Science AMA Series: I'm Dr. Patrick McCarthy, interim president for the Giant Magellan Telescope. I'm leading the team building the world's largest telescope. AMA!

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Abstract

Hi Redditors, I'm Pat McCarthy, and I'm looking forward to talking about life as a working astronomer with you! A little about me: I'm best known for my work observing the formation of the earliest galaxies and my study of distant low frequency cosmic radio sources. In the late 1990s, my colleagues and I were among the first to explore the distant universe – galaxies and quasars more than halfway back towards the big bang! I joined the Carnegie Observatories as a Carnegie Fellow in 1988, after completing my PhD at the University of California at Berkeley. In 1991, I received the Hubble Fellowship, during the second year of its program and I joined the faculty at Carnegie in 1993. For more than a decade I worked at Carnegie in an office next to the one used by Einstein during his summer visits to Pasadena and just above Edwin Hubble's office. I was part of the team that developed the last, and most powerful instrument, to be deployed on the Hubble Space Telescope. This instrument has allowed us to see galaxies when the Universe was only 500 million years old! I am now working to support development of the next generation of giant telescopes on the ground, telescopes that Hubble could only dream of. Today, I lead the team of scientists and engineers building the Giant Magellan Telescope (GMT), an enormous instrument comprised of seven primary mirror segments—the seven largest mirrors ever made—that will stretch to more than 80 feet across once complete. The GMT will explore the cosmos to observe the first stars in the universe, offering images 10 times sharper than those coming from the Hubble Space Telescope. Since 2008, I've served as the head of the non-profit corporation, GMTO, that is charged with carrying out the development, construction and operation of the telescope and related facilities. My day-to-day responsibilities include ensuring that the telescope and its instruments will be able to address the key questions at the forefront of astrophysics in 2020 and beyond. Proof! Edit: 3:55pm EDT That's all, folks! I'm logging off now. I have had a great time chatting about the Giant Magellan Telescope as well as the state of astronomy. Thanks for all of the interesting and thought-provoking questions. Be sure to follow @GMTelescope and like Giant Magellan Telescope on Facebook to keep up-to-date on future developments. Until next time - Pat

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REDDIT

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DR_PATRICK_MCCARTHY R/SCIENCE

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Can you please compare and contrast the capabilities of the top telescopes in the world and explain what this telescope hopes to observe that the others cannot? Thank you very much for this ama, it is a very interesting topic.

work2improve

The power of a telescope is set by its aperture – the diameter of the primary mirror. Larger apertures collect more light (proportional to the square of the diameter) and they have better angular resolution due to the large number of independent waves of light that they sample. The largest optical and infrared telescopes in existence today are 8 to 10 meters in diameter. They have made remarkable

CITATION:
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contributions, but we are reaching the limits of what they can do.

Observing the most distant galaxies is one of the main drivers for large telescopes. Astronomers around the world, myself included, have made single observations of 100 hours or longer with the current largest telescopes staring at very faint galaxies trying to measure their redshifts. Our goal is to see galaxies as far back in time as possible - close to the big bang. In the previous century, Edwin Hubble and his colleagues at Mt. Wilson, using the then world's largest telescope, also spent 100 hours over many nights trying to measure the redshifts of the most distant galaxies. Like Hubble and his team, many of our observations have been frustrating simply because we cannot collect enough photons to get a good measurement. The GMT will provide us with a light collecting power that Hubble could only have dreamed about.

The other main forefront in astronomy now is the study of planets around nearby stars. In this case resolution, rather than sensitivity, is the limiting factor. Our ability to image planets separately from their stars is limited by the fundamental physics of light and optics. The GMT will provide a factor of three improvement in angular resolution over current telescopes and will allow us to image many more planetary systems.

Thank you for doing this AMA. I always wondered... Heads of big science projects... How do you convince the policy makers that write the cheques of the importance of this work? Politicians always want results in their term timespan, and tangible results while we're at it... "Don't we have that Hubble spacey thing already and how much more stars do we really need to see?"

Rxke2

Good question! Sometimes the process of getting the green light to start a project is harder than the engineering itself. In our field, we assemble a committee of eminent scientists from around the world every ten years to review the important questions and then make recommendations to government agencies regarding the top priorities. In the US this process is run by the National Research Council – an arm of the National Academy of Science. In 2000 they wrote a report that said that a 30 meter class telescope designed to study the early Universe and planets around other stars is the top priority for astronomy projects on the ground. These blue-ribbon panel reports help us make the case that society benefits by enabling curiosity-driven science that address questions of importance to us as a species – Where did we come from? How did it all begin? And ultimately, Are we alone?

Other than maintenance and cost, are there any physics based advantages to a ground telescope over an orbiting telescope?

etc_initd_yourmom

There are a number of advantages associated with ground based telescopes – one is that they are easier to get to! Space has some great attractions, but there are real challenges. In addition to the cost and maintenance issues that you mention, there is the problem of outdated technology. The time needed to develop and launch a space platform ensures that much of the technology is a generation or two behind by the time it reaches orbit. With ground-based facilities we can swap out detectors, electronics and most optical components to ensure that we have the most up-to-date technology.

As for physics-based advantages, one of the largest is that the telescope is sitting on a fixed and stable platform (the ground!) and you don't have to lift it into orbit. This frees one from the tight limits on mass and volume associated with launch and the power constraints that come from small solar panels used in orbit. Your tool kit on the ground is much larger.

It would seem that you are full of great questions today, /u/etc_initd_yourmom!

Hello!

Could you tell us a bit about the theoretical/practical limits of today's astrotelescopy? Is there, for instance, any chance that we might be able to take a reasonably detailed picture (i.e: not a dot) of some of the closer earth-like exoplanets we've found in the not-so-far future?

Is there any point where the solution to getting better images from space won't be to build an even bigger telescope?

Thank you for your time!

yoloswag1337pro

Thanks for the great question! I'll answer this one first since it has the most upvotes.

/u/danielranennest has delivered an excellent answer already, but I will elaborate more. He makes a good point that the size of a filled aperture needed to resolve an Earth-like planet is rather impractical!

The GMT will be able to make images that will allow us to see earth-like planets as separate from their central star, but they will just be a "dot" as you note. The best approach would be build an "interferometer" – an array of smaller telescopes that combined together to make an image equivalent to that from a single mirror as large as the spacing of the individual telescopes. Interferometers are currently being used to image the surfaces of stars, but they are not large enough, nor sensitive enough to resolved planetary disks around other stars. For this problem, a free-flying array of telescopes in space might be the best approach – but this is a tall order!

How should we, as concerned US scientists, deal with the anti-science rhetoric so prevalent in our political spectrum today?

etc_initd_yourmom

I believe that as citizens, as well as scientists, we should be conscious of the content and tenor of public discussions and rhetoric around scientific issues. It is important that we articulate the role of science in society while understanding that governments have many pressing priorities. It is worth reminding people, politely, that so much of our high-tech society sprang from scientific research, both in the 20th century and in more recent times. Much of this was sponsored by public organizations and national agencies (NASA, NIH, NSF, DOE…). Science has a great return on investment – but it takes time and the connections are not always easy to recognize. Our partners are mostly universities and they have a long-term view on the value of science and scholarship.

Serious question: Do you believe in aliens? Or quite simply life beyond Earth? Do you believe the telescope you are building might confirm their existence?

trollkien_devourer

I occasionally wonder – do aliens believe in us? Seriously, the question you pose – is there life beyond the Earth, is a surely the most profound question we face. The remarkable thing is that we can now approach this as a scientific question rather than a question of "belief". As /u/Jooshwa points out, the numbers are pretty staggering. I can't keep track of "Quadrillions" and the like, but we do know that the number of planets within the Hubble volume (the observable Universe) is on the order of 10^{22} – 10^{24} (10 raised to the 22nd or 24th power) – that is 10 followed by 23 zeros! One can then multiply this by the fraction of planets in the habitable zone (where water is liquid) and probability of life on any planet

to get an estimate of the number of planets with life, as discussed in the comments below.

What we hope to do with the GMT is to identify planets with chemical signatures of life in their atmospheres. I expect that this is our best approach to answering the life question in the coming decades. There are a number of molecules that are indicators of biological activity. oxygen is perhaps the best indicator, but there are others. Methane, in conjunction with oxygen is also a good indicator as they usually don't exist together. There is lots of methane on Jupiter, but little oxygen, and as far as we know, no life. The methane in the Earth's atmosphere comes mostly from large mammals (you know what I mean) and from decaying plant matter. Together with methane, oxygen is a good indicator of biological processes.

The great physicist Enrico Fermi once asked "where is everybody?" – meaning why haven't aliens visited us? Perhaps we can "smell them" - that is: find them from chemical signatures in their atmospheres. It would be a good start.

Hello!

Thank you for your contribution to astronomy. Question: What are these mirrors made of, that makes them so powerful?

voilavj

/u/danielraennest got it right! The glass that we use is made by the Ohara Corporation of Japan. It is a borosilicate glass with a very low, and very uniform, rate of thermal expansion. It takes 20 tons of glass to make one of our mirrors, so we will need 160 tons in the end to make the seven mirrors and the operating spare. That's a lot of glass. The mirrors are coated with a film of Aluminum that is only a few atoms thick. It is one of the strange aspects of telescope building that we build hundreds of tons of steel and glass to hold a few grams of Aluminum in just the right shape so we can collect the few photons that have travelled billions of years to reach our telescope!

Here is a link to an article and videos about how the mirrors are made!

My questions are: What are the first generation instruments that will be implemented on the GMT? And how far along are they in planning and construction?

Also: Which adaptive optics system are you planning to implement, and are you going a similar route than the E-ELT of making a prototype system that can be tested on a smaller telescope first? (Like the new 4 Lasers on UT3 in Paranal for example)

Also as someone in Europe I can't get around but notice: The collecting area of the GMT will be an equivalent of 22m. So the biggest Telescope currently under construction is the E-ELT from ESO with a primary collection area of 39 meters! As both are not finished it is kinda a bit overstated to name it the biggest telescope under construction, as it clearly is not.

ktv13

We are planning a number of instruments for the GMT during its first years of operation. Our first instrument is a precision high-resolution spectrograph that will allow us to study exoplanets and the chemistry of stars and intergalactic matter. Other instruments under development include a wide-field optical spectrograph, an adaptive-optics imager and spectrograph and a mid-Infrared spectrograph. The precision high-resolution spectrograph is in the detailed design phase having passed its earlier design reviews. The other instruments are in the preliminary design phase.

You can find more information about GMT's instrumentation here.

The adaptive optics system uses the same adaptive mirror technology as used on the Large Binocular Telescope, Magellan, and now being fielded on Europe's Very Large Telescope. Like the VLT, we will use a constellation of laser guide stars using technology developed in collaboration with ESO, the TMT, and the Keck Observatory. This will allow us to obtain high resolution images nearly anywhere on the sky.

Wow thanks for doing this ama. In my physics class last year we were talking about your project and analyzing it. My question is: The main problem in those very big mirrors is that they curve at the ends which results in a flaw in calculations/ observations. How will you take care of such an issue with the massive mirros you will put in place? Thanks!

TheBisBis

The mirrors do have a very curved shape, but we can manufacture them to the right shape with great accuracy – better than twenty nanometers, or one twentieth a wavelength of light. The challenge is keeping the mirror aligned and in focus in response to gravity and temperature variations that distort the shape of the mirrors. To do this we monitor the light from a star in real time and adjust the position and shape of the mirrors every 30 seconds. This technique is called 'Active Optics' (you might think of it as a fancy version of the autofocus on your digital camera), as opposed to 'Adaptive Optics'. The latter corrects distortions from the atmosphere.

What are you personally more excited to view/investigate with the telescope new capabilities?

that_motorcycle_guy

/u/osarusan has asked a very similar question, so I am going to answer you both here!

My personal interest is to find the first stars and galaxies in the universe – to see as close to the Big Bang as we can. We hope to understand the masses and chemical compositions of the first galaxies. This will help us better understand how the first stars formed and how massive supernovae seeded subsequent generations of star formation.

Do you own any small telescopes? If so, do you ever find yourself looking through the eyepiece?

I can't imagine the amount of man-hours that go into making such a monstrous telescope as the GMT... I've ground and polished a couple of telescope mirrors from scratch and the work is pretty extensive... But it is super interesting and rewarding, I feel like with a homemade telescope you no longer observe the stars, you commune with the cosmos...

I can only imagine what it will feel like for you when the GMT gets first light...

You will be like a Star God!

patanwilson

On a few occasions I have been able to look through the eyepiece of a small telescope in Chile - The 6.5 meter diameter Magellan telescope.

Seriously, looking through the eyepiece on the Magellan telescope is something I will never forget. The rings of Saturn looked awesome, it is as if you were there.

I look forward to the time when we have an eyepiece on the GMT!

Morning Dr. McCarthy,

I have 2 questions that have been puzzling me related to Astronomy, I hope you can answer them or point me to some information.

First Question: There is chatter on the internet about a huge but hidden object that is in an supposed elongated orbit around our Sun. It has various names, including " Niburu, The Ninth Planet, Plant X, " Are you aware of these stories? If so, could you clarify some of the rumors and un-truths about this object? Does it exist? what does NASA say about it? I heard it is on a 3,500 Year orbit and currently is out past Pluto but it is hidden behind the Sun. Possible?

Question 2: The Vatican operates a Telescope on Mount Graham, and the Lucifer device, which is a Large Binocular telescope that looks in the near Near-infrared spectrum, Are you aware of why the Vatican is so interested in Astronomy and what they are using this device for? What could they be watching for?

Thank you for taking the time out of your day to answer our questions.

My question is centered around

hightechhippie

Thank you for the questions! I am going to have our Observatory Scientist, Bob Goodrich, answer the first portion.

Question 1: Bob- "This is a real report. We have not been able to take a picture of this planet (yet!), but it was deduced from its gravitational effects on other objects in that same region of space. This is actually quite similar to how Neptune was discovered. Its gravitational influence on Uranus, which was discovered visually, led astronomers to predict its existence, and indeed it was later found with a telescope. One reason we have not seen this planet is its great distance from the Earth. With continued study of the other objects it influences gravitationally, astronomers can fine tune their predictions, and hopefully get images of the planet in the near future. Once found, the GMT using adaptive optics will be able to take high resolution images of this mysterious Planet 'X'."

Question 2: Pat- "The Vatican has a long history in astronomy. As you may recall they were involved in discussions with Galileo regarding his groundbreaking observations with the first astronomical telescope. For a long time now the Vatican Observatory has been a solid contributor to basic science and the questions that they are interested are well aligned with the global scientific community and its great to see them working at the observatory in Arizona as well as in Rome."

Hi there! What in your opinion is the most interesting object that can possibly be made observable by this new telescope?

AcrobaticPiano

One that no one has thought of! The goal of building the GMT is to discover new and unexpected phenomena in the universe.

How do you keep the large glass clean from dust?also what would be the first thing you would want to look at?

iamjibin

Good question! The mirrors are open to the sky during the night, and facing more or less upwards. So they will collect dust. We will clean the mirrors twice per week using a technique called "CO_2 snowing." This effectively removes most of the dust particles from the mirror surface. Once a year we will wash each mirror, and in alternate years we strip off the coating and apply a fresh layer of aluminum.

I answered your question about the early science here.

Hey, congratulations and great work, a slightly unrelated question: will this be able to take clear pictures of the equipment of the first moon landing and finally debunk conspiracy theories once and for all? Thanks and it's very exciting living in the high definition era of man!

HighPriestofAtheism

Even the GMT will not be able to take an image showing the shapes of the equipment left on the Moon. However, astronomers and space scientists have bounced a laser off the retroreflectors left on the Moon and seen the return light. These reflectors have been used to test fundamental theories of gravity, as well as to measure the slow recession of the Moon from the Earth.

How difficult is it to get a job working in the space industry and what kind of experience do people look for when hiring? As an undergrad and aspiring astrophysicist, I would like to know what I should do in my coming years to prepare.

Dexterbama

The most useful thing to do in the stage of your career is to seek out other astronomers and get involved in research while diligently studying physics.

If you wish to be an astronomer you need to study physics and mathematics and go to graduate school in astronomy or physics. There are, however, many pathways to a career in space-related industries. Observatories and telescope projects are always looking for qualified engineers, computer scientists, data analysts, and tech-savvy people with the desire to learn and make a difference.

While it is difficult to become a professional astronomer, nearly anyone with the passion and drive to succeed can do so. Even I managed to get a job in astronomy!

What do you think of the ongoing problems with the Thirty Meter Telescope's construction? If the TMT cannot be built, could GMT make up for the loss?

ckfinite

We wish our colleagues at the Thirty Meter Telescope the very best success.

You mean largest as in EELT and TIM? Why are you calling the GMT the largest?

accrama

There are three projects all aiming to be the next largest telescope in the world. We aspire to be the first on the sky at that point we will be the world's largest telescope. That's why we're calling this AMA the "Building the World's Largest Telescope."

Thank heavens for a real astrophysics AMA today, unlike a certain AMA yesterday!

What are the capabilities for studying the atmospheres of exoplanets? I guess you will not be using GMT for hunting exoplanets, that seems like a waste of time for a telescope like this compared to Kepler, which will probably be dead by then, and TESS?

Exoplanets are so fascinating, do you have a favourite exoplanet?

Thank you for your time!

Dalroc

Our Observatory Scientist, Bob Goodrich, has ventured a response on this one:

Studying exoplanets is a high priority for GMT. One aspect of that is studying their atmospheres. This is often done by taking spectra of the star, and watching as the exoplanet passes either in front of or behind the star. If it passes in front, the exoplanet's atmosphere absorbs light with some pattern. Subtracting the light of the star before the planet transits leaves the signature of the planet's atmosphere. Similar techniques are used when the planet passes behind the star (where the reflected planet's light disappears from the spectrum, and hence you get a reflected spectrum. These observations are difficult, and require careful techniques. The GMT instruments are designed to provide this capability, and the large GMT mirrors provide a lot of photons, another key requirement.

GMT will also be looking for planets using Doppler shift techniques. In particular, one of the goals is to be able to find Earth-like planets. Using transit techniques, Kepler has found thousands of exoplanets and in the future TESS will discover exoplanets orbiting very bright stars. The GMT will follow up a select set of these with complementary observations, particularly atmospheric studies. GMT will also be able to use adaptive optics to look for Jupiter-mass exoplanets which are just forming. Kepler and TESS were/are blind to these exoplanets.

What are some of the first things you'd like to point the telescope at? Can you put the level of detail of what we might see in laymen's terms?

osarusan

Thank you for the question! Please see my reply to you and/u/that_motorcycle_guy which is linked here.

How will the imagery from Magellan compare to that of the James Webb telescope also currently under development?

etc_initd_yourmom

The Webb telescope will have unprecedented sensitivity, particularly in the infrared. The angular resolution, however, is limited by the 6.5 meter diameter of the Webb. Using adaptive optics, the 25-meter diameter GMT will allow us to take images that are three times sharper than those from the Webb. Working together the GMT and JWST will make an extraordinarily powerful combination.

Since the universe is expanding from the point of the big bang would we be able to ascertain to a reasonable degree of certainty in what direction the big bang occurred? What happens to the initial point of the big bang after it exploded, does this point in space remain empty?

JellyMule

There are many textbooks that describe this issue, and it is a challenging one to visualize. It's better to think of the big bang as a time when all of space was in a single place, rather than a place where the universe began.

Hi Patrick, firstly I just want to say I hope you wake up each morning and think, man my job is cool, I am an awesome dude. Secondly what are your biggest hopes for the GMT?

paranoidsystems

Thanks /u/paranoidsystems, I do have an awesome job! My hope is that we discover something completely unexpected!

My municipality switched a large portion of our streetlights to LED bulbs. Bully for them for saving electricity except rather than taking down an n-lumen tungsten bulb and replacing it with an n-lumen LED, they've taken down an n-watt tungsten and replaced it with an n/4 bulb which puts out n*3 lumens. The environmentalists have convinced them that they've done a good thing.

How do we convince politicians that LED light pollution is simply removing one environmental harm and adding another?

roman_fyseek

Miguel Roth, former Director of Las Campanas Observatory in Chile and current member of GMTO's Chilean team, helped us with this answer.

LED streetlights can be very good for everyone, if used well. It's important not to over-illuminate, which is bad for many reasons including health effects, safety and light pollution. Amber LEDs with the right temperature and power output are environmentally friendly, astronomically friendly, and save everyone money.

There was a recent report that said 80% of US children had never seen the Milky Way. Light pollution is something that affects all of us, and the right LEDs can be part of the solution.

what should be the first telescope that a 8-10 year old should own ? when did you first get interested in astrophysics

chillax146

One that she/he will use. It is important that the young astronomer get their telescope out to a dark sky.

I got my first telescope on my 9th birthday, and have been hooked ever since! As it happens, the first object I pointed to turned out to be Saturn.

Will there be any way for a person from the public to get a chance to use it?

SeldonsHari

We will ensure that there's a way for anyone with a really great idea to propose to use the telescope. We hope that the public will be able to participate in observations with the GMT via the web, and visit the site during the day, if you happen to be in Chile.

What made you decide to become an astronomer?

Bajinto

As a fourth-grader I started reading astronomy books and got my first telescopes. That's when I decided that's what I wanted to do. I went through a period in high-school when I wanted to be a rock-star but I realized that wasn't going to work.

When I took high school physics that's when I was convinced I wanted to become an astronomer. A few teachers made an enormous difference in my life and so to all the teachers out there I say 'thank you.'