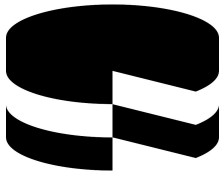
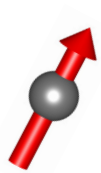
Fermi gas: Drude-Sommerfeld model

specific heat (microscopic probe)



white dwarfs

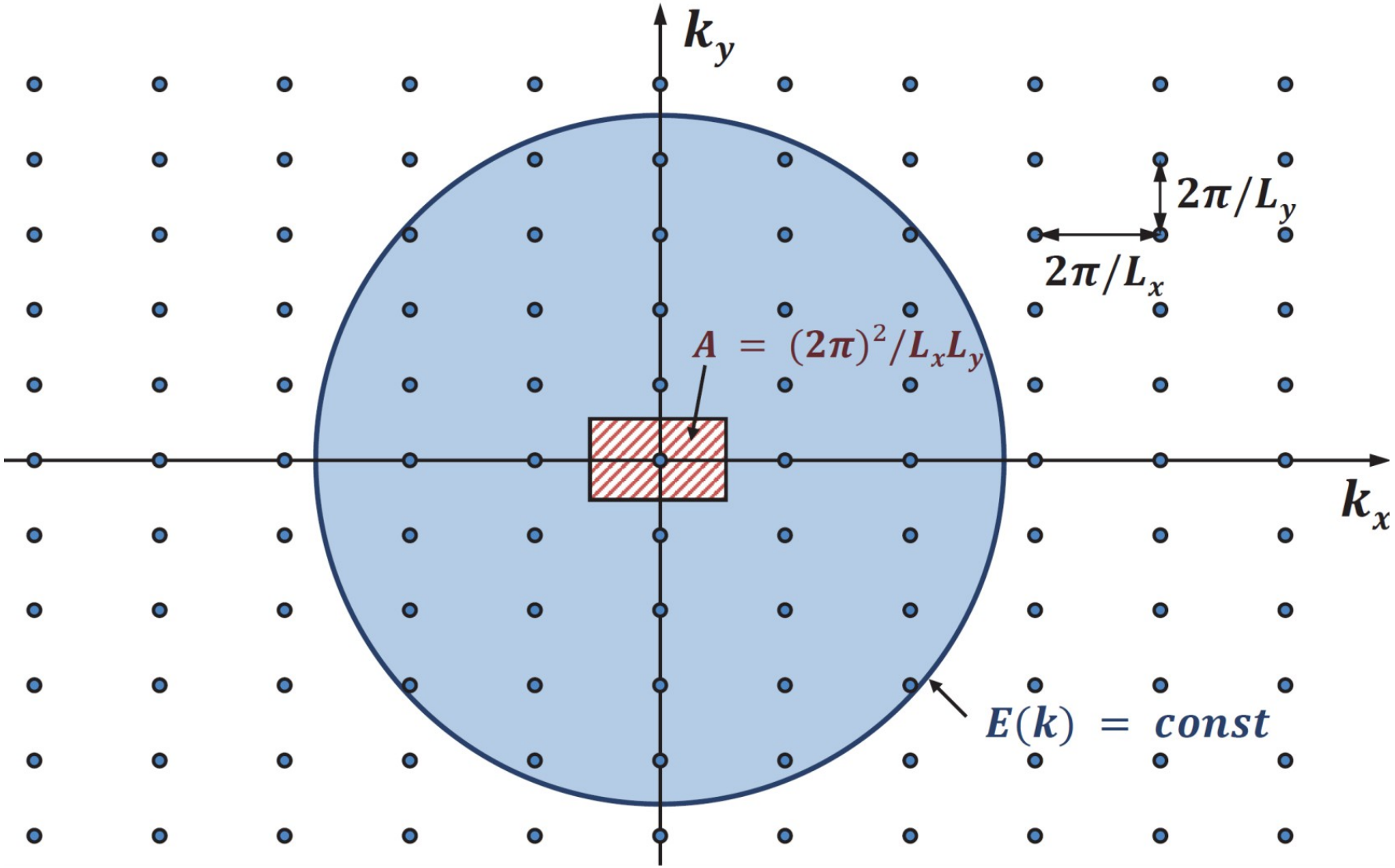
Arnold Sommerfeld



by Alexander Tsirlin, Leipzig University

Lecture 18: December 13, 2023

Allowed q-vectors



Gross and Marx, Festkörperphysik

Fermi energy

Metal	n (10^{22} cm^{-3})	E_F (eV)	T_F (K)	k_F (10^8 cm^{-1})	v_F (10^8 cm/s)
Li	4.70	4.72	54 800	1.11	1.27
Na	2.54	3.16	36 700	0.91	1.05
Rb	1.15	1.85	21 500	0.69	0.79
Cu	8.45	7.00	81 200	1.35	1.55
Au	5.90	5.51	63 900	1.20	1.38
Ag	5.86	5.49	63 700	1.20	1.39
Be	24.2	14.14	164 100	1.92	2.21
Zn	13.10	9.39	109 000	1.56	1.79
Al	18.06	11.63	134 900	1.74	2.00
Pb	13.20	9.37	108 700	1.57	1.81

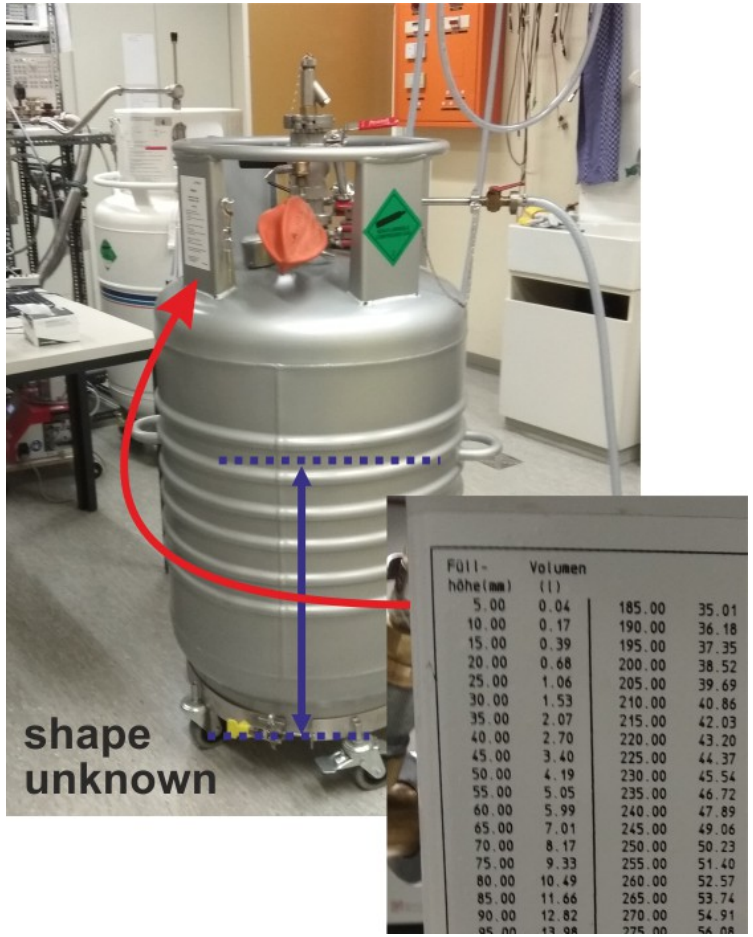
Gross and Marx, Festkörperphysik

Why we need density of states?

Image credits: Jenie Yolland, Parched, own photo (CC-BY-SA)

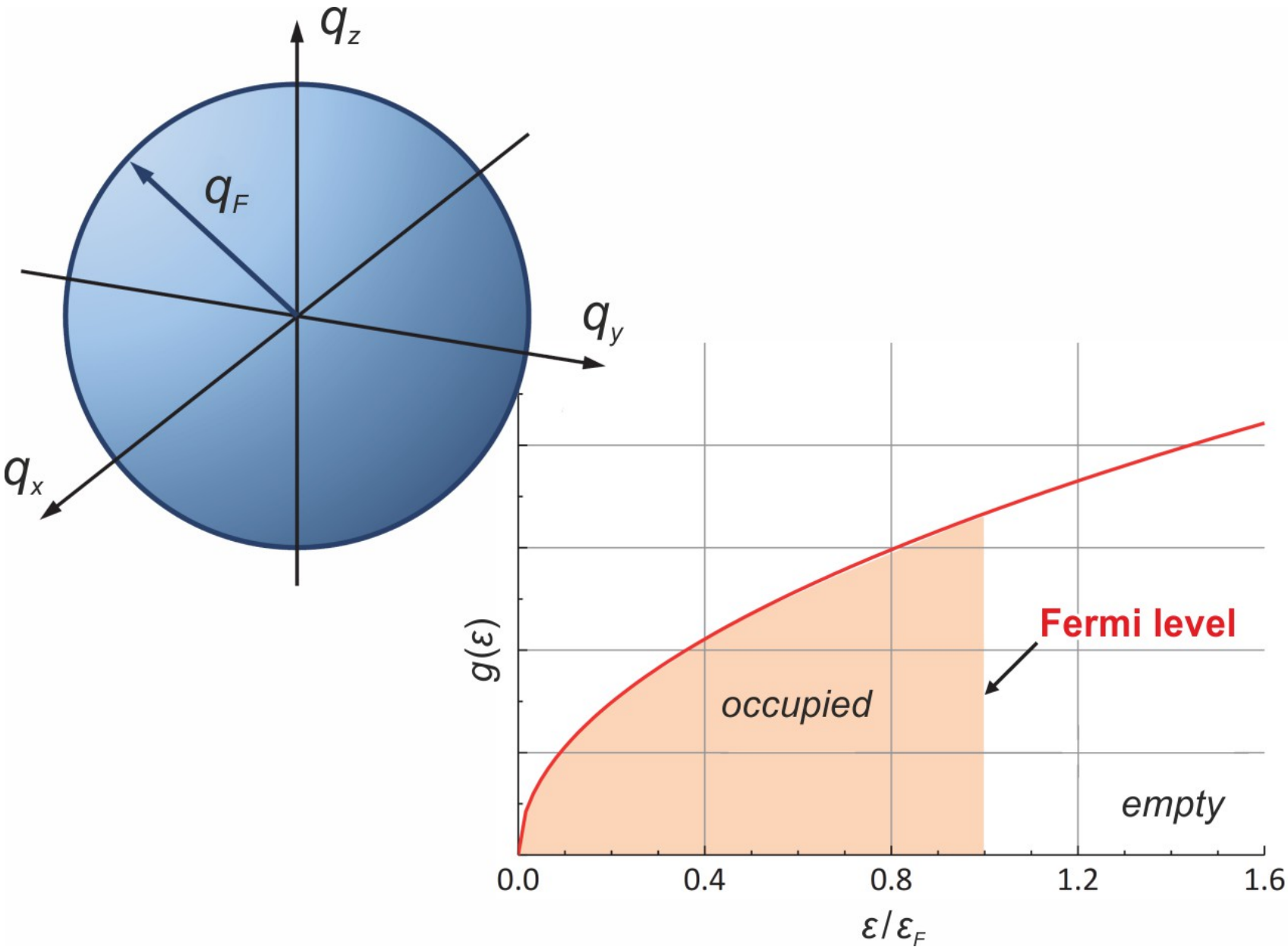
Why we need density of states?

Why we need density of states?



Density of states (DOS) simplifies the analysis,
especially when we do not see what is inside

Fermi gas: states



Gross and Marx, Festkörperphysik

Next Tuesday (19.12): **tutorial in SR 218** instead of ThHS

Changes in the schedule

Next Tuesday (19.12): **tutorial in SR 218** instead of ThHS

Regular lectures on 3.01 (11:15) and 4.01 (9:15)

No lectures on 10.01 and 11.01

Lectures re-start on 17.01

Fermi gas: pressure

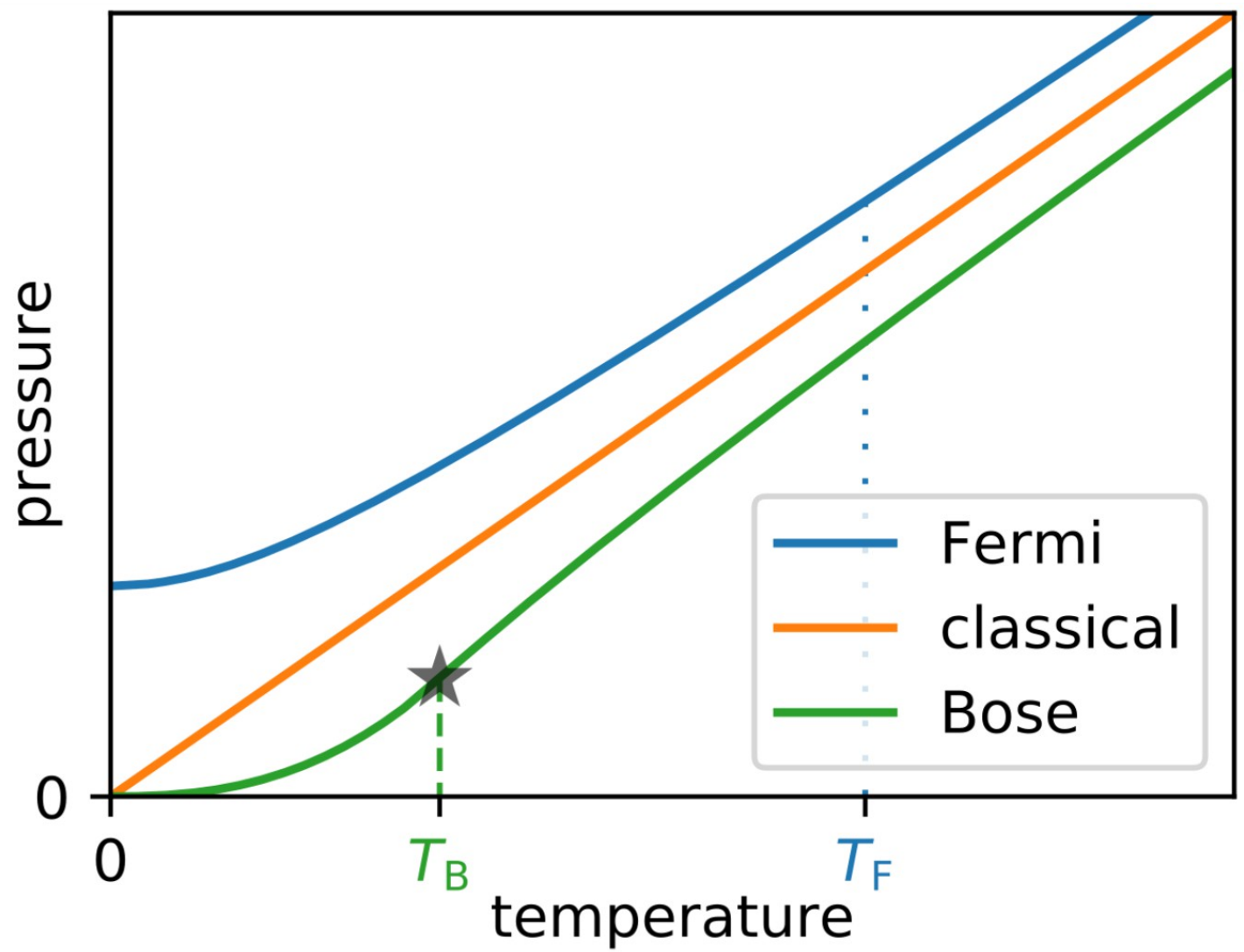
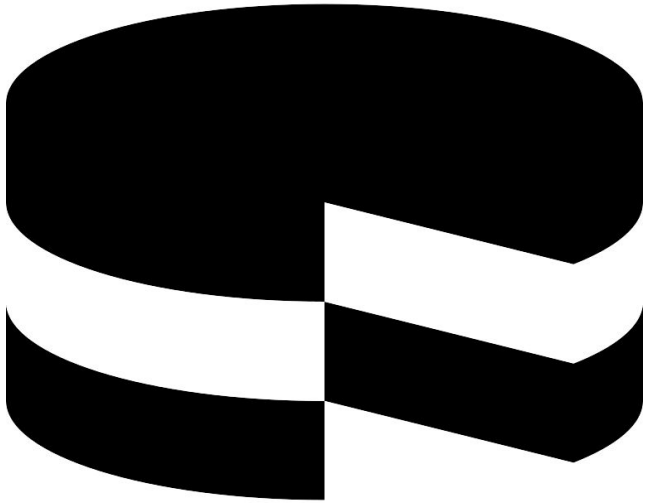


Image credit: Nanite (CC-zero)



Material

white dwarfs as Fermi gas

Stellar evolution

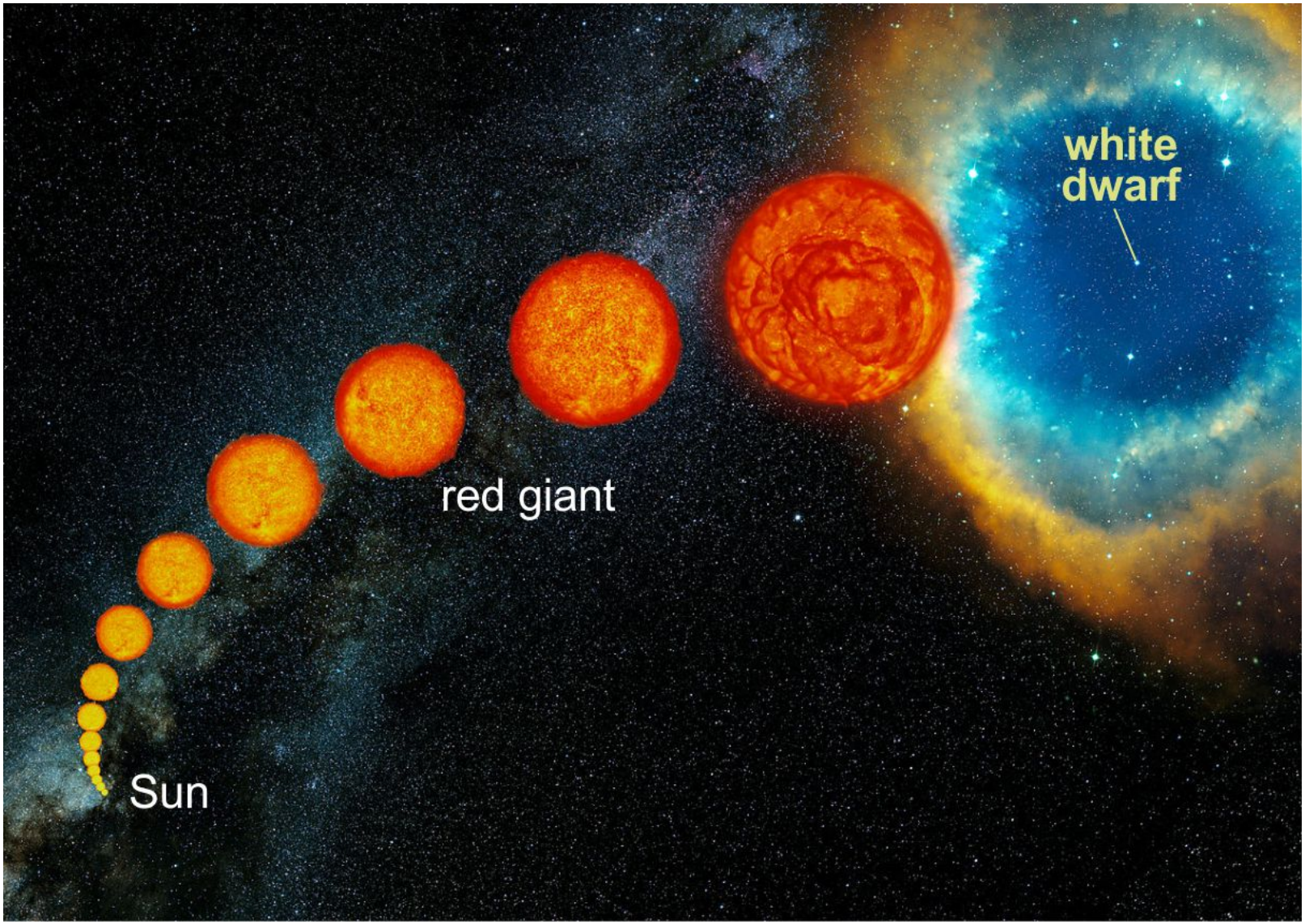
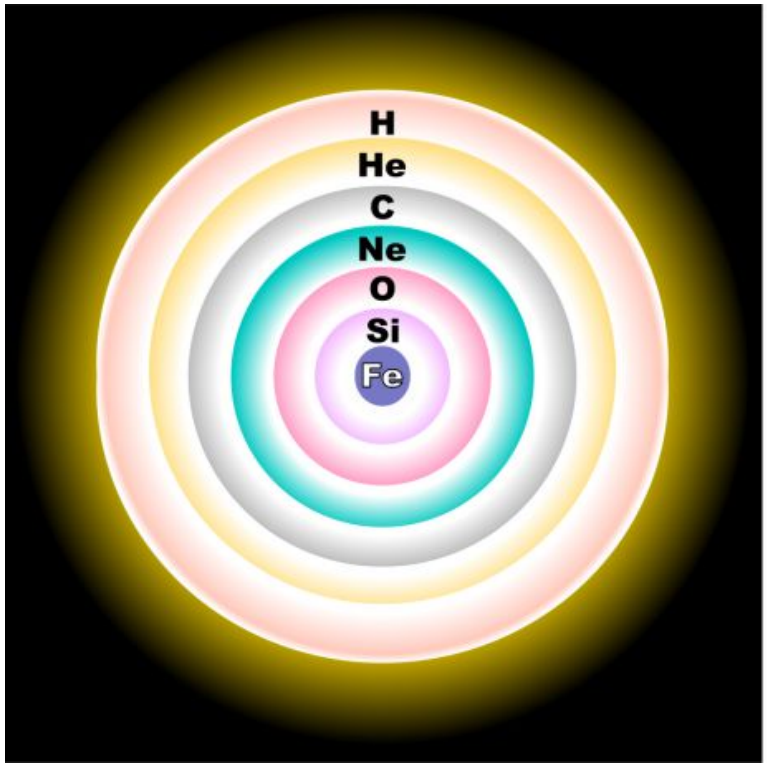


Image credit: ESO/S. Steinhöfel (CC-BY-SA)

White dwarfs



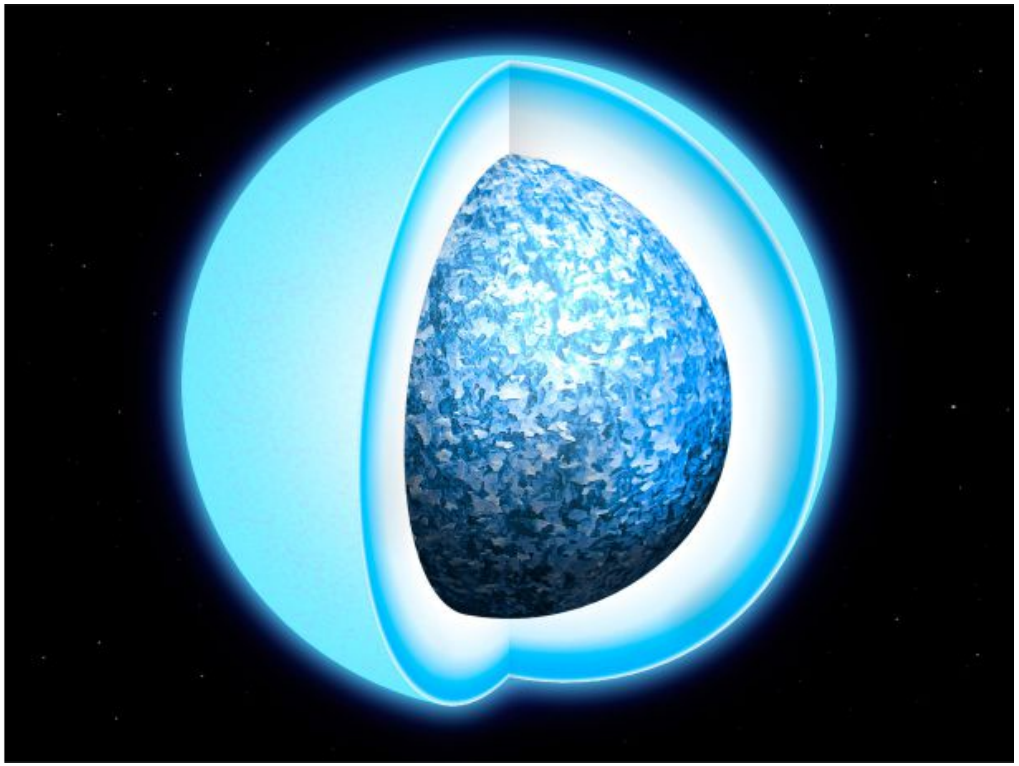
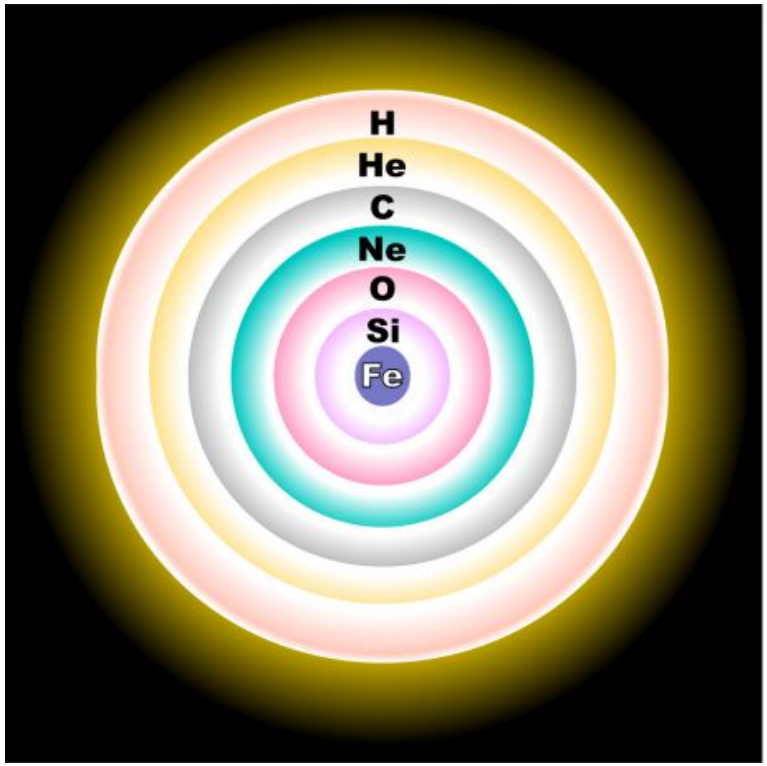
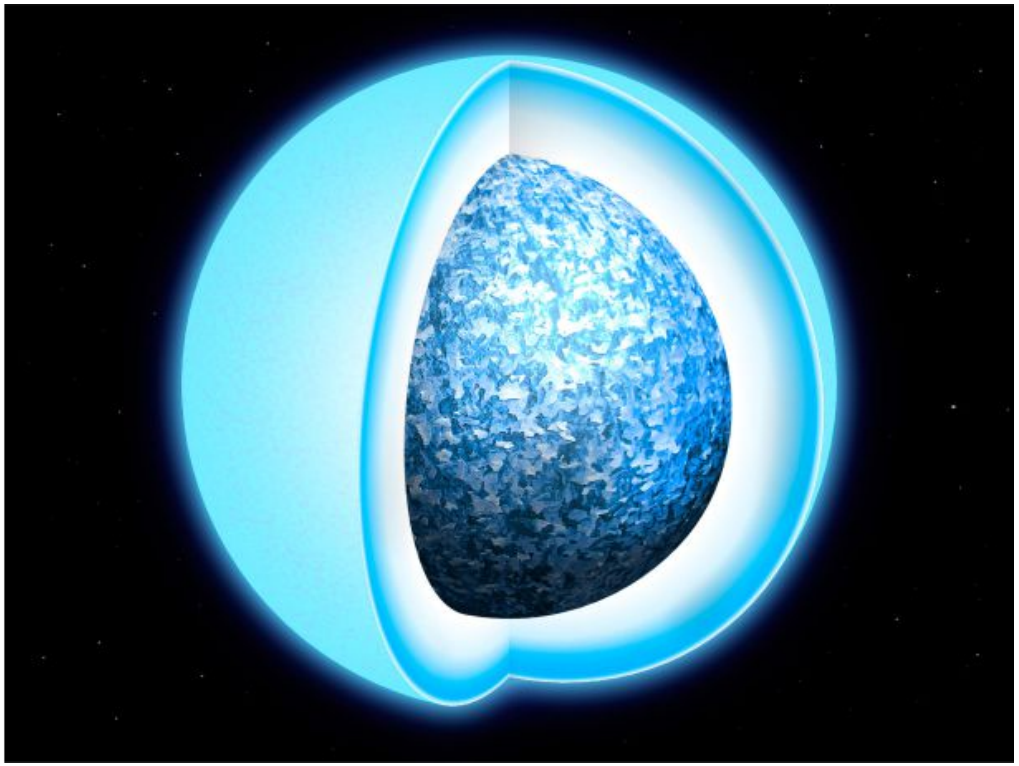


Image credit: Rursus (CC-BY-SA) and Mark Garlick (fair use)



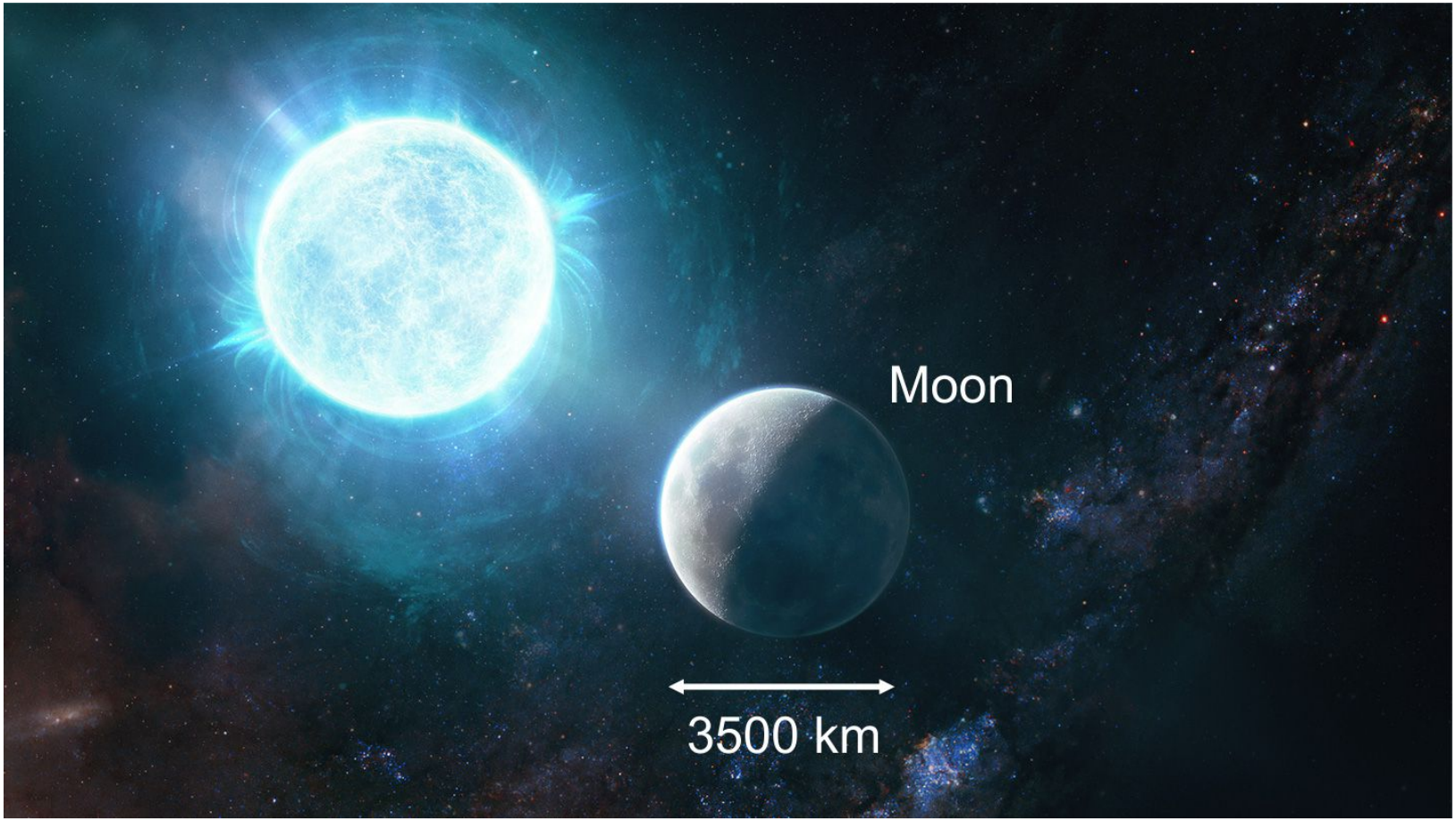


Subrahmanyan Chandrasekhar (1910–1995)

early 1930's: Fermi gas to explain the stability of white dwarfs

1983: Nobel Prize in Physics

Image credit: Rursus (CC-BY-SA) and Mark Garlick (fair use)

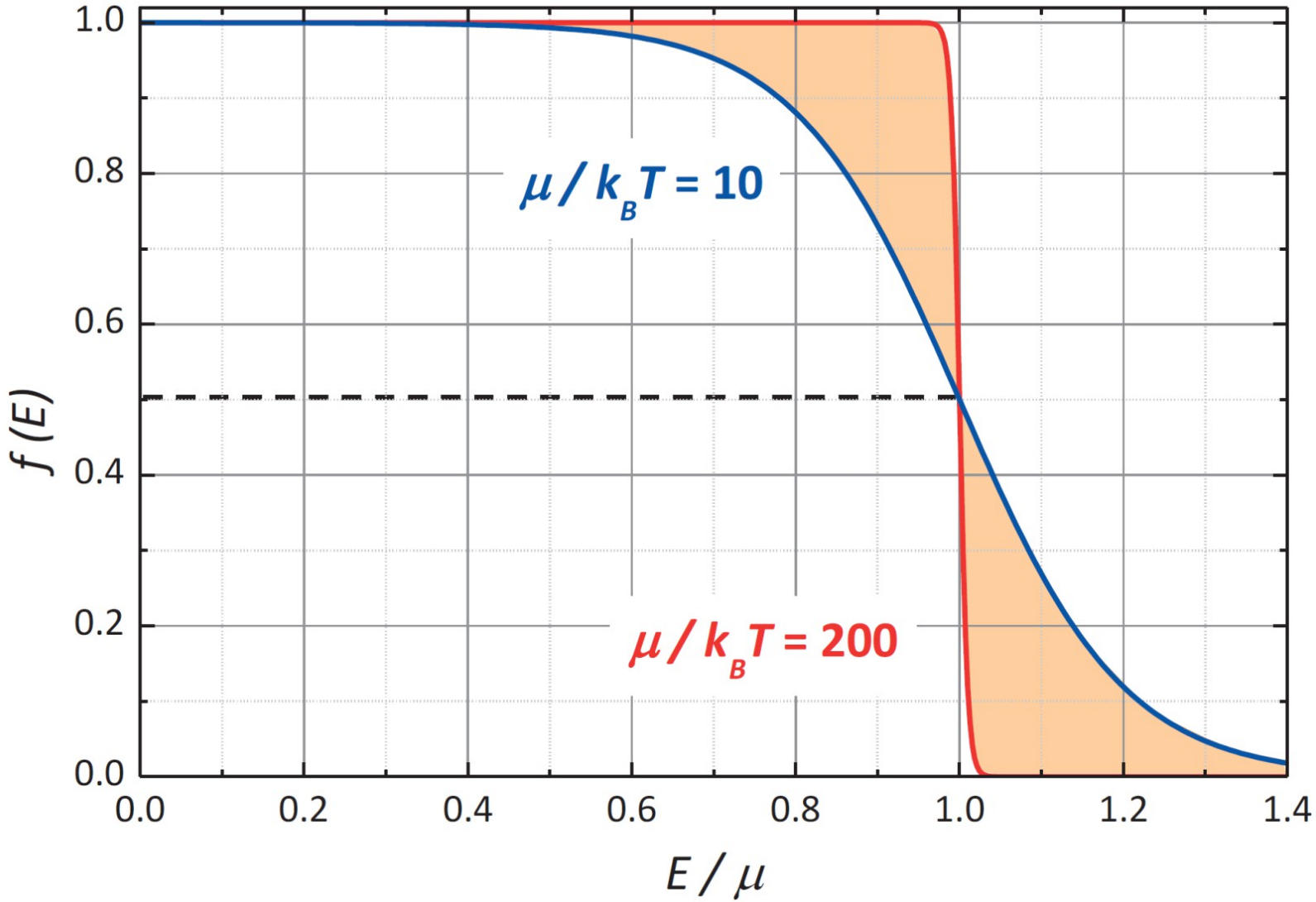


Chandrasekhar limit: mass $= 1.4\, m_{\mathrm{Sun}}$

heavier white dwarfs are unstable and become neutron stars

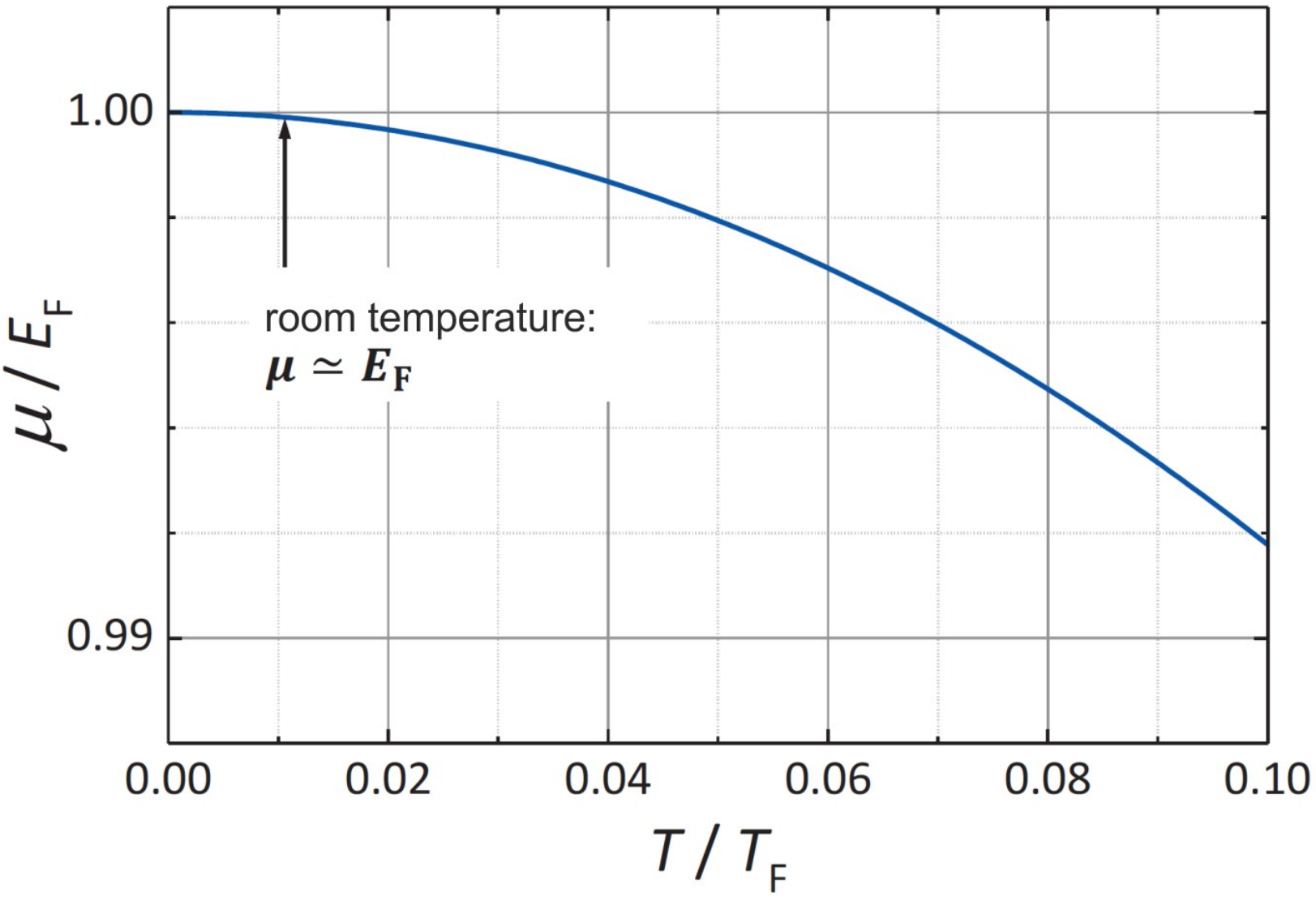
Image credit: Giuseppe Parisi (fair use)

Fermi-Dirac distribution



Gross and Marx, Festkörperphysik

Chemical potential



Gross and Marx, Festkörperphysik

Person

Arnold Sommerfeld

Arnold Sommerfeld

Arnold Sommerfeld

Image credit: Joeb07 (CC-BY-SA)

Arnold Sommerfeld

- 1886–1891: studies of mathematics and physics in Königsberg
- 1891: PhD in mathematical physics
- 1893–1897: assistant to Felix Klein in Göttingen
- 1897–1906: associate professor in Clausthal-Zellerfeld and Aachen
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- alumni – Nobel Prize winners:

  Werner Heisenberg
  Peter Debye
  Wolfgang Pauli
  Hans Bethe
  Linus Pauling
  Isidor Rabi
  Max von Laue

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Sommerfeld himself
was nominated **84 times**,
but never received the prize

Arnold Sommerfeld
1868–1951

Experimental technique

specific heat as a microscopic probe

Phonon vs. electronic contributions

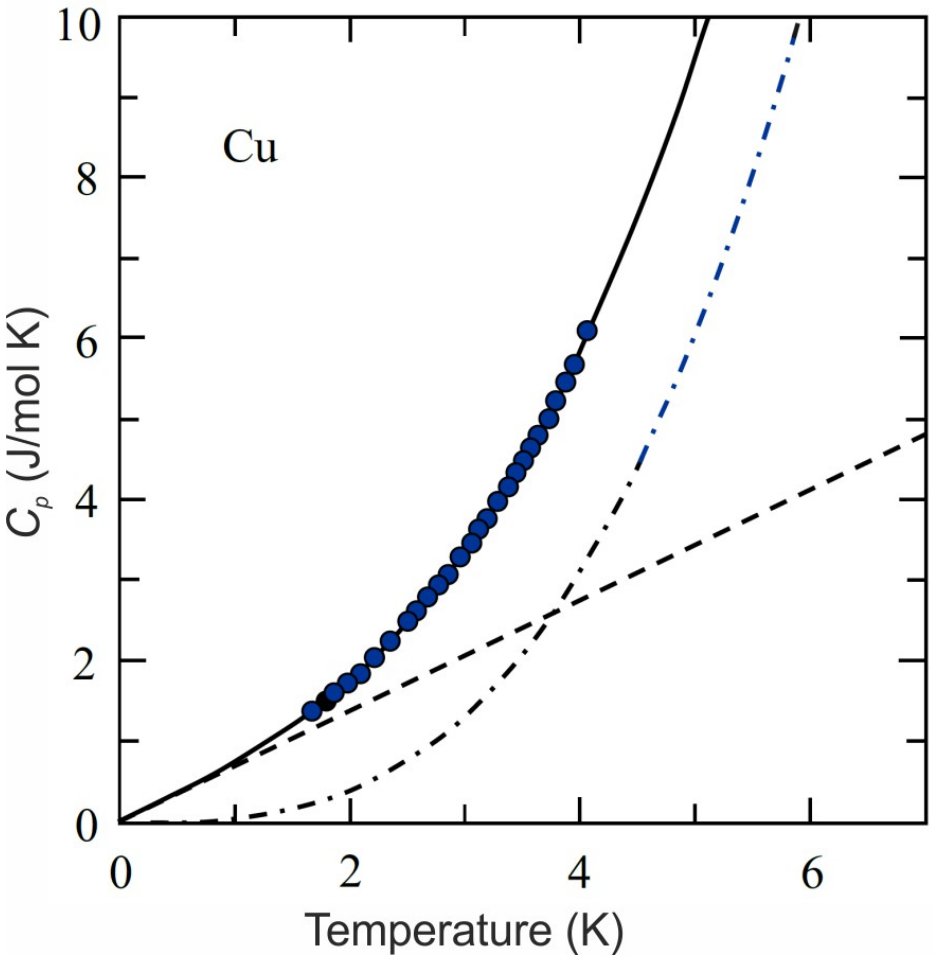

Image credit: Hunklinger, Festkörperphysik

Phonon vs. electronic contributions

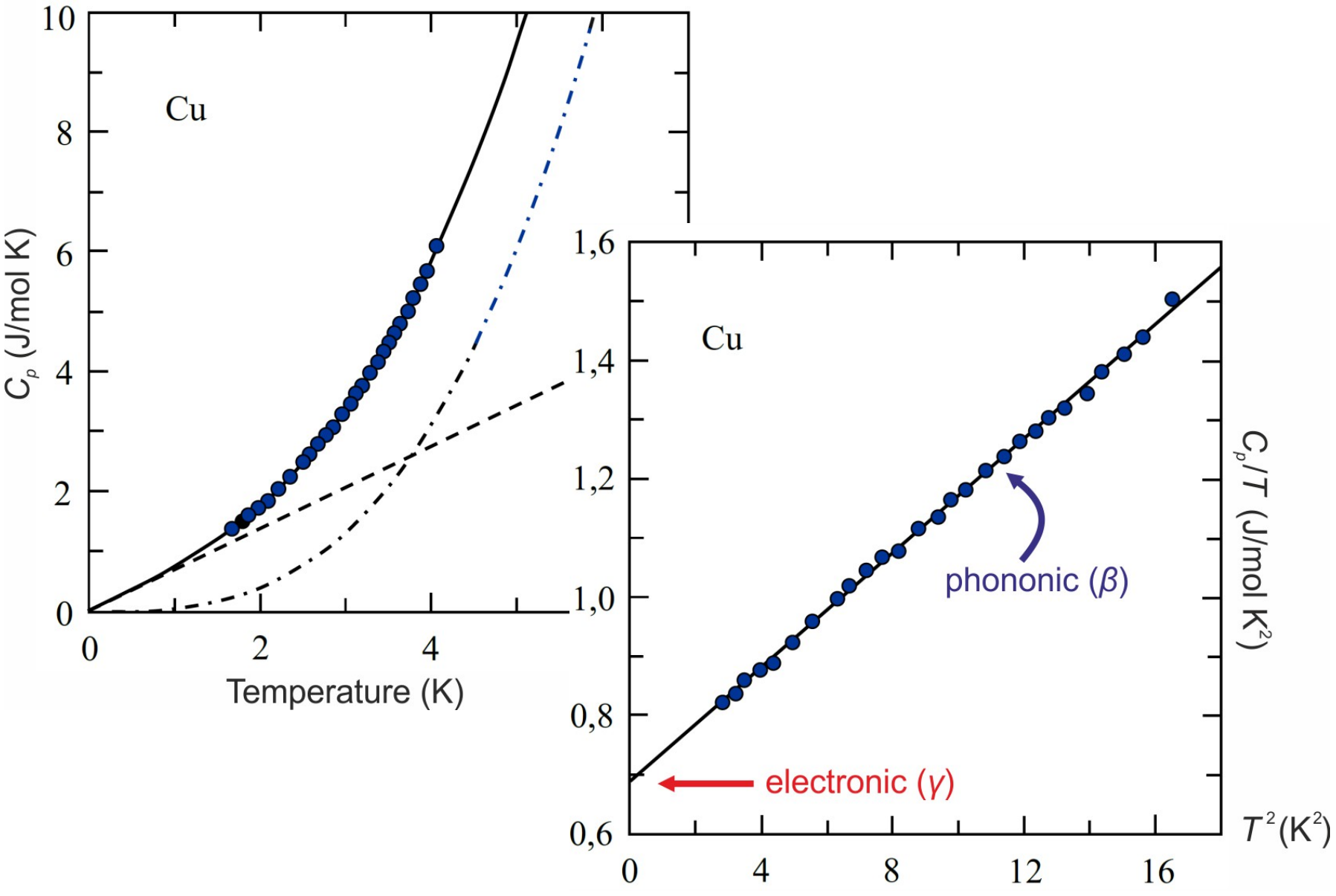

Image credit: Hunklinger, Festkörperphysik

Sommerfeld coefficients

Metal	γ_{exp} $(10^{-3}$ J/mol K$^2)$	γ_{theor} $(10^{-3}$ J/mol K$^2)$	$\gamma_{exp}/\gamma_{theor}$
Li	1.63	0.749	2.18
Na	1.38	1.094	1.26
K	2.08	1.668	1.25
Rb	2.41	1.911	1.26
Cs	3.20	2.238	1.43
Fe	4.98	0.498	10
Co	4.98	0.483	10.3
Ni	7.02	0.458	15.3
Cu	0.695	0.505	1.38
Ag	0.646	0.645	1.00
Au	0.729	0.642	1.14
Sn	1.78	1.41	1.26
Pb	2.98	1.509	1.97

Gross and Marx, Festkörperphysik

ELEMENT	273 K		373 K	
	κ (watt/cm-K)	$\kappa/\sigma T$ (watt-ohm/K^2)	κ (watt/cm-K)	$\kappa/\sigma T$ (watt-ohm/K^2)
Li	0.71	2.22×10^{-8}	0.73	2.43×10^{-8}
Na	1.38	2.12		
K	1.0	2.23		
Rb	0.6	2.42		
Cu	3.85	2.20	3.82	2.29
Ag	4.18	2.31	4.17	2.38
Au	3.1	2.32	3.1	2.36
Be	2.3	2.36	1.7	2.42
Mg	1.5	2.14	1.5	2.25
Nb	0.52	2.90	0.54	2.78
Fe	0.80	2.61	0.73	2.88
Zn	1.13	2.28	1.1	2.30

Source: Ashcroft and Mermin, Solid State Physics