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

Stephen J. Crothers¹ and Pierre-Marie Robitaille²

¹Tasmania, Australia, thenarmis@yahoo.com

²Department of Radiology and Chemical Physics Program
The Ohio State University, Columbus, Ohio 43221
robitaille.1@osu.edu

OSS19 Meeting of The American Physical Society (F02.00005)
March 30, 2019
HR Diagram
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.
Where:

\[ L = \frac{4\pi cGM (1 - \beta)}{k_0} \]

L is the luminosity

\( c \) is the speed of light in vacuum

M is the stellar mass

\( G \) is the universal constant of gravitation

\( k_0 \) is the stellar opacity

\( \beta \) is a pure number relating gas pressure, \( P_G \), and radiation pressure, \( P_R \), to total pressure, \( P \).

\[ P_R = (1 - \beta)P \] and \[ P_G = \beta P \]
“...there is no general relation between
the masses and luminosities of stars...”
“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 appear 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 ↔ B and B ↔ C

Then…

A ↔ 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

<table>
<thead>
<tr>
<th>Intensive Properties</th>
<th>Extensive Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Mass</td>
</tr>
<tr>
<td>Pressure</td>
<td>Energy</td>
</tr>
<tr>
<td>Density</td>
<td>Enthalpy</td>
</tr>
<tr>
<td>Concentration</td>
<td>Entropy</td>
</tr>
<tr>
<td>Specific Volume</td>
<td>Volume</td>
</tr>
<tr>
<td>Color</td>
<td>Heat Capacity</td>
</tr>
</tbody>
</table>
The concept of intensive and extensive properties is so important that Peter Landsberg wanted to establish it as

The 4th Law of thermodynamics

“If one side of an equation is extensive (or intensive),
then so must be the other side”

S.G. Canagaratna

The Stefan-Boltzmann Law

\[ L = \varepsilon \sigma A T^4 \]

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

Temperature is intensive.
L and A are homogeneous functions of degree 2/3. \( L/A \) is intensive.

The Stefan-Boltzmann Law is thermodynamically balanced!


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

\(L/A\) is intensive.

*\textbf{T must always be intensive}*

C, G, \(\beta\), \(k_o\), \(\varepsilon\), and \(\sigma\) 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.


“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”.