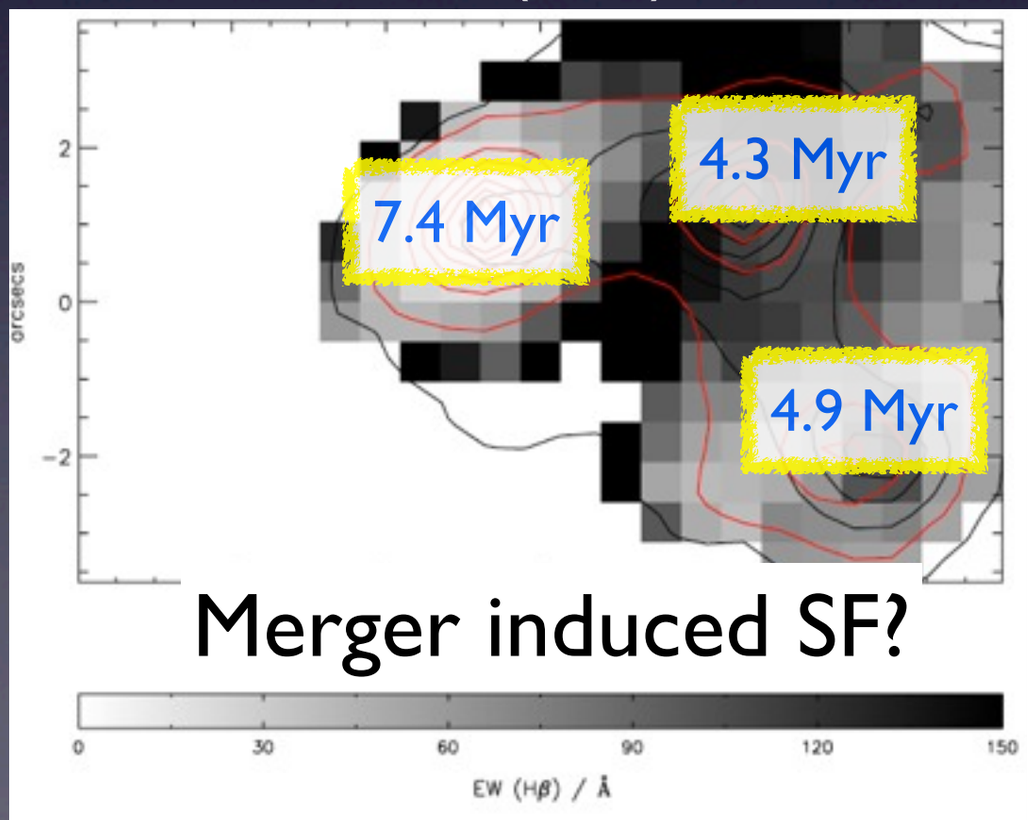

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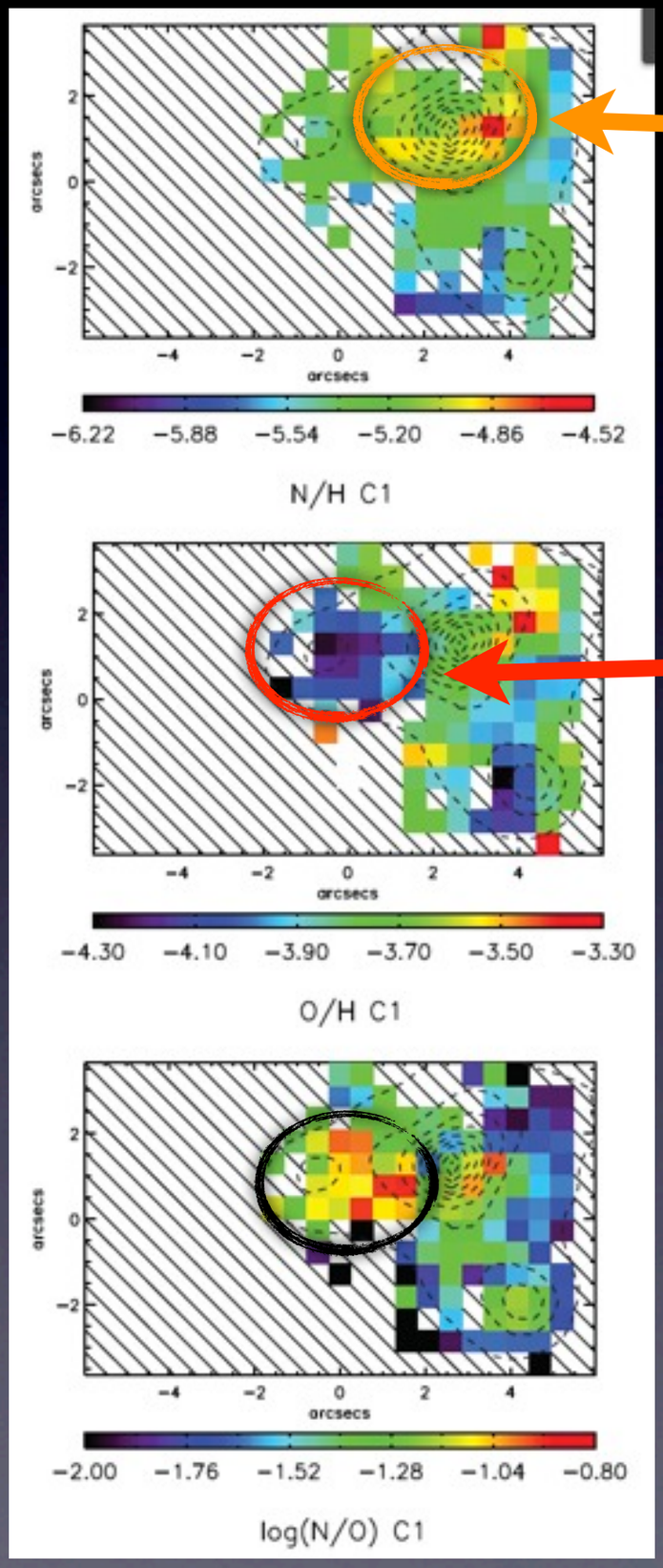

Ejecta of WR stars hasn't had time to cool/mix?
Spatial res^{n} not high enough to see it?

Accretion of metal-poor gas?
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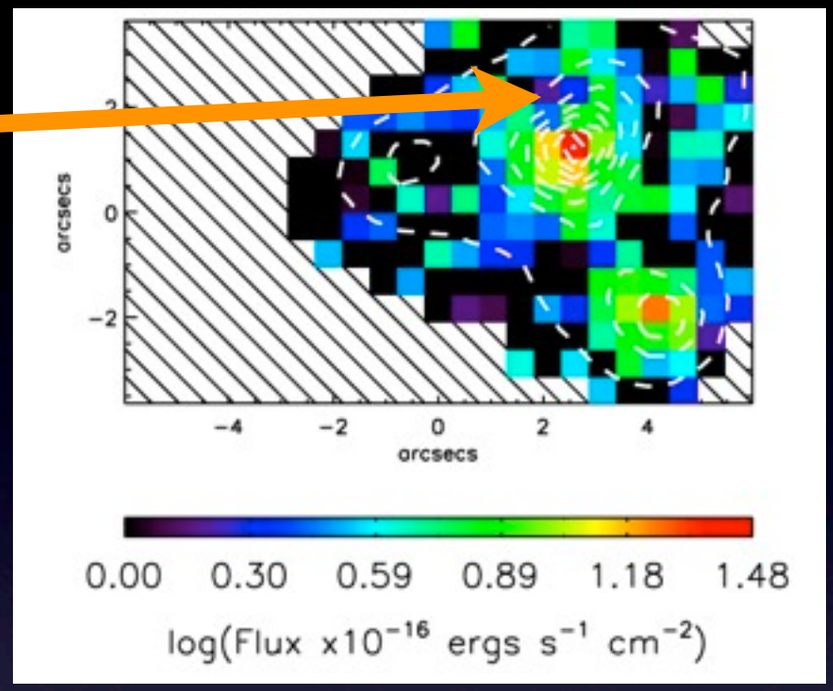
WR emission



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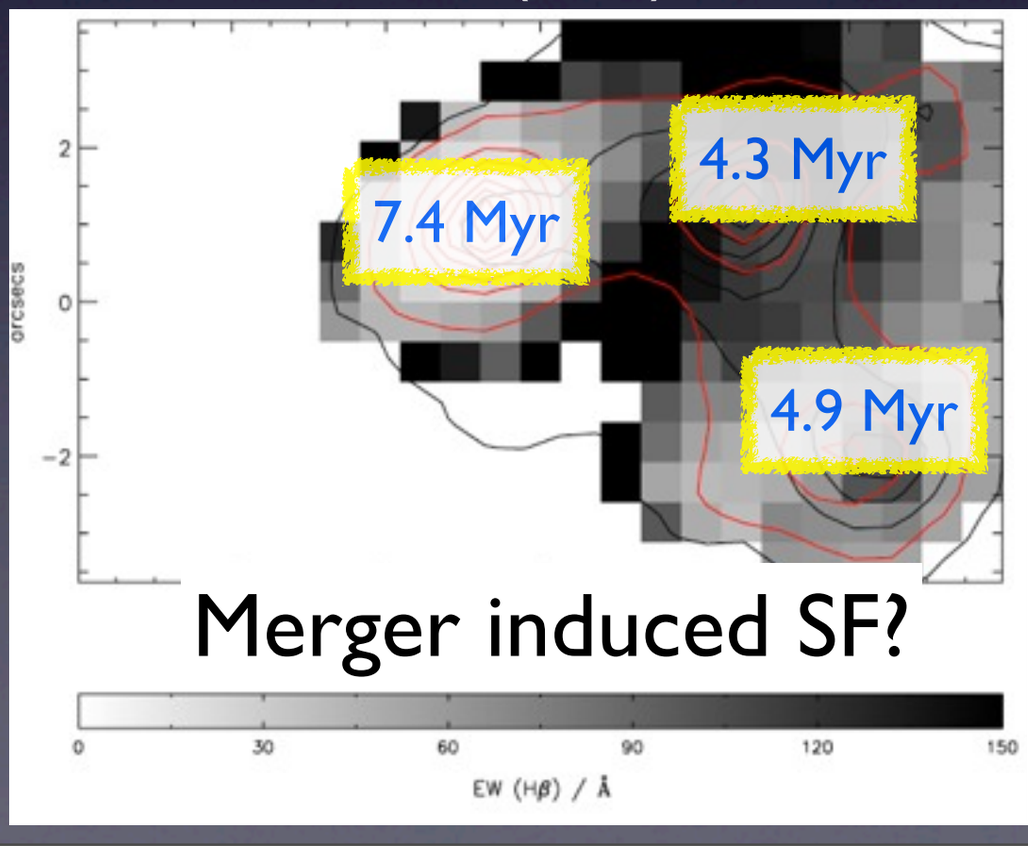
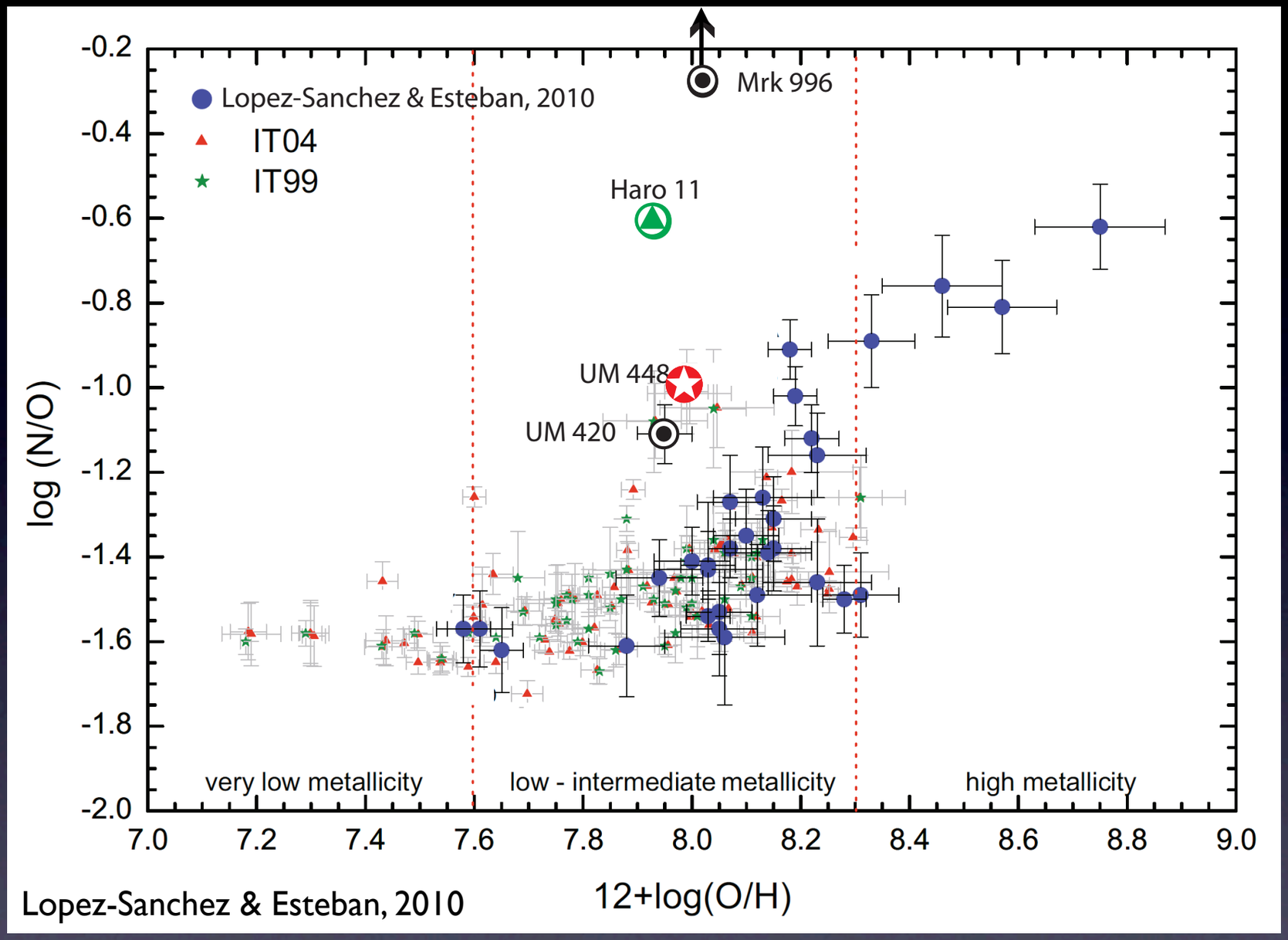


Merger induced SF?

Impact of IFU Analysis on Abundances



Lopez-Sanchez & Esteban, 2010

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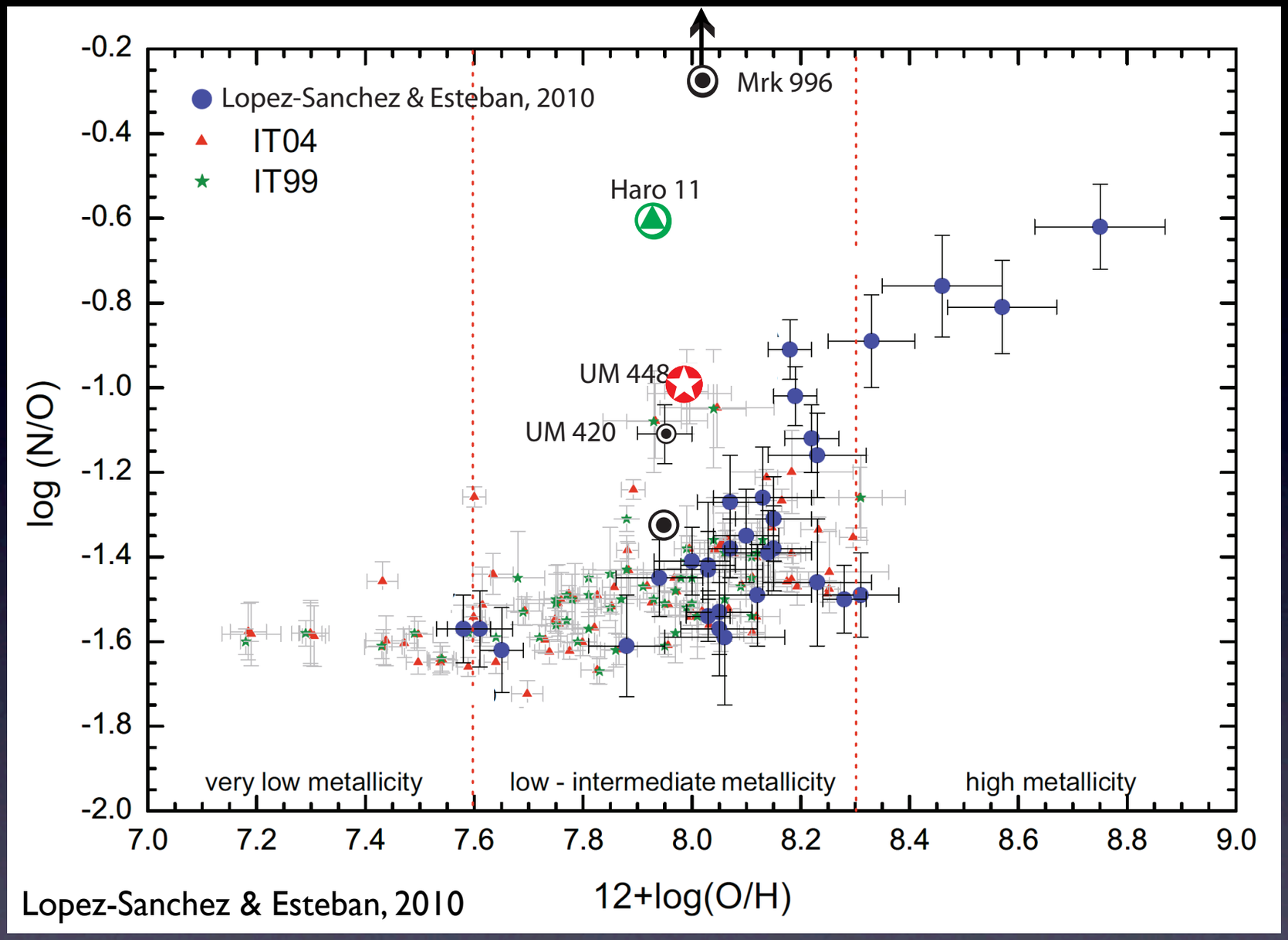

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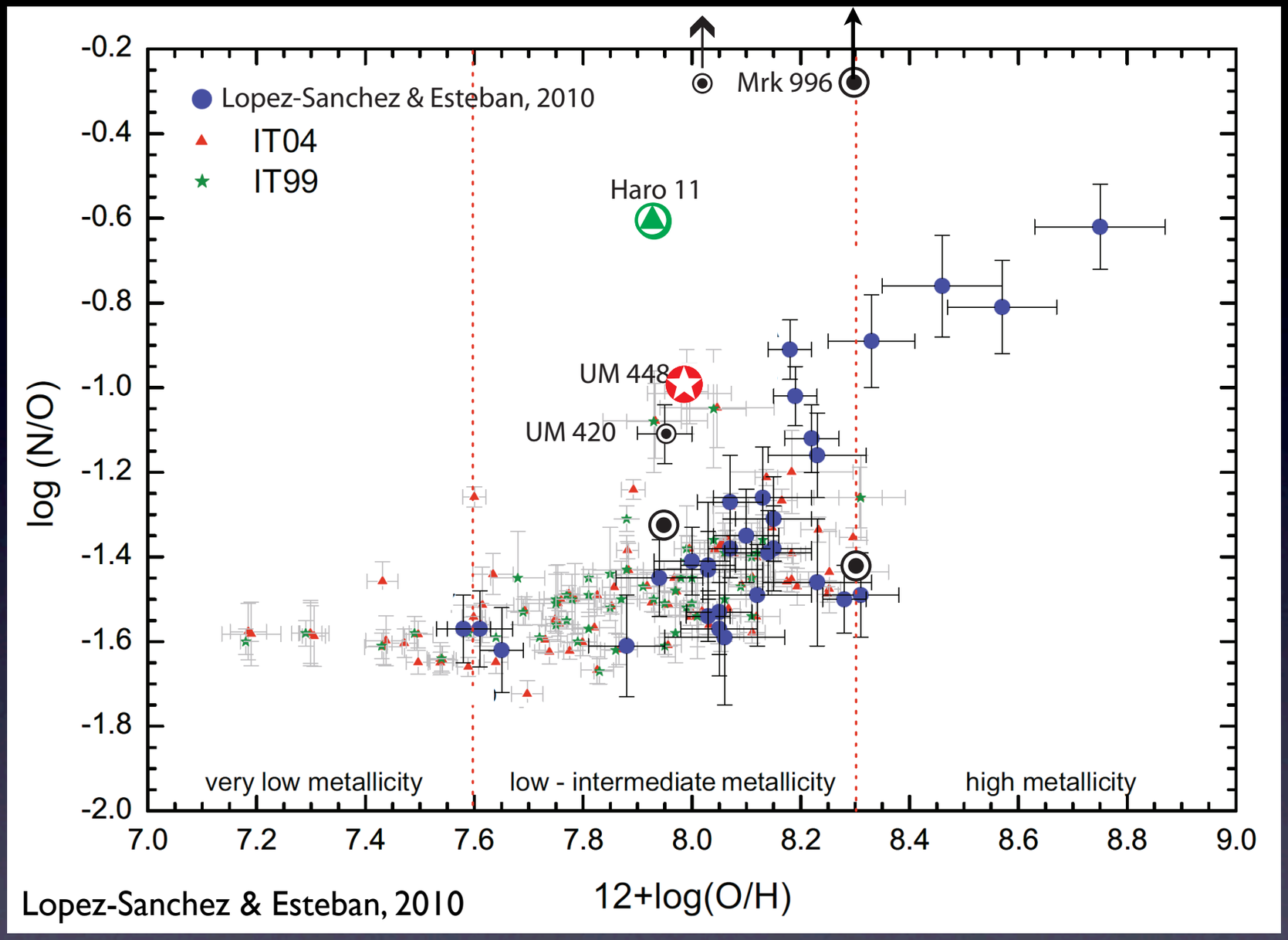

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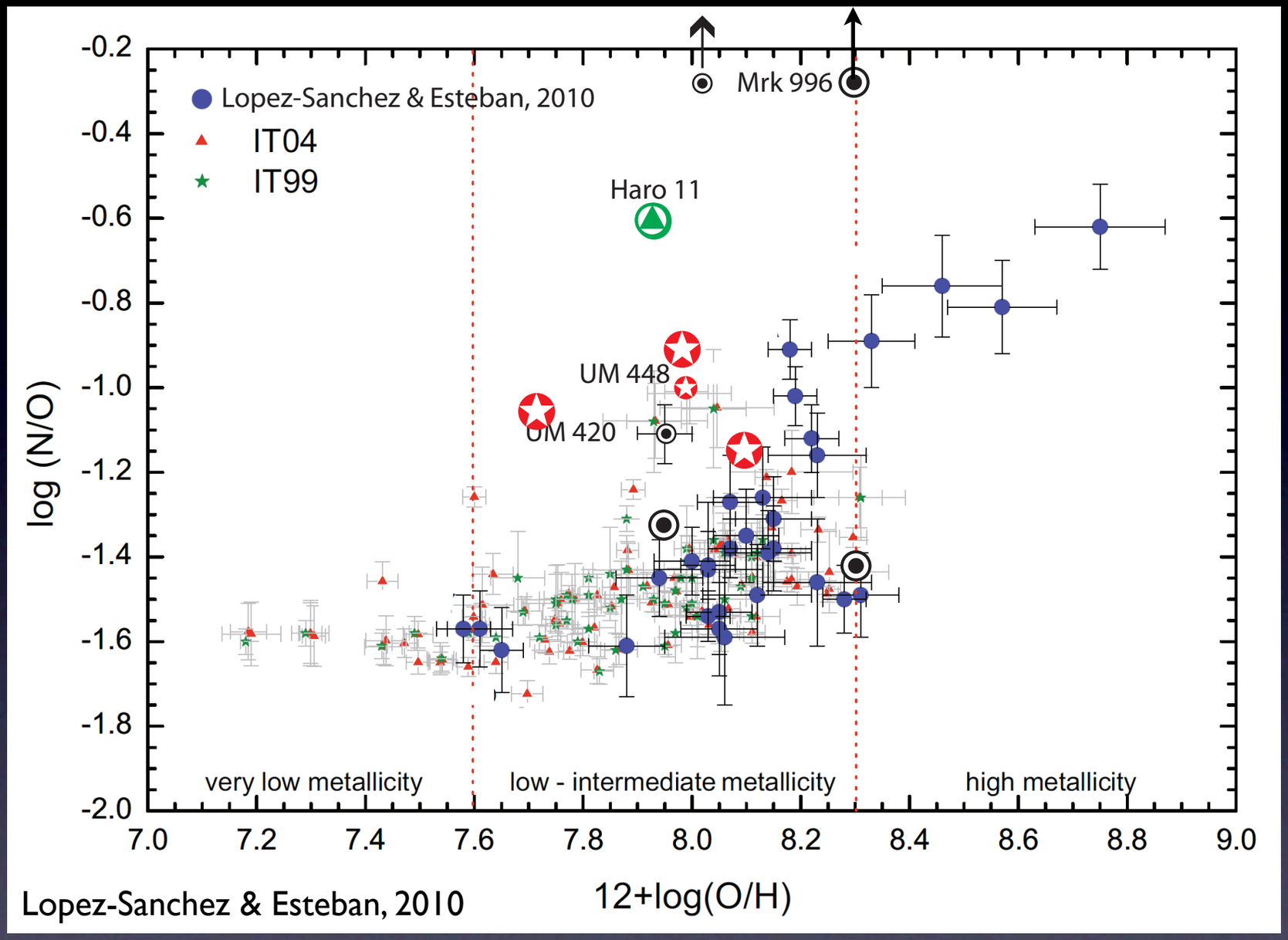

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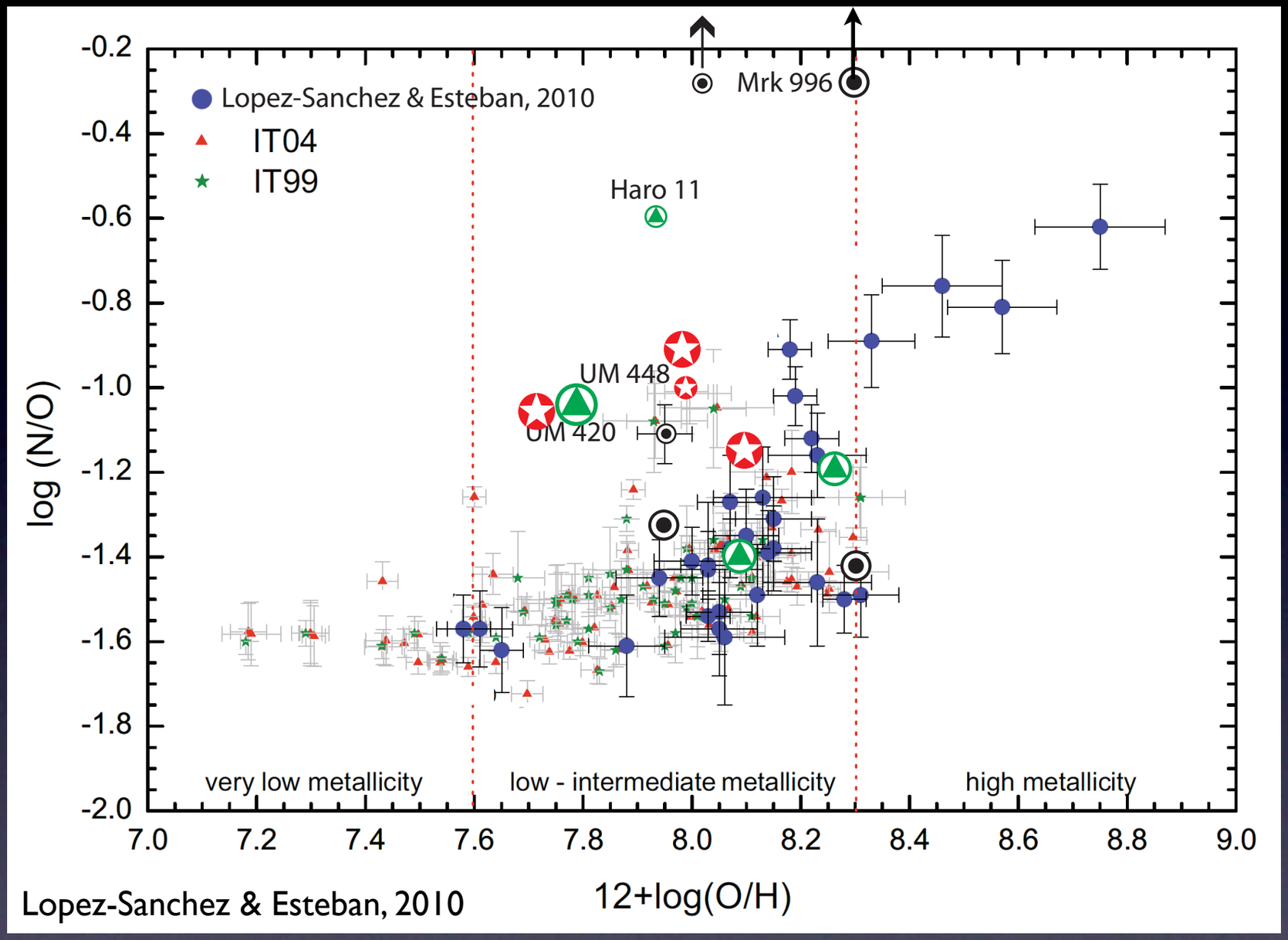
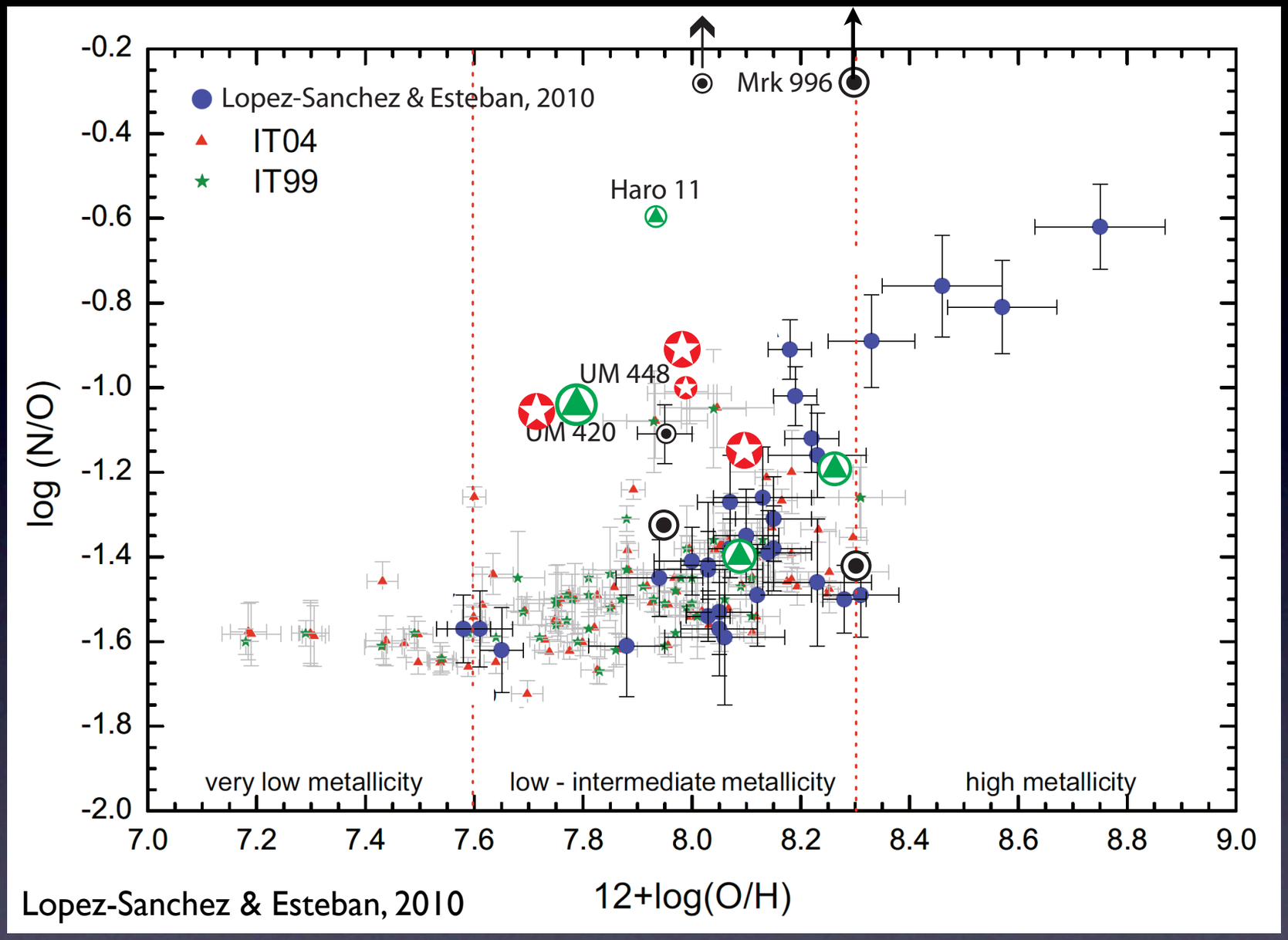


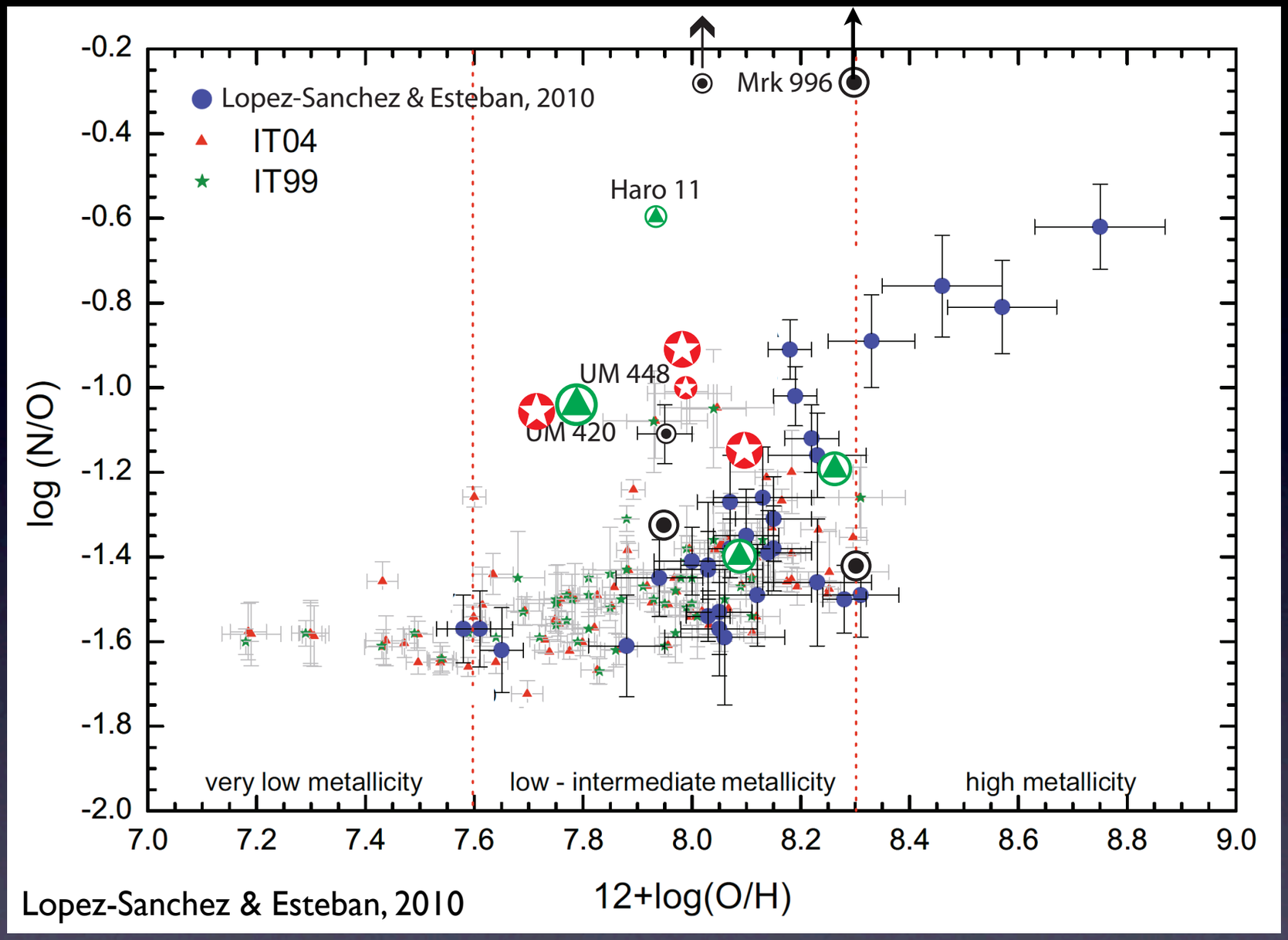
Lopez-Sanchez & Esteban, 2010

Impact of IFU Analysis on Abundances



Can we rely on luminosity-weighted measurements (i.e. long-slit, global spectra etc) to reliably represent the physical properties of high-z galaxies? What are we missing?

Impact of IFU Analysis on Abundances



Can we rely on luminosity-weighted measurements (i.e. long-slit, global spectra etc) to reliably represent the physical properties of high-z galaxies? What are we missing?

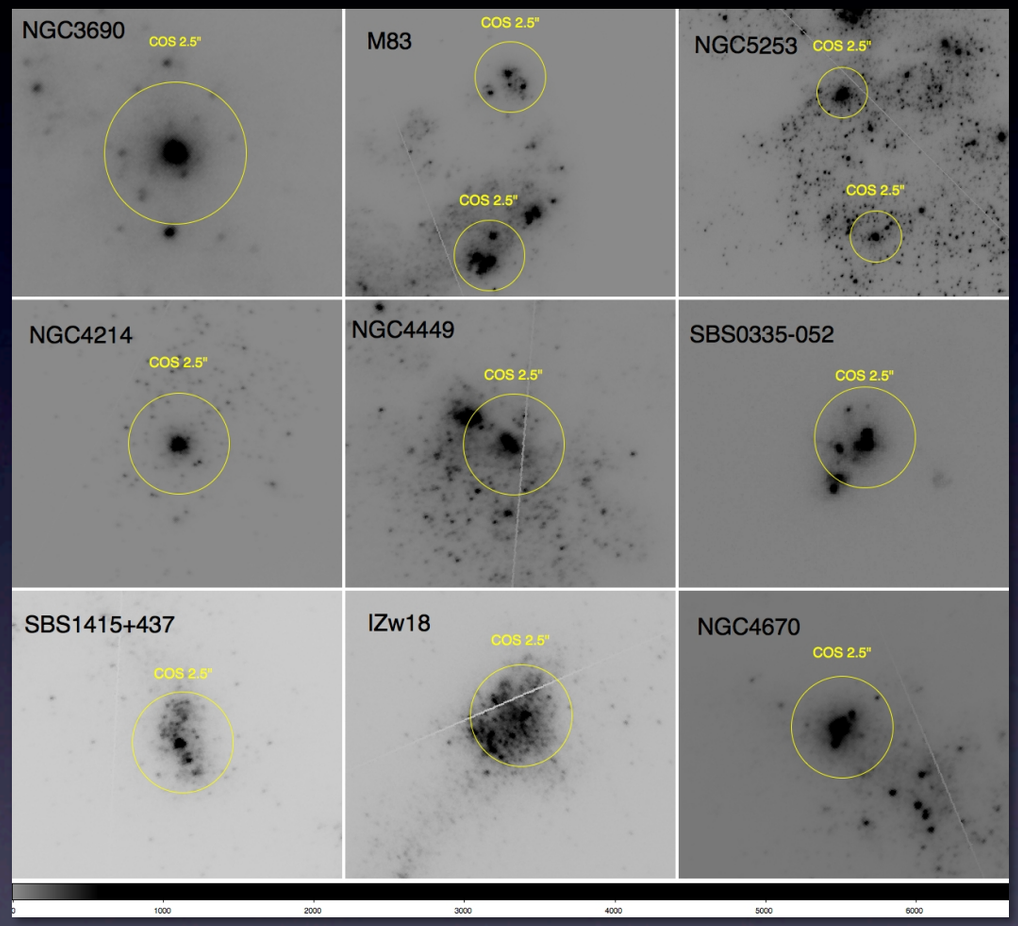
- Kobulnicky +(1999) found good agreement for O/H after applying Δ(O/H)±0.1 to global results
- O/H systematically underestimated (and N/O over-estimated) when using global SDSS spectra of HII regions with different properties (Pilyugin et al. 2012)

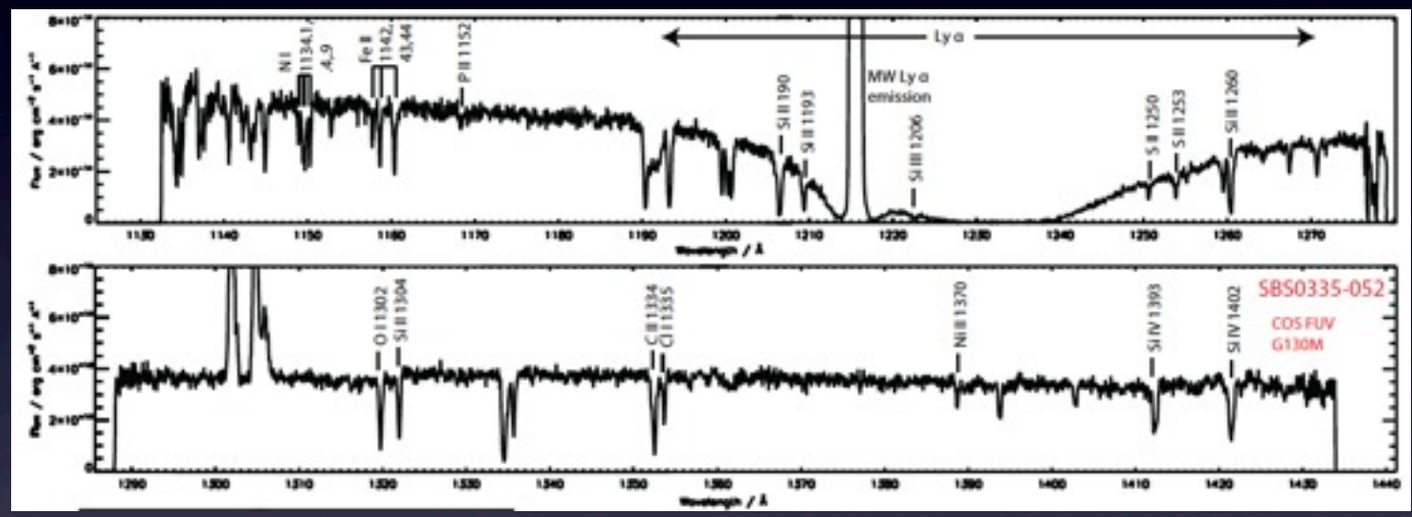
Constraining the SFHs of nearby SF-Galaxies

Combining HST/COS with GMOS/IFU

James et al. 2012c (in prep)
Aloisi et al. 2012 (in prep)

ACS/SBC images with COS aperture





Are neutral-gas abundances different from ionized-gas abundances ?

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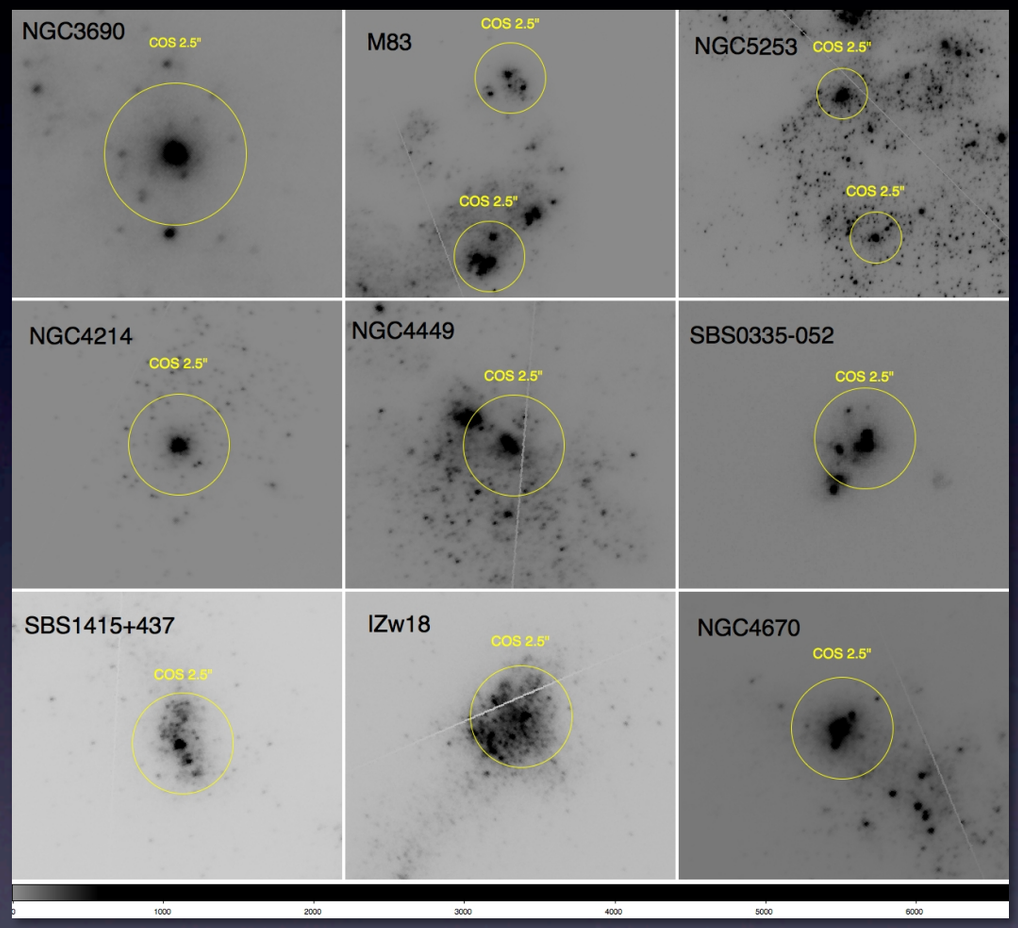

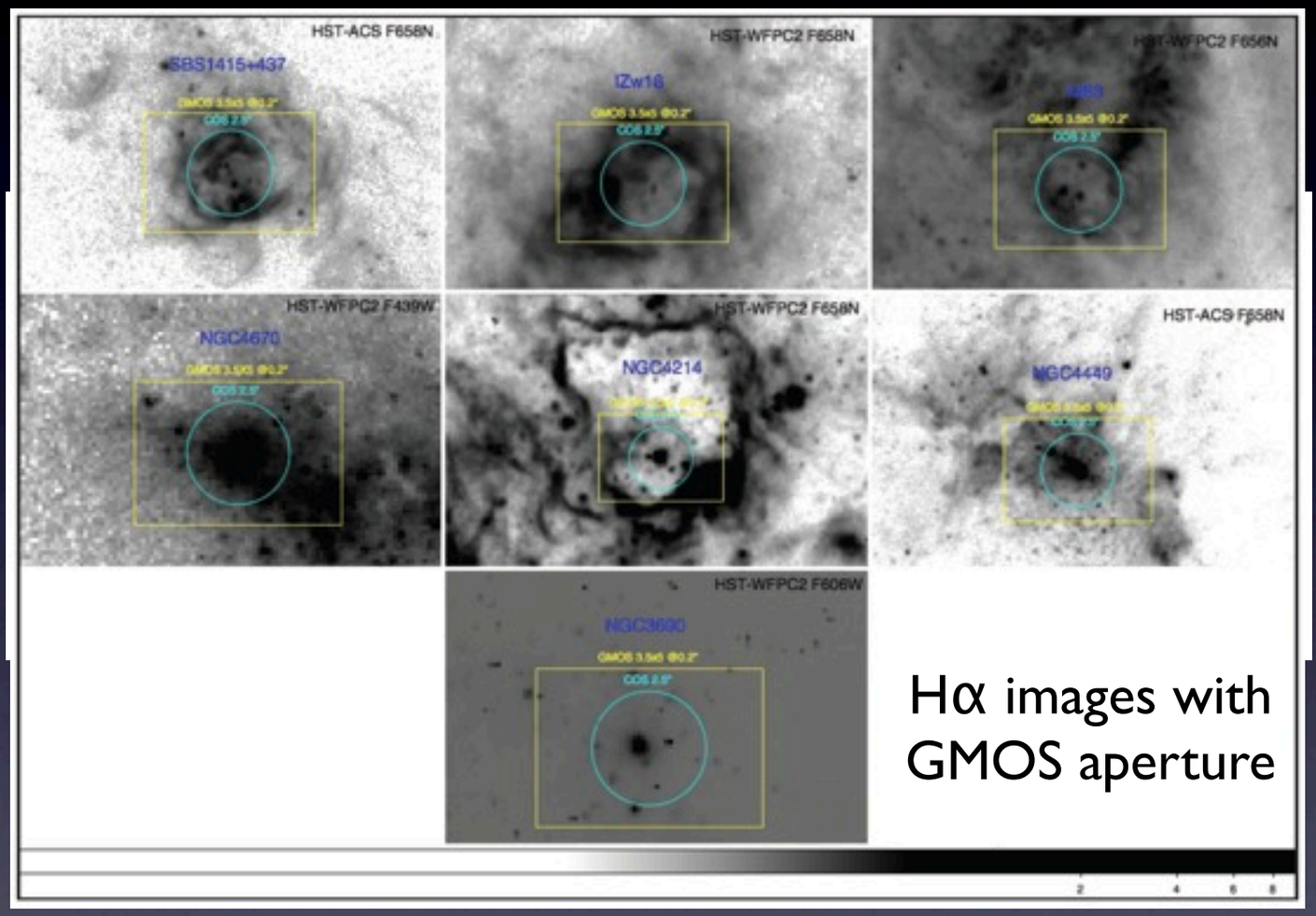

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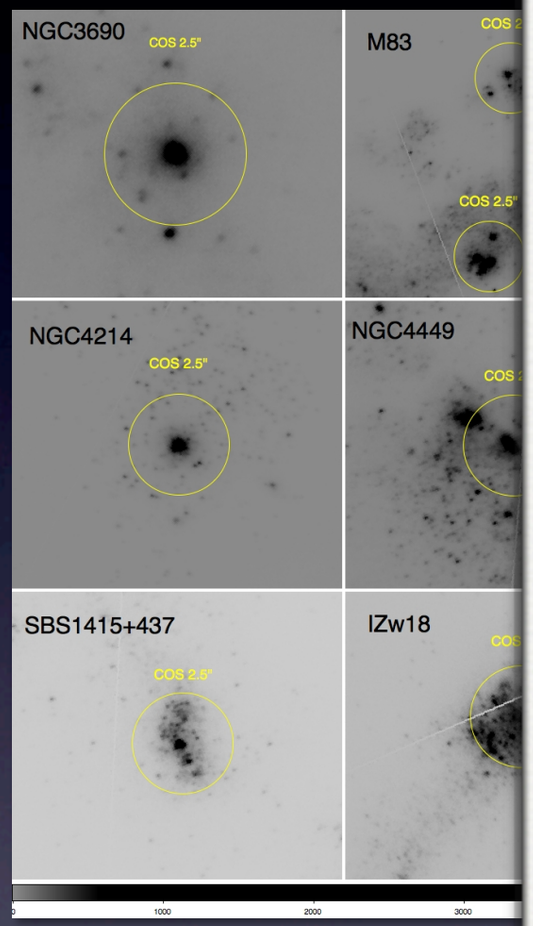

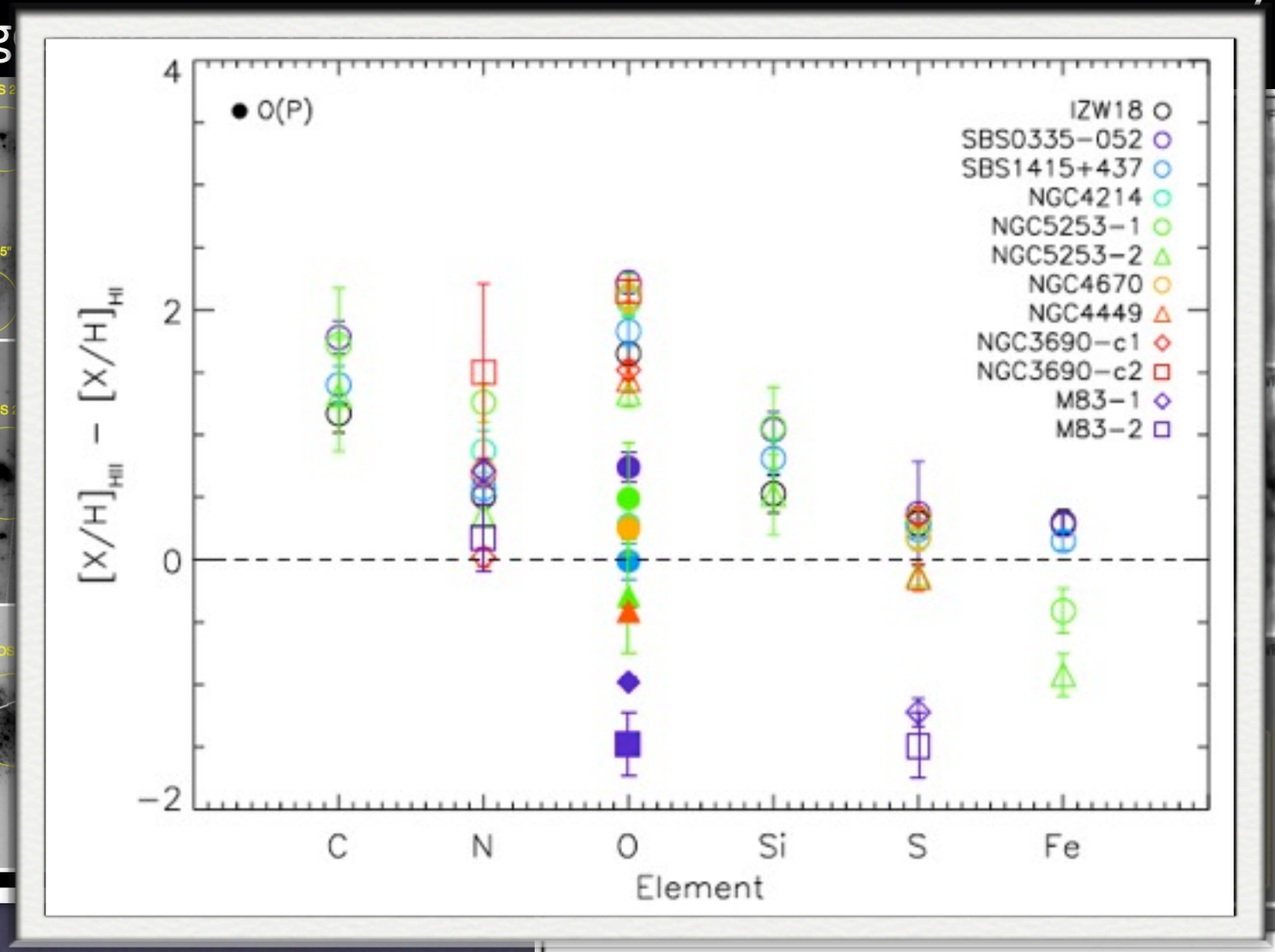

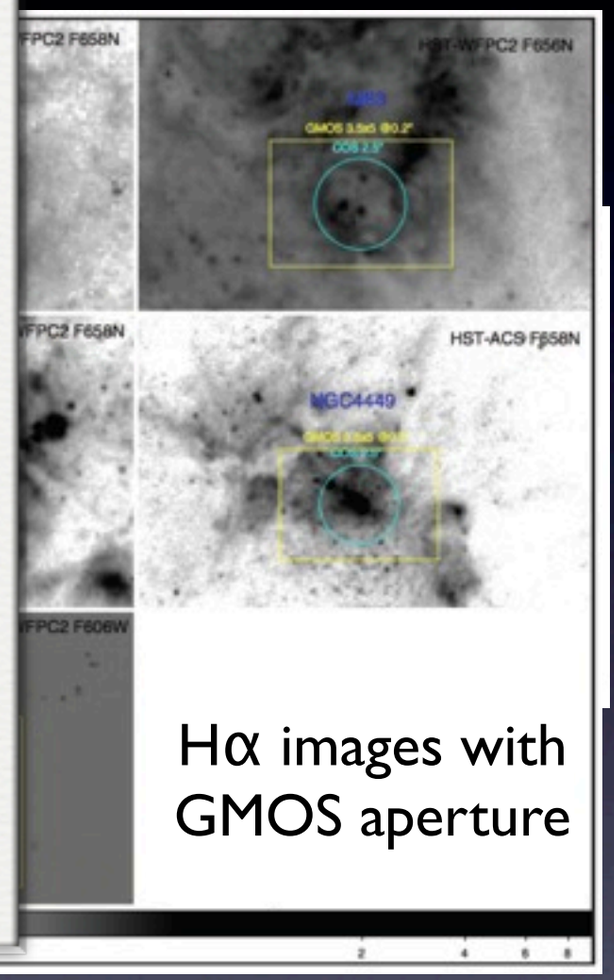

Hα images with GMOS aperture

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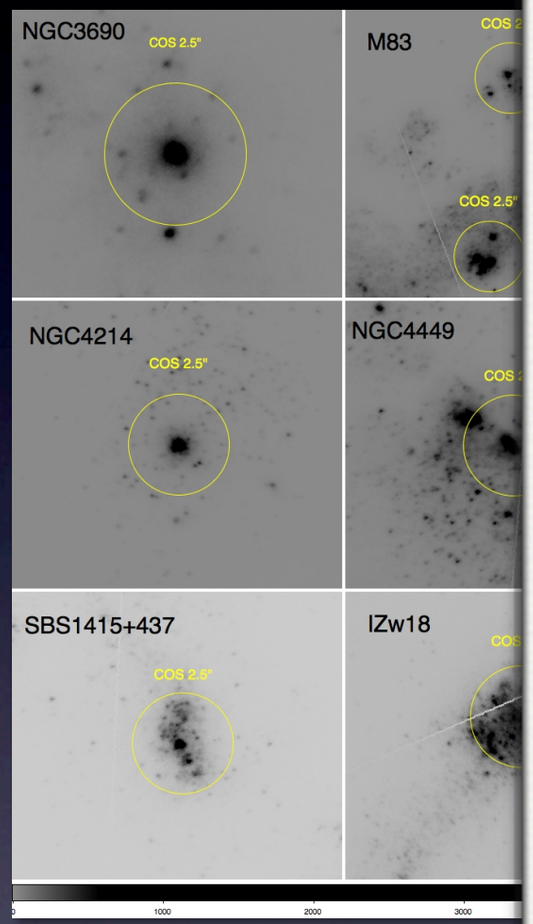
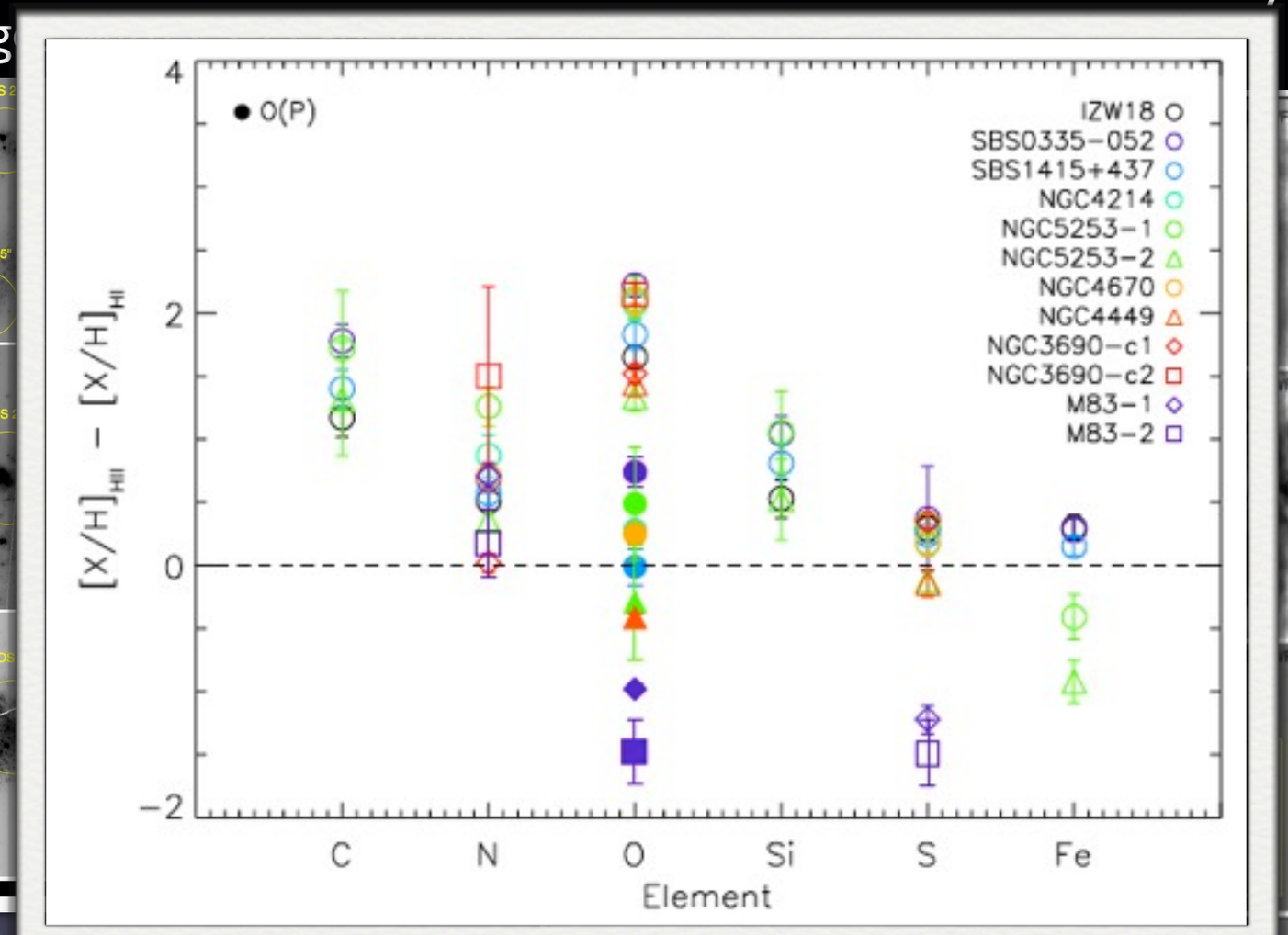
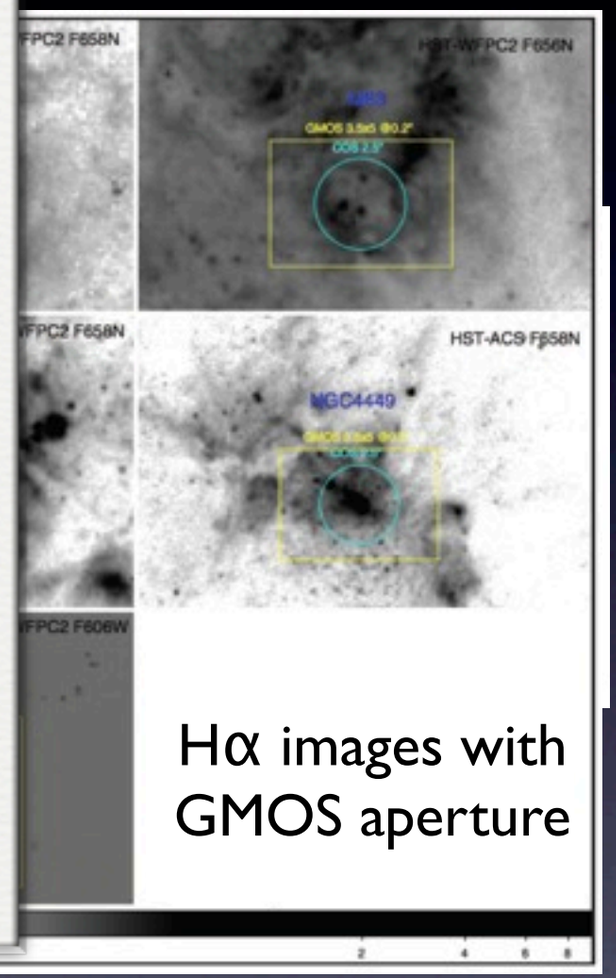






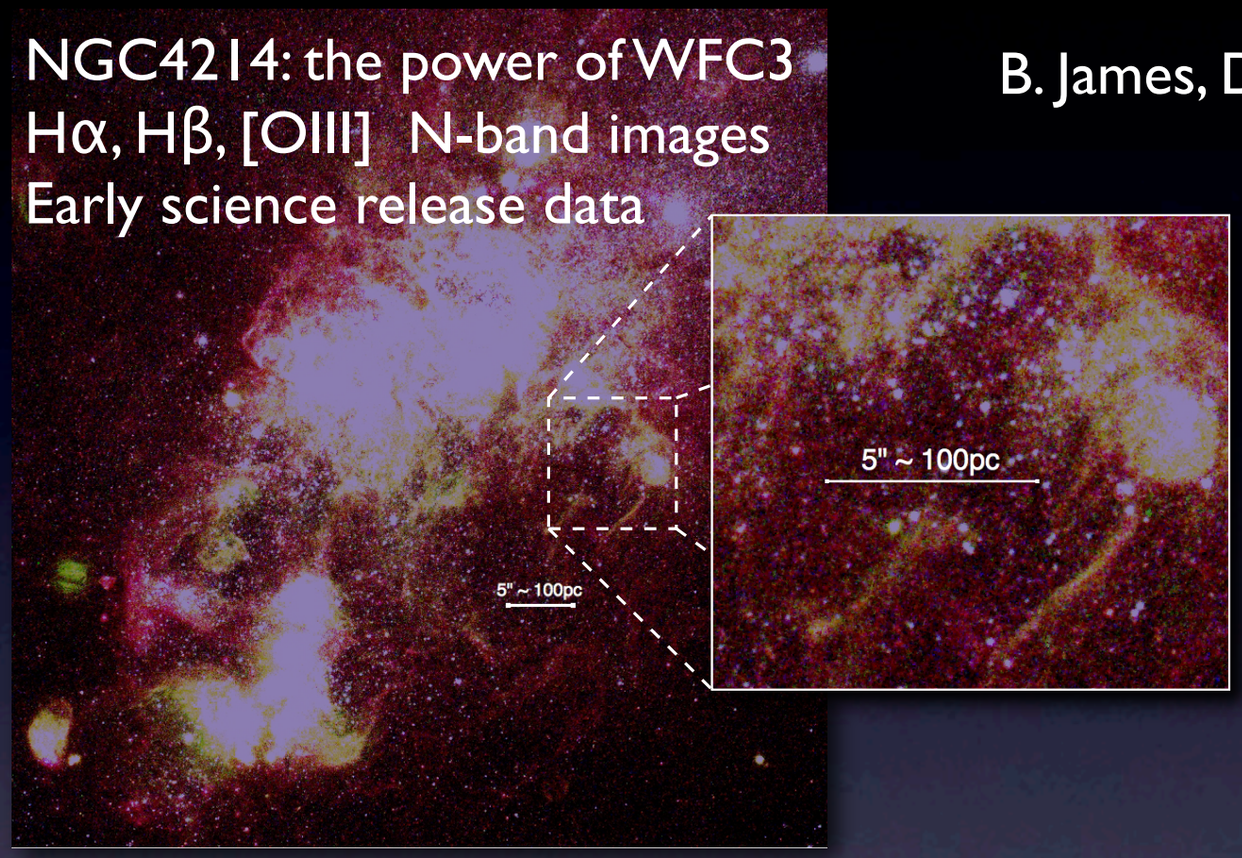
Hα images with GMOS aperture

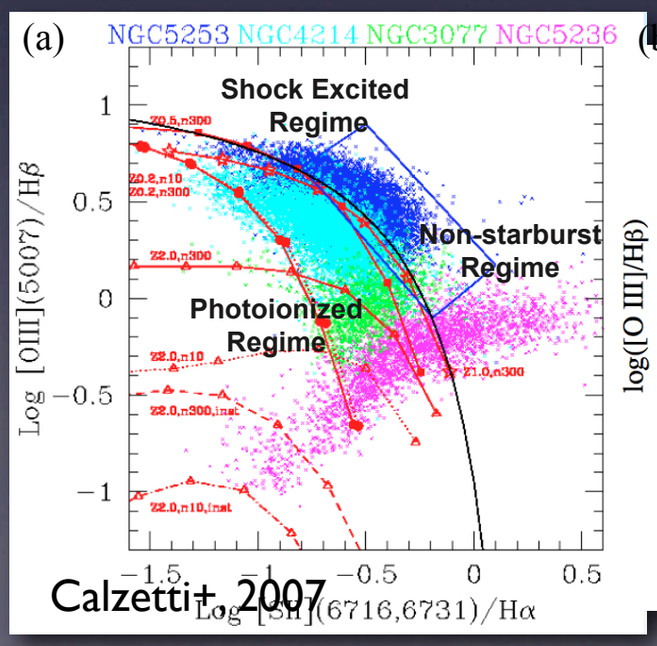
Are neutral-gas abundances different from ionized-gas abundances ?

Different mixing timescales between phases allow us to constrain SFH by comparing the neutral & ionized gas abundance patterns & ratios (Fe-peak, CNO, α-elements)

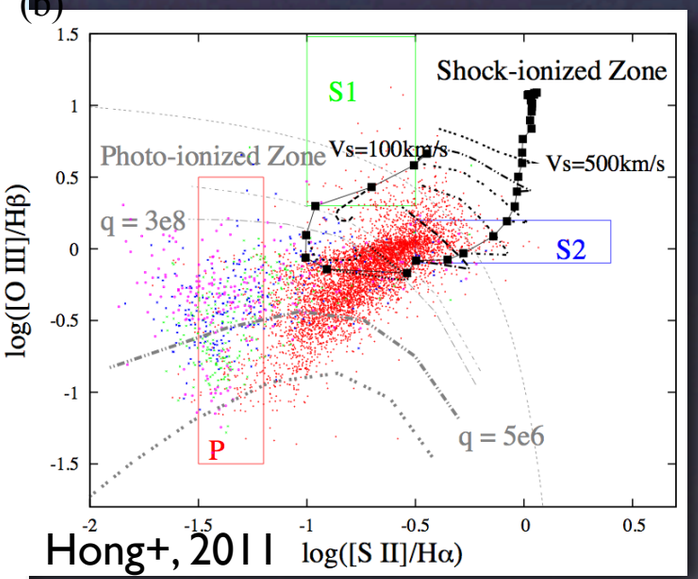
Diagnosing Ionization Mechanisms in BCDs with HST/WFC3 narrow-band imaging

B. James, D. Calzetti, L. Kewley, M. Westmoquette & A. Aloisi





Calzetti+, 2007



Hong+, 2011

- Cycle 20: 10 orbits (PI James)
- Imaging 2 BCDs Mrk209, Mrk71
- D~5Mpc so 10pc~0.4”
- [OII]3727, HeII 4686,[OIII], Hb, Ha, [SII] 6716, [SII] 6731, (+ cont^{m})
- Map electron density and O/H
- Map WR emission
- BPT diagram - shocks/AGN/ photoionisation?
- Role of feedback in energetics, structure & SF in BCDs

Conclusions

- BCDs can help us understand the formation and evolution of the first galaxies in the early universe
- IFU data is *essential* in furthering this understanding by allowing us to **map** their kinematical, chemical and stellar properties
- We can explore the **cause of SF** by combining kinematical & stellar population age maps
- Assess the **effects of SF** by conducting **spatially resolved analyses** by (i) deriving 'true' ionised-gas abundances & (ii) locating areas of localized enrichment/ depletion
- Studying the ionised- and neutral-gas abundances will provide even *deeper* understanding of SF within BCDs, as will the effect of feedback.