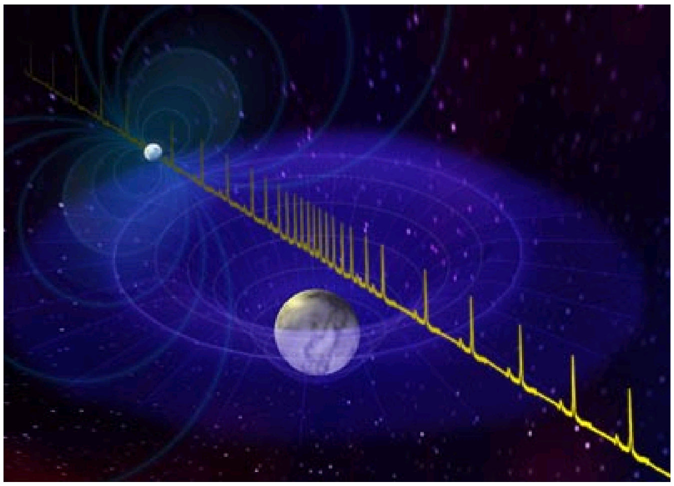
Neutron star is most massive yet

Oct 30, 2010 14 comments



Shapiro delay caused by nearby white dwarf companion

Using a technique that exploits general relativity, astronomers in the US and the Netherlands have identified a neutron star that has a mass nearly twice that of the Sun. The object is the most massive neutron star ever determined with reliable precision, and its existence, say the researchers, rules out much of the exotic matter hypothesized to occur inside these ultra-dense burnt out stars.

Neutron stars form when stars exhaust all of their nuclear fuel and implode under their own weight. The immense gravity forces protons and electrons together, leaving a ball made up largely of neutrons that has a density up to ten times that of atomic nuclei. Theorists have proposed that the huge pressure inside such an object could lead to a number of different forms of exotic matter. One of these is a material known as a Bose–Einstein condensate, in which particles act together as a single quantum entity. Alternatively, the neutrons might split to form a "soup" of free quarks and create what is known as a "quark star".

The bigger the better

One way to discriminate between these different hypotheses is to look for the existence of very massive neutron stars. Exotic particles (if they existed) would repel each other less than neutrons do, and so would provide less resistance against gravitational collapse. This means that the mass value at which an exotic neutron star implodes to form a black hole would be lower than that of a conventional neutron star. In other words, an object of this composition could not exist above a certain mass.

Astronomers have previously identified neutron stars that might weigh as much as 2 solar masses, which is significantly greater than the 1.4–1.5 solar masses considered typical of neutron stars. However, such mass measurements have been imprecise. The new work, carried out by Paul Demorest of the National Radio Astronomy Observatory (NRAO) in Virginia and colleagues, takes advantage of an effect of general relativity known as the Shapiro delay, which is the delay experienced by a radio signal as it passes through the gravitational potential of a massive object.

The idea is to measure very precisely the arrival time of radio waves

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Paul Demorest

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Nature **467** 1081

from a spinning neutron star known as a pulsar, which is in orbit around a centre of gravity shared by a companion star. The pulsar emits bursts of radio waves separated by a very well defined interval – generally a few thousandths of a second – and this interval will be delayed very slightly as the companion star passes between it and the Earth, owing to the companion star's gravitational field. The exact shape of the curve that describes how this delay varies throughout the cycle of the binary system reveals the inclination of the orbital plane compared to the Earth's line of sight, while the magnitude of the delay tells us the mass of the companion star. Combining these data with measurements of the orbital period and the pulsar line-of-sight speed yields a value for the pulsar mass.

Apr 1, 2010

A clean way to measure

Demorest and co-workers point out that this approach is a very "clean" way of measuring the pulsar mass because, unlike alternative methods, it relies on a single type of data. But the Shapiro delay is a very weak effect. The researchers were able to optimize their measurements by using a binary system, known as J1614-2230, in which the orbital plane is almost exactly edge-on as seen from the Earth and in which the companion star is comparatively massive – both characteristics that increase the magnitude of the delay. They observed the system over the course of one complete nine-day orbit in March this year using an instrument known as GUPPI on the NRAO's Green Bank radio telescope. From these observations they calculated the pulsar to have a mass of 1.97 solar masses, with error bars of ±0.04 solar masses (*Nature* **467** 1081).

This figure is significantly higher than the previous record for precisely measured neutron star mass – 1.67±0.01 solar masses. And it is, say the researchers, high enough to rule out a wide range of models positing the existence of exotic matter inside neutron stars. Feryal Ozel of the University of Arizona, lead author of a companion paper to be published in *Astrophysical Journal Letters*, says that among the exotic particles to get the chop are hyperons, kaon condensates and free quarks. She says that if quarks are to exist in the core of neutron stars then they must strongly interact with one another, as they do inside normal matter, in order to withstand the star's huge gravitational field.

Frits Paerels of Columbia University in New York, who was not involved with the work, agrees. "This measurement really does not appear to leave a lot of wiggle room for models of neutron stars that involve exotic condensates," he says. "It also starts to close in on the models based on quark matter. Indeed, it comes very close to ruling out quark stars."

About the author

Edwin Cartlidge is a science writer based in Rome

14 comments

Comments on this article are now closed.

1 **Ragtime**
Oct 30, 2010 3:30 AM
Prague, Czech Republic

Well, black holes simply doesn't exist, as Einstein expected and some massive collapsars (quark or strange stars) are formed instead. The recent evidence of fourth generation of particles could prohibit the collapse of quarks into singularity, too..

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2 **kasuha**
Oct 30, 2010 2:18 PM
Prague, Czech Republic

Quote:

> *Originally posted by* ***Ragtime***
> Well, black holes simply doesn't exist,

If an object is dense enough to not let any light escape it's as good as a black hole regardless whether there's a singularity or not inside.

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3 **Ragtime**
Oct 30, 2010 3:28 PM
Prague, Czech Republic

Quote:

> *Originally posted by* ***kasuha***
> Quote:

> *Originally posted by* ***Ragtime***
> Well, black holes simply doesn't exist,

If an object is dense enough to not let any light escape it's as good as a black hole regardless whether there's a singularity or not inside.

Well, I don't know if it's good, but it's definitely not the black hole in general relativity sense. Actually, the same effect, which can prohibit the formation of singularity may prohibit the formation of event horizon around collapsar (albeit both these effects aren't probably tightly connected mutually, because we know about both white holes, i.e. quasars, too).

Dense aether model explains it in the following way: if gravity field corresponds the energy density, then the this energy density results into additional dark matter field, which surrounds collapsar and makes it relatively lighter, then the mass, leading into collapse from pure general relativity perspective. In addition, the layer of more dense vacuum around collapsar prohibits the establishing of total reflection mechanism, which is responsible for formation of event horizon.

In such way, many quark and strange matter stars may be actually "black holes" without singularity and event horizon, predicted with general relativity.

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4 **Jarek Duda**
Nov 1, 2010 9:19 PM
Cracow, Poland

Is there a clear black hole evidence?

About black hole doubts, I was recently on a seminar about that there is practically no light bending in observations of Sagittarius A*:
spiedl.aip.org…GetabsServlet

Looking important, but ignored doubt is considering proton decay, which is practically inevitable in some particle models like supersymmetric and would be helpful to explain nonzero baryon number of our universes (if they could be created in big bang, they should be also destroyable) ...
... it would be nature's failsafe against infinite densities - if baryon number doesn't have to be conserved, in such extremal conditions like in neuron star center, it could became statistically essential that neutrons could decay into pure energy ... which finally could be radiated as X-rays and maybe could explain beyond GZK cosmic rays ... ?

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5 **Ragtime**
Nov 2, 2010 8:50 AM
Prague, Czech Republic

Quote:

> *Originally posted by* ***Jarek Duda***
> .. there is practically no light bending in observations of Sagittarius A*..

Thank You, there is some explanation of it www.extinctionshift.…topic_05.htm

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6 **John Duffield**
Nov 2, 2010 6:29 PM
United Kingdom

Quote:

> *Originally posted by* ***Ragtime***
> ...but it's definitely not the black hole in general relativity sense...

That's not quite right, Ragtime. It's not a black hole in the sense of the Misner/Thorne/Wheeler interpretation of general relativity. But it is still a black hole in the sense of the Weinberg interpretation of general relativity. In the latter, there's no point-singularity at the centre, everything just grinds to a halt at the event horizon.

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7 **Jarek Duda**
Nov 2, 2010 7:49 PM
Cracow, Poland

If there is no point-like singularity, there should be a volume of SOME STATE OF MATTER having finite density - larger than any exotic concepts like quark star - what is it??
If proton decay is possible - if while big bang there was created more baryons than antibaryons ... shouldn't these baryons be just destroyed (neutron -> a few photons + antineutrino) before reaching infinite densities in neutron star core?

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8 **Ragtime**
Nov 3, 2010 10:55 AM
Prague, Czech Republic

Quote:

> *Originally posted by* ***Jarek Duda***
> If there is no point-like singularity, there should be a volume of SOME STATE OF MATTER having finite density - larger than any exotic concepts like quark star - what is it?

I can imagine for example neutrino star, i.e. star formed with pure neutrinos. In addition, we have an evidence of fourth generation of quarks and neutrinos. Recently the process known as an electroweak burning was proposed for extending of collapsar lifetime.

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9 **Jarek Duda**
Nov 3, 2010 6:27 PM
Cracow, Poland

Such eventual transformation into neutrino star would also require breaking baryon number conservation - some kind of proton decay.
There should be some density/temperature limit above which such hypothetical process could be statistically essential - so it would start in the center of star - created energy and (anti)neutrinos should escape into outer regions (gradually or in explosion) ... but how neutrinos could condensate gravitationally? (especially they are probably Majorana particles...)
About quark stars - we know only about compositions of two and three quarks, there are hypothesized pentaquarks ... but how to extrapolate it into a quark star??
And about these new neutrinos - I've seen such news, but it also says that SM has another hole - it's much too early to patch it with fourth generations which would bring many other unobserved consequences.

Edited by Jarek Duda on Nov 3, 2010 6:29 PM.

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10 **Jarek Duda**
Nov 7, 2010 11:26 AM
Cracow, Poland

As natural evolution of black holes, there is considered evaporation by Hawking radiation - as I've read it can create only massless particles(?) - so to conserve baryon number, they would have to be massless ones ...
Since practically all black hole theories I've seen require breaking this conservation law, so maybe it's done much simpler - not after creating mass singularity, but just before: preventing infinities ...

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11 **MJBridger**
Nov 7, 2010 2:01 PM

Hollow Neutron Stars?

You could have a neutron star that was hollow, so it could be very big without being a 'black hole'.
The hollow centre would actually have a low gravity vector, being suurounded by the mass. I imagine this would be a very rare object of course, but then there are quite a lot of stars!

As for black holes, I think they may not exist because Einstein's gravity shift equation says objects within their Schwarzchild radius may produce negative frequency radiation, which is valid as e.m.waves/photons are neither negative or positive. All objects can radiate!

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12 **lysdexia**
Nov 10, 2010 6:54 PM
Stockton, United States

What bullshit!

There are no black holes: physicsworld.com…43970#comment8733. The more-massive neutròn stars are clear proof against them. Also, the neutròn star is supposed to be layered, with neutròns above and quarks below.

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13 **Kelwinben**
Nov 12, 2010 11:57 AM

Good

I thought them measuring the properties of neutron stars would soon destroy many theories.

I just wish they would kill this one. As quoted above...

"it could squeeze
together so much that it would
collapse into a black hole"

The formation of an event horizon (the hallmark of a black hole) is dependant on enough compacted mass to generate enough gravity to prevent light from escaping.

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14 **Bruce201098**
Nov 25, 2010 1:59 PM

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