Final Lecture P630 12/4/02

The Future of Nuclear Astrophysics

Talks for Dec 6, 9, 11

Dinner Dec 10 Tuesday at 7 pm 1000 Pleasant Ridge Rd.

Astrophysics ~~of~~ from solar neutrinos

(a) Total ^8B ν flux gives central temp. to $\sim 1\%$, $\phi \propto T^{24}$

(b) Can measure CNO ν in future. About 1-2% of sun's energy from CNO

$^{12}C + p \to {}^{13}N + \gamma$
$^{13}N \to {}^{13}C + \nu + e^-$
$^{13}C + p \to {}^{14}N + \gamma$
$^{14}N + p \to {}^{15}O + \gamma$
$^{15}O \to {}^{15}N + \nu + e^-$
$^{15}N + p \to {}^{12}C + \alpha$

~~[illegible]~~

$^{12}C + p \to {}^{13}N + \gamma$
~~$^{13}N + p \to {}^{14}O + \gamma$~~
~~$^{14}O \to {}^{14}N + \nu + e^+$~~
~~$^{14}N + p \to {}^{15}O + \gamma$~~
~~$^{15}O \to {}^{15}N + \nu + e^+$~~
~~$^{15}N + p \to {}^{12}C + \alpha$~~

CNO ν flux very sensitive to metals in solar interior.

Only about 3% of sun's mass is in outer convective zone: This is $\sim 30\ M_{Jupiter}$.

If a metal rich "Hot Jupiter" accreted onto sun in past it would have ~~[illegible]~~ increased metal content of convection zone. See /life/sun/255.mov

We observe total ~~metal~~ content of convection zone today. This suggests metal content of core could be lower?

Use measured CNO ν flux to constrain amout of fall back material.

"This is the final search for the planet Vulcan"

(c) Helliosysmology has led to astrosysmology and the standard solar model is our basis for all stellar evolution models. The great sucsess of the standard solar model suggests our theory of a large variety of other stars is in good shape

(d) Fine details of stellar structure and solar cycle. Even very small changes in the sun are very important for the Earth's climate.

Show SOHO presentation

The r-process

It is important to find site for r-process, presumably in core collapse supernovae somehow. We need to find where neutrons come from.

Cosmic rays

~~For~~ Supernova shocks accelerate the cosmic rays. However this does not work for the very highest energy cosmic rays. These have to much energy to be contained by the B field inside a supernova remenant. Question how large is the flux of very high E ~~E~~ 10^{20} cosmic rays. What are they protons or heavy ions? Where did they come from?

Gamma ray bursts

Very energetic explosions that send jets of gamma rays over cosmological distances. Perhaps model is "hypernova"

Collapse of a single very massive star ~~to~~ that is rotating to form a black hole and jets.
There may be some common physics in gamma ray bursts and supernovae.

Black holes

More astrophysics than nuclear astrophysics.
Growing X-ray observations of accretion disks around black holes.

Gravitational radiation

LIGO [laser interferometer gravity observatory] is starting to operate in Lousiana and Washington state.

Gravitational radiation from time dependent mass quadrupole.

Note graviton is spin 2 ⟹ hence quadrupole moment. No dipole gravitational radiation

Possible sources. Merging neutron stars

Asymmetric core collapse supernovae. Spherical symmetry yields no radiation.

Rotating neutron stars. If NS has a mass qudrupole moment that is not alligned with the spin axis then it will emit gravitational radiation. One can search for radiation at known pulsar frequencies.

Example: Thermal conductivity depends on magnetic field so it is possible to have a small asymmetry aligned with magnetic field. Only need very small distortion in shape to produce significant radiation.

High Energy Neutrinos

See F. Halzen's talk on Ice Cube

High energy cosmic rays strike photons

$$p + \gamma \rightarrow n + \pi^+$$

and pions decay to produce high E ν. Note also produce π^0 which give high E γ

Expect γ flux $\sim$ ν flux