

List of figure

List of tables

Preface

Acknowledgements

The Sun's basic characteristics

1 Our star, the Sun

- 1.1 The Sun's basic characteristics
- 1.2 How far away is the Sun?
 - 1.2.1 Planetary orbits
 - 1.2.2 The relative scale of the solar system
 - 1.2.3 Tycho Brahe and Johannes Kepler
 - 1.2.4 Kepler's laws of orbital motion
- 1.3 The measurement of the astronomical Unit by parallax; Inferior planet transits
 - 1.3.1 Transits of Venus; 17th century, 1761, 1769, 1874, 1882 transits and expeditions
 - 1.3.2 Radar measurements of the astronomical unit
 - 1.3.3 The astronomical unit precisely defined
- 1.4 How big is the Sun?
 - 1.4.1 The size and volume of the Sun
 - 1.4.2 The mass and density of the Sun

2 Power generation in the Sun

- 2.1 Energy
 - 2.1.1 Kinetic energy
 - 2.1.2 Potential energy
 - 2.1.3 Virial theorem
- 2.2 Atomic structure
 - 2.2.1 Elements and atoms
 - 2.2.2 Atomic number
 - 2.2.3 Atomic weight
 - 2.2.4 The periodic table
 - 2.2.5 Isotopes
 - 2.2.6 Ions
 - 2.2.7 Terminology of atomic description
 - 2.2.8 Photons and radiative transfer
 - 2.2.9 Electron energy absorption
 - 2.2.10 Radioactivity
 - 2.2.11 Radioisotope decay
 - 2.2.12 Decay chains
 - 2.2.13 Radiometric dating
- 2.3 Electromagnetic spectrum
 - 2.3.1 Black body radiation and the Planck distribution; Temperature
 - 2.3.2 Stellar magnitudes
 - 2.3.3 Absolute magnitude; Parsecs & light years
 - 2.3.4 Spectral classifications
 - 2.3.5 Hertsprung-Russell diagram
- 2.4 Luminosity; Effective temperature
 - 2.4.1 Emission spectra and lines
 - 2.4.2 Hydrogen emission lines
 - 2.4.3 Absorption lines
 - 2.4.4 Helium; Molecular velocity and atmosphere retention
- 2.5 How do we know that the Sun gets its power from nuclear fusion?
 - 2.5.1 Gravitational collapse time
 - 2.5.2 Nuclear fusion within the Sun
 - 2.5.3 Proton-Proton chain

- 2.5.4 Other proton-proton fusion chain variants
- 2.5.5 Fundamental forces operating within fusion processes
- 2.5.6 The coulomb barrier
- 2.5.7 Energy production rates; Fusion power
- 2.5.8 Solar lifespan
- 2.5.9 Lifespans of other stars; Lifespan, luminosity and mass
- 2.5.10 Carbon Nitrogen Oxygen cycle

3 Solar form & structure

- 3.1 Solar structure
- 3.2 Equations of state
 - 3.2.1 Mass conservation
 - 3.2.2 Hydrostatic equilibrium
 - 3.2.3 Energy conservation
 - 3.2.4 Solar dynamical timescale
- 3.3 Energy transport zones
 - 3.3.1 Radiation within the Sun
 - 3.3.2 Convection within the Sun
- 3.4 Standard stellar model
 - 3.4.1 Stellar core temperatures
 - 3.4.2 Pressure and density – Polytropes
- 3.5 Pulsations and pressure waves
 - 3.5.1 Solar rotation
 - 3.5.2 Electromagnetic Doppler shift and the Lorentz factor
 - 3.5.3 Helioseismology
- 3.6 The photosphere
 - 3.6.1 Solar differential rotation
- 3.7 The Sun's magnetic fields
 - 3.7.1 A brief overview of magnetism
 - 3.7.2 Magnetic force and field strength
 - 3.7.3 The Zeeman effect
 - 3.7.4 Solar magnetic fields
 - 3.7.5 Solar dynamo and field generation
- 3.8 The Sun's atmosphere
 - 3.8.1 Chromosphere
 - 3.8.2 Corona
 - 3.8.3 Solar wind and magnetosphere interaction

4 Observation and features of the Sun

- 4.1 Introduction and observation of the Sun
- 4.2 Early historical records
- 4.3 Telescope types
 - 4.3.1 Optical astronomical telescopes
 - 4.3.2 Solar telescopes
- 4.4 Instrumentation
 - 4.4.1 Astronomical imaging
 - 4.4.2 Specialised instrumentation: coronagraphs, spectroscopes and magnetographs
- 4.5 Satellite observation
- 4.6 Photosphere
 - 4.6.1 Limb darkening
 - 4.6.2 Granulation
- 4.7 Sunspots
 - 4.7.1 Sunspot lifetimes
 - 4.7.2 Sunspot magnetic field strengths & polarities
 - 4.7.3 Sunspot temperature and Evershed flow

- 4.7.4 Sunspot counts and classification
- 4.7.5 Solar cycle
- 4.7.6 The Maunder minimum and longer term variations
- 4.8 Faculae
- 4.9 Chromospheric and eruptive features
 - 4.9.1 Spicules
 - 4.9.2 Prominences and filaments
 - 4.9.3 Flares
 - 4.9.4 Flocculi and plage
- 4.10 Coronal structures and events
 - 4.10.1 Coronal loops
 - 4.10.2 Mass ejections (CMEs)
 - 4.10.3 Streamers

5 Nebulae and the formation of the Sun

- 5.1 Galactic morphologies and the Milky Way
 - 5.1.1 The Milky Way and the Sun's position
 - 5.1.2 Stellar populations.
 - 5.1.3 Binary and multiple star systems
- 5.2 The nebulae
 - 5.2.1 Planetary nebulae
 - 5.2.2 Dark nebulae
 - 5.2.3 Emission nebulae
 - 5.2.4 Reflection nebulae
- 5.3 Nebulae form and collapse
 - 5.3.1 Energy considerations
 - 5.3.2 Collapse criteria (Jeans length and critical mass)
 - 5.3.3 Collapse dynamics

6 Stellar evolution and destiny

- 6.1 Solar evolution and destiny
 - 6.1.1 Helium fusion – the alpha and triple alpha processes
 - 6.1.2 Electron degeneracy
- 6.2 Solar evolutionary stages
- 6.3 Red giants
- 6.4 White dwarves
- 6.5 Massive star evolution
 - 6.5.1 Chandrasekhar limit
 - 6.5.2 Neutron degeneracy
- 6.6 Pulsars and neutron stars
 - 6.6.1 Formation of neutron stars
 - 6.6.2 Neutron star size
 - 6.6.3 Rotation and conservation of angular momentum
 - 6.6.4 Integrity and density of rotating neutron stars
 - 6.6.5 Synchrotron radiation from pulsars
 - 6.6.6 Neutron star magnetic fields
- 6.7 Supernovae
- 6.8 Black Holes
 - 6.8.1 Black hole size & density
 - 6.8.2 Black hole detection

7. Supporting mathematical derivations and descriptions.

- 7.0 Nomenclature
- 7.1 Synodic period
- 7.2 Kepler's 3rd law

- 7.3 Energy; derivation of kinetic and potential energy equations
- 7.4 Distance modulus equation
- 7.5 Rydberg formula
- 7.6 Kelvin-Helmholtz timescale
- 7.7 Equations of state
 - 7.7.1 Mass conservation
 - 7.7.2 Hydrostatic equilibrium
 - 7.7.3 Energy conservation
 - 7.7.4 Energy transport - radiation
 - 7.7.5 Energy transport - convection
- 7.8 Dynamical timescale
- 7.9 Stellar core temperatures
- 7.10 Core pressure and density – Polytrope models
- 7.11 Mass : luminosity relationship
- 7.12 Conditions for interstellar cloud collapse: Jeans length
- 7.13 Conditions for interstellar cloud collapse: Critical mass
- 7.14 Escape velocity

Bibliography and suggested further reading

Additional works and credits

References

Online sources & resources

National observatories

Picture credits

Physical constants and units

List of figures

1. The Sun
2. Elliptical orbits
3. Orbital inclination
4. Aphelion and perihelion
5. Opposition and conjunction
6. Inferior and superior conjunction
7. Planetary synodic period
8. Elongation and conjunction points for Venusian orbit
9. Copernicus's determination of the relative Sun-Venus distance
10. Copernicus's determination of the relative Sun-superior planet distance
11. Measuring the distance to Venus using transits
12. Solar parallax
13. Meudon 62cm refractor
14. Bawdsey manor, Felixstowe, England
15. Structure of the atom
16. The periodic table
17. Standard model fundamental particles
18. Compton scattering
19. The electromagnetic spectrum
20. Planck distribution of black body radiation
21. Star field showing Vega
22. Hertsprung Russell diagram
23. Solar spectrum showing emission lines of hydrogen and helium
24. Solar spectrum showing Fraunhofer absorption lines
25. Proton-Proton fusion chain variants
26. Solar structure overview
27. Hydrostatic equilibrium

28. Solar granulation
29. The thermodynamics physics of solar granulation
30. Convection cells and super-cells within the photosphere and convection Zone
31. Relativistic Doppler effect for electromagnetic spectrum absorption lines
32. Graph of Lorentz factor
33. The Sun in H α
34. Sunspot group on photosphere; July 2012 (NASA/Goddard)
35. Magnetic activity above the photosphere (NASA Trace Satellite 2010)
36. Hale's 1919 photograph of the Zeeman effect within a sunspot
37. Solar magnetogram (NASA/Skylab 1974)
38. Model of magnetic flux density (NASA/Solar Dynamics Observatory, 2010)
39. Prominence extending into the chromosphere (Observed during Solar eclipse, 2006)
40. The chromosphere seen on the solar limb/edge (NASA Hinode satellite, 2007)
41. Solar chromosphere showing spicules (NASA Hinode satellite, 2006)
42. Total solar eclipse, November 2012 (NASA Goddard)
43. Solar corona at near to solar maximum and solar minimum.
44. Solar wind and magnetic flux near Earth and Mars (NASA/SDO)
45. Parker spiral representation of slow speed solar wind.
46. Open magnetic flux line source of solar wind.
47. Foucault and Fizeau's photograph of the Sun; 2nd April 1845
48. THEMIS Solar Observatory, Teide, Tenerife
49. The Sun showing large sunspot group, 23rd Oct 2014.
50. Sunspot group AR9715, December 2001.
51. The solar cycle and Maunder minimum
52. Sporer's law (The Butterfly diagram)
53. Reconstructed historical solar activity record using carbon isotopes
54. Solar disc showing faculae
55. Sun's northern pole region showing spicules
56. Eruptive loop prominence, March 2011.
57. Spray prominence, March 2011.
58. Coronal cloud, November 2012.
59. Solar filament, November 2010.
60. M1.5 flare (August 2004; AR0633)
61. Coronal (fan) loop (September 2014)
62. Coronal mass ejection (September 2014)
63. Coronal streamers and CME
64. The Hubble classification of galaxies
65. The Andromeda galaxy (NASA/JPL)
66. Globular cluster 47-Tucana (ESO)
67. Eclipsing binary light curve
68. Comet C/2013 A1 showing nebulosity
69. Orion nebula
70. Strömgren sphere
71. Planetary nebula NGC3132
72. Dark nebula LDN483
73. Reflection nebulosity in M45 – Pleiades star cluster
74. Evolution of Sun through red giant phase
75. Sirius A & B taken from Chandra X-ray Observatory
76. Mass : radius relationship for white dwarf stars
77. The Crab nebula; three colour composite image from the ESO
78. Neutron star (pulsar) rotation and emissions schematic
79. Pulsar emissions driven by accretion from binary companion
80. X-ray, optical & infra-red image of Kepler's supernova remnant
81. Synodic period
82. Binary system

List of tables

1. Electron shell capacities
2. Atomic nomenclature
3. Spectral luminosity classes
4. Hydrogen emissions; Lyman series
5. Hydrogen emissions; Balmer series
6. Approximate stellar lifespans
7. Lorentz factor
8. Solar wind characteristics
9. Basic characteristics of type I and II spicules
10. Basic characteristics of quiescent and eruptive prominences
11. Solar flare classification
12. Solar emission categories
13. Comparative characteristics of some well-known red giant stars
14. White dwarf spectral classifications
15. Supernovae classification and characteristics
16. Planetary synodic periods
17. Energy levels in hydrogen electron shells
18. Hydrogen emission line series and wavelengths
19. Lane Emden solutions for density ratios