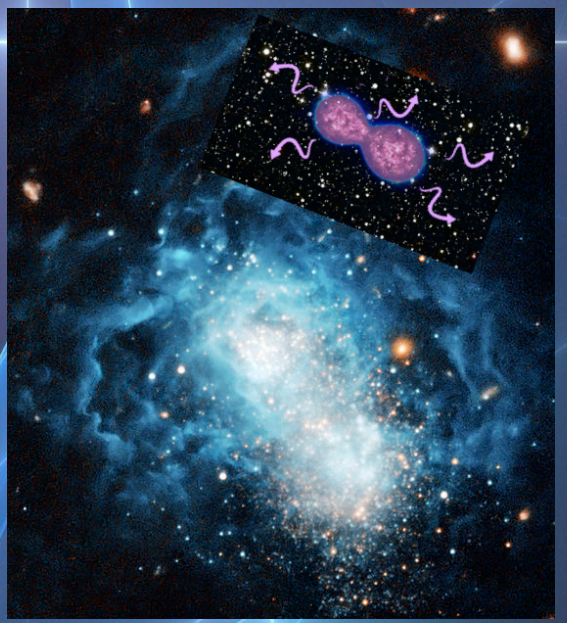
How to spot a GW progenitor

– for the first time ever –

Dorottya Szécsi

Nicolaus Copernicus University



Research summary

9th July 2025

Formation channels of binary black holes:

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

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

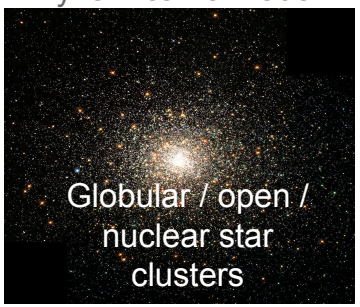
AGN-disks

e.g. Antonini & Perets (2012), Tagawa et al. (2020)

Pop - III

e.g. Inayoshi et al. (2017)

Dynamical formation



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

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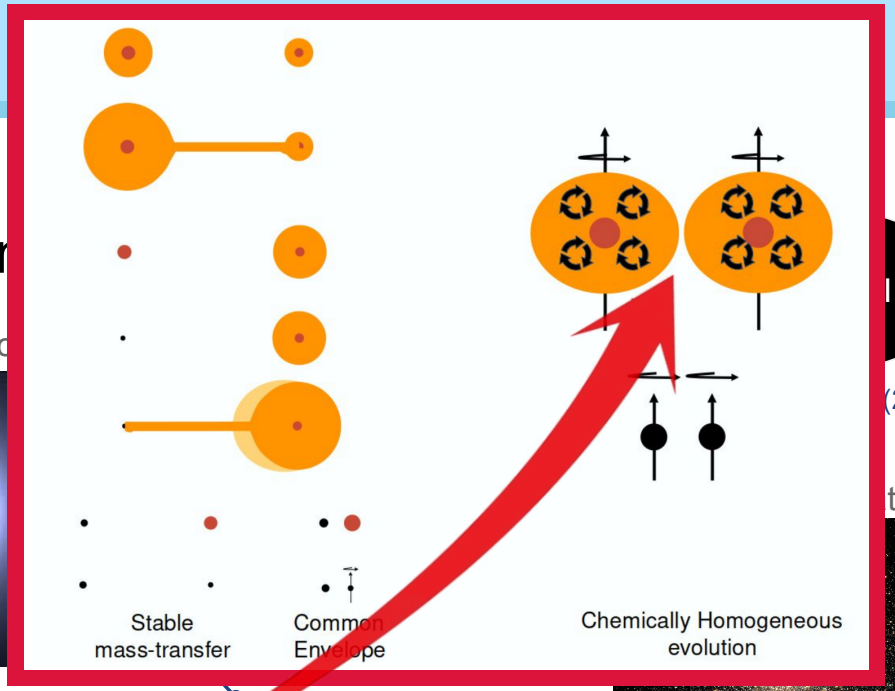

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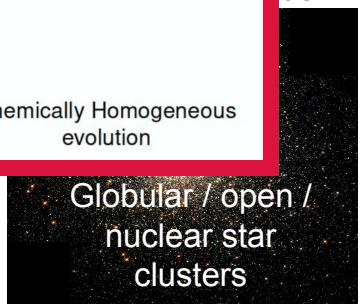

Globular / open / nuclear star clusters

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

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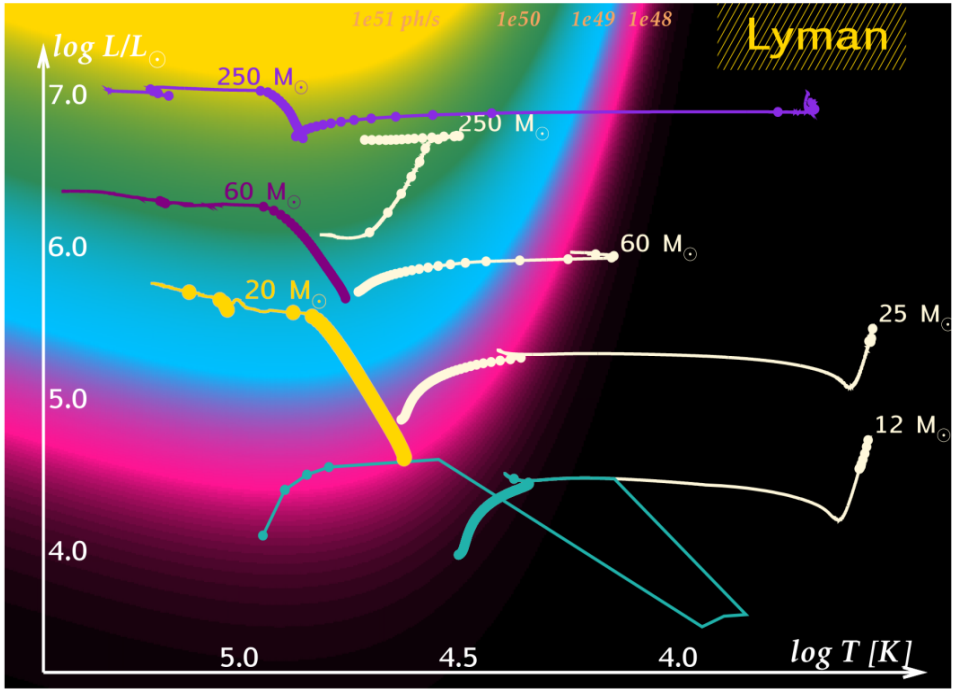
Miriam Garcia (CSIC-INTA, Spain)

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

Jiří Kubát (ASU CAS, Prague)

Jiří Krtička (Masaryk Uni, Brno)

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



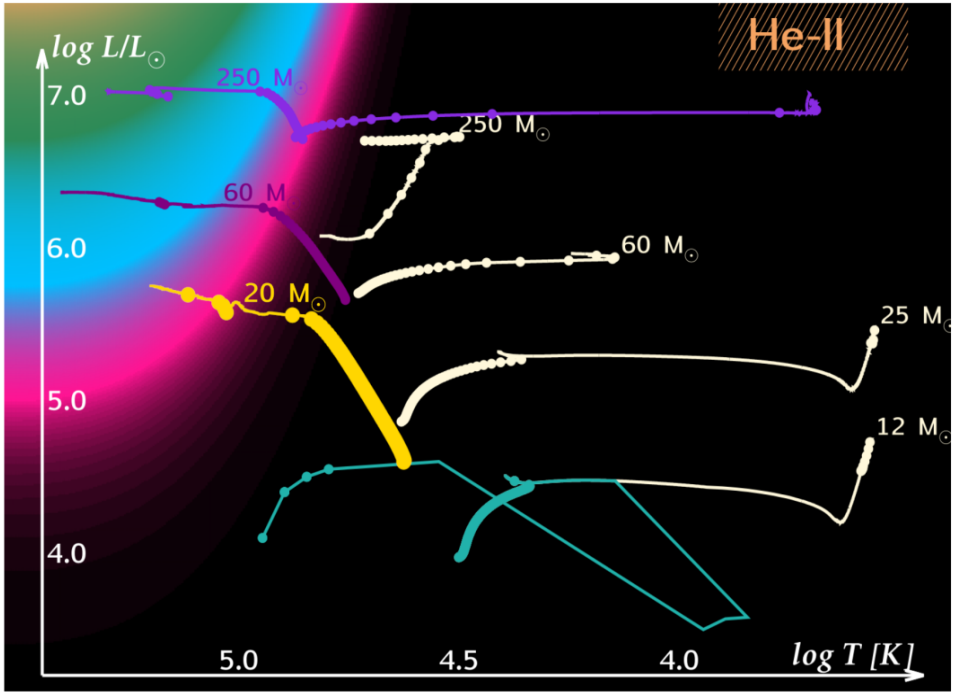
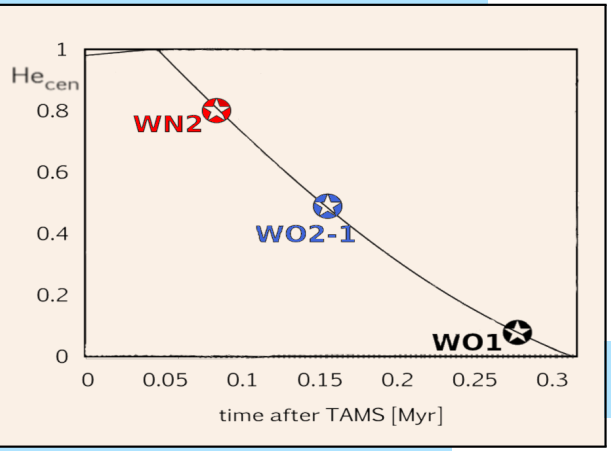
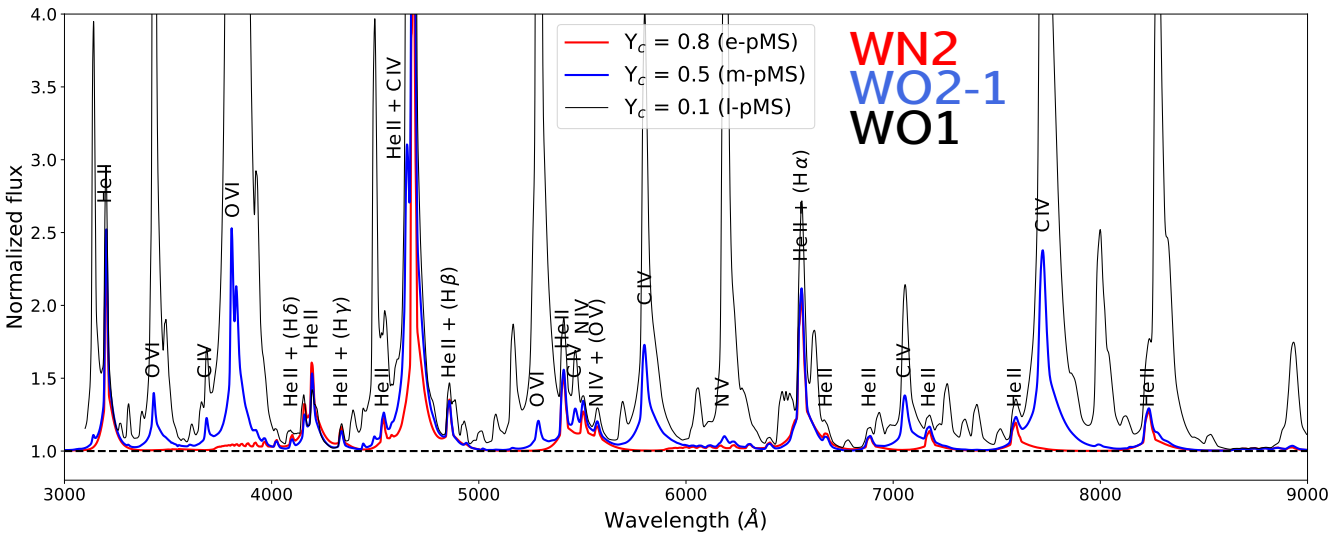


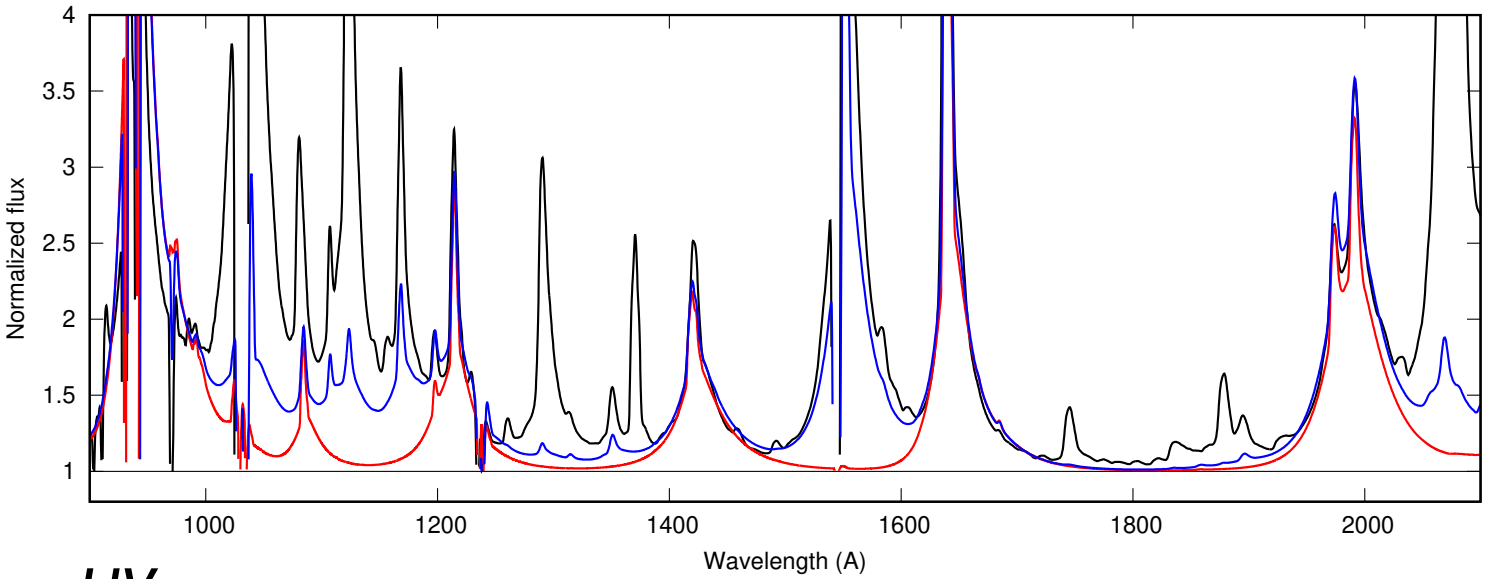
Fig. 7. Hertzsprung–Russell diagrams with background colors representing the number of Lyman (*left*) and He-II (*right*) continuum photons emitted by a black body with a given temperature and luminosity. Units are associated with colors (pink: 10^{48} ph s^{-1}, blue: 10^{49} ph s^{-1}, green: 10^{50} ph s^{-1}, yellow: 10^{51} ph s^{-1}). Stellar evolutionary model sequences are labeled with their initial masses. They are taken from the BoOST project (Szécsi et al. 2022), except for the turquoise line which is a stripped binary model taken from Götberg et al. (2017). White lines mean Milky Way composition, where all models evolve the 'normal' way (although the most massive ones turn to the left eventually: this is classical Wolf–Rayet evolution). Purple and golden lines mean I Zw 18 composition, with one of the very massive models evolving normally (initial rotational velocity of 100 km s^{-1}) and the other chemically homogeneously due to fast rotation (500 km s^{-1}). Every 10^5 yr of evolution is marked with dot on the tracks. Including the 20 $M_\odot$ model into our population synthesis runs (with a sufficiently long star-formation episode, see Table 1) hardens the combined spectra considerably (reaching close to the observed I(4686)/I(β) ~ 0.02), as the late phases of this model enter the pink zone in terms of He-II photons while not leaving the blue zone in terms of Lyman photons. For more details on the population synthesis and spectral hardness, see Sects. 2.3 and 3.2, respectively.

spectra for GW progenitors (with PoWR code): O and WO (!) stars

optical



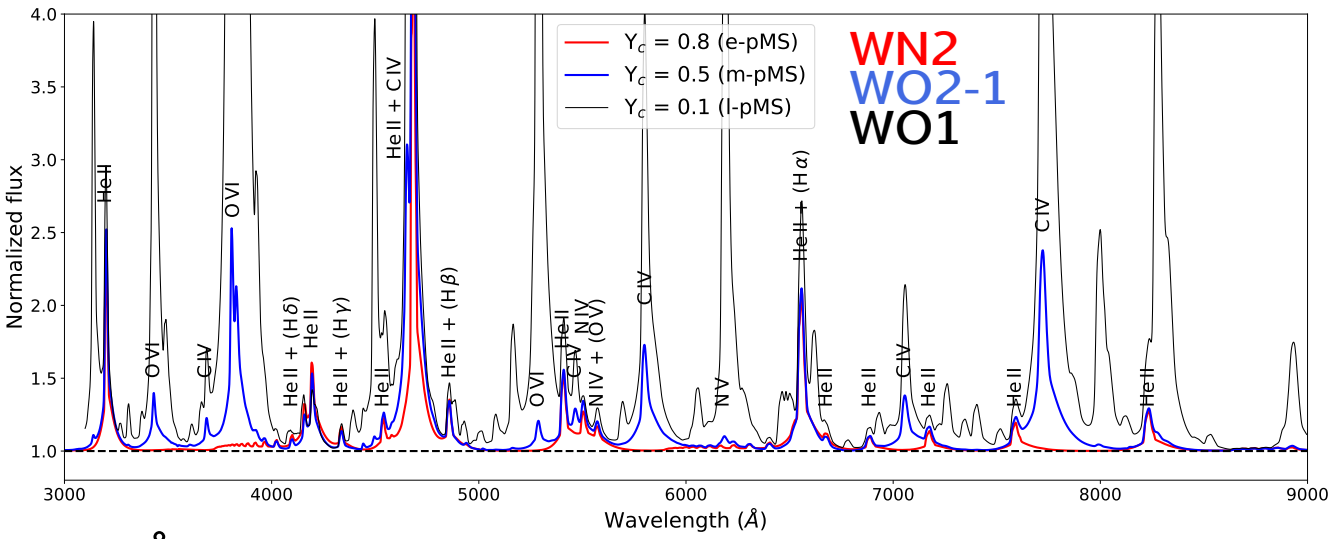




UV

Szécsi+25 (A&A)

optical



3000 Å 9000 Å

Available measurements:

Izotov+97 (MMTO 6.5m) 3700 Å–6800 Å

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

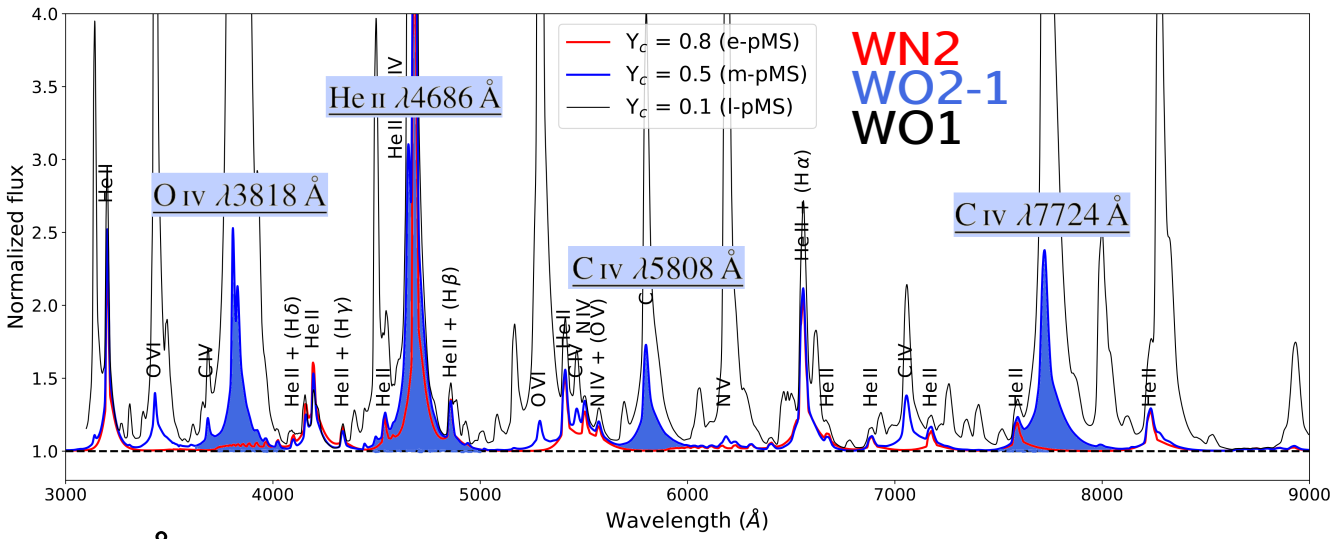
Thuan+05 (MMTO 6.5m) 3200 Å–5200 Å

name of dwarf galaxy:

I Zwicky 18

Szécsi+25 (A&A)

optical



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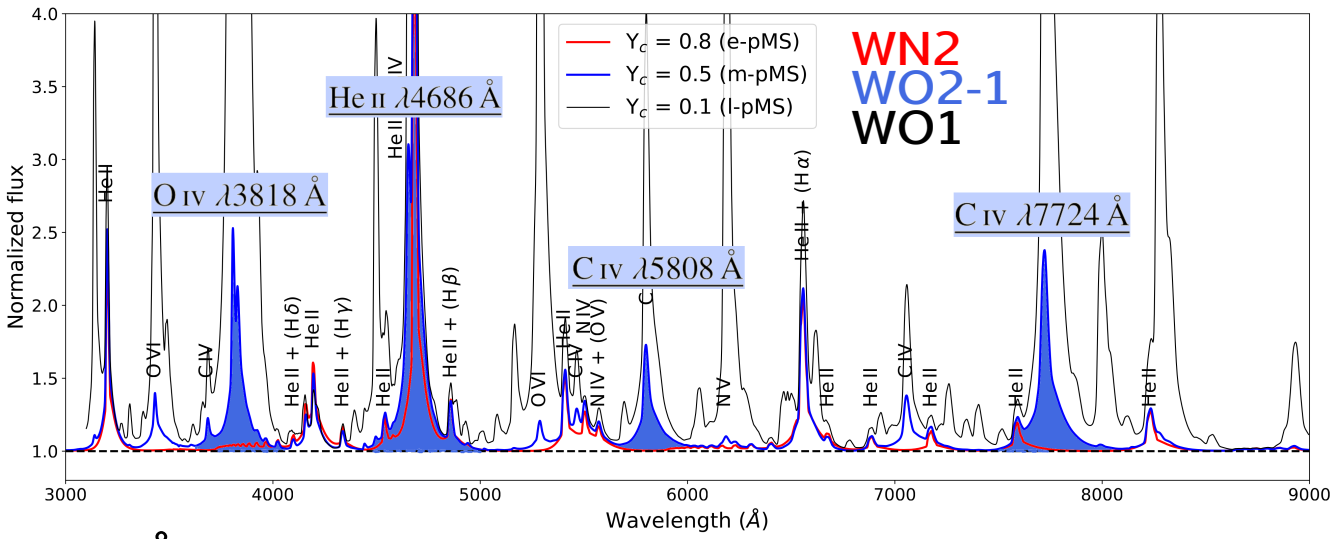

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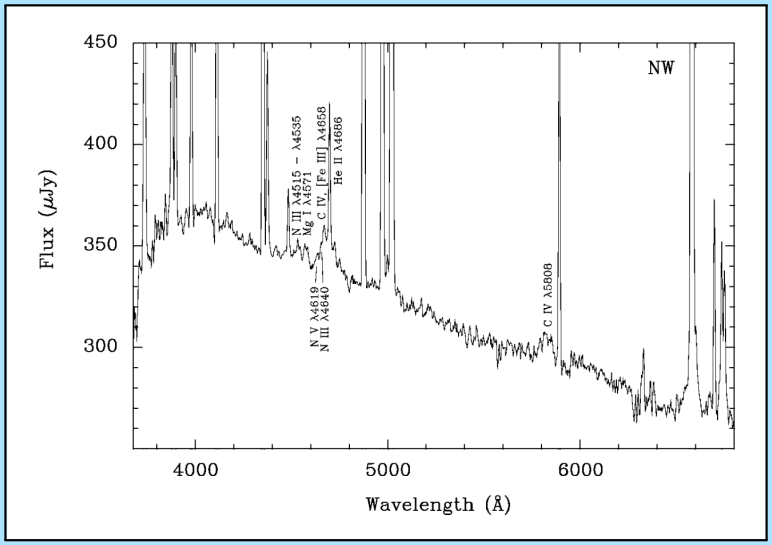

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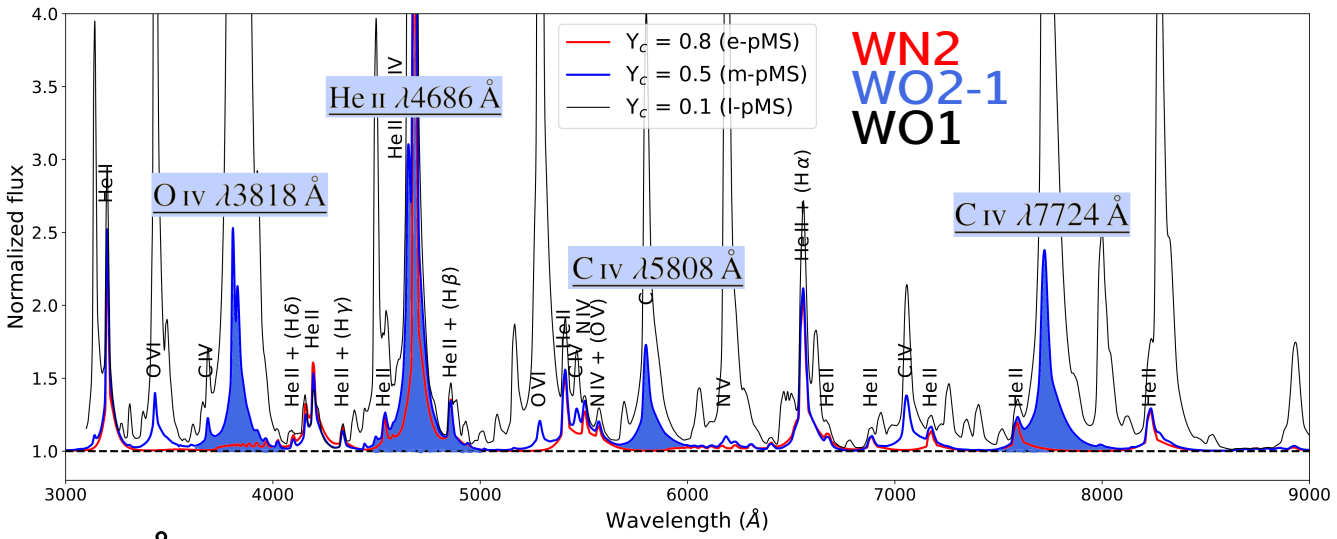

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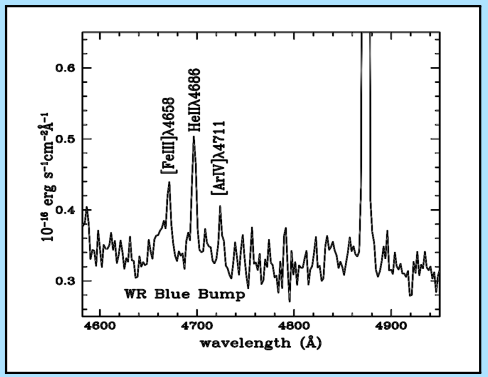

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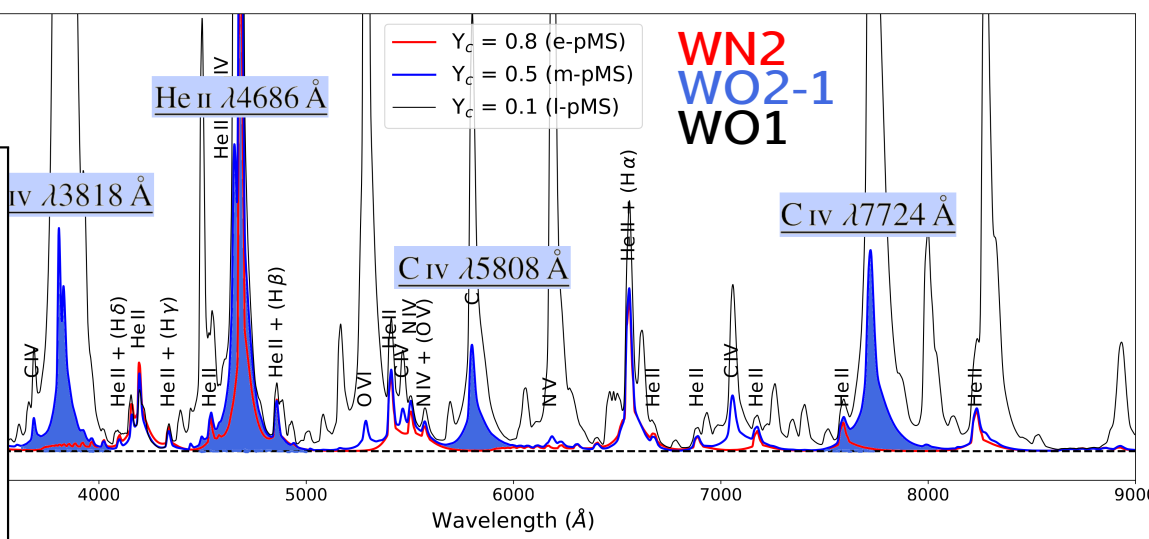

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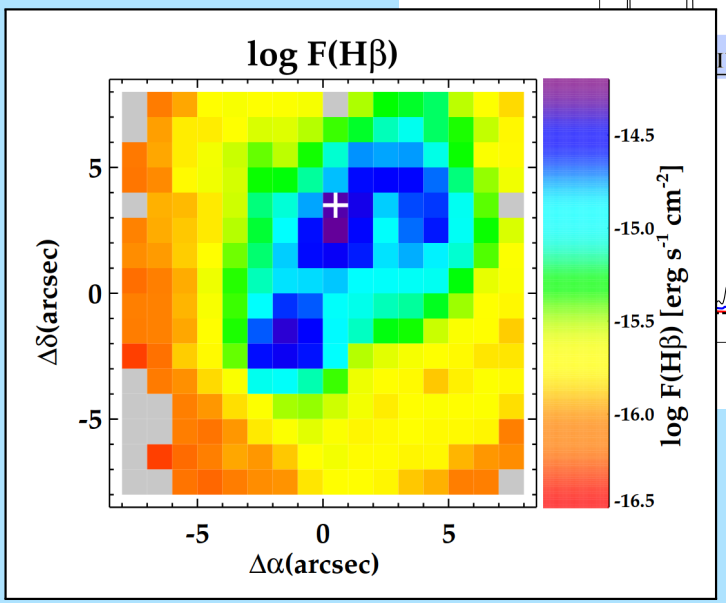

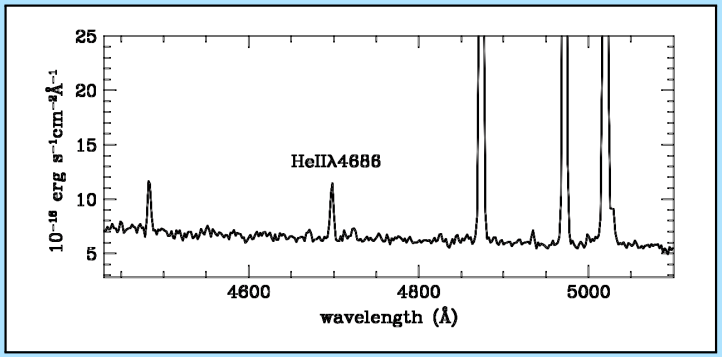

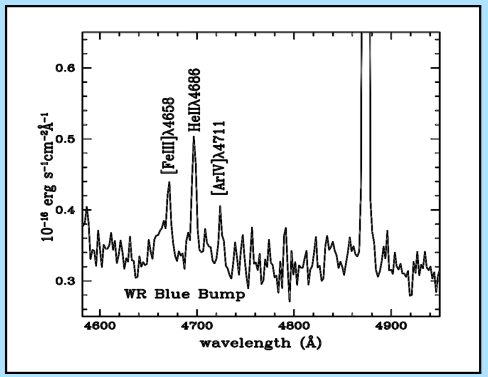

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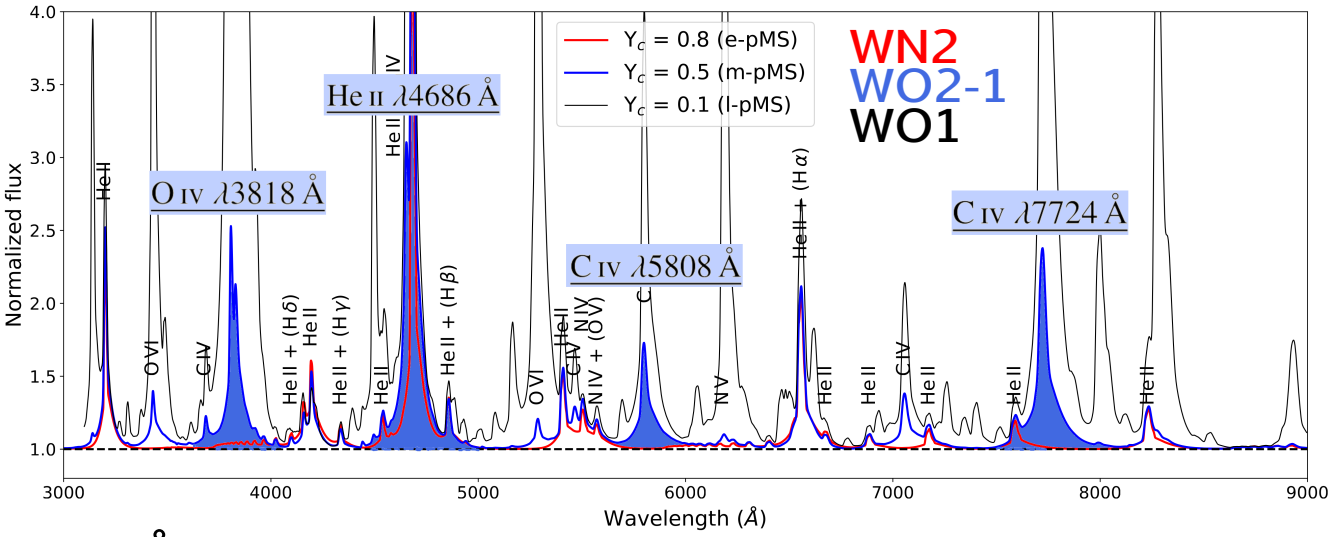

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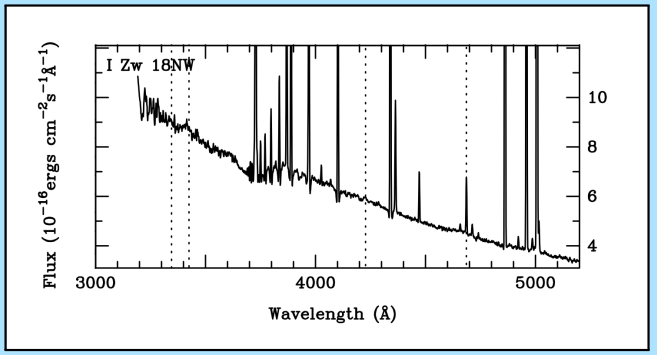

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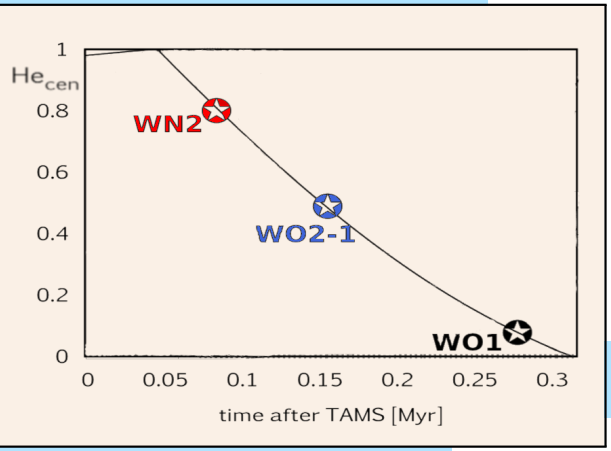

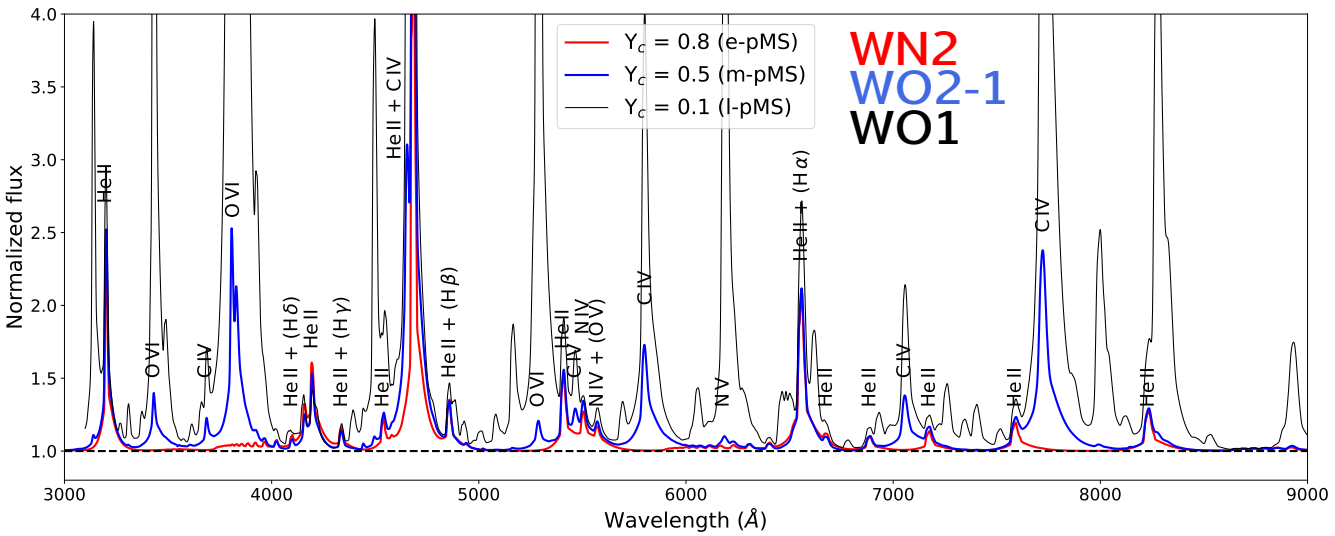

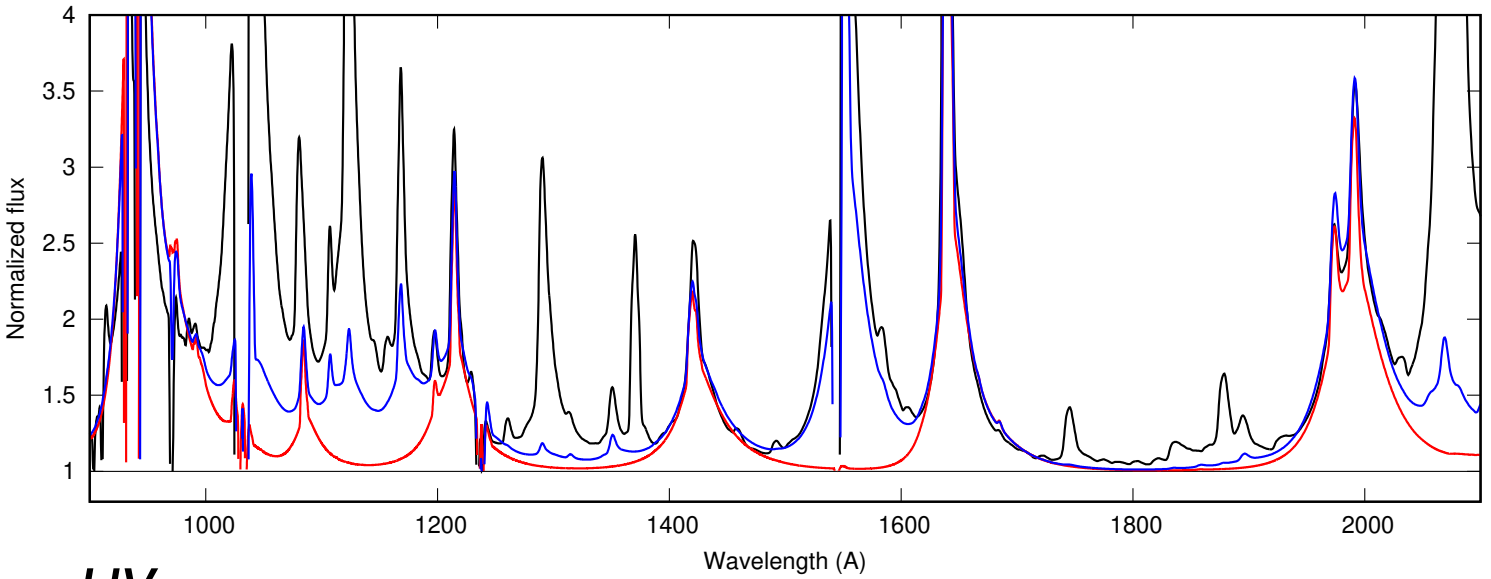

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Brown+02 (HST *STIS*) 1160 Å–1710 Å

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

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

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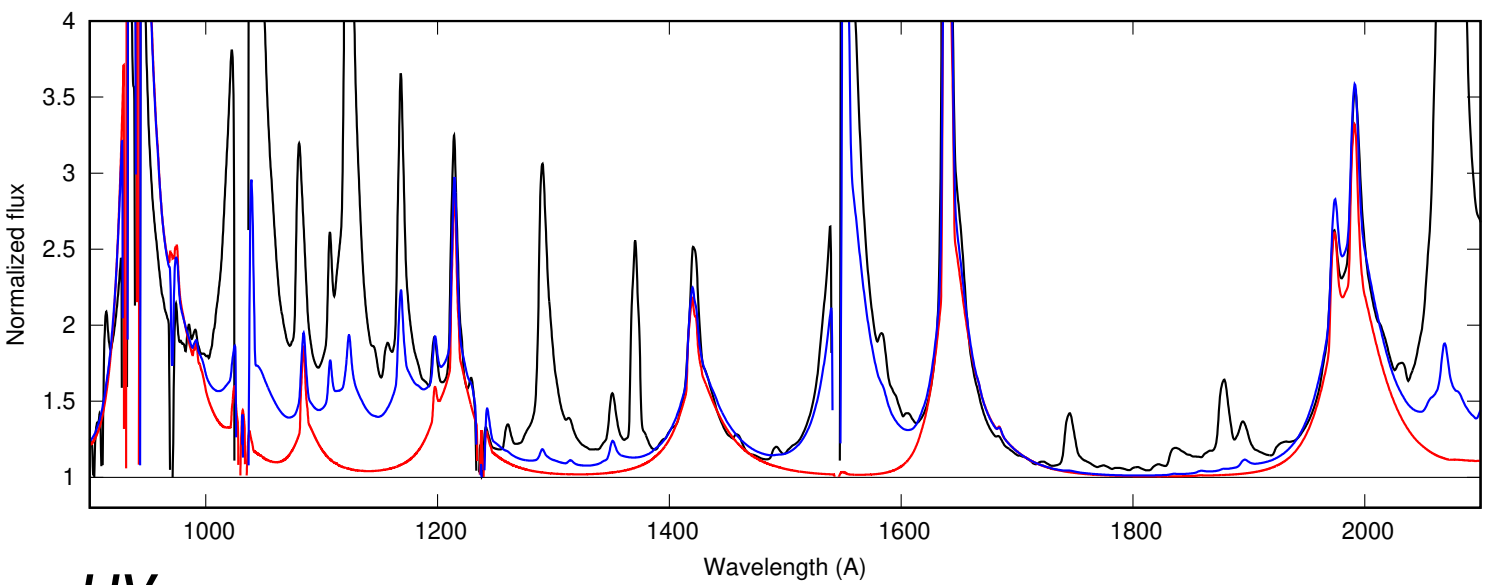

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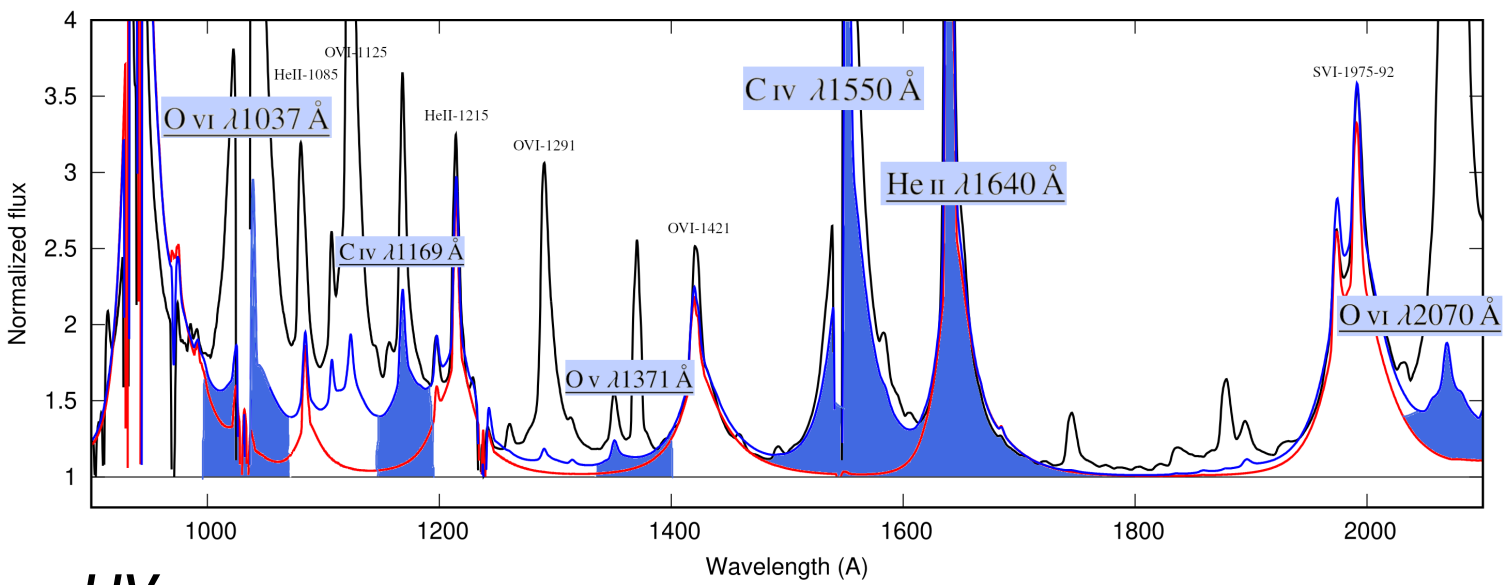

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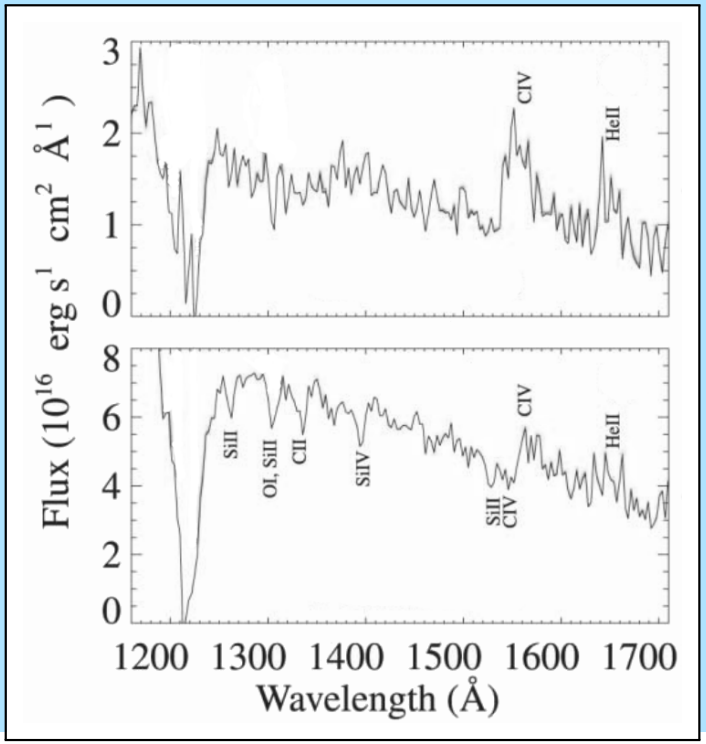

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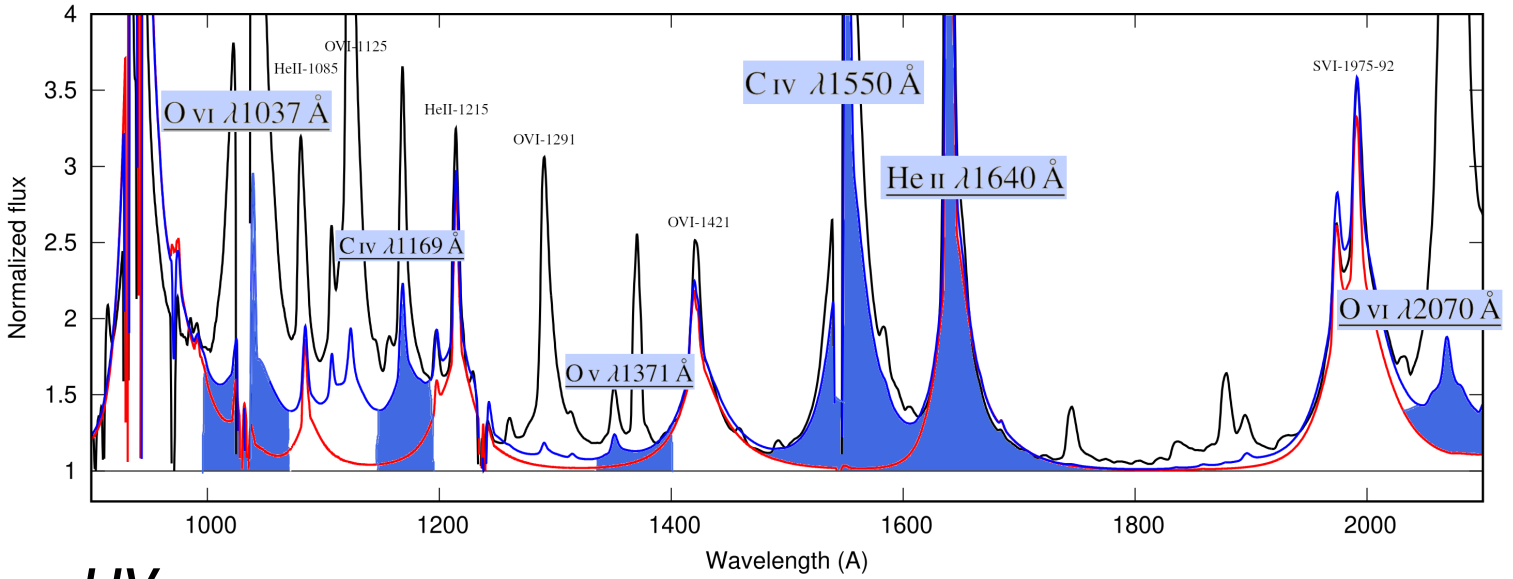

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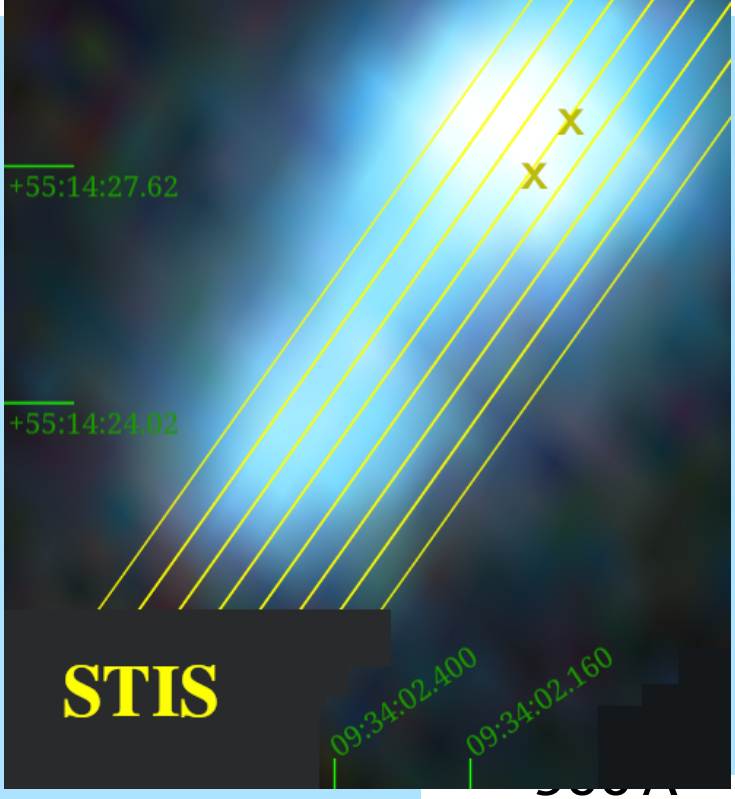

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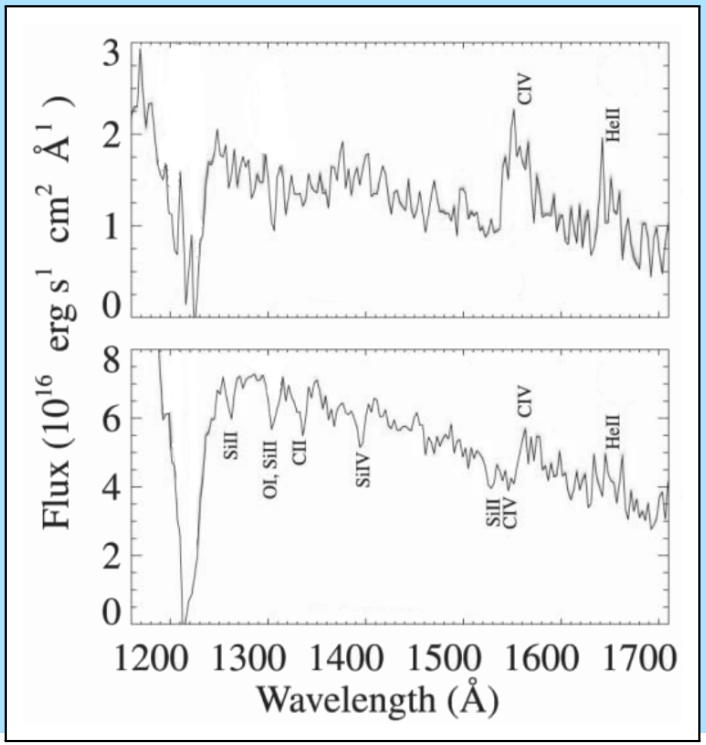

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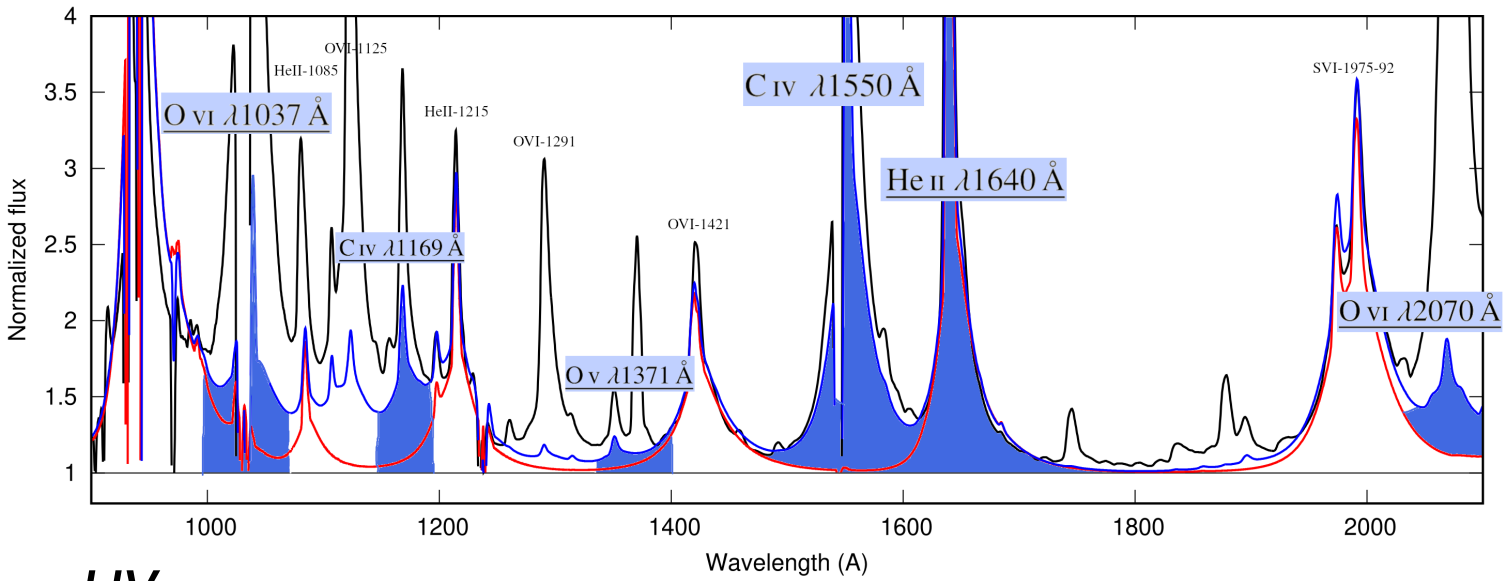
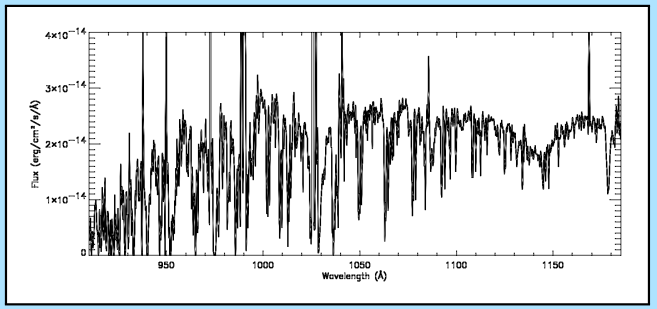


UV

Szécsi+25 (A&A)

Lecavelier des Etangs+04

910 Å–1185 Å



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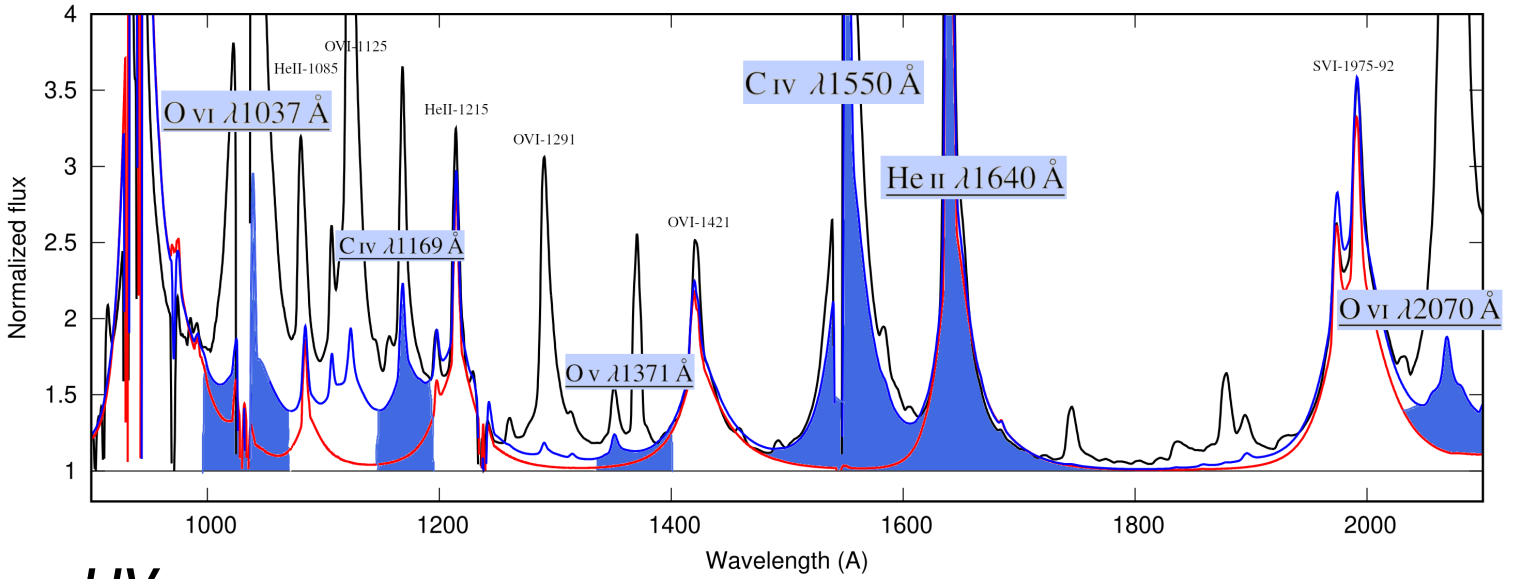

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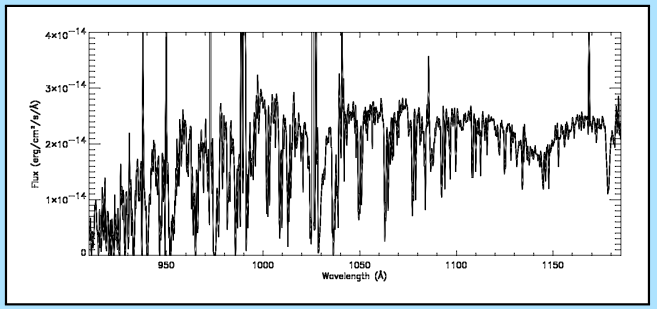

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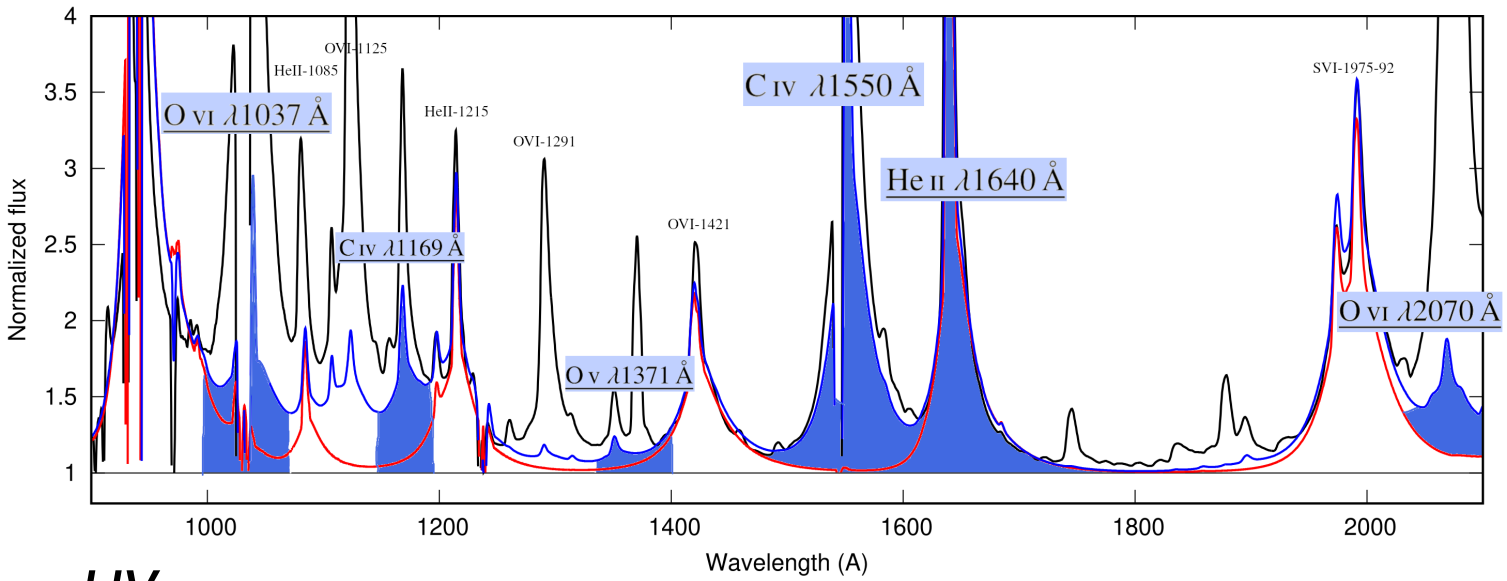

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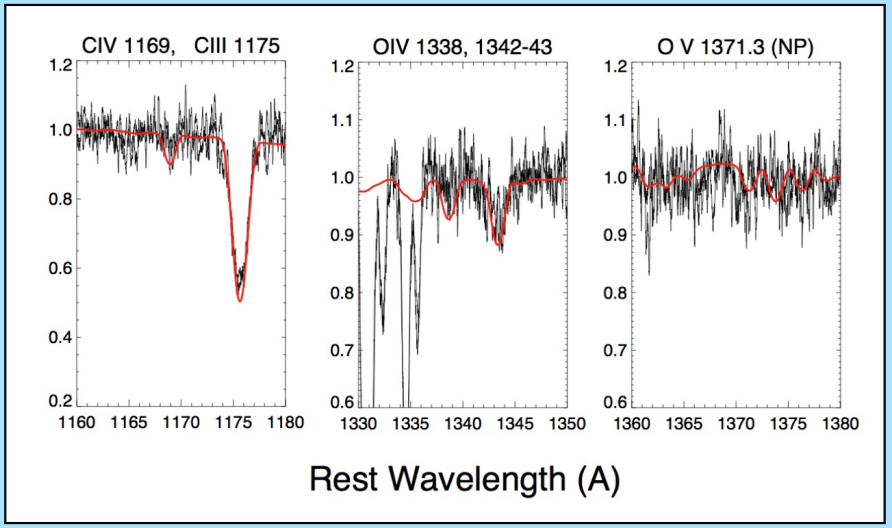

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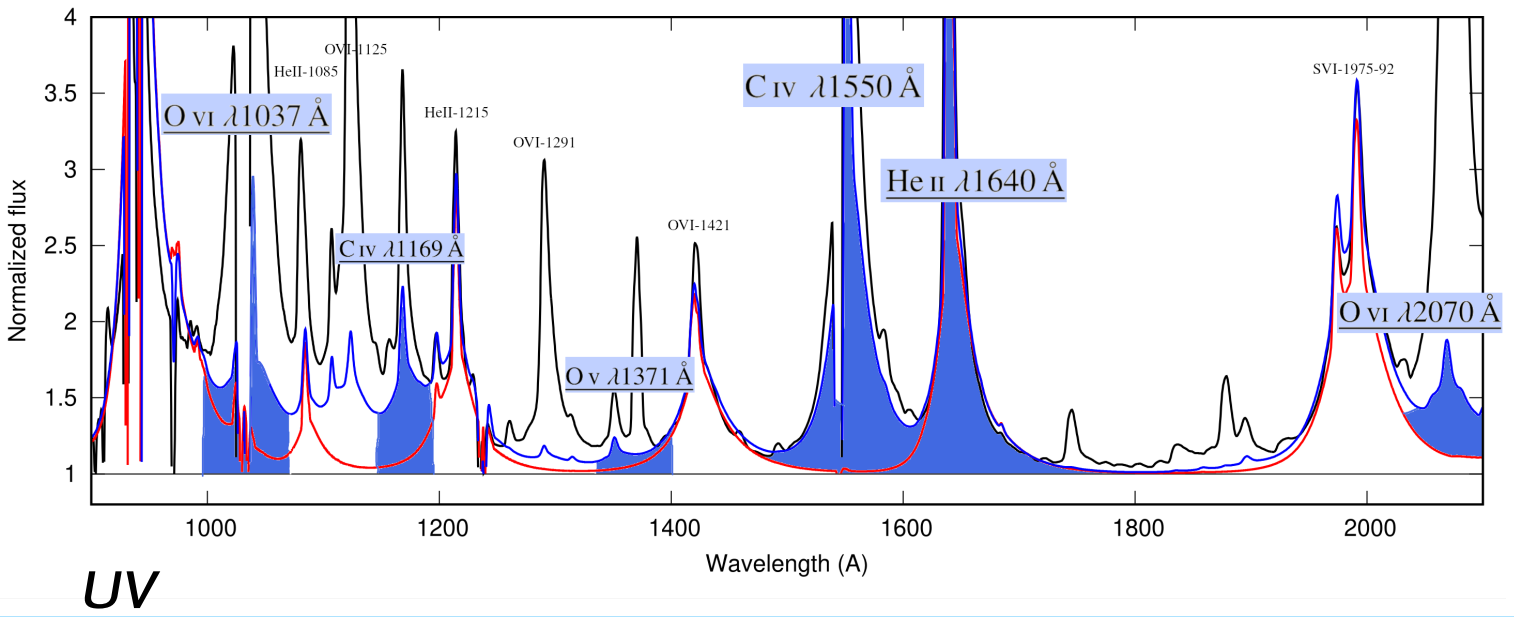

UV

Szécsi+25 (A&A)

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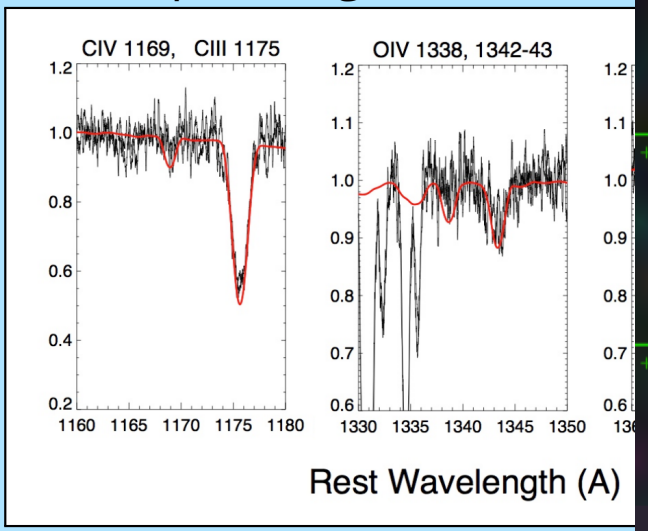

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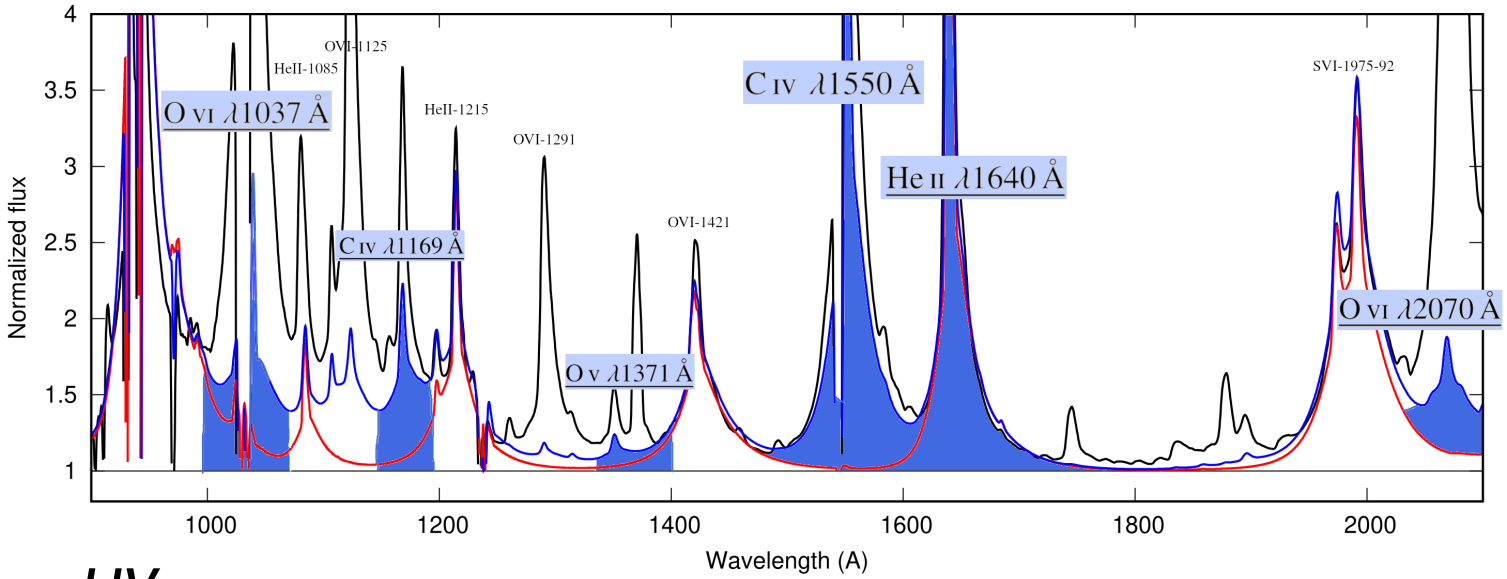

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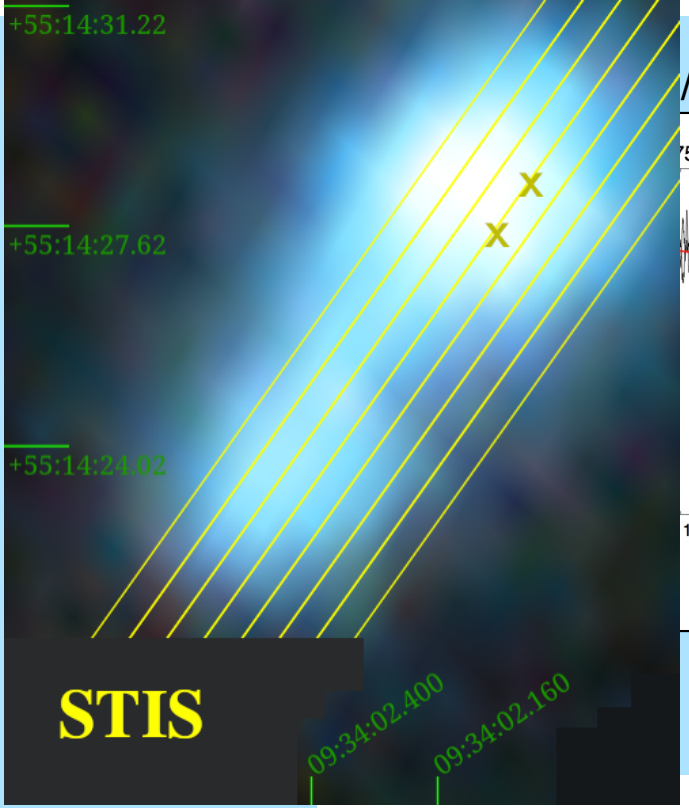

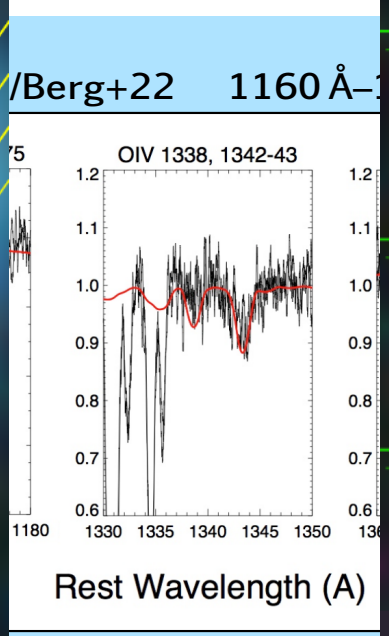

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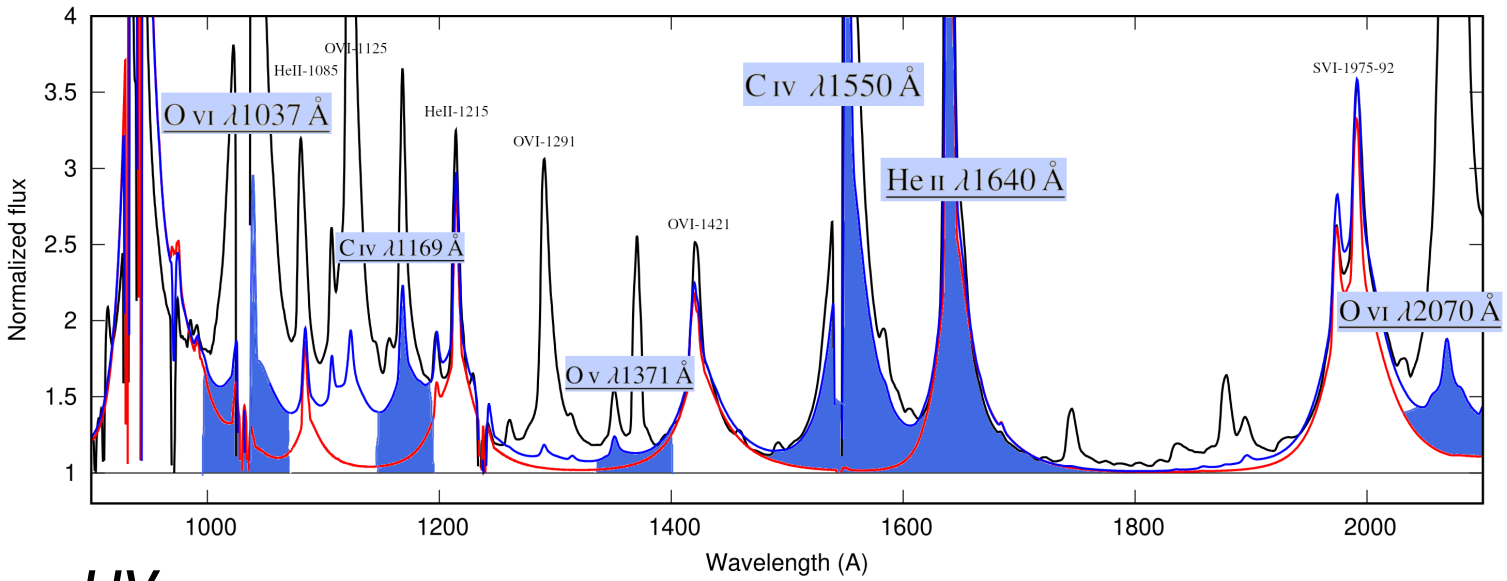

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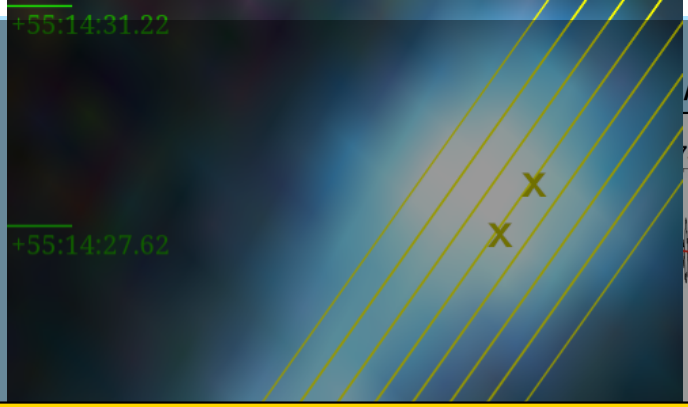
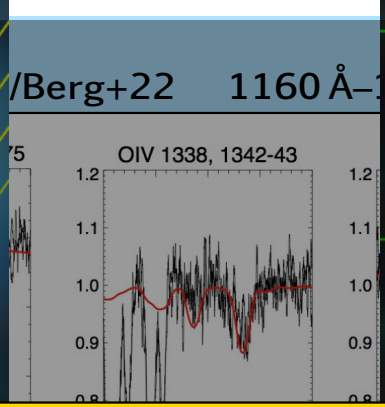
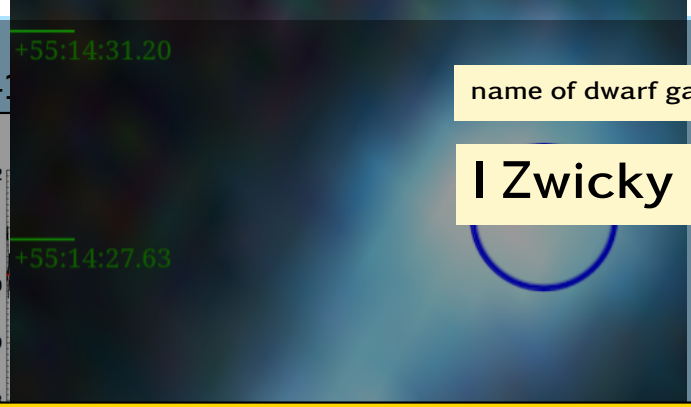
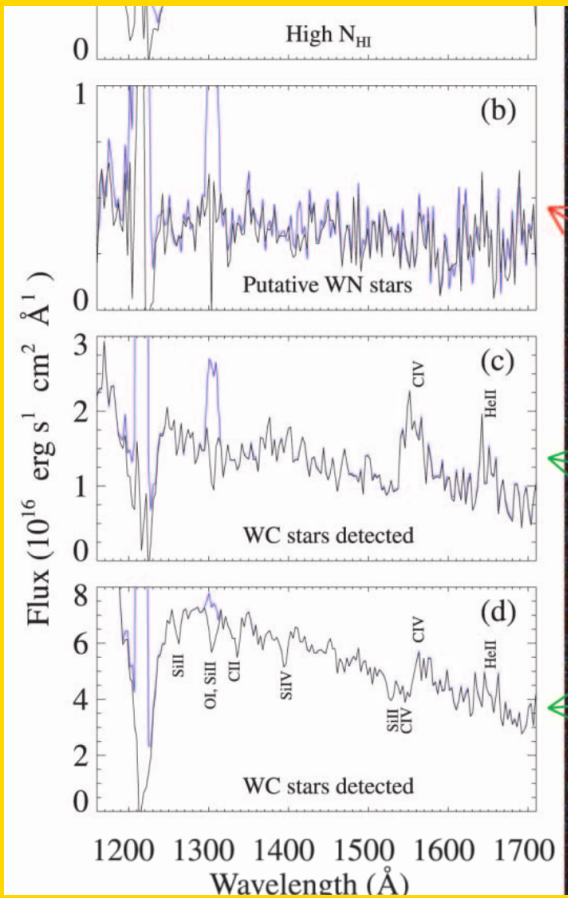


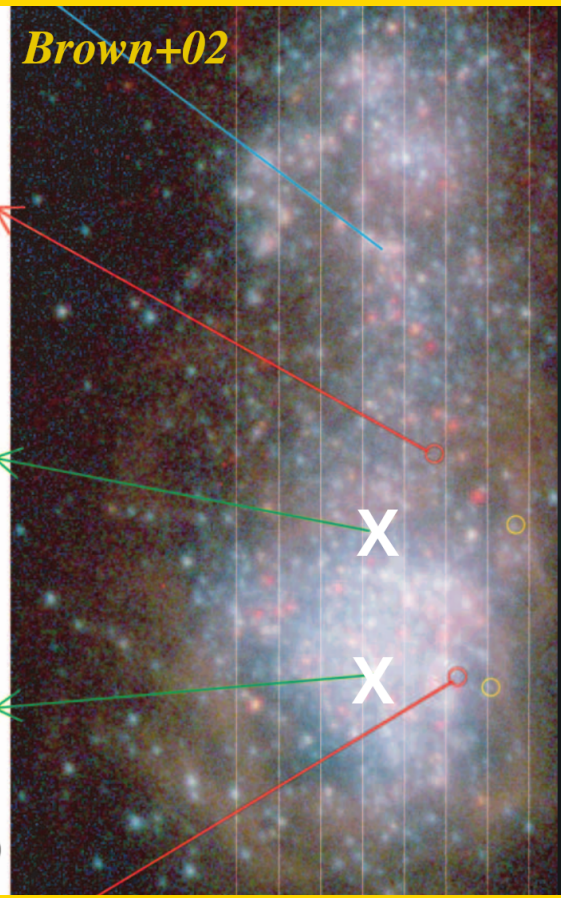


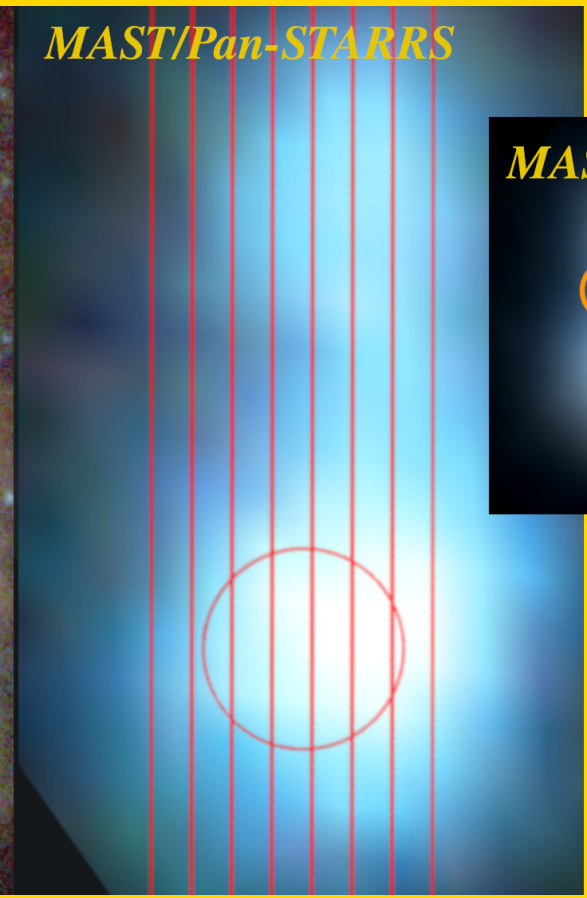


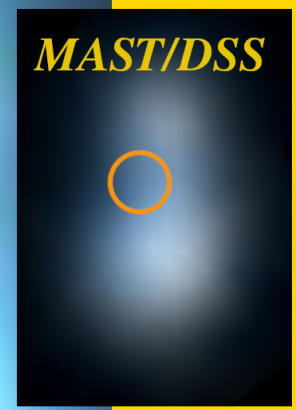
name of dwarf galaxy:

I Zwicky 18









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UV

Szécsi+25 (A&A)

Conclusions...

- Available literature cannot exclude our models
- Proving them though?
- sign-post: WO bump around O-VI-3818 (wideness: ~24Å)
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- in those *individual* spaxels where He-II-4686 and C-IV-5808 are also found in emission (wide bumps)

- far-reaching impact: proving the existence of a theorized channel to GWs

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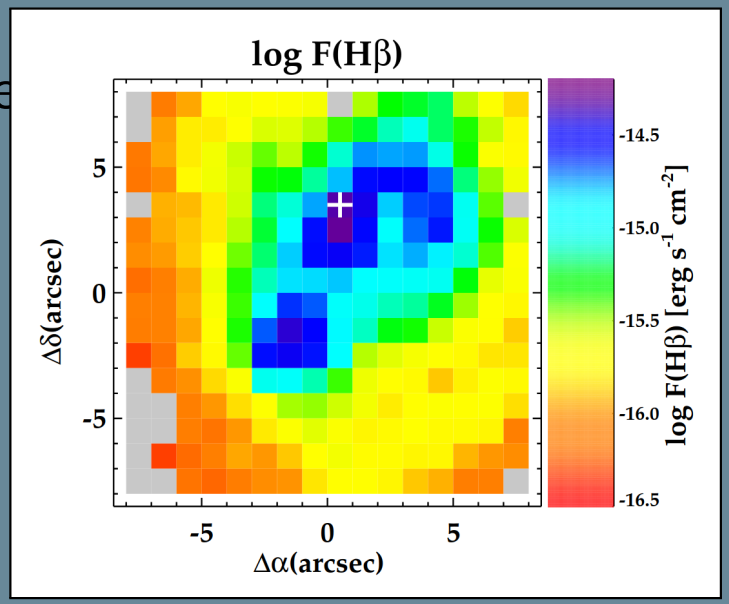
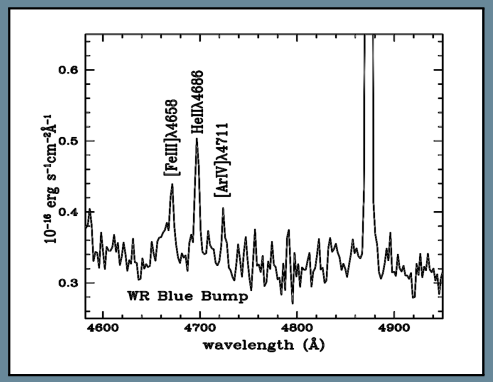
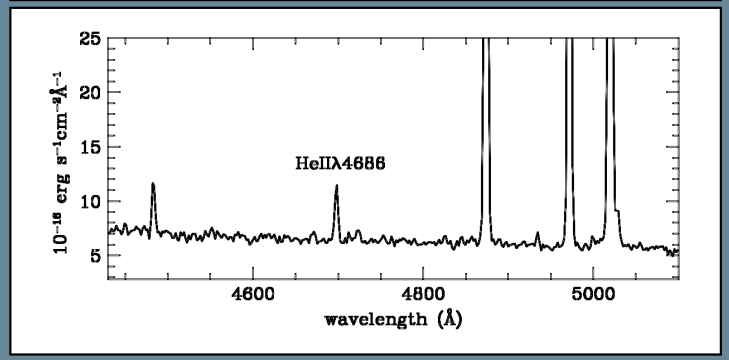




Kehrig+15 4440 Å–5200 Å



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