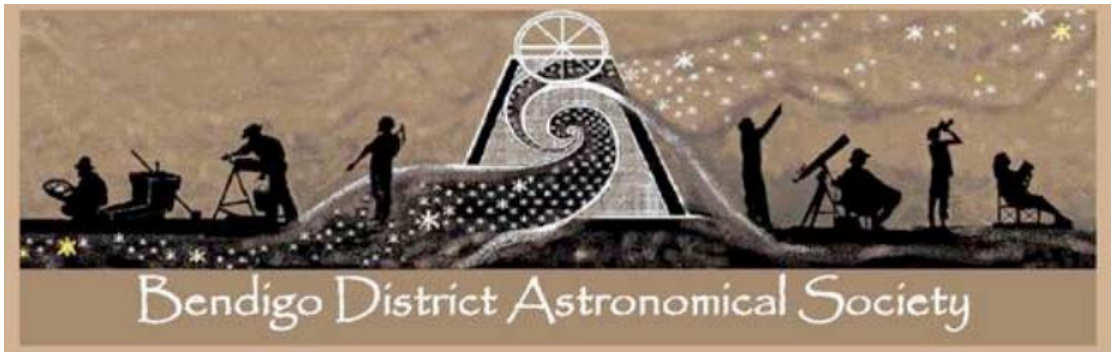

BDAS Astronomy Presentation

Discovery Centre Bendigo

7:30 pm, Wednesday 6th June, 2007

Gas Giants

by

Michael Gallagher

Notes to accompany the presentation

BDAS

Introduction

Apart from the Sun, the gas giants Jupiter and Saturn are the most starlike things in our immediate neighbourhood. Exploring them has taught us much about the origins of the Solar System.

Astronomers have recently begun to detect other gas giant-sized planets in orbit round other stars. They have also begun to observe young stellar objects and newly forming planetary systems. Our understanding of the formation of stars and planets is developing apace.

In 2007, we are on the threshold of an exciting new phase of astronomical research. Astronomers are creating the tools to discover the properties of other planetary systems and even the surfaces and atmospheres of their planets.

My aims in this presentation are to:

1. Stimulate wonder about the universe we live in. After close examination by remote spacecraft missions, the Jupiter and Saturn Gas Giant systems have proved to contain marvellously complex, completely unexpected, very different, exciting other worlds. We have recently discovered that they are just other instances of large planets in orbit round their own stars.

2. Provide some detail of how we learn about other worlds and their origins.

3. Indicate, by delving in and displaying selected samples, the voluminous amounts of information that astronomers freely make available to the general public.

The other important part of this evening's program, weather permitting, is observation through telescopes. I hope we have a clear sky for viewing Jupiter and Saturn, the Carina Nebula and some open star clusters that were formed not so long ago. I thank BDAS members for making their equipment available.

I have prepared more material than can be covered in one presentation. If you would like to explore in more depth the concepts presented this evening, there is a CD-ROM available for purchase. See the last page for details.

The notes that follow relate to the set of web pages prepared for the occasion.

Michael Gallagher
6th June 2007

Part 1. Gas Giants

- Part 1. Index

1 Solar System
- All its constituents formed from a fragment of molecular cloud.
- In addition to the central star it has:
  - Four Rocky Planets close to the Sun
  - Many Icy Bodies, most out at the edge. An astronomical frontier
  - Four Giant Planets, each with a moon system formed along with the planet from the original solar nebula
- Jupiter and Saturn have sufficient mass for metallic hydrogen to form in their interiors – they are Gas Giants.
- We have just begun to discover jupiter-sized planets orbiting other stars

2 Flypast of Earth movie taken by the MESSENGER spacecraft en route to Mercury, August 2005

3.1 Size of the inner Solar System
- Earth is 150 million km from the Sun
- It takes light eight minutes to reach Earth from the Sun
- The average Earth-Sun distance is used a distance measurement, the Astronomical Unit (au)

3.2 It will take MESSENGER six and a half years to attain Mercury orbit.
- It has to shed much angular momentum before it slows enough for orbit insertion. Six carefully calculated close planetary passes are required.
- A major challenge to astronomers modelling the formation of stars, planets and moons is to explain how particles in collapsing molecular clouds shed their angular momentum

3.3 Animation of MESSENGERS trajectory to Mercury orbit insertion

3.4 Sun - Earth Centric animation of MESSENGERS trajectory

4 Travelling out to the Kuiper Belt, an animated simulation
- Mars 1.5 au
- Jupiter 5 au
- Saturn 10 au
- Uranus 20 au
- Neptune 30 au
- The inner Rocky Planets disappear into the Sun's glare.
- The Solar System is vast.

5 Plans of the Solar System at different scales

5.1 5 au - out to Jupiter's orbit

5.2 100 au - out to Sedna

5.3 1,000 au - Orbital extent of Sedna

5.4 10,000 au - Inner Extent of Oort Cloud

5.5 100,000 au - Outer Extent of Oort Cloud

5.6 100,000 au - the only parts of the Solar System we have observed directly
- Note: the distance to Alpha Centauri is approximately 300,000 au.

6 Molecular Gas Clouds in the Southern Milky Way. (Ask telescope owners to show you some of these objects,)

- Southern Cross
- Alpha and Beta Centauri, "The Pointers"
- The Coal Sack – a quiescent molecular cloud containing sufficient material to form thousands of stars. It obscures the Milky Way.
- Eta Carinae Nebula – An active star forming region
- Open Star Clusters - groups of similar aged stars, each formed from a particular fragment of molecular cloud
    - The Jewel Box
    - 1C2602 - The Southern Pleiades
    - NGC 3532 and NGC 3114
- 2M1207 (location only. The object is too dim to see at this scale or in small telescopes.)
    - It is a Brown Dwarf with a directly imaged planetary companion
    - The system is approximately 8 million years old
    - The system is a member of the TW Hydrae Association (TWA) Moving Group (The closest newly formed group of stars to the Sun)

7 Eta Carinae Molecular Cloud Panorama. Stars and planetary systems are forming in this complex of clouds.

- Find a 7,000 x 7,000 pixel 49 MB version of the image in the Larges_Files folder on the CD-ROM

8 Molecular Cloud Collapse Simulation - Matthew Bate, UKAFF

- Starting conditions
    - a fifty solar mass, turbulent molecular cloud
- Computation details:
    - 100,000 CPU hours
    - 10^{16} FLOPS i.e. 10 million billion arithmetic calculations per second
- Find a higher resolution 306 MB version of the simulation movie in the Larges_Files folder on the CD-ROM

9 Orion Nebula Mosaic. New stars and planetary systems are forming here.

- Find an 18,000 x 18,000 pixel, 24 MB version of the image in the Larges_Files folder on the CD-ROM

10 Proplyds in the Orion Nebula (The Orion Molecular Cloud). Proplyds are newly formed protoplanetary disks, an initial stage in the formation of stars and planetary systems.

- Link to an essay summarising, in a general way, details of the gravitational collapse of molecular cloud fragments to form stars and planets. (On the CD-ROM)

11 Objects formed from Molecular Cloud Collapse

11.1 Main Sequence Stars

11.2 Location of the Sun on the Main Sequence
- Masses and Luminosities are expressed in Sun units
- Star Spectral Class Labels were created when astronomers were trying to make sense of the many different types of stars in the galaxy

11.3 Solar mass stars move off the main sequence towards the end of their lives
- They become Red Giants, then White Dwarfs

11.4 Giant stars also become Red Giants
- At the end, they explode as supernovae. Their end points, neutron stars and black holes are not shown on the diagram

11.5 All the stars on the Main Sequence generate energy via hydrogen fusion.
- Space could be made on the diagram for substellar objects, not massive enough to attain hydrogen fusion, which also condense from Molecular Clouds.

11.6 Brown Dwarfs are not massive enough to sustain hydrogen fusion
- But they do attain deuterium fusion

11.7 Gas Giants lack sufficient mass to attain deuterium fusion

12 We have recently discovered hundreds of Jupiter-sized planets in orbit around other stars.
- A considerable number of them are surprisingly close to their stars.
- We have not seen these planets directly. We know of their presence from the way they affect the light emitted from their parent stars.

13 The first image of an exoplanet - 2005

13.1 In 2005, an exoplanet, 2M1207 was imaged directly.
- It is a 5 jupiter-mass planet
- It orbits a Brown Dwarf at a distance of 55 au.
- Its companion status to the Brown Dwarf has been established with a high level of certainty
- Its mass and distance estimates are tentative.

13.2 2M1207b is widely separated from its companion brown dwarf.
- The planet probably formed directly from the molecular cloud, (rather than condensing from the protostar disk of its companion)

13.3 2M1207b may be enclosed in a dusty disk from which moons could form

13.vltThe discovery was made with the ESO's Very Large Telescope (VLT)
- The observatory's facilities give an indication of the resources required to examine our stellar neighbourhood in fine detail.

A link to notes about the 2M1207a and 2M1207b. (On the CD-ROM)
A link to the discovery confirmation paper. (On the CD-ROM)

14 The first details of exoplanet atmospheres and surfaces - 2007

14.1 Spitzer Space Telescope projects have detected infrared light from “Hot Jupiters”, jupiter-sized planets that orbit their parent stars closely.
- “Hot Jupiters” are blasted by 20,000 time more energy per second than Jupiter

14.2 HD 189733b has a thick atmosphere that distribute heat around the planet by extraordinarily high velocity winds

14.2 HD 149026b is a saturn-sized, solid lump that is hotter than some low mass stars

Part 2. Jupiter

- Part 2. Index

1 In 1610, Galileo that Jupiter was a mini solar system with its own set of orbiting moons.

2 Modern small scopes give better views of the Jupiter System than Galileo's primitive telescope
- Galileo stimulated Newton.
- The theory of Gravity resulted.
- We use it to model the solar system with extraordinary precision and accuracy.

3.1 Various spacecraft have captured global views while visiting Jupiter
3.2 The Hubble Space Telescope gives us a view that compares favourably with images captured by spacecraft close to Jupiter
3.3 The behaviour of the giant storm, Oval BA, has held the attention of planetary meteorologists in recent years.
3.4 Advances in CCD technology and freely available image processing software enable amateurs to image Jupiter in previously unimagined detail
3.5 Large telescopes with Adaptive Optics systems can rival the resolution of the Hubble Space Telescope
3.6 A passing spacecraft captures detail unattainable from Earth or near Earth orbit.
- Oval BA taken earlier this year by the New Horizons Mission, en route to Pluto and the Kuiper Belt
- A link to notes about Oval BA on the disk, courtesy of James Wight.

4 Our most detailed information of Jupiter and its moons was obtained by the Galileo Mission to Jupiter, 1989 to 2003.

5.1 The Galileo Spacecraft and its complex set of data gathering equipment.
- Note 1. The absence of solar panels - Jupiter is too far from the Sun for them to work. Power is obtained from Radioisotope Generators.
- Note 2. The High-gain Antenna, here labelled a sun shield, is crippled in a partially opened state. After launch, the Parkes 64 m Radio Telescope was refurbished to enable the mission to succeed via the low gain antenna transmissions alone. There was plenty of time for the required work to be done in time – it took Galileo over six years to reach Jupiter.

5.2 Parkes 64 m Antenna
5.3 A receiver for the Parkes 64 m Antenna

6 Galileo's journey to Jupiter
- First images of Asteroids, captured en route.

7 Images of Shoemaker-Levy Comet fragment impact on Jupiter, captured en route.

8 Descent of the Jupiter Atmosphere Probe
- Surprisingly high concentrations of noble gases were detected.
- Astronomers had to revise solar system formation theory as a result.

9 Galileo's orbital tour.
- Each orbit was carefully planned well in advance to gather data during close passes of the Galilean Satellites

10 Some details of Jupiter's atmosphere
10.1 Great Red Spot - a storm large enough to swallow two or three Earths, It may have been first noticed by Cassini in 1665, and has possibly been raging for atleast 350 years.
10.2 Atmospheric vortices animation. These are small storms, only 3,500 km across.
10.3 Teasing out the detail of Jupiter's atmospheric layers via infrared imaging. The Great Red Spot's cloud deck protrudes high above the rest of the atmosphere.

11 Aurora on Jupiter, caused by the interaction of the solar wind with the planet's magnetic field and the upper atmosphere

12 Jupiter generates radiation via internal processes. Infrared imaging from Earth and Galileo radiation hot spots in detail.

13 Jupiter's ring system was not discovered until the Voyager missions. (Since then ring systems have also been discovered on Uranus and Neptune.)
13.1 The main ring and its halo
13.2 Details of ring structure and the relationships of ring moons to the rings
13.3 Details of the orbit of the ring moon Amalthea

14 Io - the most volcanically active body in the Solar System
14.1 Global views showing active volcanic plumes
14.2 Detail of active plumes
14.3 Sodium cloud extending into space from Io
14.4 Night time map of Io's volcanically active regions

15 Europa - an ice covered moon

16 Surface details of Europa

17 Ice-rafts on Europa's surface, compared with areas on Earth imaged at the same resolution
17.1 630 m per pixel
17.2 180 m per pixel
17.3 54 m per pixel
17.5 30 m per pixel
17.6 26 m per pixel

18 Our exploration of Europa via high resolution imaging has hardly begun

19 Two intriguing hypotheses have emerged from exploration of Europa
19.1 Is Europa's under surface a mass of warm convecting ice?
19.2 Is there an ocean of liquid water underneath Europa's ice surface?
- Both scenarios have possible habitats for life forms

20 Ganymede - the Solar System's largest moon has a rich tapestry of surfaces
21 Ice and minerals on Ganymede's surface
22 Impact crater details
22.1 Antum crater - material from the impacting body is visible
22.2 High resolution detail of an impact crater's rim and floor
22.3 Old dark-floored impact craters with subsurface ice layers exposed in the rims
22.4 Fresh impact craters
22.5 Fractured craters
23 Gravity anomalies on Ganymede detected by radio Doppler shift

24 Callisto - the most distant and densely cratered of the Galilean Moons
25 Callisto surface details at various resolutions
26 Asgard Impact Structure on Callisto
26.1 Asgard hemispheric view
26.2 Colour mosaic of the Asgard region
26.3 Monochrome mosaic of the Asgard region
26.4 Infrared image of part of the Asgard structure overlaid on a base map
27 USGS Map of Callisto

A link to a high resolution part of the Callisto Map on the disk
A link to the full resolution complete USGS PDF Map of Callisto on the disk

28 Internal structures of the Galilean Moons and Jupiter
28.1 Io
28.2 Europa
28.3 Ganymede
28.4 Callisto
28.5 Jupiter

29 Orbit details of Jupiter's satellites

30 Demise of Voyager

31 Global animation of Jupiter's atmosphere captured by the Cassini Mission en route to Saturn

Part 3. Saturn

- Saturn Index

1 Saturn's backlit ring system

2 Aurora on Saturn

3 Saturn's seasons

4 Blueness of Saturn's atmosphere

5 Ring and Moon views
5.1 Rings with Pandora
5.2 Rings with Mimas
5.3 Edge on rings with Enceladus
5.4 More edge on view with Dione, Janus, Tethys and Mimas in frame
5.5 Size of the ring particles teased out by radio signal interference experiment
5.6 Spin rates of the ring particles teased out via infrared imaging

6 Pan, a ring shepherd moon

7 Newly discovered Pallene and Janus/Epimetheus rings

8 Janus and Epimetheus, Saturn's dancing moons

9.1 Enceladus blasts icy particles into surrounding space
9.2 Enceladus generates the E ring
9.3 Tectonic shearing generates Enceladus' icy plumes
9.4 Enceladus' fractured surface
9.5 Enceladus' fractured surface – zoom out
9.6 Enceladus' fractured surface – global view

10 Approaching Phoebe, an outer moon, a captured asteroid of comet
10.1 from 143,000 km
10.2 from 77,000 km
10.3 from 32,000 km

11 Backlit Titan with Saturn's rings and Enceladus in the foreground

12 Titan's upper atmosphere
12.1 - natural colour image
12.2 - ultraviolet image showing multiple layers

13 Descent of the Huygens Probe to Titan's surface
13.1 from150 km Upper atmosphere
13.2 from 20 km Mountains and plains
13.3 from 6 km Drainage channels
13.4 from 2 km
13.5 from 600 m
13.6 from 200 m

14 Titan landscape from the Huygens Landing Point
14.1 Lander image from surface
14.2 Lander image juxtaposed with an Apollo mission image for scale comparison

15 Titan surface features from orbit

15.1 Icy volcano
15.2 Wind dunes
15.3 Lakeshore and islands
15.4 Flypast strip over a complex of lakes
15.5 Drainage channels fed by methane springs
15.6 Rain fed drainage channels
15.7 Long, wide, deep drainage channels

16 Relative sizes: Saturn and eighteen of its moons

17 Details of Saturn's Satellites and Rings
17.1 Details of Saturn's rings, inner moon orbits and the ring crossing points of spacecraft that have visited Saturn
17.2 Details of outer satellite orbits
17.p Details of Pioneer 11's journey to Saturn (1973-1979)
17.p.1 Trajectory of Pioneer 11
17.p.2 Pioneer 11's ring plane crossings

A link to an account of Pioneer 11's journey to Saturn on the disk

Appendices

1 Relative Sizes of Jupiter and Saturn
1.1 Saturn compared to the Earth-Moon Distance
1.2 Jupiter compared to the Earth-Moon Distance
1.3 Jupiter compared with the Sun

2 Giant Planet Interiors: Jupiter, Saturn, Uranus and Neptune

3 Terrestrial Planets and the Larger Satellites

4 Links to selected source sites

A CD-ROM version of this presentation is available. It is in the form of an indexed set of web pages that can be read via web browsers running on IBM, Macintosh or Unix computers. Obtain the disk from:

BDAS
PO Box 164
Bendigo
Vic 3552

The cost is $10 or $12 posted.