THE FASCINATING UNIVERSE OF VARIABLE STARS

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AAVSO Speakers Bureau
ALCON 2009
David Fabricius discovered “omicron ceti” in 1596
- Brightened from 3rd to 2nd magnitude, then disappeared – thought to be nova. (Actually disappears from view varying from 2nd to 9th magnitude)
- Re-observed in 1609 by Fabricius, and re-discovered in 1631 by Johann Fokkens Holwarda who determined 11 month period
- Johannes Hevelius observed in 1639 and 1642, and named the star “Mira” – *The Wonderful*

Earlier ancient discovery records unclear. Hipparchus may have discovered Mira in 134 BC

As an aside - Fabricius and his son Johannes discovered sunspots before Galileo (1611)!
Geminiano Montanari discovered “beta Perseii” in 1667
- Brightness varies from 2.1 to 3.4 magnitude in 2.87 days
- Period of less than 3 days credited to John Goodricke in 1782-83
- In 1881 Edward Pickering theorized (correctly) that it was an eclipsing binary star system

European, Arab, and Chinese cultures knew its variability and considered it evil
- “Demon’s Head” – Arab
- “Mischief-maker” – Arab
- “Satan’s Head” – Hebrew
- “Lilith” – Adam’s legendary demonic first wife – Babylon/Hebrew
- “The Spectre’s Head” - Europe
- “Piled-up Corpses” - Chinese
Chinese astronomers have the first recorded histories of supernova
- Over 20 candidates identified over the past 2000 years.
- Confirmed dates include 185, 393, 1006 (brightest and also recorded in Egypt, Iraq, Italy, Japan and Switzerland), 1054 (Crab nebula remnant shown above)

In 1572 Tycho Brahe observed SN 1572 and argued it was very far from earth – contradicting the Aristotelian idea the world beyond the Moon and planets was immutable.
### Film and CCD’s have lead to discovery of most Variables

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Variable Stars Identified</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1596</td>
<td>1</td>
<td>Mira</td>
</tr>
<tr>
<td>1696</td>
<td>3</td>
<td>Mira, Algol, c Cygni</td>
</tr>
<tr>
<td>1796</td>
<td>11</td>
<td>Includes first Cephei discovery in 1784</td>
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<tr>
<td>1896</td>
<td>430</td>
<td>75 by photography</td>
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<tr>
<td>1996</td>
<td>31,187</td>
<td>Most by photography</td>
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Today’s Categorization of Variable Stars

- Pulsating Variables
  - Periodic expansion and contraction of surface
  - Includes Cepheids, RR Lyrae, RV Tauri, Long Period, Semi-regular

- Eclipsing Variables

- Eruptive Variables –
  - Supernovae, novae, dwarf novae, cataclysmic variables
Pulsating Variables
Radial and non-radial motion

Examples of Different Types of Pulsating Variables

Cepheids –
Period 1-70 days
Magnitude variation - .1 – 2.0 mag

RV Tauri –
Period up to 100 days
Magnitude variation up to 3.0 mag
Long Period Variables (LPV)
Multi-filter Amateur Observations of U Crv
(Periods 80-1000 days, Magnitude variation 2.5 – 5.0 mag)

Mira, the “First” LPV, Continues to Amaze

In 1997 Hubble Space Telescope resolved the binary star in Mira, and detected matter either being swept from its surface by its companion or having its atmosphere heated by the companion.

GALEX Ultraviolet Images detected a 13 light-year long “tail” in 2006

Eclipsing Binaries

The diagram illustrates the apparent magnitude changes of Algol A and Algol B over time (days), showing primary and secondary eclipses.

The lower part of the diagram depicts Algol on a graph with a phi angle of 0.00.
An Unusual Bright Eclipsing Binary is the Center of a Major Astronomy Outreach Campaign – Epsilon Aurigae

- Eclipse begins Aug. 11, 2009
- Minimum light begins Dec. 19, 2009
- Mid-eclipse Aug. 4, 2010
- Eclipse ends May 13, 2011

To Learn More and Get Involved, go to www.citizensky.org
Erupting variables are - stars that have occasional violent outbursts caused by thermonuclear processes either in their surface layers or deep within their interiors.

- Major Types
  - Supernovae
  - Recurrent Novae
  - Cataclysmic Variables
Supernova Evolution –
Large Stars Evolve to Neutron Stars and Black Holes

At the end of their lives, Stars Evolve Through Stages of Shell Burning With massive stars burning Heavier Elements.

- All Stars > 0.8 M☉
- Heavier Stars
- Heaviest Stars

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Supernova Death!
A Different Type of Supernova – Type Ia
A “Standard Candle”

- Two normal stars are in a binary pair.
- The more massive star becomes a giant...
- ...which spills gas onto the secondary star, causing it to expand and become engulfed.
- The secondary, lighter star and the core of the giant star spiral inward within a common envelope.
- The common envelope is ejected, while the separation between the core and the secondary star decreases.
- The remaining core of the giant collapses and becomes a white dwarf.
- The aging companion star starts swelling, spilling gas onto the white dwarf.
- The white dwarf’s mass increases until it reaches a critical mass and explodes...
- ...causing the companion star to be ejected away.

http://www.pha.jhu.edu/~bfalck/laprogenitor.jpg
Supernova SN 2007le
(in NGC 7721 - Constellation Pisces)

October 4, 2007
December 19, 2007
September 2, 2008

Photos taken using Dall-Kirkham Cassegrain 12" Global-Rent-a-Scope in Mayhill, NM
Gordon Myers
AAVSO Measurements of SN 2007le
Cataclysmic Variables

Key Properties –

• Binary Star System

• Stellar Material Flows from red dwarf star onto accretion disk surrounding white dwarf companion

• Flow stops and starts

• Orbital period 78 minutes up to around 10 hours

• “Hot spot” where stream hits accretion disk is often hotter and brighter than either star
Cataclysmic Variable Mass Flow

Roche lobes in three dimensions

http://www.vikdhillon.staff.shef.ac.uk/seminars/lives_of_binary_stars/
CV Amateur Measurements

(First attempt measuring SDSS1524+22 Using 12” GRAS Scope in New Mexico with 3 minute exposures)
AAVSO Mission:

The AAVSO is an international non-profit organization whose mission is: to observe and analyze variable stars; to collect and archive observations for worldwide access; to forge strong collaborations between amateur and professional astronomers; and to promote scientific research and education using variable star data.

Key Benefits:

- Become part of the amateur/professional community
- Submit variable star observations; have access to 17 million observations made since 1911
- Detailed Sky Charts for comparison stars
- Excellent training material on variables and observing
- Special sections focus on Long Period Variables, Cataclysmic Variables, and Data Mining
- Free mentoring
- Free access to remote telescope network
- Two annual meetings with numerous valuable presentations
- Speakers Bureau with Outreach material

More and More observers are shifting to CCD’s
Outreach Request –
Help teach the next generation astronomy and science

Questions from High School Seniors –
May, 2009

- Why is the Milky Way called the Milky Way?
- Why are stars so far away yet easy to see with the human eyes?
- Is it really possible for us to live in space one day?
- What gases make up stars? What happens if something touches a star?
- What is going to make the sun die?
- What makes the planets follow their orbit and not move off course?
- How fast do stars move?
- How long does a star usually live?
- How were planets made?
- What makes planets different from one another?
- Why do stars go through different stages to become giant stars or dies?
- What do you do on cloudy nights?
- What would happen if we didn’t have any stars in our universe?

The Best Example: Dr. Michelle Thaller’s -
References

- One Universe – Tyson, Liu, Irion
- Astronomy Today – Chaisson, McMillan
- Modern Astrophysics – Carroll, Ostlie
- Cataclysmic Variable Stars – How and Why They Vary – Coel Hellier (Springer Praxis publisher)
- Pro-Am Collaboration – Pamela Gay (AAVSO Presentation)
- Variable Stars and the Stories They Tell – Mike Simonsen (AAVSO Presentation)

- Key Websites:
  - www.aavso.org
  - http://www.vikdhillon.staff.shef.ac.uk/seminars/lives_of_binary_stars/cv.html
  - www.cbastro.org
  - http://galileo.rice.edu/sci/fabricius.html
  - www.jpl.nasa.gov
  - www.hubblesite.org

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