

Light in New Regimes

*“Is a new theory of light and matter needed
at the highest energies?”¹*

Joel Leigh

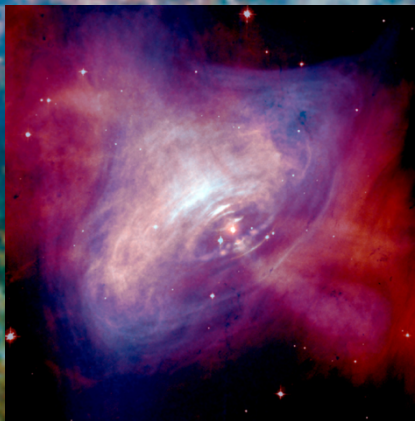
¹Connecting Quarks With the Cosmos, National Research Council, © 2003 National Academy of Sciences

Overview

- Motivation
- Questions
- Neutron Stars & QED
- Polarized X-Rays
- A look to the future (past)

Motivation

- The laws of physics must be tested at the highest energies
- Discover new physics!



Images courtesy <http://CHANDRA.harvard.edu>

Central Pulsar in M1

Movie courtesy <http://CHANDRA.harvard.edu>



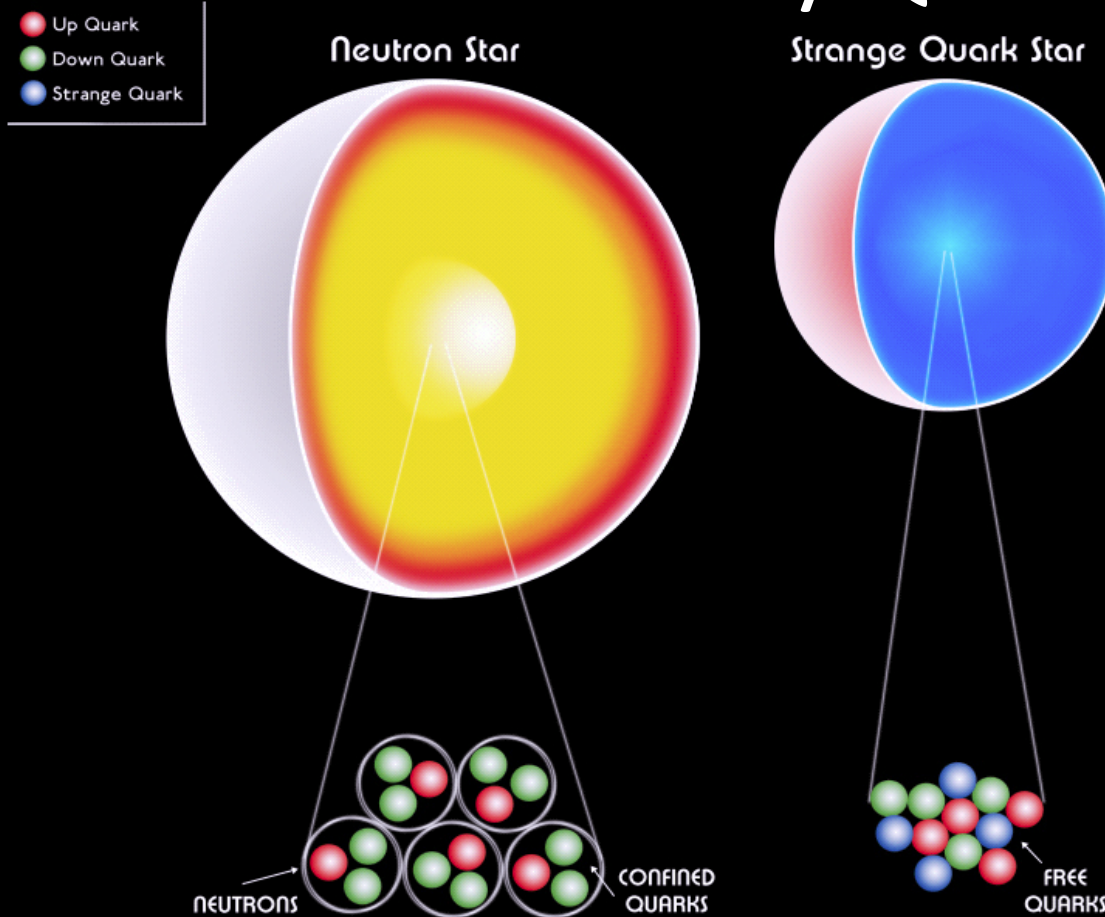
GR

A simulated Black Hole of ten solar masses as seen from a distance of 600km

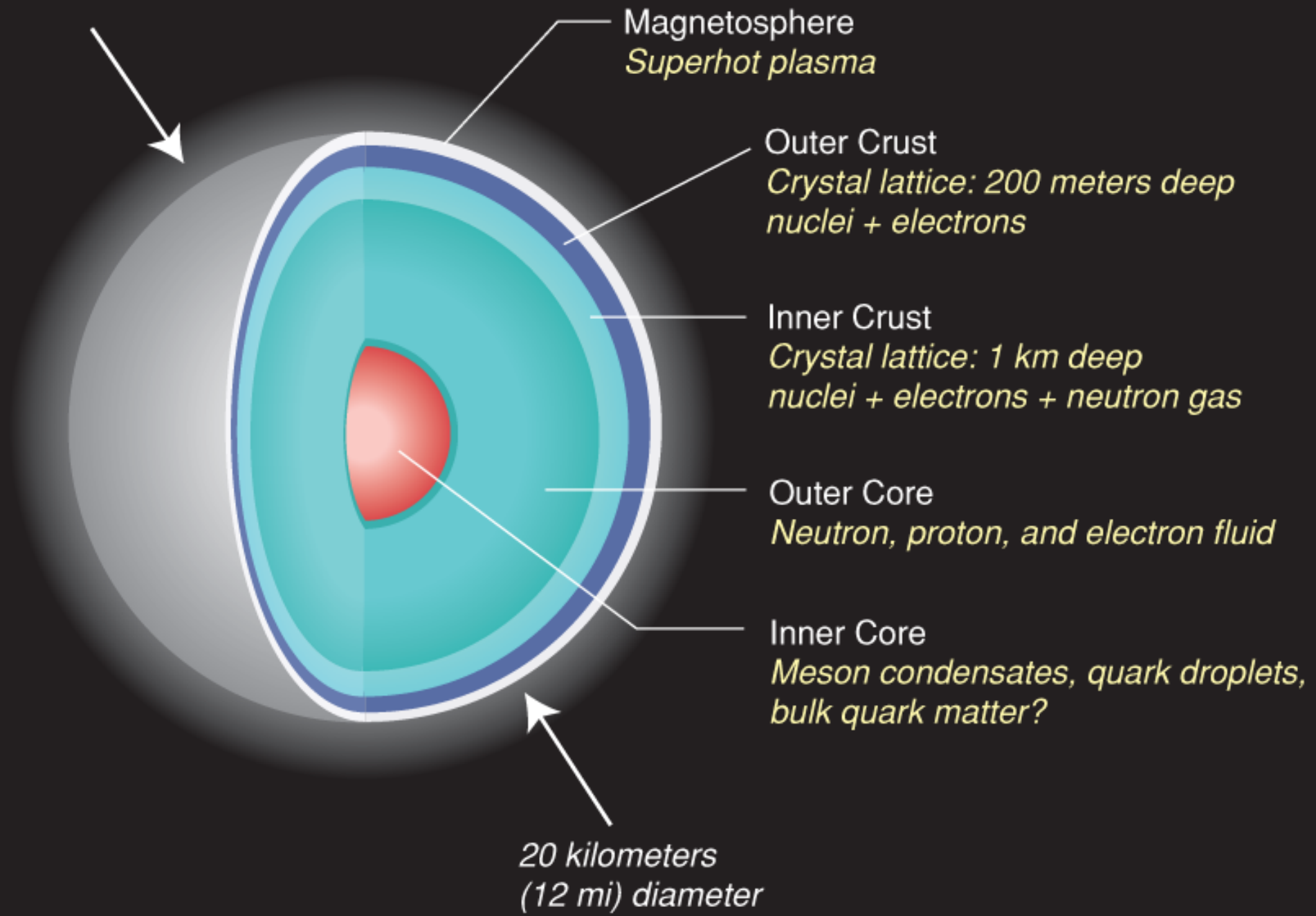
- How do atoms emit near event horizons?
- Do frame dragging and time dilation effect spectra the way we expect them to?

Image courtesy <http://www.spacetime.travel/>

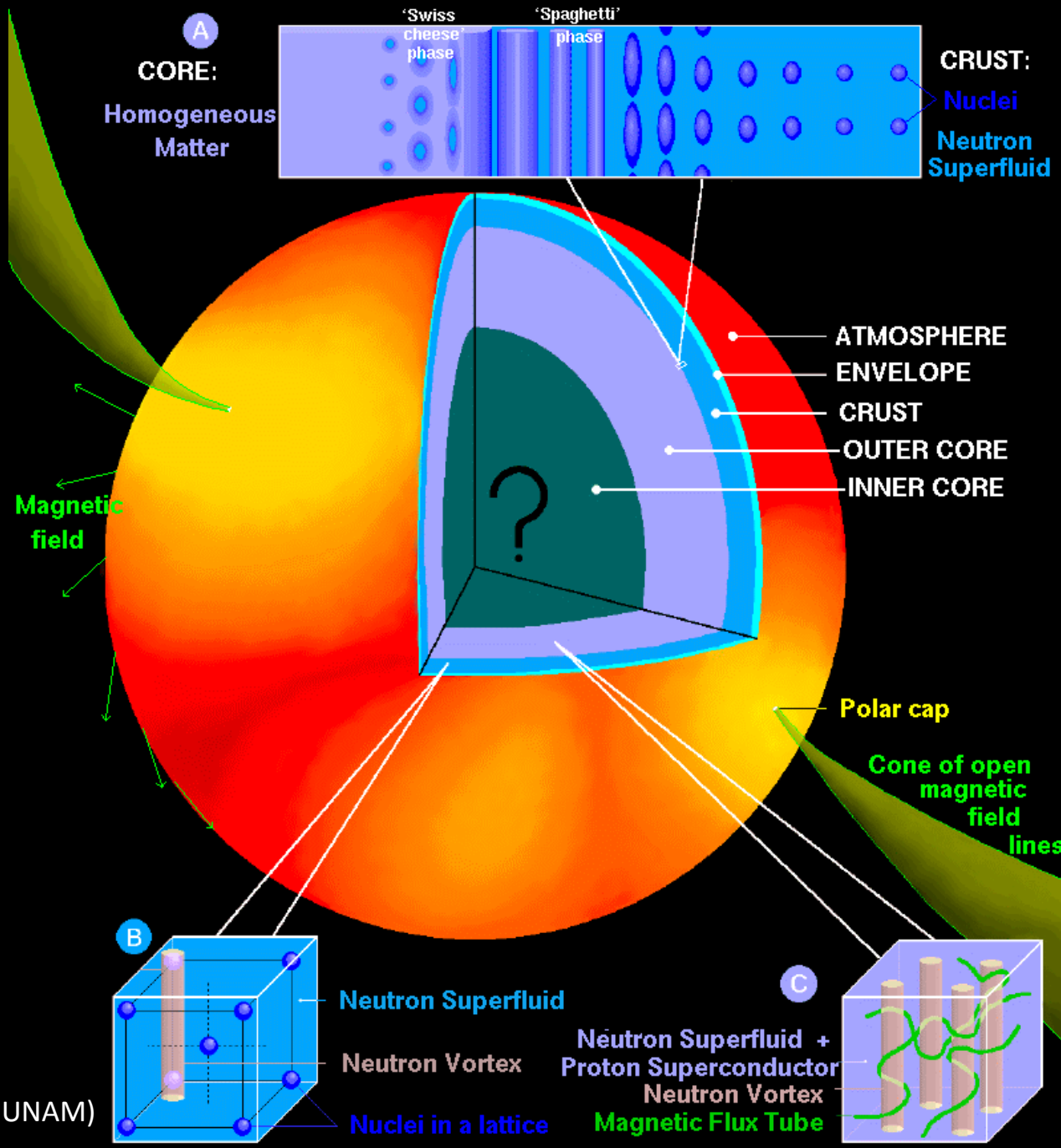
Solid State/QCD



- Are there exotic phases of matter inside compact objects? How do nucleons interact there?
- Are there Q stars? Preon Stars?

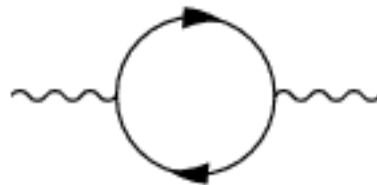


A NEUTRON STAR: SURFACE and INTERIOR



QED

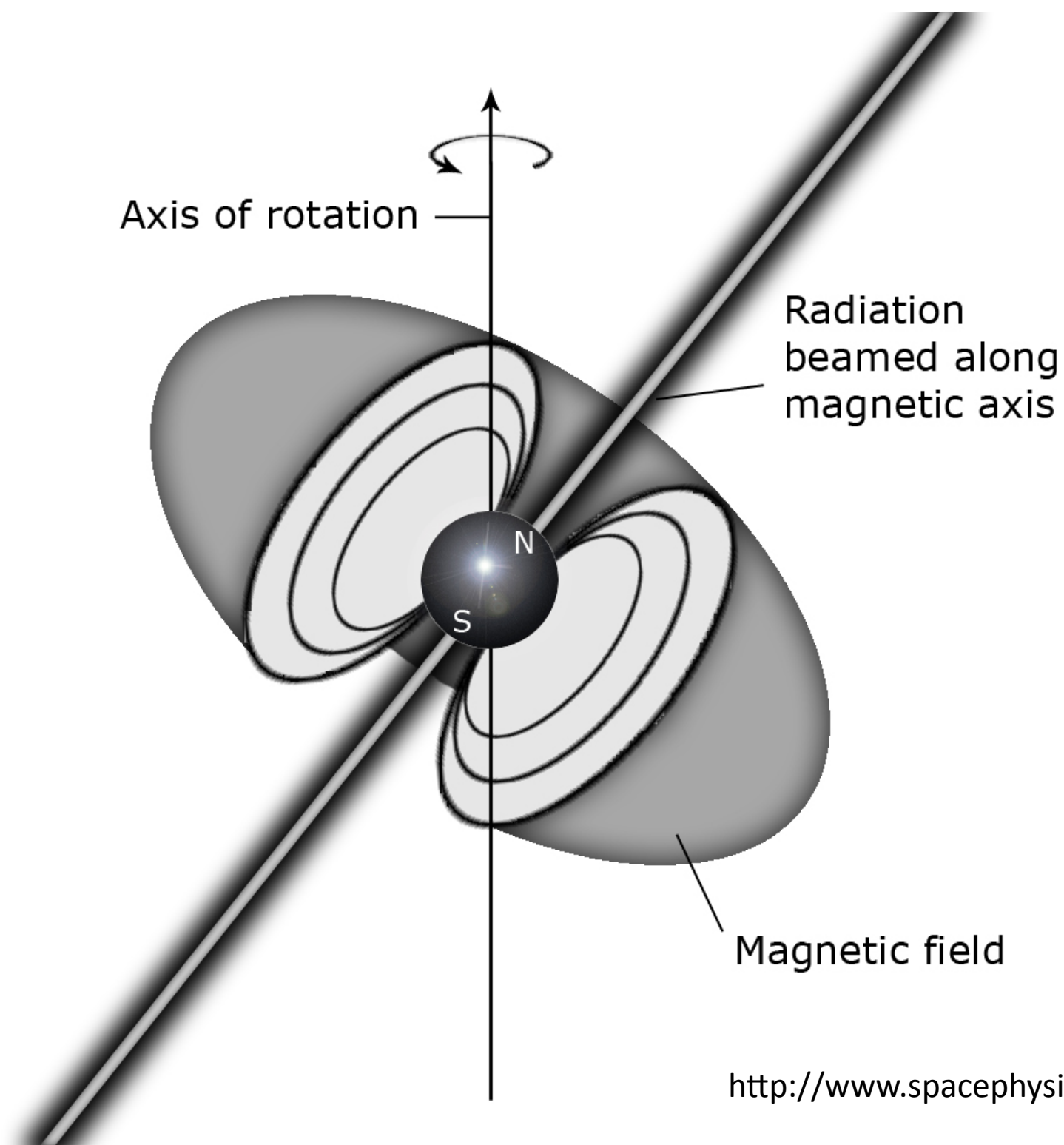
- “The Jewel of Physics”²
- Tested to extreme precision
 - ❖ Lamb Shift
 - ❖ Vacuum Polarization
 - ❖ Hyperfine Splitting
- It’s Feynman’s baby, are you questioning it?



²Feynman, Richard Phillips (1998). *Quantum Electrodynamics*. Westview Press; New Ed edition
Image courtesy Pál Hidas KFKI Research Institute for Particle and Nuclear Physics

Checking QED in high B

- QED has been tested in the lab in B fields of about 10^5 Gauss (as of 2003)
- Neutron Stars provide extreme testing grounds for QED because of high B fields
- 10^{12} Gauss, 10^{15} for magnetars!
- Beyond the critical energy, polarized x-rays should be detected



Detecting Polarized X-Rays

- High B environment
- Landau Levels
 - ❖ Cyclotron frequencies quantized
 - ❖ Spin states have different transitions to ground
 - ❖ In very high B fields one spin state's transition to ground is forbidden
- Look for signature structure in spectra

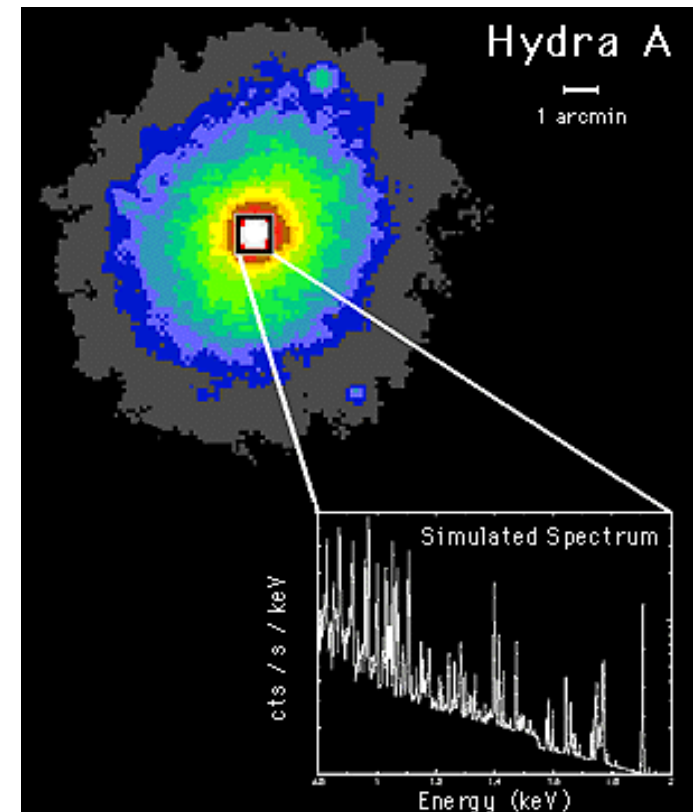


Image courtesy <http://imagine.gsfc.nasa.gov>

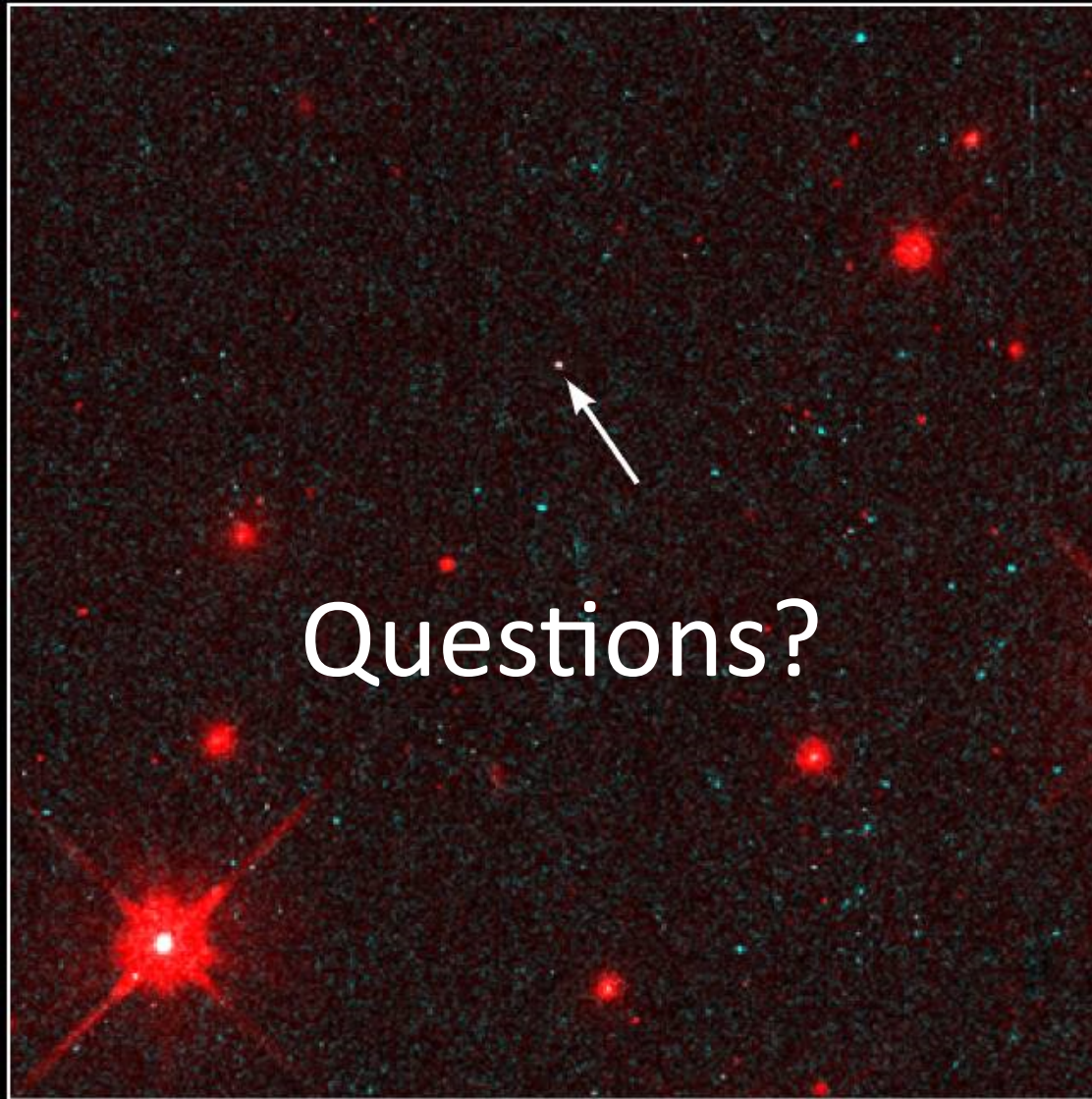
Next Time

A 3D rendering of a large space telescope, likely the James Webb Space Telescope, shown from a perspective looking down the length of the telescope. The primary mirror is a large, circular, golden-colored structure with a grid of segments. A secondary mirror is visible in the center of the primary mirror. The telescope is set against a dark background filled with stars.

- What new results have been obtained?
- What experiments have been built/need to be built?
- What questions still remain unanswered?

Works Cited

- Carroll, Bradley W., Ostlie, Dale A., An Introduction to Modern Astrophysics, Pearson Addison Wesley, San Fransisco, 2007
- Chandra X-Ray Observatory Homepage, Harvard-Smithsonian Center for Astrophysics, <http://chandra.harvard.edu/>
- Hester, et. al, *HST and Chandra Monitoring of the Crab Synchrotron Nebula*, Astro-ph, 2002
- Connecting Quarks With the Cosmos, National Research Council, National Academy of Sciences, 2003



Questions?

Isolated Neutron Star RX J185635-3754 HST • WFPC2

PRC97-32 • ST ScI OPO • September 25, 1997

F. Walter (State University of New York at Stony Brook) and NASA

Particle Physics

- Where do high energy cosmic rays come from?
- How do they make it here through the CMB?

