Cape Cod Astronomical Society - Minutes of the December 3, 2015 meeting

Attendance: 24 members and 1 guest

The meeting was held at the Dennis-Yarmouth High School Library.

Tonight's speaker is a member of CCAS: Jim Lynch of Woods Hole Oceanographic Institute. Dr. Lynch is the recipient of the Robert W. Morse Chair for Excellence in Oceanography, and is a senior scientist in the Applied Ocean Physics and Engineering Department at WHOI.

In addition to Jim's presentation, below, the following items were discussed:

- Joel asked who our guests were at this meeting and Dennis Mascio introduced himself. Dennis also attended our pre-meeting dinner. Joel invited members to come to the observatory, as it would be opened after the meeting.
- Bernie described some of the projects he's working on (e.g., occultations, variable stars…Algol, celestial navigation, sunspots, solar spectroscopy). He could use some volunteer help with D-Y students and the upcoming lunar occultation of Venus, and some help with other student projects.
- Peter spent a few minutes describing how Algol ("A") dims visually due to the passing of Algol B (its less bright companion).

In Mike's absence, Peter introduced Dr. Jim Lynch, and his presentation:

<u>Black Holes…Their Ins and Outs (Mostly Outs)</u>

- Concept began with John Mitchell in 1783. He suggested that a star's surface gravity might be great enough that not even light could escape it. Also postulated the concept of a dark star a few miles in diameter could have the mass of the Sun. Laplace's math later proved it (formulas work as long as it is understood that while light has no mass it has energy).
- Post Newtonian, Einstein Field Equations as described by John Wheeler: "Matter tells spacetime how to curve, and spacetime tells matter how to move."
- Further refinement came from Karl Schwartzschild. He developed an exact metric for curved spacetime in the presence of a static, spherically symmetric, massive object.
- While Einstein welcomed Schwartzschild's calculations, he and Eddington dismissed the presence of a singularity.
- Bethe's work on fusion in stars (but what happens when the fuel runs out?) and others working on Quantum mechanics, led Chandrasekhar to come up

with the Chandrasekhar Limit…that smaller stars like our sun, up to 1.44 times the sun's mass, would eventually become white dwarves.

- Zwicky proposed that stars more massive than the Chandrasekhar Limit went supernova and left a neutron star. Zwicky also proposed dark matter. Oppenheimer and Snyder stated that stars with more than three solar masses turn into black holes (a term coined by Wheeler, who also did calculations in the 1950s that laid to rest the last major objections to black holes).
- Sizes: small as a single atom (primordial); 10 miles in diameter (stellar); size of the solar system (supermassive). The latter probably exists at the center of every large galaxy…ours is called Sagittarius A.
- Wheeler on black holes: it has no hair (black holes are relatively simple objects having mass, angular momentum and electric charge). Simplest black hole: accretion disks, event horizon, time distortion, tidal forces, density (but see below for supermassive black holes), where does the matter go (also, see below)?
- Strongest nuclear reaction: for example, fusion in the sun about 0.7%, rotating black hole up to 42%.
- Time and space crossing the horizon of a large black hole: normal for the traveler; slow for the observer.
- Density – regular black holes are extremely dense but supermassive black holes not so much (regular density is proportional to mass; black hole density proportional to M^{-3}). Where does the matter go: we don't know, but it is either compressed or it travels somewhere else.
- Falling into a black hole…try not to…really. As you approach, its size is misleading since spacetime is distorted by intense gravity, the universe fades into a shrinking circle behind you, then blackness in all directions.
- More complicated, a rotating black hole (Kerr Metric) rotates faster due to the star condensing (conservation of angular momentum), and the black hole radius is even smaller so rotation is even faster; up to C/2. Penrose proposed that energy could be removed from a black hole by an object entering a black holes rotation. "Penrose Process" results in the black hole losing angular momentum.
- Hawking radiation: emission of positive energy by a black hole…no longer a one-way street.
- Planck Scales – quantum mechanics gets melded with general relativity.
- Temperature – since black holes radiate energy (Hawking radiation), they have temperature and can evaporate over time.
- Entropy has to be conserved. Hawking said information was lost, but Susskind and others theorized information is encoded in the event horizon. Hawking lost a bet. One theory: a black hole acts as a hologram since the 3-D interior of the black hole can be described by the surface information. Conflict with "The Firewall" concept.
- Solution #1: ER (Einstein-Rosen) paper stated that two black holes could be connected via wormhole ("ER Bridge"). Also EPR (Einstein-Podelsky-

Rosen), a paper that described the entanglement of particles and criticized "spooky action at a distance", and ER=EPR a conjecture in physics stating that entangled particles are connected by a wormhole..

- Solution #2: Fuzzballs – Mathur gave a string theory description of black holes in 2002.
- Black holes can be created, possibly by the LHC. Could they "eat" the earth? No; if these miniature black holes exist, they have hit earth for millions of years. Also, due to Hawking radiation, these black holes would decay at extremely small time scales (i.e., rapidly).

Questions:

Do stars fall into black holes. *Yes: these are quasars. A visual model might be comet Shoemaker-Levy falling into Jupiter.*
How fast do black holes rotate? *Half the speed of light..*

The meeting was adjourned at 9:00 PM.

Next meeting: January 7, 2016.

Respectfully submitted,
Gus Romano, CCAS Secretary