Student questions: Greg Taylor colloquium on "Science at Low Frequencies with the Long Wavelength Array"

3/29/17

Question 1: What is the Jy? and what exactly are the units?

1 Jansky = 10^{-23} Watts s^{-1} cm^{-2} Hz^{-1} It is a unit of flux density and describes the brightness of a radio source. A moderately bright source has a flux density of 1 Jy at 1 GHz.

Question 2: What future projects does LWA1 have planned?

Detecting exoplanets and measuring their magnetic fields.

Question 1: Are there other (possibly more prime) locations for the construction of such a product?

Sure, everybody should have an LWA station. Then the more of them there are the greater the scientific capability will be.

Question 2: What are the major sources of radio waves you are looking for?

Planets, Stars, Pulsars, Active Galaxies, Supernovae

Question 1: How do your analysis techniques distinguish between anomalies and a new discovery?

In order to qualify as a discovery we make sure that we get repeated detections and also understand the properties of the object detected in terms of its spectrum and temporal behavior. We also make sure that it moves with the sky and is not fixed in azimuth and elevation as one would expect for a terrestrial emitter.

Question 2: How has interference from other radio waves and other wavelengths near earths orbit affected your study?

Interference typically only affects about 2% of the observing so it really hasn't been a problem for us outside of a couple of specfic occasions when we had to mitigate some local power line noise.

Question 1: Does the location matter as far as where you choose to place your array, for example, would you yeild better results at higher elevations and sunnier locations?

Any flat (or evenly sloped) land, away from population centers should work.

Question 2: Speaking of giant solar flare, if the other planets happened to be directly aligned with Earth when this happens, would they take the blunt of the blow?

Mercury and Venus have little or no magnetic fields so they wouldn't interact with the Coronal mass ejection. So no help there.

Question 1: What unit is a Jansky?

See above

Question 2: You mentioned that Jupiter 's radiation does damage to Juno when it comes to close, what exactly does it do to Juno?

The high energy particles in Jupiter's radiation belts degrade the electronics onboard Juno. Eventually Juno will be crashed into Jupiter so as not to contaminate any of the moons like Europa.

Question 1: In relation to exoplanets, why the number of arrays (stations) planned?

Every station added increases the sensitivity and imaging capabilities of the LWA which grows in proportion to N^2, where N is the number of stations.

Question 2: For clarification, the study of Jupiter using the stations would maybe hint at Io euptions, among others, correct?

Yes, relativistic particles from Io help to create the coherent radio outbursts that we see from Jupiter.

Question 1: What are possible causes for the emission flares from Jupiter in the low frequency range?

The emission we see from Jupiter at low frequencies is thought to be caused by the electron cyclotron maser instability.

Question 2: What methods can you use to improve the sensativity of the diodes and/or the array as a whole.

Since the sensitivity is governed by the temperature of the sky, the only thing that we can do to increase the sensitivity is to have more dipoles within each station and/or have more stations.

Question 1: Can you study Giant Radio Galaxies using LWA?

Yes, although to get good enough angular resolution we need to also add the VLA antennas.

Question 2: What is the motivation behind the shape of LWA antenna?

The LWA antenna has an "inverted V" dipole shape to give it good performance over a wide range of frequencies. It is bent at an angle of about 45 degrees to give us more sensitivity at the horizon.

Question 1: How much advancement is possible to widen the bands on the VLA? As in how the 4-band system was modified to a wider more sensitive system.

The VLA currently operates from 1-50 GHz, from 240-440 MHz, and from 50-80 MHz. It would be easily possible with today's technology to cover from 50 – 1000 MHz, all it would take is money.

Question 2: Could a few additional beams and MHz be added to reduce the overall number of antennas?

No, see above.

Question 1: Could a simple lighting rod near the array help protect them from lightning strikes? or would it interfere with the array and produce unwanted noise?

Any lightning rod that was large enough and tall enough to protect the array would also interfere with how the station operates (degrade sensitivity, alter beam shape, etc.).

Question 2: Could UNM join forces with our state schools (ASU, NAU, UofA) to help enlarge the array? (an array the size of Arizona sounds like a pretty good size).

YES! Let's do it.

Also is there any summer research programs at NRAO with the VLA or LWAs?

Yes, NRAO has an REU program and starting in the summer of 2018 UNM will also have an REU program where students can get involved with the LWA. Thanks for asking!

Question 1: You showed a video of a meteor with solar winds moving emissions in waves around the meteor. What is being emitted from the meteor that can be moved by solar winds?

Not sure what you are referring to here. The radio emission that we see from meteors is not affected by solar winds.

Question 2: You mentioned that Jupiter has high circular polarization. Have you detected any other objects emitting anything as high in circular polarization as Jupiter?

Not yet. Some stellar masers are known to be highly circularly polarized but most of their transitions are outside of the LWA frequency range.

Question 1: How much did it cost to make one of the station and what is the most expensive equipment at the station?

The cost of the station is about $1,000,000 for the "pile-of-parts", it also requires a fair amount of labor (some assembly required). The most expensive equipment are the electronics in the digital signal processor that does the beamforming.

Question 2: What type of material are each satellite at the stations made out of?

The dipoles are made out of aluminum.

Question 1: Could the telescope be used to track the changes in greenhouse gases around our planet? Or any other environmental effects?

The closest we can get to this is the study of lightning which traces large thunderstorms.

Question 2: Why is the telescope capable of picking up data everywhere but the one spot? Why would you have to set up another telescope in Australia just to get the data if the Californian telescope picks up the rest of the sky?

When I was talking about the ability to image the entire sky I pointed out a region where we cannot observe because the Earth gets in the way. To get around this limitation and see the entire sky we would need an array somewhere in the southern hemisphere (like Australia).

Question 1: Has your program ever picked up any frequencies that you could not explain?

Yes, there was some strange interference that was causing us problems several hours a day for months but eventually it went away.

Question 2: While studying black holes, have you documented any planets or large solid bodies being sucked up by the black hole itself?

Regretably, no.

Question 1: Do you have great enough resolution to look at Psyche in order to gather data to support the hypothesis that it is in fact a planetary core?

Possibly. We might be able to do a radar experiment where Arecibo or some other telescope capable of transmitting within our band hits Psyche with a pulse train and then we receive the signal with the LWA.

Question 2: The array operates between 10-88 Mhz, but how much power (Watts) is used to push through the ionosphere?

The LWA is a receive only, passive, instrument.

Question 1: Stupid question: but why is Jupiter so bright? You said that you plan to use this technique to see other planets but the only planet we were able to see in our solar system is jupiter, so we can only see one of 8? What are the odds that we will see another jupiter in anpther solar system. Or would all the other solar systems look empty? Can we only see the big gas planets? Or that the planets have to be a certain size with a certain magnetic pole to be seen?

We can see Jupiter thanks to its strong magnetic fields which allow for emission between 30 MHz and where the ionosphere cuts off (around 10 MHz). The other planets have cut-offs in their emission below 10 MHz.

Question 2: Wait! If jupiter was closer to the sun of another solar system then we would have what you called a hot jupiter which means that its order of magnitude brighter? Is that posible to have a big plant so close to a star? if they were close enough would they appear as one dot? Or would the resolution of your system be able to determine that there is a sun and a planet there? What would you expect to see?

Yes, it is entirely possible to have Jupiter size planets within the orbit even of Mercury. We would not in that case resolve the hot jupiter and the star, but we could still detect the emission.

Question 1: Why is Arizona the best place to build your array?

Because it is an interesting distance (about 400 km) from our two stations in New Mexico.

Question 2: How do LWAs compare to millimeter satellites that are current expanding in popularity?

Not sure what the question is here, the LWA is very different from a millimeter satellite (whatever that is – cubesat maybe?).

Question 1: You mentioned that you rarely see meteors at 74MHz (I think that was the frequency). Why is that? Also, what causes the persistant trains you seem on some meteors?

The emission is much brighter at low frequencies. We don't yet understand why. The persistent trains are also not all that well understood but thought to be driven by some sort of chemical reaction.

Question 2: I may have missed this in your talk, but how can an object be circularly polarized and how does that help you find candidates?

A few emission mechanisms, like the electron-cyclotron maser instability that produces jovian bursts, have almost all the photons oscillating in the same circular fashion (movement of the tip of the E-vector). We call this circularly polarized.

Question 1: On what timescale does it take for an image to be formed from the time it observes a signal to it being displayed on the screen? I would'nt imagine it to be exactly live because from my understanding there is a good amount of computation that goes on to produce an image.

Correct, it takes about 20 seconds to produce each image, so the LWA TV images are not quite real time.

Question 2: Is the software to utilize international distances for baselines already developed? How could you ensure coherence between well separated stations?

Yes, the software for long baselines has already been written. Coherence is ensured by tuning to the same frequency, and keeping track of the absolute time when writing the data.

Question 1: If we were able to put these on the moon would the data be much more detailed and or would we see more than we can now?

There would probably be even less radio frequency interference. Otherwise it would look pretty much the same.

Question 2: Could these be augmented again tp pick up lower and higher than they can now? and if lower what could we see that is different than what we see now?

Yes, we could go to both higher and lower frequencies. If we went to lower frequencies we would not be able to see the sky because the ionosphere becomes opaque.

Question 1: How many coronal mass ejections are discovered by LWA per year?

There is typically about 1 CME every week (depending strongly on the phase of the solar cycle) and they are discovered mostly by optical satellites like SOHO.

Question 2: Can LWA differentiate noise in the region of space being observed from the object being studied?

Not sure what the question is.

Question 1: What kind of change can bee seen if you change the size of the dipole antennas? I mean, what would happen if you increase or decrease the size?

Changing the size of the dipoles would change the frequency response (smaller dipoles work better at receiving smaller wavelengths).

Question 2: Similar to the previous question, why every array consist in about 255 dipole antennas array? Is there a reason for that number? What would happen if you increase or decrease the number of dipole antennas?

The number of dipoles influences the sensitivity of the station. Better sensitivity allows us to detect fainter objects.

Question 1: How does the LWA and radio frequencies help u understand black holes and dark matter?

By measuring the full spectrum of radiation coming from the vicinity of black holes we can better understand acceleration mechanisms at work. Low frequencies are not particularly helpful for the study of dark matter which does not emit electromagnetic radiation so far as we know.

Question 2: Why does more than LWA need to be built? Does it pick up more information or allow greater study to have more than one?

Yes, we can combine LWA stations to synthesise a much larger telescope with much greater angular resolution than that of an individual station.

Question 1: Have you made any discoveries about Mars with the LWA? Or have you ever detected storms on Mars?

Nobody has used the LWA to look at Mars yet, nor do we have any reason to expect that we would detect it.

Question 2: You mentioned there was a possibility of detecting exoplanets and exomoons. What kind of information could we get from detecting an exoplanet or exomoon with the LWA?

If we can detect exoplanets and exomoons with the LWA that would provide us with a way to measure the magnetic field strength, the rotation rate, and the orbital period of the exomoon.

Question 1: If I heard you correctly, you mentioned that with the LWA, you could see 1000 meteorites an hour. Amazing! Is that an average hour, or during a meteor shower?

That is an average hour. During a meteor shower the rates might go up by a factor of 100 or more.

Question 2: You refererred to resolution issues with super massive blackholes and active galactic nuclei (and other tricky imaging scenarios, such as angular resolution). Are the resolution issues resolvable with better equipment or techniques, over time, so you would eventually be able to decipher the images you are looking at? Or are resolution problems limitations that indicate an inability to study those areas with the resources you have available in this program? In other words, my question is do you try and get better equipment so you can see AGN (etc) or not waste your time, just use the LWA's for the low frequency measures of dispersion where it works better?

If we can build an LWA station in Arizona that could give us the angular resolution needed to make useful observations of AGN and their supermassive black holes.

Question 1: How has the LWA helped to further our understanding of dark matter and dark energy?

It hasn't. We can't do everything.

Question 2: What kind of future endeavors can be expected from the LWA in both the near and distant futures?

The most exciting possibility is the detection of exoplanets, hopefully in the near future.

Question 1: Is there any interference with the radio frequencys that your telescopes are detecting?

Not much. We loose about 2% of our observing time to RFI.

Question 2: What has been the biggest discovery that you have seen that came from a radio telescopes?

There have been several nobel prizes awarded for discoveries from radio telescopes – including for the discovery of pulsars.

Question 1: What is the best pattern that is most efficient to set up a station?

We call it "pseudo-random". It is a pattern that minimizes the sidelobe response from the beam created by the array.

Question 2: Why is it 256 Per station?

So that we have excellent signal-to-noise ratio and can obtain good calibration.

Question 1: You suggest trying to have these stations all over the united states, however I am wondering why we don't instead build additional stations like LOFAR or Australia's MWA. If we made array's all over the world of the same type wouldn't this be better for increased angular resolution, pipeline creation, and more?

Our design is better than that of LOFAR in the frequency range where we overlap. We have very limited overlap with MWA. Note that the MWA and LOFAR use different designs and have different frequency ranges.

Question 2: Is beam forming done while the array is observing, or is this a post processing step? If it is post processing does that mean we can beam form in any direction at any time making the instruments incredibly versatile?

Beam forming is done in real time to reduce the data rate and allow for sustained operation. It is actually possible with an LWA station to record all the data from all the dipoles and form beams in the post-processing, but we can only sustain this data rate for about 1 minute and then we need to spend ~15 minutes writing out the data.

Question 1: Was the Long Wavelength Array placed in New Mexico for a geographical reason (is New Mexico the ideal place for this radio telescope)?

New Mexico is a good place for the LWA because (1) there are large areas in the state where the population density is quite low; (2) The Very Large Array is already in New Mexico so we can combine the LWA with the VLA effectively; and (3) UNM faculty were interested in having their own radio telescope, which is a lot easier when the facility is nearby.

Question 2: Why is the range of the electromagnetic spectrum studied by this telescope so unexplored? Is it hard to study, and does that make the information gathered by the LWA potentially inaccurate?

Until recently we did not have the computation power to take in signals from 256 dipoles and process it all quickly enough. I'm pretty sure the data is ok.

Question 1: What is the maximum distance with which you can collect data and what resolution with your array?

Current baselines are limited to about 90 km which corresponds to an angular resolution of about 10 arcsconds.

Question 2: During your presentation, you described bursts from Saturn. What causes the bursts and what is their composition?

Saturn has a magnetic field which can interact with the solar wind to produce radio bursts at low frequencies. Saturn has has massive storms that produce lightning that we can also detect.

Question 1: What was your first experience with a telescope?

The first I remember is showing Halley's Comet to about a thousand people at the campus observatory at Duke University.

Question 2: Which do you think is most important to study at this point in time? Black holes, dark matter, dark energy, space-weather prediction, etc... ?

I'll go with space-weather prediction since I think this could be pretty important to saving us from harm. I also like the study of black holes for understanding these interesting objects.

Question 1: Was there a lot of complicated circuitry required to change the relative phasing of your dipoles, or were you able to do signal mixing purely digitally?

We do all the phasing digitally, but its still pretty complicated.

Question 2: To what tolerance did the spacing of your dipoles have to be accounted for in designing your mixing hardware and software?

We only required accuracy to a fraction of a wavelength, so for placement that was only about 5 cm.

Question 1: You mentioned that Jupiter's emission shows up in your data at 1 GigaJansky, and then went on to say that has implications for the detection of exoplanets and maybe even exomoons. This made me wonder: have you measured how strong the emission is from any of Jupiter's moons as well, and if so is that what leads you to the consider the possibility of exomoon detection?

Jupiter and Io (the closest big moon) work together to create the powerful emission that we see. So far as I'm aware the other moons don't contribute much in the way of relativistic particles.

Question 2: Is the Juno mission able to incorporate any of the measurements you're getting of it near Jupiter in its mission operations?

Yes. I hope to see some interesting papers come out describing the combined observations.