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Future Directions for Einstein @Home

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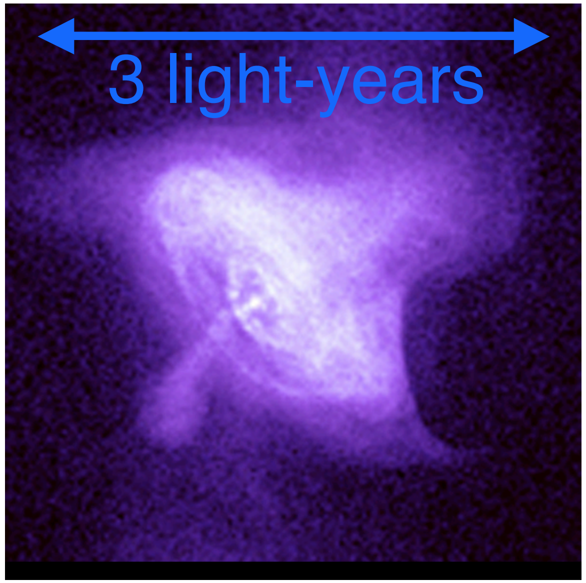
Overview of Einstein@Home

- **Launched** in 2005. Work done at the Albert Einstein Institute and the University of Wisconsin.
- **Science**: search for *gravitational waves* from rapidly spinning neutron stars, using data from an international detector network.
- **Users**: typically about 60 000 active hosts.
- **BOINC Setup**: standard, but with “locality scheduling” features enabled.
- **First formal publication**: appearing in Physical Review D later this month.

What are we looking for?
Neutron Stars

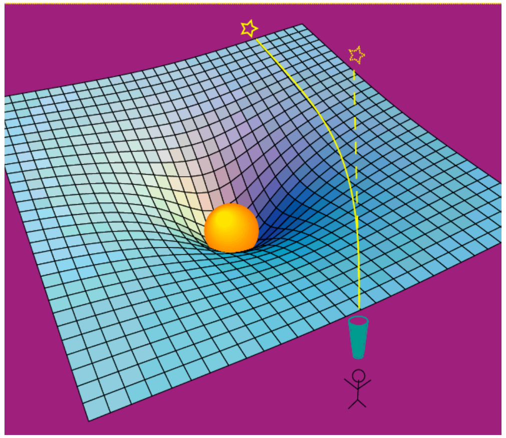
- Predicted by Chandrasekhar in 1930 and discovered by accident in 1967.
- Formed in explosion (supernova) at the end of the life of an ordinary star.
- Protons and electrons of ordinary matter ‘crushed together’ to form a ‘giant atomic nucleus’ made of neutrons.
- Neutron stars have masses similar to our Sun but a radius of only about 10 km! They can spin very rapidly (> 700 rotations/second).
- Very strong gravity: “almost” a black hole. Light can still escape, but barely!.
- A few thousand are visible as ‘radio pulsars’ but our Galaxy is expected to contains hundreds of millions.
- Rapidly spinning neutron stars should emit gravitational waves. These are known to be weak, but we do not know **how** weak.

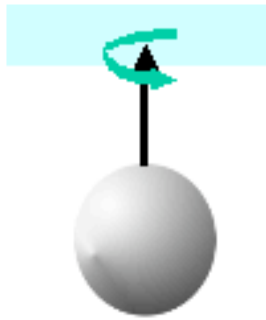


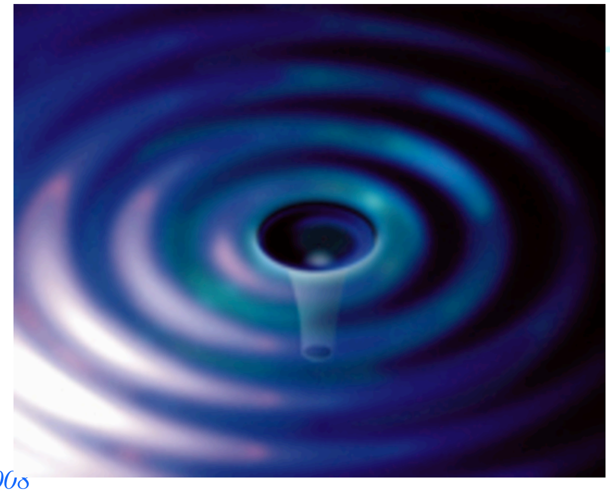
Crab Nebula (1054 AD)
R = 12 km, P = 33 msec,

What are Gravitational Waves?

- In Einstein's theory of General Relativity, mass and energy curve the geometry of space-time.
- If rapidly spinning neutron stars have small bumps or "mountains" then they can produce "ripples" in the geometry of space-time which travel outwards from the star at the speed of light.
- Einstein predicted their existence in 1916. He estimated the ampitude of these waves and concluded that they were too weak to detect.
- **Einstein was wrong about this**: in the coming years we will detect these wave directly!







The most sensitive gravitational wave detectors

All became operational during the past ten years.

Past and Current Einstein@Home Searches

- **LIGO S3 data (600 hours)**
  60 x 10 hours coherent integration
  Results presented on-line.
  No detections.
- **LIGO S4 data (510 hours)**
  17 x 30 hours coherent integration
  Results paper completed in May 2007, just appearing now
  No detections.
- **LIGO S5 data (840 hours)**
  28 x 30 hours coherent integration
  First search (S5R1) completed about one year ago.
  Post-processing finished, results under review in LIGO Scientific Collaboration.
- **LIGO S5 data (3618.5 hours)**
  84 x ~40 hours coherent integration
  Search just finishing now (S5R3) and post-processing starting
  First search using the best available incoherent combination method
- **LIGO S5 data (5280 hours)**
  121 x ~40 hours coherent integration
  Search just starting now (S5R4)

What's Coming?

- Gravitational wave detectors are getting better.
  - 2009, LIGO S6 (factor of two improvement)
  - 2013, Advanced LIGO (another factor of five improvement)
- Soon hope to have Graphics Processing Unit (GPU) code available for Nvidia graphics cards, giving an order-of-magnitude improvement in processing speed. This should allow longer coherent integration times, increasing the sensitivity
- We will provide all the screensaver code nicely packaged so that users can modify it or write their own. Based on new SDL graphics library (no more GLUT).
- Discussions within the LSC about also packaging the science code to allow users to do additional optimizations
- Searches for radio pulsars in short-period binaries, using radio data from Arecibo

Search for radio pulsars in short period binaries

Science Motivation

- Current searches for radio pulsars lose sensitivity when orbital period < 50 minutes
- But our Galaxy should contain binary neutron stars with periods as short as 4 - 6 minutes!
- These short-period systems have high orbital velocities, which magnifies relativistic effects
- Important for gravitational physics: predict Galactic binary inspiral rates; LISA calibration sources
- We have developed a (computationally expensive) detection technique for stars in binaries with periods > 10 minutes

Data source: Arecibo PALFA

Psychological Motivation

- Hope to find new relativistic pulsars on an annual basis. These discoveries should be exciting for Einstein@Home volunteers and help in retaining and attracting them

Technical Issues

- Radio pulsar search workunits will be shorter (~ 4 hours) and use smaller data sets (2MB) than current Einstein@Home gravitational wave searches. And the data sets are only used once!
- Mixture of locality and non-locality scheduling
- Should we let users control the mixture of workunits?