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Matthew Hayes (SU)
Jens Melinder (SU)
Phillippe Amram (Marseille)

THE FEEDBACK OF SUPER STAR CLUSTERS ON THE ISM

WHY IS FEEDBACK IMPORTANT?

- Responsible for different ISM phases
- Changes morphology and star formation history of the galaxy
- Affects our understanding of Galaxy evolution
- Metal enrichment of the IGM
- Possible source of re-ionization of the universe (escape of LyC photons)

HOW TO ADDRESS THESE PROBLEMS?

- Find local analogues of high-redshift star forming galaxies
- The clusters responsible for the feedback can be analysed in detail.
- The galactic scale effects of feedback can be resolved.

HOW TO ADDRE

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- The galactic s
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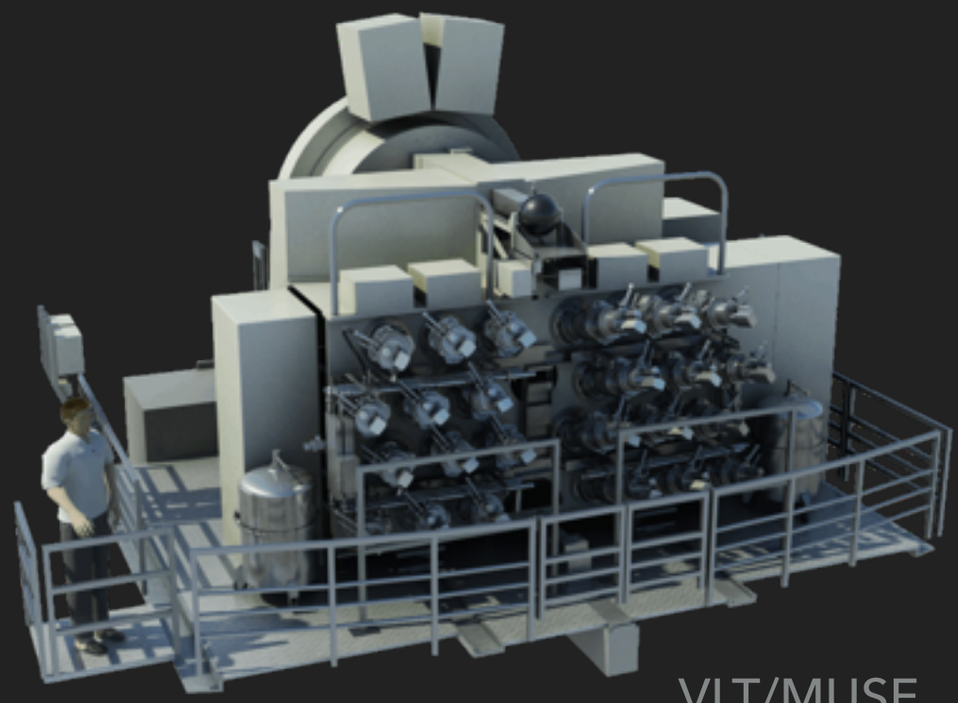
ESO 338-IG04

OPTICAL EMISSION LINES AS ISM TRACERS

- (Forbidden) line ratios trace properties ISM.
  - extinction
  - ionisation
  - temperature
  - density
  - abundances
  - comparison with photo-ionisation models

- Integral Field Spectroscopy with MUSE at the VLT
- 1’x1’ IFU with 0.2” pixel scale, 90000 spectra.



VLT/MUSE

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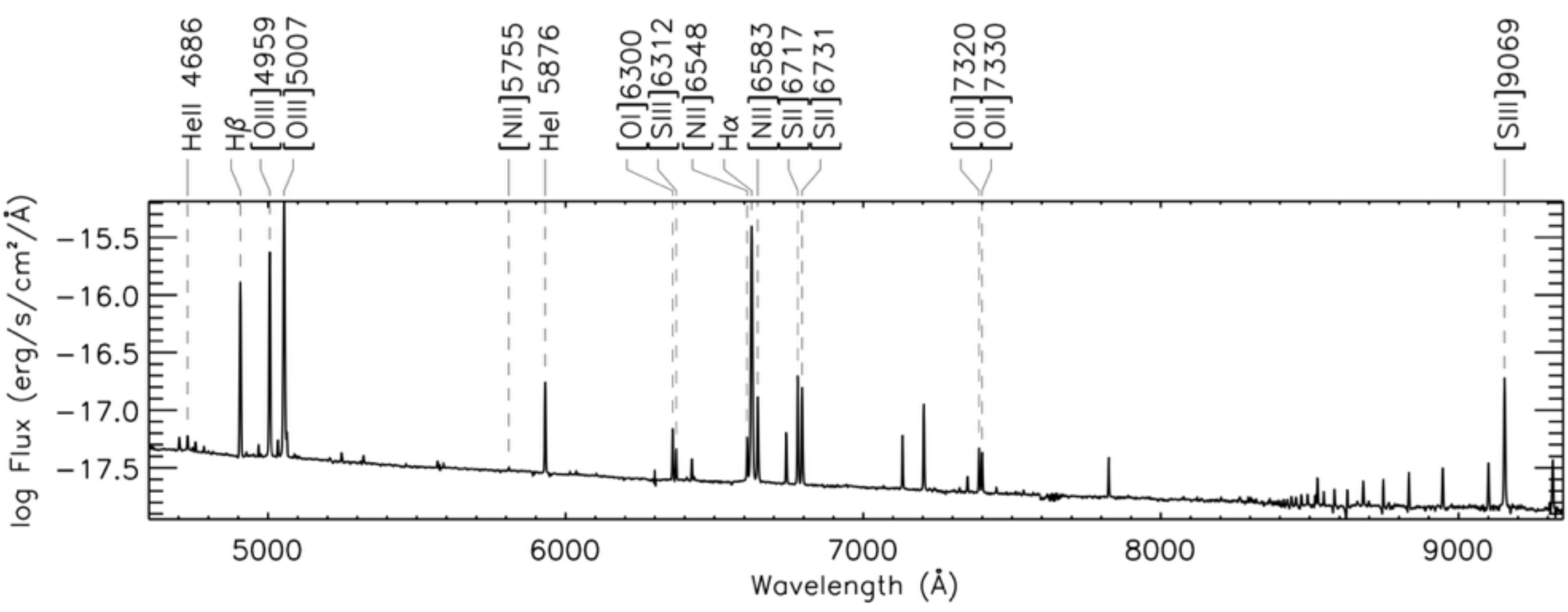


ISM PROPERTIES OF ESO 338-IG04

- MUSE observations of local LBG analogue ESO338-IG04 (Bik et al, 2015a,b, Bik et al, in prep)
- Galaxy contains many super star clusters (Ostlin et al, 2003) and is surrounded by a large ionised halo.
- Mv = -19 mag
- HI mass: 1.4×10^9 Msun (Cannon et al, 2004)
- Stellar mass 4×10^9 Msun (Ostlin et al, 2001, Bergvall & Ostlin, 2002)
- 12+log(O/H) = 7.9 (Guseva et al, 2012)
- Distance: 37.5 Mpc

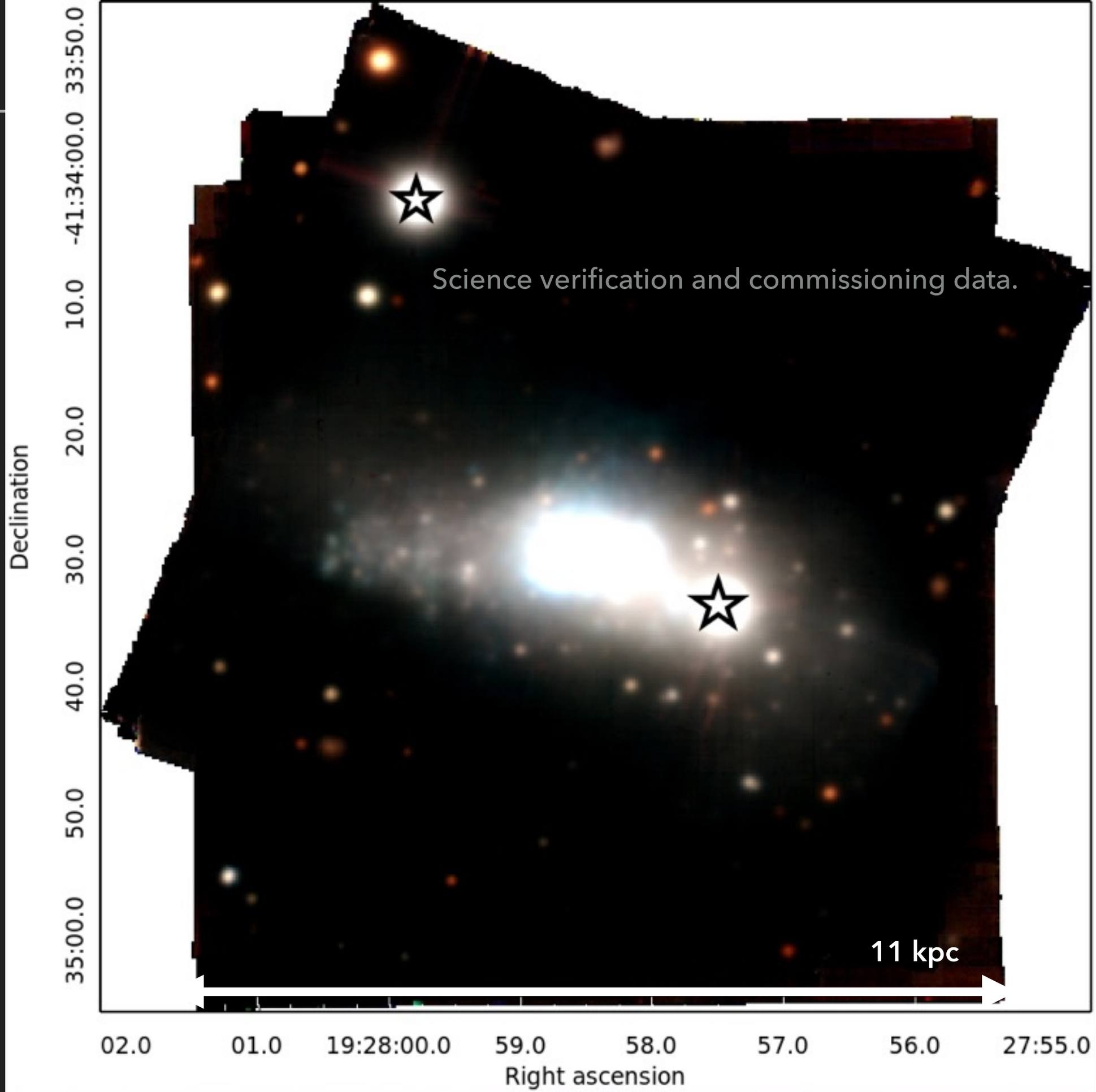
Blue UV (F140LP)

Green: Visual (F550M)

Red: Hα (FR656N)

credit: Jens Melinder

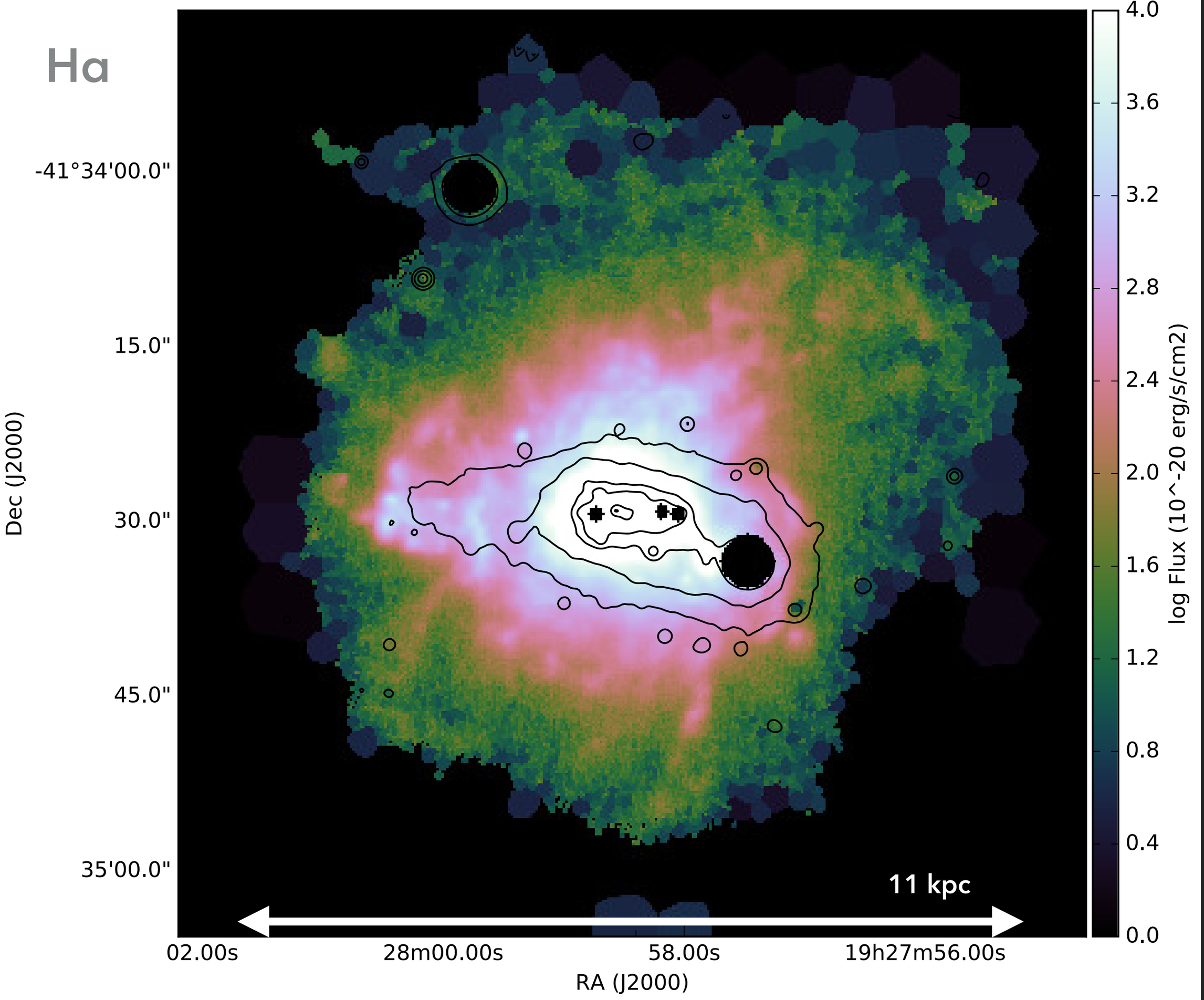
ESO338



Science verification and commissioning data.

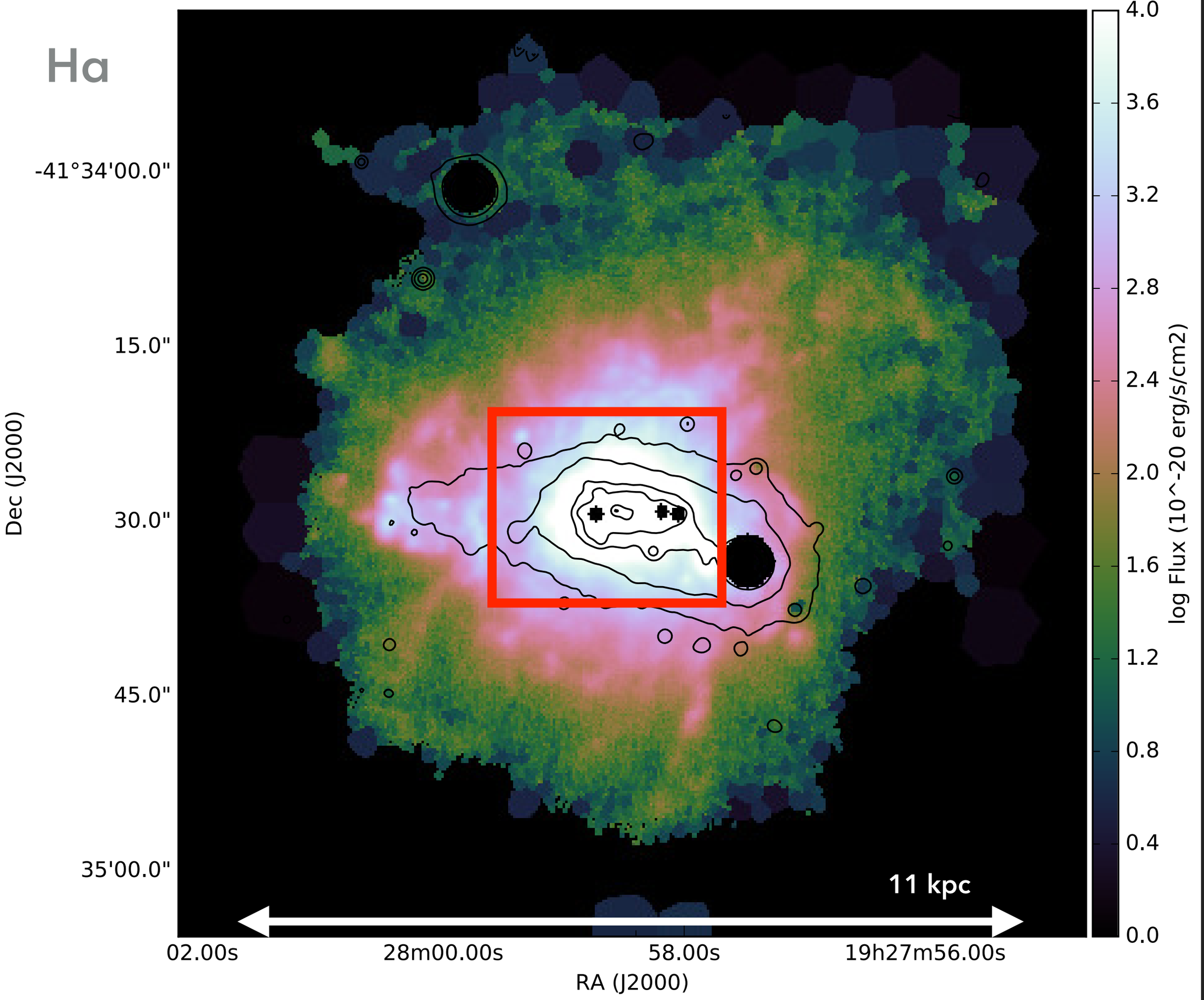
ESO

Ha


-41°34'00.0"
15.0"
30.0"
45.0"
35'00.0"
Dec (J2000)
11 kpc
02.00s
28m00.00s
58.00s
19h27m56.00s
RA (J2000)
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
log Flux (10^-20 erg/s/cm2)

ESO

Ha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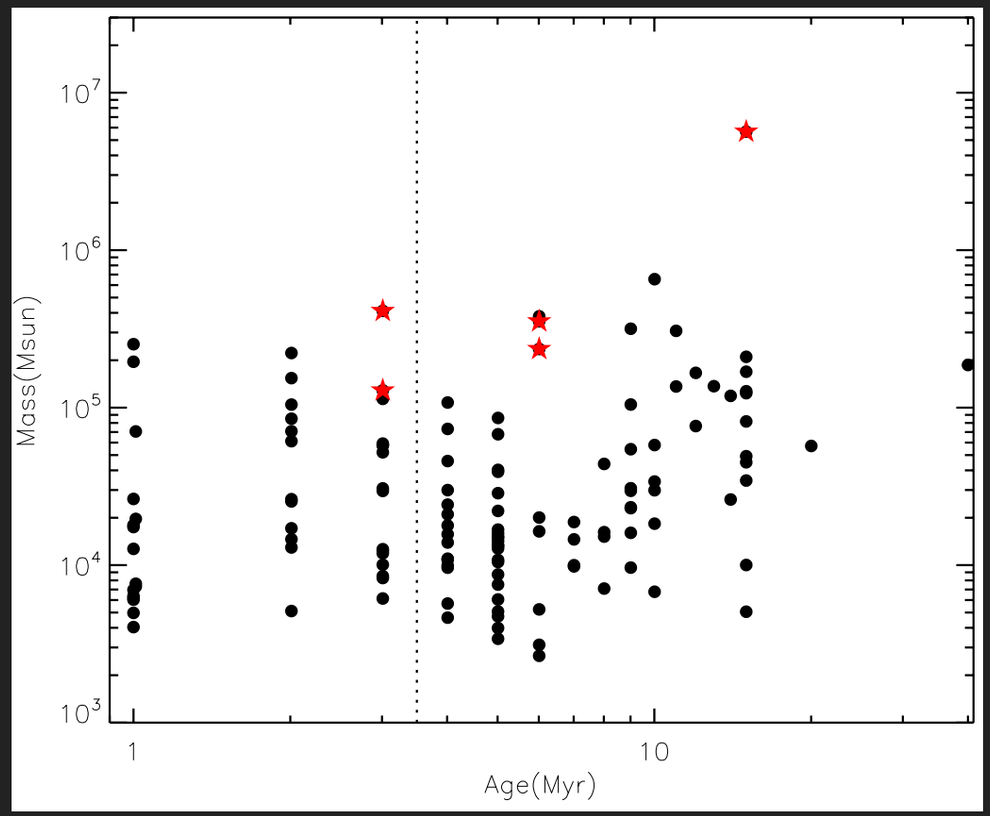
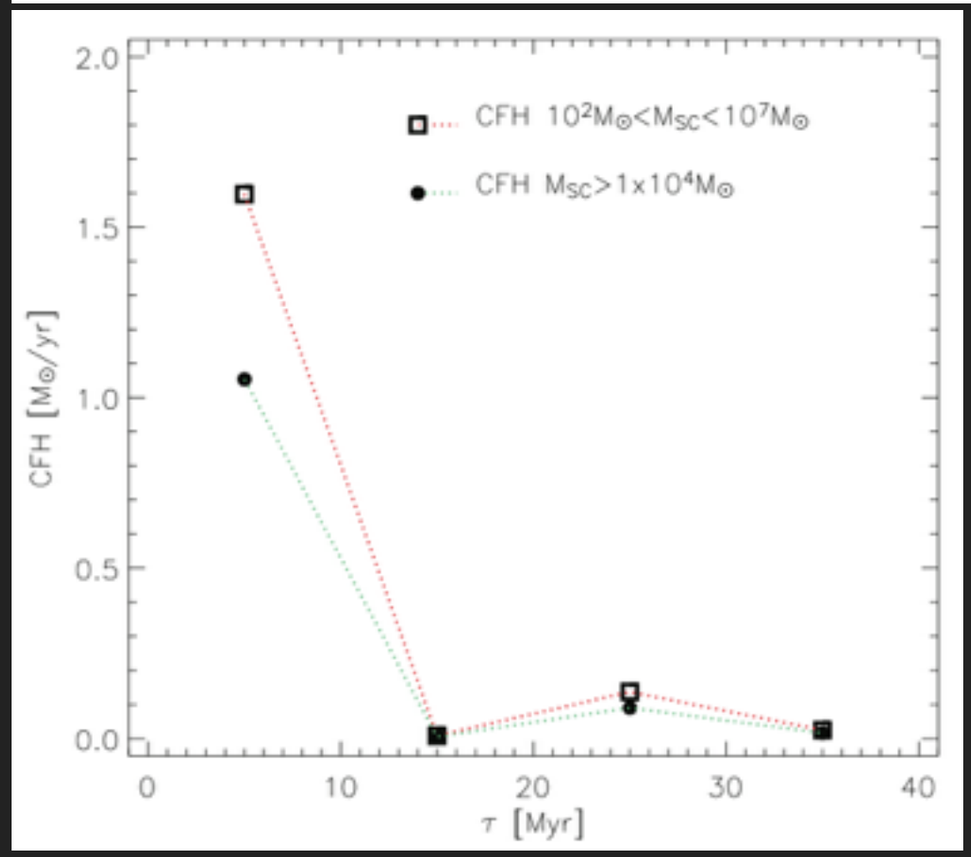
CLUSTER POPULATION

- Many young, massive super star clusters (Östlin et al, 2003)
- Cluster formation history peaks at very young ages.
- Most massive cluster (cluster 23)
  - dynamical mass of 1.3×10^7 Msun (Östlin et al, 2007)
  - Blown a huge bubble around the cluster.





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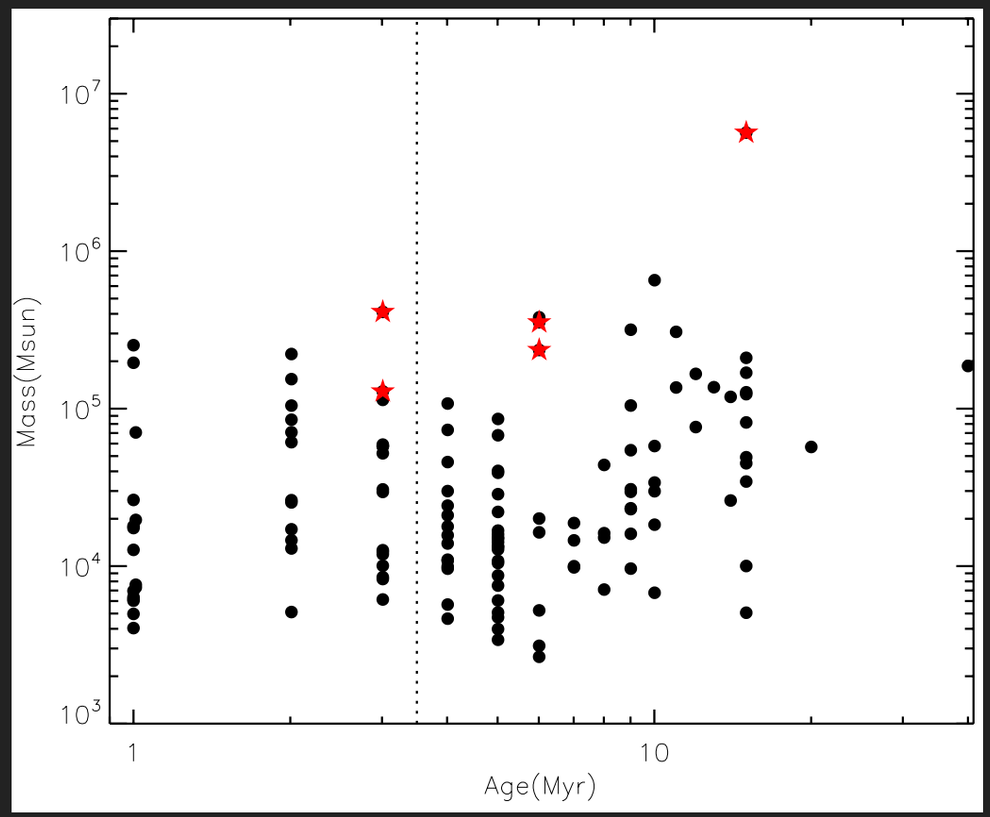
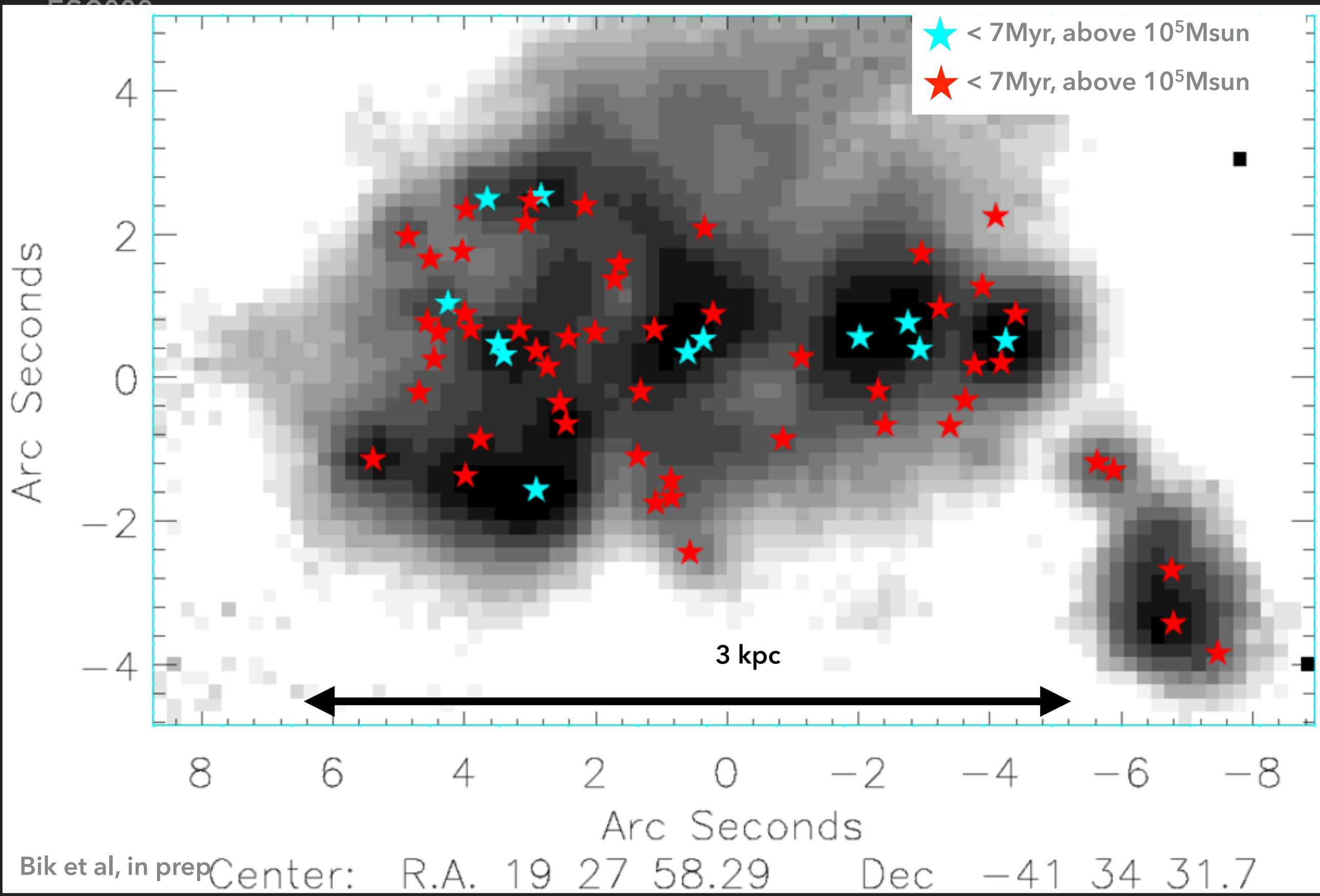


IONISATION

- Ionisation traced by [SII]/[SIII]
- Center of galaxy highly ionised
- Most massive young clusters located in highest ionised region.
- Extreme conditions in vicinity of SSC.

Bik et al, in prep



Bik et al, in prep

Cluster 23, bubble with radius of 150 pc

< 7Myr, above 10^5Msun

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3 kpc

Arc Seconds

Arc Seconds

Center: R.A. 19 27 58.29 Dec −41 34 31.7

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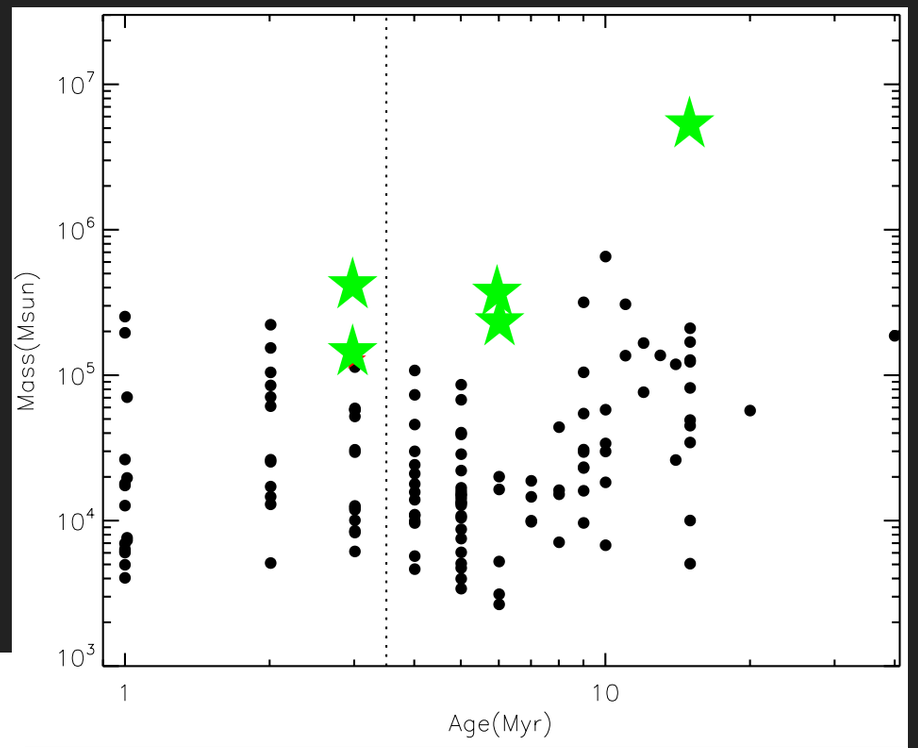
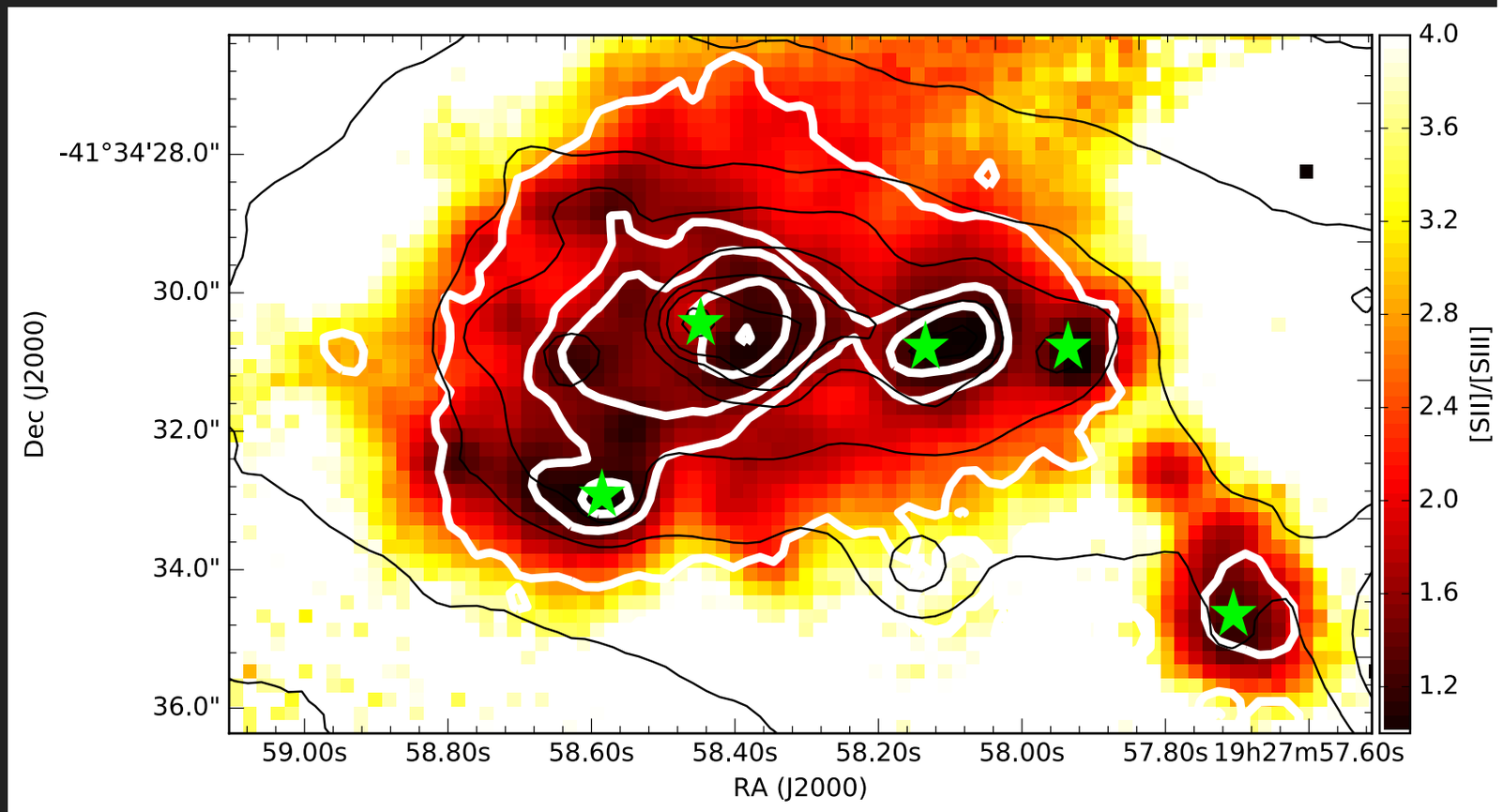
Bik et al, in prep

HEII EMISSION: WR STARS AND DIFFUSE GAS

- Broad HeII λλ4686 A emission: WR stars with strong winds.
- Narrow HeII emission, diffuse gas.
- Cluster 23: narrow emission peaks away from the cluster.



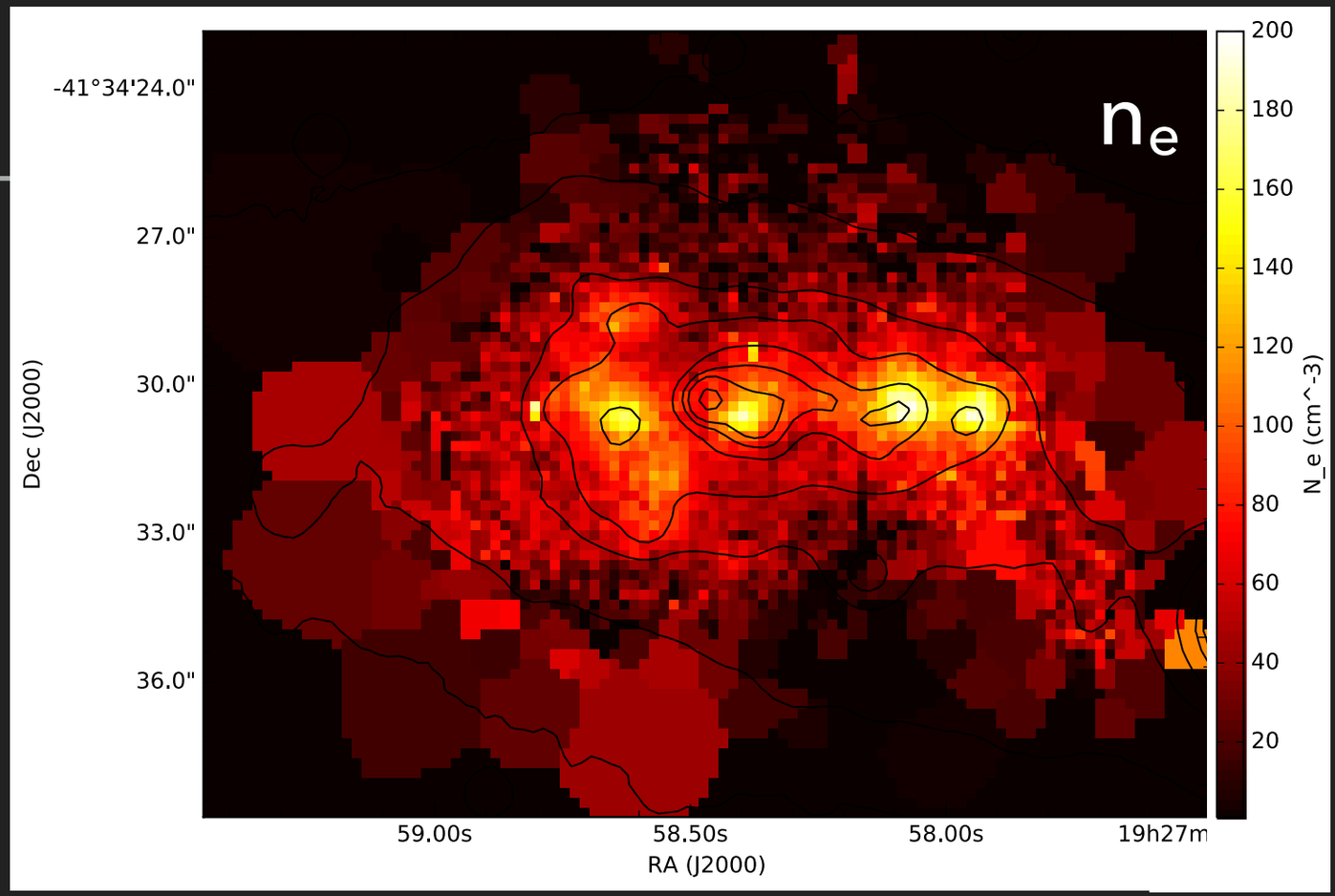


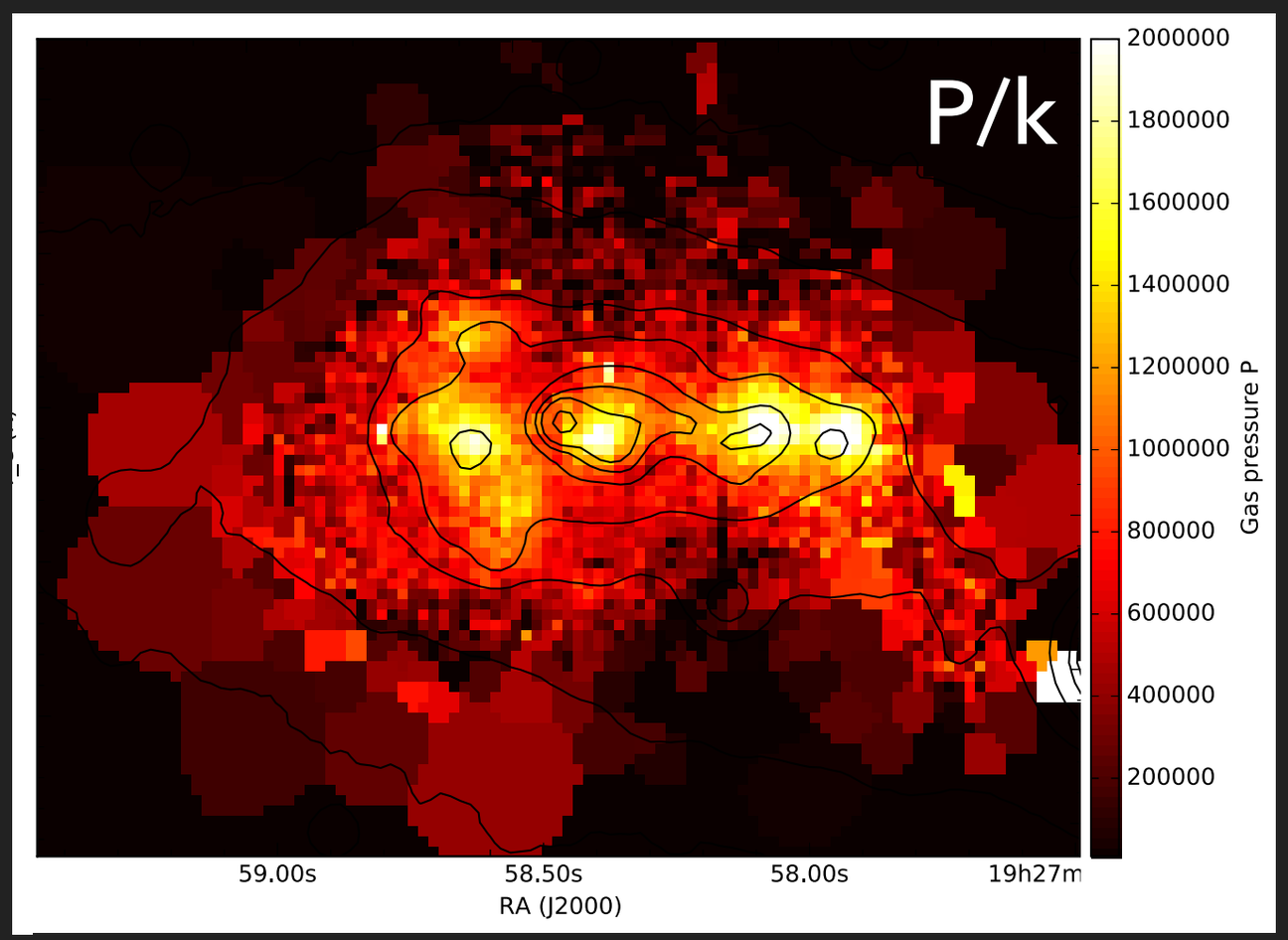
GAS PROPERTIES

- Density and gas pressure
- temperature ~constant: 12000K

- Density very low in outer halo and ~200 cm^3 towards some of the densest HII regions.
- Highest pressure in the central part of the galaxy.

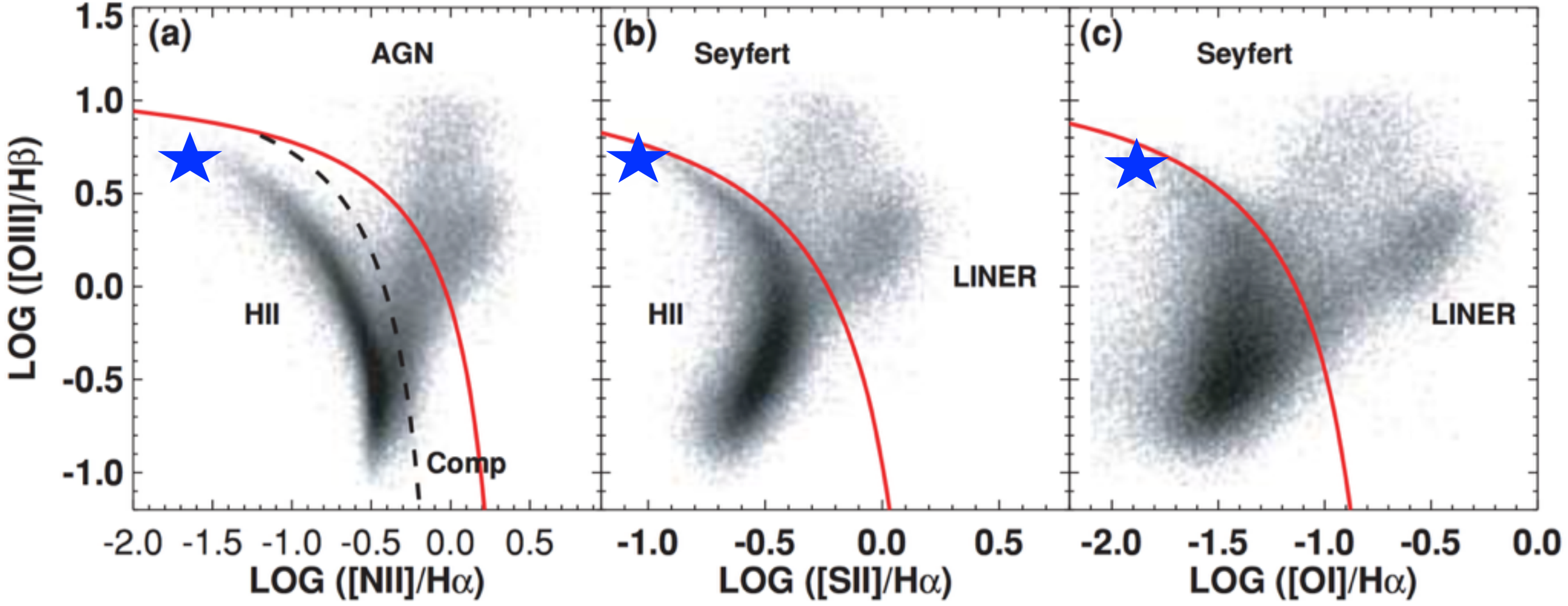
Bik et al, in prep





RESOLVED BPT ANALYSIS, SHOCKS IN ESO 338?

- OI/Halpha ratio good traces of shocks (Veilleux & Osterbrock, 1987)



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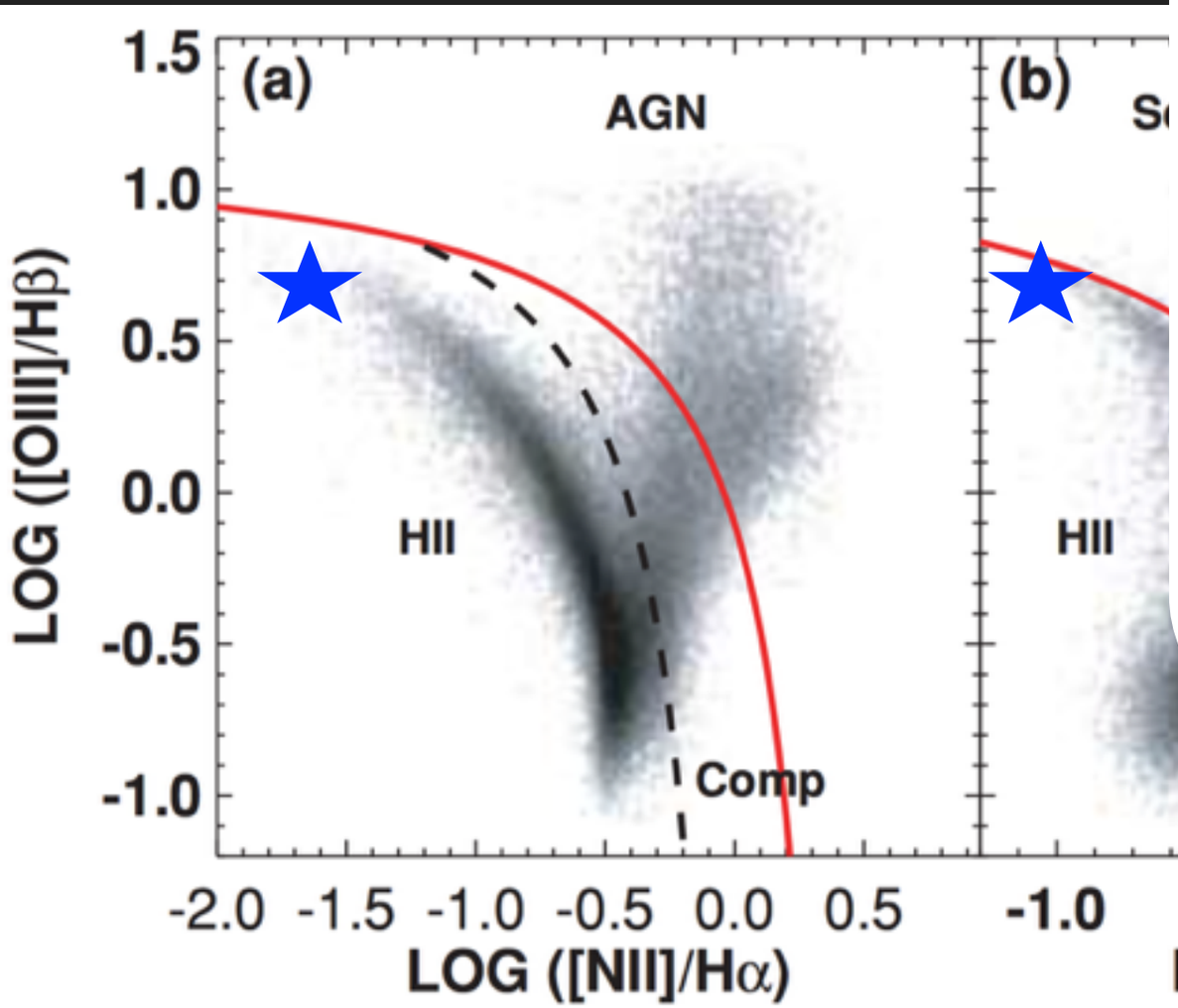

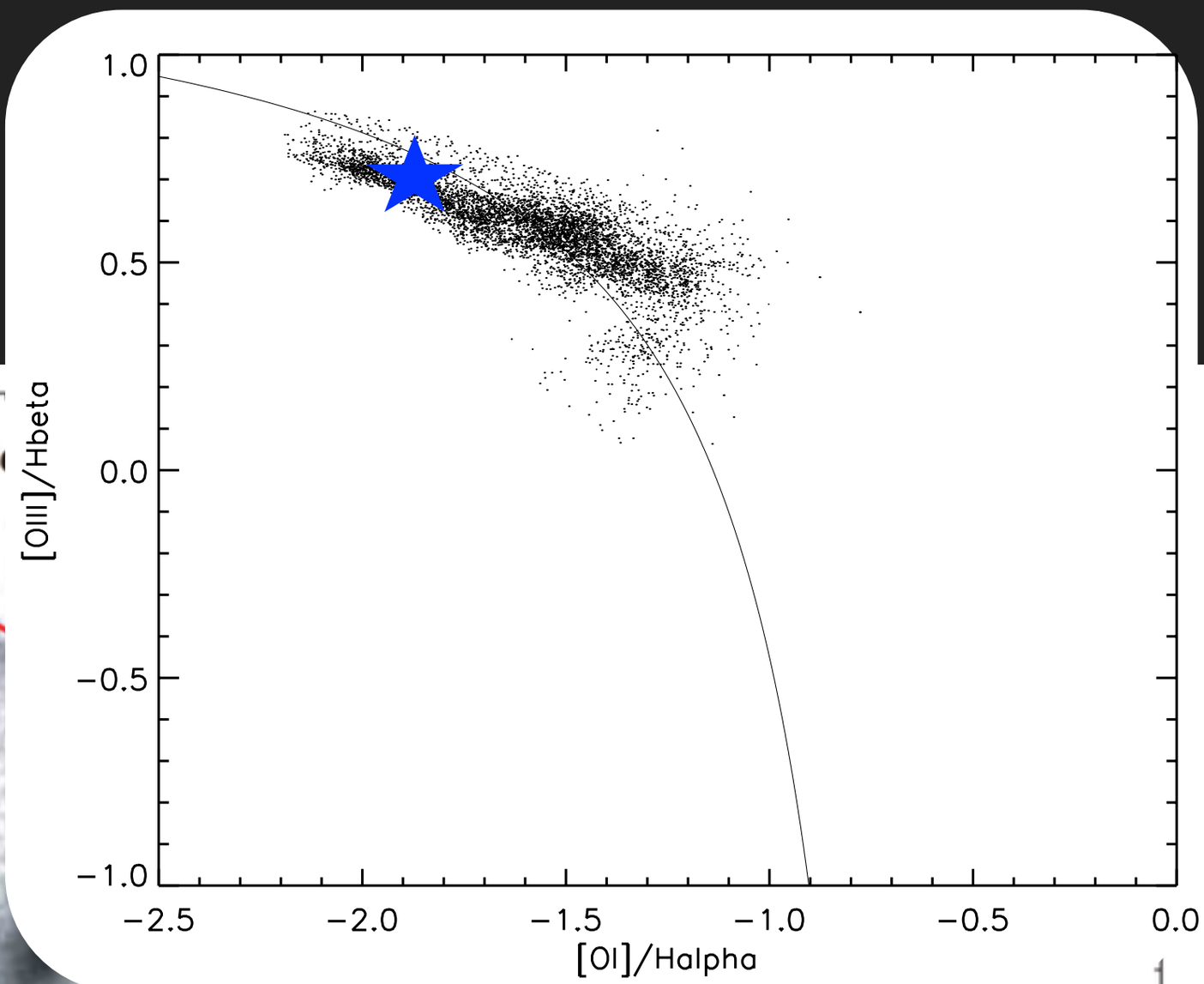

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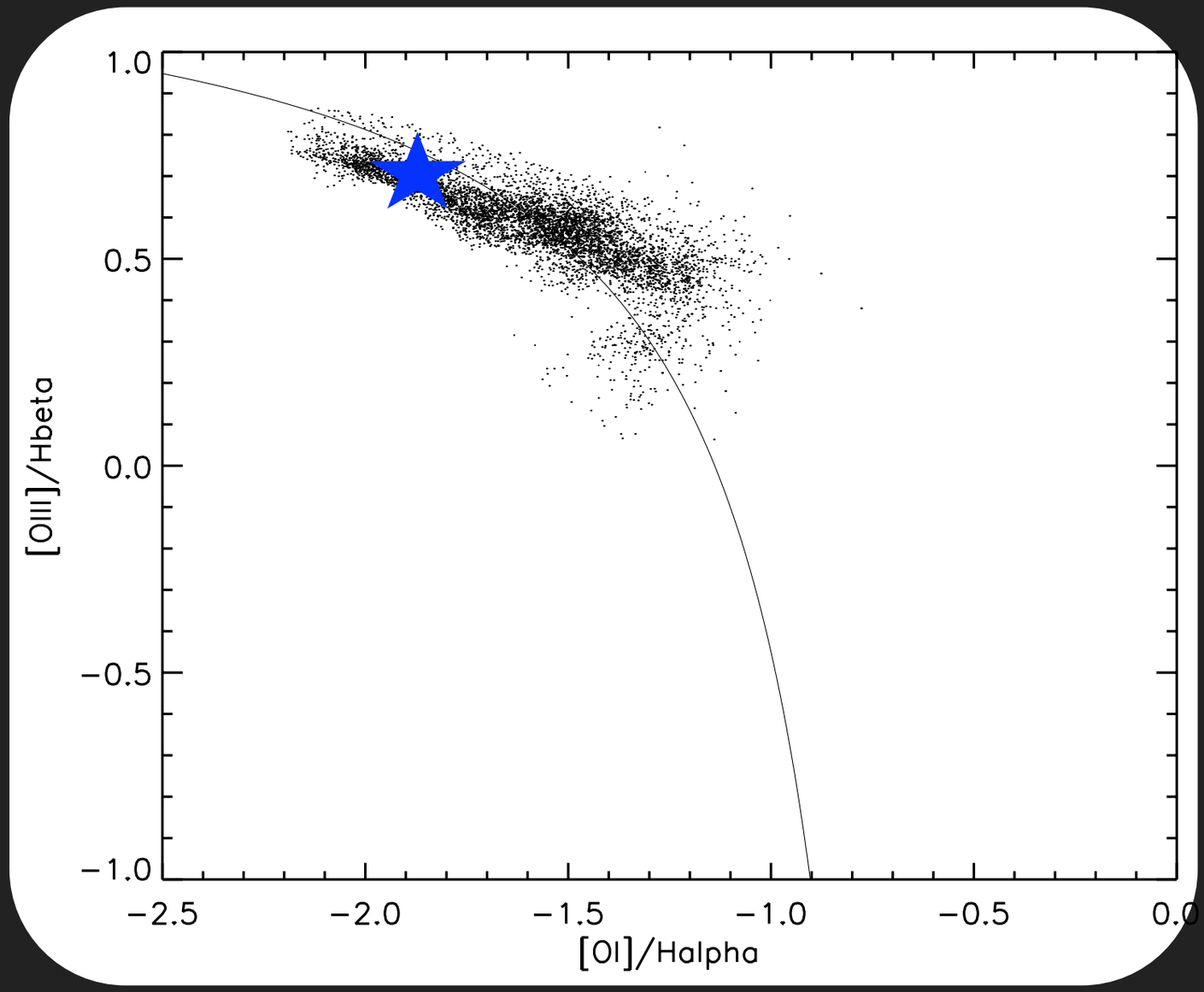
- Expanding gas of overpressure HII region shocking in lower-ionised gas?



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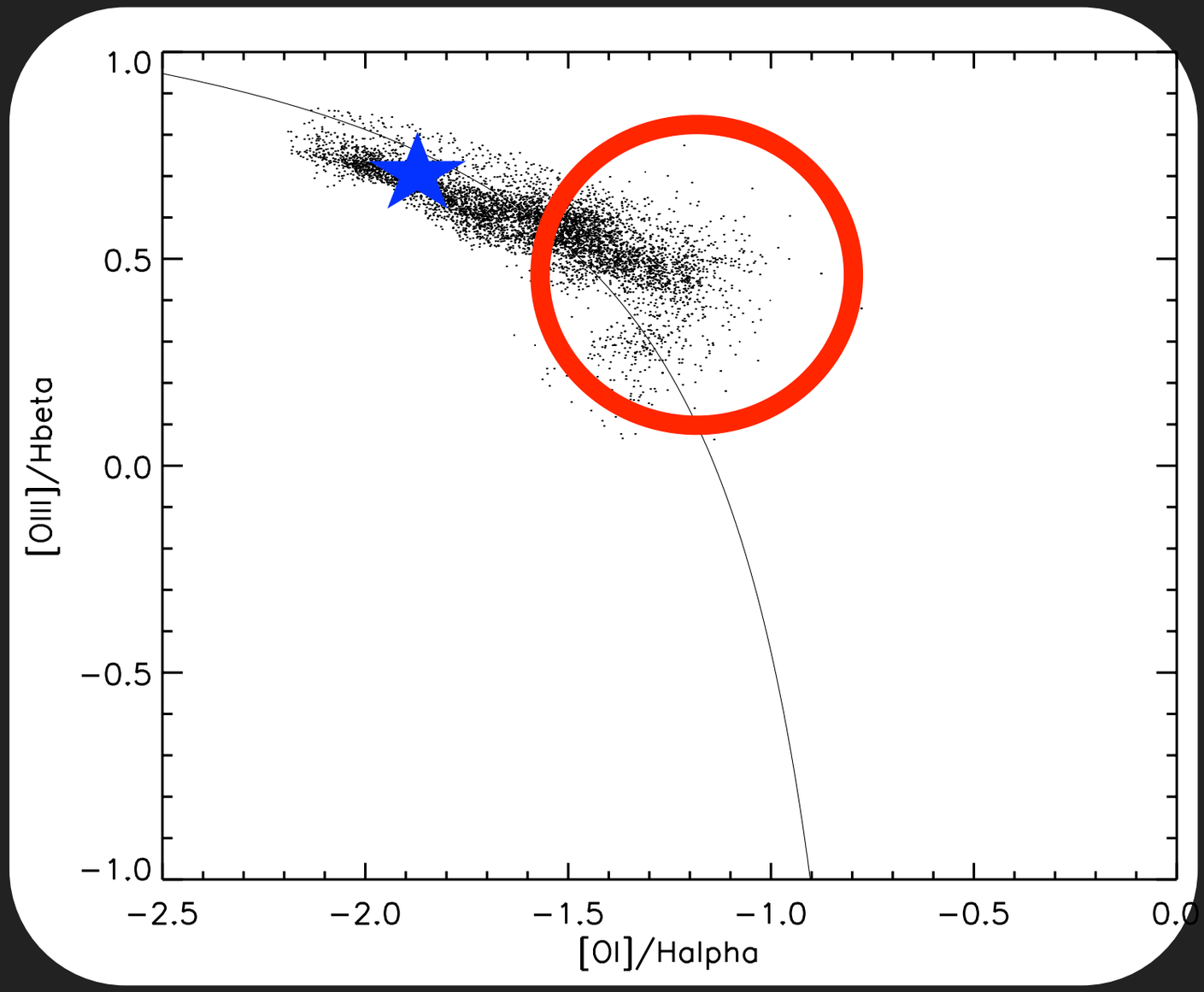
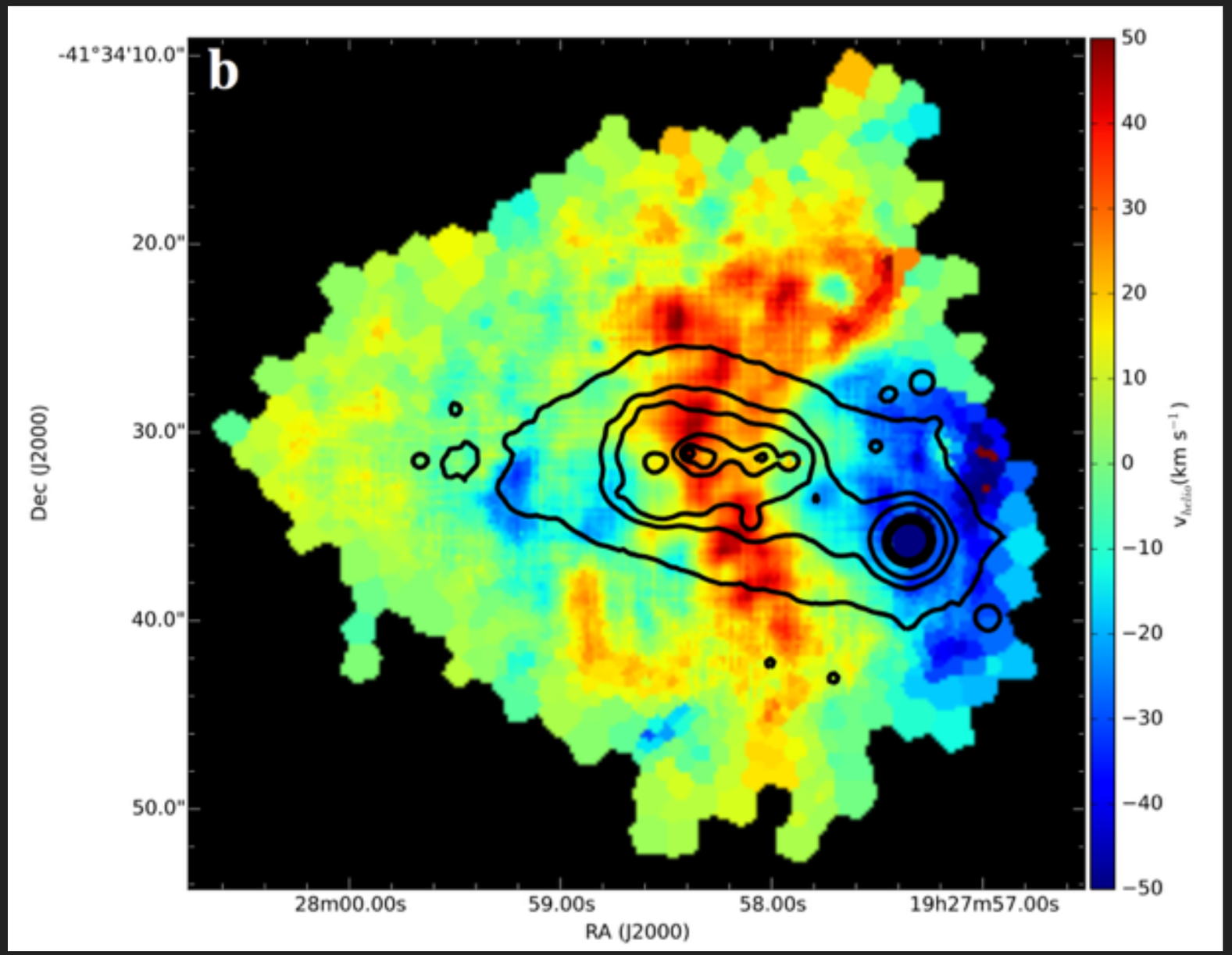


GALACTIC WIND

- Ha velocity map
- Two redshifted outflows
- Possible driving source: cluster 23
- Correlated with enhancements in Lya (Östlin et al, 2009)



Bik et al, 2015

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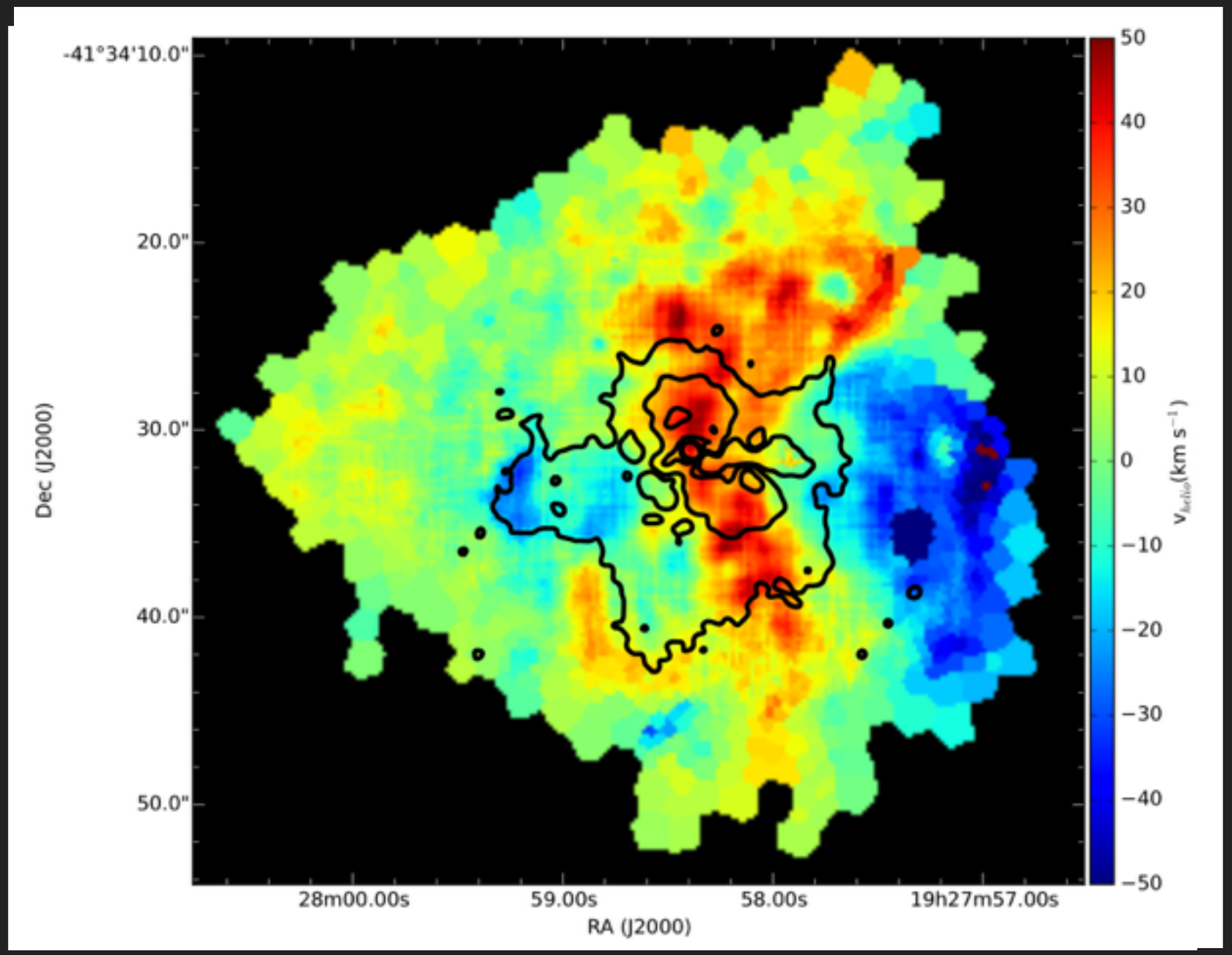
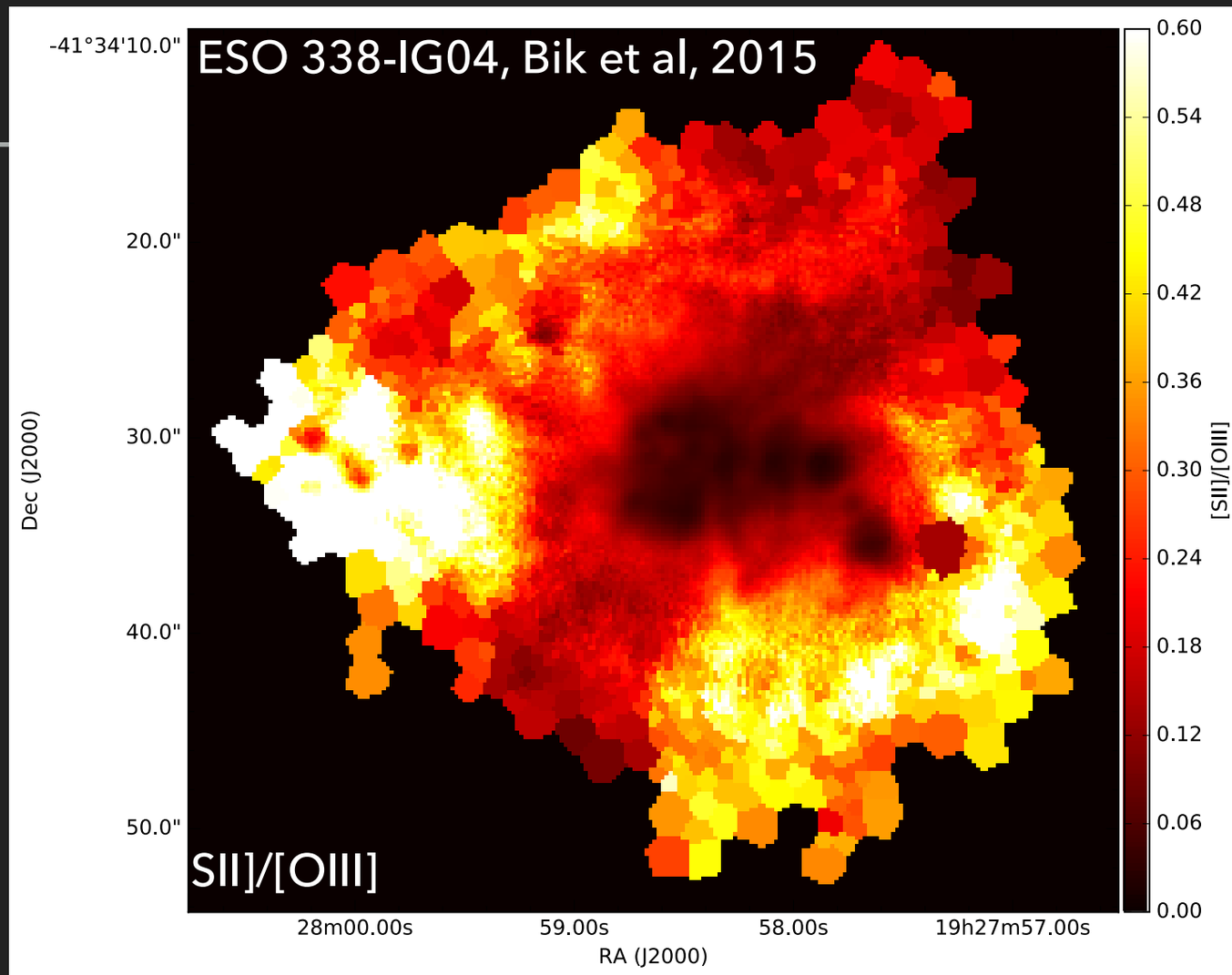
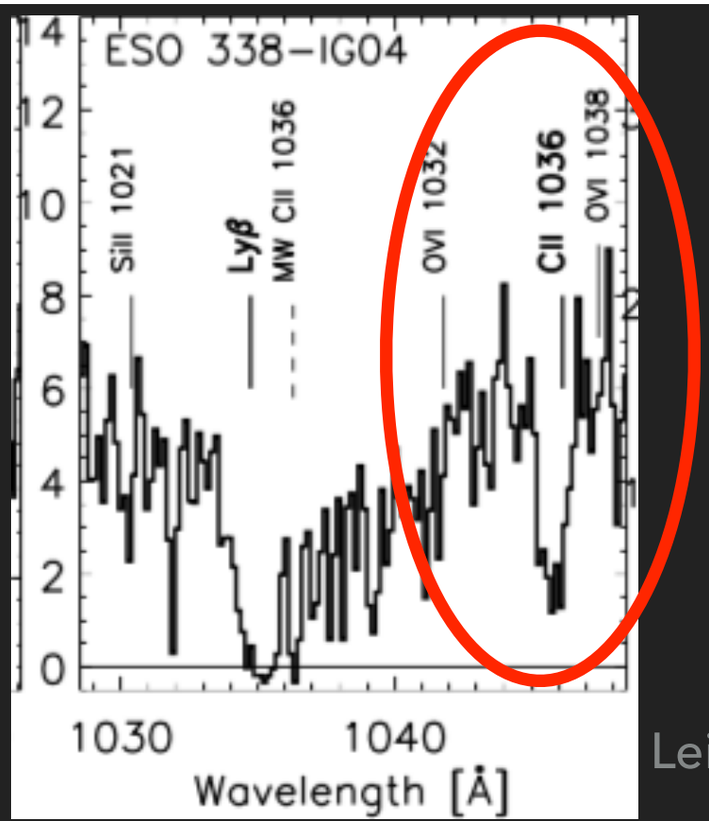


Bik et al, 2015

CAN LYC ESCAPE THE GALAXY?

- Ionization cones (Zastrow et al, 2011,2013, Bik et al, 2015)
- gas highly ionised and optically thin for LyC photons.
- Halo partly density bounded.
- Indirect LyC escape fraction estimated to be 16 % based on absorption line spectroscopy (Leitet et al, 2013)





Leitet et al, 2013

SUMMARY

- Local analogues of high-redshift star forming galaxies can be studied to understand the detailed impact of feedback on the ISM of galaxies .
- ESO 338:
  - ISM strongly modified and by super star clusters
  - center highly ionised and possibly expanding in surrounding gas, causing shocks.
  - Ionisation cones could facilitate LyC escape
  - Galactic winds could facilitate Lyα escape
- Analysis of a larger sample of high redshift analogues is in preparation.