Searching for magnetic fields in merger products

Ingrid Pelisoli

WARWICK
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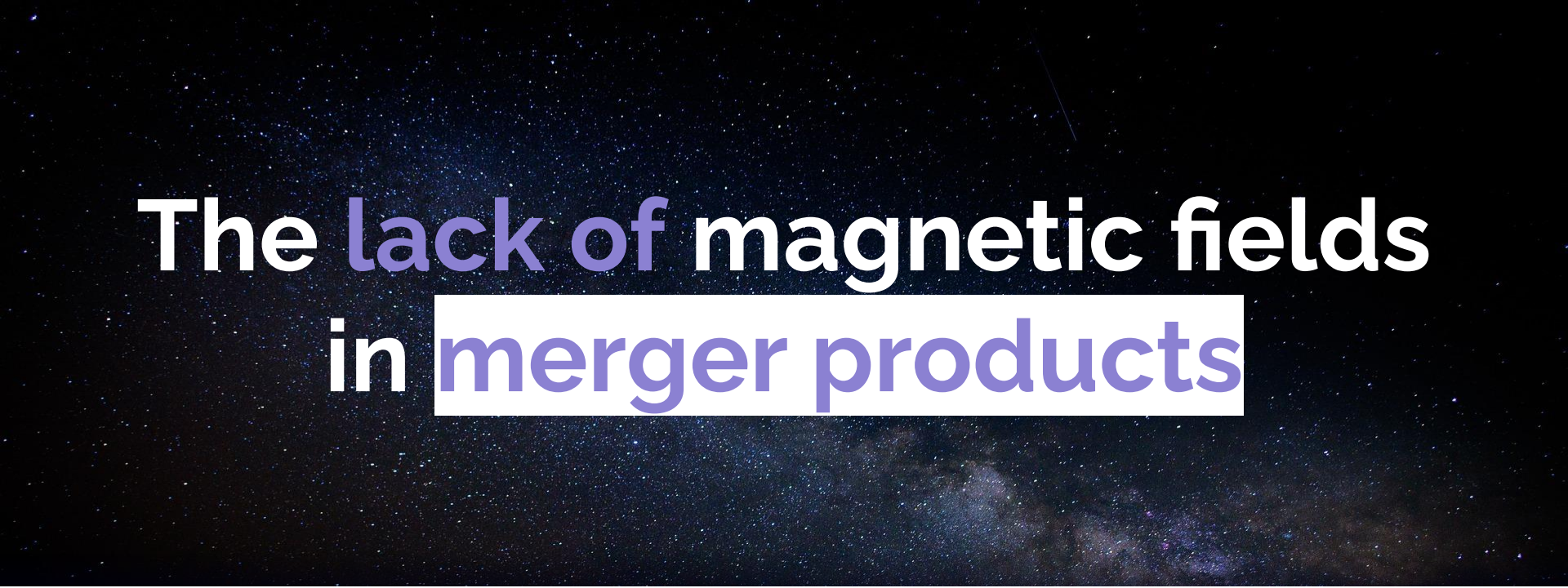
Stellar Magnetic Fields from Protostars to Supernovae
27th of October 2023



The lack of magnetic fields in merger products

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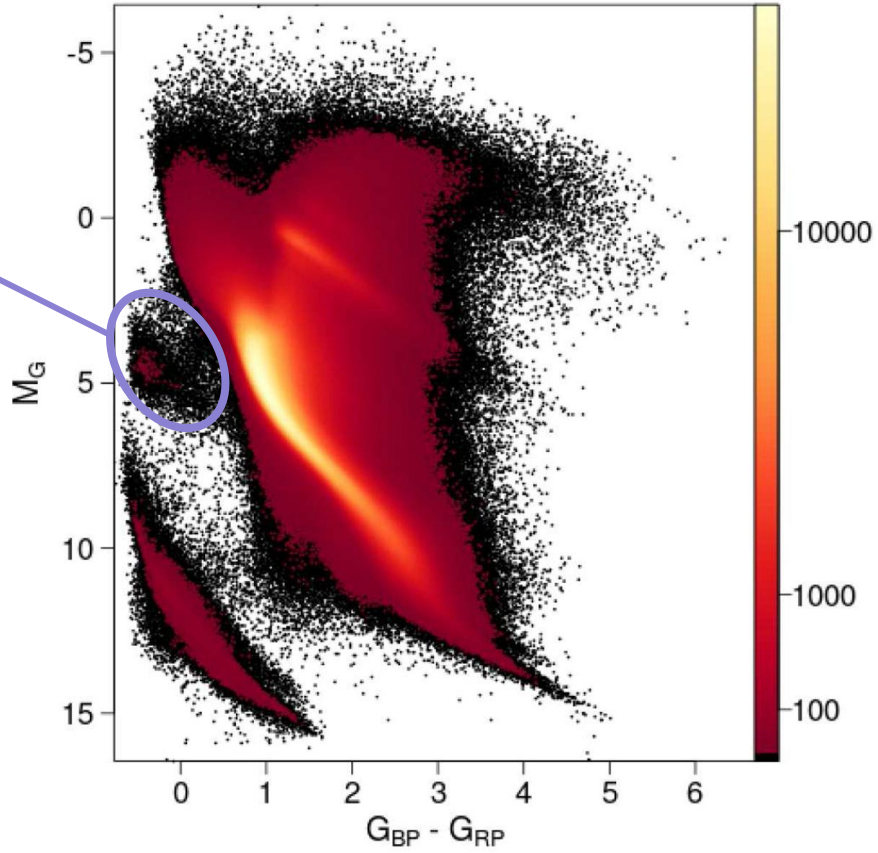
Which products?

Hot subdwarfs



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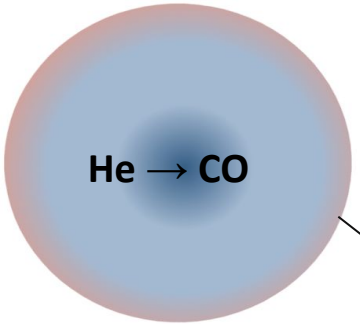
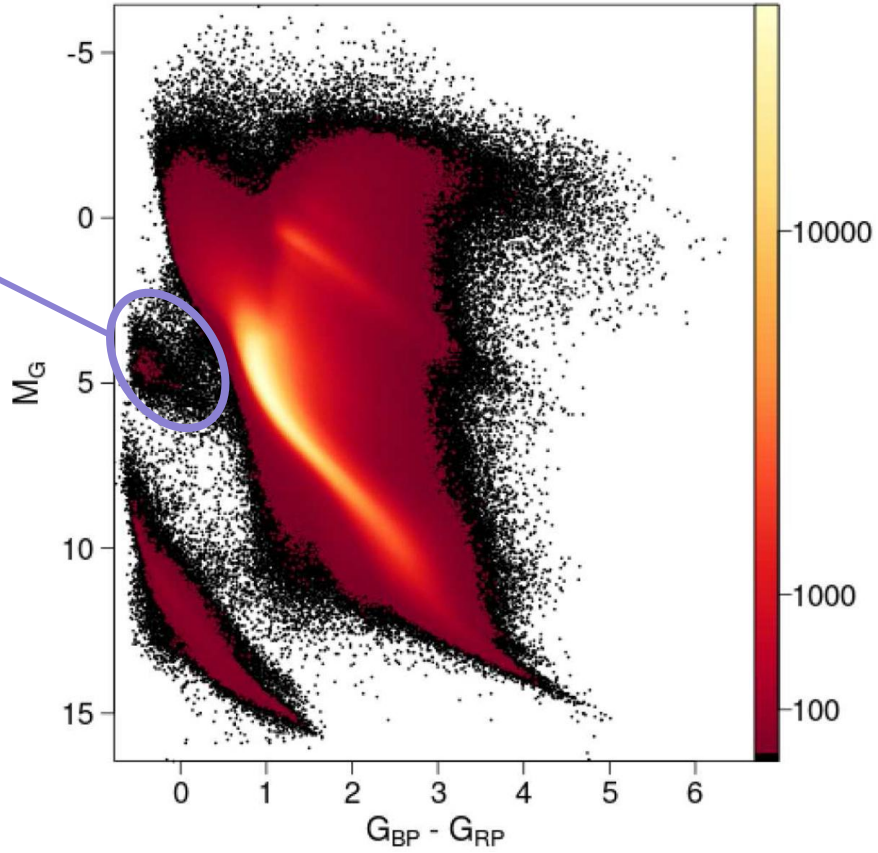


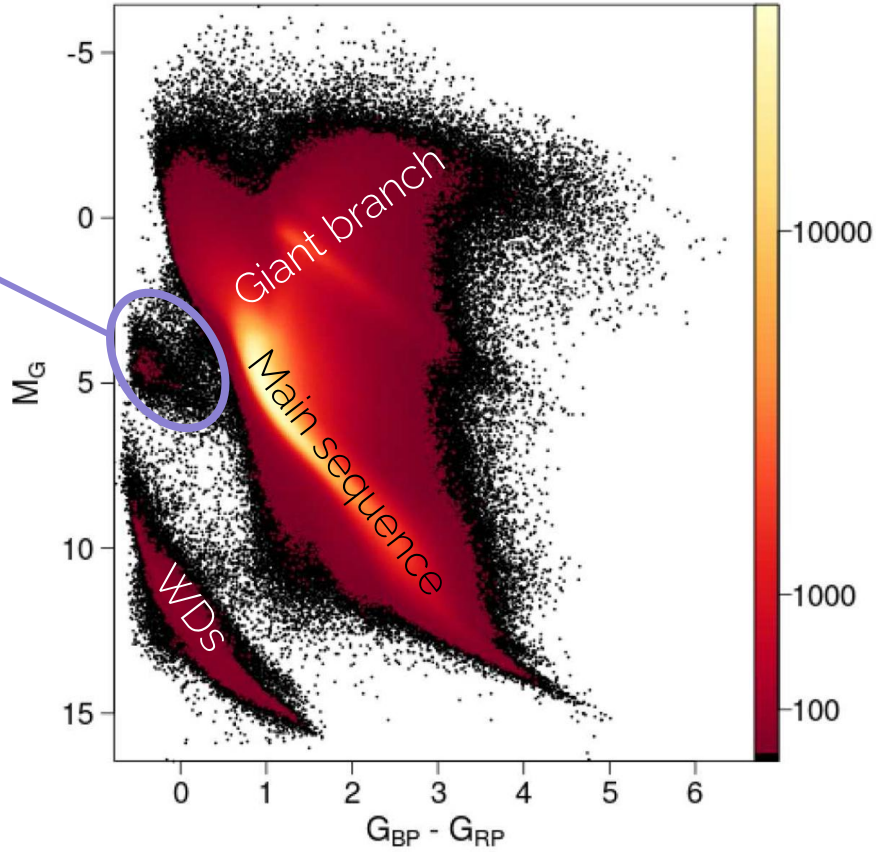
thin H layer



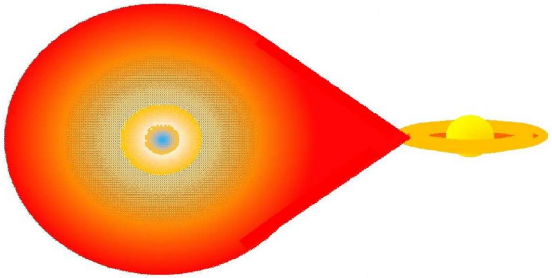
Why hot subdwarfs?

Hot subdwarfs

They can only be formed by binary interaction!



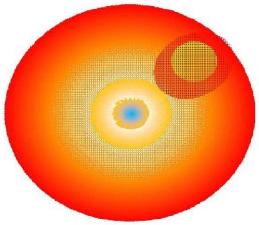
The formation of hot subdwarfs



Stable Roche-lobe overflow

↓

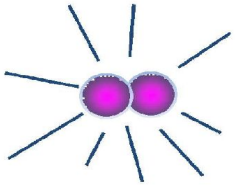
wide binary



Common envelope

↓

close binary



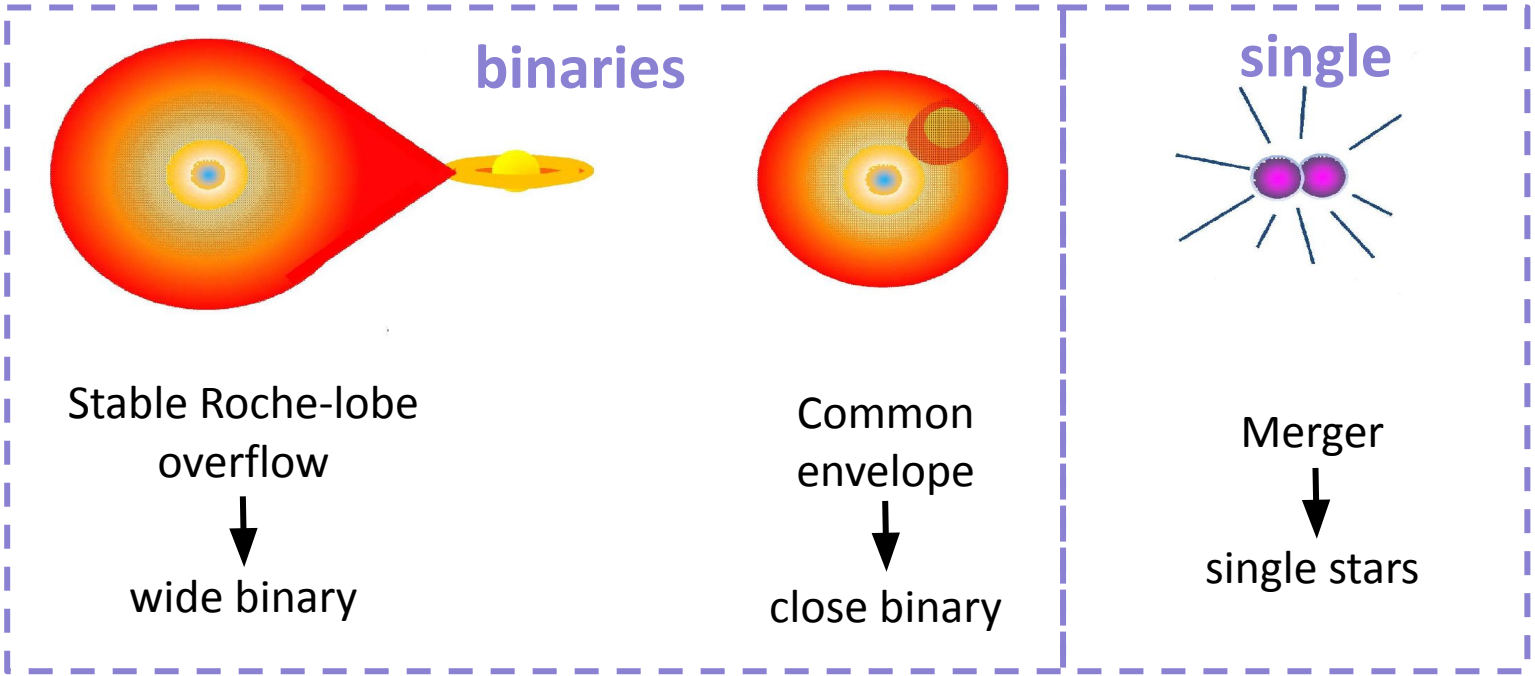
Merger

↓

single stars

Maxted et al. (2001): high binary fraction → Han et al. (2002, 2003): binary formation models → **Pelisoli** et al. (2020): evidence of interaction (wide companions are spun up)

The formation of hot subdwarfs



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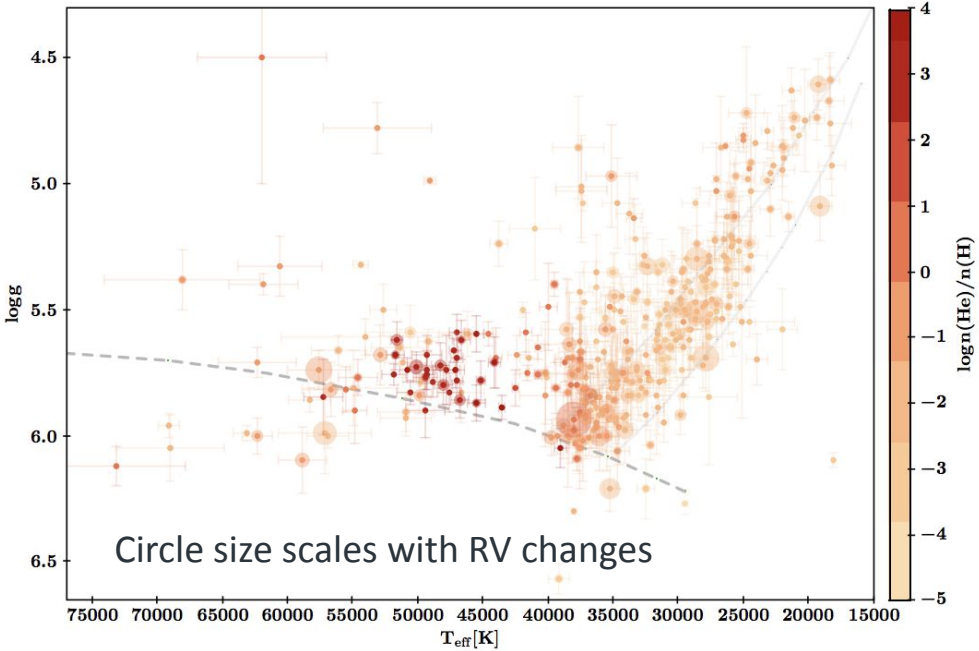
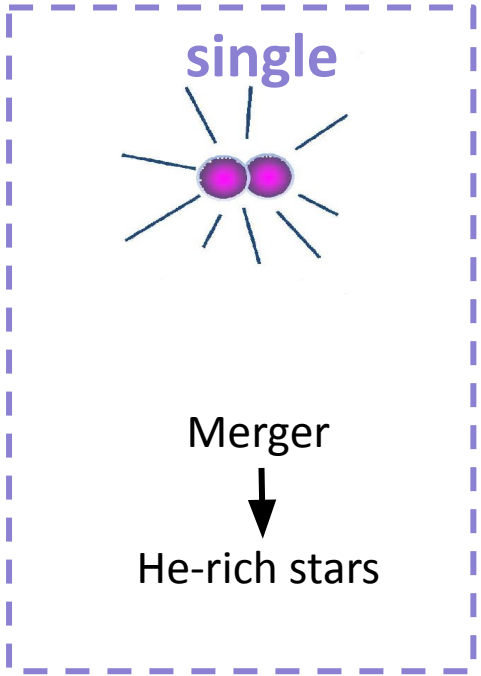


Geier, Dorsch, **Pelisoli** et al. 2022: no RV variability in He-sdOs from SDSS and LAMOST



There is growing evidence that He-sdOs are merger products.

If they form through binary interaction, they should have a high magnetic fraction, right?

*See Matteo Cantiello's talk in week 1.

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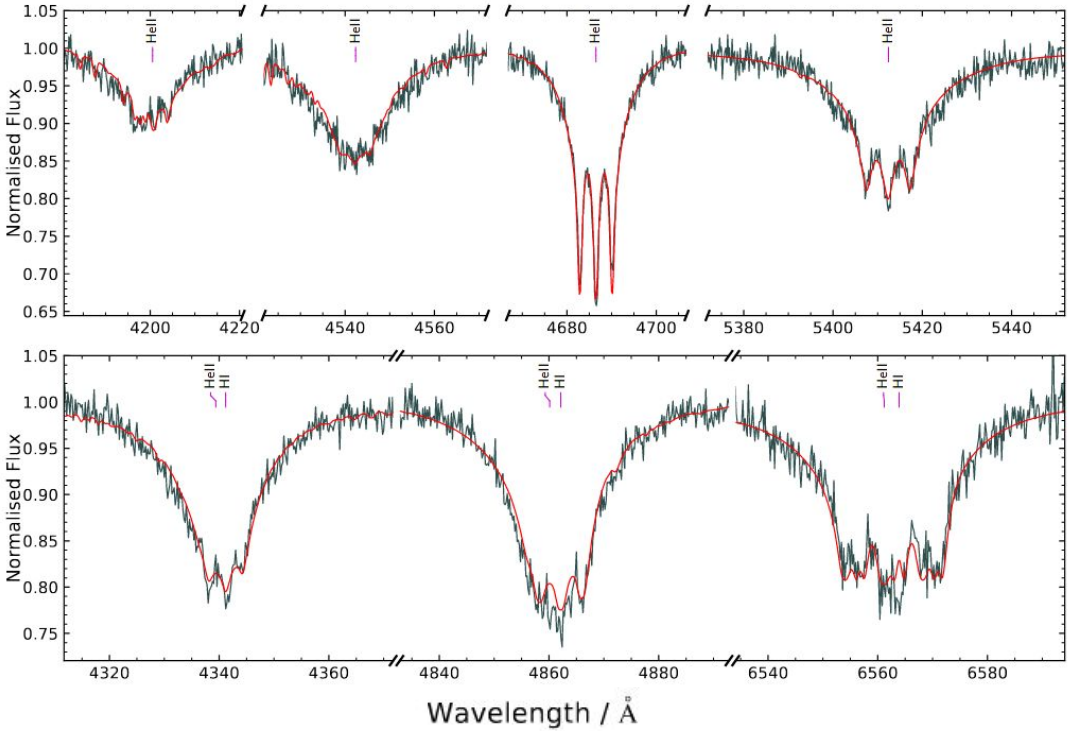
Wrong!

- 6000 hot subdwarfs spectroscopically confirmed.
  (Culpan, Geier, Reindl, **Pelisoli** et al. 2022, A&A, 662, 40)
- *Zero* magnetic (until very recently).

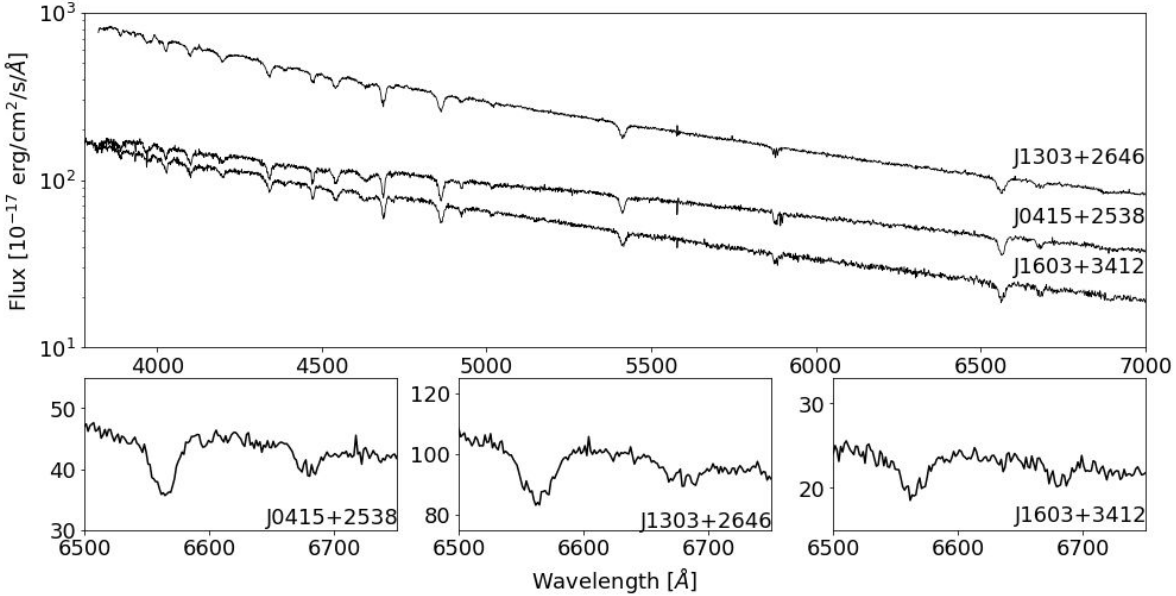
One magnetic hot subdwarf found *by chance*



B = 353 ± 10 kG

Dorsch, Reindl, **Pelisoli** et al. 2022, A&A, 658, 9

Three magnetic hot subdwarfs in SDSS



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than about 1 or 2 kG in strength occur in at most a few percent of hot subdwarfs." Therefore it came by some surprise when a helium-rich sdO star was recently discovered to show Zeeman splitting ([11], see Fig. 1), indicating the presence of a ≈300 – 700 kG magnetic field.

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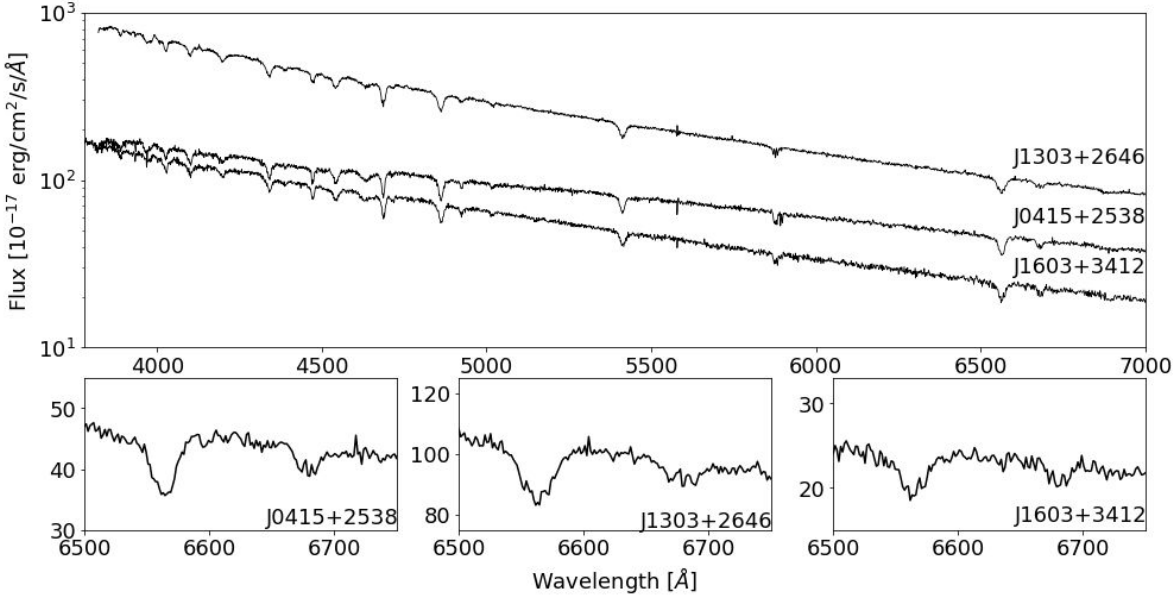

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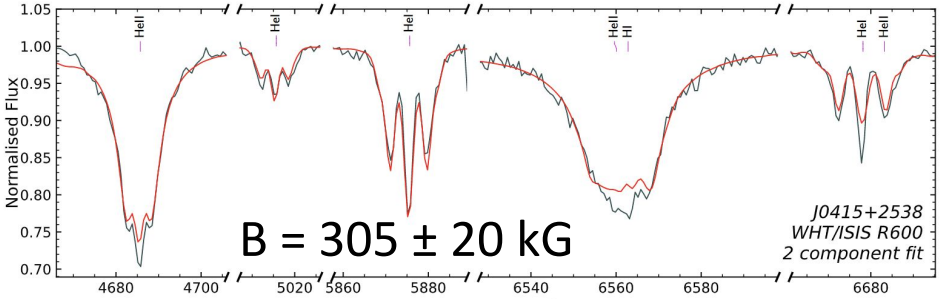

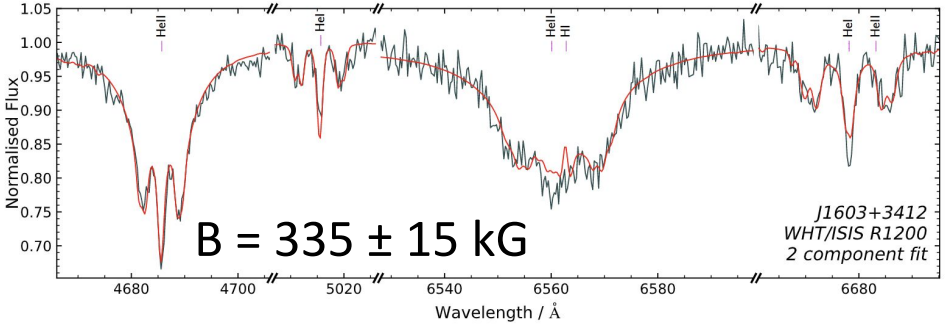

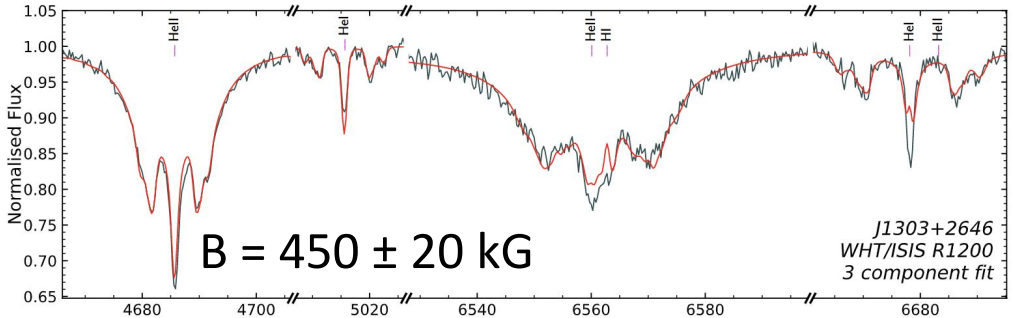

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Still wrong!

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  (Culpan, Geier, Reindl, **Pelisoli** et al. 2022, A&A, 662, 40)
- $0.147^{+0.143}_{-0.047}\%$ are magnetic.

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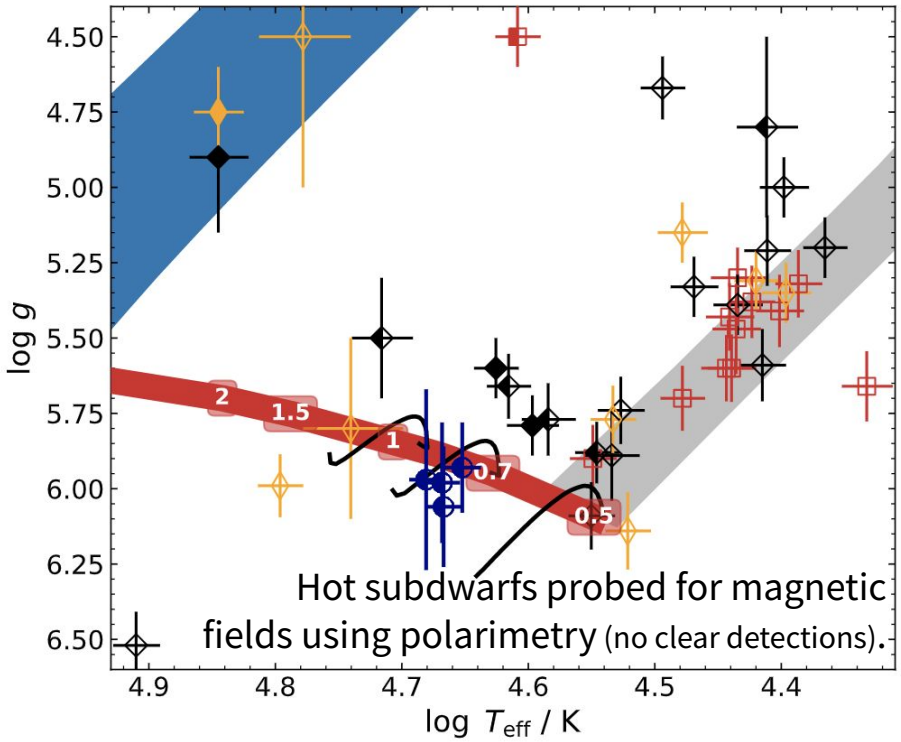
A third of these should be mergers!

*"Magnetic fields in mergers are unavoidable" – Ph. Podsiadlowski's talk in week 2.

The fraction is low not for lack of trying



See Elkin (1996), Elkin (1998), **Bagnulo** et al. (2012), **Landstreet** et al. (2012), Randall et al. (2015)

"It appears that globally simple fields of more than about 1 or 2kG in strength occur in at most a few percent of hot subdwarfs, and **may be completely absent** at this strength."

Black diamonds = single stars

Red squares = close binaries

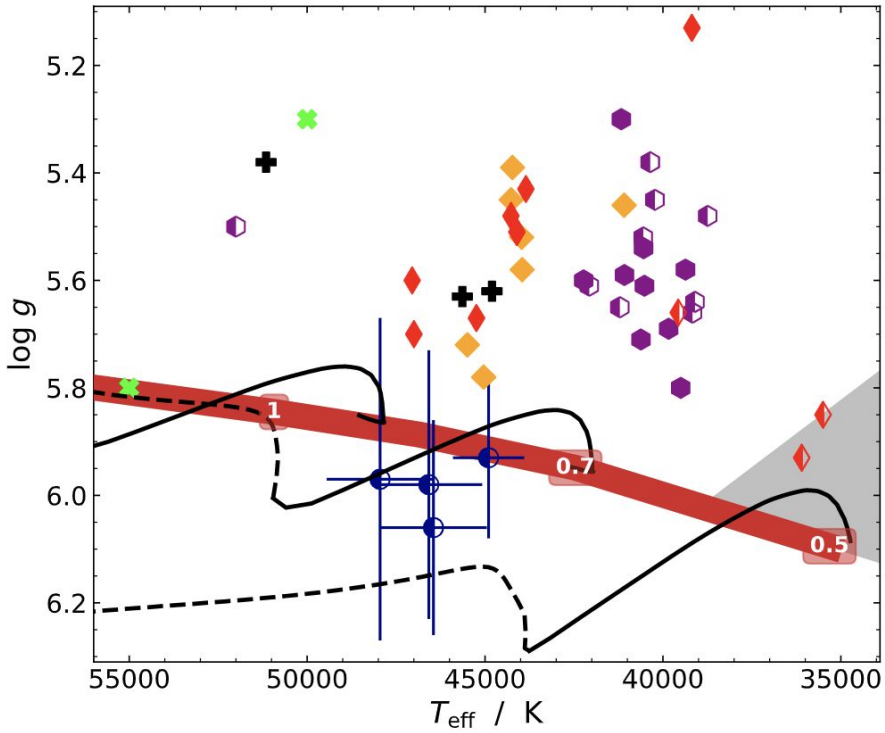
Orange thin diamonds = unknown

Open symbol = He-poor

Filled symbol = extreme He-rich (low H)

Half-filled symbol = intermediate He-rich (high H)

The fraction is low not for lack of trying



Other He-rich objects with spectra that would have revealed magnetic fields, but no fields were detected.

Green X = CO rich He-sdOs (Werner+ 2022)
Purple hexagon = N-rich
Red diamond = C&N rich
Orange diamond = C-rich
Black plus sign = C-rich, N-poor
Filled symbol = extreme He-rich (low H)
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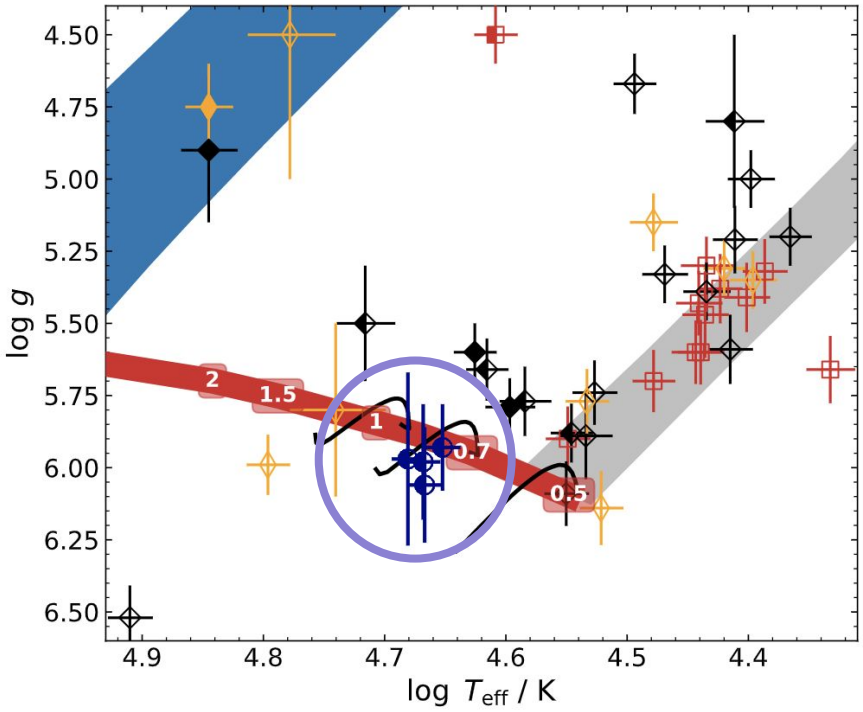
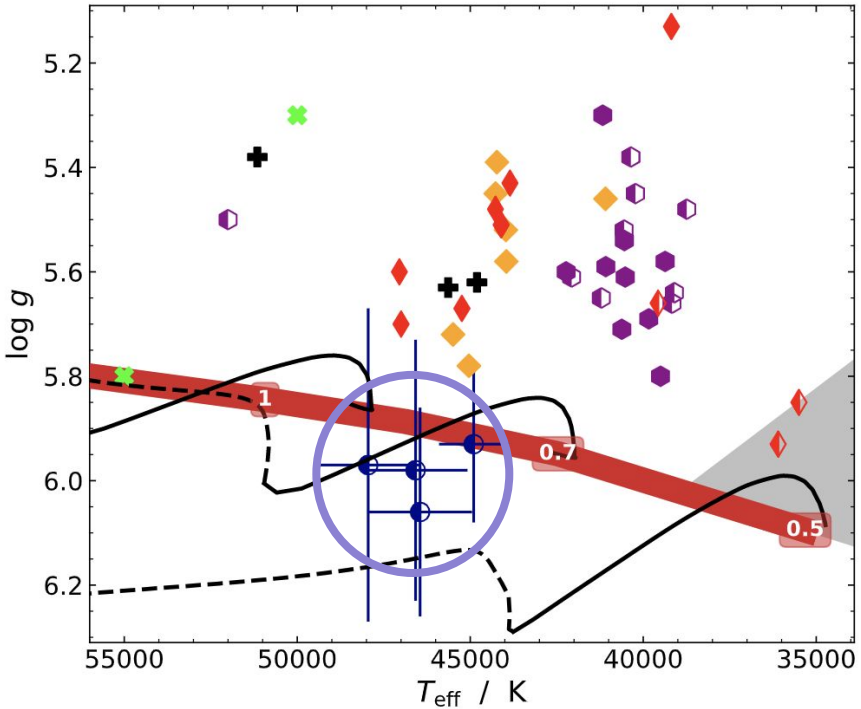
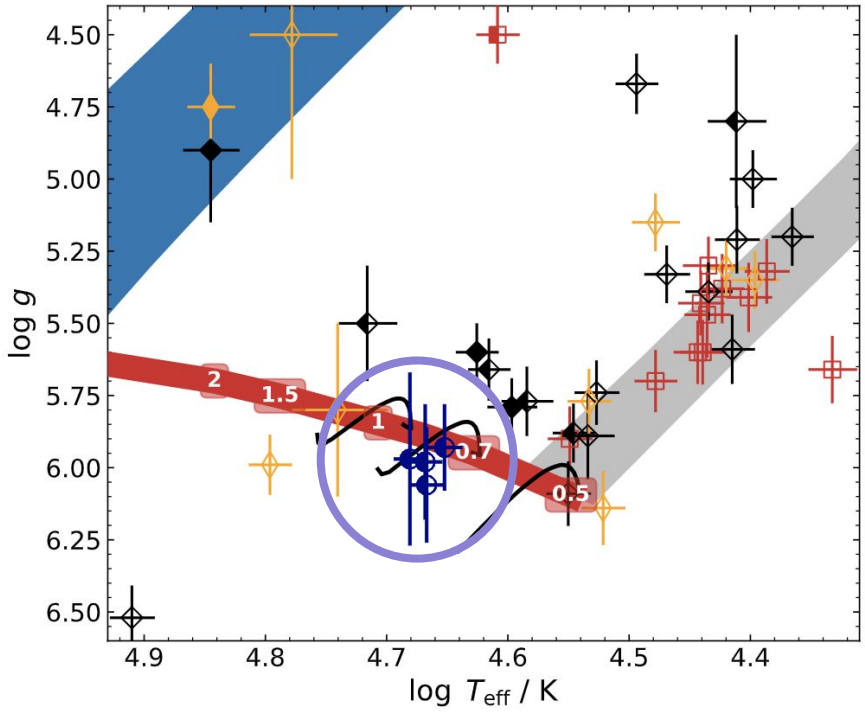
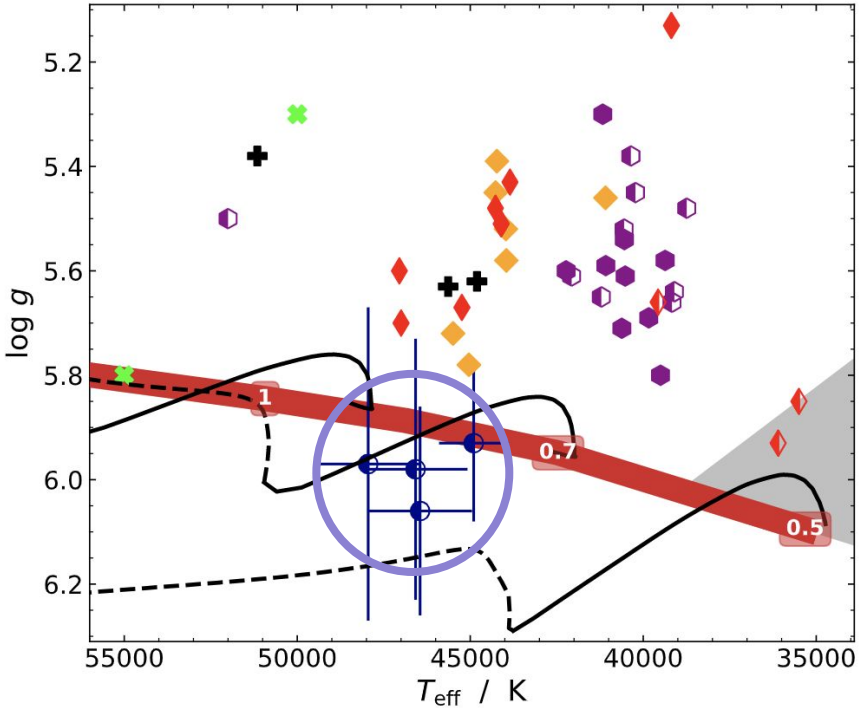
The four magnetic subdwarfs stand out from the rest





The four magnetic subdwarfs stand out from the rest, and are very similar to each other





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- All have helium-rich atmospheres (He-sdO class).

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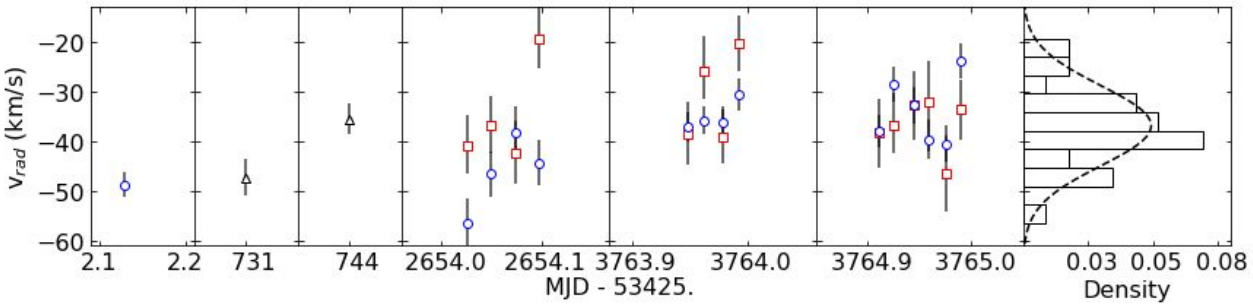

The four magnetic subdwarfs stand out from the rest, and are very similar to each other

- All have helium-rich atmospheres (He-sdO class).
- All are apparently single.
- Similar T_{eff} and log g.

} merger products

	J0809-2627	J0415+2538	J1303+2646	J1603+3412
$T_{\rm eff}$ (K)	44900 ± 1000	46580 ± 1500	47950 ± 1500	46450 ± 1500
log g	5.93 ± 0.15	5.98 ± 0.25	5.97 ± 0.30	6.06 ± 0.20
$\log n({\rm He})/n({\rm H})$	+0.28 ± 0.10	−0.10 ± 0.15	+0.25 ± 0.15	+0.07 ± 0.15
$B_{\rm avg}$ (kG)	353 ± 10	305 ± 20	450 ± 20	335 ± 15
$v_{\rm rad}$ (km s^{-1})	33 ± 2	−17 ± 10	−37 ± 8	6 ± 5
$v_{\rm rot} \sin i$ (km s^{-1})	< 40	< 45	< 60	< 65
R ($R_\odot$)	$0.184^{+0.011}_{-0.010}$	$0.148^{+0.020}_{-0.015}$	$0.19^{+0.05}_{-0.04}$	$0.14^{+0.06}_{-0.04}$
L ($L_\odot$)	123^{+19}_{-16}	91^{+29}_{-21}	160^{+100}_{-60}	70^{+80}_{-40}

Conclusions

- Mergers can generate magnetic fields.

“Conclusions”

- Mergers can generate magnetic fields.
- But **not always** (?)
  - 1/3 of hot subdwarfs are mergers, less than 0.5% found to be magnetic.

What is happening?!

- Only specific merger conditions lead to a magnetic field?
  This would explain why the four magnetic are similar to each other and different from the rest.
- The generated field is typically too low to be detected?
  Potentially testable: single hot subdwarfs rotate slowly, they were probably slowed down by a magnetic field – how strong this field needs to be?
  However, this does not explain the similarity between the only known magnetic systems.
- The field takes long to emerge?
  Seems to be the case for white dwarfs, though not necessarily for the merging ones.
  And again, this does not explain the similarity between the only known magnetic systems.
- …

What is happening?!

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- The field takes long to emerge?
- …

How can we find the answer?

Problem: the current observed sample is not complete or uniformly selected!

I want to solve that: uniform characterisation of a 500pc volume-limited sample.

ERC Starting Grant: “The origin of magnetic fields in compact objects”.
Please come for a chat if you have any input/suggestions!

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