

Science AMA Series: We are scientists working on the first-ever NASA mission dedicated to studying pulsars, the ‘weird’ stellar objects that were accidentally discovered 50 years ago. Ask Us Anything!

NASAGoddard¹ and r/Science AMAs¹

¹Affiliation not available

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Abstract

That’s all we have time to answer now! Thanks for all your pulsar related questions. You can stay up-to-date on the mission here: <https://www.nasa.gov/nicer>. And learn more technical information about NICER here: <https://heasarc.gsfc.nasa.gov/docs/nicer/>. Pulsars are rotating “lighthouse” neutron stars that began their lives as stars between about seven and 20 times the mass of our sun. They spin hundreds of times per second, faster than the blades of a household blender and they possess enormously strong magnetic fields, trillions of times stronger than Earth’s. For the first time, NASA has a mission to study pulsars using X-ray technology to uncover mysteries of the cosmos while paving the way for future space exploration. This two-in-one mission is called NICER-SEXTANT and it’s currently aboard the International Space Station. NICER (the Neutron star Interior Composition Explorer) uses 56 telescopes to study the structure, dynamics and energetics of these spinning neutron stars. What makes up their cores is not known, but if these super-dense objects were compressed much further they’d collapse into black holes. SEXTANT (the Station Explorer for X-ray Timing and Navigation Technology) uses NICER’s observations to test - for the first time in space - technology that uses pulsars to create a GPS-like system. This technology could support spacecraft navigation throughout the solar system, enabling deep-space exploration in the future. More background: <https://www.nasa.gov/feature/goddard/2017/nasa-continues-to-study-pulsars-50-years-after-their-chance-discovery> Read about five famous pulsars from the past 50 years: <https://nasa.tumblr.com/post/163637443034/five-famous-pulsars-from-the-past-50-years> We are: · Dr. Keith Gendreau – NICER Principal Investigator, NASA’s Goddard Space Flight Center · Dr. Zaven Arzoumanian – NICER Science Lead, NASA’s Goddard Space Flight Center · Dr. Craig Markwardt – NICER Calibration Lead & Neutron Star Scientist, NASA’s Goddard Space Flight Center · Dr. Luke Winteritz – SEXTANT Systems Architect, NASA’s Goddard Space Flight Center · Dr. Jason Mitchell – SEXTANT Project Manager, NASA’s Goddard Space Flight Center · Dr. Rita Sambruna – NICER Program Scientist, NASA Headquarters · Dr. Stefan Immler – NICER Deputy Program Scientist, NASA Headquarters · Dr. Slavko Bogdanov – Pulsar/Neutron star Scientist, Columbia University Communications Support: · Aries Keck – NASA’s Goddard Space Flight Center · Clare Skelly – NASA’s Goddard Space Flight Center · Claire Saravia – NASA’s Goddard Space Flight Center · Dr. Barb Mattson – NASA’s Goddard Space Flight Center · Sara Mitchell – NASA’s Goddard Space Flight Center Don’t forget to follow the NICER mission at www.nasa.gov/nicer and @NASAGoddard on Twitter and Facebook!

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Read about five famous pulsars from the past 50 years: <https://nasa.tumblr.com/post/163637443034/five-famous-pulsars-from-the-past-50-years>

We are:

- [Dr. Keith Gendreau](#) – NICER Principal Investigator, NASA's Goddard Space Flight Center
- [Dr. Zaven Arzoumanian](#) – NICER Science Lead, NASA's Goddard Space Flight Center
- [Dr. Craig Markwardt](#) – NICER Calibration Lead & Neutron Star Scientist, NASA's Goddard Space Flight Center
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What would happen if two or more pulsars collided?

[Brock1313](#)

This is a really good question. In most circumstances, there are not enough pulsars to literally collide head-on. However, if two pulsars are orbiting each other in a [binary pulsar system](#) then they will slowly inspiral due to emission of [gravitational waves](#). Eventually (billions of years) the pulsars will coalesce. It is thought that inspiral-based neutron star coalescence is one source of gamma-ray bursts (GRBs), which are the most powerful explosions in the universe. The explosion will be an immense conversion of nuclear-density matter (i.e. a giant gamma-ray explosion) and conversion into a into a black hole. (--Craig)

Are there any theories to guide you as to what you're looking for when observing the pulsars, or are you just starting from scratch? Also is there a difference in the elemental composition in a pulsar from a normal star?

[Merrine](#)

From its very beginning, NICER was formulated based on answering several key research science questions. These questions are motivated by both historical observations of pulsars and theories of pulsars. For example, theory makes predictions how how dense pulsars are, and also makes predictions for how the emission from the star escapes the system and arrives at the earth (hint: strong gravity and magnetic fields can distort and reprocess X-rays). Here is an example research paper on the topic (<https://arxiv.org/abs/astro-ph/0609325>). NICER will observe pulsars, measure the emission, and compare to the theoretical models to place constraints on how dense the pulsars are.

To your second question, pulsars (and neutron stars in general) are very different than normal stars. They are mostly made of neutrons, in what may be described as a single giant nucleus. They are supported from collapse into a black hole by the quantum pressure of degenerate neutrons. Yes! Quantum mechanics keeps stars from collapsing into black holes. (--Craig)

How exactly is SEXTANT testing XNAV technology in this mission? What observational parameters of pulsars are being used for this test?

Also, why is that NICER is chosen as a payload mission on ISS and not an individual standalone project?

And lastly, how many pulsars will be observed during this 18 months time period? Do you have any specific targets, based on what criteria?

[Imagine a name](#)

I'll answer your first question:

SEXTANT's primary goal is to provide the first demonstration of real-time, on-board X-ray pulsar navigation, by implementing a fully functional XNAV system in a challenging ISS/LEO orbit. This means that it will maintain an onboard estimate of the NICER/ISS orbit based only on the X-ray detection data from the NICER instrument (and an initial seed state), as it sequentially observes a series of pulsars. Our performance goal is to maintain 10 km orbit determination accuracy, over a period of 2 weeks, with a stretch goal of achieve 1 km accuracy. We have planned for two multi-week primary XNAV experiments where the SEXTANT team controls the observing schedule, we will conduct opportunistic on-orbit experiments while the NICER science team controls the schedule, and conduct ground experiments using NICER data, our ground software, and our unique SEXTANT XNAV lab testbed (XLT)---a hardware-in-the-loop testbed that can emulate the onboard signal environment that would be

seen by and X-ray detector like NICER in arbitrary orbit regimes or deep space trajectories. Secondary goals are to study XNAV in deep space trajectories, study the utility of pulsars for time keeping and clock synchronization, and expand the catalog of XNAV-worthy MSPs. To achieve the primary goal, SEXTANT has provided an XNAV "app" (we actually call it that) which runs in the NICER flight software. The app first filters the raw X-ray detection stream, which consists of a timestamp, energy estimate, and various flags, for each detected event, to try to discriminate X-ray source signal from background events (e.g., detections caused by high-energy charged particles) and improve the signal to noise ratio of the stream. It collects batches of filtered events from each observed pulsar, as they are observed sequentially, and once enough events have been collected for a particular pulsar, an estimate of the observed phase and frequency is made and passed to our navigation software to update an estimate of the instrument's state (position and velocity, and other optional parameters). The navigation software used by SEXTANT is an XNAV-updated version of the high-heritage Goddard Enhanced Onboard Navigation System (GEONS), which is an implementation of the extended Kalman filter algorithm with high-fidelity dynamics models and various measurement models, of course for SEXTANT, the measurement model of interest corresponds to the pulsar phase and frequency type. - Luke W

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I'll answer your second question: To achieve our science requirements, we did the following: 1) determined how much X-ray telescope we would need: what total collecting area, sensitivity, energy resolution, and timing resolution 2) looked at how to minimize the costs to NASA's Science Mission Directorate which was the primary stakeholder for NICER. Ultimately, this translates to minimizing costs to taxpayers. 3) considered what ISS has to offer: established infrastructure, defined interfaces. And found that we could build an instrument which has tremendous scientific capability at a low cost by leveraging the ISS. In the end, we built an instrument with an order of magnitude improvement in timing resolution, sensitivity, and energy resolution compared to the last major X-ray timing mission at a small fraction of its cost. -Keith G

What powers the pulsars? Stars are powered by fusion, but pulsars should be made mostly out of neutrons. Is it the leftover energy from the supernova that created them?

[Quacken8](#)

Great question. For the most part, pulsars only have the energy left over from the supernova that created them. They are hot, so they can radiate thermal X-ray emission, and they are often rotating quickly, so they can somehow radiate their rotational energy. (in this case, it would be somewhat like a dipole radiator). Once this energy is exhausted, it is believed that pulsars will turn off and become a cold and dark neutron star. There are strong suspicions that our galaxy is a "graveyard" of old neutron stars floating around.

That being said, there are exceptions. If a neutron star is orbiting a binary companion, that companion can donate matter (gas), which will come crashing down on the star. The star can glow so hot from this interaction, that it will glow in X-rays (millions of degrees). Also, eventually enough hydrogen gas can

collect on the surface of a neutron star that a short flash of fusion can occur (about 10 seconds), which converts the hydrogen to helium. This can go on for the life of the binary system, which may be billions of years. (--Craig)

What is the largest, and brightest, pulsar discovered to date?

[RupertPupkiin](#)

At present, we don't have any good measurements of pulsar sizes so we can't say what the largest pulsar known is. This is something NICER will attempt to determine for several nearby pulsars for the first time. The brightest pulsar discovered to date is [ULX-1 in the NGC 5907 galaxy](#). -Slavko B

What is the largest, and brightest, pulsar discovered to date?

[RupertPupkiin](#)

The most well-known pulsar is the [Crab Pulsar](#), and it is indeed very bright, in X-rays, radio and optical light. In fact, we use the Crab as a beacon to calibrate NICER's X-ray optics and detector systems. Pulsars are small in an astronomical context: they are the size of a city like New York City. But actually how big or small they are is an important science question NICER will seek to answer, but they do pack the whole mass of the sun in that small space. The nuclear physics at these extreme densities are not well known, and some theories predict the star will be a bit more "fluffy" (and thus bigger) and other theories predict they will be very compact (smaller). NICER will figure out which it is. (--Craig)

How regular is the rotation of a typical pulsar? I guess it needs to be fairly regular or at least predictably irregular to use for the GPS-alike experiment. follow up....is the regularity common across all known pulsars?

[BenMottram2016](#)

You are exactly right. To be useful for navigation (at least in the way we use them for SEXTANT) they need to be predictable, which is really what we mean by stable. The stability of known pulsars varies greatly. I'll leave it to the pulsar scientists to explain what makes some pulsars so stable and others less so, but a subset of the millisecond pulsars (MSPs) are indeed extremely stable, similar to the stability of the atomic clocks that stabilize the radio beacons from the GPS satellites. The most stable MSPs are predictable to a few microseconds over months or years which translates to a couple parts in 10^{14} if we assume, say $1\mu\text{s}$ in 1yr, which is in the realm of atomic clocks. So far, such stability measurements have been made with radio observations from ground-based telescopes, which are thought to be limited by dispersion effects (frequency dependent propagation speed variations caused by interstellar gas clouds, charged particles, etc). The X-rays signals that NICER detects are essentially immune to dispersion effects, and so NICER, being the most precise X-ray timing instrument ever put in orbit, will establish the stability of MSPs to greater precision than possible before. In fact, this is one of NICER's science goals.

-Luke W

Hi, you mentioned that pulsars generate an extremely strong magnetic field. I'd presume that such a field would have whole range of effects on "nearby" objects, like planets, comets, etc. Does a pulsar significantly alter the orbits/trajectories of such objects? And if so, would the extent/way in which the orbit is altered depend on the chemical composition of the object? (E.g. would the way in which the

orbit of a gas giant is altered depend on the composition of its atmosphere?) Sorry if these are silly questions, and thanks in advance!

[hermitofthenorth](#)

Thanks for these questions. The magnetic fields are not so strong that they alter objects in our solar system. However, if there is gas near the pulsar, the magnetic fields are strong enough to steer and channel the gas onto "hot spots" on the magnetic poles. While this type of gas can just come from the galactic neighborhood, it more likely come from a star that is orbiting with the pulsar. NICER uses theoretical predictions of hot spots to compare with the data to make constraints on the magnetic fields as well as gravity profile. (--Craig)

Two dumb questions, that I would like for the NASA nerds to answer(if they are not offended).

The question is will you guys ever be able to create a pulsar in a lab? You say a pulsar is a strong-magnetic field. So would you think an alien civilization uses pulsars to travel through space?

[toomanynames1998](#)

Pulsars and neutron stars are at the extremes of gravity (mass density) and magnetic fields that cannot be created in the laboratory, and probably will never be created anywhere on earth. In fact, be thankful that creating extremely strong gravitational or magnetic fields is so difficult, because they would be dangerous for your health and everyone else's health on the earth. We do not know much about whether there are alien civilizations, or how they could travel, but using pulsars would probably be difficult. I would like to point out that we simulate an X-ray emitting pulsar in the lab by having an X-ray emitter that is driven by a computer that has a database of X-ray pulse profiles. We use this to test our detectors and the SEXTANT processing algorithms. (--Craig) (--Craig)

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Regarding *lab pulsars*, While we cannot physically create neutron stars on Earth, we have created a table-top pulsar emulator that produces X-rays, which we call the XNAV Laboratory Testbed (XLT). The XLT drives a Modulated X-ray Source (MXS) that produces X-rays such that a detector on a bench top would think it is observing a prescribed pulsar target, and would even think it is moving on a trajectory, if so prescribed. (--Jason M.)

Quick question, who came up with the name?

[zenyattatron](#)

NASA's explorer program is very competitive. When there are calls for proposals, they are oversubscribed by a large factor and very often it takes multiple attempts to get selected. Each attempt is an improvement over the last. Years ago, we submitted "NICE" for Neutron Star Interior Composition Explorer. NICE was not selected that round and we improved the design for the next competition. "NICER" is the result. We did not think it would stick- but it did. -Keith G

Are slower spinning pulsars necessarily older/younger than faster spinning pulsars? Or does the spinning have less to do with age and more to do with the size/type of the original star?

[MikeCian](#)

Hi MikeCian, thanks for your question!

Generally speaking, pulsars gradually spin down if they're in isolation -- that is, if they're not interacting with other stars. That's because the energy they radiate away (in the form of light and particles) ultimately derives from their spin. So, yes, a slower-spinning pulsar is likely older than a faster-spinning one, but there are important exceptions. Certainly the size and magnetic field strength of the progenitor star has something to do with the spin rate when the pulsar is born (presumably in a supernova explosion), but there are also random events called "glitches" that cause a pulsar to temporarily speed up its spin before resuming the gradual slow-down. More dramatically, a "dead" pulsar can be spun up to super-high rates (thousands of revolutions per second) and brighten again by drawing matter from a companion star, in a process we call "accretion". The pulsar landscape is very rich, and part of the fun for us is to try to understand how spin rate, magnetic field strength, age, progenitor properties, and many other known and unknown characteristics, relate to each other and give us the collection of neutron stars and pulsars we see today. (--Zaven)

I'm starting college this month with the goal of studying astrophysics. Studies of this kind are right up my alley of interests. Do you have any tips for how I could end up in this line of work? How can I make the best of my education to get there? And finally are there any possibilities for internships in studies like these?

[Froguy1126](#)

Hello there! Astrophysics is a great subject to study and it requires knowing many topics - from physics to chemistry to biology. And lots of math! The best tip I can give you is to work HARD. Stay curious, and ask many questions to your professors, to forums like this one, to your colleagues. It is about discovering new things and it requires determination and focus, as things may get hard. As for internships, NASA offers various avenues through its summer internship program at Goddard (or other Centers). You can participate to any kind of project, from data analysis to model development to hardware. Being involved in a project is the best way to learn! NICER already has a program for interns with great success. Go to intern.nasa.gov for opportunities. - Rita S.

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[Froguy1126](#)

Hi! When it comes to possibilities for internships - check out this website: <https://intern.nasa.gov/> - Aries Keck

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[Froguy1126](#)

NICER has typically had 12-25 interns every summer and sometimes during the school year. Interns have made a big contribution to NICER in many ways. It is good for the project to get fresh views and it is good for the interns to get experience and learn. Some of our first interns now work on NICER. - Keith G

For NICER, what advantage does the array of 56 "smaller" x-ray concentrator optics provide vs having just a single "larger" one? Is each one "tuned" to look for something different?

[john_eric](#)

NICER has 56 "smaller" optics for several reasons. Having a bunch of smaller modules means that NICER as a system is tolerant to failure of one (or a few) modules. It's also less expensive to assemble and test small modules than it is to do precision alignment of a very large optic. NICER's optics are concentrator optics, meaning they do not form a full X-ray image at the focal plane, but that's OK because the detectors are single-pixel X-ray detectors. Each of the modules is meant to be identical but because of process variation, they all have their own slightly different performance characteristics. This is part of what we are doing with calibration; making sure that we understand and can quantify the performance variations. (--Craig)

Difference between a pulsar and a magnetar?

[Quacken8](#)

A pulsar is a kind of magnetar. Magnetar is a special kind of pulsar which has the observational signatures of having extremely high magnetic fields. A "normal" pulsar would have a magnetic field in the 10^{12} Gauss range (million million Gauss); a magnetar would have a field about 100 times that (10^4 Gauss = 100 million million Gauss). At that level of magnetic field, bizarre effects happen such as the [vacuum itself becomes polarized](#). Because of the strong magnetic field, magnetars tend to emit much of their rotation energy as electromagnetic energy (and related sub-atomic particles), and for this reason most magnetars we observe today are slow rotators. I.e. most of the rotational energy has been emitted away. (--Craig)

Can you compare a pulsar to a black hole in term of mass and size?

Which one appear to be more common? Which are the bigger/smaller on average?

Does a pulsar emit light? From the ray only or all of it's surface?

Does planet still orbit around a pulsar?

How does a pulsar is formed? (Like black hole? Massive red star into pulsar or BH ?)

[Zykingo](#)

Several questions. Black hole vs. neutron star mass. Generally speaking in an astronomical context, a neutron star is between about 1 and 2 solar masses, whereas a black hole can be larger. In a cosmological context, it is possible there could be microscopic black holes, but these are formed in the early universe, not by stellar processes. More common? This is an open question. There are probably many more neutron stars in our galaxy because the stellar evolution processes that produce them are more common. However, many neutron stars in our galaxy could be hidden if they cold and/or are not

near a source of matter that could "light up." Does a pulsar emit light? Optical light is possible. The Crab pulsar is well known to be an optical pulsar. Many pulsars are radio, X-ray or gamma-ray emitters. Does a planet still orbit around a pulsar? Yes, there have been claims about planets around pulsars. These are discovered because the planet disturbs the motion of the pulsar, and this can be detected by detailed timing measurements. How is a pulsar formed? It's too difficult to answer here in short form. Most pulsars are formed when a massive star evolves to supernova; the outer layers of the star is ejected in the supernova explosion, and the hot nuclear core of the star remains. If it is rapidly spinning, it will likely be a pulsar. (--Craig)

Thank you for doing this AMA!

What conditions are necessary for a pulsar to form? When in the process of stellar evolution would pulsars be?

[ColdS3](#)

It's difficult to answer such a question in such a short format. Massive stars, about 3-10 times our sun's mass, evolve much more quickly. The cores process nuclear material rapidly until they exhaust their nuclear fuel. In this case, it means that fusion occurs between Hydrogen and Hydrogen, Helium and Helium, Nitrogen, Oxygen, etc., until Iron is produced. Fusion of nuclei heavier than iron require energy *input* rather than producing energy output, so that is the end of the stable fusion sequence. Eventually enough mass of iron is produce in the center of the star, with too little nuclear fusion, that radiation pressure cannot support the core any longer, and collapse occurs. This is a supernova explosion. The central core of the star collapses, and the outer shells of the star is blown out, which forms the supernova remnant. The core becomes a neutron star, and if it is rapidly spinning, a pulsar. This is the approximate stellar evolutionary process; of course there are many details along the way that I skipped! (--Craig)

Will JWST be able to see pulsars and (if so) has anyone submitted proposals to use JWST to do any pulsar study?

[osxpert](#)

Yes, JWST will be able to see pulsars at other wavelengths, not X-rays like NICER. SO JWST will probe different aspects of neutron star physics and equally important. However, JWST is an all-purpose observatory which will have many different targets - while NICER focuses primarily on neutron stars. The proposal cycle for JWST will start soon and everybody can submit a proposal to observe their favorite source. Stay tuned! <https://jwst.nasa.gov> - Rita

From what I understand, our physics seems to "break down" when it gets to super extreme circumstances eg. first second after big bang. Can this be seen in super dense/hot materials in pulsars and equally extreme objects?

[Froguy1126](#)

Pulsars are at the extreme of both gravity and magnetic fields. We are not able to produce such high fields in our terrestrial laboratories, so we observe pulsars with X-ray observatories such as NICER. I would not say our understanding "breaks down," but rather there are a lot more uncertainties at the extremes, and that is why we seek innovative ways to make measurements to constrain the extremes. (--Craig)

First off thank you guys for your work. I'm currently studying to be an Astrogeologist, but pulsars are one of the coolest pieces of stellar physics in my opinion.

I sat in on a colloquium for gravity wave astronomers a few months ago and in passing they mentioned using pulsars to detect gravity waves using changes in the pulse timing. When do you think such applications for pulsars will be possible?

[cedderick](#)

Hi! Glad you asked. yes, pulsars can be used to detect gravitational waves from particular types of sources, merging supermassive black holes. There are already a few experiments going on: Pulsar Timing Array, Nanograv, European Pulsar Timing Array. -rita

A heavy mass spinning that fast and producing huge magnetic fields sounds intense, but also useful. Other people mentioned pulsars as ways to accelerate a spacecraft, but could there be other ways to harness the energy of these things? Large gravity, changing magnetic fields, rotation itself, and high quantities of light all sound like potential sources to me.

I guess my broader question is about the applicability of your findings. Of course having this knowledge itself is useful, but are there any specific applications your team dreams of?

Thank you for your work, and disseminating your knowledge to a large group of diverse people. It's great what you guys are doing.

[brownaj010](#)

It's more or less a science fiction question. And in fact, such a pulsar-generator was written about by the science fiction author, futurist and physicist name Robert L. Forward. The book is called "Dragon's Egg," and it's about humans who visit a neutron star and discover that life is living on the surface! (-- Craig)

Since pulsars are only detectable from a given point when their radiation beam is pointed toward that point, how would that impact using them as "lighthouse stars" for deep-space exploration? That is, if the pulsars you study are all detectable from earth, wouldn't they lose value as natural lighthouses once a spacecraft gets far enough away from earth that the angle to the pulsar no longer allows for detection of the radiation beam?

[thagr8gonzo](#)

You're correct, thagr8gonzo. Fortunately, we would have to be *very* far away for *all* of the pulsars of interest to be visibly poor enough to cause problem. There are many more challenges we will have to overcome before this will be an issue for exploration, particularly in our celestial area. Ultimately, a fully autonomous navigation system would be able to monitor and adjust performance to accommodate the motion of the spacecraft relative to the pulsars, and when pulsations were no longer visible from a specific target, the system would no longer schedule observations on that specific target until such time as pulsations could be detected again.

How far away would a pulsar have to be before NICER could no longer detect it?

[MikeCian](#)

The [brightest pulsar](#) observed at X-ray energies is situated in a distant galaxy 40-50 million light years away. NICER may discover even more distant ultra-luminous sources like this pulsar. -Slavko B

With the amount of pulsars that are currently being discovered, would it be possible for NICER to witness one collapsing into a black hole? If not, why not?

[MikeCian](#)

Most pulsars are expected to simply spin down and cool off. They don't become black holes. They will become too dim to be detected, and float through our galaxy as cold relics of past star formation. Some pulsars (or neutron stars) are in orbit around a companion, which can provide additional mass transfer. I.e. "feed" the neutron star with more matter. That can be enough to push a neutron star over the edge of stability and cause it to become a black hole. This happens on the stellar evolutionary time scale of hundreds of millions to billions of years. So, unfortunately, the occurrence is so rare that it is unlikely we will detect a pulsar transforming into a black hole. (--Craig)

Now that NICER is active, how much more can we learn about pulsars than we could before?

[MikeCian](#)

NICER provides an order of magnitude improvement in sensitivity, energy resolution, and timing resolution than the last major X-ray timing observatory. With NICER we expect to be able to predict the radius of a Neutron star to a precision of 5%- an order of magnitude improvement. This allows us to rule out or allow various models about the composition of the very cores of Neutron stars. -Keith G

Is there anything I could do to "listen" to pulsars at home?

And I mean like, point some collector/antenna at the sky where there is a known pulsar, and be able to find its frequency somewhere in the noise with Matlab or something?

I love reading about all this cutting edge science, but there's something immensely satisfying being able to do something even horrendously simple (in comparison) by myself.

[Vewy_nice](#)

Apparently, it can be done. These folks at RTL-SDR document folks who have tried and succeeded (<http://www.rtl-sdr.com/detecting-pulsars-rotating-neutron-stars-with-an-rtl-sdr/>). However, they had access to a 30 meter telescope, which is not common in peoples' back yards! At that link, they also estimate that it may be possible with smaller telescopes for the brightest pulsars. Our Deputy PI Zaven, who is in the room, mentions that at Greenbank there is an 8 meter radio telescope available for teachers to try pulsar searches, and that they have struggled to detect radio pulsars with this telescope. The issue is noise in the receiver; a cooled receiver will do better. And other issue is getting as wide a bandwidth as possible to maximize the amount of signal.

NICER detects X-rays, which are absorbed by our earth's atmosphere. That is why we need to fly our observatory in space to detect X-ray pulsars. (--Craig)

Hi Luke, I hope things are going well with NICER and SEXTANT. Do you know how well the GPS is performing? Also, do you have any sources for the GPS timing requirements for SEXTANT?

[viliamklein](#)

Hi William. Thanks, things are going great for NICER and SEXTANT. The GPS is performing very well. The top level requirement for NICER is to timestamp each photon is 100ns RMS to GPStime. For SEXTANT, we don't have a hard requirement, but have been saying timing knowledge of 1microsecond suffices, b/c the Pulsars aren't timed much better than that, i.e., the models don't predict much better than that...yet. -Luke W

Can a pulsar collapse all by itself into a black hole spontaneously just by eating? That is, not considering a merging of two pulsars.

[schmick](#)

Yes, this is known as accretion-based collapse of a neutron star into a black hole. Neutron stars are supported by the quantum pressure of degenerate neutrons. That is a mouthful! Degeneracy pressure is a powerful thing, but it is not limitless. If you pile enough matter onto a neutron star, the matter can overcome the degeneracy pressure and cause the star to collapse into a black hole. The source of this matter is almost always a companion star. In other words, two stars that formed together as a binary pair, and one went supernova to a neutron star, and the other stuck around to donate mass. (--Craig)

Given how XNAV still requires fairly exotic equipment, what advantages does it offer compared to traditional Apollo-style astronavigation via an, ahem, *sextant*?

[DDE93](#)

Hi DDE93. To the first part of your question, actually, there isn't anything exotic in the NICER detector system. In fact, the detector is based on an off-the-shelf detector made by Amptek. The only thing you may consider exotic, would be the effort required to make sure the hardware will work in space. There are a number of publications that describe NICER here (https://heasarc.gsfc.nasa.gov/docs/nicer/nicer_docs.html), specifically Gendreau, K.C., Arzoumanian, Z. et al. 2016, Proc. SPIE 9905, Space Telescopes and Instrumentation 2016 (22 July 2016) which covers the design and development.

For the second part, if you think about more modern astronavigation, or celestial navigation (CelNav), eg., via star tracker/camera, you are observing angles between bodies, and not time directly. Also, in the modern version, where you use solar system bodies as the bright targets, the ephemeris error/uncertainty grows as you go deeper into space, which reduces your accuracy. Since the pulsars are essentially *clocks*, they provide a direct measurement of time, since you can watch them tick. (-- Jason M)

A pulsar map was used on the pioneer plaque correct? Do you think this was the best option to use as a sort of gps for aliens to locate us?

[Froguy1126](#)

Yes, correct: when Carl Sagan, Frank Drake, and collaborators designed the Pioneer Plaque, they chose to mark the location of the Sun in our Galaxy by reference to 14 pulsars from among those that were known at the time. The map appears as a "starburst" pattern on the plaque, and it also was used for the follow-on Voyager Record. The Wikipedia page, https://en.wikipedia.org/wiki/Pioneer_plaque, has more details. Whether it was the "best option"... I think it may have been the only option! If any advanced civilization ever comes across these pulsar maps, they will have to do some work to decode the map, to work out which pulsars are being referenced and from where/when they were observed when the plaques were launched, but it should be a tractable problem. I can't think of any other

celestial phenomenon they could have used instead that is as precise, predictable, long-lived, individually identifiable -- and any other desirable characteristics of navigation beacons you'd care to name -- than pulsars. (--Zaven)

Do you expect to observe any star quakes?

[thesamprice](#)

There are such things as "star quakes" which are better known in a pulsar context as [pulsar glitches](#). This would be a sudden de-coupling between the rigid/brittle crust and the more fluid interior. Some pulsars are known to be more glitchy than others. (--Craig)

What is the difference between a pulsar and a magnetar? Is a magnetar just a specific type of pulsar with an abnormally strong magnetic field?

[JoeTheAverageSchmo](#)

Hi JoeTheAverageSchmo,

Craig already answered a similar question from Quacken8:

A pulsar is a kind of magnetar. Magnetar is a special kind of pulsar which has the observational signatures of having extremely high magnetic fields. A "normal" pulsar would have a magnetic field in the 10^{12} Gauss range (million million Gauss); a magnetar would have a field about 100 times that (10^{14} Gauss = 100 million million Gauss). At that level of magnetic field, bizarre effects happen such as the vacuum itself becomes polarized. Because of the strong magnetic field, magnetars tend to emit much of their rotation energy as electromagnetic energy (and related sub-atomic particles), and for this reason most magnetars we observe today are slow rotators. I.e. most of the rotational energy has been emitted away. (--Craig)

Would you be able to distinguish a pulsar/neutron star from a regular star if it was pointed at earth, its "radiation poles" were exactly on the axis of their spinning and it emitted visible/x-ray?

[Quacken8](#)

So-called aligned rotators would have a steady hot spot. If that were pointed at the earth, or anywhere else for that matter, there wouldn't be any pulsed emission, just steady emission. There are neutron stars which have remarkably steady emission, and they are consistent with being a warm, isolated neutron star (example: [RX J1856.5-3754](#)). (--Craig)

How does the core of a pulsar work? What does matter do at such extreme pressures? And does it change as the pulsar cools?

[Quacken8](#)

What happens at the core of a pulsar is an open scientific question. In all likelihood, the core is a superfluid. There are probably exotic states of matter there, such as [Kaon Condensation](#). There are some theories that the properties of the neutron star itself changes as it ages. For example, the magnetic field structure may change. (--Craig)