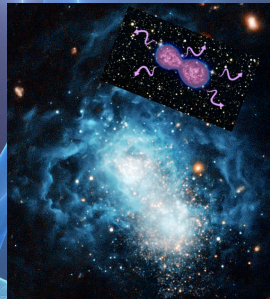


Does I Zwicky 18 harbor GW progenitors?

The story of a dwarf galaxy
and what I learned in the past 12 years

Dorottya Szécsi

Nicolaus Copernicus University



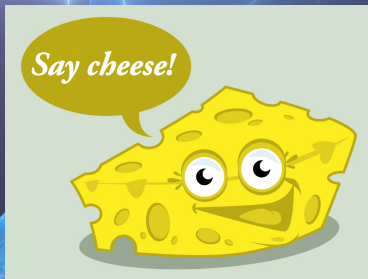
Research seminar, Nice, France
27th May 2025

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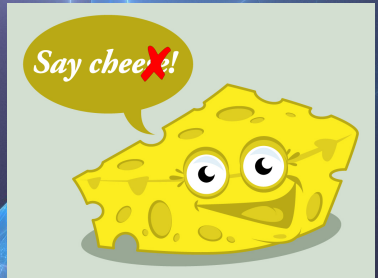
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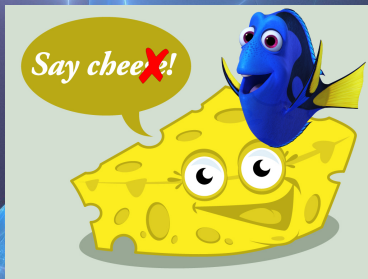
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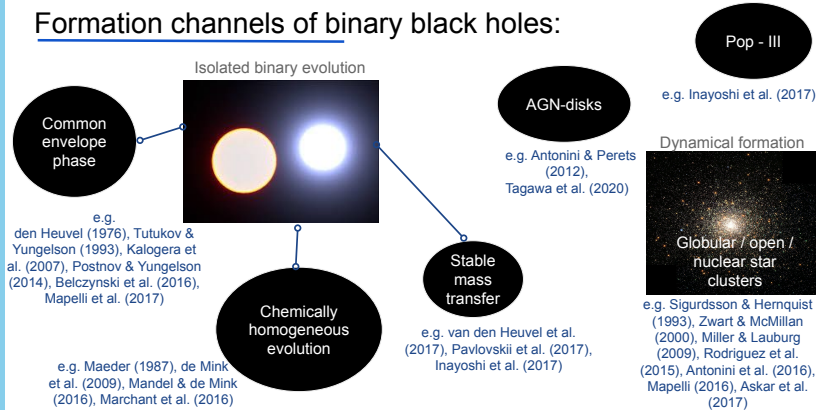
Dorottya Szécsi

Nicolaus Copernicus University



Research seminar, Nice, France
27th May 2025

Formation channels of binary black holes:



Credit for slides: R. Sarwar

Formation channels of bin

Isolated binary evolution

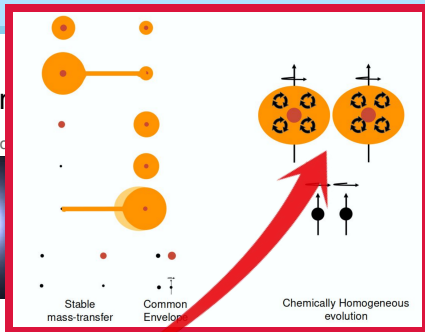
Common
envelope
phase



e.g.
den Heuvel (1976), Tutukov &
Yungelson (1993), Kalogera et
al. (2007), Postnov & Yungelson
(2014), Belczynski et al. (2016),
Mapelli et al. (2017)

Chemically
homogeneous
evolution

e.g. Maeder (1987), de Mink
et al. (2009), Mandel & de Mink
(2016), Marchant et al. (2016)



Stable
mass
transfer

Common
Envelope

Chemically Homogeneous
evolution

nuclear star
clusters

e.g. van den Heuvel et al.
(2017), Pavlovskii et al. (2017),
Inayoshi et al. (2017)

e.g. Sigurdsson & Hernquist
(1993), Zwart & McMillan
(2000), Miller & Lauburg
(2009), Rodriguez et al.
(2015), Antonini et al. (2016),
Mapelli (2016), Askar et al.
(2017)

Credit for slides: R. Sarwar

It all started with Sara Heap...

who told Norbert Langer, who told me...

and then Carolina came along:

THE ASTROPHYSICAL JOURNAL LETTERS, 801:L28 (6pp), 2015 March 10

[doi:10.1088/2041-8205/801/2/L28](https://doi.org/10.1088/2041-8205/801/2/L28)

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THE EXTENDED He II $\lambda 4686$ -EMITTING REGION IN IZw 18 UNVEILED: CLUES FOR PECULIAR IONIZING SOURCES

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ABSTRACT

New integral field spectroscopy has been obtained for IZw 18, the nearby lowest-metallicity galaxy considered to be our best local analog of systems forming at high redshift (z). Here we report the spatially resolved spectral map of the nebular He II $\lambda 4686$ emission in IZw 18, from which we derived for the first time its total He II-ionizing flux. Nebular He II emission implies the existence of a hard radiation field. He II-emitters are observed to be more frequent among high- z galaxies than for local objects. Therefore, investigating the He II-ionizing source(s) in IZw 18 may reveal the ionization processes at high z . He II emission in star-forming galaxies has been suggested to be mainly associated with Wolf-Rayet stars (WRs), but WRs cannot satisfactorily explain the He II-ionization at all times, particularly at the lowest metallicities. Shocks from supernova remnants, or X-ray binaries, have been proposed as additional potential sources of He II-ionizing photons. Our data indicate that conventional He II-ionizing sources (WRs, shocks, X-ray binaries) are not sufficient to explain the observed nebular He II $\lambda 4686$ emission in IZw 18. We find that the He II-ionizing radiation expected from models for either low-metallicity

He-II ionization in IZw18 (NW region)

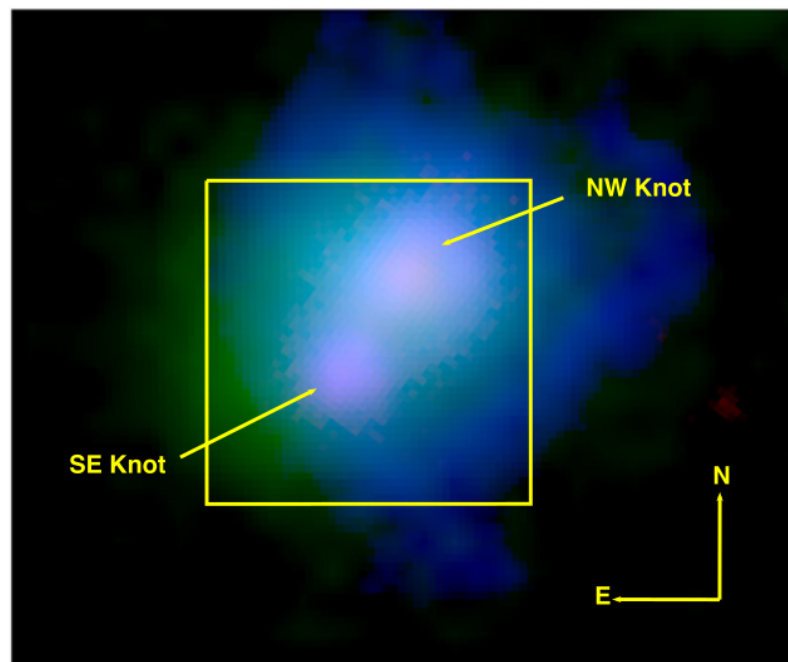
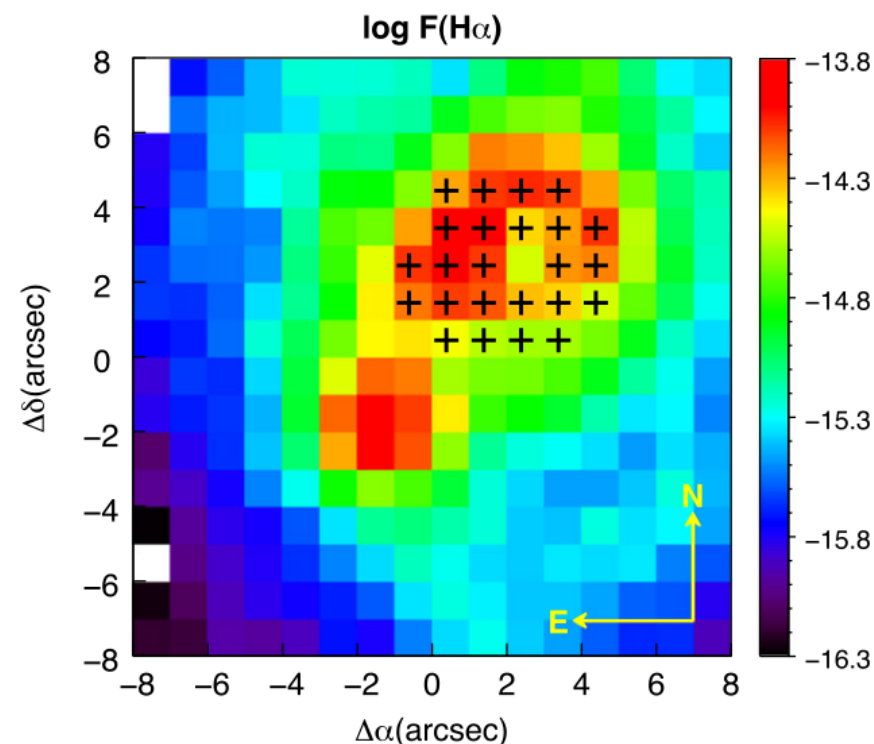


Figure 1. Color-composite image of IZw 18 (blue = H α from Palomar, green = far-UV/GALEX, red = SDSS r'). The box represents the FOV (16'' $\times$ 16'') of the PMAS spectrograph over the galaxy main body and the extended H α halo. The PMAS FOV is centered on the coordinates R.A. (J2000.0) = 09^h:34^m:02^s.2 and decl. (J2000.0) = +55 $^{\circ}$:14':25''.



Low-metallicity massive single stars with rotation

Evolutionary models applicable to I Zwicky 18^{★,★★}

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Received 27 May 2015 / Accepted 29 June 2015

ABSTRACT

Context. Low-metallicity environments such as the early Universe and compact star-forming dwarf galaxies contain many massive stars. These stars influence their surroundings through intense UV radiation, strong winds and explosive deaths. A good understanding of low-metallicity environments requires a detailed theoretical comprehension of the evolution of their massive stars.

Aims. We aim to investigate the role of metallicity and rotation in shaping the evolutionary paths of massive stars and to provide

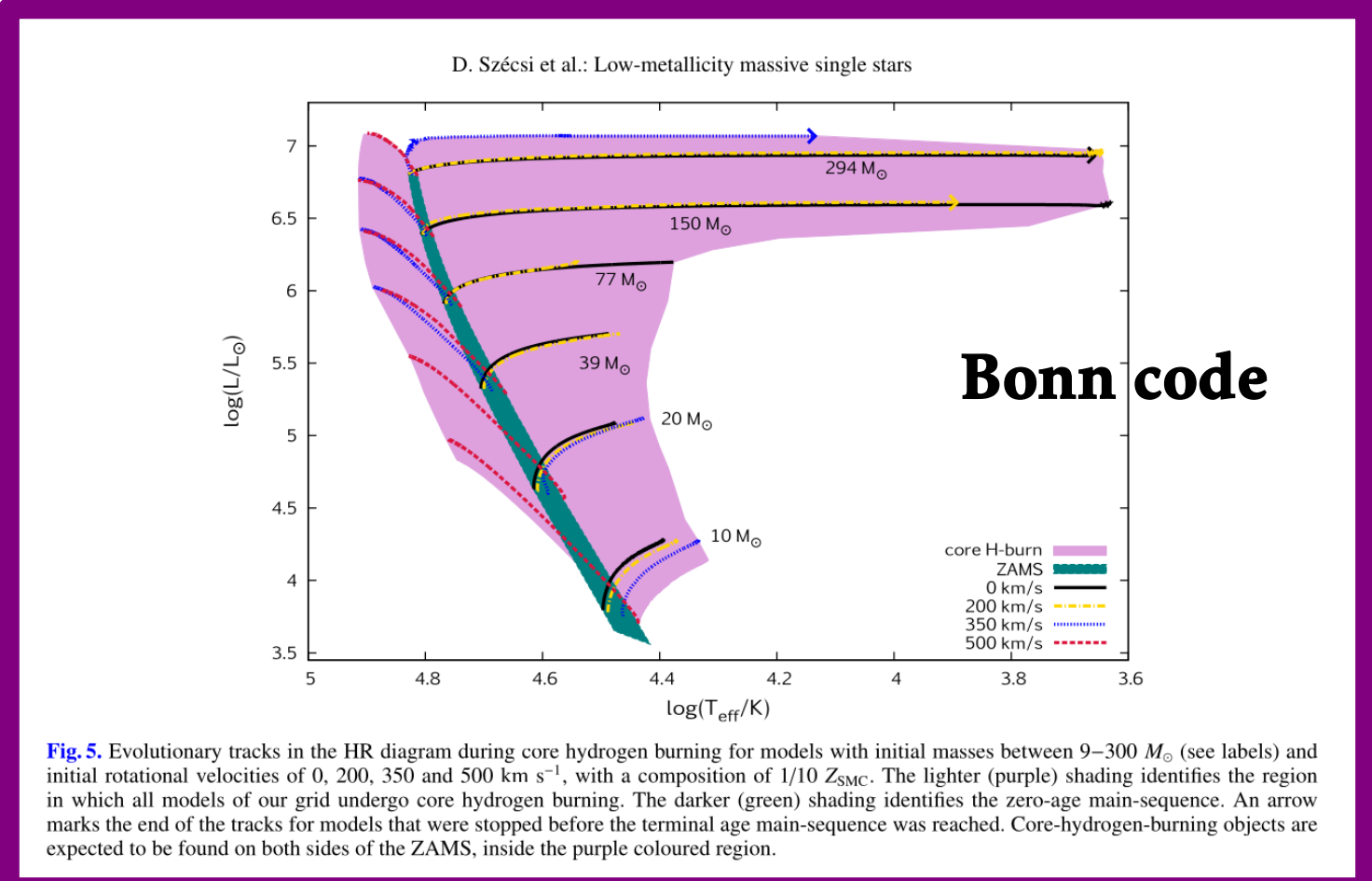


Fig. 5. Evolutionary tracks in the HR diagram during core hydrogen burning for models with initial masses between 9–300 $M_{\odot}$ (see labels) and initial rotational velocities of 0, 200, 350 and 500 km s^{-1} , with a composition of 1/10 Z_{SMC} . The lighter (purple) shading identifies the region in which all models of our grid undergo core hydrogen burning. The darker (green) shading identifies the zero-age main-sequence. An arrow marks the end of the tracks for models that were stopped before the terminal age main-sequence was reached. Core-hydrogen-burning objects are expected to be found on both sides of the ZAMS, inside the purple coloured region.

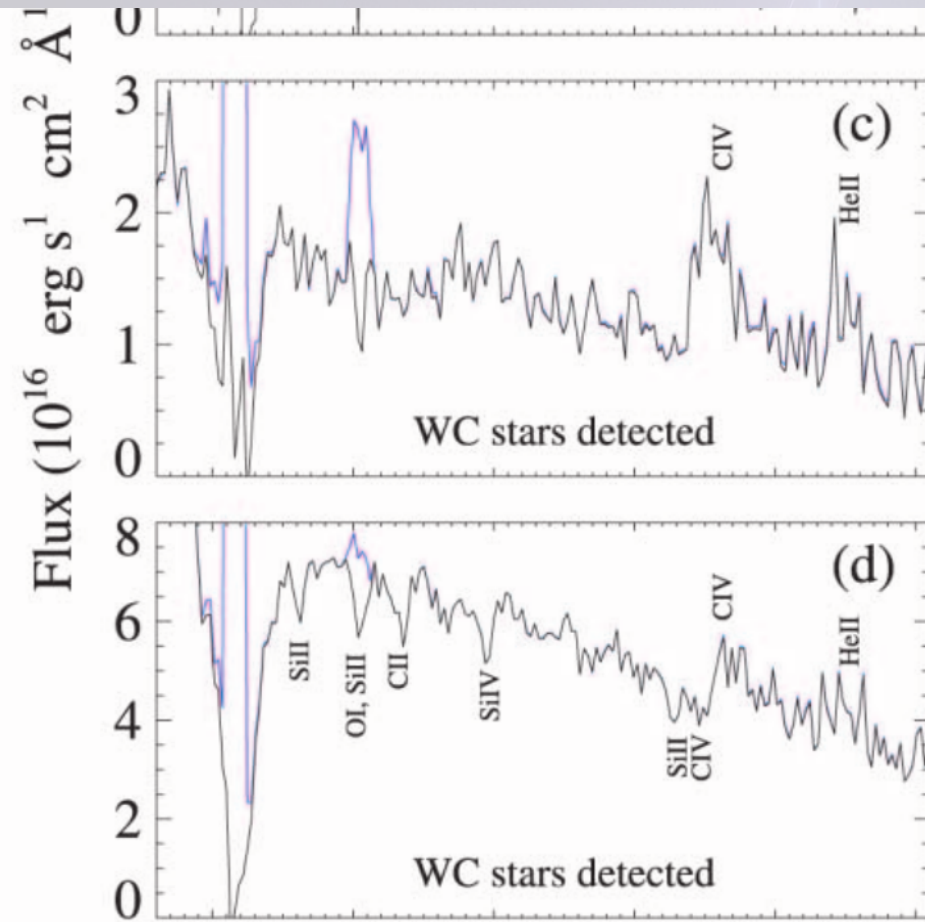
¹ Argelander-Inst.
e-mail: doron
² Department of
³ Astronomical
⁴ UK Astronomical

Received 27 March 2015

Context. Low-metallicity massive stars influence their surroundings through intense UV radiation, strong winds and explosive deaths. A good understanding of low-metallicity environments requires a detailed theoretical comprehension of the evolution of their massive stars.

Aims. We aim to investigate the role of metallicity and rotation in shaping the evolutionary paths of massive stars and to provide

There are *some* WCs...



Brown+02

Brankica came along...

The “TWUIN collaboration”

A&A 623, A8 (2019)

<https://doi.org/10.1051/0004-6361/201834360>

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**Astronomy
&
Astrophysics**

Low-metallicity massive single stars with rotation

II. Predicting spectra and spectral classes of chemically homogeneously evolving stars

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⁶ Ústav teoretické fyziky a astrofyziky, Masarykova univerzita, Kotlářská 267/2, 611 37 Brno, Czech Republic

⁷

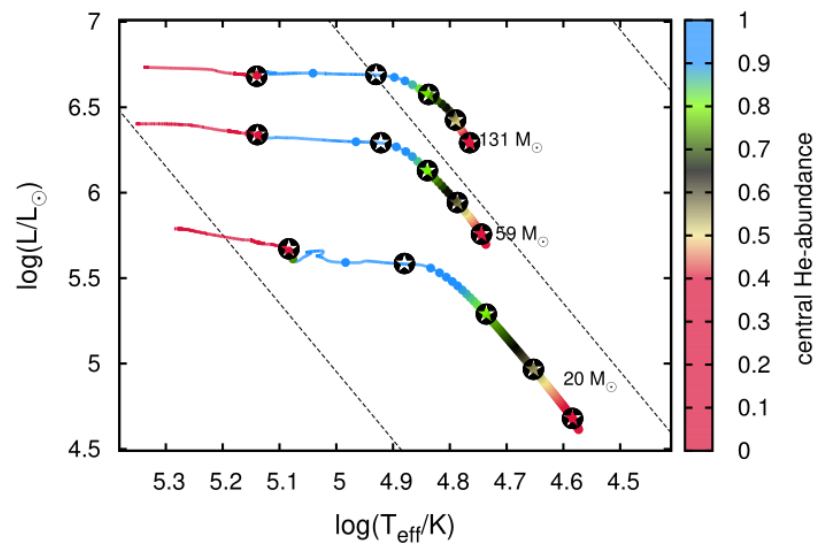


Fig. 1. HR diagram of our models (black symbols) and their corresponding evolutionary sequences. The sequences are taken from Paper I and Szécsi (2016). Initial masses are labeled, showing where the tracks start their evolution, proceeding toward the hot side of the diagram. Colors show the central helium mass fraction, and dots represent every 10^5 years of evolution. Dashed lines mark equiradial lines with 1, 10, and $100 R_{\odot}$ from left to right. The black symbols represent the models for which we computed synthetic spectra. From right to left: black symbols correspond to evolutionary phases with surface helium mass fractions of 0.28, 0.5, 0.75, and 0.98, and the fifth symbol on the very left corresponds to a central helium mass fraction of 0.5, i.e., the middle of the CHeB phase.

PoWR code

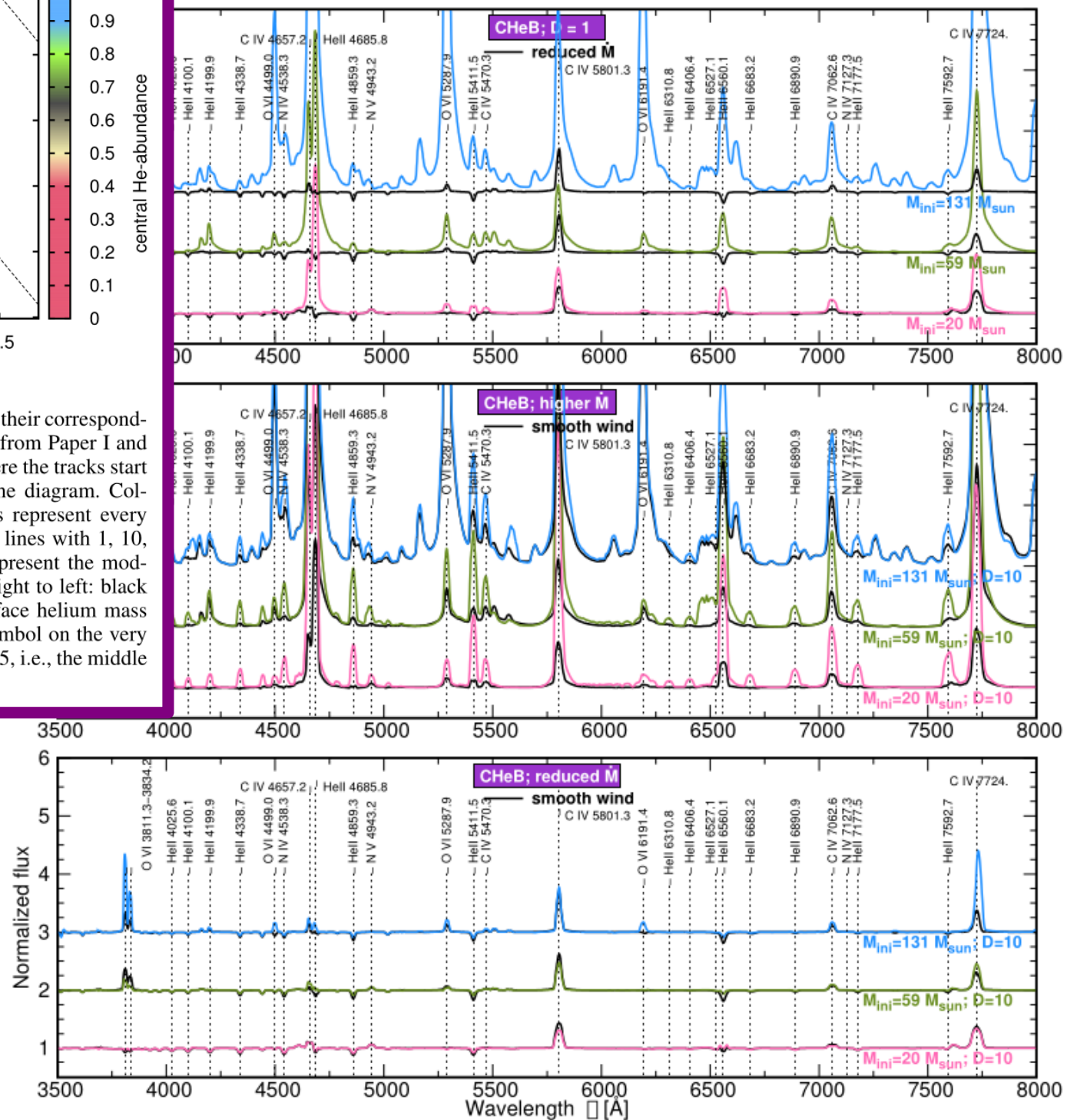
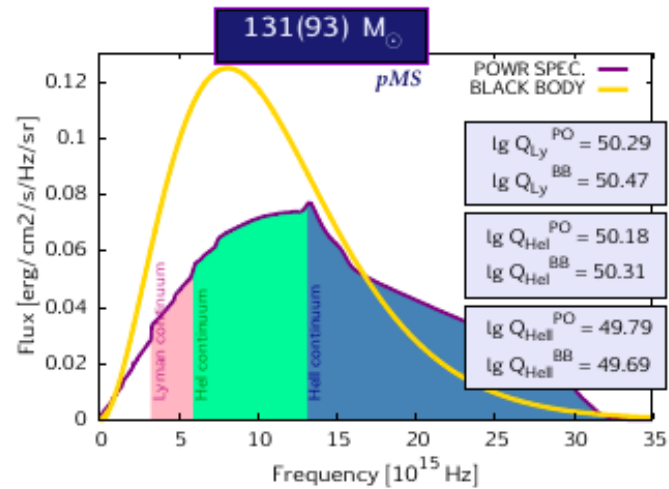
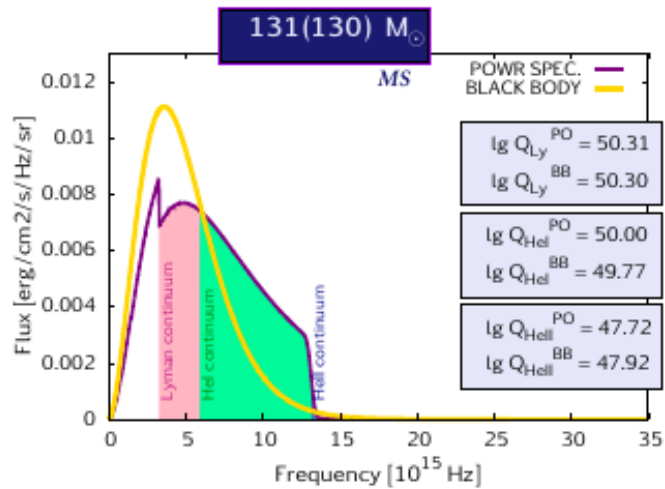
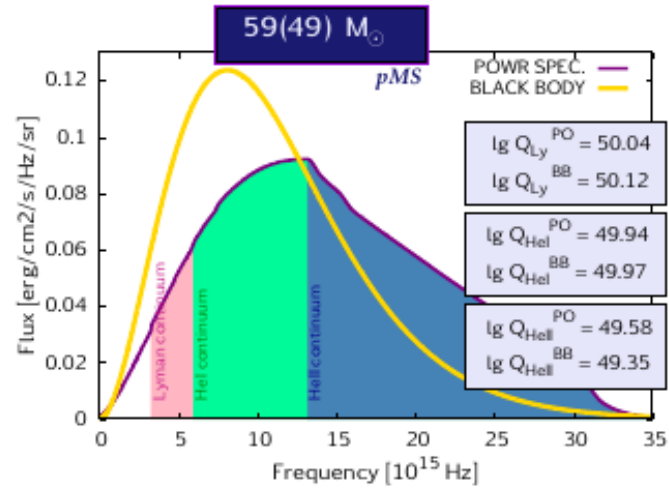
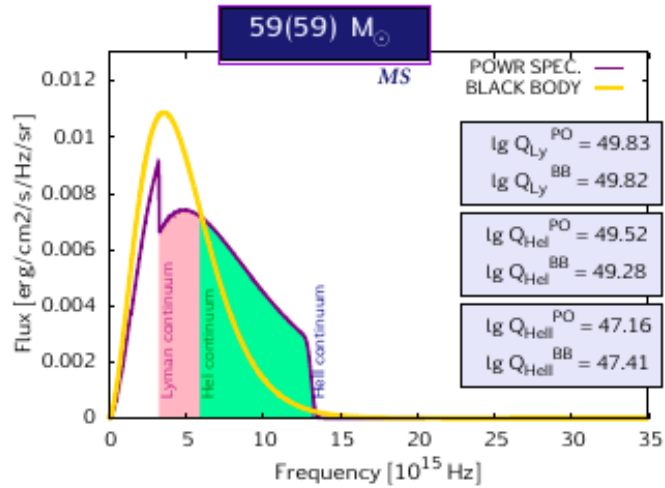
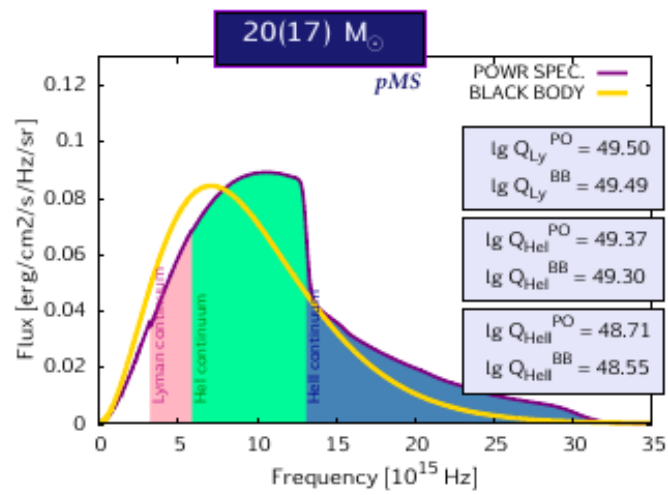
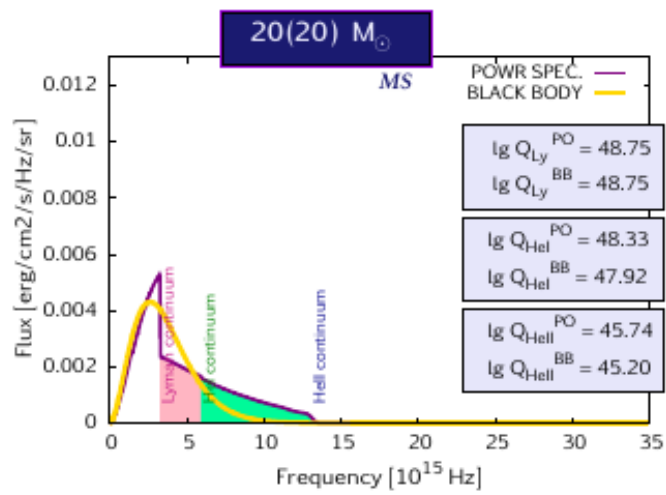


Fig. 4. Top panel: same as Fig. 3, but for the CHeB evolutionary phase with $Y_{\odot}$ as given in Table 1. Middle and lowest panels: same as the top



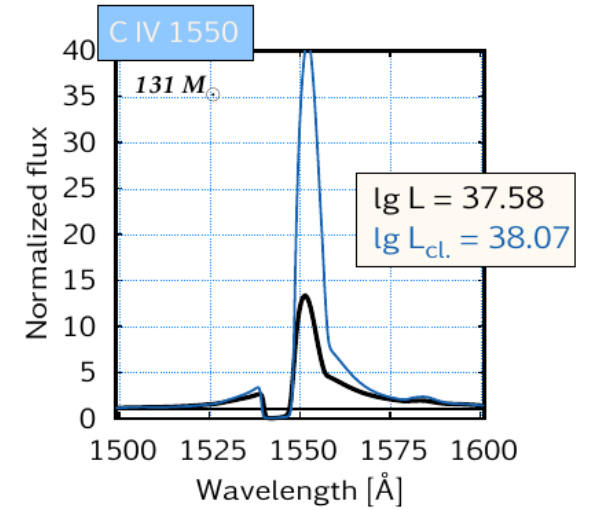
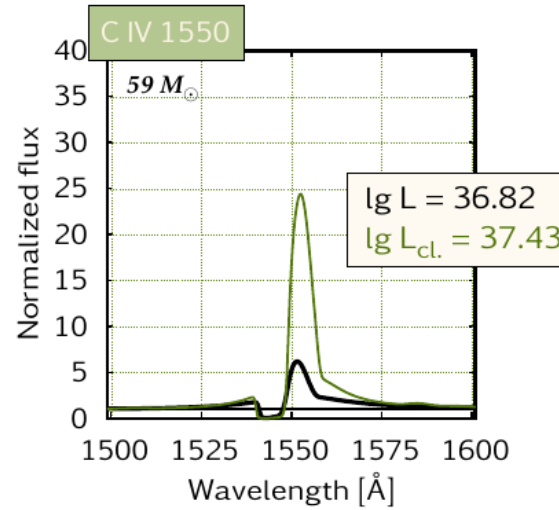
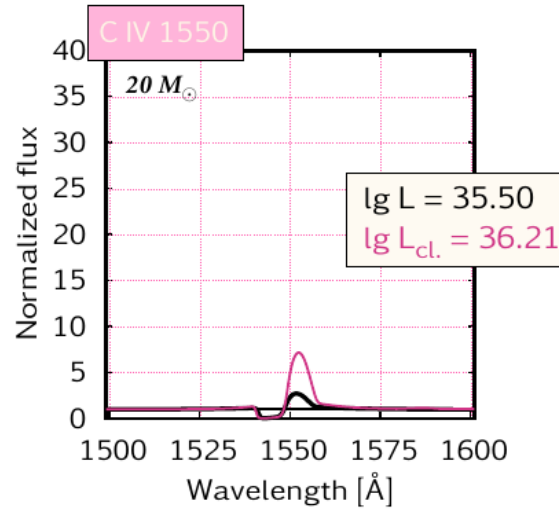
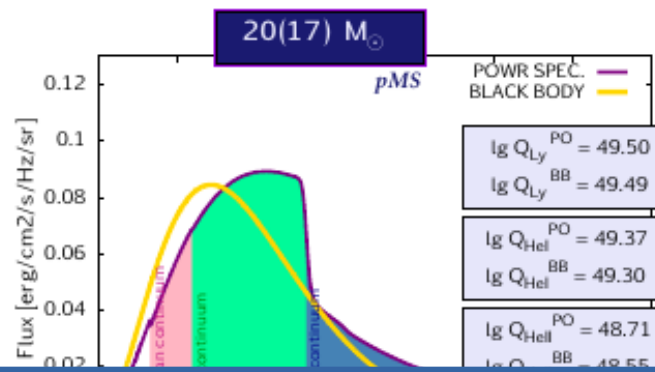
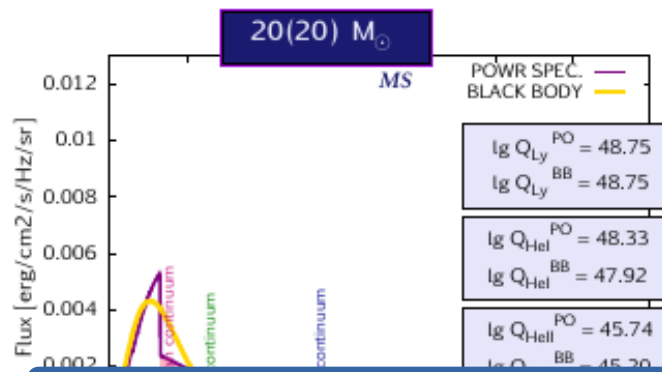
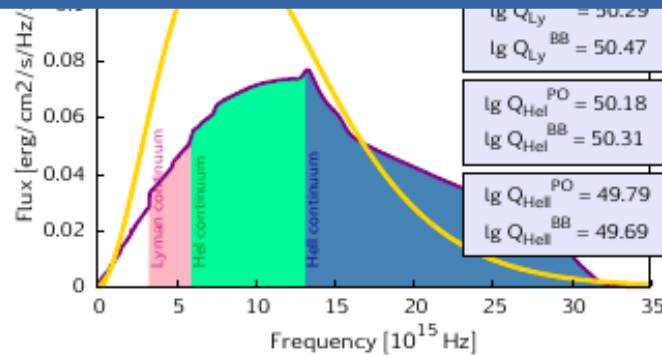
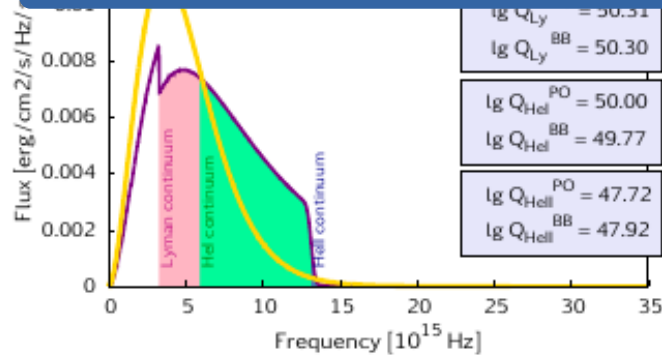


Fig. 3. Normalized flux around the UV-line C IV $\lambda 1550 \text{ Å}$ in three spectral models with initial masses as indicated in the top left corner of the panels. Line luminosity (computed by integrating the area under the line) is given in the framed boxes in units of $\log(\text{erg s}^{-1})$; $\lg L$ stands for unclumped (clumping factor $D = 1$) while $\lg L_{\text{cl.}}$ for clumped ($D = 10$) wind, see details in [Paper II](#). When creating the synthetic population here (Sect. 2.2 and Sect. 3.1), we always apply the unclumped models' predictions (i.e. black line). Other emission lines are presented in Figs. A.1-A.2.



3rd paper submitted in 2019...

Astronomy & Astrophysics manuscript no. output
April 25, 2019

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LETTER TO THE EDITOR

Chemically homogeneously evolving stars as the source of photoionization and C IV emission in dwarf starburst galaxies

Low-metallicity massive single stars with rotation. Part III.

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Received April 25, 2019; accepted ...

ABSTRACT

Chemically-homogeneously evolving stars have been proposed to account for several exotic phenomena, including gamma-ray bursts, gravitational wave emissions and certain types of supernovae. Nonetheless, their existence has not yet been observationally proven. Here we provide a new piece of evidence that these stars may indeed exist in nature. In a metal-poor dwarf galaxy, I Zwicky 18,

Referee report

- OIV 3818 ??
- CIV 5808 ??
- CIV 7724 ?
- HeII4686 ?
- **UV** OVI 1037
- HeII 1640, OVI 2070, also CIV 1550... ??????

*...explain all available observations
from the literature*





No one knows if CHE stars exist...

- GW (-emitting compact object) progenitors
- lGRB progenitors
- supernova Ib/c
- ...

direct observations missing!!

**Basically looking for the parent stars of
Gravitational Waves...**

What to do if you don't know stg?

What to do if you don't know stg?

- ASK FOR HELP

Frank Tramper (CSIC-INTA, Spain / KU Leuven)

Miriam Garcia (CSIC-INTA, Spain)

Brankica Kubátová (ASU CAS, Prague)

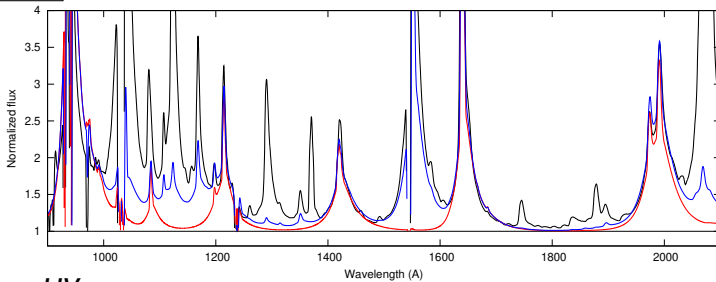
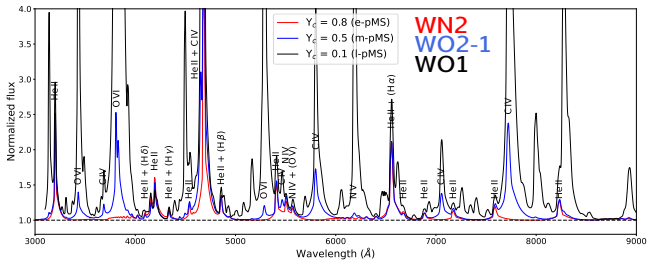
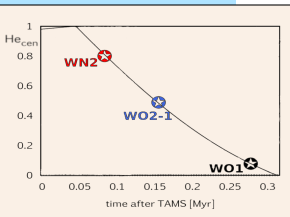
Carolina Kehrig (IAA/CSIC, Spain / MCTIC Brazil)

Jiří Kubát (ASU CAS, Prague)

Jiří Krtička (Masaryk Uni, Brno)

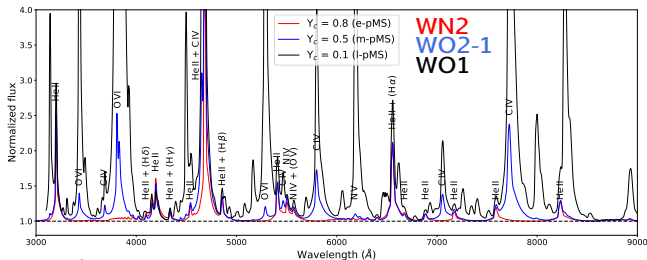
Andreas A.C. Sander (Uni Heidelberg, Germany)

optical



UV

optical



3000 Å

9000 Å

Available measurements:

name of dwarf galaxy:

←————→
Izotov+97 (MMTO 6.5m) 3700 Å–6800 Å

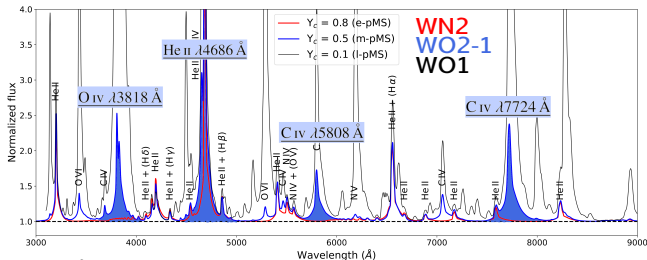
I Zwicky 18

$\longleftrightarrow$
Kehrig+15 (PMAS 3.5m, *integrated field*) 4440 Å–5200 Å

Thuan+05 (MMTO 6.5m) 3200 Å–5200 Å

Szécsi+25 (subm.)

optical



3000 Å

9000 Å

Available measurements:

←————→
Izotov+97 (MMTO 6.5m) 3700 Å–6800 Å

name of dwarf galaxy:

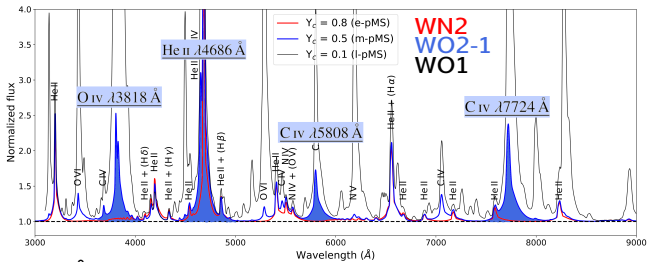
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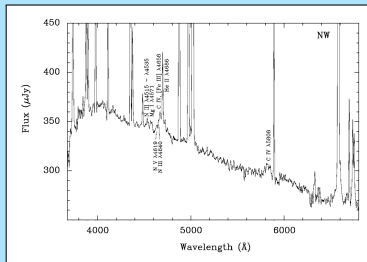
Szécsi+25 (subm.)

optical



3000 Å

9000 Å



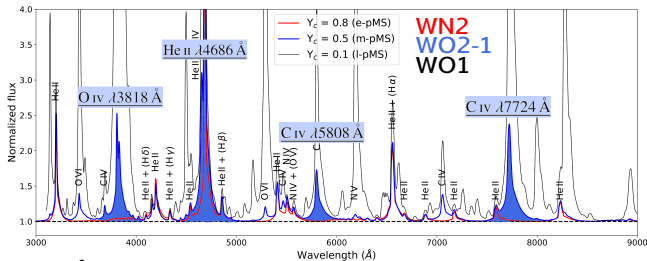
name of dwarf galaxy:

I Zwicky 18

Izotov+97 3700 Å–6800 Å

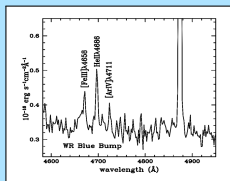
Szécsi+25 (subm.)

optical



3000 Å

9000 Å



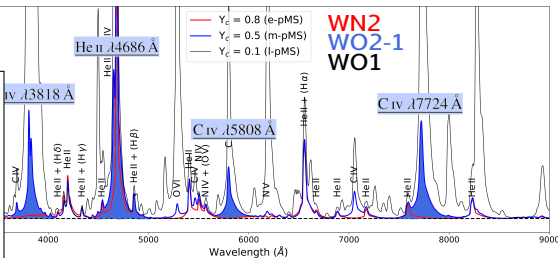
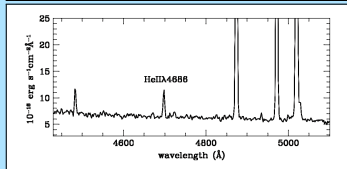
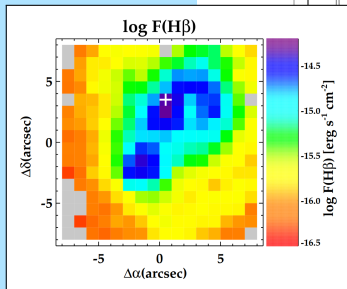
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I Zwicky 18

Kehrig+15 4440 Å–5200 Å

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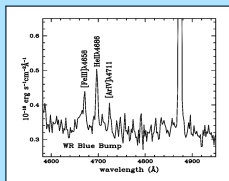
optical



9000 $\text{\AA}$

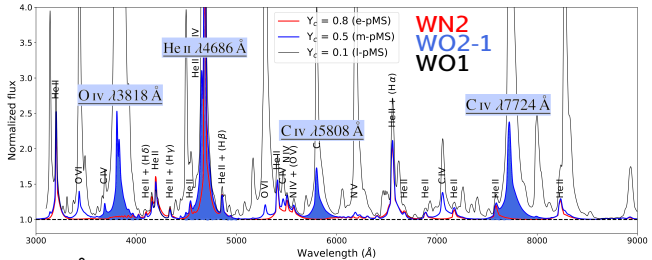
name of dwarf galaxy:

I Zwicky 18



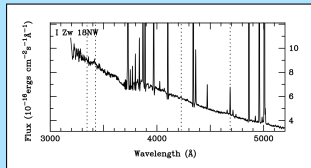
Kehrig+15 4440 $\text{\AA}$ –5200 $\text{\AA}$

optical



3000 $\text{\AA}$

9000 $\text{\AA}$

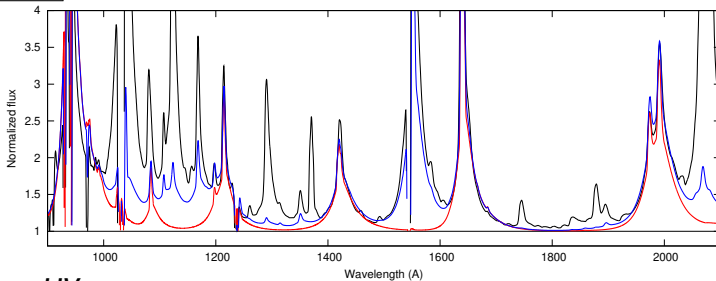
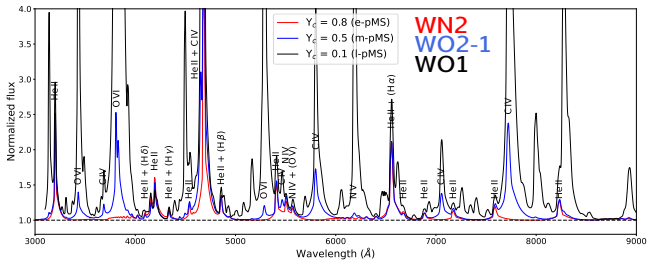
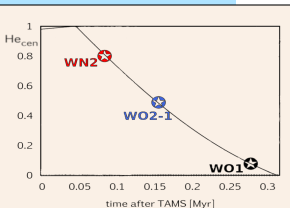


name of dwarf galaxy:

I Zwicky 18

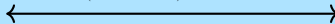
Thuan+05 3200 $\text{\AA}$ –5200 $\text{\AA}$

optical



UV

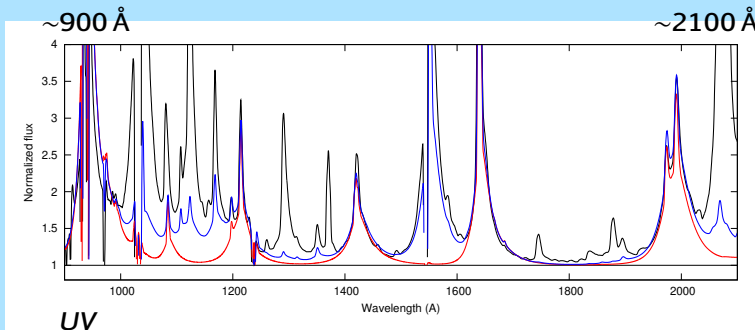
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Lecavelier des Etangs+04 (FUSE) 910 Å–1185 Å



Heap+15/Berg+22 (HST COS) 1160 Å–1645 Å



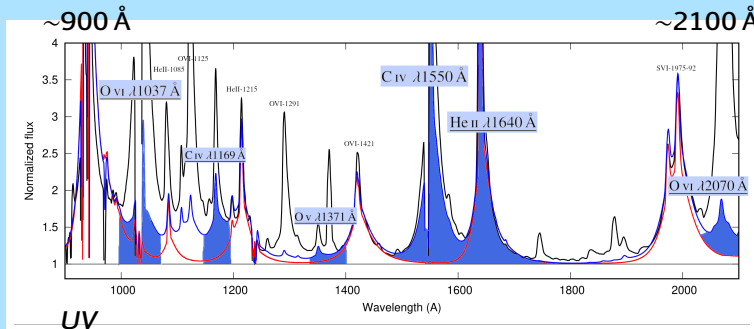
Brown+02 (HST STIS) 1160 Å–1710 Å



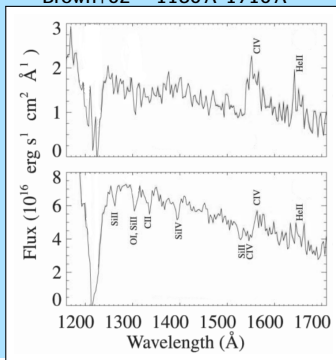
Lecavelier des Etangs+04 (FUSE) 910 Å–1185 Å



Heap+15/Berg+22 (HST COS) 1160 Å–1645 Å

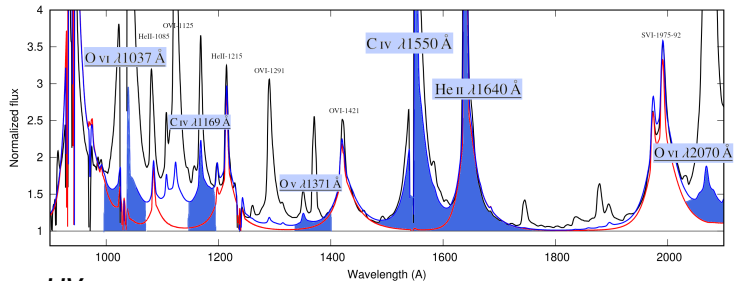


Brown+02 1160 Å–1710 Å



~900 Å

~2100 Å



UV

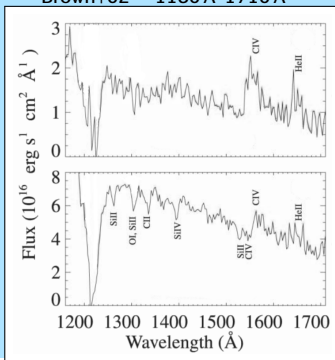
STIS

+55:14:31.21

+55:14:24.04

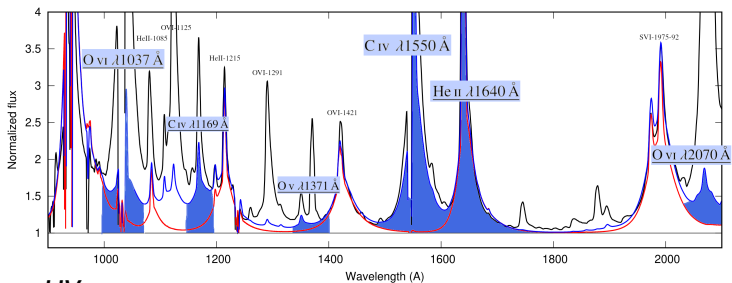
09:34:02.400
09:34:01.920
09:34:01.440

Brown+02 1160 Å–1710 Å



~900 Å

~2100 Å

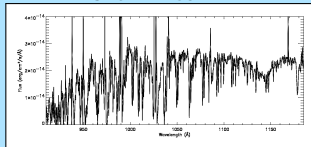


UV

Szécsi+25 (subm.)

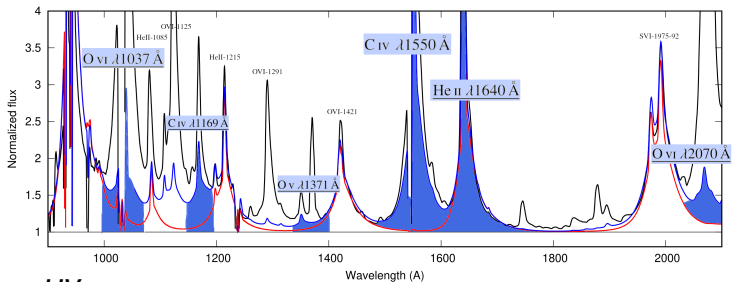
Lecavelier des Etangs+04

910 Å–1185 Å



~900 Å

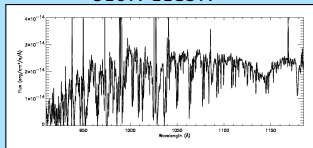
~2100 Å



UV

Lecavelier des Etangs+04

910 Å–1185 Å



FUSE

+55:14:24.02

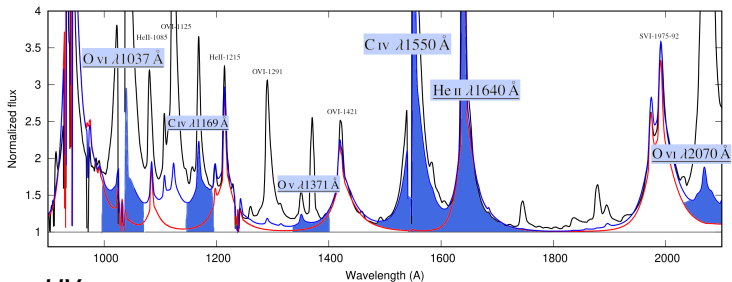
09:34-04.800

09:34-02.400



~900 Å

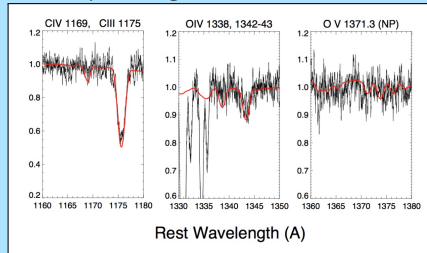
~2100 Å



UV

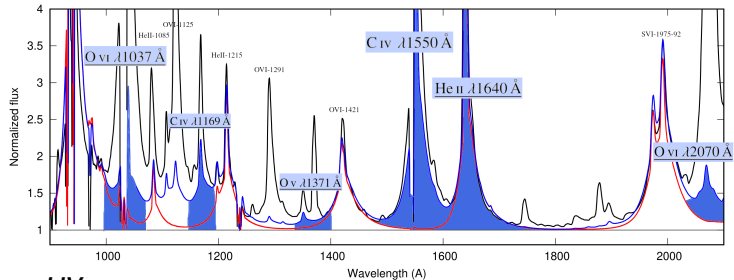
Szécsi+25 (subm.)

Heap+15/Berg+22 1160 Å–1645 Å



~900 Å

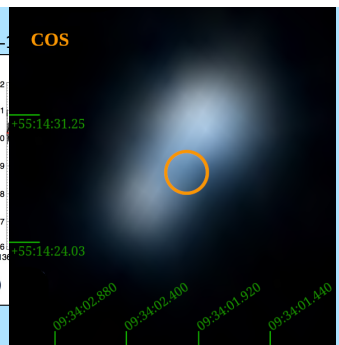
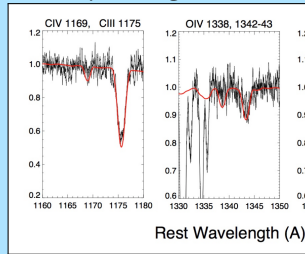
~2100 Å



UV

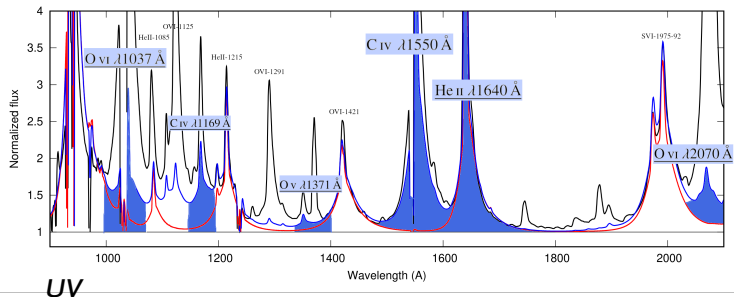
Heap+15/Berg+22 1160 Å

COS

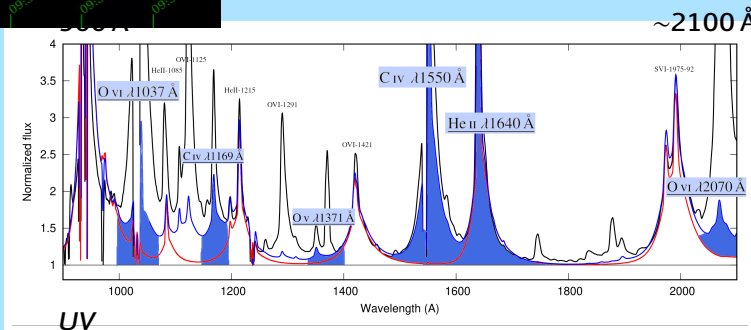
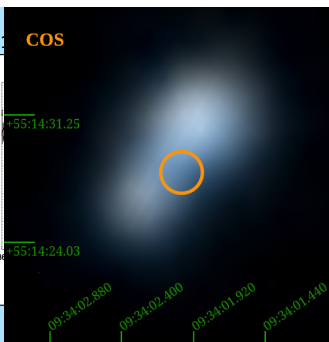
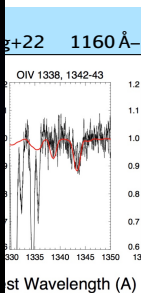


~900 Å

~2100 Å

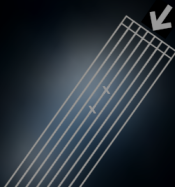


Szécsi+25 (subm.)



STIS

+55:14:31.21



g+22 1160 Å

COS

name of dwarf galaxy:

I Zwicky 18

+55:14:31.25

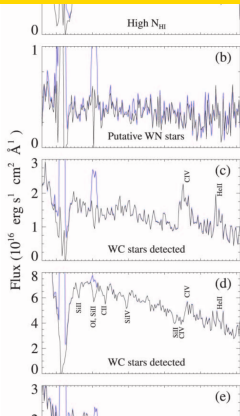
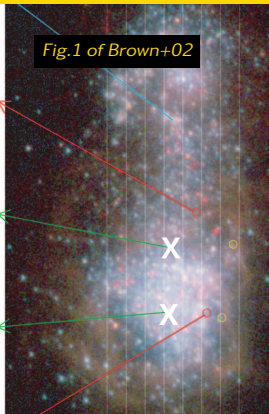


Fig.1 of Brown+02

MAST archive



1000 1200 1400 1600 1800 2000

Wavelength (Å)

UV

Szécsi+25 (subm.)



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Home Page

MAST: IZw18

Displaying 18 of 6136 Total Rows

UGCA 166, radius: 0.00250°

Filters

Clear Filters Edit Filters... Help...

- | Filter | Count |
|---|------------|
| MIRI/FU | (0 of 24) |
| COS/FUV | (0 of 23) |
| ☒ STIS/FUV-MAMA | (16 of 20) |
| SWP | (0 of 15) |
| COS/NUV | (0 of 14) |
| UVOT | (0 of 12) |
| FOS/RD | (0 of 11) |
| ACS/SBC | (0 of 10) |
| STIS/CCD | (0 of 8) |
| ☒ COS | (2 of 7) |
| MIRI/IMAGE | (0 of 7) |
| Photometer | (0 of 5) |
| HRS | (0 of 5) |
| GPC1 | (0 of 5) |
| GALEX | (0 of 4) |

Edit Columns...

Action

1

2

3

4

5

6

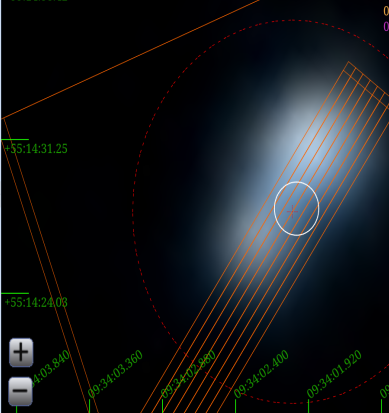
7

8

9

AstroView

World's largest



AstroView Settings

Move To:

 GoGrid Lines: ☐ OnSearch Radius: ☐ On[RA, DEC]: ☐ OnCrosshair: ☐ Off

Background Survey:

DSS

More Surveys:

Select...

Close



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Displaying 18 of 6136 Total Rows

UGCA 166, radius: 0.00250°

Filters

Clear Filters Edit Filters... Help...

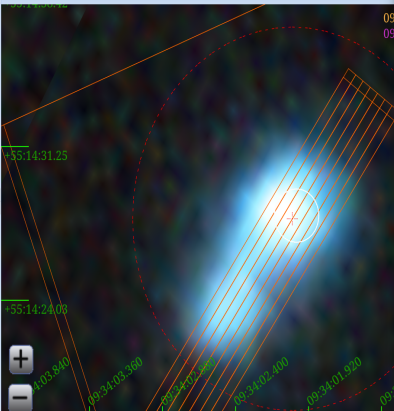
- ☐ MIRI/FU (0 of 24)
- ☐ COS/FUV (0 of 23)
- ☒ STIS/FUV-MAMA (16 of 20)
- ☐ SWP (0 of 15)
- ☐ COS/NUV (0 of 14)
- ☐ UVOT (0 of 12)
- ☐ FOS/RD (0 of 11)
- ☐ ACS/SBC (0 of 10)
- ☐ STIS/CCD (0 of 8)
- ☒ COS (2 of 7)
- ☐ MIRI/IMAGE (0 of 7)
- ☐ Photometer (0 of 5)
- ☐ HRS (0 of 5)
- ☐ GPC1 (0 of 5)
- ☐ GALEX (0 of 4)

List View

Edit Columns...

	Actio
☐	
☐ 1	
☒ 2	
☐ 3	
☐ 4	
☐ 5	
☐ 6	
☐ 7	
☐ 8	
☐ 9	

AstroView



AstroView Settings

Move To:

Go

Grid Lines: ☐ On

Search Radius: ☐ On

[RA, DEC]: ☐ On

Crosshair: ☐ Off

Background Survey:

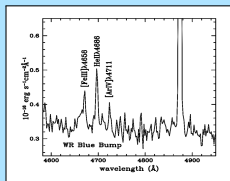
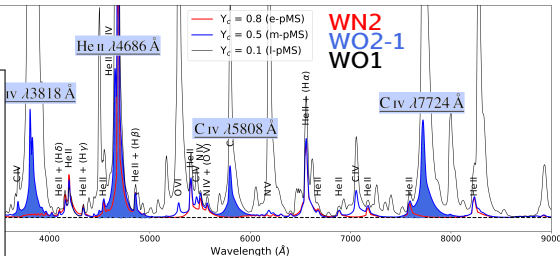
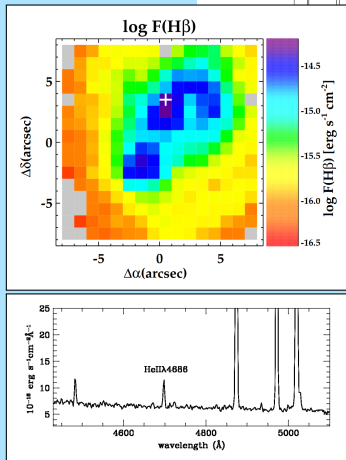
PANSTARRS

More Surveys:

Select...

Close

optical

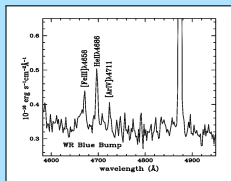
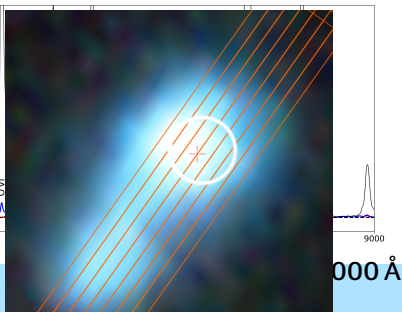
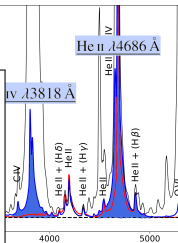
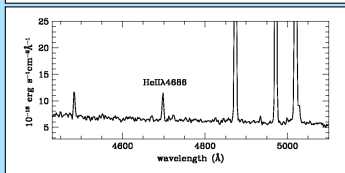
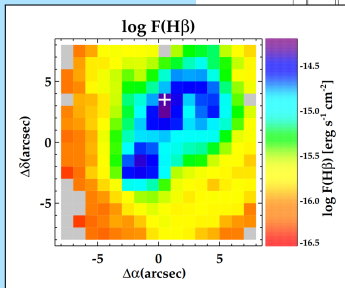


Kehrig+15 4440 $\text{\AA}$ –5200 $\text{\AA}$

name of dwarf galaxy:

I Zwicky 18

optical



Kehrig+15 4440 Å–5200 Å

name of dwarf galaxy:

I Zwicky 18

Conclusions...

- Available observations cannot exclude
chem.hom. GW progenitors in I Zw 18!
- Proving them though?
 - I Zw 18 is in Ursa Major... Northern Hemisphere! → **MUSE**
 - OVI-3818 could be a sign-post (of WO stars,
confirming our theory) → **MEGARA? KECK?**
- do the same for other starburst/dwarf galaxies ...
- do the same for high-z galaxies (JWST) ...

