Student questions: Danny Jacobs' colloquium on "New Horizons in Experimental Astrophysics: Exoplanets and the Cosmic Dawn"

9/14/16

Question 1: What are you looking for in the atmospheres of the planets orbiting red dwarfs? If you're looking for signs of life, then wouldn't the constant flares coming from the red dwarf severely hamper attempts of life to gain a foothold on the exoplanet?
A: We're looking for molecules, like Water and Ammonia, that tend to be created in life processes. The effect of flares on life are currently a hotly debated topic! They might help too, we just don't have enough data to say yet.

Question 2: How did the science team in charge of finding a site for HERA make their decision? Did they need to navigate regulations and hurdles to install expensive and intrusive structures in the desert?
A: We decided to put HERA in the South African desert because very few people live there and the government has passed laws to restrict radio emissions near the telescope. A quiet spectrum is a rare and precious thing!

Question 1: How did you and your team decide on making x amount of HERA hexagonal dishes? Why is that the goal amount rather than a few more or say a few less? Is there a certain number of dishes needed to get a clear image of space?
A: Theory says that the instrument will be most sensitive if the dishes are packed closely. Face-centered packing gets the dishes as close as possible to each each other. If you play with this long enough you see that its got a hexagonal symmetry, so it made sense to use that shape on the edge. We'll need 250 dishes to get the image we want.

Question 2: Why do we need HERA and the James Webb Space Telescope, if they are both imaging basically the same thing what makes HERA or James Webb necessary in activity with the other? Will the data collected from the combination of the two give a better image and story of what happened in the first billion years, or will they provide essentially the same information?
A: JWST finds galaxies, HERA images the space around the galaxies. If we put them together we get a complete picture of both the large and small scales.

Question 1: What causes these massive flares from M-stars?
A: M-dwarfs are highly convective, which means they boil like a pot of water. This motion generates magnetic fields much larger than our Sun. When they snap and pop we get flares.

Question 2: What to you expect (or hope to learn) from the data collected by HERA and JWST?
A: We hope to find out why the first stars formed and when that happened.

Question 1: Why construct HERA out of wood?
A: HERA uses wood telephone poles and 2x4s in a few other places. This is done to keep the cost under budget. We only need the wood to meet a tolerance of 3-5 inches averaged across the array.

Question 2: Why do red dwarfs flare so frequently?
A: M-dwarfs convect, churn, much more strongly than our Sun. This generates large and unstable magnetic fields. When fields snap they make flares.

Question 1: Do you lose any information by budgeting and making a lesser quality array, even though there are more of them?
A: Good question! We do lose information. We lose both resolution and sensitivity. If we had a larger array we could see smaller details, and if we could steer the dishes we could cover more sky.

Question 2: How do astronomers tell the age of the whole universe if we're bound by light emitted 13.8 billion years ago?
A: Because as we look back, we see things get smaller and hotter. Extrapolating back with relativity, we can see that things would be infinitly small 13.8 billion years ago.

Question 1: How much does it cost to make SPARCS?
A: We've budgeted about 5M dollars.

Question 2: Do the target red dwarfs for SPARCS have planets/planetary systems and is this a criteria to be a target for SPARCS?
A: Two of them are known to have planets. We have to keep the solar array pointing at the sun so SPARCS can only look at a fairly narrow slice of the sky at a time. We picked known Mdwarfs in this range that spanned the typical age range. That way when we look at stars with planets we'll know something about each different age.

Question 1: How is the sun-synchronous orbit of SPARCS maintained? It seemed like there was currently a lot of flexibility in the orbit of the cubesat, which must mean that there was a similar amount of control available to the cubesat.
A: The orbit is a neat trick! Due to the Earth's pear-like shape one can make an orbit that slowly precesses, meaning it passes overhead every orbit at a slightly different time. Do it at the right altitude and you can make one that orbits over the terminator and always sees the sun.

Question 2: What is the process for calibrating and correlating the HERA data bunker?
A: This is a big question! In the field the voltage of the antenna is measured by a voltmeter and converted into a digital number very fast. These numbers are then sent back through the big optical fiber to the data bunker. There a very large computer multiplies every antenna by every other antenna. This means that if there are N antennas, you get N^2 multiplications. This is a lot of data! The output of this process then goes to the calibrator system which uses the fact that many of the measurements are expected to look alike and uses a system of linear algebra equations to find a solution to enforce that assumption. The output is correlated and calibrated data!

Question 1: If the HERA installation can't slew to manually change where it points in the sky and must instead rely on the Earth's rotation and orbit, how do you overcome the limitation of getting data from only a small section of the sky?
A: The signal we're looking for comes from the Hydrogen created in the Big Bang, so it is visible in any direction. It doesn't matter where we look!

Question 2: Where should an amateur start if they want to build their own small radio telescope array, like PAPER?
A: Build yourself a Very Small Radio Telescope (VSRT) which you can make from an old satellite dish and cheap parts from the internet. Google it! Or better yet, ask Judd Bowman for parts ;)

Question 1: Why do the red dwarf stars tend to have more stellar flare activity than the G type stars like our Sun?
A: They convect more. See answer above.

Question 2: In the PAPER array, how come some of the gaps between the rows were larger than the others? I thought that they would be all pretty close to each other to try and maximize the amount of photons collected.
A: Good question! The spacing sets the resolution, wider spacing gives you finer resolution. We tuned the spacing to give a resolution of about 1 degree which matches the size we think the voids might be.

Question 1: What power source will be used for the PAPER and HERA arrays, given their remoteness?
A: We ran power lines 70km out from the nearest town. Also there are four huge backup dynamos which run on deisel.

Question 2: If UV dissociation from flares causes the formation of ozone, shouldn't its effects on planetary atmospheric composition be self-limiting?
A: Not sure what you mean by self-limiting. The problem isn't necessarily that the flares drive the atmosphere, but that the flare-generated ozone could mask the ozone caused by bio-generated O2.

Question 1: Concering HERA, will decreasing the size of the collecting dishes and increasing their numbers create a higher sample collection, or is it unnecessary?
A: Yes! Data volume increases with the square of the number of antennas. We've tuned the size of the dish to give us the optimal sensitivity at the size scales we're after.

Question 2: Will HERA only be concerned with the expansion of the universe or will it be studying other things in the universe?
A: In addition to the cosmological signal we're also looking for exoplanet aurora emissions, SETI, and other things which go blip.

Question 1: What level of sensitivity is required to detect the 21-cm signal from the Epoch of Reionization?
A: We think we need about 1000 hours of time, which will take about two years of observing to get.

Question 1: For the SPARCS project, how will the launch and entering orbit process work? Will there be a launch specifically designated for deployment of the cubesats or will a rocket typically have multiple payloads for different missions?
A: We'd most likely be a secondary. They'd eject us once the primary was safely deployed and far away.

Question 2: You mentioned there would be overlap between the JWST and HERA when they are both operational. Have you already communicated with the JWST team and will you be coordinating efforts into exploration into the early universe?
A: Yes, there are also team members who work in both areas.

Question 1: How can we tell that the planet around Alpha Cen is rocky?
A: From the shape of the transit light curve we get the size of the planet and from the speed we get the orbit and from the orbit the mass. With the mass and size, we know the density!

Question 2: How do solar flares affect a habitable-zone planet's environment?
A: We aren't sure! The biggest problem for us in the short term is that they make it very hard to detect life in the atmospheric gasses. Presumably they also affect life, but we'll need a lot more data to find out how.

Question 1: How long will SPARCS be in space? Will it come back to Earth or stay in space?
A: SPARCS will be about 800km above the Earth for one year. In that time we'll observe ~20 stars. SPARCS will stay in space for a few years and then eventually de-orbit.

Question 1: How much did it cost to build the HERRA ?
A: About $20M.

Question 2: What are the conditions required to set up the satellite/telescope in isolated areas ?
A: Power internet and no radio interference! (cell phones, TV, FM, etc)

Question 1: Is there any motivation why the shape of HERA telescope to be a hexagon?
A: See answer above

Question 2: Regarding SPARCS and the observation of red dwarf stars, how would the binary systems of red dwarf stars affect our detection possibility for identifying exoplanets?
A: Good question, I don't know! We generally don't look for planets in binary systems because its hard.

Question 1: Could you elaborate more on the specifics of how you use the drone to calibrate the radio telescopes?
A: for more check our latest paper, https://arxiv.org/abs/1610.02607

Question 2: For the SPARCS mission, what is the lifespan of the Cubesat and camera? You talked about one rotation (one year) span but I would like to know how long the cubesat will last.
A: We'll build everything to last two or three years. All that matters is it lasts 1 year, but its sometimes hard to predict how long it will actually last.

Question 1: In your talk, you mentioned that the Earth has been around for roughly 1/3 the span of the universe, which is a significant amount of time. In your opinion, assuming life exists elsewhere, do you believe Earth life is one of the first?
A: Once life got started, it moved pretty quickly. Our galaxy was around a long time before life formed here, so its likely we weren't the first.

Question 2: Couldn't you double the space in between individual telescopes to increase the resolution?
A: Yes! But the features we've tuned the size of the dishes and the spacing to exactly match the spatial scales of the bubbles and islands that we're hoping to detect.

Question 1: Why are solar flares only visible in the ultraviolet spectrum?
A: I don't know! I do know that the the region above the surface of the sun is about a million degrees (much hotter than the actual surface). If something is a million degrees it will glow brightest in the UV.

Question 2: How much will HERA be able to "see" compared to the VLA?
A: It will be able to see further back in time but it will not have the resolution the VLA does.

Question 1: Given the extreme remoteness and low population density in the Karoo desert, is it necessary to reach out to local (or seasonal, or nomadic) populations to explain the facility and research? If so, how is this being done?
A: This is an interesting question. The SKA (which operates the site) does do outreach to locals. At the Australian site theres been a good connection to the Aboriginal people who let us build the MWA.

Question 2: Given that red dwarfs flare frequently, is it conceivable that advanced life could inhabit them? Our society would be crippled by a Carrington event, which makes it hard to imagine technologically advanced species developing on, inhabiting, or using as way stations planets around frequently flaring stars.
A: Unknown and hotly debated! Perhaps flares could be used profitably some way. Life finds a way.

Question 1: Why does the SPARCS cube sat have two antennas for uplink and downlink? Can't one use a duplex antenna and save space on the cubesat?
A: Space isn't really the issue. The two antennas work at very different bands, and are optimized.

Question 2: How is the internal reflection taken care of with the HERA dishes? Considering this is a very sensitive measuement.
A: This is actually probably the single most important thing we're currently working on. Reflections introduce spectral ripple which can interfere with the spectral line cosmological signal. We're currently studying the finer points of the feed and doing lots of simulations to make sure we get this right.

Question 1: What is it about red dwarfs that make them such a good/popular candidate for having planets in orbit around them?
A: Same reason Willie Sutton gave for robbing banks, "Cause that's where the money is!". Red dwarfs are the most common kind of star, and they tend to have planets at the rate of one in four to one in two. Theres lots of theories for why this might be.

Question 2: Why would you build such a small telescope into a cubesat, and then expect it to accomplish such an important task? Wouldn't you want to use a bigger telescope for seeing further?
A: The key isn't the size, it's the amount of time above the atmosphere. No other telescope on the planet or in orbit can give us a dedicated year of time!

Question 1: You had mentioned in one of your graphs, where there was a "dotted black line" that indicated the required data needed to be collected on each star/exoplanet system to determine the composition of the atmosphere. Is this a goal that is set in order to justify a more reliable average in regards to spectroscopy or is there another reason for this goal for each exoplanet/star system?
A: Flares tend to happen on the same time scale as the star's spin period; if we measure a complete rotation we probably have seen everything there is to see. That line indicates a full rotation for each star, which we would get with about a month on each star.

Question 2: In the 3d video, there were areas in the observable universe that were void of the hydrogen (21cm wavelength). What could be some of the reasons for these areas?
A: This is exactly what we want to see. The voids are caused by light from stars causing the hydrogen to evaporate. We want to see when this happened.

Question 1: Is there an astronomical reason that so many of the new telescopes, radio or optical, are being built in the southern hemisphere instead of the northern?
A: Not really. The best optical and high frequency radio sites require altitude and are in Chile and La Palma, Spain. The best radio sites require remoteness. Its interesting that both are in the south!

Question 2: What agency will be launching the SPARCS and how much will this cost?
A: SPARCS is a proposed NASA mission and will cost ~$5M.