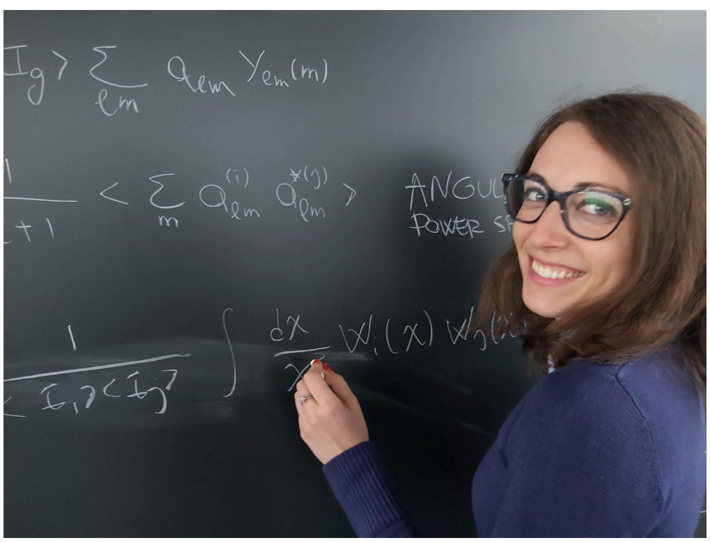
Sifting Junk for Dark Matter

Elena Pinetti searches for dark matter using JWST calibration images that other researchers discard.

By **Katherine Wright**

For as long as she can remember, Elena Pinetti, a dark matter hunter at the Flatiron Institute's Center for Computational Astrophysics, wanted to be a scientist. In high school she fell in love with Maxwell's equations and the fact that all of electromagnetism could be described by only four laws. "It is just beautiful to see that four equations can explain so many phenomena," she says. "It made me want to be a theoretical physicist."

Pinetti's first foray into theoretical physics was as an undergraduate working on a project that looked at the gravitational waves emitted by pulsars—which she completed mere months before the first gravitational waves were experimentally detected. "It was amazing," she says. "It was such a great start to my career." From there, Pinetti took an internship in a group studying dark matter, a topic she doesn't expect to stop working on. *Physics Magazine* caught up with Pinetti to find out more about her work and about why searching for dark matter gives her such a buzz.



Credit: E. Pinetti/Flatiron Institute

All interviews are edited for brevity and clarity.

What kind of dark matter particles do you search for?

All of them—I don't have a favorite. My approach is to look at what instruments are available and then to see what I can do with those instruments. So, I've worked on searches for many dark matter candidates—WIMPS, axions, sterile neutrinos, sub-giga-electron-volt dark matter. Until we find dark matter, I think we should look everywhere and for as many candidates for dark matter as we can.

Do you think there is just one kind of dark matter particle, or will scientists end up finding many?

Most likely there will be a standard model of dark matter particles. If you consider just the matter in the Universe—ignore the energy—only 20% is normal matter. To explain that matter we have 17 fundamental particles. Dark matter makes up 80% of matter, so most likely we will need a huge number of dark matter particles to explain it.

If there is a plethora of dark matter particles out there, why do you think none have been found yet?

We didn't discover every particle in the standard model of particle physics at the same time. It took millennia to go from finding materials, like iron, to uncovering atoms and then electrons and protons. For a long time, we thought that protons were the basic particles, until we discovered protons are made up of quarks. We just need to find one type of dark matter particle and then keep going.

You recently used data from the JWST to search for

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axions. Can you tell us about that?
I did a pilot study (see **Viewpoint: Detecting Axion-Like Dark Matter with the JWST**), and I've recently done a **bigger study** that used over 15,000 JWST spectra to look for an axion signal. Axions are some of the best motivated dark matter candidates, as they solve not only the dark matter problem but an outstanding puzzle in particle physics known as the strong *CP* problem (see **Viewpoint: Homing in on Axions?**)

When searching for dark matter, the first thing you must decide is where in the Universe to look. Popular places to look are the Galactic Center or galaxy clusters. The reason for that popularity is that these are places that we expect should contain a lot of dark matter. The problem is that these places also contain a lot of astrophysical sources of light, like stars and gas clouds. That makes the signals from them very messy, and it's hard to definitively say "this signal is from a dark matter particle" and not from something else.

With the JWST data I do something completely different, which is look at so-called blank-sky images. Every time an astronomer observes their favorite galaxy, they also observe the neighboring sky that is "empty"—a blank-sky measurement. The reason they do that is that to understand how much light is coming from the target galaxy, they need to subtract the local background light. But blank-sky measurements also contain information and are captured in places where there should be a lot of dark matter and little astrophysical emission covering it up.

JWST has captured an enormous amount of data. How do you decide which of it to use?
I can use every single observation from the JWST, as they all include blank-sky measurements. Astronomers think of these observations as uninteresting background, but for dark matter searches it is gold.

In the pilot study, I looked for signals in the blank-sky fields next to one galaxy. I showed that blank-sky images could be used for dark matter searches and that even with a short amount of observing time my method was competitive with other dark matter search methods. Now I'm using a huge number of spectra, and I have already improved the bounds on the masses of quantum chromodynamics axions and axion-like particles by over 2 orders of magnitude. The more time I wait, the more blank-sky observations there will be, and the more my results will naturally improve.

Dark matter is inherently dark. What signal are you searching for in the JWST data?
Dark matter is very dark, but it doesn't have to be completely dark. There are models that predict that axions should decay into photons. This decay is highly suppressed, which is why we haven't seen it yet. It is this light that I am searching for. I am focused on axions with masses of a few electron volts, because this mass range is still unconstrained—no other experiment can currently reach that mass window. The light from the decay of such axions is in the infrared and optical range, which is why it makes sense to use the JWST, which has amazing resolution at these frequencies.

So far, all dark matter searches have turned up empty. What keeps you motivated in your search?
Being a scientist is really like being a detective. You know there's a mystery that needs to be solved, and it won't be easy, otherwise someone would have already solved it. So, we keep looking and we keep digging until we find something. The day that we do discover dark matter—and I believe we will—it will be the discovery of the century. Being able to make that discovery will have been worth all the effort.

Katherine Wright is the Deputy Editor of ***Physics Magazine.***