Lecture 1 : What are the stars?

Despite being the second most abundant element in the observable universe, Helium is rather rare on Earth. It is so rare that Helium was first discovered in the spectrum of the Sun, during a solar eclipse in 1868, observed from Guntur (Andhra Pradesh, India). This first lecture of the series takes us through the early evolution of Astrophysics when such amazing discoveries began to take place through scientists' efforts to explain celestial observations using known laws of physics.

The lecture begins with the reason for the "limb darkening" of the Sun, and the discovery of Helium in the Sun. It then explains the late 19th century ideas on "Stars as globes of gas", supported against gravity by the pressure of the gas. The equation of "hydrostatic equilibrium" is derived.

Either the well was very deep, or she fell very slowly.. - Astrophysics, by its very nature, demands an all-round understanding of Physics - whether its calculating the free-fall time of a gravitationally bound object or estimating the central temperature of the Sun. In the supplementary section the students would find a set of problems which have mostly been posed in the lecture itself to help the students have a proper understanding. To facilitate the students' overall grasp of the material, a list of general Physics and Astrophysics books has also been included.

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Astronomy & Astrophysics : An Introductory Survey

A lecture series by Prof. G. Srinivasan

A 'Golden Jubilee Celebration' Event of the Astronomical Society of India

Lecture 1 : What are the stars?

[Supplementary Material : Dr. Sushan Konar]

Suggested Problems

1. We can estimate the mass (or the radius) of the Sun easily using high-school physics. However, to do that, we also need estimates of other physical quantities.

   (a) Which are the quantities that you need to know the value of to estimate the mass and the radius of the Sun? How do you find those? (Leave the fundamental constants out.)
   {You can read about Eratosthenes' technique to estimate the radius of the Earth, to learn about the innovative methods early scientists emplyed for Astronomical measurements.}

   (b) Estimate the mass and the radius of the Sun. Find the average density of the Sun. Compare this with the average density of the Earth.

2. (a) What measurements must be made (from the Earth, say) to estimate the surface temperature of the Sun? What is the underlying assumptions made (about the Sun) for this estimate?

   (b) Assuming that the Sun is primarily made up of Hydrogen, what is the state of the matter at the surface, given that the surface temperature of the Sun is $T_\odot^{\rm s} = 6000°$K.

3. A typical O-type star has $M \simeq 10\ {\rm M}_\odot$ and $R \simeq 10\ {\rm R}_\odot$.

   (a) Find the time it would take a thermal photon to travel from the centre to the surface of the star. Compare this time-scale with that in the case of the Sun (shown in the lecture). (Use Virial theorem to find the average interior temperature of the star.)

   (b) If the luminosity of such a star happens to be 10^5 times that of the solar luminosity. What would be its approximate surface temperatuer?

4. Assume that the gravity is supported entirely by gas pressure at the centre of the Sun. (This is not entirely correct as the radiation pressure also contributes). Assume also that the gas at the centre of the Sun is Hydrogen. From the mass and the radius estimated in Problem.1, show that it is justified to treat the gas at the centre of the Sun as ideal gas. (Take care to use the correct state of the gas at the centre (Problem.2).)

5. Dig a tunnel through the centre of the Earth. Calculate the period of oscillation of a stone. Write your answer in terms of relevant physical quantities related to the Earth. Now use this formula to estimate the time-period in case of the Sun. Of course, the Sun being a gaseous object, one can not dig a tunnel through it. What is the significant of this time-scale in the context of the Sun?

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Reference Books : General Physics & Astrophysics

1. Classical Mechanics
   (a) H. Goldstein, C. Poole & J. Safko, 2002, ***Classical Mechanics***, Addison-Wesley
   (b) L. D. Landau & E. M. Lifshitz, 1969, ***Mechanics***, Pergamon Press
   (c) N. Rana & P. Joag, 2001, ***Classical Mechanics***, Tata McGraw-Hill
2. Classical Electrodynamics
   (a) J. D. Jackson, ***Classical Electrodynamics***,
   (b) D. J. Griffiths, ***Introduction to Electrodynamics***,
   (c) L. D. Landau & E. M. Lifshitz, 1975, ***Classical Theory of Fields***, Pergamon Press
3. Quantum Mechanics
   (a) D. J. Griffiths, 2005, ***Introduction to Quantun Mechanics***, Pearson Education
   (b) R. Shankar, 1994, ***Principles of Quantum Mechanics***, Plenum Press
   (c) J. J. Sakurai, 1994, ***Modern Quantum Mechanics***, Addison-Wesley Publishing Company
4. Thermodynamics & Statistical Mechanics
   (a) P. B. Pal, 2007, ***An Introductory Course of Statistical Mechanics***, Narosa Publishing House
   (b) R. K. Pathria & P. Beale, 2021, ***Statistical Mechanics***, Elsevier
   (c) L. D. Landau & E. M. Lifshitz, 1980, ***Statistical Physics I, II***, Pergamon Press
5. E. Hecht & A. Zajac, 1998, ***Optics***, Addison-Wesley
6. B. H. Brandsen & C. J. Joachen, 1983, ***Physics of atoms and molecules***, Longman Scientific & Technical
7. A. R. Choudhuri, 1998, ***The Physics of Fluids and Plasmas***, Cambridge University Press
8. F. H. Shu, 1981, ***The Physical Universe: An Introduction to Astronomy***, University Science Books
9. F. H. Shu, 1991, ***The Physics of Astrophysics I***, University Science Books
10. T. Padmanabhan, 2000, ***Theoretical Astrophysics I***, Cambridge University Press
11. A. R. Choudhuri, 2010, ***Astrophysics for Physicists***, Cambridge University Press

Special Interest :

Biman Nath, 2012, ***The Story of Helium and the Birth of Astrophysics***, Springer

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