

Question 1:

Dear Cheap Astronomy – What's a particle?

Probably the best answer is that particles are those things detected by particle detectors. Unfortunately this can range from dust detected by atmospheric particle detectors to those things detected within the large hadron collider – which are a special category of those things that particle accelerators accelerate and particle colliders collide.

Most definitions of particles attribute them a material nature and they are sometimes, but not always, small composite parts of a larger whole. Thus sub-atomic particles like quarks comprise the nucleons of an atom – and atoms then comprise lots of things we are familiar with in the macro world. It gets trickier if you want to include photons in the definition, since they are clearly not matter even though they can push a solar sail. So you might call them massless particles with momentum – and let's remember they have wave-particle duality, so they can be both waves or particles, although you might equally argue they are neither waves nor particles, but different things altogether that exhibit characteristics of both waves and particles. But then it gets even trickier since quantum physicists will argue that electrons can also have wave particle duality. Indeed if you ask a quantum physicist what a particle is you'll be told a particle is a collapsed wave function, where a particle's existence is calculated as a probability wave, meaning it could be here or there or nowhere – but as soon as you introduce a particle detector that probability wave collapses and you find a particle with a real physical presence and location.

An overarching consideration here is to acknowledge that English language semantics allows a speck of dust to be a particle as much as a vastly smaller atom can be a particle. If we do just focus on the realm of sub-atomic physics, we can identify particles which have no underlying components – sometimes called elemental or fundamental particles. Examples are electrons and quarks which are generally considered point-particles with no apparent size or volume, in which case the word small becomes redundant. In our mathematical modelling of what the real world may be like, they are just considered points of quantity in a coordinate field – where a particle's mass is a coordinate in the Higgs field and its charge is a coordinate in the electromagnetic field for example

Mind you we've previously assumed that atoms were the irreducibly-small components of all things in our larger macro world, but we know now that an atom is quite large and has a complex internal structure composed of many smaller components. We know this from particle collider experiments, where we fling charged nuclei around a magnetized path and get them to collide with each other. So, by definition we collide particles to identify the smaller particles that those bigger particles are composed of. Indeed, this relationship is captured in the particle physics lexicon – there are composite particles, like protons which are composed of elemental particles, like quarks and electrons. Any list of particles include bosons and hence include photons as well, though most written definitions of particles tend to step around photons, preferring to imply particles are mostly the components of matter

So really, what is a particle? One could reasonably conclude that a particle is whatever we decide to call a particle, an all-encompassing definition can't really be nailed down. And even in the narrow frame of sub-atomic physics, there's some uncertainty of what is and isn't a particle, notwithstanding uncertainty is a defining characteristic of most things that are considered particles. On the bright side, they are lots of things that definitely aren't particles and bricks even though they are small chunks of matter that form components of much bigger things. And if something looks like a duck and quacks like a duck, then it's probably not a particle – it's a duck.

Question 2:

Dear Cheap Astronomy – What sort of Astronomy is done on the ISS

Conducting astronomy from a moving platform has its challenges. Of course the Earth itself is a moving platform, both rotating on its axis and also orbiting the Sun – but those motions are relatively slow. You can set a cheap backyard telescope, like our own Sky Station 1, still-operational after all these years, and keep observing Saturn – just shifting the scope every now and again to keep it in view. Things get a bit more challenging at higher magnifications, since things move out of view that much faster, so you have to get calibrated motor drives to stay locked on things. So staying locked on anything as you orbit the Earth nineteen times a day is certainly going to be challenging.

Of course the Hubble Space Telescope orbits the Earth 15 times a day, but its entire design is built around the need to stay locked on a target for up to 24 hours if need be thanks to Hubble's pointing control system, composed of reaction wheels and magnetic torquers. The standard line is that if the telescope were in Los Angeles, it could hold a beam of light on a dime in San Francisco which for the non-US folk is more or less Canberra to Melbourne or say Paris to Munich. You can't do this with the ISS since there's moving parts, people walking around, spaceships docking, the occasional engine fire to maintain orbit – all which would cause a lot of wobble. But you can still do astronomy in other wavelengths, as well as monitoring for particles, where your goal is mostly just detection and the measurement of energy levels rather than achieving long exposure times.

Nonetheless, the neutron star interior composition explorer, which NASA somehow acronimble into NICER, scans the sky for x-ray emissions – first using the GPS satellite network to accurately time the position and location of an X-Ray source – and once the x-ray source is identified NICER can lock onto that point in the sky using a star tracker for alignment of the detector unit which can be moved around with a gimbal system. It generally scans 3 or four targets per orbit this way, steadily building up a database on each source with each pass.

The Monitor of All-sky X-ray Image (MAXI) is a JAXA (Japanese Space Agency) instrument which uses a different approach – conducting an ongoing survey of almost the entire sky as the ISS orbits the Earth every ninety six minutes in its laterally-shifting orbit. X-ray sources such as x-ray pulsars and accreting black holes are often transient – meaning they are easily missed if we aren't continuously scanning the sky for them. MAXI and NICER tend to work in tandem to maximize data gathering on pulsars and black holes.

Another JAXA instrument is CALET the Calorimetric Electron Telescope, which is mostly a particle detector for cosmic rays – which are high energy electrons, protons and heavier nuclei – although it also detects gamma rays. It's objectives are to better understand cosmic rays and their sources, as well as to find evidence for dark matter – something it is still trying to do.

And then there's the AMS, the Alpha Magnetic Spectrometer which is a CERN instrument – yes those same folk that brought you the Large Hadron Collider also have a space instrument. The AMS detects cosmic rays and can also detect antimatter - has found a remarkable number of positrons in cosmic rays. This has raised lots of speculation about the antimatter being the product of dark matter annihilation. But as we've discussed previously on this podcast the concept of dark matter annihilation seems like grasping at straws a bit. There's certainly a hefty weight of circumstantial evidence for dark matter existence – in the rotation of galaxies, and gravitation lensing including the oft-cited example of the bullet cluster. But it's invisible, transparent and only interacts with other things via gravitation – making it frustratingly difficult to observe directly. So by speculating that dark matter particles might annihilate with themselves, we at least get something to look for.

Current candidates for dark matter annihilation candidates range from positrons to stranglets and to axions, which are themselves largely hypothetical particles. Dark matter theorists don't seem to spend as much time considering why dark matter might annihilate with itself in the first place, which does seem odd behavior for particles which otherwise represents around 85% of all matter in the Universe. You'd think that all that self-annihilation would start reducing its numbers somewhat. But anyway, this is how science works. We start with a few wild ideas, steadily debunk most of them and then see what's left.

So, as always, it's best just to watch this space, something we can readily fdo from the International Space Station.