AUDIO TRANSCRIPT:

Conversation with DOUGLAS BONN

Interview took place…

keywords: physics, quantum physics, waveforms

DOUGLAS: …Becomes important when we talk about solids, so if you want to go from wind to earth to use the old separation, or really just to go from a gas to a solid how we talk about them changes a bit

DENISE: Ok, so let's talk about the wave, the classical

DOUGLAS: Right so sound is…the sound you know in air is a longitudinal wave, so it's a compressional wave that's high pressure/ low pressure, and it's longitudinal meaning that the motion of the air molecules is in the same direction as the propagation of the wave. So that's what sound is, a longitudinal wave involving compression and refraction of the air, so that's sounds and it's a phenomenon in air and water. But it also moves through solids in a similar way, but some other things can happen in solids that don't happen in air and water.

DENISE: Ok,

and then I understand that the phonons are like the vibrations of the lattice, the crystal lattice, I think most solids are crystalline or what?

DOUGLAS:

Well not all solids are, but we mostly talk about crystalline solids because things are simpler there, so we usually start with the…we make choices about things that are going to be soluble, and one of the choices we make is to work on crystalline solids. So in air it was a vibration, so the air molecules are moving relative to one another and that's a sound wave, in a solid your medium is different, so air, it's this chaotic…the molecules are moving every which way, and within that chaos a wave can still propagate in an orderly way, but the molecules themselves are going every which way, in a crystalline solid the atoms are all held in a lattice, that is, that lattice is whatever the crystal structure that solid is. But you can have the same thing happen, now we don't have them completely free to move, they're sitting on a lattice and they're jiggling around a little bit on their lattice. If you cool them down, they jiggle less and less and less because temperature is motion, but you can also propagate something like sound in that lattice and again you can have the same longitudinal compression wave. So you can have atoms pushing on one another and getting the propagation that way.

DENISE: Ok so that's how it works.

DOUGLAS: Yes. But it can do other things. A solid can sustain sheer waves which a gas can't. You're recording sound but I will frequently resort to pictures if I can find my pen. *(scribbles on whiteboard)* So all a sound wave is doing is if you can imagine this *(dotting marks on whiteboard)* as my molecules… so, there's more and less dense stretches of atoms, so it's bunching up and it's getting more diffuse, and this thing goes from bunchy to less bunchy, bunchy to less bunchy, so it's oscillating and it's propagating in that direction, so the bunching up direction is the same as the propagation direction, and that's what we mean by a longitudinal wave. In a crystal lattice *(drawing on whiteboard*) so now we have our ions in a lattice, so they're more organised but the same thing can happen, these ones could push together closer *(drawing on whiteboard, marker squeaking)* and these ones also get closer and in between further apart, and that can propagate that way. So that's the same thing, it's just in a more organised medium but a sheer wave can happen in a solid too, which is that *(drawing on whiteboard)* these ones can go this way, *(drawing continues)* but be propagating that way and that's a transverse wave, so the motion of the atoms, the atoms are going up and down like this, but the waves propagating that way, so more like a…

ARJUNA: Like a sign code?

DOUGLAS: Well like a wave on a wire, so the wave on a guitar string is a transverse wave, if you had an infinitely long string the waves travelling that way, but the wires moving this way, or a water surface, surface on water are water waves propagating one way but the water is moving that way, so solids can sustain transverse and longitudinal waves, so that's actually different kinds of sound in a solid than in a liquid or a gas.

ARJUNA: What determines whether it's transversal or sheer or…?

DOUGLAS: Well, you can launch any of them, so what determines it is what the motion is relative to the direction of propagation, so a solid can have sound waves of all, can have waves of all of these kinds. We reserve the term sound for the thing that just propagates longitudinally.

DENISE: That's the descriptor of the wave, of that particular wave, and the transversal one, does it have a name?

DOUGLAS: They're uh, if these are charged they're called optic modes, and that's cos we can couple to them with light, cos light is an electromagnetic wave so if these are charged and they're transverse they're relatively easy to couple with light, so you can get photons interacting with phonons, is one thing you're asking about the differentiation of so…the photon's another wave, so it's a transverse wave, but it's kind of the weirdest wave for people to grasp, which is it's a wave that has no medium. It doesn't need a medium to propagate, it can propagate in empty space and it's a self-sustaining electric field oscillating one way, a magnetic field oscillating the other way, and they keep each other going. So it's a transverse electric and magnetic field propagating uh…

DENISE: And the phonons, they need a medium to propagate?

DOUGLAS: Yes, yes. Either a gas or a liquid which we just call sound, or in a solid you can have sound and then these other related kinds of waves.

DENISE: Ok, since we're talking about sound and photons, how about heat, how does heat waves…

DOUGLAS: Well heat is, if I look at my solids, so heat is a random motion of these atoms, so the same motion that goes into sound is also related to heat, it's just heat will be a random chaotic motion, but gets more chaotic as you go in temperature. There's a whole quantum mechanical description of this that's a little bit different.

DENISE: Oh there's quantum mechanical description of heat? Give me that *(laughs)*

DOUGLAS: Well, so we, how would I…let me think about this. So now, I have these atoms on a lattice, so let me show you how I sketch it out quantum mechanically *(wipes whiteboard with cloth).* So, we would actually look at what's called normal modes of this lattice, so what are all the different ways that this lattice can vibrate. And then we'll categorise them according to momentum and energy, and momentum goes as one over the wavelength, so a low momentum wave is a very long wavelength, like a sound wave is a very long wavelength.

For sound there is a linear relationship between those two, so a very long wavelength is down here, a short wavelength might be something where they're going like this [sounds of marker scribbles on board] and the distance between motions this way and motions that way may be down at the scale of a single atom. So, way up here at very short wavelengths or high k's we're at length scales where single atoms are pushing against one another. And down here we're at long length scales where there's these sort of slow rolling motions through the solid. In quantum mechanics on this discrete lattice, there isn't a continuous line of these, there's a bunch of discrete states. There may be a lot of them but they're discrete, separate from one another. So what you do with temperature is that if you go to very, very low temperature they all stop, so there is no random motion except for a quantum mechanical thing called zero point motion, so even at absolute zero the theoretically lowest temperature you can get to in quantum mechanics the atoms still jiggle around a little bit. But then temperature is them jiggling around more, but in quantum mechanics what that means is that you have, you start occupying the higher energy states here. So as you add more thermal energy to a system, you start to populate the higher states, rather than them all sitting down in some low state. So temperature in a quantum mechanical view is something that let's things thermally occupy more energetic states, whereas at low temperatures they will sit down at lower states.

ARJUNA: And that's the same in water and solid and…how does the behaviour in solids…

DOUGLAS: Well, I can kind of sketch with you for solids here, [sketching on board] liquids and gases get treated quite differently, so a gas is the kind of opposite extreme, it's this chaotic fluid, that we don't have this orderly description of…

DENISE: Ok, so that straight line even if occupied by other different points are solids?

DOUGLAS: Yes, and you can draw a straight line like that for a liquid too, for a gas and the slope of it is the speed of sound, so the actual slope of this line is the speed of the sound wave, but it won't have the discrete broken up energy levels that you get in a solid at low temperatures.

DENISE:

That is something I hadn't come across yet *(laughs)*

DOUGLAS: And these normal modes, if I go down to the atomic scale, so if I…we'll just work in one dimension because it's easy to visualise. So this crystal structure you can imagine is a bunch of ions sitting on the sites of the crystal, and they have forces between them which I'll just cartoon-wise treat as spring [sketches on board] so I can draw something like this with two masses and then a spring between them, and then springs representing connection to the rest of the crystal. So, this has if I stay in this one dimension, has two modes of oscillation, so they can either go like this, or they can go like that [likely motioning to a board where this has all been drawn] in a real solid you now have 10 to the power of 23 of these, there's a lot of atoms, this has two modes, a real solid will have 10 to the power of 23 modes, which is what all these little dots here are, is different modes of oscillation, plus the transverse mode. So once I allow things to move in another direction I can also have it going this way, or this way, at a third dimension they can go this way, or this way, or any combination of all of those things.

DENISE: In terms of the formalisation of the mathematical representations of that, you use quantum field theory?

DOUGLAS: Yeah.

DENISE: Because you're talking about oscillations.

DOUGLAS: Yeah, so the machinery of quantum field theory just gets applied in particular ways in solids.

DENISE: Ok, so something I read and I don't, well I can't image it in my head, so phonons are treated as bosons, and you're talking about solids, so can you explain it? [laughs] Well you know why I ask, because of the exclusion principle right? If it's solid I assume you're talking about [? 0.15.11]

DOUGLAS:

Well solids…so the difference between a boson and a fermion is what it's spin is, and spin is a purely quantum mechanical thing, that gets given a name that's reassuring that maybe you know what it is, but it's really a purely quantum….it does some things that are a little bit like the object is spinning, but really you just think of it as a quantum property.

DENISE: It's a mathematical object.

DOUGLAS: So, things can have integer spins or half integer spins, the things that have integer spins are bosons, the things that have half integer spins are fermions. So the phonon, let's say all of these are ions that have a spin of a half, the phonon is not one of these objects. It's an oscillation so you have to…figure out quantum mechanically, what is the spin of this object that's really a wave, and it's a spin 0 object. It has no spin. There are more complicated things you can do, so typically it's a boson, you can couple it to an electron and then things get more interesting, but at a first blush it's a boson.

DENISE: But it can be coupled with an electron, so what can you do [? 17.14.5]

DOUGLAS: A whole bunch of things happen. The field that I work in is not just that I'm looking at crystalline solids like this but that I'm looking at crystalline solids that also have electrons that are free to move around. This might be, for the sake of argument, a lattice of positive ions (marker scribbling on whiteboard) and then there's some electrons that are free to move around in this lattice and again there's a quantum mechanical treatment of all of this, and that electron is definitely a fermion so it's a spin a half moving around in a lattice of things that could be, they can have all sorts of spin, spin 0, spin ½, an integer spin, spin of 7 halves, it depends on the particular ion, whether it's a silicone ion or a gold ion or an iron ion. The ions will have their own spin physics, and then there's the spin physics of the electrons, so that lattice is all positively charged, and the electron is negatively charged so you know there's strong, coulomb attraction between the two and the combination of these coulomb retractions, and then the repulsive retractions between the ions is what makes the whole crystal structure hold together in the way it is, it decides on a situation that's energetically the stable place it's going to sit. But then if we, let me back up slightly, the usual way we discuss this problem in solids is we actually look at this lattice and then we just think about one electron moving through the lattice, which is a ludicrous approximation because there's 10 to the power of 23 electrons, they're really close to one another they're like charged, so the coulomb force tells you they repel each other really strongly, so there's a soup of really strongly. So, there's a soup of really strongly interacting electrons pushing against each other here yet for kind of deep, well I won't say deep, for somewhat complicated reasons it turns out we can get away with ignoring all the electron electron interactions, and just think about a single electron moving through this lattice, and the electron's a wave because it's a quantum mechanical object. In some length and scale it's a wave, so we come up with a theory of this wave of electrons moving through a lattice, and you can think of the lattice as a grid, and you know, you're a filmmaker, you know that waves moving through grids give you diffraction if you…colours, and all of this interesting stuff. So we do a problem like that which is a quantum mechanical wave diffracting through a 3 dimensional grid of atoms, and that's the modern theory of electrons and solids, and that theory is how we differentiate between say gold as a metal and diamond as an insulator, and silicone as a semi-conductor is based on that. Just treating one electron moving through the lattice. The thing we're all interested in here is all this situations where that falls apart. So we're interested in strong interactions that we can't brush under the rug, we have to include, and one of those, a bunch of those, involve an interaction between this crystal structure and the phonons in the crystal structure and the electrons, so one of them, a problem worked on by one of my theory colleagues, Mona Berciu, looks at something called the strong polaron problem. A polaron is if you get a motion of these ions which is strongly coupled to an electron, so I have these two positively charged ions and I have a negatively charged electron with it's spin, so that electron pulls the two ions in, and then you can imagine [sound of marker on whiteboard] if it's quite a tight local interaction between the 2, that that object can move around together, and that object then is a combination of an electron and the lattice doing something. So it's a combination of an electron and a phonon, which is, all lattice distortions, all sounds are phonons.

DENISE: And

it's going to move around in the same?

DOUGLAS:

Yeah, and this thing you can imagine, so if the electron moves over here now we have this strong attractive interaction here, so these two ions will move in to close to it, and what that looks like is as if this electron and a distorted lattice moved over to here, so it looks like they're moving together, and that creature gets its own name, it's called a polaron. The strong polaron problem is one of the classic problems in our field where we're studying a strong interaction that goes beyond the usual simple model of electron moving in a solid.

DENISE:

Since you're doing the research here, what would be the applications of finding out?

DOUGLAS: So, I could give my first answer which is, I don't care, I do this because I'm super curious in the fundamentals of this. Where this actually goes, one of the things that crops out of this, is super connectivity, which is the thing that I've spent most of my career studying. So another thing that can happen if this electron interacts with the lattice, I showed it as if they're moving around together, but actually the electron moves around at very high velocities in the solid a lot of the time. So what can happen is an electron might pull these ones in close to it, this is a cartoon picture but it's good enough to…and then this electron skitters off somewhere else, but the ions have a mass that's a thousand times electron, so they actually move quite slowly relative to the electron. So the electron's gone that leaves behind a distortion in the lattice that sort of looks like there's a more concentrated bit of positive charge, and that's going to look attractive to another electron. So another electron sees that and comes skittering in, cos the electrons are whizzing around much more quickly. And then what that looks like is that that electron attracted this one to follow it, so even though electrons repel one another, electrons in a solid can look like they attract each other and that is what leads to super connectivity, so that's an electron phonon interaction, so the one electron interacts with the phonons, and the phonons then interact with the second electron, so it's an interaction between two electrons mediated by another quantum mechanical object, which is the phonon. If you have a lot of electrons around and a pretty strong interaction with the lattice, the electrons can actually form a pair called a Cooper pair, after the person who first described this model. And now a Cooper pair is a boson, because it's two spin and a half objects, they usually anti align with one another and become a spin zero object which is a boson, and the big exciting difference between bosons and electrons, is bosons can all occupy the same quantum mechanical state so when this happens in a solid, all of the electrons that participate in this pairing can go into the same quantum mechanical state which has all these weird properties like zero electrical resistance which then becomes useful.

DENISE:
What would that include in terms of [? 26.56.0] that would include quantum computing, or are you talking about something else?

DOUGLAS: Well, the quantum computing's very exciting and still in the future, just the fact that this state has zero electrical resistance is something that we use already, so the phenomenon was discovered in the early 1900s, so it's actually old. Yeah, I can show you charming old picture of scientists 100 years ago and they're doing work in their suits etc etc. but, around about the 60s people figured out how to make electromagnets under the super node, so the exciting property was the super node it's not the only the only interesting property but the one that gets everyone excited as the electrical resistance is zero, so electricity can flow without any impedance. So if you do, if you both made electromagnets as kids at some point in your life, you're around a wire, around a nail and pick up paper clips or something like that. So you basically make an electromagnet but do it with super connecting wire which means if you join the two ends of the wire and get the current going it'll just keep going through the coil forever.

ARJUNA: Is that unique to this?

DOUGLAS: It's a unique property of a super connector having zero electrical res [? 28.24.6] and it's not just low, it's zero, so if you set the, it's a kind of perpetual motion, if you set the current going it'll go forever. And this is in, it's biggest application is every MRI machine. Have you ever had an MRI done?

DENISE: No, I haven't

DOUGLAS: But you've seen pictures of them as this cylindrical donut thing, and what's in the donut thing that you get slid through is a big electromagnet made out of a super connector, because it has to produce a high field that's stable and it doesn't cost you…once you get the current going you don't have to keep feeding energy in to keep the current going. You do have to keep it cold though because it's only a phenomenon at low temperatures, so your cost is refrigeration but you don't have to keep pumping electrical current into the magnet.

ARJUNA:

What you said earlier about this being quite weird, what did, when all the electrons are occupying the same quantum state, you said that was kind of a weird…[laughs]

DOUGLAS: Then it's, one of the interesting things about it is that it's a macroscopic quantum mechanical phenomenon, so if I put a piece of a super connector in front of you all of the electrons are actually acting together there. Usually we think of quantum mechanics as something that only rears its head when you get down to atomic and molecular length scales, but this is now something where all of the electrons in something that's macroscopic act together as a single quantum mechanical wave function, and that's needed for this zero electrical resistance state and a few other properties it has. It's very much needed for its potential use in quantum computing, because quantum computing requires the electrons to act coherently in a quantum mechanical fashion.

ARJUNA: You said earlier about the phonon also couples, I forget what you said, it also couples with, I can't remember (*Denise & Arjuna laugh*)

DOUGLAS:

Well, they interact with the electrons, I've talked about photons potentially interacting with them

ARJUNA: And what happens when they couple with photons?

DOUGLAS: A whole bunch of different things, there's many different processes, so you can have…

ARJUNA:

When I read about quantum tunnelling, where, I mean this is just reading New Scientist articles about where it borrows energy from the photons to pass through things that they're not supposed to

DOUGLAS:

Yeah, so you can have exchange of energy between photons and phonons in a variety of different processes

ARJUNA: Is that unusual?

DOUGLAS: No no. They are common effects, all of the interactions you see of light with solids that you find interesting in optics, I mean you use these as a visual artist, you use these phenomena all the time. They all, many of them come down to interactions between light and some crystalline lattice or the electrons in that crystalline lattice or both. There's a bunch of different processes, sometimes it's just that it can absorb the light so then you get things with different colours depending on what light it absorbs. So that's kind of the most common thing, it's either absorbed or it's transmitted, and that will depend on details of the properties of the lattice. But it can do funnier things, it can take a photon, say at a green wavelength, and it comes in and it absorbs just a bit of the energy of the photon, and it re emits a lower energy photon and takes what energy it gained and makes a phonon. So you can have a photon come into a solid and just get absorbed or just get transmitted, and that's what mostly gives things the colours, but you can also have it come in at one colour and out at another colour, having emitted or absorbed a phonon in the solid. That's called, the earliest version of that is something called the Raman effect after an Indian physicist of the early 20th century.

DENISE:

Something, Arjuna, that you found that we are curious about is negative latitude, what the hell is that? (*Arjuna & Denise laugh)*

DOUGLAS: I

didn't know what the hell you were talking about so I had to go look it up, cos at first I thought you were talking about a cosmological thing, and then I just randomly googling around discovered this paper that I had read a few years ago, so it's something that was recently discovered as a possibility in sound waves, and I don't know that much about it so I would have to, if you wanted an intelligent answer from me I would have to go back and read the paper, but effectively what is was is that there's an effect that can happen with sound that looks like a gravitational effect but within opposite sine's, it's not like they've created something that's going to let me levitate you but there's a term in a mathematical description that looks like gravity with an opposite sine.

DENISE: So just the negative?

DOUGLAS: Yeah.

ARJUNA: But the idea that sound has gravity is pretty strange to me.

DOUGLAS: Well, sound is a motion of atoms right? So, sound involves the motion of things that have mass, so you can think…you can include gravity in your description of sound propagating.

ARJUNA: But it's the medium not the sound.

DOUGLAS: Yeah, so gravity is acting on the medium but then you need to ask the question, given that gravity is acting on the medium how does gravity play a role in the motion, because sound is motion of the objects in that medium, so what happens if you throw gravity into that problem. And it turns out there are some extreme situations you can get to in sound propagation where you have terms where you have to think about the effect of gravity, and it looks like, as I said I would have to go back and reread the paper but it looks like there's a term that can look as if sound has an opposite force on it due to gravity, hence the negative gravity term. That term is just there to get you excited about the article right (*laughs)* it's a sort of a PR…so if you can find a cool way of sucking people into your otherwise dry paper…

DENISE: It's getting people to read the articles right, because people are always scared of the maths, so that's the way…so if I understood you correctly you said the phonons, the oscillations are in solids and liquids and air, the same way. I don't know if the questions make sense? So, the phonons coming out of here, they shift once they are, so I take my finger, so the vibration would shift when it comes through air or it becomes something else completely different?

DOUGLAS: No, so you can, you could have vibrations at the surface of your skin that are coming from whatever's shaking around in you and that couple a little bit what's inside. You don't do, mostly that's a random motion that's heat.

DENISE: Yes, that is my question. My question is about; so, I touch him and then hot right, so transfer of energy, of kinetic energy going on here, so that's the phonons?

DOUGLAS: Yes. Heat in a solid involves this population of phonons, and how the warmer you are the more we populate higher and higher energy phonons, then that may, so in a gas you don't actually have phonons, you have this random motion, this is kind of randomly moving thermally excited phonons so it's really a description of heat in a phonon language that's allowed by being in a crystal structure. Once you get out into air you describe it differently.

DENISE: It goes from my hand to his shoulder?

DOUGLAS: Well, there's a difference, there's an impedance mismatch between you and the air and that mismatch is not as great between a solid to a solid, and it's relatively low between a similar sold to a similar solid, so the more different the two media are maybe the more difficult it is for the heat to transfer from one to another. That all gets very weird at low temperatures, at room temperature you don't even think quantum mechanically, you just think about thermodynamics and how heat flows and we don't worry much about this quantum mechanical description.

DENISE: And the low temperatures?

DOUGLAS: Oh weird stuff! I am saying just if you put your hand on his shoulder we would just have a classical description of a flow of heat between you. We don't worry about phonons or anything, we just talk about heat flow between you.

DENISE: But it could be described using phonons instead of classical…could be?

DOUGLAS:

Yeah. And you would make your life much more difficult and not gain anything at room temperature, but at low temperature other weird stuff can happen. So, we might have to worry about, we have two crystal lattices of two different materials and we actually have to think about processes, so now I think of my phonon as this little quantum mechanical object moving around with some energy. And it can do funny things like reflect off of the surface, so there's an impedance mismatch between two similar materials that we would have to think about. So mostly we avoid the quantum mechanical description at room temperature, but there are funny things that can happen at low temperature where we have to bring that in.

ARJUNA: So, this would mean there would be no heat transfer?

DOUGLAS:

Right, so in my field where we try to go to very, very low temperatures we run into problems getting heat transfer to happen and it's something named after a Russian physicist that worked on this called Kapitsa, so it's Kapitsa resistance.

DENISE:

Thank you. Do you have any more…?

ARJUNA: I read a lot of popular articles and they made claims like, that the phonons describe a different mode of heat transfer, there is conductivity…

DOUGLAS:

Yeah, I can conduct heat across this interface in a couple of different ways, so if these are metals I do have my electrons still skittering around here, so they can conduct heat by actually flowing across the boundary. The ions can't so they're stuck in their places, so they're moving heat around by transferring vibrations, by having phonons propagate so those two mechanisms of heat transport are two distinct parts of conduction, so you usually hear of three modes of heat transport, so there's conduction, convection and radiation. But in solids conduction is broken down into what the electrons do and what the phonons do.

ARJUNA: And their different names?

DOUGLAS: Electron conduction and phonon conduction, yeah we don't…it seems like we come up with names sort of indiscriminately but sometimes we just stick to something simple. So it's electron and phonon conduction of heat, so that's why for instance if you touch a cold metal it will suck the heat out of you much faster than a cold insulating object, and that's because of the ability of the electrons to quite quickly transport heat. That's why you cook with metal too typically, because it transports heat well and that's because the electrons are good at transporting heat.

….

ARJUNA: Ok, thank you *(Denise & Arjuna laugh)*

DOUGLAS: Where's this all fit into your ontological epistemological studies of knowledge and…?

DENISE: Wow, it's, I mean it's obviously at a level of speculation that is also slightly more at a philosophical level but also at the level of aesthetics right, the imaging of it. And I think the main idea as I said before is shifting from thinking about thinking and actually the mind in terms of modelled after the photon and thinking with the phonon. So when I asked you my question about if I touch him like that, a way of being in relation that would involve the physicality of it, instead of just the distance, with the light, distance, sound, so…

DOUGLAS: Well one is mediated by photons mostly, although speech is mediated by sound waves but, you never would typically think of it as phonons, and then there's heat.

DENISE: I have a few short pieces about heat and talking about global warming, really taking heat seriously, so if you think for instance talking about work - I mean not heat and energy, but heat is one kind of transfer but what is being another one changing, and trying to think about the accumulation of those gases up as actually an accumulation of internal kinetic energy of human beings doing the work, so that's where the transfer idea is coming in. So of course in addition to thinking, we have to think about and have intelligent ways of dealing with global warming. I think one of the ways would be thinking how human are physical, not only humans but everything that is involved in that. So that's the kind of things that we are talking about, speculating about, but we wanted to speculate with a little bit of intelligence, not just you know like "oh..!" (laughter) and yeah I think when I came across phonons, it wasn't long ago, I had no Idea. I mean the whole field, so I used to walk and go what are they doing there? [? 47.28.9] institute, and then I read about it and it's a whole new universe and language, and possibly a sensibility if you pay attention to the solids because we assume that this is bad, makes no, there is no relationship between me and the table unless I have to use it, but in a way there is

DOUGLAS: One thing you should know—you maybe stumbled into me one way or another… This institute actually has too much to do, as we all do, but we actually have a pretty strong interest in engaging with the arts. We haven't done a lot with that yet, but it's something that we talk about and as time allows, we want to do more in that direction. I'll show you a couple of little pieces, I have an artist friend of mine who has done science related art with me for many years, he's actually made things out of super connectors.

DENISE: I'd like to see, yes.

DOUGLAS: But we have some interest in keeping a conversation like that going.

[END OF RECORDING]

Transcript by Collective Text
(Monia Dafa & Sabrina Henry with the artists)