WEBVTT

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00:00:05.250 --> 00:00:14.519
Richard Partridge: I'm pleased to introduce Jim Paulo Kersey who's going to tell us about axiom and accion like articles Giampaolo

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00:00:15.420 --> 00:00:22.770
Gianpaolo Carosi: Great, thank you very much. I'd like to thank the organizers in general for putting together to to really nice array of talks. I've been able to

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00:00:23.250 --> 00:00:29.010
Gianpaolo Carosi: Catch some of them when I've had time. So we're gonna be talking to you today about accion is actually on like particles.

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00:00:30.000 --> 00:00:34.500
Gianpaolo Carosi: There's been some earlier talks I think they've touched on some of this, this, but the

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00:00:35.310 --> 00:00:46.200
Gianpaolo Carosi: main motivation that I think a lot of us are here for is trying to discover what the nature of dark matters. This is kind of one of the premier mysteries and physics and it has been for better part of a century.

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00:00:47.040 --> 00:00:57.270
Gianpaolo Carosi: Ever since physically noticed there were issues with the comic cluster and very Ruben really put dark matter on the map with all her galaxy rotation curbs.

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00:00:58.050 --> 00:01:07.380
Gianpaolo Carosi: The evidence has since been accumulating over many, many observational scales. So I'd like to also point out these really nice talks by Tim Tate

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00:01:07.890 --> 00:01:20.880
Gianpaolo Carosi: Tracy slatter enjoy Cooley on dark matter indirect dark matter searches in theory, as well as some technology talks that have a lot of overlap with what I'll be talking about today from 7019 detectors from Kent Irwin.

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00:01:22.020 --> 00:01:23.550
Gianpaolo Carosi: Is a sheen. I'm in

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00:01:26.280 --> 00:01:35.610
Gianpaolo Carosi: Addition to dark matter in the late 70s. There was actually another problem in physics, and that is why the neutron did not have a measurable electric dipole moment.

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00:01:36.660 --> 00:01:39.510
Gianpaolo Carosi: So now you've asked me this would give a dipole moment of, you know,

12
00:01:40.230 --> 00:01:45.450
Gianpaolo Carosi: 10 to the minus 16 electronic centimeters, which is very easy to measure.

13
00:01:46.590 --> 00:01:52.200
Gianpaolo Carosi: But there's been some exquisite experiments that over the years of push this boundary lower and lower and lower.

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00:01:52.710 --> 00:02:05.010
Gianpaolo Carosi: And this is very peculiar because you know the, we know that the neutron is a is a constituent particle is made out of corks to expect from QC ed that there should be some sort of charge separation.

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00:02:05.820 --> 00:02:13.920
Gianpaolo Carosi: The fact that there isn't implies that there might be some other symmetry, keeping things quiet.

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00:02:15.480 --> 00:02:22.800
Gianpaolo Carosi: This is the solution that was come up with by Roberto patch and Helen Quinn in the late 70s when they were at Stanford.

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00:02:24.330 --> 00:02:30.750
Gianpaolo Carosi: They postulated that there was a new you want symmetry that would be spontaneously broken in the early universe.

18
00:02:31.140 --> 00:02:42.540
Gianpaolo Carosi: And this promoted the symmetry this symmetry breaking scale within dynamically relax this data parameter down to effectively zero

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00:02:43.530 --> 00:03:00.540
Gianpaolo Carosi: And Weinberg and will check realized very quickly after this new human. So a tree was populated that this would create a new Goldstone bows on and they dug this pose on the axiom. I think other names I've heard around where the hayslett glad they chose the accion in the end.

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00:03:01.620 --> 00:03:10.200
Gianpaolo Carosi: So this remnant actually on expectation value basically Knowles out the QC at CP violation and allows you to get zero.

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00:03:10.650 --> 00:03:16.140
Gianpaolo Carosi: And there's only really one free parameter that theory. And that's where the symmetry breaking scale happens

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00:03:16.830 --> 00:03:24.840
Gianpaolo Carosi: And initially, it was not that the secretary breaking scale was close to other scales that were used to like the week scale.

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00:03:25.530 --> 00:03:35.880
Gianpaolo Carosi: This would give axioms that have masses of hundreds of KGB, and it would be actually fairly well easily detectable. And so they were searches that were done both in

24
00:03:37.170 --> 00:03:43.620
Gianpaolo Carosi: In reactors and deemed of experiments that rule that out and the symmetry breaking scale was raised, higher, higher, higher

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00:03:44.310 --> 00:03:54.510
Gianpaolo Carosi: Conversely, there's a function between the symmetry breaking, and the mass, the hiring make the symmetry breaking, the lower the mass and the lower the coupling ordinary particles.

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00:03:55.050 --> 00:04:08.820
Gianpaolo Carosi: And so as a result of became a natural dark matter candidate and there's two kind of general classes and models. The K as Vz models which couple of leptons and then DFS Z which couple both to leptons and corks

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00:04:11.310 --> 00:04:31.590
Gianpaolo Carosi: So dark matter, of course, has a huge range of masses, and this is a this is a cartoon I've borrowed from X KC D talking about everything up to supermassive black holes at the highest mass ranges down to where I'll be talking about, which is axons at the very lower into the mass range.

28
00:04:33.420 --> 00:04:41.220
Gianpaolo Carosi: Another way of looking at this is to look at the mass scale in terms of frequencies and so frequencies.

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00:04:41.580 --> 00:04:48.420
Gianpaolo Carosi: Are going to be talked about a lot in this. A lot of the detection strategies that I'll talk about will be converting accion

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00:04:48.930 --> 00:04:58.020
Gianpaolo Carosi: From an arrest mass to a detectable photon and that's usually directly translated into the frequency. And so if we look at kind of upper bounds.

31
00:04:58.950 --> 00:05:07.380
Gianpaolo Carosi: That are set from stellar evolution from how axons were provide alternative Cooley mechanisms to starters.

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00:05:07.920 --> 00:05:15.930
Gianpaolo Carosi: You can put upper bounds, you know, a roughly around to the minus two EV so other talks I think in this series or ANYTIME. I'LL wimps.

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00:05:16.830 --> 00:05:24.930
Gianpaolo Carosi: Which will be more on the GV to even TV scale masses. So these are extremely light particles relevant to that.

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00:05:25.920 --> 00:05:37.560
Gianpaolo Carosi: Now there's a limit, also in terms of how many Fernandez, you can put into a galaxy. And that means that the lower mass particles really have to be bolt ons and needed accion is our bows on

35
00:05:38.670 --> 00:05:55.320
Gianpaolo Carosi: So the lower bound is really set by the size of the dark matter Halo. How many, you know, dark matter particles that needs to be in a you know a dwarf galaxy effectively and that's down the kind of the 10 minus range, all the way down there.

36
00:05:56.520 --> 00:06:03.780
Gianpaolo Carosi: Are there's a transition point between the two depending on when the patchy Quinn symmetry was broken.

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00:06:04.560 --> 00:06:21.480
Gianpaolo Carosi: If it was broken in the very early universe. You know, before inflation or during inflation, then all bets are off. It could be a very large frequency and range. However, if it's broken after inflation due to the various mechanisms in the early universe, such as the misalignment mechanism.

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00:06:22.530 --> 00:06:34.380

Gianpaolo Carosi: There's a much more limited scope in which they can be. And so one of the really interesting things is, you know, you're able to probe particles that might actually give probes inflation for the very low mass

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00:06:35.460 --> 00:06:45.630
Gianpaolo Carosi: And other you know detection schemes like the gravitational wave observatories, or I should say the CMT observatories, they'll look for gravity waves like be modes.

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00:06:46.230 --> 00:06:59.820
Gianpaolo Carosi: If those are ever observed in those could actually roll out those lower mass acceptance. So there's a number of constraints, both from astrophysics and cosmology. I'll be focusing mostly on direct detection and direct experiments.

41
00:07:03.090 --> 00:07:10.560
Gianpaolo Carosi: So there's a number of couplings. And when I talk about a couple of different types of coupling is of accion see the nuclei to electrons.

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00:07:11.070 --> 00:07:26.820
Gianpaolo Carosi: But the primary coupling on and we talk about is axioms two photons. And one of the reasons this is such an interesting strategy is that you can create very, very high density photon fields either magnets on laser fields or in the sun.

43
00:07:28.770 --> 00:07:40.920
Gianpaolo Carosi: And in addition, the loop that these accion interactive two photons with a generally have a large number of cancellations. And so there's very little bottle dependency in this particular town.

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00:07:41.520 --> 00:07:47.760
Gianpaolo Carosi: But you can still get axioms couple into electronic nuclei. And there are experiments that have been focused on that as well.

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00:07:49.140 --> 00:07:56.550
Gianpaolo Carosi: There's another way of looking at the axon couplings. So this is split into a variety of different ways in which you actually on could couple

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00:07:57.060 --> 00:08:01.320
Gianpaolo Carosi: The first one, which you see here in green. That's the accion to two photon coupling.

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00:08:01.860 --> 00:08:11.940
Gianpaolo Carosi: And this could be either the accion decaying to two photons. Now the lifetime of that is expecting to be extraordinary along to the 50 years or so. So it's effectively a stable particle

48
00:08:12.300 --> 00:08:16.200
Gianpaolo Carosi: But you can turn that around. You can look at photons colliding creating accion

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00:08:17.040 --> 00:08:32.490
Gianpaolo Carosi: You can look at a photon being provided by a strong magnetic field interacting and creating a new photon when the actual interacts also be talking about a few experiments that look for the coupling to nuclei. This can cause lots of dipole moments or

50
00:08:33.570 --> 00:08:42.270
Gianpaolo Carosi: Nuclear moment interactions as you go for spin dependent energy shifts or looking for how the coupling have an excellent couples to

51
00:08:43.830 --> 00:08:46.410
Gianpaolo Carosi: The electric field analogous to the photoelectric effect.

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00:08:49.590 --> 00:08:57.000
Gianpaolo Carosi: So I've tried it. I tried to lay out the various experiments and there's a tremendous number of really very interesting experimental techniques.

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00:08:57.810 --> 00:09:10.170
Gianpaolo Carosi: Into kind of three broad categories. The first i got i talked about our laboratory experiments and these include both laser systems in which you're trying to generate accion strong magnetic field and then detect them again.

54
00:09:11.160 --> 00:09:23.130
Gianpaolo Carosi: Or into in fifth fourth experiments, experiments they look for deviations gravity and so I, those are effectively things you can do in the laboratory, we have more or less complete control.

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00:09:25.170 --> 00:09:44.070
Gianpaolo Carosi: There's another type cold sore accion searches and. And for this you rely on the sun as a very dense photon field to provide a large number of axons and then these would be detected on Earth by having these actions be reconverted into detectable photons, such as X rays.

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00:09:45.210 --> 00:09:54.240
Gianpaolo Carosi: Finally, there's a broad category of axons searches that look for dark matter with it with the action itself is a dark matter background.

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00:09:55.020 --> 00:10:05.520
Gianpaolo Carosi: That can be thought of as more a coherent source of that of dark matter particles, rather than the kind of width web centric view where you're looking for individual scattered events.

58
00:10:06.420 --> 00:10:16.590
Gianpaolo Carosi: So I'm going to go through a couple of different detection technologies for accion dark matters, but the plot that I'm showing here on the right hand side. This is a specific

59
00:10:17.790 --> 00:10:31.710
Gianpaolo Carosi: Case for accion two photon couplings. So the, the y axis there is the coupling to two photons of the accion and then the x axis that you see is the x equals mass and EV

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00:10:32.880 --> 00:10:45.210
Gianpaolo Carosi: Now the standard QC accion is is yellow band that kind of goes from about 10 minus seven EV at the very low end of the coupling range up to about one at the at the upper part of the range.

61
00:10:46.410 --> 00:11:00.120
Gianpaolo Carosi: That band was what what we call the QC dx. Yeah, and that's the action on that actually saw the strong CPU problem which has a very strong relationship between the coupling scale and the mass range.

62
00:11:02.430 --> 00:11:12.300
Gianpaolo Carosi: Now you can relax that relationship. If you decide that you do not need an axiom to solve the strong CP problem and you relax the

63
00:11:13.620 --> 00:11:23.910
Gianpaolo Carosi: The connection between the mass of the particle and the signature rating scale that you come up with an entire general class or particle is called the axiom like particles routes.

64
00:11:25.020 --> 00:11:27.330
Gianpaolo Carosi: And there's a number, number of different

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00:11:29.160 --> 00:11:41.400

Gianpaolo Carosi: Possible hints from astrophysics, such as unexplained cooling of white worse if they cool much faster. Faster than you expect from just the known neutrino emission

66
00:11:42.900 --> 00:11:52.020
Gianpaolo Carosi: There's also this mystery of why the universe looks so optically transparent to TV.

67
00:11:53.160 --> 00:12:07.830
Gianpaolo Carosi: Cameras, they should have interactions and pair production that causes them to slow down, but the universe appears to be anomalously transparent. It's possible that these accelerate particles are some of them are turning into

68
00:12:09.000 --> 00:12:17.190
Gianpaolo Carosi: accion so these photons trained axioms in the magnetic fields of the interstellar mediums and then later on, converting back to detectable photon.

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00:12:18.000 --> 00:12:25.560
Gianpaolo Carosi: And so, these, these are some small astrophysical hints that could say that there's some other accion like particle that's out there.

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00:12:26.220 --> 00:12:36.150
Gianpaolo Carosi: And I should also mention that actually like ultra light accion like particles are actually ubiquitous in string theory it could be an entire x the inverse, as they say.

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00:12:36.930 --> 00:12:48.930
Gianpaolo Carosi: With accion down to 10 the minus 33 up as a discovery of subs extremely ultra light actually on my part of those will actually be some evidence for strength theory that that's quite exciting right there.

72
00:12:51.450 --> 00:13:00.450
Gianpaolo Carosi: There. See that the theory is undergoing a lot of really interesting new ideas as well. It's an active area of development. There's a new prediction.

73
00:13:00.810 --> 00:13:18.660
Gianpaolo Carosi: Out recently put this paper. This is a paper that came out in June, from a group of UC Berkeley. Looking at accion that would actually have much higher coupling. So this green band is what they're predicting that would that would be in the realm of experiments that

74
00:13:19.830 --> 00:13:22.620
Gianpaolo Carosi: Are slowly coming online right now and

75
00:13:24.690 --> 00:13:29.970
Gianpaolo Carosi: Would have much higher couplings, and they would have the kind of classical yellow band that you see.

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00:13:31.680 --> 00:13:42.570
Gianpaolo Carosi: So we're going to start by talking about the laser searches. So the premier laser shirt that's going on right now is called out to any light particles search experiment is based

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00:13:43.680 --> 00:13:46.740
Gianpaolo Carosi: In Germany at the desi

78
00:13:47.970 --> 00:14:08.190
Gianpaolo Carosi: The idea is you have a laser on one continuous wave laser you excite one side of a fabric fabric row. So this is the production cabinet here, you get a large amount of resin power back and forth of the photon field with a main magnet. So the orange. There is a dipole magnet.

79
00:14:09.420 --> 00:14:18.060
Gianpaolo Carosi: And these are effectively called light shining to walls experiments. Some of these photons will then convert to accion they would pass through the barrier.

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00:14:18.510 --> 00:14:28.230
Gianpaolo Carosi: And then be reasonably reconverted into detectable photons and then detected with some kind of single photon counters. So just T S is on the other side.

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00:14:29.070 --> 00:14:35.040
Gianpaolo Carosi: And so this is a experiment we have both sides of the of the production side and the cup and the

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00:14:35.670 --> 00:14:45.090
Gianpaolo Carosi: Conversion side, they're very challenging because the power here is the power ago from a photon to accion and then back from an accion to a photon.

83
00:14:45.480 --> 00:15:01.440
Gianpaolo Carosi: That power goes as that coupling to the fourth power. So that's why these experiments extremely challenging right now they're

expecting signal powers come around 10 minus 25 watts or so using a 30 walk continuous wave laser

84
00:15:02.850 --> 00:15:20.880
Gianpaolo Carosi: And some of the parameters of the experiment include the finesse, you know, how high of a resonance, you can get with your open resonator system and the current experiment is around, you know, 10 meters or so. And that's being put together, it should be operational the next few years.

85
00:15:22.590 --> 00:15:23.700
Gianpaolo Carosi: Looking ahead,

86
00:15:26.550 --> 00:15:36.750
Gianpaolo Carosi: There's actually a an experiment experimental concept I should say that would follow up on this, you can see, and then the plot of the right you'll be seeing these exclusion plots.

87
00:15:37.980 --> 00:15:47.520
Gianpaolo Carosi: pretty frequently. But if you look at the Alps to and kind of that dark red that's supposed to be, what, to be able to tell the next year, next few years.

88
00:15:48.930 --> 00:16:01.470
Gianpaolo Carosi: These are broadband searches in the sense that you just need to have enough photon energy to create the accion as long as you have that photon energy. Energy any accion have any power can be created below that photonic energy

89
00:16:03.150 --> 00:16:08.880
Gianpaolo Carosi: So eventually, they would like to have a much larger system. This is the Jura concepts which be

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00:16:09.750 --> 00:16:24.750
Gianpaolo Carosi: About a kilometer long so when an order of magnitude long longer much higher magnetic field strength and about two they're aiming for 2.5 megawatts of stored energy. So, this is basically a feasibility experiment.

91
00:16:25.830 --> 00:16:40.530
Gianpaolo Carosi: That they're looking at for long term and they're hoping to be able to get down to kind of the 10 to the minus 12 inverse GV coupling, which if you recall that the code Genesis could actually rule out or or discover out particles in that region.

92

00:16:43.380 --> 00:16:54.630
Gianpaolo Carosi: I'm going to switch over now to the the CERN accion solar telescope casts experiment. These look for particles being generated exhale particles being generated the photon fields of the sun.

93
00:16:55.500 --> 00:17:06.660
Gianpaolo Carosi: They're not only looking for accion is being generated from just the permit comp effect is two photon coupling, but also looking at potentially accion to electron

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00:17:07.560 --> 00:17:17.040
Gianpaolo Carosi: Interactions as well, which you can see it from the to kind of boost in shapes here of the you know the black and the red that you can kind of see TV and get them out there.

95
00:17:17.850 --> 00:17:35.370
Gianpaolo Carosi: And that is that these photons within be thoroughly boost into they'd have kind of the interview spectrum of the sun. So that you'd be looking for kind of ke VI mass chaos right ke VI energy photons, so x rays. And so this is the, the most recent results. They were actually able to

96
00:17:36.900 --> 00:17:53.640
Gianpaolo Carosi: Start getting into plausible accion candidates, this one be dark matter. These would be directly produced and usually we think of the dark matter as being a little bit lower mass for the production mechanisms, but this is so extremely exciting and could have discovery potential

97
00:17:56.910 --> 00:18:11.160
Gianpaolo Carosi: Cast has a long history was using a LSC dipole magnet, the early days. But right now, there's a lot a lot of momentum to the next phase, the experiment called I accept the international accion Observatory.

98
00:18:11.640 --> 00:18:21.540
Gianpaolo Carosi: And this is a much, much larger experiment, this would actually have dedicated magnet system about 600 millimeter bore eight bores

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00:18:22.320 --> 00:18:33.630
Gianpaolo Carosi: And a variety of x ray detectors and get several orders of magnitude lower in its can reach and be able to cut into a lot of the potential accion mass range.

100
00:18:34.350 --> 00:18:49.620

Gianpaolo Carosi: There's currently a a mid level version of this called baby XO which has been being put together. Desi in Germany. And that's going to be kind of this initial proof of concept before the very large system gets put together over the next decade or so.

101
00:18:52.350 --> 00:19:01.290
Gianpaolo Carosi: I'm going to switch now over to another. We've heard about lasers searches and searches for solar axioms. I want to switch to accion as dark matter candidates.

102
00:19:01.800 --> 00:19:11.370
Gianpaolo Carosi: And the classic version of this is the accion Halo scope technique. This is a technique that was originally developed by peers to keep it in a late 80s.

103
00:19:11.820 --> 00:19:21.240
Gianpaolo Carosi: And the idea is you have a resonant microwave cavity that is immersed in a strong magnetic field. The accion since it's a extremely light particle

104
00:19:22.080 --> 00:19:32.700
Gianpaolo Carosi: And we believe is in the 10s hundreds of micro review mass ranges, but it's so cold dark matter candidate, it means that the deployment wavelengths be extremely long

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00:19:33.390 --> 00:19:42.750
Gianpaolo Carosi: Coherence leave links could be hundreds of meters or more. And so you decide your experiments, much smaller than the actual coherence of the axon signal.

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00:19:43.320 --> 00:19:53.580
Gianpaolo Carosi: And one way to think of it is, it, it, it's more of a general oscillation electromagnetic oscillation. That's interacting with your microwave capital.

107
00:19:54.120 --> 00:20:02.490
Gianpaolo Carosi: But Mike we have cavity kind of acts like a matching network to match you to the actions of frequency. And so when the resonance of the cavity.

108
00:20:02.790 --> 00:20:14.370
Gianpaolo Carosi: Matches the frequency of the accion you get an enhancement by the quality factor of the cavity and I'll go through this a little more detail, but the key finger here is that

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00:20:15.510 --> 00:20:19.200
Gianpaolo Carosi: We're looking for very small amounts power Tim is 24 watts or so.

110
00:20:21.330 --> 00:20:25.530
Gianpaolo Carosi: Here's a slide to give you a little bit of intuition. So a lot of times

111
00:20:26.160 --> 00:20:36.030
Gianpaolo Carosi: We think of dark matter experience. You can think of these extremely rare WIMPs coming in and having a hard scatter and you're looking for these very low energy events.

112
00:20:36.540 --> 00:20:44.730
Gianpaolo Carosi: The accent is different. The accion is essentially can be thought of as a extremely weekly. Coupled oscillator. And so this is a nice little

113
00:20:45.510 --> 00:20:52.320
Gianpaolo Carosi: You know, just tabletop experiment. One of my colleagues, Aaron show it Fermilab did where he took a Newton's cradle and put two magnets on

114
00:20:53.040 --> 00:21:04.170
Gianpaolo Carosi: And just slowly. You know, the one on the right. There is an example of the accion field. And what it does is it interacts coherently with the resonance of the microwave cavity.

115
00:21:04.560 --> 00:21:19.350
Gianpaolo Carosi: And it slowly builds up power when you're at that same resonant frequency. If you had a system that had a different frequency, it would not resonate the system. And so you can use that almost like a bad Pass Filter as you slowly build a power into the accion Kathy.

116
00:21:22.080 --> 00:21:32.160
Gianpaolo Carosi: So the search strategy and sometimes you can think of this as a, you know, thousands of different experiments were just looking at each individual frequency for a set amount of time.

117
00:21:32.850 --> 00:21:40.830
Gianpaolo Carosi: The, the Dickey radiometer equation is really what sets the scan rate of Earth experiment. So you have a signal noise ratio and wish, you'll

118
00:21:41.790 --> 00:21:51.060

Gianpaolo Carosi: Declare that you've found an assay on are there something that appears to be an accion signal and that equation is made of, you know, the power that you get from the accion

119
00:21:51.960 --> 00:21:59.430
Gianpaolo Carosi: Over the noise temperature of your system that's effectively your background how much both physical noise and electronic noise is added to your system.

120
00:22:00.120 --> 00:22:09.270
Gianpaolo Carosi: And then you multiply that by the square root of the integration time how long you sit there and CO adding noise over the bandwidth of your experiment.

121
00:22:10.320 --> 00:22:22.470
Gianpaolo Carosi: So let's run through some of the numbers here. So we have for the accion it's at max experimental talk about in a minute. We have about an eight Tesla magnet with about a roughly 130 leader microwave cavaney in

122
00:22:23.400 --> 00:22:38.760
Gianpaolo Carosi: The quality factors or or 100,000 or so. And there's a form factor which I'm gonna get to in a second, which is basically the amount of coupling your accion has to any particular mode of your resident cavity. So those are basically the knobs that that we can turn

123
00:22:39.840 --> 00:22:54.300
Gianpaolo Carosi: Mother Nature, of course, gives us the coupling the mass and the local density and the coupling of the mass or are not known, but they're bounded at least to this range, the density is something we have a rough estimate of from

124
00:22:55.170 --> 00:22:59.970
Gianpaolo Carosi: From looking at how you know we move around in the Milky Way.

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00:23:01.860 --> 00:23:07.440
Gianpaolo Carosi: So as I mentioned before, even with our large eight Tesla magnets, a large or magnet.

126
00:23:08.430 --> 00:23:26.460
Gianpaolo Carosi: We only get are expecting 10 minus 2030 watts of power. And so in the kind of micro TV mass range and versus a scale for my creepy accion is a one gigahertz photon. We're talking, you know, a few 10s to hundreds of accion produced photons per second in this mass range.

127
00:23:28.680 --> 00:23:35.970
Gianpaolo Carosi: The integration time, as I mentioned, we we don't actually know what the accion masses, we still a free prouder of 30

128
00:23:36.960 --> 00:23:47.010
Gianpaolo Carosi: So we have to be able to scan over a large number of frequencies, we're limiting the amount of time we consider it anyone experiment we usually have that set to 100 seconds or so.

129
00:23:48.780 --> 00:23:55.950
Gianpaolo Carosi: And of course the background. This is where a lot of the r&d work has been done over the last decade or so the system noise temperature

130
00:23:56.640 --> 00:24:03.000
Gianpaolo Carosi: Is both the physical temperature and the noise mere electronics that are added your amplifiers to get them to a technical signal.

131
00:24:03.690 --> 00:24:14.910
Gianpaolo Carosi: The quantum limit, which I'll discuss a little more later. And it is frequency dependent and so at about one gigahertz. It's around 48 mil Calvin or so and it goes up linearly

132
00:24:15.750 --> 00:24:25.770
Gianpaolo Carosi: So right now we're operating the next experiment around hundred Mela Calvin or sell. So we're still firmly dominated. But as we go and frequency will begin to be become quantum

133
00:24:26.430 --> 00:24:31.830
Gianpaolo Carosi: Quantum limited by the linear profiles, we have. And there's ways to get around that, which I'll discuss in a minute.

134
00:24:33.030 --> 00:24:45.240
Gianpaolo Carosi: So I mentioned, real quickly, the form factor. So this is an example of the electric field that you would see from a transverse magnetic mode. This is a kind of a basic mode of a cylindrical cavity.

135
00:24:46.530 --> 00:24:55.710
Gianpaolo Carosi: And this particular mo. This is with no way of tuning the frequency would have a form factor of roughly six 9% or so. And that just has to do with the integration.

136
00:24:56.130 --> 00:25:04.020

Gianpaolo Carosi: Of the the mode over the the solenoid feel, which is effectively uniform. If you look at, say, a higher order mode.

137
00:25:04.770 --> 00:25:14.190
Gianpaolo Carosi: So there's the team 011 there's a note in between the two. And this gets back to the idea that the the the cavities that we're using in the end the detector apparatus.

138
00:25:14.520 --> 00:25:25.800
Gianpaolo Carosi: Is very small relative to the size of the actual accion oscillation. So the fact that it sees this oscillation sees this as one unit. The integration would be effectively zero

139
00:25:26.490 --> 00:25:38.310
Gianpaolo Carosi: So there's only a few moments, which we have to determine via simulations and with other techniques to look at the cavities electric field profile that actually interact with the axiom.

140
00:25:39.900 --> 00:25:43.680
Gianpaolo Carosi: Now you can turn this power and signal noise ratio into a scan rate.

141
00:25:44.040 --> 00:25:58.140
Gianpaolo Carosi: And that scan rate is given by this equation here. I'm not going to go through all the little details which parameter eyes to approximately what we expect for the DMX experiment to give us kind of a general scan rate, but I can't say that the coupling there.

142
00:25:59.190 --> 00:26:07.770
Gianpaolo Carosi: That point three six. That's the more pessimistic DFS the limits case Vz is about a factor of 2.7 higher than that.

143
00:26:08.220 --> 00:26:14.640
Gianpaolo Carosi: And so the difference in scan speed between looking for something at the more optimistic case Vizio sensitivity.

144
00:26:15.180 --> 00:26:33.360
Gianpaolo Carosi: And the more pessimistic DFS is he is roughly a little more than factor 50 we have to slow down the other things that are to note are the magnetic it goes to the magnetic field to the fourth power. So having a factor of two higher magnetic field.

145
00:26:34.410 --> 00:26:49.980
Gianpaolo Carosi: You to have much time to factor of 16 higher in terms of your actual scan MRI. So there's a there's a big premium to be made on

having a larger magnetic fields and as well as getting your noise temperature down that goes as a recipient of the square power.

146
00:26:52.080 --> 00:26:59.790
Gianpaolo Carosi: So the cavities that we have right now just a simple cartoon to show you how we tune them. They're basically a metallic structures which we have a

147
00:27:00.540 --> 00:27:11.490
Gianpaolo Carosi: Kind of a baseball bat sized tuning rod and the inside, which we moved from the edge to the center. So that's a resonant mode you can see there. We take data right at the top of this mode.

148
00:27:12.000 --> 00:27:18.060
Gianpaolo Carosi: And basically, the most of the noise and the outside is suppressed because it's outside the panel.

149
00:27:18.960 --> 00:27:32.130
Gianpaolo Carosi: And you can move that and you can move in frequency and that is how we do our search for us to microwave copy system, and most of the microwave cavity systems. I'll discuss some other ones may hear operate in more or less the same way.

150
00:27:33.570 --> 00:27:46.440
Gianpaolo Carosi: So here's the next experiment in its entirety. To give you an idea. It has uses a super nothing amplifiers, which we'll talk a little bit more in a second. Those are based on

151
00:27:48.420 --> 00:27:56.160
Gianpaolo Carosi: Joe some junctions and they rely on very small amounts of magnetic field essentially zero magnetic field regions.

152
00:27:56.610 --> 00:28:09.750
Gianpaolo Carosi: So if you recall, we have a Tesla magnet very close to it. So we have to do is we have to actually have a second magnet system appear to negate the field from our made our large dipole system Justin's region.

153
00:28:10.830 --> 00:28:26.520
Gianpaolo Carosi: Is a this second magnet system. This is a zero field region here which we can have not only our cryogenic amplifiers or quantum amplifiers, but all the circuit leaders all the switches all the magnetic sensitive components.

154
00:28:27.060 --> 00:28:38.010

Gianpaolo Carosi: Go into that region right there and the experiment has a delicious refrigerator on it to be able to get the main system noise down as cold as it can roughly we're operating at around 100 Milla Calvin right now.

155
00:28:40.200 --> 00:28:48.360
Gianpaolo Carosi: I'd like to discuss some of the enabling technology. One of those is really the Microsoft squid amplifier and I like to

156
00:28:48.960 --> 00:28:56.550
Gianpaolo Carosi: You know, mention, you know, Kent Irwin give a wonderful talk during is about two yeses. He introduced the the DC squid.

157
00:28:57.510 --> 00:29:16.320
Gianpaolo Carosi: This is very similar as a as a design modification that was perfect at UC Berkeley for us to john Clark's group. And the idea is that you couple this to Microsoft resonator, and that allows you to actually raise the frequency above the usual DC squid limits.

158
00:29:18.300 --> 00:29:29.640
Gianpaolo Carosi: I think it did a very nice job. But just to remind people, the you squid itself is basically a super nothing the loop with to do some junctions in between.

159
00:29:30.210 --> 00:29:41.550
Gianpaolo Carosi: And you can put a voltage bias on this and get effectively a flux, flux to voltage transducer so you can put this very close to a

160
00:29:42.300 --> 00:29:58.950
Gianpaolo Carosi: Signal an inductor signal that then is extremely sensitive and the data show here in the middle is from one of these devices as you bring the physical temperature down you can get very close to the quantum limit for this particular device.

161
00:30:00.780 --> 00:30:20.010
Gianpaolo Carosi: The. These are two double systems also, as I mentioned, is or Microsoft resonate here by putting a raptor diode on there, which is basically a attainable capacitor, you can create a tenable resonance structure. And this allows you to tune the frequency of your, your amplifier. This is a

162
00:30:21.060 --> 00:30:30.960
Gianpaolo Carosi: 20 dB or so, as a factor of hundred in gain you can tune that frequency. These are very low cues, the accuser, you know, 10s to hundreds

163
00:30:31.860 --> 00:30:43.740
Gianpaolo Carosi: Much, much broader band than the than the cavity line with which would be laid on top of this, but you can basically move the two together and optimize your signal as you continue to take data.

164
00:30:45.780 --> 00:30:46.170
Gianpaolo Carosi: There's

165
00:30:46.440 --> 00:30:47.310
Gianpaolo Carosi: Another type of

166
00:30:47.340 --> 00:30:48.570
Gianpaolo Carosi: Far, yes.

167
00:30:48.840 --> 00:30:53.940
Richard Partridge: We've an occasional glitches. Sometimes they helped if you turn off your video.

168
00:30:54.780 --> 00:30:55.650
Gianpaolo Carosi: Oh yeah, absolutely.

169
00:30:56.790 --> 00:30:58.170
Richard Partridge: Let me go ahead and do that real quick.

170
00:30:58.890 --> 00:31:00.450
See if I can do that on the fly.

171
00:31:04.560 --> 00:31:05.250
Yes.

172
00:31:06.330 --> 00:31:09.210
Gianpaolo Carosi: Sir. It's not letting me go out of it.

173
00:31:12.690 --> 00:31:13.410
There we go.

174
00:31:14.850 --> 00:31:15.900
Gianpaolo Carosi: How's that, is that better.

175
00:31:18.090 --> 00:31:18.900

Richard Partridge: Yes, thanks.

176
00:31:20.280 --> 00:31:20.610
Richard Partridge: Thanks.

177
00:31:20.640 --> 00:31:29.250
Gianpaolo Carosi: So, um, there's another type of amplifier which we started using more recently called a justice and parametric amplifier and it's basically a variation on a theme.

178
00:31:30.210 --> 00:31:41.550
Gianpaolo Carosi: The JP, as we're also provide a bit UC Berkeley by our funds to decrease group and they also use Joseph junctions and they use a squid. That's basically bias with a shock capacitor

179
00:31:42.780 --> 00:31:51.480
Gianpaolo Carosi: But the way that you get amplification here is you have a pump tone of pumped on that sent in there and then any signal that comes through mixes with that punk tone.

180
00:31:51.900 --> 00:32:00.780
Gianpaolo Carosi: Through this superconducting elements and Dan Harmon. This city is in this allow energy to be transferred from the pump tone to a signal tone.

181
00:32:01.350 --> 00:32:17.820
Gianpaolo Carosi: And these are exclusive, these are these are wonderful devices you can tune them also by putting a small flux bias underneath that tunes the resonant frequency of the amplifier in a similar way that we tuned the the MSA

182
00:32:20.160 --> 00:32:28.950
Gianpaolo Carosi: So we run both of these amplifiers, the MSA is our good somewhat below about a few gigahertz the GPA is have been used up to

183
00:32:30.060 --> 00:32:32.610
Gianpaolo Carosi: 10s of gigahertz or so and hire

184
00:32:34.200 --> 00:32:44.280
Gianpaolo Carosi: The way we operate them is very similar. So what I'm showing here or there are two different plots one with an MSA, which is a to port device which we can switch in and out of circuit.

185
00:32:44.790 --> 00:32:56.850

Gianpaolo Carosi: The other one is with a GPA. On the right hand side. And the only difference really operationally is the GPA has a circulator their non reciprocal devices that allow

186
00:32:57.510 --> 00:33:05.790
Gianpaolo Carosi: Photons to move in one direction, but not return and the other directions basically zero dB. One way 20 DB have lost the other way.

187
00:33:07.290 --> 00:33:14.340
Gianpaolo Carosi: And so the GPA can actually be operated. If you don't put any power on it effectively like

188
00:33:15.330 --> 00:33:22.050
Gianpaolo Carosi: A perfect mirror. It's basically a superconductor. And you can just bounce signals directly off and she by turning the GPA off.

189
00:33:22.680 --> 00:33:33.990
Gianpaolo Carosi: We can actually just bounce signals off and characterize the system, the MSA, however, looks like a very large resistor. So we have to actually have to physically remove that using additional switches

190
00:33:35.220 --> 00:33:45.180
Gianpaolo Carosi: So the first operations we had with the idioms experiment with the MSA and subsequently we've transitioned to JP as moving forward.

191
00:33:47.220 --> 00:34:03.570
Gianpaolo Carosi: Now here's an example of some data that we've taken as want to go through the process of how the accion signal is is collected. What we do is we look over small bandwidth a bit larger than the cavity resonance and we integrate

192
00:34:04.590 --> 00:34:09.360
Gianpaolo Carosi: Noise and any accion signals that might be there to a certain signal noise threshold.

193
00:34:10.770 --> 00:34:21.480
Gianpaolo Carosi: We then move the accion resonance. So the, the cavity resonance and repeat that we continually do that and add up a signal and anything above

194
00:34:22.350 --> 00:34:25.890

Gianpaolo Carosi: That threshold gets flagged as a potential accion candidate.

195
00:34:26.670 --> 00:34:36.120
Gianpaolo Carosi: Now there's a couple of possibilities. You can have either just noise, statistically, you can get signals that are above the threshold and what you can do there is you can just

196
00:34:36.900 --> 00:34:49.170
Gianpaolo Carosi: rescan that region and the blue lines. The blue points here aren't initial scan and you can see that there's 2.2 points here that actually it was above our candidate threshold.

197
00:34:50.100 --> 00:35:01.590
Gianpaolo Carosi: The orange is data with a subsequent rescan and you can see that there's a there was a statistical anomaly that disappeared after subsequent rescan so it wasn't a persistent signal.

198
00:35:02.580 --> 00:35:13.620
Gianpaolo Carosi: However, in the middle you can see there is a persistent signal. And so what this turned out to be was we we do have a synthetic accion channel in which we can send in

199
00:35:15.120 --> 00:35:25.590
Gianpaolo Carosi: Blinded signals we have a team that knows that mixes up an axiom line shape and puts it into the very base of the cabinet very weakly couple of the cavity.

200
00:35:26.160 --> 00:35:41.790
Gianpaolo Carosi: And that system with regards to the gas to injection allows us to calibrate and look for any particular accion. Well, it allows us to calibrate our system, make sure we're picking up all the axioms that we would expect to see

201
00:35:43.320 --> 00:35:50.730
Gianpaolo Carosi: A very cool thing I like about this experience that we ever see a signal that we can ascribe to, you know, fake accion

202
00:35:51.360 --> 00:36:02.880
Gianpaolo Carosi: One way we can roll out candidates is by either moving into a mode that does not couple the accion. And so if we saw who moved to a mode and we were still seeing a signal through

203
00:36:03.750 --> 00:36:15.750

Gianpaolo Carosi: That's a good hint that we're seeing external external events like radio towers like that coming in another knob that we have is we have the magnetic field.

204
00:36:16.590 --> 00:36:22.770
Gianpaolo Carosi: We can always turn the magnet DOWN AND IF WE SINCE IT GOES since the power goes is via the

205
00:36:23.220 --> 00:36:35.820
Gianpaolo Carosi: Via the fourth we can turn it down and see that single go down the same amount. So that's kind of a smoking gun. And so far, we have unfortunately not found that yet, but we have a way to easily confirm if it's actually on or not.

206
00:36:37.410 --> 00:36:44.580
Gianpaolo Carosi: So we have multiple experiments actually operating the same time. The first one is, there are large main cavity system, but we have a

207
00:36:44.940 --> 00:36:59.340
Gianpaolo Carosi: Second higher frequency cavity system, which we call our sidecar cavity to test out different technologies. That's not really sensitive to primordial accion QC axiom, but I wouldn't be sensitive sensitive to these outs or accelerate particles.

208
00:37:01.170 --> 00:37:03.420
Gianpaolo Carosi: Recently we've published data in the

209
00:37:05.130 --> 00:37:09.360
Gianpaolo Carosi: 650 to 800 megahertz range this data.

210
00:37:10.740 --> 00:37:13.800
Gianpaolo Carosi: Is published in two bins. The first

211
00:37:15.840 --> 00:37:25.320
Gianpaolo Carosi: Was done with a microscope squid amplifier and the subsequent run was done with the GPA and this was published this lot this last

212
00:37:26.370 --> 00:37:34.860
Gianpaolo Carosi: March and currently we're increasing our scan rate as we go up in frequency, you know, get that little bit

213
00:37:36.240 --> 00:37:42.810

Gianpaolo Carosi: I should also mention there's new RF technologies that we're applying one includes a new traveling wave parametric amplifier to

214
00:37:43.800 --> 00:37:56.040
Gianpaolo Carosi: This user is basically a long array of Joseph injunctions that are phase match with a pump so similar to the GPA, the GPA is are relatively narrow band, you know, a few matter hurts or so.

215
00:37:57.570 --> 00:38:11.190
Gianpaolo Carosi: The traveling way impairments and fires, though, are much broader been you know gigahertz of instantaneous bandwidth. And so these would be very interesting. And we're exploiting them right now as possibilities for multiplexes or other other techniques.

216
00:38:12.360 --> 00:38:20.940
Gianpaolo Carosi: Here's an example. We actually had this system placed on the same project paddle that we're using for the GPA and it's attached to our

217
00:38:21.540 --> 00:38:32.460
Gianpaolo Carosi: sidecar Kathy system which matches that frequency range kind of the four to eight gigahertz range and they're fairly close to quantum live within factor to quantum one

218
00:38:35.100 --> 00:38:46.650
Gianpaolo Carosi: So moving up in frequency is actually quite challenging. As I mentioned, our current county system is around 130 liters or so and uses a coop to have these kind of two to four inch

219
00:38:47.490 --> 00:38:56.310
Gianpaolo Carosi: Size tuning rods, the one in the middle is the one we're actually operating right now up to about it will eventually get up to about 1200 megahertz.

220
00:38:57.450 --> 00:39:14.010
Gianpaolo Carosi: However, to go higher, the rods become too large and you end up not being the correct scale. So to go above kind of a gigahertz or so about 1.2 gigahertz and up we are switching over to what we call it for copyright

221
00:39:15.060 --> 00:39:24.630
Gianpaolo Carosi: These multi cavity systems. As a reminder, the accion sees this experiment as one system and so you have a coherent accion signal.

222

00:39:25.080 --> 00:39:35.550
Gianpaolo Carosi: That's all you can do is you can increase the scan rate relative to individual cavities by taking advantage of that coherence your accion is adding currently

223
00:39:35.880 --> 00:39:50.040
Gianpaolo Carosi: The noise me individual cavities should add incoherently so there's a square of improvement in the power that you get for for axioms that are for cavity systems that that are coherently adding a signal.

224
00:39:52.080 --> 00:39:53.820
Gianpaolo Carosi: So here's kind of our notional

225
00:39:54.900 --> 00:40:03.480
Gianpaolo Carosi: Operation range for the next decade or so we're currently, as I mentioned, operating in the gigahertz range right now, we call run one see

226
00:40:04.560 --> 00:40:15.210
Gianpaolo Carosi: The blue kind of hash mark is what we're planning to go with our next generation to experiment. So the forecast the array. It's going to be able to get us up to about two gigahertz or so.

227
00:40:15.960 --> 00:40:26.430
Gianpaolo Carosi: We're in a planning phase right now through the new dark matter initiative to to extend that multi cavity systems, up to around four gigahertz.

228
00:40:27.360 --> 00:40:36.180
Gianpaolo Carosi: Beyond that, beyond that we're looking at larger magnet systems as well as squeezing or single photon counting. And so, and

229
00:40:36.720 --> 00:40:51.030
Gianpaolo Carosi: I'm going to get to a little more of the details of squeezing in a second here. But this is effectively the at max operation strategy for the next decade or so basically detect or rule out the DFS Z class accion to 10 gigahertz.

230
00:40:52.380 --> 00:40:56.070
Gianpaolo Carosi: Other experiments that are actually come online than the last few years as well.

231
00:40:58.230 --> 00:41:09.360

Gianpaolo Carosi: A one is a NSF sponsored experiment called haystack. It's a Yale experience very similar in concept to the at max experiment smaller in size. It's about a

232
00:41:10.110 --> 00:41:25.770
Gianpaolo Carosi: two liter cavity, but the magnets little bit stronger to 9.4 Tesla system, they've been using GPS, since they started. There's a couple of results out right now, which I want to hear and they're looking at a much higher mass range kind of the

233
00:41:27.690 --> 00:41:41.430
Gianpaolo Carosi: You know 5.7 gigahertz, and they're about factor of two away from chaos Vz sensitivity and that a lot of that has to do with the fact that, you know, you lose volume very quickly as you try to scale your system down

234
00:41:42.570 --> 00:41:51.030
Gianpaolo Carosi: Because the resonant frequency basically goes as one of our, our, and so by going to a smaller cavity you've cut out a tremendous amount of your

235
00:41:51.810 --> 00:42:00.510
Gianpaolo Carosi: Of your back of your single source. Nevertheless, they have some very cool experiments that they're doing on squeezing, which I'll get to in a second.

236
00:42:02.130 --> 00:42:12.720
Gianpaolo Carosi: There's other around the world. There's experiments at the Center for axiom precision physics in South Korea. This is using a couple of new

237
00:42:13.590 --> 00:42:28.290
Gianpaolo Carosi: Ideas and cavities, including phase matching different multi cell cavities. You can see on the left, they have an initial experiment that was recently published and you can see that in the head of the red reaching here about 1.6

238
00:42:30.120 --> 00:42:41.820
Gianpaolo Carosi: Gigahertz about 6.7 micro up and they're doing some really cool stuff on server. Nothing microwave cabbies using why Vizio to try and really high cube cavities as well.

239
00:42:44.070 --> 00:42:49.530
Gianpaolo Carosi: Also, there's the Oregon experiment, the oscillating resident group experiment and the rest of Western Australia.

240
00:42:50.160 --> 00:42:59.970
Gianpaolo Carosi: They're looking much higher frequency of the kind of the 2627 gigahertz range. They've spent taken data recently with a small prototype.

241
00:43:00.360 --> 00:43:09.450
Gianpaolo Carosi: And they're looking at higher order modes of the the resident structure, as I mentioned, you know, at max is primarily looking at the fundamental teams are one zero like mode.

242
00:43:09.780 --> 00:43:18.840
Gianpaolo Carosi: They're looking at, you know, teams are 20030 they couple less they accion but they're naturally a much higher resonance frequency

243
00:43:19.560 --> 00:43:35.460
Gianpaolo Carosi: And so they have some notional aspirations to try to get closer to the kind of chaos Vz acronyms here but there, they will be sensitive to these accion light particles and they're relying on upgrades of high magnetic fields and getting past the quantum limit.

244
00:43:37.110 --> 00:43:45.090
Gianpaolo Carosi: So quantum wanna. That's one of the big things that's going to be slowing us down in the near future for these classes experiments. As I mentioned before, you know,

245
00:43:45.720 --> 00:43:52.170
Gianpaolo Carosi: Have a gigahertz quad on limit goes linearly with the frequency. And so we're looking at, you know, 24

246
00:43:52.860 --> 00:43:58.890
Gianpaolo Carosi: Milla Calvin for fun records. But as you get up to the five gigahertz range. Now you're looking at a quarter to Calvin.

247
00:43:59.670 --> 00:44:10.860
Gianpaolo Carosi: And that's that slows your experiment down tremendously to get the same signal noise ratio gets to take a lot more data because that scan rate goes as temperature square ever temperature, squirt.

248
00:44:12.210 --> 00:44:21.390
Gianpaolo Carosi: The Haystack experiments does a really interesting work recently with individual cavity systems to try and do squeezing to try and get past that quantum limit.

249

00:44:21.990 --> 00:44:34.950
Gianpaolo Carosi: So I'm gonna type that in a second. In addition, you can look at single photon detection, which is kind of taking that to the natural conclusion and only measure the power throw away any face information and that also gets you past quantum limit.

250
00:44:36.540 --> 00:44:40.710
Gianpaolo Carosi: Let's talk a little about the squeezing. This is a really cool technique. I'm gonna try and go through it.

251
00:44:42.240 --> 00:44:55.680
Gianpaolo Carosi: In a little bit of detail here, but the way you can model the system is what's shown in green is that you have a cavity, it's hooked up to it. An accion source that's K sub A. It is an oscillating source.

252
00:44:56.310 --> 00:45:06.930
Gianpaolo Carosi: You also have losses in the walls of your cafe, you can model that is just a resistor. You're just losing. And that's what you know the more losses, you have the lower quality factory Cappy.

253
00:45:07.890 --> 00:45:19.740
Gianpaolo Carosi: What you can do is you can also inject power. You can send in power at a specific phase. And there's two ways. You know, the phase information in these

254
00:45:20.700 --> 00:45:32.580
Gianpaolo Carosi: These are these are operators that are Mishra operators that are has had both the phase and the amplitude information. So if you send in phase information you can squeeze the vacuum.

255
00:45:33.330 --> 00:45:45.780
Gianpaolo Carosi: Any added noise in your system. If it's out of, out of phase with that gets amplified and so the comparison here between the no squeezing and once you take your, your signal which has which is

256
00:45:46.500 --> 00:45:56.130
Gianpaolo Carosi: Just in the X and the Y quarters there as you add noise. You've increased that whole thing. And then as you add a yoke an amplifier to just one is JP is

257
00:45:56.700 --> 00:46:06.450
Gianpaolo Carosi: Your signal noise ratio stays about the same there if you squeeze it if you actually, you know, it has one of the quarter ensures at the expense of the other

258
00:46:07.050 --> 00:46:16.440
Gianpaolo Carosi: And then boost the signal in the other quarter. Sure, you can get a larger signal to noise ratio. And so that's the basic concept.

259
00:46:17.160 --> 00:46:24.030
Gianpaolo Carosi: You can get a broader sillerman ratio. So you can kind of see this here, you have a signal tone, which

260
00:46:24.630 --> 00:46:35.340
Gianpaolo Carosi: Window, you get a little bit of degradation, because it's more complicated system of your signal power. The ratio between your signal your noise floor has gone up tremendously.

261
00:46:35.880 --> 00:46:48.600
Gianpaolo Carosi: You can kind of see here this is like looking at a single cavity structured cabling mode, you've effectively made a much more broadband signal. So you can integrate more of the accion

262
00:46:49.980 --> 00:47:03.810
Gianpaolo Carosi: Mass range off of resonance and that allows you to take wonder steps and they've demonstrated effectively a factor of two enhancement in the scan rate. This is currently being investigated for accion searches in the haystack group.

263
00:47:05.580 --> 00:47:12.480
Gianpaolo Carosi: If you take that to the full extreme. What you can do is you can do photon counting photon County. If you take that

264
00:47:13.080 --> 00:47:20.250
Gianpaolo Carosi: That phase or representation representation of an oscillation in which you have either amplitude or your phase.

265
00:47:21.240 --> 00:47:38.520
Gianpaolo Carosi: Where you can do is you can actually take that phase region and smear all the way around your face is completely undefined. But you know exactly what your amplitude is, you know, how many photons, you have in your system and this is effectively a photon county experiment.

266
00:47:39.720 --> 00:47:49.080
Gianpaolo Carosi: And this, you know, led to the Nobel Prize by Sergei Hirsch and 2012 we did this for Q amp D and Adams.

267

00:47:49.830 --> 00:47:58.140
Gianpaolo Carosi: There was actually a ripper Adam experiment that was done called care act in the late 90s, early 2000s that tried to utilize us they tried to use

268
00:47:58.590 --> 00:48:09.450
Gianpaolo Carosi: Revenue items that would be detecting these photons from the accion field generated in your microwave cavity and then you would you read out individual photons.

269
00:48:10.050 --> 00:48:16.980
Gianpaolo Carosi: So by getting rid of the the access the information that you really don't need from the phase.

270
00:48:17.940 --> 00:48:30.240
Gianpaolo Carosi: You can get below that quantum limit and you basically end up in the Heisenberg limit, which is where shot noise becomes important. Some you still need to be able to detect some power from your system. So as a result.

271
00:48:31.890 --> 00:48:37.050
Gianpaolo Carosi: You know that the experiments that have been done since the late 90s, early 2000s.

272
00:48:38.220 --> 00:48:47.220
Gianpaolo Carosi: Are being reinvestigated now and I pointed to rain mariama Yale is investigating using river Adams to try and do single photon read at

273
00:48:48.450 --> 00:48:49.170
Gianpaolo Carosi: Addition.

274
00:48:50.220 --> 00:48:51.540
Gianpaolo Carosi: Chris Martin cubits

275
00:48:52.740 --> 00:48:58.980
Gianpaolo Carosi: Have been really coming of age in terms of their ability to look at single photons.

276
00:49:00.000 --> 00:49:10.620
Gianpaolo Carosi: Now these are effectively cubits based on the Justin Johnson was listed before I mentioned before, it's a single Cooper pair box, but you can shut it with a pastor

277

00:49:11.190 --> 00:49:18.720
Gianpaolo Carosi: And that can get the energy levels are in a range with her in this city is low enough, you can actually see the individual levels.

278
00:49:20.220 --> 00:49:26.640
Gianpaolo Carosi: So these are very simple devices in theory basically just having some junction with a couple of large pals between them.

279
00:49:27.150 --> 00:49:37.470
Gianpaolo Carosi: And you can couple them in your microwave cavities. So what you can do is you can see if there's a individual photon your cavity and do what they call non demolition experiments which is

280
00:49:37.920 --> 00:49:45.540
Gianpaolo Carosi: A really fascinating way of looking at it. You're actually continually sampling weekly that there's a there's a photon in the

281
00:49:45.900 --> 00:49:59.850
Gianpaolo Carosi: Cavity and you sample it a number of times before to individually to case you're not actually absorbing the photon. The photon stays there. Almost like a you know bowling ball that you'd measure anytime those non English experiments are you continually measure it.

282
00:50:00.990 --> 00:50:09.840
Gianpaolo Carosi: So these at these can be proven to be operational they currently have some issues with noise in terms of too high of Count race dark count rates.

283
00:50:10.950 --> 00:50:21.120
Gianpaolo Carosi: But there's a monetized project being led by Aaron show at the fair me lab to try and make these usable product for accion searches telescopes.

284
00:50:22.980 --> 00:50:32.520
Gianpaolo Carosi: Now there could be a tremendous amount of speed up that you can get from this and I pointed this nice paper by Conrad Leonard and Company, which showed that

285
00:50:33.420 --> 00:50:38.970
Gianpaolo Carosi: As long as you get down to shot noise limited. You can greatly increase your scanner. So they do a couple of examples.

286
00:50:39.510 --> 00:50:57.630

Gianpaolo Carosi: There's a crossover points around, you know, 10 gigahertz. If you're at the hundred mil Kelvin range which single photon counting begins to two wins that you know we look at above the counting rate of that green line above the pay cash line there.

287
00:50:58.890 --> 00:51:11.010
Gianpaolo Carosi: If you can get your temperatures lower if you can get your background levels down enough that you get less false positives that you can be begin to do that with you know 50 mil a calendar even less.

288
00:51:12.360 --> 00:51:28.680
Gianpaolo Carosi: And so if we can get our. This is one of the things we would love to be able to get part of the problem is, of course, the there's a fundamental issue with the app that single photon counters themselves are somewhat hot relative to the amount of time you have to stay cold for these searches.

289
00:51:29.880 --> 00:51:30.750
Gianpaolo Carosi: But this is an active

290
00:51:31.200 --> 00:51:32.400
Gianpaolo Carosi: Part of research. Yes.

291
00:51:33.300 --> 00:51:33.930
Richard Partridge: Five minutes.

292
00:51:34.740 --> 00:51:35.130
Gianpaolo Carosi: Okay.

293
00:51:35.160 --> 00:51:36.390
Gianpaolo Carosi: Thank you. I'll go ahead and

294
00:51:36.810 --> 00:51:42.660
Gianpaolo Carosi: quickly wrap up. So there's a couple of other experiments. I'm just going to go through them relatively quickly. Since we're running out of time.

295
00:51:43.380 --> 00:51:48.690
Gianpaolo Carosi: You can take this detector concept of a single cavity and for higher frequencies.

296
00:51:49.380 --> 00:51:57.270
Gianpaolo Carosi: You can look at it as another way of creating high form factors. By putting a bunch of dielectric modulating dielectric

297
00:51:57.750 --> 00:52:10.350
Gianpaolo Carosi: That what that does it squeezes the electric field enough that you can actually get a non negligible form factor in a dipole system. And I point to the Orpheus project, which is open resonator system that's being

298
00:52:11.010 --> 00:52:14.430
Gianpaolo Carosi: Looked at, at the University of Washington sponsored by the assignments foundation

299
00:52:16.140 --> 00:52:22.890
Gianpaolo Carosi: Kind of a similar version of that is the Mad Max experiment which is a large set of open resin.

300
00:52:23.400 --> 00:52:38.460
Gianpaolo Carosi: Sorry, a large set of dialectics there is no there's only one beer on it. And the idea is that you have a large receiver so that you have axioms that are generated each interface and they constructively interfere and you get some excess power at the end.

301
00:52:39.570 --> 00:52:42.960
Gianpaolo Carosi: This is kind of going through the prototype faces experiment in Germany.

302
00:52:44.220 --> 00:52:56.460
Gianpaolo Carosi: Eventually they want to use a very large, very ambitious 10 Tesla magnet with a meter bore, but they expect to have at least some prototypes operational the next few years. And I pointed these paper here for more details.

303
00:52:57.600 --> 00:52:59.130
Gianpaolo Carosi: Have to go lower masses.

304
00:53:00.270 --> 00:53:15.900
Gianpaolo Carosi: You can look at replacing your resident cavity with an LLC circuit and so that LC circuit X in the same way that your resonator does, but in a distributed fashion. So you actually have a tunnel system such as a Justin junction or

305
00:53:17.430 --> 00:53:27.570
Gianpaolo Carosi: Outside of your magnet magnetic field region you're sampling is a similar effect, but it is a distributed system instead of a kind of lumped element.

306
00:53:27.990 --> 00:53:37.230
Gianpaolo Carosi: Way of looking at it, rather than a microwave cavity and there's some data that's been recently taken by the slit collaboration part of at max at the University of Florida.

307
00:53:38.820 --> 00:53:50.070
Gianpaolo Carosi: Unfortunately, I have to go relatively quickly now but there's I would push to the Abracadabra experiment that's taken data recently up at the low mass range. You can see here circled in red.

308
00:53:51.210 --> 00:54:02.220
Gianpaolo Carosi: This is a clever experiment is tries to take data in a has a turtle magnet. And so there's a field free region outside that which they're actually looking for the X accion field effect.

309
00:54:03.480 --> 00:54:07.620
Gianpaolo Carosi: And you can look at either a resident search or a non resident search

310
00:54:08.910 --> 00:54:15.000
Gianpaolo Carosi: And also like to point to DM radio dark matter radio. This is a slack lead experiment.

311
00:54:15.780 --> 00:54:22.650
Gianpaolo Carosi: I think Kent or or one was going to talk about it yesterday but or the other day and ran out of time a little bit. So I wanted to give a little advertisement for their group.

312
00:54:23.430 --> 00:54:32.970
Gianpaolo Carosi: They as Pathfinder experiments. They are also looking at the low frequency range and they're partnering with the advocate app or experiment to try and really push harder than that.

313
00:54:33.930 --> 00:54:42.420
Gianpaolo Carosi: parameter space. There's a really interesting ideas that unfortunately don't too much time to go through here. I'd prefer to Kent, they have a contest experiment.

314
00:54:42.810 --> 00:54:52.860
Gianpaolo Carosi: Point eyes program to be able to get around some of that back action with these low frequency detectors by doing up conversion, which is a really clever idea.

315
00:54:53.550 --> 00:55:07.860

Gianpaolo Carosi: And unfortunately I don't have too much time there's an M Mr based experiments which is the CASPER electric and Casper when these don't coupled to the accion photon field there is the to the electric field. The glow on field or pheromones.

316
00:55:09.240 --> 00:55:19.470
Gianpaolo Carosi: Basically, the general concept very quickly is that you have some Mr material you have some spins that you can put a you can bias with external magnet.

317
00:55:19.950 --> 00:55:26.700
Gianpaolo Carosi: And then you can slowly scale fields and look for a resident enhancement. If that

318
00:55:27.450 --> 00:55:38.760
Gianpaolo Carosi: Lamar frequency equals the same as the axial incompetent frequencies so sensitive very low, kind of, you know, very, you know, Nano EV to to

319
00:55:39.570 --> 00:55:56.790
Gianpaolo Carosi: You know femto EV or less axioms. You can also look for a gradient. This is called accion wind. So you can look for gradient in the accion field as well. What's your place that electric field with the wind with what we call the accion when that gradient, you see from axiom.

320
00:56:00.180 --> 00:56:06.240
Gianpaolo Carosi: Unfortunately, I think I'm running out of time, so I don't really have to talk about that quacks experiment, the similar concept.

321
00:56:06.570 --> 00:56:20.970
Gianpaolo Carosi: In which you're actually looking for the electron accion coupling, as opposed to the nuclear accident and coupling that Kaspersky yeah so they're higher frequency and they're using gig spheres, a small Kathy I refer you to their paper and they have a very recent result as well.

322
00:56:22.020 --> 00:56:32.460
Gianpaolo Carosi: And finally there's a fit for searches where you actually are looking for the accion as a force mediator. So you're not actually looking for dark matter. It's another laboratory experiment.

323
00:56:33.030 --> 00:56:48.540
Gianpaolo Carosi: But you're looking for time very big fields that Dr. Spin per session and the Ariadne experiment right now is building a squid Mac magnetometer to try to look for these just slight deviations in in

324
00:56:49.710 --> 00:56:56.820
Gianpaolo Carosi: In how interactions are happening inside point to their experiments. And while they're there has some prototypes coming out soon.

325
00:56:57.930 --> 00:57:05.970
Gianpaolo Carosi: So just to summarize accion or first postulate is strong saw the strong CP problem they make a natural cold dark matter candidate.

326
00:57:06.600 --> 00:57:13.680
Gianpaolo Carosi: Asked him like particles are really a generic consequences to string theory I may explain some anomalous astrophysical measurements.

327
00:57:14.100 --> 00:57:32.040
Gianpaolo Carosi: There's a broad set of protection strategies that exists, including generating and detecting accion in the lab or detecting accion generating the sun or detecting dark matter axioms. There's a huge amount of parameter space that's being explored right now.

328
00:57:33.750 --> 00:57:42.150
Gianpaolo Carosi: This techniques really relying on detection of coherence signals so they they leverage quantum metrology and really interesting prospects and of

329
00:57:42.630 --> 00:57:55.590
Gianpaolo Carosi: Quantum enable technology over the next decade or so. So I think these experiments are really pose to rapidly explore for outer space. And I hope actually discovered the accion in the next 10 years or so. So thank you.

330
00:57:58.260 --> 00:58:10.320
Richard Partridge: THANK YOU, JOHN Paulo for really a wonderful clear and very comprehensive talk on this subject. So I'm going to be turning off the recording.

331
00:58:11.850 --> 00:58:12.450
This paper.