S. GEORGE DJORGOVSKI: And now let's move to high energies. This, by the way, is artist's concept of NuSTAR, which is a satellite observes gamma rays -- right now, circling overhead. And it's run out of this building, Fiona Harrison and her team. And it's studying phenomena that emit radiation high energies, like a creeping black holes and what have you.

The whole field started after World War II, with first rockets used to probe things. And so again, the surplus German V-2 rockets were used to do the first astronomy from space. And this particular experiment with the x-rate detector, they were hoping to detect x-rays from the moon, sun -- obviously. And the same time, they discovered first extra-solar x-ray sources. They didn't see the moon. And they also discovered presence of the uniform x-ray background on the sky, which we now know is due to bazillions of quasars and similar things. But that resulted in Nobel Prize for Riccardo Giacconi only 40 years later. But it's better late than never.

A large number of x-ray missions have been up there since then. Here's some of the more famous, or more important, ones. The one on top left is nicknamed Einstein. It was first really serious x-ray satellite that did x-ray maps of the sky and discovered all kinds of sources. Its successor in 1990s was ROSAT, or Rontgensatellit-- German obviously -- and that produced a much better x-ray survey of the sky.

And that was followed by one of NASA's great observatories, Chandra, which has essentially resolution like optical telescopes but in the x-rays. And also can take spectra in x-rays, which are almost like low-resolution spectra invisible light from the ground. And its counterpart from European Space Agency is called XMM-Newton, and you can see they kind of look the same. And this also kind of looks that way, and the reason is they have to have a long focal lengths. The long focal lengths are due to the fact that x-rays are really hard to focus. But it's possible, and it's done with so-called grazing incidence mirrors.

Now I think last week somebody asked good question or guessed the answer to my question. Why can't we focus gamma rays? We still can't focus gamma rays. For any material to work as a mirror, the spacing between crystal lattice elements -- atoms, right? -- has to be less than the wavelength of that radiation. And typically metallic crystals, whatever, it's on the order of angstroms. And so once you start getting to wavelengths that comparable to our angstrom or smaller, they're just going to go in between. This is why x-rays are used as x-rays. That's why they see through human body.

So you can trick x-rays by tilting your mirror in such a way so that in perspective, the spacing between individual atoms is much smaller than if you were looking at face up. And so then you can get reflection at a very oblique angle. So that means that you have to make parabolic mirrors that are really, really deep, because you are bouncing off those edges of the parabola. And because they're coming almost in parallel way, then you can nest whole bunch of mirrors together. And this is how they're done. This is set of mirrors for Chandra, which I believe are the most precise mirrors ever made for anything. Forget what precision it is.

So it's possible to focus x-rays, not so much for gamma rays. Gamma rays will go through everything, occasionally interact with something. And so our gamma ray telescopes are really gamma ray detectors. Detector itself captures gamma rays in some way, and you measure where it came from or something.

The kinds of detectors that are used in x-ray and gamma astronomy essentially all started as particle physics detectors. The first ones were proportional counters, which is just like a Geiger counter. We probably know how that works. There is almost vacuum tube with an anode and cathode. And say x-ray comes and knocks out an electron. So there is a net charge, which you can pick it up from the gas.

A slightly better nuclear physics detectors are scintillation crystals. Where there is interaction of a gamma ray with some material, that creates a little flash of light that you can pick up with sensitive photomultiplier tubes. But more modern ones are sort of like CCDs, only for x-rays and even some gamma rays. They're made out of strange metallic combination, like cadmium zinc telluride. And that thing there is the set of four of them in a focal plane of NuSTAR. So that's how they can actually take pictures, once you can at least focus it.

Another way to go about this is to use Earth's atmosphere as your detector. So you have a high-energy gamma ray hit some unfortunate atom in the upper atmosphere, splits it, gives it some momentum. You have moving charges, electron and rest of the ion. Then they knock out other atoms and ionize them and so on. And so they keep dividing the energy.

So from one high-energy gamma ray, you can generate a whole bunch of others. And at first, they all have so much momentum that they can move faster than speed of light in the air. And that creates Cherenkov radiation, which is like electromagnetic sonic boom. So you can see flashes of light from high-energy gamma rays in the sky, and pick them up. And that's done with big photon bracket mirrors like these.