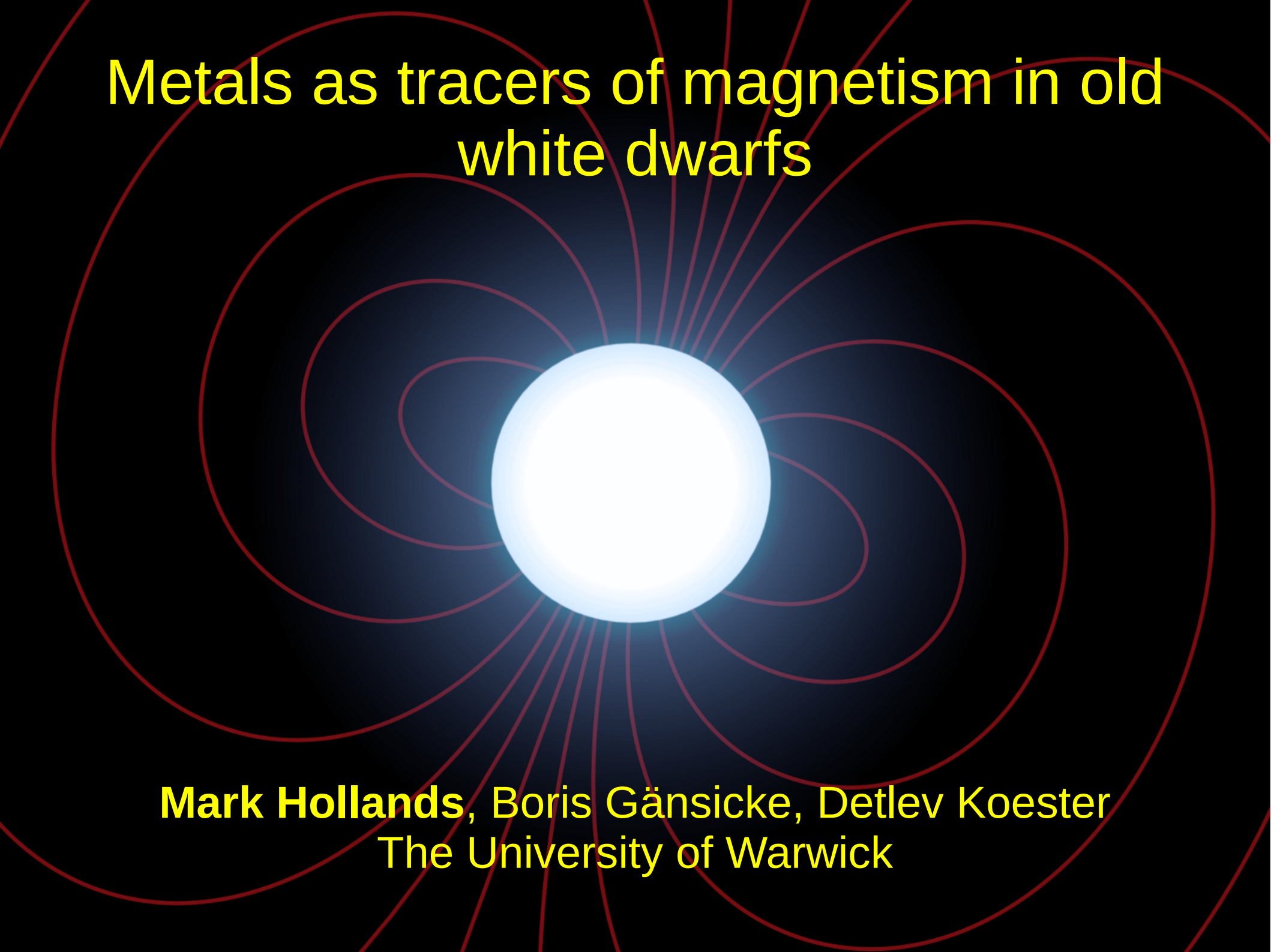
Metals as tracers of magnetism in old white dwarfs



Mark Hollands, Boris Gänsicke, Detlev Koester
The University of Warwick

Talk Outline

- White dwarfs and magnetic white dwarfs
- Probing cool white dwarf magnetic fields
- Magnetic field origin

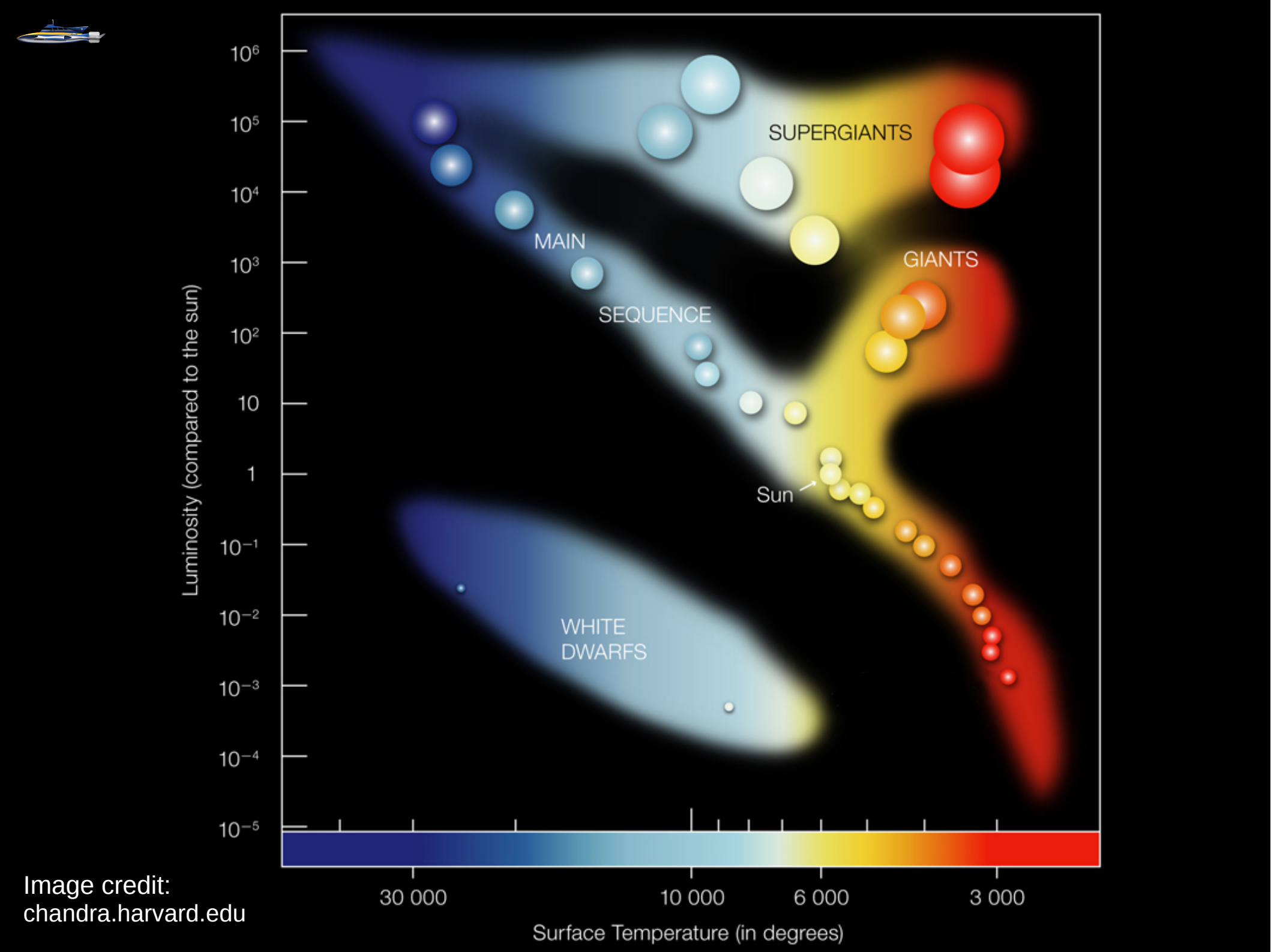
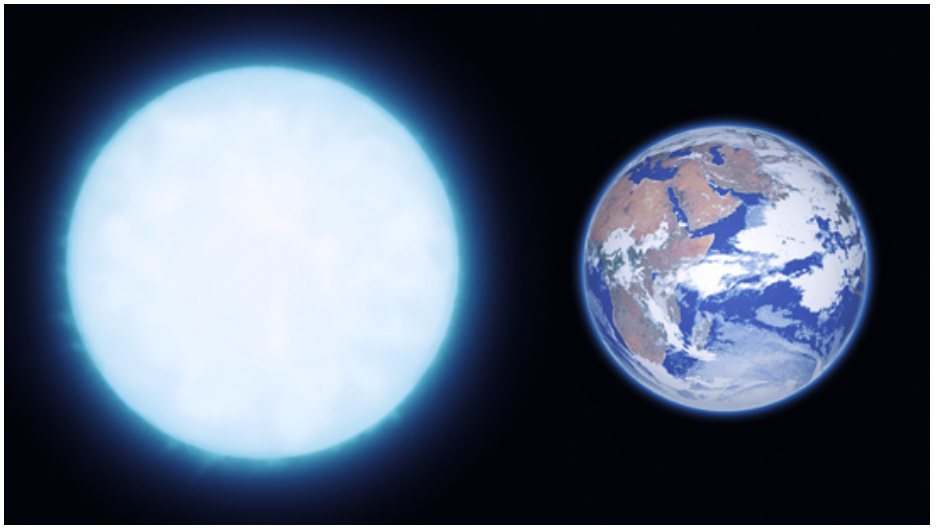


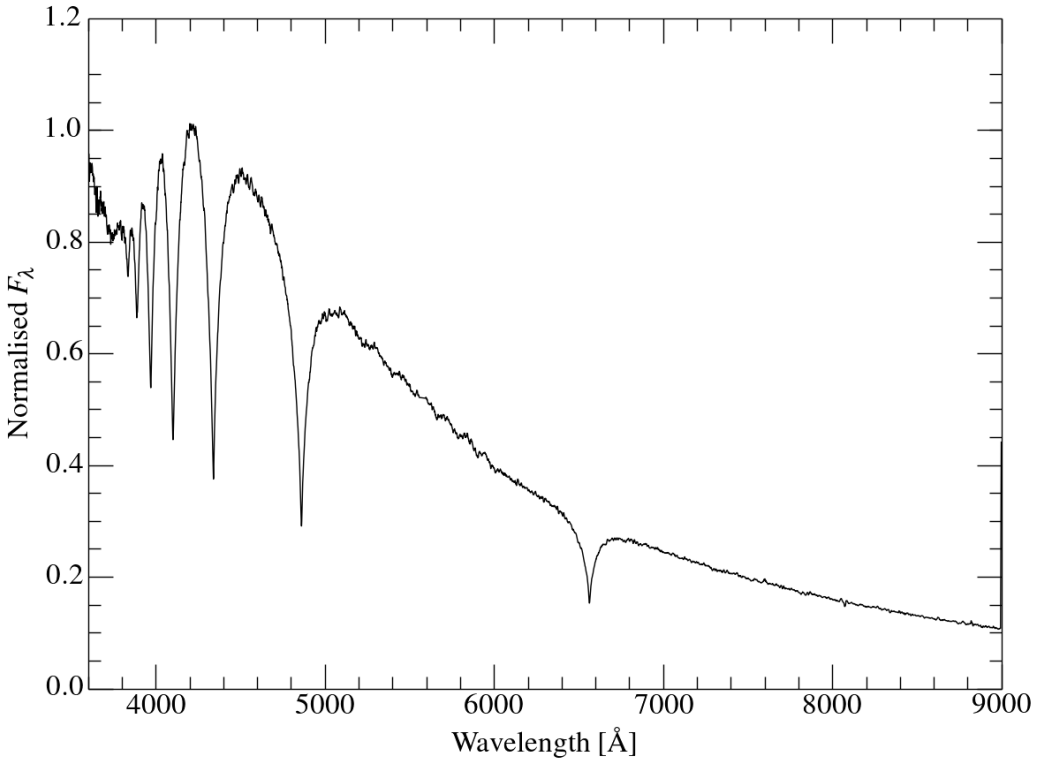
Image credit:
chandra.harvard.edu

White dwarfs

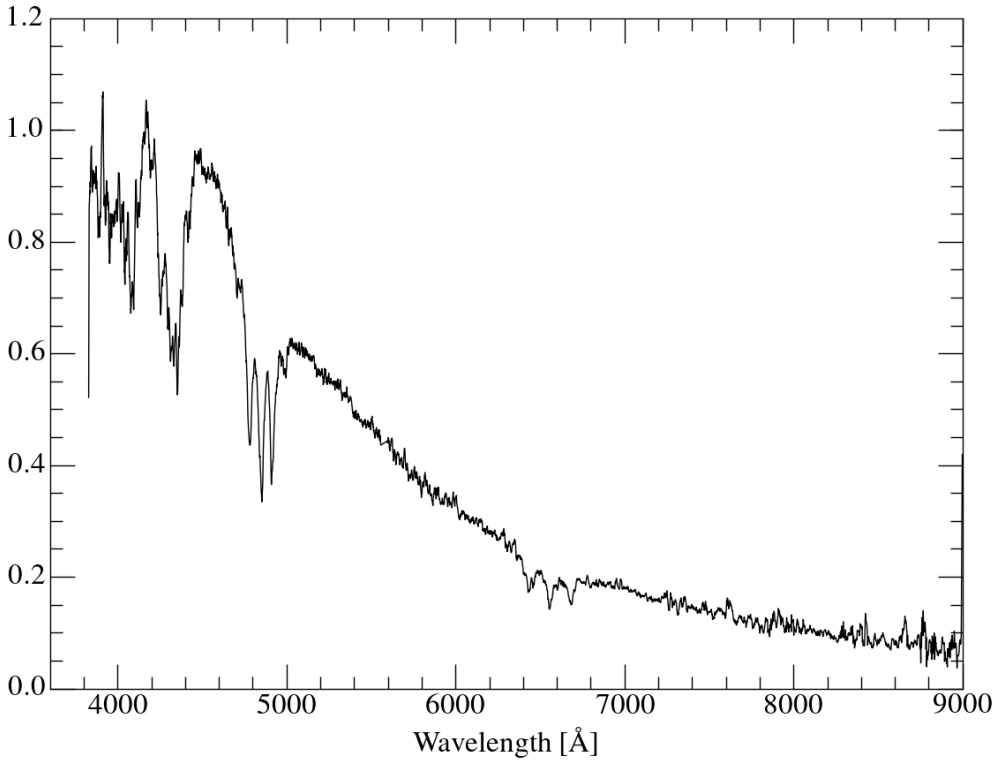
- Stellar remnant supported by degenerate electrons
- Typical stellar parameters:
  $M = 0.6\ M_{\mathrm{Sun}}$
  $R = 0.012\ R_{\mathrm{Sun}} / 1.3\ R_{\mathrm{Earth}}$
  $\log(g) = 8$
- Temperatures observed: 200000 → 3500 K
  $t = 0$ → 10 Gyr



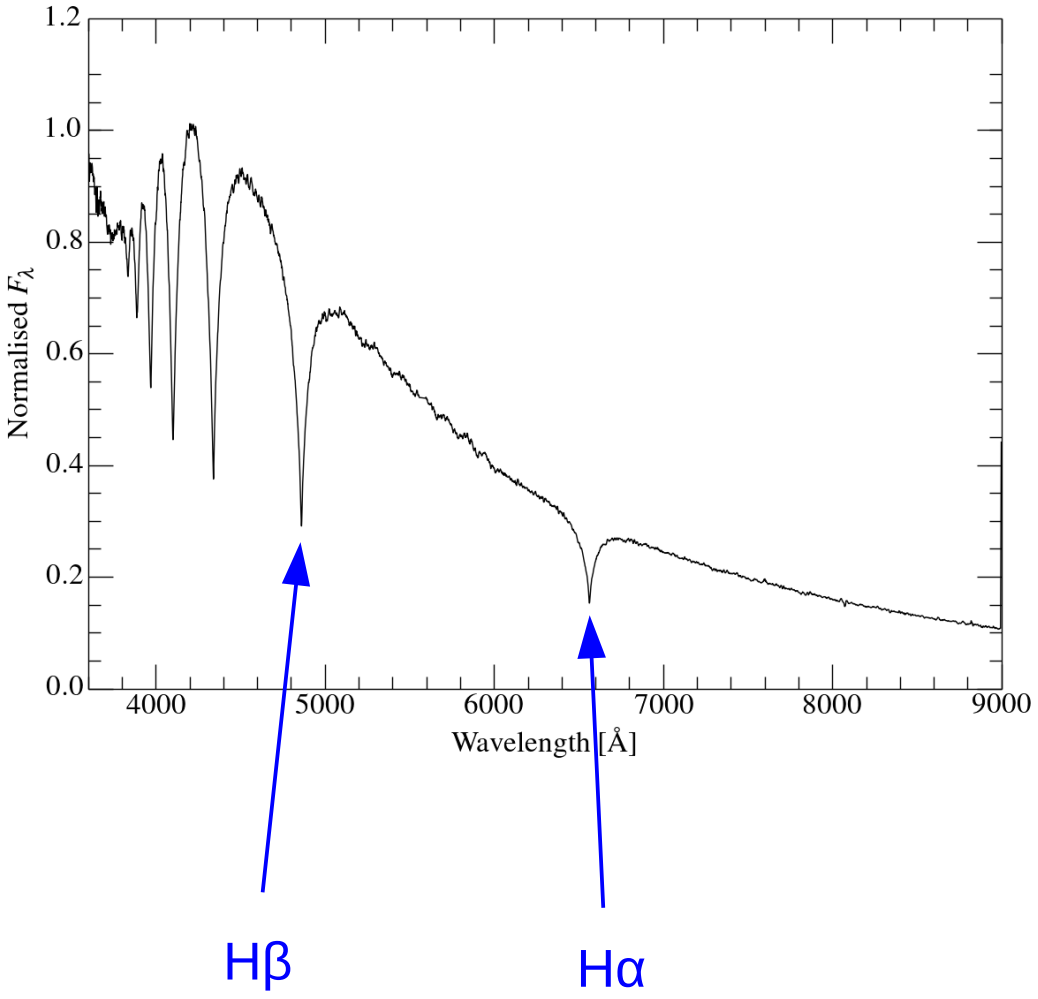
NON-MAGNETIC



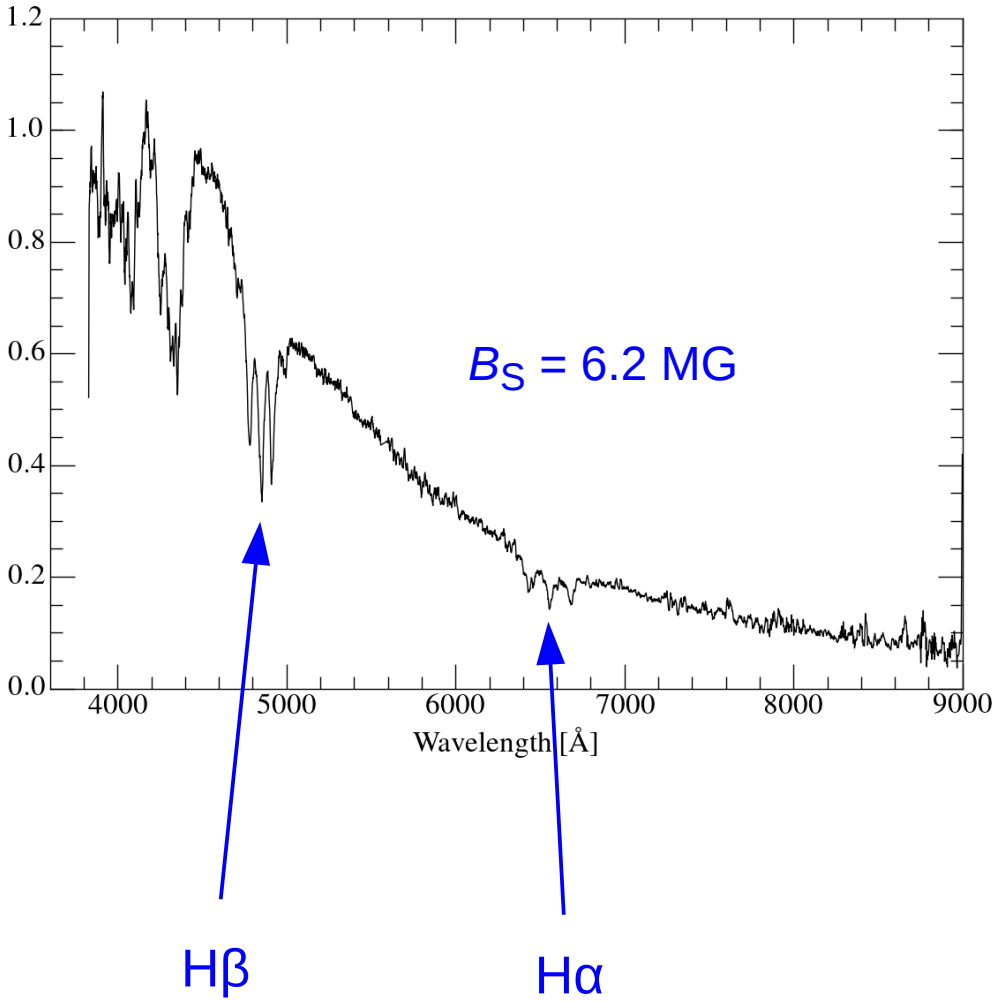
MAGNETIC



NON-MAGNETIC

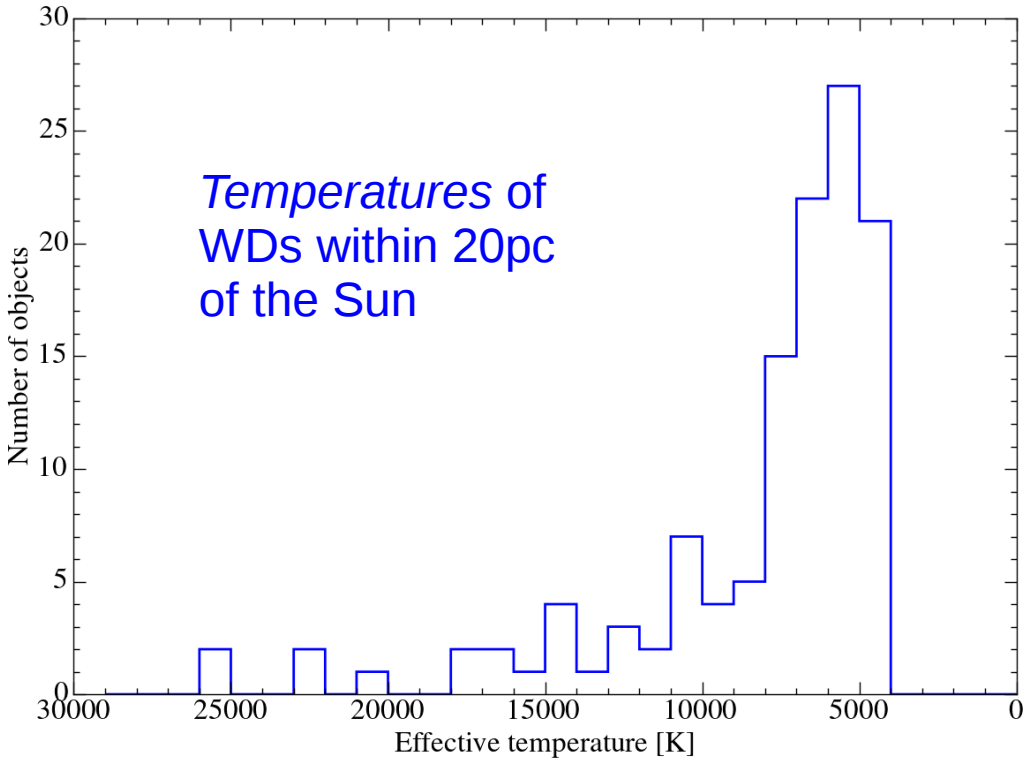


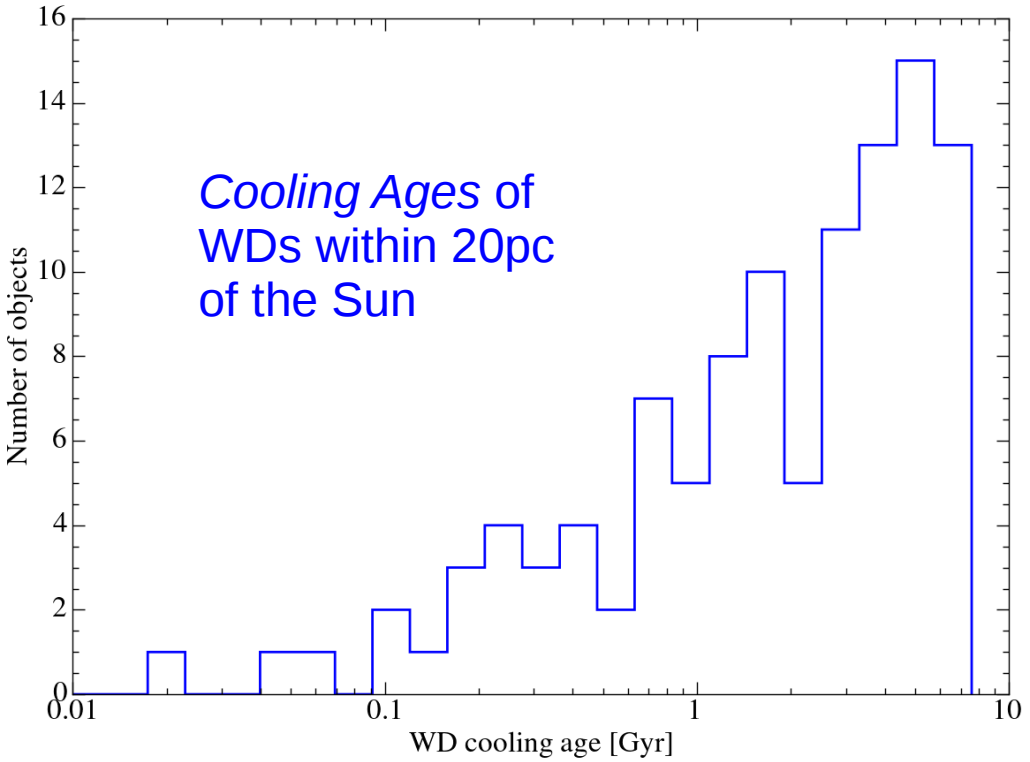
MAGNETIC



Cool white dwarfs

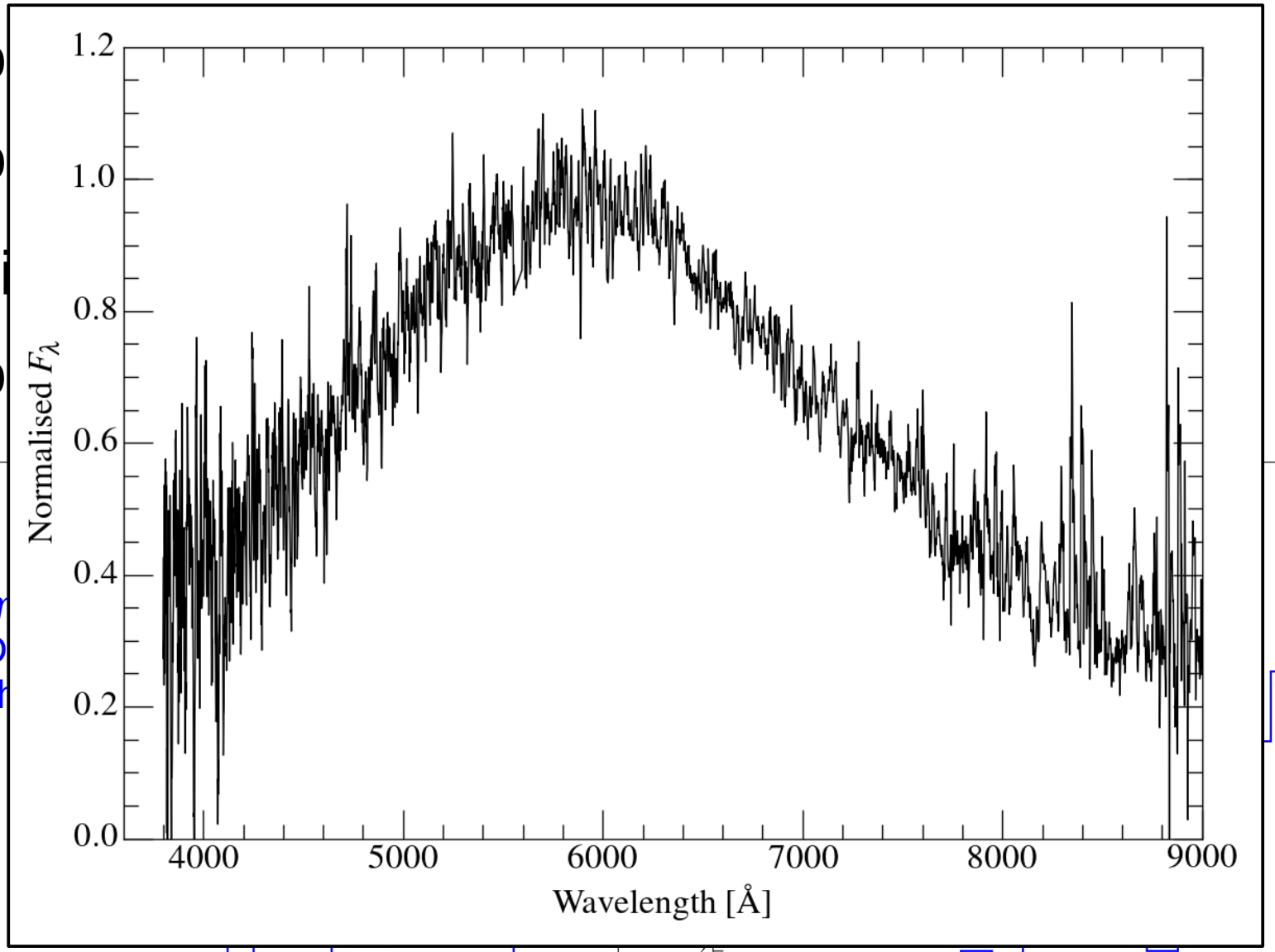
- No Helium lines below ~12000K
- No Hydrogen lines below ~6000K
- Faint: $L \sim R^2 \cdot T^4$
- Dominate volume limited samples of WDs





Cool white dwarfs

- No
- No
- Fai
- Do



Tem
WD
of th

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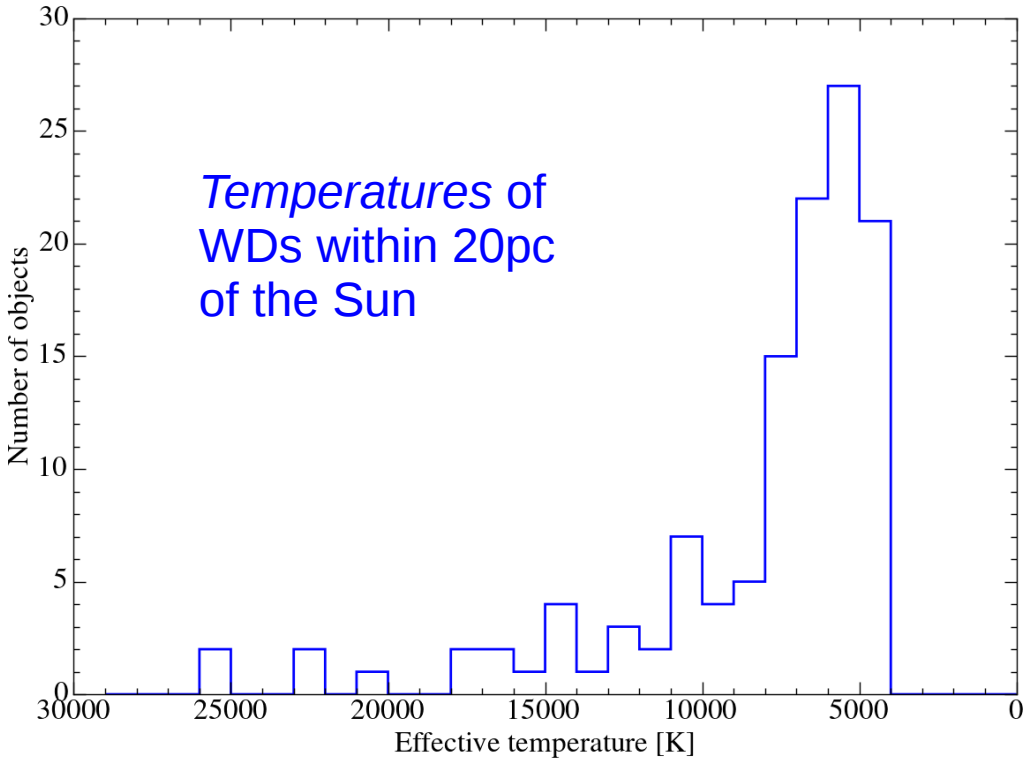

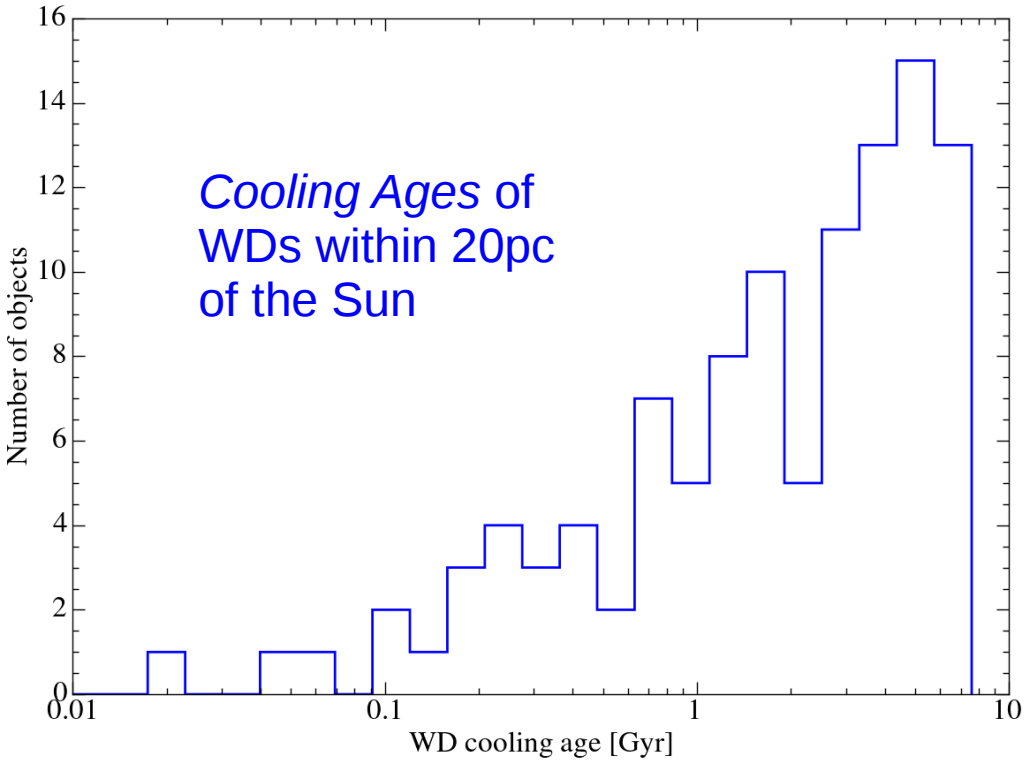

Cool white dwarfs

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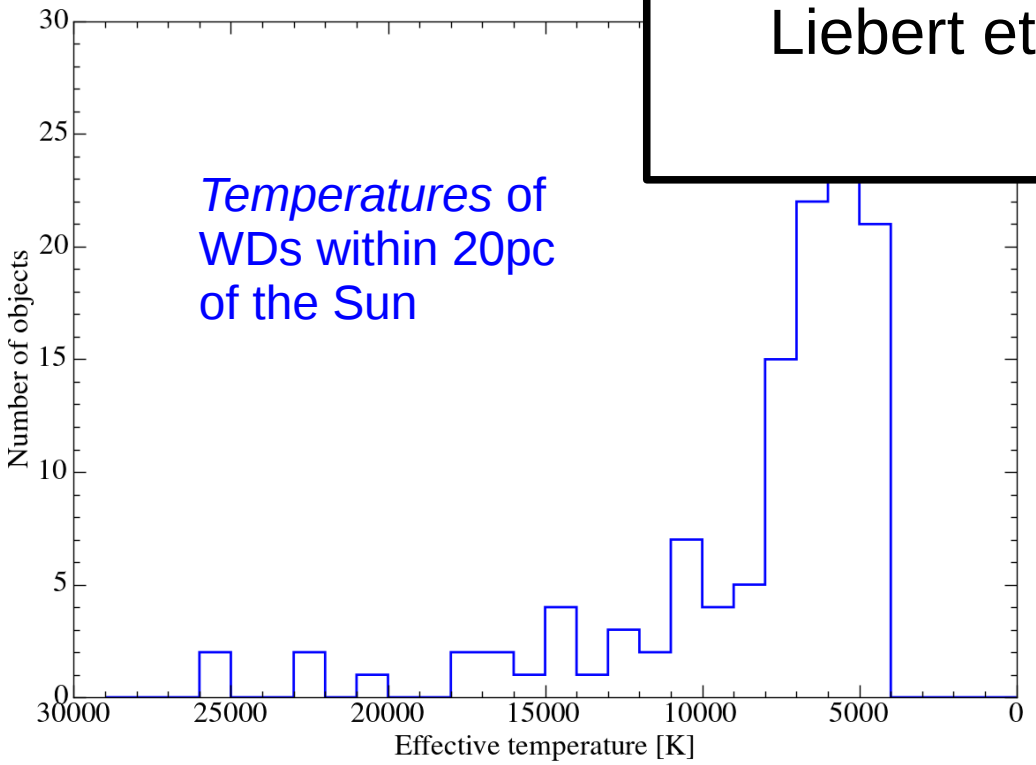
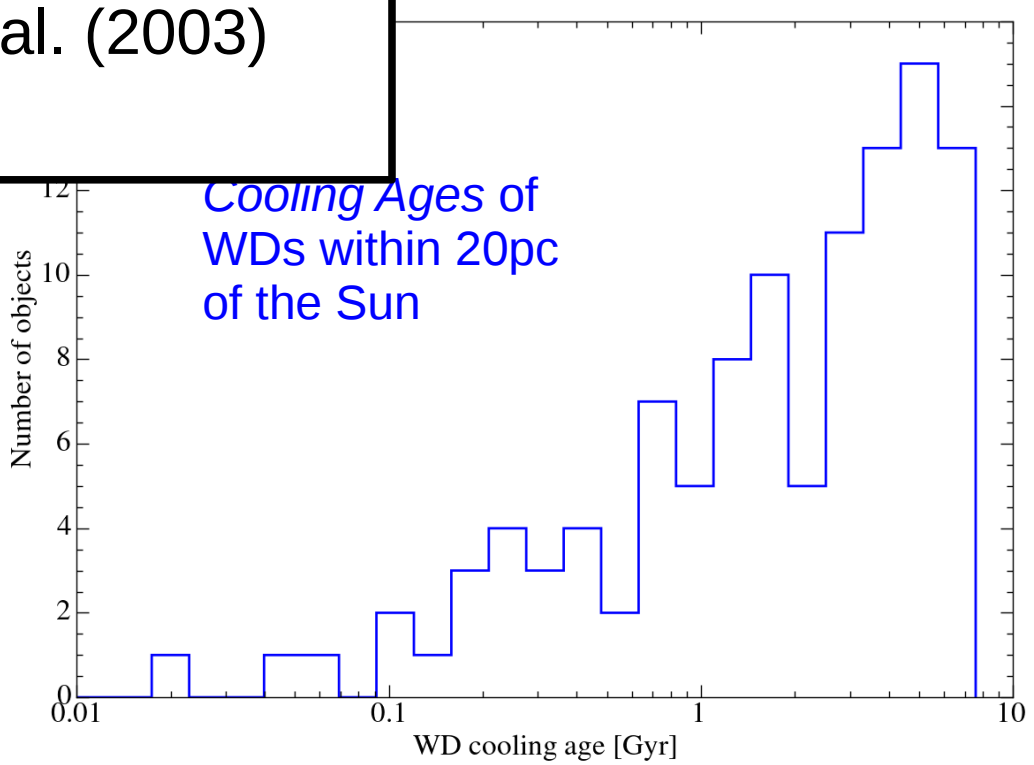
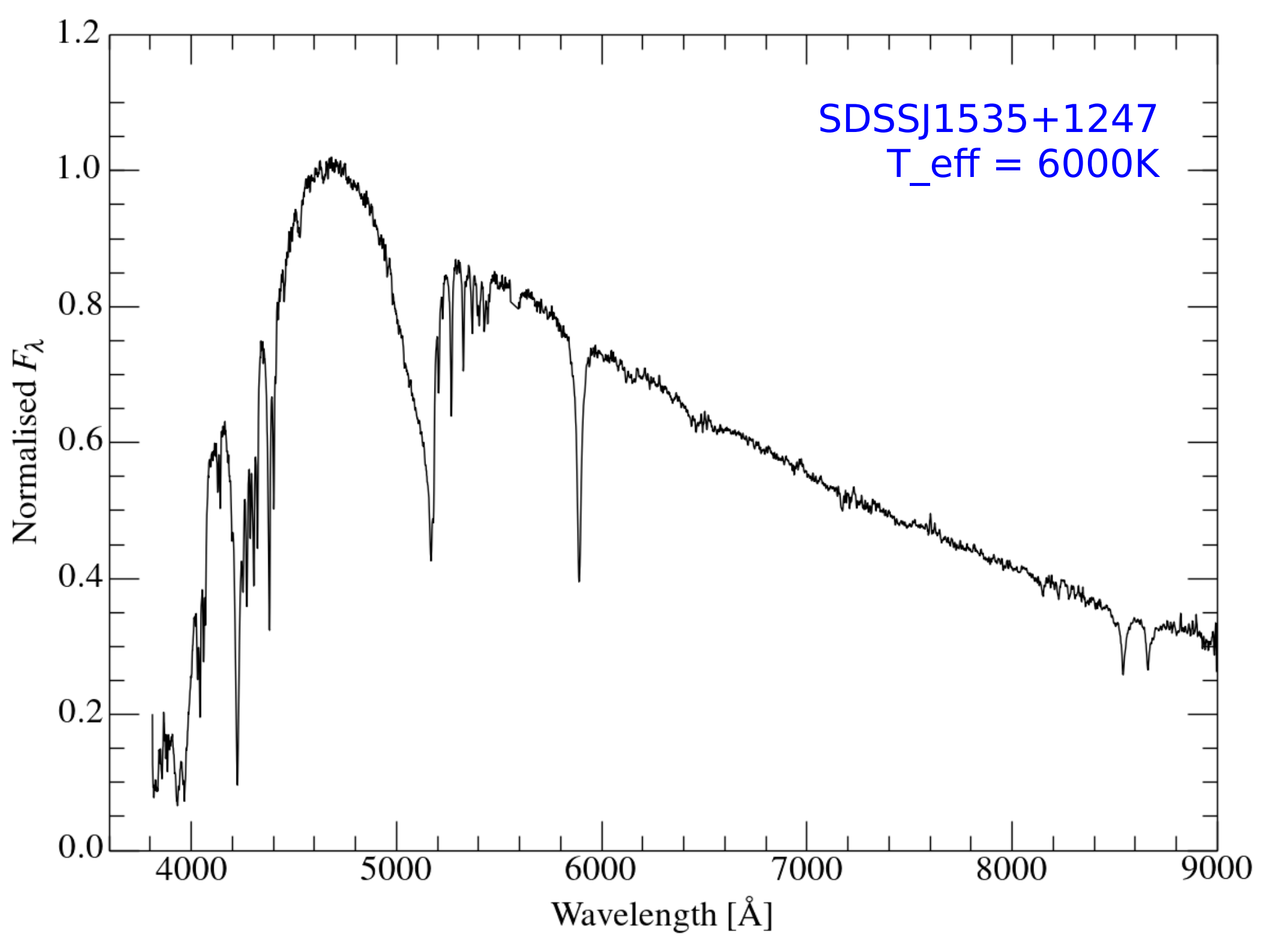
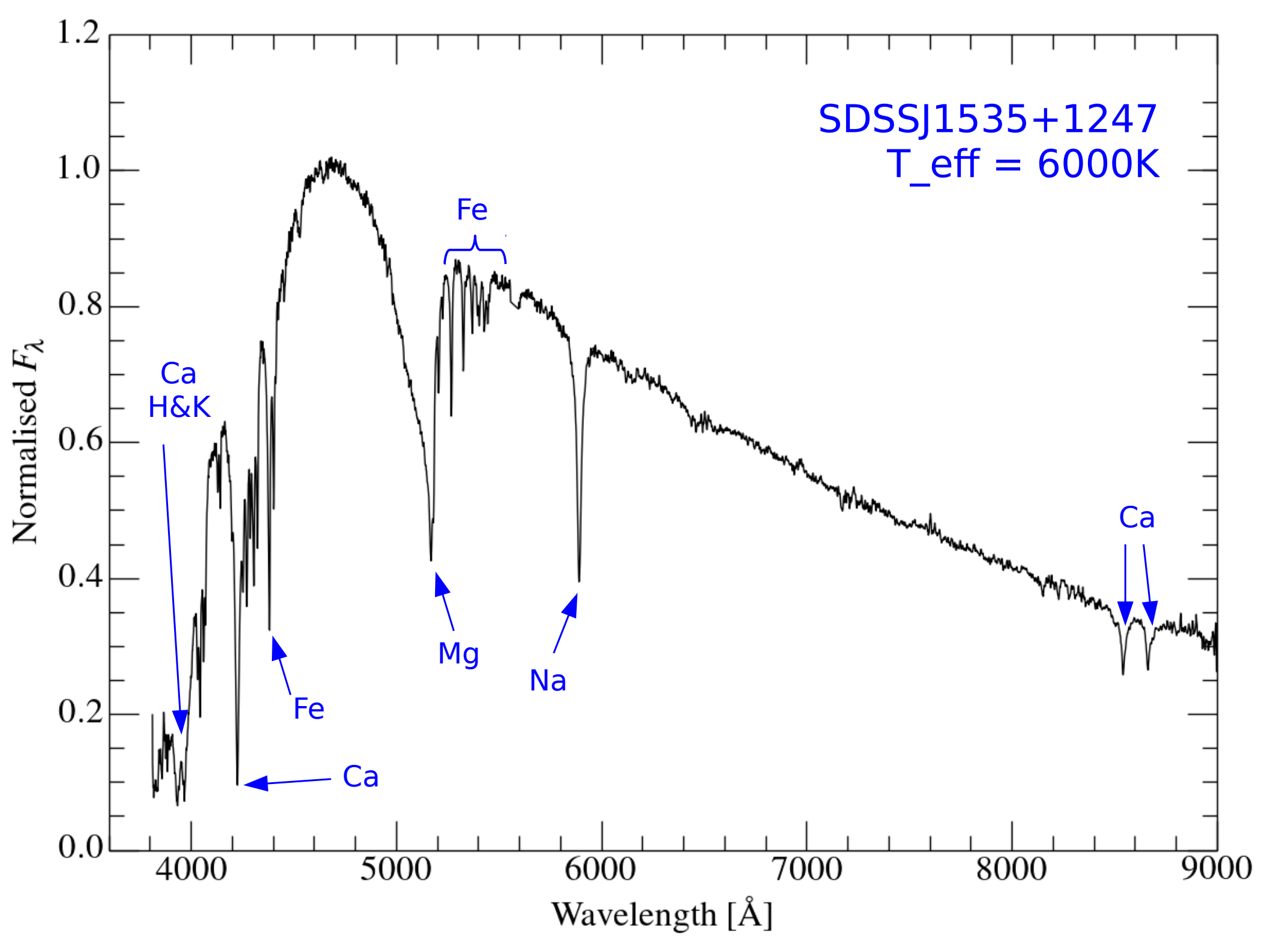
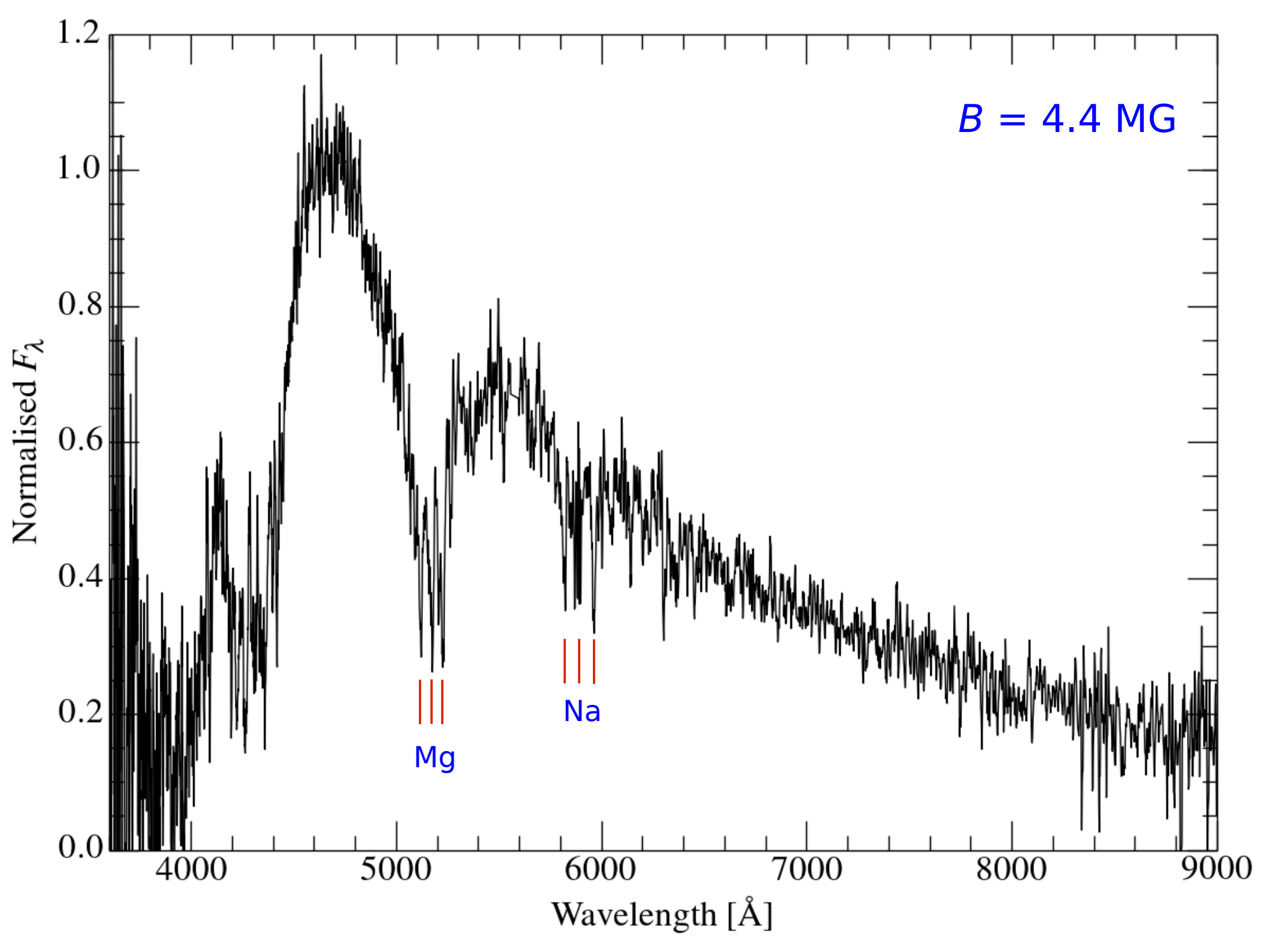
Fabrika et al. (1999)
Liebert et al. (2003)

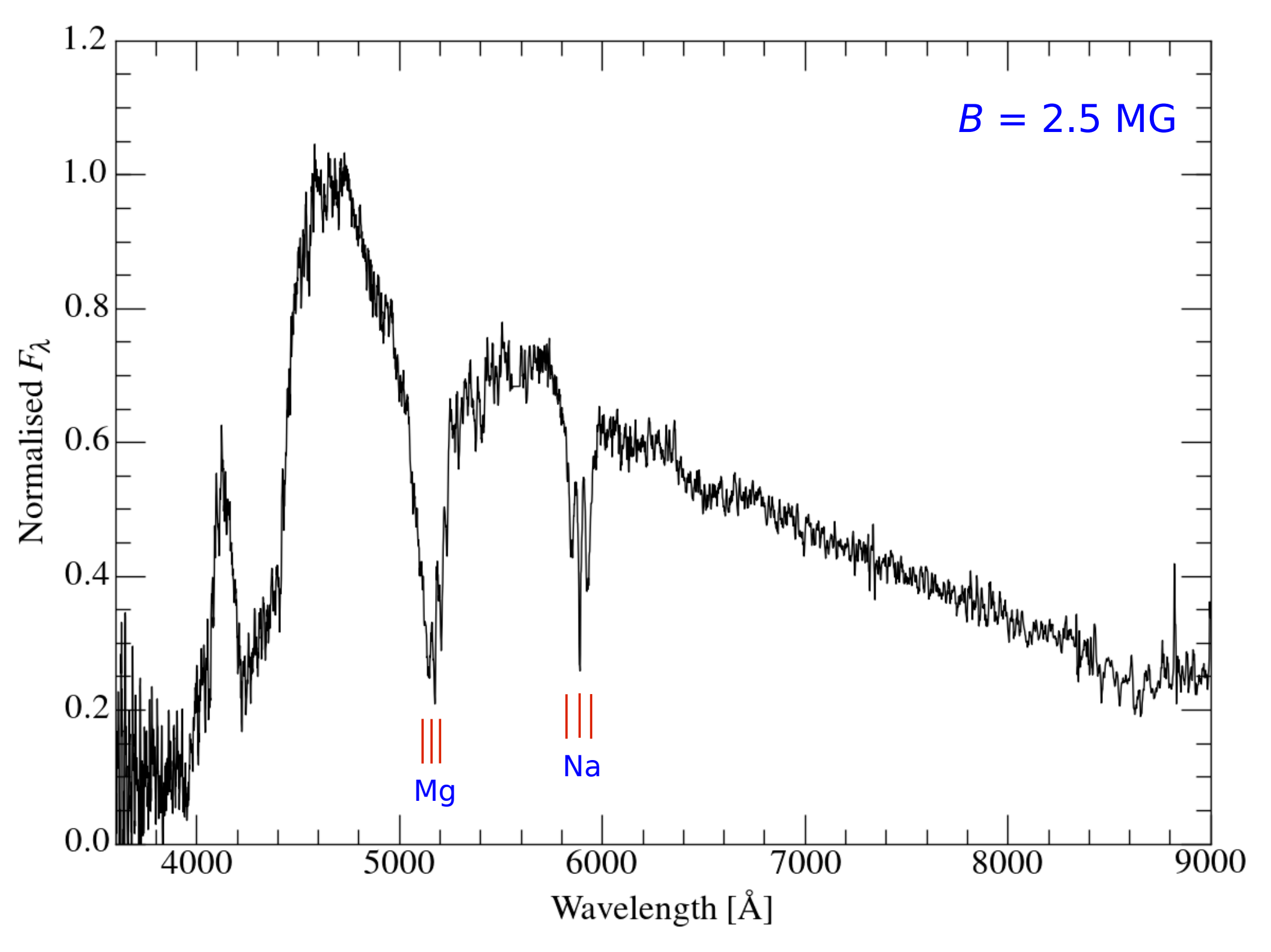


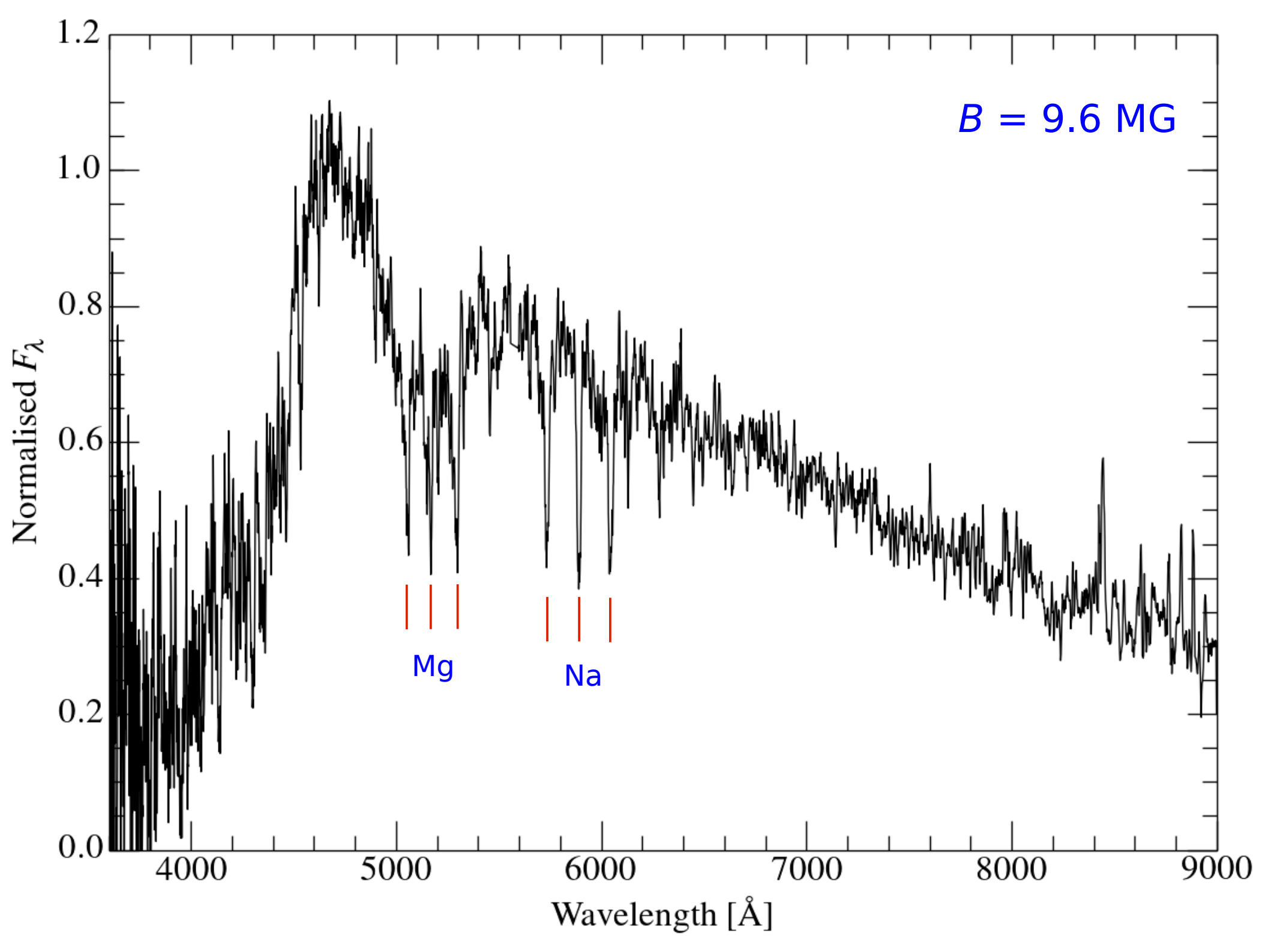



SDSSJ1535+1247
T_eff = 6000K
Normalised F_λ
Wavelength [Å]
0.0
0.2
0.4
0.6
0.8
1.0
1.2
4000
5000
6000
7000
8000
9000


SDSSJ1535+1247
T_eff = 6000K
Ca
H&K
Fe
Ca
Fe
Mg
Na
Ca
Normalised F_λ
Wavelength [Å]
0.0
0.2
0.4
0.6
0.8
1.0
1.2
4000
5000
6000
7000
8000
9000

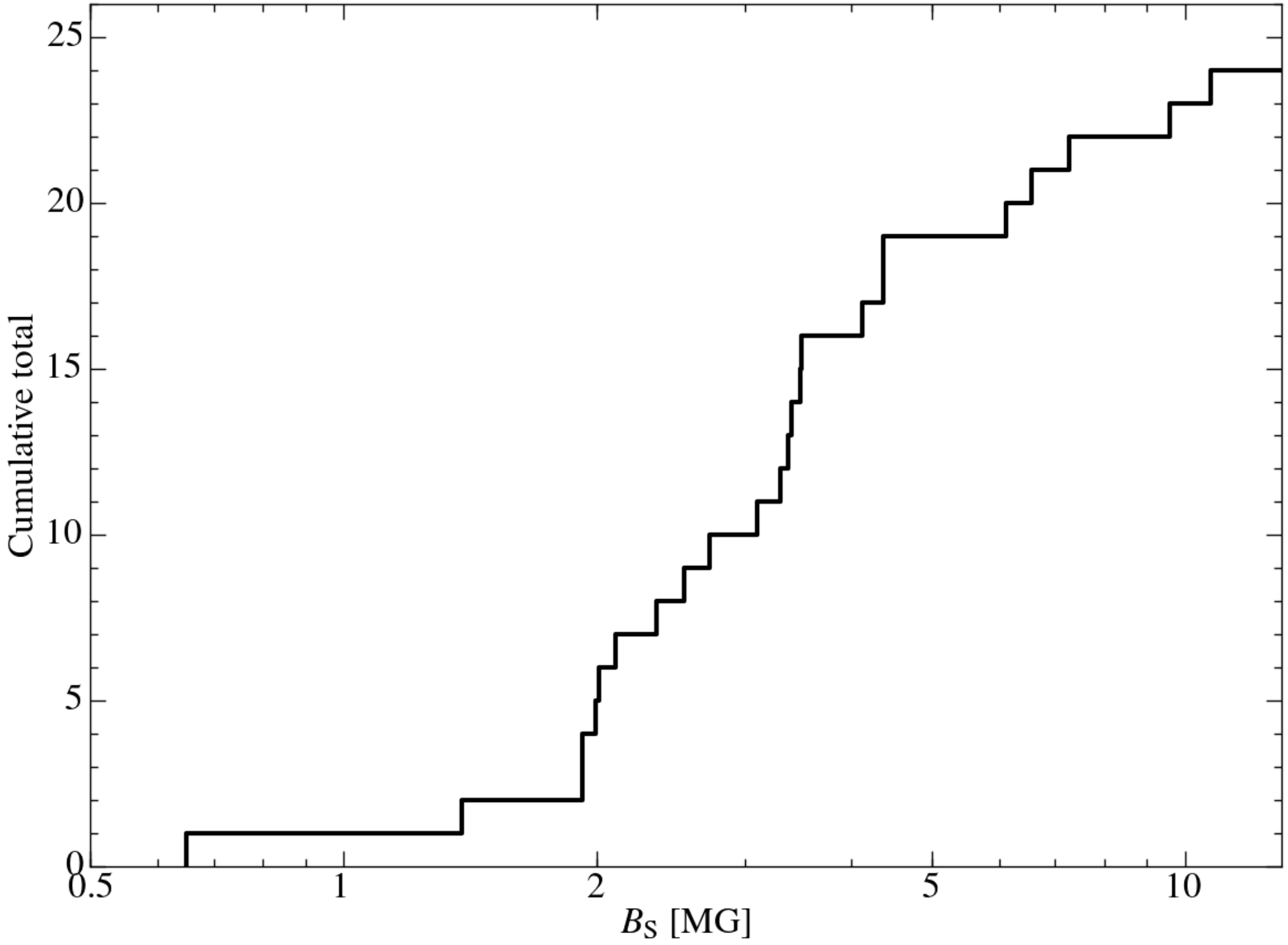

B = 4.4 MG
Mg
Na
Normalised F_λ
Wavelength [Å]
0.0
0.2
0.4
0.6
0.8
1.0
1.2
4000
5000
6000
7000
8000
9000

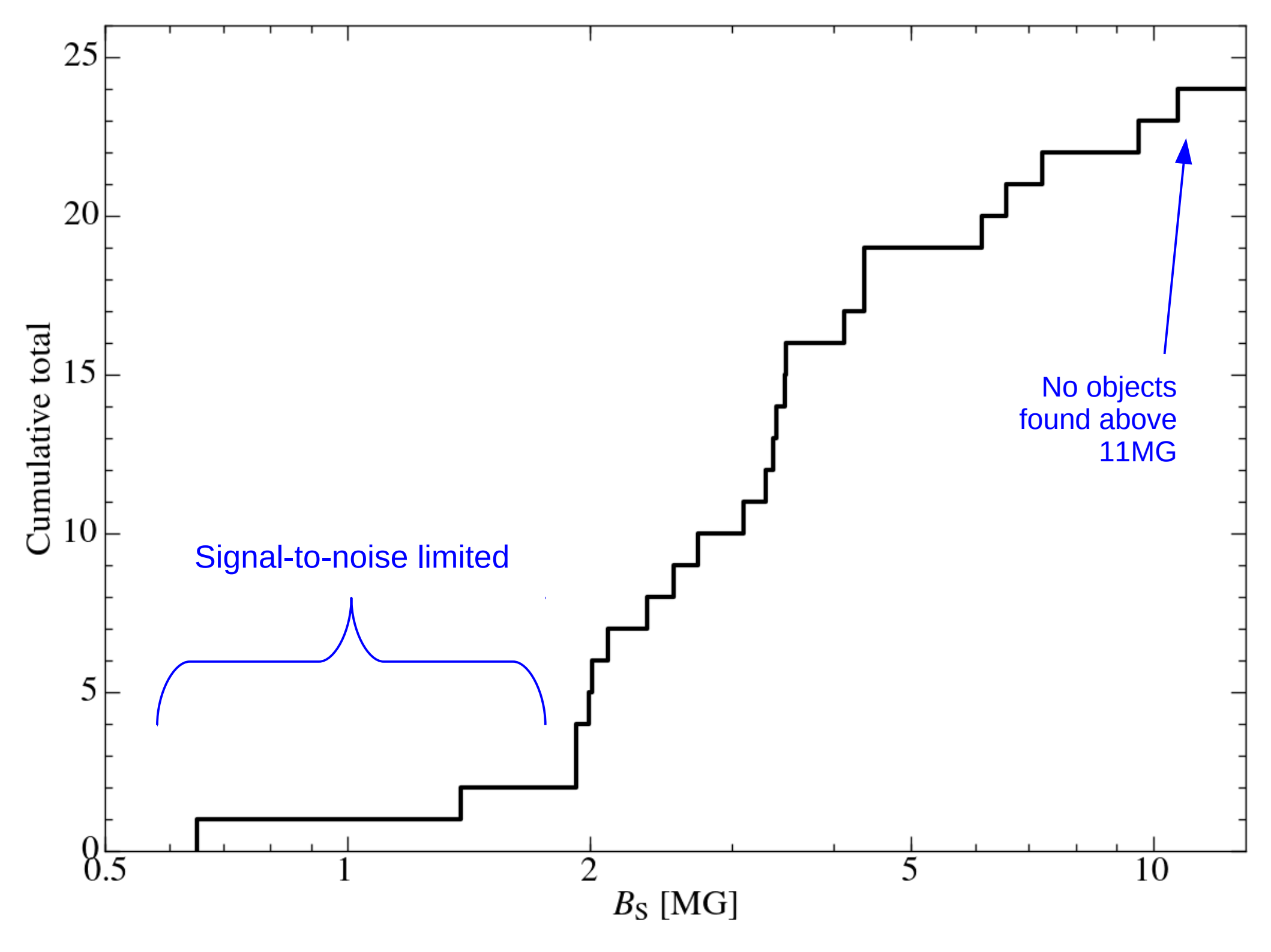

B = 2.5 MG
Mg
Na
Normalised F_λ
Wavelength [Å]
1.2
1.0
0.8
0.6
0.4
0.2
0.0
4000
5000
6000
7000
8000
9000


B = 9.6 MG
Mg
Na
Normalised F_λ
Wavelength [Å]
0.0
0.2
0.4
0.6
0.8
1.0
1.2
4000
5000
6000
7000
8000
9000

Cool magnetic WDs

- 24/154 in our sample are magnetic
- Minimum incidence = 16±3%.
- ~4% for T >10000K / age < 0.5Gyr
  (Kepler et al. 2013, *MNRAS* 429, 2934)
- Field strength distribution?

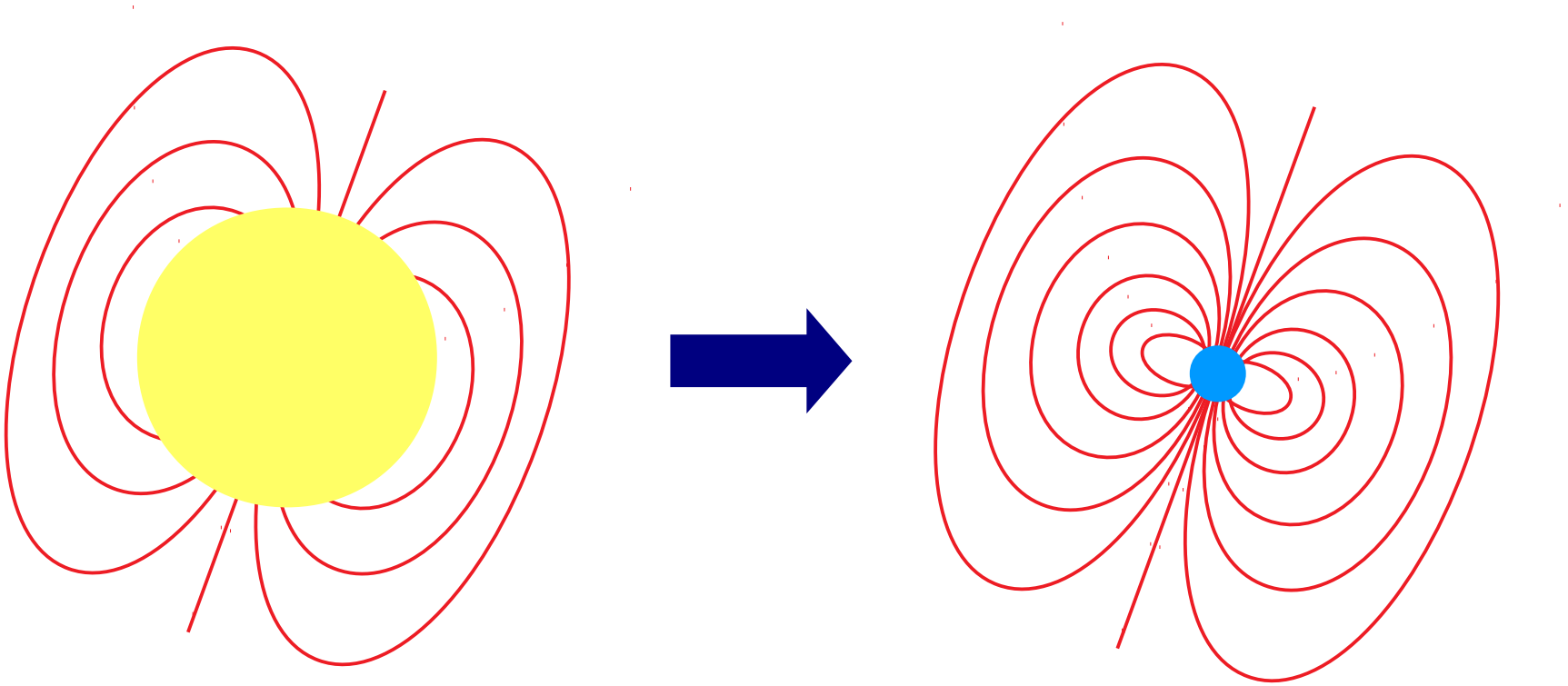

25
20
15
10
5
0
Cumulative total
0.5
1
2
5
10
B_S [MG]


Cumulative total
25
20
15
10
5
0
0.5
1
2
5
10
B_S [MG]
Signal-to-noise limited
No objects
found above
11MG

Field origin of isolated WDs?

- Fossil fields
- Binary merger
- Cores of giant stars

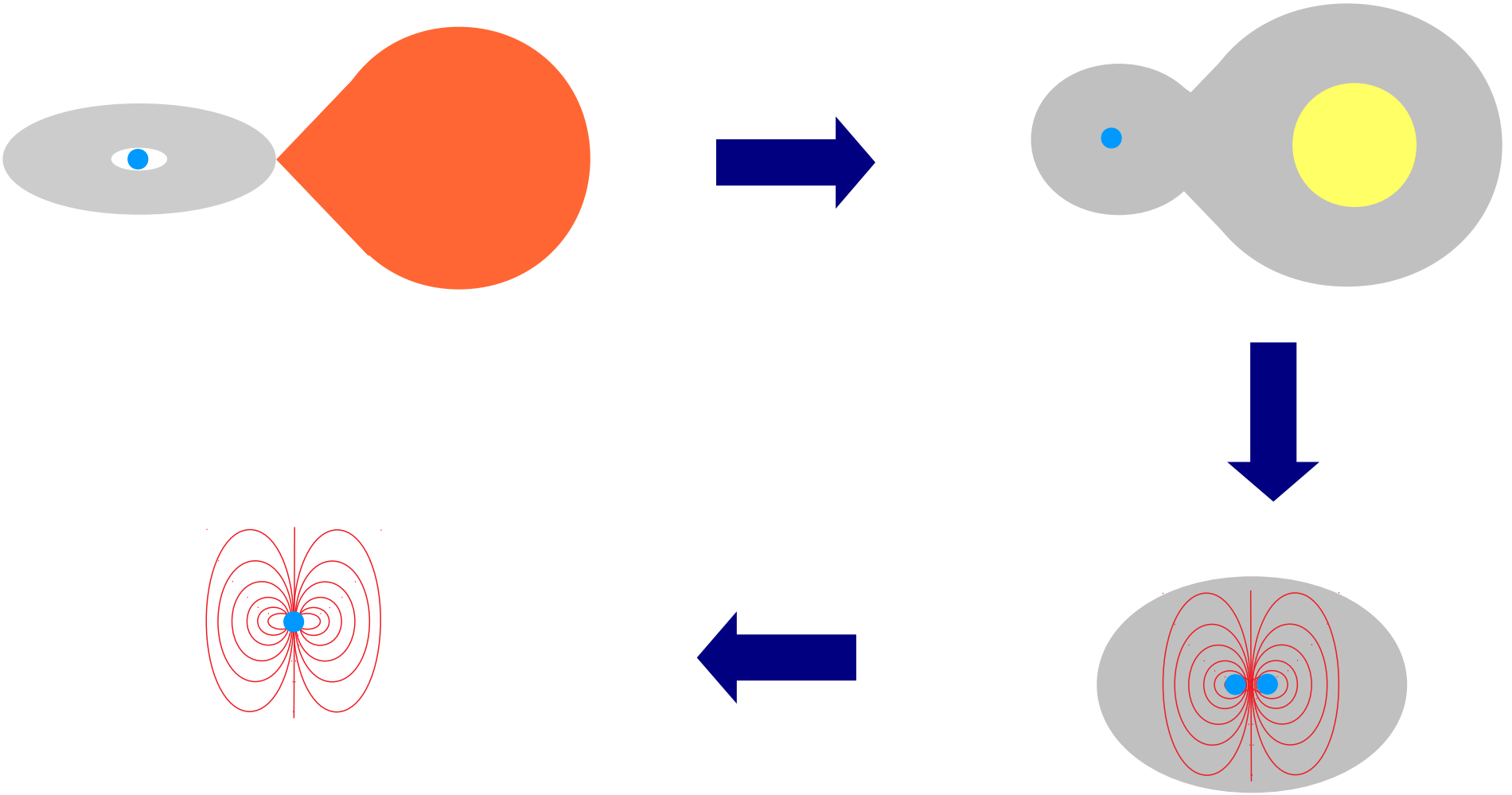
Fossil field



$$B_{\mathrm{WD}} / B_{\mathrm{MS}} = \left(R_{\mathrm{WD}} / R_{\mathrm{MS}}\right)^{-2}$$

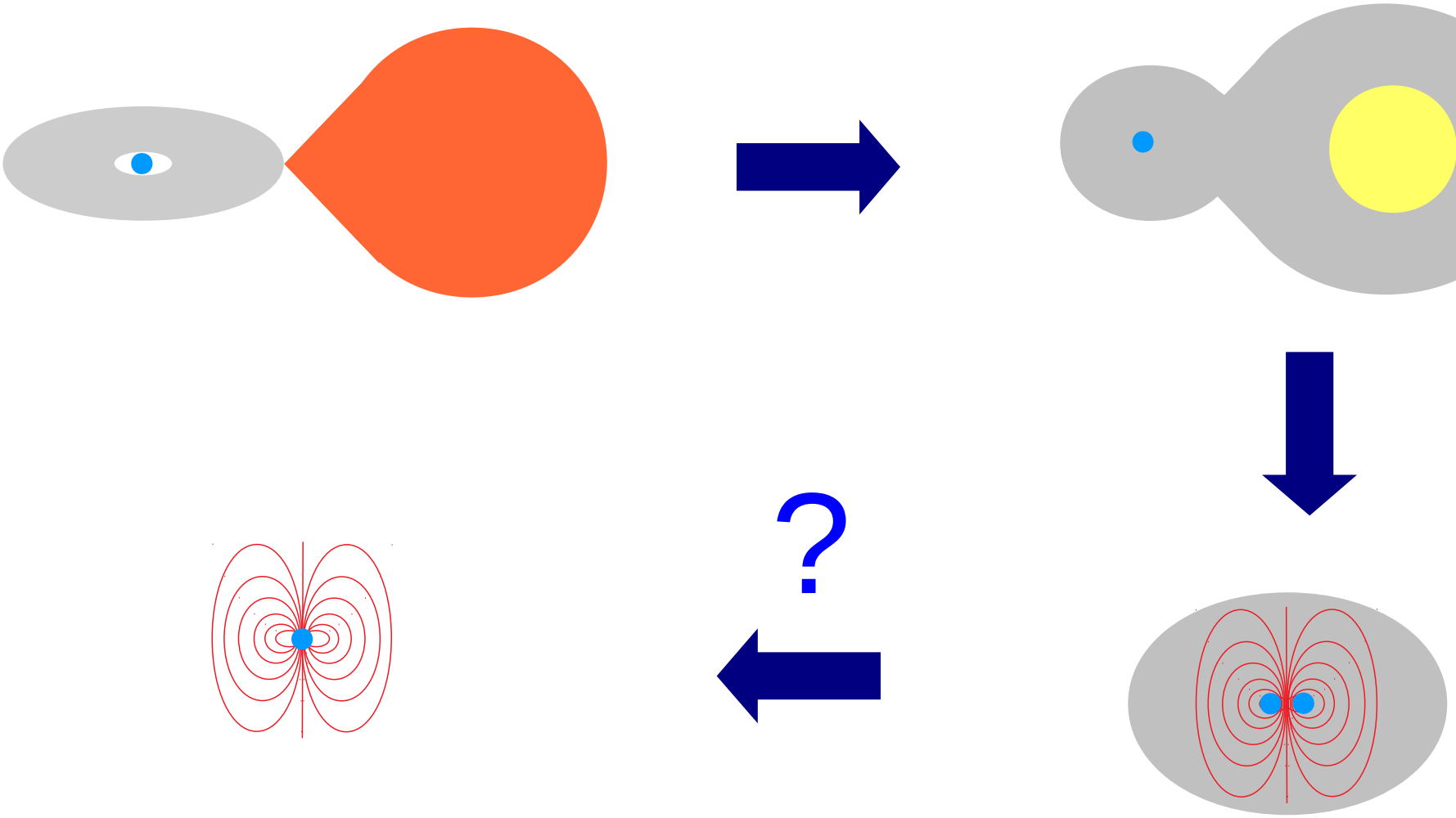
Angel and Landstreet (1970), *ApJ* 160, L147

Binary merger



Tout et al. (2008), *MNRAS* 387, 897

Binary merger



Tout et al. (2008), *MNRAS* 387, 897

Giant-core dynamo generation

- Angular momentum pumping inwards triggers dynamo between radiative core and convective envelope
- Matter passing through core-envelope boundary deposits magnetic helicity in the core
- Field remains buried during the WD stage
- Ohmic diffusion causes field to emerge over Gyr time scales

Kissin and Thompson, a/b (Submitted 2015)
arXiv:1501.07217
arXiv:1501.07197

Summary

- Metals can probe cool WDs for magnetic fields
- Surface fields found 0.6–11MG
- Magnetic fraction much higher for cool (<8000K) WDs than hot WDs (>10000 K)
- Field generation: At least two channels contribute to the magnetic population at different WD ages