Eddington's Mass-Luminosity Relationship: A Violation of the Laws of Thermodynamics

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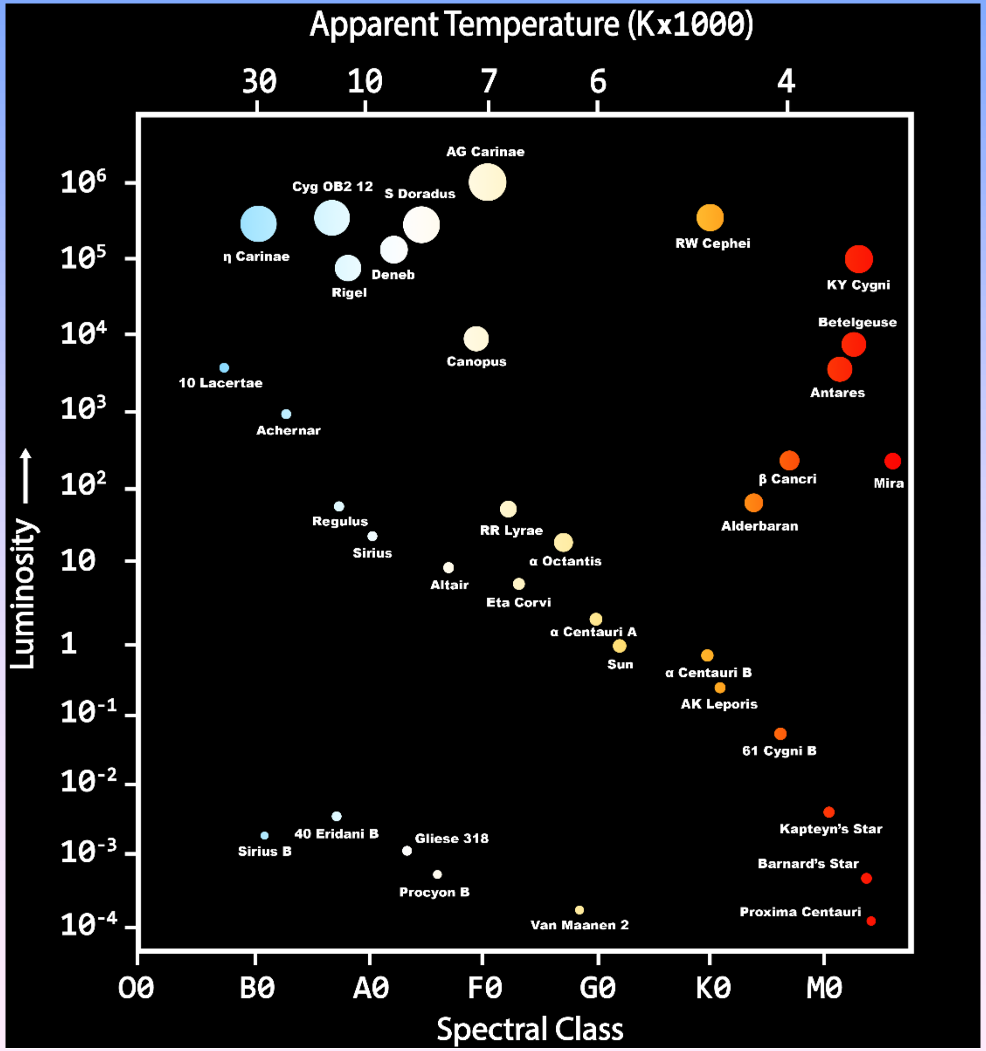
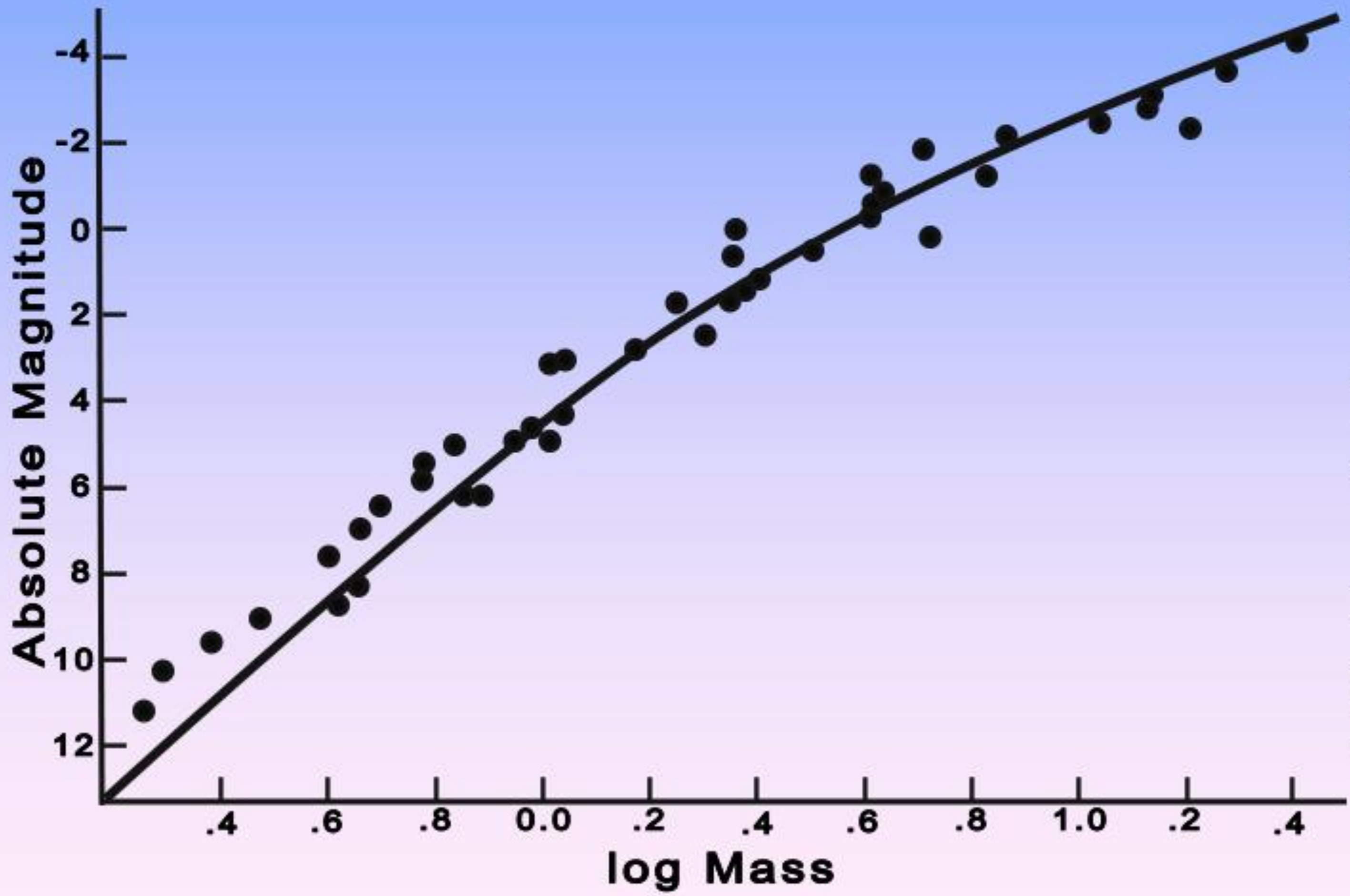
HR Diagram



Apparent Temperature (Kx1000)
30
10
7
6
4
Luminosity
10^6
10^5
10^4
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
AG Carinae
Cyg OB2 12
S Doradus
η Carinae
Deneb
Rigel
RW Cephei
KY Cygni
Betelgeuse
Antares
Canopus
10 Lacertae
Achernar
β Cancri
Mira
Alderbaran
Regulus
Sirius
RR Lyrae
α Octantis
Altair
Eta Corvi
α Centauri A
Sun
α Centauri B
AK Leporis
61 Cygni B
Kapteyn's Star
Barnard's Star
Proxima Centauri
40 Eridani B
Sirius B
Gliese 318
Procyon B
Van Maanen 2
O0
B0
A0
F0
G0
K0
M0
Spectral Class

A.S. Eddington, On the relation between the masses and luminosities of the stars, Mon. Not. Roy. Astron. Soc., v.84, 308-322 (1924).



Eddington derived a mathematical relationship between the mass and luminosity of the stars based on ideal gases in hydrostatic equilibrium.

There was only one additional requirement.

Namely, that the resulting line must pass through mass and luminosity values for the star Capella

A.S. Eddington, On the relation between the masses and luminosities of the stars, Mon. Not. Roy. Astron. Soc., v.84, 308-322 (1924).

$$L = \frac{4\pi cGM\left(1-\beta\right)}{k_0}$$

Where:

L is the luminosity

c is the speed of light in vacuum

M is the stellar mass

G is the universal constant of gravitation

k_o is the stellar opacity

β is a pure number relating gas pressure, P_G, and radiation pressure, P_R, to total pressure, P.

$P_R = (1-\beta)P$ and $P_G = \beta P$

James Hopwood Jeans

"…there is no general relation between

the masses and luminosities of stars…"

E.A. Milne, Sir James Jeans - A Biography, Cambridge University Press, Cambridge, 1952, p. 27.

"No words are needed to praise Eddington's achievement in calculating the state of equilibrium of a given mass of gas, and in calculating the rate of radiation from its surface. What was wrong was Eddington's failure to realize exactly his achievements: he had found a condition for a star to be gaseous throughout; by comparison with the star, Capella, he had evaluated the opacity in the boundary layers; and he had made it appears unlikely that the stars in nature were gaseous throughout. His claims were the contrary; he claimed to have calculated the luminosity of the existing stars; he claimed to show that they were gaseous throughout; and he claimed to have evaluated the internal opacity of the stars. Jeans deserves great credit for being the first critic to be sceptical about these claims of Eddington's theory, in spite of the attractive plausibility with which the theory was expounded. I think that even today there is much misconception amongst astronomers about the status of Eddington's theory"

Zeroth Law of Thermodynamics

$$A \leftrightarrow B \quad \text{and } B \leftrightarrow C$$

Then…

$$A \leftrightarrow C$$

But the law also implies that temperature is an intensive property.

The temperature of an object cannot depend on extensive properties

which in combination do not yield an intensive property!

Intensive versus Extensive Properties

Intensive Properties	Extensive Properties
Temperature	Mass
Pressure	Energy
Density	Enthalpy
Concentration	Entropy
Specific Volume	Volume
Color	Heat Capacity

Intensive versus Extensive Properties

The concept of intensive and extensive properties is so important that Peter Landsberg wanted to establish it as

The 4th Law of thermodynamics

P.T. Landsberg, Thermodynamics with Quantum Statistical Illustrations, Interscience Publishers, New York, 1961, p. 142.

Equations: Intensive versus Extensive Properties

"If one side of an equation is extensive (or intensive),

then so must be the other side"

S.G. Canagaratna

Intensive and Extensive Properties: Underused Concepts, *J. Chem. Educ., 1992, v. 69, no. 12, 957-963*.

The Stefan-Boltzmann Law

$$L = \varepsilon \sigma A T^4$$

$$\frac{L}{A} = \varepsilon \sigma T^4$$

Temperature is intensive.

L an A are homogeneous functions of degree 2/3. *L*/*A* is intensive.

The Stefan-Boltzmann Law is thermodynamically balanced!

Pierre-Marie Robitaille and Stephen J. Crothers, Intensive and extensive properties: Thermodynamic balance, Physics Essays, Volume 32: Pages 158-163, 2019

A.S. Eddington, On the relation between the masses and luminosities of the stars, Mon. Not. Roy. Astron. Soc., v.84, 308-322 (1924).

$$\frac{L}{A} = \frac{cGM\left(1-\beta\right)}{k_0 r^2} = \varepsilon\sigma T^4$$

L/A is intensive.

***T* must always be intensive**

C, G, β, k_o , ε, and σ are constants and do not contribute to thermodynamic balance.

M is extensive but r^2 is non-extensive. It is a homogeneous function of degree 2/3.

The RHS of Eddington's Mass-Luminosity expression (the central term) is not intensive!

As a result, Eddington's expression is a violation of thermodynamics.

The stars cannot be treated as ideal gases!

Conclusion

The mass-luminosity relation is invalid.

The stars are condensed matter.

Robitaille, P.-M., Forty Lines of Evidence for Condensed Matter — The Sun on Trial: Liquid Metallic Hydrogen as a Solar Building Block, *Progress in Physics*, v.4, pp.90-142, (2013), http://www.ptep-online.com/2013/PP-35-16.PDF

"*We must conclude that we have been misled altogether in the theory of the mass-luminosity relation or that in dense stars like the sun the material behaves as a perfect gas*".

A.S. Eddington, The Internal Constitution of the Stars, Dover Publications, Inc., New York, 2nd edition, 1959, 1st edition 1926