WEBVTT

1
00:00:03.149 --> 00:00:14.759
thomas rizzo: Okay, so we're happy to have with us. Aaron Rubin from slack was going to start today off and he's going to give us the second lecture on presence in future dark energy probes. Take it away, Aaron.

2
00:00:15.480 --> 00:00:16.020
Good.

3
00:00:17.400 --> 00:00:18.060
Aaron Roodman: Thank you.

4
00:00:19.619 --> 00:00:23.430
Aaron Roodman: More morning or good afternoon escapes me being everyone

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00:00:31.860 --> 00:00:35.250
Aaron Roodman: Alright, I hope everyone can see my slides.

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00:00:37.980 --> 00:00:38.790
Aaron Roodman: So yeah, so

7
00:00:38.820 --> 00:00:41.550
Aaron Roodman: I'm here in Redmond I'm professor in Slack.

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00:00:43.200 --> 00:00:46.440
Aaron Roodman: My pleasure to present my second lecture to you so

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00:00:48.210 --> 00:01:00.240
Aaron Roodman: The title is present and future dark energy probes yesterday I talked about the presence focusing on measurements we cleansing by the dark and disturbing. Today I'm going to talk about the future.

10
00:01:02.640 --> 00:01:03.180
Aaron Roodman: So,

11
00:01:04.770 --> 00:01:12.720
Aaron Roodman: This area of science has attracted so much interest and excitement that they're there a panoply of new

12
00:01:13.920 --> 00:01:26.100

Aaron Roodman: Projects performing galaxy surveys of various sorts to attack the problem of dark energy, as well as actually a host of other scientific questions.

13
00:01:27.210 --> 00:01:43.740
Aaron Roodman: There. This is actually isn't even comprehensive other there are one or two other projects that have that aren't quite galaxy surveys, but or other kinds of surveys exist, too. But there for big projects to come to underground

14
00:01:45.120 --> 00:01:46.470
Aaron Roodman: The Rubin Observatory.

15
00:01:48.270 --> 00:02:05.730
Aaron Roodman: Desi dark energy spectroscopic instrument Euclid a space. Space Telescope from the European Space Agency and the Nancy Roman space telescope which had been called W. First, a NASA Space. Space Telescope.

16
00:02:07.170 --> 00:02:19.860
Aaron Roodman: So today I'm going to tell you about the ground based projects and largely ads because those are the ones I'm working on, personally, and those are further along in construction.

17
00:02:21.810 --> 00:02:24.810
Aaron Roodman: I'll talk mostly about the ribbon Observatory, which is

18
00:02:26.850 --> 00:02:37.410
Aaron Roodman: Projects that many of us at slack are working on and hopefully I'll have enough time. I'll tell you a little about Desi, which I'm also a member of person.

19
00:02:38.730 --> 00:02:41.160
Aaron Roodman: So let's let's launch in

20
00:02:44.340 --> 00:02:48.270
Aaron Roodman: We're gonna start with the VC room and Observatory now um if

21
00:02:49.590 --> 00:02:59.250
Aaron Roodman: Recently we we changed the name of the project. It had been Ellis st which used to mean large not fixed Survey Telescope.

22
00:03:00.540 --> 00:03:03.480
Aaron Roodman: But today means legacy survey of space and time.

23
00:03:04.680 --> 00:03:09.120
Aaron Roodman: The Rubin Observatory. There's the engineering drawing is shown on

24
00:03:10.770 --> 00:03:11.550
Aaron Roodman: The left

25
00:03:13.200 --> 00:03:27.150
Aaron Roodman: You know, here's a, here's a CAD model person to give you a scale of the of the instrument and and the right is the camera and we're building this camera which is going to be the world's largest digital camera.

26
00:03:28.170 --> 00:03:39.750
Aaron Roodman: Or I would say here, but it's going to be built at slack. It is being built that slide. Now, together with the survey is going to be a killer movie of the scope

27
00:03:40.920 --> 00:03:45.000
Aaron Roodman: It's an optical Near Infrared Survey of the entire Southern Hemisphere.

28
00:03:46.170 --> 00:03:52.560
Aaron Roodman: To depth of 27th magnitude. So if you're calibrated magnitude says extremely dim objects.

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00:03:54.420 --> 00:04:01.470
Aaron Roodman: And it will be imaged hundreds of times close to 1000 times in six

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00:04:03.210 --> 00:04:10.140
Aaron Roodman: Wavelength bands over 10 years and the mantra of the project, which I will explain is why deep and fast.

31
00:04:11.940 --> 00:04:21.480
Aaron Roodman: This is really a unique instrument any unique survey with a very wide range of science goals. One of the most important of which is dark.

32
00:04:22.740 --> 00:04:37.080
Aaron Roodman: So I want to tell you about this project in detail. And I want to point to motivate the design and I have a feeling I haven't looked at all the slides for the summer school, but often

33
00:04:38.220 --> 00:04:43.770
Aaron Roodman: These sort of experimental details instrumental details are left out of talks.

34
00:04:44.790 --> 00:05:01.410
Aaron Roodman: And so one of my ulterior motives, is to motivate the design of the raven Observatory and how to explain why we built it the way we built it, and what implications that as for the science, the science of darkness.

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00:05:03.780 --> 00:05:06.840
Aaron Roodman: Okay, but before even doing that. Maybe I'm just worried about if you're a reuben.

36
00:05:08.310 --> 00:05:13.230
Aaron Roodman: That's her on the left, she was a groundbreaking astronomer.

37
00:05:14.370 --> 00:05:28.260
Aaron Roodman: And perhaps is best known for her work, studying the rotation curves of galaxies. So the plot on the right is from her 1980 paper, looking at 21 galaxies.

38
00:05:30.390 --> 00:05:31.110
Aaron Roodman: And

39
00:05:32.490 --> 00:05:43.230
Aaron Roodman: Spectroscopic measurements of them as a function of distance from the center of the galaxy. You can see that the rotation curves have this interesting flat, flat shape.

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00:05:44.220 --> 00:05:57.390
Aaron Roodman: Which was impossible to understand if all the mass in the galaxy were in stars and this this provided one of the most compelling evidence is for dark matter.

41
00:05:58.890 --> 00:06:05.730
Aaron Roodman: It's still true today. And so we thought was quite fitting that our project was renamed in her honor

42
00:06:06.900 --> 00:06:08.160
Aaron Roodman: One other interesting

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00:06:10.380 --> 00:06:17.700
Aaron Roodman: Interesting detail is that actually she did this this work in this paper taking spectra at

44
00:06:19.470 --> 00:06:37.410
Aaron Roodman: Of the of the galaxies, the spectre were taken at the Kitt peak Observatory that with the mail telescope that's the telescope that desi instrument is mounted on today. And one of the was taken in the southern hemisphere with the

45
00:06:39.360 --> 00:06:48.330
Aaron Roodman: With the Blanco telescope that's the telescope. I used from dark energy surface. So those are really workhorse instruments. Okay.

46
00:06:49.770 --> 00:06:52.470
Aaron Roodman: Um, let's start with some of the

47
00:06:54.330 --> 00:07:02.130
Aaron Roodman: The overriding features in the design optimization for the ribbon Observatory and for the for the survey itself.

48
00:07:03.150 --> 00:07:13.080
Aaron Roodman: So if you want to get images of a very big region of the sky. So our case it's the entire southern hemisphere skyline.

49
00:07:13.890 --> 00:07:25.200
Aaron Roodman: And you want to do multiple times, you should maximize you want to maximize the face face or throughput that you can achieve, which is the product of the time do and observing time and time do

50
00:07:26.310 --> 00:07:34.530
Aaron Roodman: Is a face face. In this case it's the collecting area of the primary mirror. A times the field of view.

51
00:07:36.480 --> 00:07:48.330
Aaron Roodman: And omega. The Reuben observatories. It's on do is 340 roughly 340 meter squared degree square that is enormous. There's no other instrument close

52
00:07:51.450 --> 00:07:59.040
Aaron Roodman: One of the closest actually is the blank. I'm in dark energy camera, which is around 40 in those units. This the

53
00:08:01.620 --> 00:08:05.340
Aaron Roodman: The Subaru hype is from Pam is actually a little bit more than 40

54
00:08:07.230 --> 00:08:18.000
Aaron Roodman: Is very significant, but the next element is observing time. So the Reuben Observatory is a dedicated telescope and the camera is the only instrument.

55
00:08:18.630 --> 00:08:28.170
Aaron Roodman: So to understand the relevance that you have to understand associate the sort of the sociology of astronomy most telescopes are facilities. They're built

56
00:08:29.550 --> 00:08:35.280
Aaron Roodman: With multiple instruments that can be swapped in and out to me during the daytime for that nights observing

57
00:08:36.210 --> 00:08:49.650
Aaron Roodman: And that telescope time is is scheduled long whoever you know owns the telescope or in the case of public telescopes, you know, observers who write proposals and have their proposals accepted.

58
00:08:50.340 --> 00:09:02.820
Aaron Roodman: And so the notion is that the telescope time to share and sometimes shared quite broadly. So, for example, Subaru hikers prime cam which is Subarus the Japanese national telescope which

59
00:09:03.810 --> 00:09:21.480
Aaron Roodman: Is located on Monica and Hawaii is a shared facility and so is a, it's a big telescope. It's a, it's a very nice camera, but the the group doing certain galaxy surveys is only a small fraction of the telescope

60
00:09:23.820 --> 00:09:40.230
Aaron Roodman: So Reuben Observatory was purpose built for this survey and so has there are no proposal driven observing plans and the Reuben Observatory today. And so 100% of the time is devoted to the SST survey.

61
00:09:42.030 --> 00:09:56.700
Aaron Roodman: So that's where you start. And then you want to also maximize other aspects of your observations. You want to maximize image quality and optical throughput. So to get the most light and you get the sharpest images possible

62
00:09:57.720 --> 00:10:00.360
Aaron Roodman: So you want to go to a good astronomical site.

63
00:10:01.560 --> 00:10:05.220
Aaron Roodman: Repository is on Sarah town, which I'll show you some pictures up

64
00:10:07.200 --> 00:10:16.590
Aaron Roodman: In in chilling. There's a three mirror design to to provide excellent images. I'll talk about that. And we use

65
00:10:17.160 --> 00:10:22.110
Aaron Roodman: You know, at the time of the design. These were newer, of course, now there's there's 15 years of

66
00:10:22.980 --> 00:10:35.010
Aaron Roodman: More than 15 years of abuse of these kinds of CCD, we use a special sort of CCD that had excellent response in the near infrared, so called deactivation CCD. So I'll talk a little about that as well.

67
00:10:38.730 --> 00:10:47.460
Aaron Roodman: Okay, so our survey wide fast and D. Let's talk about each show. So why so

68
00:10:48.630 --> 00:11:03.030
Aaron Roodman: I'm the the area that the survey covers is critical for certain signs for dark energy that area is is equivalent to how much of the universe, you can observe

69
00:11:04.140 --> 00:11:09.330
Aaron Roodman: And really, the more the better. And so looking at the entire sky is a great

70
00:11:11.580 --> 00:11:16.500
Aaron Roodman: Is a great way to go. And in particular, you want to look at the Galactic caps.

71
00:11:18.480 --> 00:11:28.830
Aaron Roodman: You really can't do dark energy in the direction of the galaxy, we're just too many starters. So one wants but one wants plenty of the area away from the center of the galaxy.

72
00:11:29.700 --> 00:11:45.630

Aaron Roodman: So here's the footprint on the sky for the survey shown in each of the six bands and we call them you G R IC. Why so from the from you is into the ultraviolet.

73
00:11:46.830 --> 00:11:55.740
Aaron Roodman: Down to about 350 350 nanometers. And why isn't the near infrared up to 1000 or 1020 years

74
00:11:58.080 --> 00:12:00.900
Aaron Roodman: The colors are the the

75
00:12:01.950 --> 00:12:14.760
Aaron Roodman: Depth of the survey compared to some average which is different in each case. And one of the other features that you'd like us to have as much uniformity of depth as possible. So this is actually from a simulation.

76
00:12:15.720 --> 00:12:24.660
Aaron Roodman: That included observing conditions. So the weather matters. So every night is different in terms of our effective your images are deep your images or

77
00:12:25.350 --> 00:12:42.960
Aaron Roodman: You know, what's the dimmest object that you can see that berries and so taking repeated exposure of the same part of the sky. And as I mentioned, the design is for 825 images total in the six bands in each direction, Scott. That's an enormous

78
00:12:44.310 --> 00:12:51.450
Aaron Roodman: That's an enormous number and serves a very important purpose, it will, it should feel quite uniform

79
00:12:53.160 --> 00:13:01.860
Aaron Roodman: exposure levels across the whole time that removes an important or minimize as an important systematic in lots of different songs

80
00:13:03.360 --> 00:13:11.940
Aaron Roodman: You can also see that there are some special regions that have taken. So here's the ecliptic. So we take some images into the northern hemisphere.

81
00:13:13.140 --> 00:13:25.020

Aaron Roodman: To catch Solar System objects, those don't need as much depth because we're not looking for quite as dim objects there. So there are fewer exposures there. As you can see from the color scale.

82
00:13:25.620 --> 00:13:41.640
Aaron Roodman: And here's the plane of the galaxy. And of course, at some point, taking more exposures doesn't help you because the routing from the, from the many stars. So that's the wide aspect of Ellis St. Now one interesting thing I can point out, I'm going to go

83
00:13:42.660 --> 00:13:56.370
Aaron Roodman: To the fast case. So these pods come from various simulations of are observing and the project has not fully determined exactly how the images are going to be taken.

84
00:13:57.030 --> 00:14:10.680
Aaron Roodman: And exactly how they're taken does affect the science we do, how often or what's the minimum time between exposures in the same direction has implications for finding asteroids.

85
00:14:11.910 --> 00:14:21.510
Aaron Roodman: How the images of overlap, whether they're deterred randomly helps us in cosmological studies, reducing sources, a systematic error.

86
00:14:22.440 --> 00:14:37.320
Aaron Roodman: And then you know how the images are taking can optimize the image quality images are better. The, the higher the closer you points is enough, and they do get somewhat worse as you move to the horizon. So this is a this is a

87
00:14:40.560 --> 00:14:43.800
Aaron Roodman: Little movie. And what is shown. So the black

88
00:14:47.820 --> 00:14:49.320
Aaron Roodman: hexagon is the

89
00:14:51.630 --> 00:15:06.180
Aaron Roodman: Is the the footprint our field of view on the sky, roughly, and you can see the images being taken in this simulation across the sky. The colors correspond to the color bands eg Ric wine.

90
00:15:07.320 --> 00:15:08.130
Aaron Roodman: And

91
00:15:09.810 --> 00:15:15.120
Aaron Roodman: You can see kind of sort of how fast will style the style of the galaxy is shown here.

92
00:15:16.710 --> 00:15:23.310
Aaron Roodman: The moon is shown here is this is the moon. Here's few cryptic and this is

93
00:15:25.440 --> 00:15:30.150
Aaron Roodman: Yeah, this is at least with one algorithm. This is how we might time to stop.

94
00:15:31.200 --> 00:15:34.320
Aaron Roodman: The images that we're going to take our 15 seconds.

95
00:15:35.550 --> 00:15:42.510
Aaron Roodman: And we'll take two images seconds each, in the same location, back to back. We're going to the next location and style.

96
00:15:42.930 --> 00:15:51.390
Aaron Roodman: And of course, deciding where to point the telescope is going to be under control of an algorithm. There's no way you can do this by hand at that cadence.

97
00:15:52.290 --> 00:16:02.670
Aaron Roodman: These images will come so fast. We will you know observers sitting and watching the data come in with a hard time keeping track of what happened so everything has to be

98
00:16:07.440 --> 00:16:11.550
Aaron Roodman: Okay, well, this goes on for a while, but we don't need to watch it. One other thing that

99
00:16:13.800 --> 00:16:24.750
Aaron Roodman: We want watch closely, there are some last thing I want to point out, actually, is there some special regions from the sky will where we will take even more. There's one right there. You can see that that

100
00:16:25.950 --> 00:16:29.190
Aaron Roodman: The telescope isn't moving for some period. And there are

101
00:16:30.390 --> 00:16:42.330

Aaron Roodman: There are 10 fields so called Deep drilling field where will take more exposures than average. Those will be especially good for studying the time variability of supernova.

102
00:16:43.500 --> 00:16:44.790
Aaron Roodman: As well as other objects.

103
00:16:46.020 --> 00:16:49.200
Aaron Roodman: OK, now the last aspect.

104
00:16:52.950 --> 00:16:59.070
Aaron Roodman: Of the of the project. Hope deep so deep is jargon and astronomy for

105
00:17:00.660 --> 00:17:14.280
Aaron Roodman: If you have deep images, you're seeing the dimmest images possible and what is shown here is is a simulation of what our images will look like when we combine many, many images together.

106
00:17:15.690 --> 00:17:17.550
Aaron Roodman: And so you can do that. Obviously with

107
00:17:18.720 --> 00:17:37.230
Aaron Roodman: Once you have the images you can go add them, you can combine them. This is a false color image made from combining three of the filters together and this is simulated. This is not real data. So there's a model for the distribution and shape and morphology of galaxies.

108
00:17:40.140 --> 00:17:55.740
Aaron Roodman: But this is what we expect her just to look like. You can see a few stars very bright stars. Um, and then some fantastic another detail, but this image is not. It's definitely similarities to the alternative field.

109
00:17:58.020 --> 00:18:00.540
Aaron Roodman: Images from the Hubble Space Telescope, that you may have seen

110
00:18:02.580 --> 00:18:11.250
Aaron Roodman: Our images won't be quite as sharp as hell, of course, because we're doing this on the ground, not in space. On the other hand, the attribute field is a tiny region of the sky.

111

00:18:14.190 --> 00:18:21.810
Aaron Roodman: And we will have images of this quality for the entire southern hemisphere so truly, truly unique and remarkable data sample.

112
00:18:25.050 --> 00:18:26.790
Aaron Roodman: And in the end,

113
00:18:28.620 --> 00:18:42.000
Aaron Roodman: Here's the. This is similar to the first product actually but maybe we'll take a closer look at it. This is just one of the six bands. This is actually a little bit newer simulation. The other plot and it shows from a 10 year stack.

114
00:18:44.880 --> 00:18:47.220
Aaron Roodman: The, the depth.

115
00:18:48.270 --> 00:18:51.210
Aaron Roodman: We expect in each direction and the units are

116
00:18:52.350 --> 00:19:01.350
Aaron Roodman: So it's the, it's the depth of magnitude minus 27 and a half. And so this color are just here means there are a loser typically

117
00:19:04.110 --> 00:19:17.250
Aaron Roodman: Typically about 27.2 magnitudes, as I say, extremely dim object, you can see the level of uniformity, which is super and this is really fantastic. So

118
00:19:19.740 --> 00:19:20.970
Aaron Roodman: Okay, so

119
00:19:22.500 --> 00:19:23.760
Aaron Roodman: That's what we're aiming for.

120
00:19:25.050 --> 00:19:25.860
Aaron Roodman: Let me, let me

121
00:19:27.180 --> 00:19:44.760
Aaron Roodman: Talk more about the design of the telescope and the Campbell and the instrument as a whole. So for large at Sandia we want large telescope aperture. So the primary beer is an eight point for your mirror here it is after the glass was cast, but before mirrors figured

122

00:19:45.960 --> 00:19:47.910
Aaron Roodman: This is this is over.

123
00:19:49.980 --> 00:20:00.450
Aaron Roodman: Good dozen years ago. This picture was taken quite a while ago, actually the mirror was built with private money there were some donations made

124
00:20:03.630 --> 00:20:17.130
Aaron Roodman: To the project to get going. Before we had federal support and mirrors made at the Arizona with Stewart near lab at the University of Arizona and well here you can see what a beauty.

125
00:20:19.320 --> 00:20:27.750
Aaron Roodman: So that's the one star for March primary and the second aspect is the field of view. So here's a just a drawing of the size of the field.

126
00:20:29.400 --> 00:20:43.590
Aaron Roodman: It's 9.6 square degrees. And you can see it, you know, an artist's conception compared to the size of the full moon the full moon is happening across our focal plane is three and a half degrees across

127
00:20:44.850 --> 00:20:55.110
Aaron Roodman: And consists of so each little box is one CCD one charge for the device and we have 189 of them in the focal point.

128
00:20:56.910 --> 00:21:11.580
Aaron Roodman: That is going to be the world's largest digital camera and 3.2 megapixels and even more remarkably you know this focal plane is 64 centimeters across it is truly enormous. So I'll show you some pictures of what it looks like now.

129
00:21:13.260 --> 00:21:14.940
Aaron Roodman: So that gives us for you to do.

130
00:21:16.440 --> 00:21:27.120
Aaron Roodman: Now, how to build such a system. So how do you, how do you maintain good image quality over such an enormous field of view, that is a challenge and and

131
00:21:28.770 --> 00:21:35.130
Aaron Roodman: So it's important to say that many telescopes have small fields of view and part of the reason why

132
00:21:36.270 --> 00:21:37.680
Aaron Roodman: Is then you know

133
00:21:39.150 --> 00:21:47.280
Aaron Roodman: It's dictated by the design and the typical Richie prescient telescope actually has good images only over a small field of you.

134
00:21:48.330 --> 00:21:52.470
Aaron Roodman: Know a normal sort of a typical to mirror telescope

135
00:21:55.050 --> 00:21:56.100
Aaron Roodman: Corrects

136
00:21:57.180 --> 00:22:07.320
Aaron Roodman: For coma, as you move away from the center of the field of view and so promo is one of the standard aberrations on which of course you want to reduce

137
00:22:08.160 --> 00:22:20.760
Aaron Roodman: In our case, to get good images over a big field of view. We've gone to a three mirror design. So it's shown schematically on the left, there's the primary here, which is an Angeles shown here.

138
00:22:21.990 --> 00:22:31.890
Aaron Roodman: There's a so light comes okay so light comes in from above. Its primary here which is Angeles bounces to a secondary gear.

139
00:22:33.240 --> 00:22:40.920
Aaron Roodman: And the light comes down to the tertiary. The third year here and then focuses into the camera.

140
00:22:42.240 --> 00:22:50.370
Aaron Roodman: Which has a three lens system before getting to the focal point. Now in the camera. We can look at this

141
00:22:51.450 --> 00:22:52.410
Aaron Roodman: This ray tracing

142
00:22:53.670 --> 00:23:00.120
Aaron Roodman: Diagram. So what's shown is three different field positions across the whole field of view.

143
00:23:01.320 --> 00:23:10.590
Aaron Roodman: The rays are the, the, our form and Angeles because the primary mirrors nanosecond. So you can see them coming into focus here at the time.

144
00:23:11.850 --> 00:23:25.650
Aaron Roodman: And you can see them transmitted through these, the three. The three lenses 123 and then there's a filter and last filter interference filter for getting the focal point. Now in our ray tracing

145
00:23:27.060 --> 00:23:35.730
Aaron Roodman: Simulations we can estimate the image quality. Look at how would a spot of how would a point sources star look like at the focal plane.

146
00:23:36.600 --> 00:23:42.600
Aaron Roodman: Ignoring atmosphere turbulence. So what is the pure optical performance. So

147
00:23:43.440 --> 00:23:55.080
Aaron Roodman: Zero degrees means on access. So all to all symmetric telescope system should have a nice perfectly round spot or points for a function on axis. This does

148
00:23:55.680 --> 00:24:11.190
Aaron Roodman: There's a little bit of a spherical aberration. That's what you see here at one degree. So that's one degree from the center of the field of view. You see the spot. Still, excellent. Here's point six our acceptance and we want to stay

149
00:24:12.420 --> 00:24:21.540
Aaron Roodman: We want this quantity to be below point three our acceptance. The width of these fonts and then here's at the edge of the field of view so

150
00:24:22.140 --> 00:24:30.000
Aaron Roodman: This is radius. So it's 1.75 degrees radius from the center of the field of view. The view is three and a half degrees. So this is the very edge.

151
00:24:30.420 --> 00:24:39.240
Aaron Roodman: You can see there is a little bit of aberration. This is actually some combination of a stigmatism film and triple L, you can ask me later with oil is

152
00:24:40.260 --> 00:24:54.600
Aaron Roodman: But you can see the spot size is still very small compared 2.6 arcseconds that atmosphere will smear these out by about point. Another point six are exceptions. So these are tiny compared to that.

153
00:24:55.350 --> 00:25:08.610
Aaron Roodman: That is excellent optical design to achieve that we've had to go to a three marriage design. The third near lets you correct for a stigmatism and sometimes these kind of mirrors are called three mirror and a stigma.

154
00:25:09.600 --> 00:25:18.150
Aaron Roodman: Our particular design is based on work from Paul, I think it's Paul and Baker, will I forget whether it's one person or two. It's also

155
00:25:19.410 --> 00:25:25.080
Aaron Roodman: A fast optical system. So the f number. And that's the ratio of the

156
00:25:27.480 --> 00:25:28.110
Aaron Roodman: Of the

157
00:25:31.620 --> 00:25:32.220
Aaron Roodman: Of the

158
00:25:33.930 --> 00:25:49.350
Aaron Roodman: focal distance over the diameter of the aperture is 1.23 is an extremely fast system. And if you know anything about cameras. You might know that a fast optimal design collects more light.

159
00:25:52.440 --> 00:26:00.090
Aaron Roodman: But it is harder to do and lenses with small f numbers can be quite expensive, but they're like, well,

160
00:26:02.070 --> 00:26:06.780
Aaron Roodman: For survey where we want a big field of view. You do want this small f number

161
00:26:08.280 --> 00:26:12.480
Aaron Roodman: This is extremely small. There's no big telescope that has an f number like this.

162

00:26:14.880 --> 00:26:25.020
Aaron Roodman: It also having that small f number helps you make a very squat design. You can see actually the size of the telescope in this direction.

163
00:26:25.380 --> 00:26:40.950
Aaron Roodman: Over the size of the primary mirror is almost equal, it's, it's sort of a rectangle and that is good mechanical structure to enable rapid fluid. So slimming means moving the telescope from one side to the other. We can do it very fast five seconds for three and a half degrees.

164
00:26:42.300 --> 00:26:51.900
Aaron Roodman: Now one of the innovations we've done in this design is to put the primary mirror and the tertiary there together in the same piece of glass. Now you can see the mirror.

165
00:26:52.830 --> 00:27:02.040
Aaron Roodman: Well into the figuring and polishing process. So you can see clearly the outer Angela says here, and then the radius of curvature changes for the tertiary mirror here.

166
00:27:03.690 --> 00:27:14.460
Aaron Roodman: This is a unique design. It's if you get it right. It means your alignment is, is basically perfect and locked in forever. The mirror has been built. Well, it's done.

167
00:27:15.210 --> 00:27:28.080
Aaron Roodman: It's actually in July already on and it should work very well for us. Now you need a big focal point to, let's move on to the camera. So this is engineering drawing the camera.

168
00:27:28.980 --> 00:27:37.860
Aaron Roodman: You can see it's also fairly squat matching that f number the focal plane this year. You can see this engineering drawing the three lenses, one, two.

169
00:27:38.310 --> 00:27:55.950
Aaron Roodman: And then the third lens is actually the window to the cryostat obviously needs to be back then because you will the CC these two minus on two degrees. See also shown to the filters and you'll notice that the filters their enormous are about 80 centimeters across

170
00:27:57.210 --> 00:27:59.640
Aaron Roodman: And they're so big. There's no place to put them

171

00:28:02.040 --> 00:28:09.600
Aaron Roodman: Or no, no easy place to put them out of the way so most other cameras and filters that just slide to the side.

172
00:28:10.050 --> 00:28:18.240
Aaron Roodman: But we don't have room to do that because they would, they would go out here and block some of the white that will hit the mirrors. We have a very fancy design that moves them.

173
00:28:18.720 --> 00:28:27.090
Aaron Roodman: 90 degrees out of the way and uses a little bit of excess space here as extremely difficult mechanical design that's working for us as well.

174
00:28:28.140 --> 00:28:36.450
Aaron Roodman: Now, um, how do you design a camera of this sort. So I said the focal plane 64 centimeters, with three and a half degree field of view.

175
00:28:37.230 --> 00:28:43.200
Aaron Roodman: The point sprint function you're aiming for based on atmosphere turbulence is about point seven seconds total

176
00:28:43.770 --> 00:28:54.090
Aaron Roodman: You want to oversample that you want to make sure that the points read function is covered by at least two pixels evil things occurred if that's not the case. If you're under sample.

177
00:28:54.900 --> 00:29:03.450
Aaron Roodman: So we have point to our second pixels of 10 microns. Each, those are those are reasonable 10 micron pixels is a reasonable value.

178
00:29:04.560 --> 00:29:11.460
Aaron Roodman: We're tiled in the hundred and 8916 megapixel CCD is there four centimeters by four centimeters.

179
00:29:12.510 --> 00:29:16.680
Aaron Roodman: Those are enormous. But that's the, that's what the state of the art can deliver today.

180
00:29:18.060 --> 00:29:28.950
Aaron Roodman: Since we want to take images, very quickly. You want to see every spot of the available sign three or four nights. We don't. We can't allow much dead time between exposures.

181
00:29:29.850 --> 00:29:36.690
Aaron Roodman: And as I mentioned, we're taking to 15 second images back to that you want a short read out. You want to read out time

182
00:29:37.110 --> 00:29:44.070
Aaron Roodman: When you're digitizing all those three megapixels to take a small fraction of the 15 seconds we've chosen to design

183
00:29:44.670 --> 00:29:55.260
Aaron Roodman: For two second readout that is an extremely fast. By comparison, the dark energy camera I talked about yesterday reads out about 22 seconds. And it's a smaller again.

184
00:29:56.160 --> 00:30:06.480
Aaron Roodman: To do that we need to multiply x, we've gone to 16 channel CDs that's pushing the state of the art, it has to be a very light camera three metric tons. So we can slip

185
00:30:07.470 --> 00:30:17.400
Aaron Roodman: We also chosen to put our electronics in the Christ that I want to talk more about that. But that is something no other project is done for us lots of challenges for us. But we've done it successfully.

186
00:30:18.510 --> 00:30:27.600
Aaron Roodman: The last element I could mention is that with fast optics. So f number of 1.2 there's a very shallow depth of focus.

187
00:30:28.710 --> 00:30:38.790
Aaron Roodman: You know if you know anything about photography. Again, if you have a small f number you can get beautiful book at in your images. So there's a narrow depth of

188
00:30:40.590 --> 00:30:49.500
Aaron Roodman: Focus of the image we have kind of the inverse to with the telescope, it means that the region.

189
00:30:50.430 --> 00:31:03.120
Aaron Roodman: In Focus is very shallow and so you have to have a very flat focal point to stay inside of that that shallow region that's a real challenge for building the CCD and the focal point you've met that child.

190
00:31:06.180 --> 00:31:07.650
Aaron Roodman: Okay, this is the same thing.

191
00:31:08.670 --> 00:31:11.520
Aaron Roodman: These are spot diagram showing the image quality. I'm actually going to

192
00:31:12.390 --> 00:31:26.640
Aaron Roodman: Get this and move on. The next thing you need for good throughput throughput means how how efficiently do quite photons. So about all the possible photons. How many of them actually get into your image.

193
00:31:27.240 --> 00:31:41.730
Aaron Roodman: You lose some in the atmosphere you lose a little bit and each reflective surface because the reflected in these not 100% maybe it's 99 and 98% you lose a little bit at each optical surface because

194
00:31:42.810 --> 00:31:56.280
Aaron Roodman: Of reflections you we've put anti reflective coatings on all of our actual services to minimize that. And then the the filters themselves don't have 100% throughput. Maybe they only have 95%

195
00:31:57.450 --> 00:32:14.640
Aaron Roodman: In the end, um, the throughput as a fraction is shown here in each of the bands. So it's excellent 50 percentage or up to 65 70% and then big bands and a lot of that is some significant fraction that was due to the atmosphere itself.

196
00:32:16.950 --> 00:32:17.430
So,

197
00:32:19.050 --> 00:32:21.960
Aaron Roodman: Let's look at this look at some photos.

198
00:32:23.820 --> 00:32:37.470
Aaron Roodman: Let's see what this thing really looks like. So here's the observatory in the upper left. This is what it looked like after the mountaintop was dynamited, I should say. So the Reuben observatories being built on Sarah. The challenge p

199
00:32:38.910 --> 00:32:48.570
Aaron Roodman: There are two other telescopes near nearby basically on the same rich Gemini south. They need a Gemini south and the four meters or telescope is there.

200
00:32:49.230 --> 00:32:58.350

Aaron Roodman: They're also not that far of a 45 minute drive from Sarah to low, low, where the dark energy survey and the Blanca telescope that you can see them.

201
00:32:59.820 --> 00:33:01.650
Aaron Roodman: Across the process, the valleys.

202
00:33:03.120 --> 00:33:20.490
Aaron Roodman: So here's the here's the location with a mountain top dynamited here's the telescope down and building being built. You can see the support for the telescope. Here the outside of the down here and the support building

203
00:33:21.600 --> 00:33:37.290
Aaron Roodman: Here it is. Now the building mostly done and the dome under construction. Oh, it looks beautiful. Often the clouds say well below this mountain. This is actually am a calibration or the small calibration telescope is located in this down.

204
00:33:38.460 --> 00:33:43.920
Aaron Roodman: And then here. Here we are with the dome under construction. This is a fairly recent picture but

205
00:33:45.420 --> 00:33:47.460
Aaron Roodman: You know, we're kind of stopped for the Southern winter.

206
00:33:50.340 --> 00:34:03.120
Aaron Roodman: The telescope itself. Well, you need a giant structure to hold that hold the mirror and hold the camera in place that's shown here is under construction in a company in Spain.

207
00:34:04.890 --> 00:34:18.210
Aaron Roodman: And people give you an idea of the scale of this device. It has to move smoothly. It has to move with basically no rumble. You don't want that the the telescope and camera and need to be steady

208
00:34:19.230 --> 00:34:21.840
Aaron Roodman: At the level of, let's say, a

209
00:34:23.370 --> 00:34:30.450
Aaron Roodman: Better than point oh five arcseconds as this moves so it moves extremely smoothly on

210
00:34:31.770 --> 00:34:44.160

Aaron Roodman: This access this axis and the camera actually moves as well. It moves fast, as I said, we'll do a three and a half, three. So in five seconds is extremely fast this thing is a real beast.

211
00:34:46.140 --> 00:34:50.310
Aaron Roodman: Is has been dismantled at the manufacturer and is in pieces at the mountaintop now.

212
00:34:51.810 --> 00:34:55.590
Aaron Roodman: And then the optics. So I've shown you the primary mirror already

213
00:34:56.790 --> 00:35:11.700
Aaron Roodman: Here's the secondary mirror which has actually been been coated with it's reflective surface and cutting chamber at the observatory, typically you do that there. Because every couple of years, you'll want to recruit the mirrors.

214
00:35:12.840 --> 00:35:18.480
Aaron Roodman: That I mentioned the camera has three lenses, we have those at slack. Now those are completed.

215
00:35:20.430 --> 00:35:22.470
Aaron Roodman: You can see them. The first two lenses.

216
00:35:23.820 --> 00:35:36.750
Aaron Roodman: Were built in a in a integrated package. So here's the first lines. So this lens is 1.55 meters across, this is the largest lens ever built for astronomy.

217
00:35:37.380 --> 00:35:50.370
Aaron Roodman: It's significantly bigger than the primary and the Yerkes Observatory. That's what the Yerkes 40 inch, which was previously the largest lens for astronomy this pizza by significant fraction

218
00:35:51.900 --> 00:35:59.940
Aaron Roodman: Here's the second lens, kind of in the bottom of this package. You can see it with some multiple reflections of these are actually the the

219
00:36:01.770 --> 00:36:07.110
Aaron Roodman: The lectures that connect that hold the blast to itself. Here's the

220

00:36:08.910 --> 00:36:19.980
Aaron Roodman: Anyway, it's a it's a beautiful is the beautiful device it's sitting in our lab at slack today, waiting for us to install it in the end of this year, the beginning of next year, so

221
00:36:21.150 --> 00:36:26.220
Aaron Roodman: And here's the third lands and this is also the window of the price that door.

222
00:36:27.630 --> 00:36:32.160
Aaron Roodman: And you can see people inspecting it after its delivery. Those are beautiful, beautiful objects.

223
00:36:35.760 --> 00:36:37.110
Aaron Roodman: Hey, what about the focal plane.

224
00:36:38.250 --> 00:36:44.850
Aaron Roodman: I've mentioned already that it's the largest focal plane Kevin both sides and pixel count ever attempted

225
00:36:46.290 --> 00:36:57.420
Aaron Roodman: Here's the back of the crime stats Dewar all the vacuum equipments electronic theaters and you can kind of see this structure.

226
00:36:59.400 --> 00:37:10.710
Aaron Roodman: The claim is modular. And so there there are 25 different modular units they kind of slide in each of these slots. You can see those here. So here's

227
00:37:11.310 --> 00:37:23.610
Aaron Roodman: Here's one CCD. This is for seven years, right before seven years we built them in a night with nine CCD is kind of in a sub unit and these are in the corners. We have special CCD for

228
00:37:26.010 --> 00:37:42.240
Aaron Roodman: To measure the optimal way front so that we can control the alignment and figure the mirrors and as gliders. So these are special. But this is one of the imaging CCD so all alone. This is 144 megapixel camera and we have 21 of these units.

229
00:37:43.560 --> 00:37:55.650
Aaron Roodman: Here you can see the rest of the unit and there's an integrated package that has digitisation electronics or the CCP is right on board.

230
00:37:56.940 --> 00:38:02.430
Aaron Roodman: Has a thermal system and a mechanical system altogether. And you can see it being installed.

231
00:38:04.380 --> 00:38:15.750
Aaron Roodman: sort of pulled up from above and you know here. A lot of the focal plane is built. And one of these mind CCD units of being installed with a couple of my colleagues.

232
00:38:16.770 --> 00:38:17.550
Aaron Roodman: Watching

233
00:38:18.930 --> 00:38:19.260
Aaron Roodman: You know,

234
00:38:21.000 --> 00:38:38.340
Aaron Roodman: Watching in addition to the equipment we had to monitor this automatically we needed extra eyes on this very, very delicate process, you get an idea of the scale the focal plane from from our from our engineers. Here it is. This is true anymore.

235
00:38:41.070 --> 00:38:58.050
Aaron Roodman: Okay, maybe I'll just say a word about charge couple devices. Those are the you know CCD is really the bled OVER THE LAST LAST 40 years to revolution and astronomy, the inventors and see she's actually got the Nobel Prize, although they invented it more as a as a

236
00:38:59.160 --> 00:39:01.170
Aaron Roodman: Memory rather than imager.

237
00:39:02.850 --> 00:39:13.470
Aaron Roodman: this cool little diagram shows a little bit how they work. They're, they're a bucket brigade. So each bucket is A, this corresponds to a pixel and

238
00:39:14.910 --> 00:39:24.090
Aaron Roodman: You might have many, many pixels whole read out by a single amplifying in our case, we have a million pixels read out by each amplify

239
00:39:25.050 --> 00:39:41.520
Aaron Roodman: And to get the charge in this case the raindrops from the pixel to the amplifier. There's a bucket brigade the buckets move in one

direction into this special region for the serial register and you can see that happening here.

240
00:39:42.570 --> 00:39:46.770
Aaron Roodman: And then the serial register moves one pixel time into the amplifier.

241
00:39:47.790 --> 00:39:54.420
Aaron Roodman: And so it takes some time to do that, we do it in two seconds, but it has the advantage that

242
00:39:55.800 --> 00:40:04.590
Aaron Roodman: We only have to calibrate around 3000 amplifiers. You don't have to calibrate each of the 3 billion pixels only

243
00:40:05.580 --> 00:40:20.370
Aaron Roodman: Only a small fraction of that number that is critical because you really have to work hard to calibrate each amplifier and make sure it's working correctly doing that for 3000 of them is hard enough doing it for 3 billion might be awesome.

244
00:40:21.900 --> 00:40:28.650
Aaron Roodman: This diagram shows a little bit of the the silicon engineering that's needed. There's patterning for

245
00:40:30.180 --> 00:40:34.050
Aaron Roodman: To define the pixels. And then these

246
00:40:36.420 --> 00:40:45.030
Aaron Roodman: Basically these electrodes have their voltage varied to implement the bucket brigade move the charge physically along the line.

247
00:40:45.780 --> 00:41:01.260
Aaron Roodman: This way, and then this way to get to an amplifier and then there's some bulk region that's fully depleted where you can absorb light and in our case, our CDs or 100 microns thick that's necessary to see into the near infrared

248
00:41:02.310 --> 00:41:06.990
Aaron Roodman: Here's an image. This is a fun image projecting the flow Marion woodcut onto one of our

249
00:41:08.700 --> 00:41:10.200
Aaron Roodman: Nine CCD units.

250
00:41:11.310 --> 00:41:19.410
Aaron Roodman: That looks good, looks good. One other thing that we had to do is, is they're highly multiplex. So we actually have 16 you can't really see it here.

251
00:41:20.670 --> 00:41:22.020
Aaron Roodman: It's, it's

252
00:41:23.130 --> 00:41:36.150
Aaron Roodman: Not well Amy just barely visible. They're actually little regions, they're 16 regions and CCP and to fit them into up some special engineering of the on the silicon wafers.

253
00:41:37.020 --> 00:41:46.140
Aaron Roodman: I came running out of time, so I'm not going to go into unless you ask questions, but we had to do something quite innovative to get that to work, or rather the two companies that made CCD is for us to be

254
00:41:47.700 --> 00:41:51.420
Aaron Roodman: Okay. Actually, let's have a poll. Let's ask your question.

255
00:41:52.560 --> 00:41:59.490
Aaron Roodman: Um, and maybe if someone if if one of the organizers can put the maybe type, the

256
00:42:01.230 --> 00:42:04.470
Aaron Roodman: The address onto the chat for me would be awesome.

257
00:42:06.600 --> 00:42:07.140
Aaron Roodman: So,

258
00:42:08.460 --> 00:42:09.300
Aaron Roodman: Here's the question.

259
00:42:11.760 --> 00:42:20.520
Aaron Roodman: What do you think has been our biggest challenge in building this camera and you can see we're almost done.

260
00:42:22.380 --> 00:42:28.710

Aaron Roodman: Right. But we're we're deep into the construction. We're getting close to the one. What's been your biggest challenge a

261
00:42:31.800 --> 00:42:42.480
Aaron Roodman: The construction of the CCD that's been done by two different companies specialists and astronomical CDs. There are only a few companies that make these in the world, or a few labs.

262
00:42:43.650 --> 00:42:48.600
Aaron Roodman: And this is an enormous order for 189 of them and that's under 99 at work well.

263
00:42:50.910 --> 00:42:55.590
Aaron Roodman: As a challenge the lenses. I mentioned we have the biggest lines ever built roundtables strong

264
00:42:58.710 --> 00:43:09.150
Aaron Roodman: But certainly must be a challenge. What about limited space constraints kind of got an idea from the engineering drawing that there is a lot of equipment at into a fairly small cylinder

265
00:43:10.380 --> 00:43:12.930
Aaron Roodman: Or maybe the challenge of just holding it all together.

266
00:43:13.950 --> 00:43:22.560
Aaron Roodman: The screws and bolts that you use. Maybe that's been our biggest challenge. So, or maybe all the above. What do you think, take a second.

267
00:43:23.760 --> 00:43:25.020
Aaron Roodman: Please, and

268
00:43:26.670 --> 00:43:29.730
Aaron Roodman: This is just for fun. Make a guess at what you think our biggest challenges.

269
00:43:40.620 --> 00:43:41.790
Aaron Roodman: So, um,

270
00:43:45.060 --> 00:43:55.440
Aaron Roodman: I think that often in when we talk about the science. We're doing we leave out too much of this aspect of

271

00:43:56.580 --> 00:43:58.590
Aaron Roodman: The difficulty of building unique

272
00:43:59.610 --> 00:44:10.170
Aaron Roodman: Scientific instruments, there are significant every, every experiment. I've been part of and I built in part of building a number of experiments has had

273
00:44:11.040 --> 00:44:13.560
Aaron Roodman: All sorts of interesting difficulties along the way.

274
00:44:14.370 --> 00:44:24.900
Aaron Roodman: And I think we're happy to leave those behind and not describe them. We talked about we got what we do with our instruments. I think we're missing something there, I think. I think we're not serving students well

275
00:44:25.320 --> 00:44:37.350
Aaron Roodman: Are leaving that out. And I think we missed something about the human challenge of science in this aspect. Okay, so maybe maybe if people have. I'm hoping people have had a chance to answer.

276
00:44:38.010 --> 00:44:49.500
thomas rizzo: And luckily, we had a little bit of a technical problem, Aaron. I mean, the we sent out the link we sent it out, but it didn't seem to come as a link, it just came as an address. And people might be slow. I don't know.

277
00:44:50.190 --> 00:44:51.000
Aaron Roodman: Again, people

278
00:44:53.190 --> 00:44:59.100
Aaron Roodman: Yeah, I mean I don't have too much left of the talk. So I don't think I'm doing okay for time. I can wait another wait another 30 seconds or so.

279
00:45:06.060 --> 00:45:10.680
Aaron Roodman: Let people catch their breath. I'll catch my breath to um

280
00:45:13.650 --> 00:45:15.720
Aaron Roodman: I think it's true. If you talk to

281
00:45:17.160 --> 00:45:32.160

Aaron Roodman: Experimental physicists to build instruments even small instruments have all sorts of interesting issues, big instruments of maybe more face face for more people can regale you with stories of the challenges that they went through.

282
00:45:33.180 --> 00:45:41.940
Aaron Roodman: I i'm not fond of talking about it until everything is working. So when this cameras mounted on the top of the telescope and we're halfway taking images.

283
00:45:43.080 --> 00:45:47.280
Aaron Roodman: I could describe in a little more detail. You know what it took to get there.

284
00:45:48.660 --> 00:45:51.090
Aaron Roodman: But. But anyway, I wanted to ask this question.

285
00:45:52.290 --> 00:45:52.710
Aaron Roodman: All right.

286
00:45:53.880 --> 00:45:57.810
Aaron Roodman: Let's Let's Let's Let's look at the, let's look at the poll. Let's see.

287
00:45:59.130 --> 00:46:12.240
Aaron Roodman: Let's see. Haha Oh, excellent. Okay, so people are still answering. That's fine. So it's pretty even CC these lenses limited space fasteners. All the above

288
00:46:12.990 --> 00:46:22.320
Aaron Roodman: Well, I have to say that actually I you know I would answer, there's no one right answer to this one of course I would kind of answer all the above

289
00:46:23.190 --> 00:46:34.710
Aaron Roodman: These CC nice were really a challenge and the fact that there are 16 amplifiers when sort of the preeminent typical CCD would have to amplifiers, or maybe for

290
00:46:35.370 --> 00:46:44.760
Aaron Roodman: The fact that we have 16 cause some real serious challenges. Also the flatness or flatness requirements were very challenging to me.

291

00:46:45.930 --> 00:46:53.580
Aaron Roodman: The lenses, very difficult. They were done by a small company in Arizona, run by someone

292
00:46:55.800 --> 00:47:05.130
Aaron Roodman: Who came out of the University of Arizona optical school big challenge limited space constraints. I like in our camera to a ship in a bottle.

293
00:47:06.270 --> 00:47:09.300
Aaron Roodman: It. There is almost no unused space.

294
00:47:12.060 --> 00:47:29.070
Aaron Roodman: Very challenging. Now maybe people thought fasteners. Why are screws and bolts on this list. Trust me. We had a serious problem with the with the materials in our screws and we needed to rework.

295
00:47:30.450 --> 00:47:44.880
Aaron Roodman: All of the nine CC units to fix that problem we've gotten past that that success have been successfully done but it costs us a lot of blood, sweat and tears. So maybe all the above. Anyway, thanks for thinking about that.

296
00:47:47.220 --> 00:47:49.980
Aaron Roodman: Yeah, there's their stories. One could tell about all

297
00:47:51.870 --> 00:48:02.820
Aaron Roodman: Right. Let me, let me. Maybe I'll move on and move on. So there's just a little bit of time left. I want to mention come back to cosmology and then I'll spend the last five minutes talking about desert.

298
00:48:04.380 --> 00:48:14.130
Aaron Roodman: So there is a big group of scientists working already hard to get ready for data from the room service story and

299
00:48:15.270 --> 00:48:18.750
Aaron Roodman: Their predictions for how well we'll be able to measure.

300
00:48:20.130 --> 00:48:24.330
Aaron Roodman: The dark energy equation, the state. So here's this is

301
00:48:25.920 --> 00:48:30.540
Aaron Roodman: Good accuracy and omega zero W zero so the

302
00:48:31.560 --> 00:48:44.820
Aaron Roodman: Constant of the the intercept of W. It's time dependent. Here's why. The slope of music. This is after one year of data. You can see the scale is different than what he wants.

303
00:48:45.330 --> 00:48:53.070
Aaron Roodman: This, this would be, you know, this will be an extremely exciting results to see if if our measurements are consistent with

304
00:48:54.690 --> 00:49:02.880
Aaron Roodman: Minus one and zero or not. And then after 10 years windows even better. The scales have changed by almost the factor to here.

305
00:49:04.980 --> 00:49:13.140
Aaron Roodman: And this is what we expect today how things were really play out. We'll see their systematic effects that might make it worse. But often

306
00:49:14.430 --> 00:49:25.710
Aaron Roodman: The most most scientific experiments I worked on that actually done better than expected. As we learn how to how to deal with our data. We learn as we go.

307
00:49:26.520 --> 00:49:40.410
Aaron Roodman: So there's fantastic potential for dark energy from the literature. Okay, I'm gonna use the last five minutes. Talk about the other project on the ground. This is Desi, the dark energies, but it's not because

308
00:49:41.760 --> 00:49:50.670
Aaron Roodman: It's actually the construction is now complete and commissioning was underway, when the, when the kind of work I had to stop for the pandemic.

309
00:49:54.180 --> 00:50:07.740
Aaron Roodman: It's goal is, it's a galaxy survey, but it's not an imaging surveys, a spectroscopic survey and the goal is to collect 35 million spectroscopic redshift from four different kinds of galaxies.

310
00:50:08.910 --> 00:50:15.660
Aaron Roodman: Bright galaxies that are the nearby universe allergies large a red galaxies.

311
00:50:16.800 --> 00:50:18.720

Aaron Roodman: Red ships of point 421

312
00:50:19.920 --> 00:50:32.850
Aaron Roodman: emojis emission line galaxy. So those are particularly good for determining the ratchet from spectra those we can reach further out, up to 01 point six and then quasars, USA.

313
00:50:34.110 --> 00:50:36.480
Aaron Roodman: Which we can see even deeper because of these bright

314
00:50:37.710 --> 00:50:48.720
Aaron Roodman: And for many of them will observe the quasar itself is kind of a backlight to observe what's called the lineman alpha forest. So that's hydrogen gas.

315
00:50:49.980 --> 00:50:53.400
Aaron Roodman: That we can see its introduction of the light from the sun.

316
00:50:55.050 --> 00:50:56.370
Aaron Roodman: And here's kind of a

317
00:50:57.780 --> 00:51:01.140
Aaron Roodman: An illustration of the structure we expect to see

318
00:51:02.970 --> 00:51:09.420
Aaron Roodman: And as I said, the instrument is done. Here are some pictures from it, it's mounted on the

319
00:51:10.290 --> 00:51:20.040
Aaron Roodman: Mail for meter telescope it Kitt peak, the male and the Blanco are twins were built in the late 60s and early 70s there virtually identical

320
00:51:20.550 --> 00:51:36.510
Aaron Roodman: These are the US National telescopes formula telescopes, um, the focal plane instead of CCD is is fibers and you can see the 35,000 fibers in the focal point.

321
00:51:38.190 --> 00:51:51.690
Aaron Roodman: And the fibers. So here's kind of a 10th of the focal plane assembled with fibers and the fibers are attached to a two degree of freedom motor, they can move the fiber lap of

322
00:51:51.690 --> 00:51:54.000
thomas rizzo: Aaron four minutes to go, sorry.

323
00:51:55.140 --> 00:51:55.500
thomas rizzo: Thank you.

324
00:51:56.820 --> 00:52:06.810
Aaron Roodman: So the, the, these mini motors can move the fiber laterally in a over sort of a patrol radius of a centimeter and a half or so.

325
00:52:07.590 --> 00:52:22.140
Aaron Roodman: And so we can for every image we can move the fiber, so that the galaxy. We want will be shining down that tiny fiber. Now if you're familiar with the Sloan Digital Sky Survey. You might know that

326
00:52:23.310 --> 00:52:35.400
Aaron Roodman: They did something similar with a metal plate with holes cut in it and the fibers manually inserted into those holes with 5000 fibers. There's no way to do links.

327
00:52:36.570 --> 00:52:41.070
Aaron Roodman: Instead, these, these remarkable little fiber Petitioners were invented.

328
00:52:42.330 --> 00:52:44.130
Aaron Roodman: There's a optical director

329
00:52:45.210 --> 00:52:57.630
Aaron Roodman: Here's one of the lenses, not quite as big as the LSC one but at 1.2 meters quite enormous. Um, here's another part of the optical system and you can see the whole director structure shown here.

330
00:52:58.830 --> 00:53:03.540
Aaron Roodman: In the fibers feed specter graphs and there are 10

331
00:53:05.580 --> 00:53:19.500
Aaron Roodman: Of these units built each one handles 500 fibers and then each factor graph has three arms and there's a there's a to die products that split the light into kind of a

332
00:53:21.030 --> 00:53:25.710
Aaron Roodman: A UV central and an interactive or near infrared portion

333
00:53:26.970 --> 00:53:32.730
Aaron Roodman: To give us the resolution in wavelength and the resolution in redshift that we desire.

334
00:53:34.470 --> 00:53:39.510
Aaron Roodman: So it's all done and it started to work. And now we're waiting to start up again.

335
00:53:41.550 --> 00:54:02.190
Aaron Roodman: Here's the first light spectrum. So this is an image taken elsewhere overlaid with 5000 fibers this in their nominal locations and here's the spectrum from one fiber on on n 33, you can see a beautiful spectrum, it is with different lines identify

336
00:54:05.700 --> 00:54:21.750
Aaron Roodman: Now, the goal is, you know, one of the main scientific goals for dark energy is to make a home basically was effectively a whole diagram using the berry on acoustic isolation feature. And this is the kind of quality data that's expected

337
00:54:22.830 --> 00:54:32.640
Aaron Roodman: Out to redshift. So three and a half with extremely precise measurements made kind of in the sweet spot of point five to 1.5 and then again around 2.5

338
00:54:33.510 --> 00:54:45.630
Aaron Roodman: So this is going to be a spectacular instrument. There are all sorts of interesting science when can be combining data from desi with data from the urban Observatory as well. So we're really excited about that.

339
00:54:47.550 --> 00:54:57.420
Aaron Roodman: So, the future is really bright in this area, and I'll just conclude actually with just a little bit about the prospects for Reuben Observatory.

340
00:54:59.790 --> 00:55:11.640
Aaron Roodman: Those of us working in the camera or focus on on finishing the camera. We think that will happen next year should be installed on the cell scope in the following year. And then we hope to start our tenure survey.

341
00:55:14.190 --> 00:55:17.580
Aaron Roodman: Probably in 2020 late 2022 or 2023

342
00:55:18.690 --> 00:55:24.510
Aaron Roodman: And that there's a picture of when I was visiting the mountaintop in 2012

343
00:55:25.650 --> 00:55:31.530
Aaron Roodman: And as I say, We're excited. We're excited for all the science to come here and I think that open, please. Thank you.

344
00:55:35.070 --> 00:55:38.430
thomas rizzo: Thanks Aaron for a great talk. Let's turn it over to the Q AMP a

345
00:55:42.870 --> 00:55:43.290
Richard Partridge: Higher

346
00:55:44.490 --> 00:55:45.300
Richard Partridge: We've got a

347
00:55:45.570 --> 00:55:47.490
Richard Partridge: Few questions here.

348
00:55:50.820 --> 00:56:00.720
Richard Partridge: First question, and this is on site seven. Actually, there's three questions are all sort of on the same topic here. So I'm going to

349
00:56:02.070 --> 00:56:03.960
Richard Partridge: Combine the first two questions. First,

350
00:56:05.130 --> 00:56:16.710
Richard Partridge: One is, does the telescope only take images in one band at a time. The second question sort of answers. The first one is, why do you need to tell the sky with only one band at the time in the movie.

351
00:56:18.180 --> 00:56:22.350
Richard Partridge: So, you know, you can address the sequencing here.

352
00:56:23.220 --> 00:56:33.000
Aaron Roodman: Sure. So obviously, each image. There's the, you know, filters are monolithic they cover the whole focus on. So we do one filter the time

353
00:56:34.620 --> 00:56:52.860
Aaron Roodman: The over the course of the night, we may change filter several times that because the filter changing is so difficult. It's not fast and so there's some time loss and change filters. So when we optimize the observing strategy, you do want to keep that

354
00:56:54.120 --> 00:56:58.980
Aaron Roodman: In mind. And so we don't change filters down, often, but you know what this

355
00:57:00.300 --> 00:57:16.560
Aaron Roodman: With this visualization shows is the kind of the way that might work. So here the orange. That's I band images are being taken to a lot of the night, and maybe at some point it will switch there it goes to switch to read, which is z band.

356
00:57:18.090 --> 00:57:22.080
Aaron Roodman: And you can see over the course of the night, you would take images and a few filters.

357
00:57:23.190 --> 00:57:24.330
Aaron Roodman: There's also

358
00:57:25.920 --> 00:57:37.110
Aaron Roodman: You know, depending on how bright the night is depending on whether the moon is off, you want to take images on the blue side of the red side preferentially because the amount of sky glow is different in different ways.

359
00:57:38.880 --> 00:57:40.470
Aaron Roodman: But nobody answers your question.

360
00:57:41.640 --> 00:57:43.140
Richard Partridge: Okay, and

361
00:57:44.430 --> 00:57:52.620
Richard Partridge: Yeah. Good answer, and related question is how are they observing bands decided for Reuben.

362
00:57:54.030 --> 00:57:56.400
Aaron Roodman: Oh. So how did we decide

363

00:57:57.450 --> 00:58:00.900
Aaron Roodman: On these maybe that's

364
00:58:01.920 --> 00:58:04.440
Aaron Roodman: All I'm that

365
00:58:05.610 --> 00:58:11.670
Aaron Roodman: Roughly these bands are similar to the ones used by the Sloan Digital Sky Survey and

366
00:58:14.010 --> 00:58:21.810
Aaron Roodman: The band passes that slowing us have actually become pretty standard in the astronomical community. It does actually help

367
00:58:23.130 --> 00:58:28.350
Aaron Roodman: Comparing or combining images from different observatories. If the bands are roughly similar

368
00:58:29.730 --> 00:58:35.160
Aaron Roodman: So that you know the choice of these band passes, definitely.

369
00:58:37.200 --> 00:58:38.430
Aaron Roodman: Follow Sloane

370
00:58:40.530 --> 00:58:48.510
Aaron Roodman: You don't want them to be too wide. So there between 100 and 250 nanometers. Why, um, you want

371
00:58:49.440 --> 00:58:53.610
Aaron Roodman: As you want to cover the full band towns. One thing that we've done that is different.

372
00:58:54.240 --> 00:59:01.740
Aaron Roodman: Is that we've made sure there are no gaps and we've actually when you build a filter you don't you know the

373
00:59:02.280 --> 00:59:20.700
Aaron Roodman: These filters are made from hundreds of layers hundreds of very thin layers of different materials different dielectric materials or interference filters. So you build up interference to give good throughput in band and then almost no throughput out of it.

374

00:59:22.020 --> 00:59:23.370
Aaron Roodman: Now when you design them.

375
00:59:25.140 --> 00:59:32.670
Aaron Roodman: Well, the constructed versions are often not exactly what you design. It's inevitable and

376
00:59:33.450 --> 00:59:43.980
Aaron Roodman: They're so large, you're concerned about uniformity across the filter and actually it's quite bad to have gaps, because it's real problems for understanding for the metric richer to have a gap.

377
00:59:44.520 --> 00:59:54.210
Aaron Roodman: So we've made the science of the band pass with a little bit of a slow, they're not as sharp as you could make them that was done purposely to make sure that they overlap.

378
00:59:57.750 --> 00:59:58.170
Richard Partridge: Okay.

379
01:00:01.980 --> 01:00:09.180
Richard Partridge: Next question is, what's coma. It's on the optical side mentioned as a common aberration that we want to do.

380
01:00:10.020 --> 01:00:23.130
Aaron Roodman: Oh, comma, comma. OK, so the classical aberrations are the focus and you can see the focus here as you go out of focus your image starts to grow in size.

381
01:00:23.850 --> 01:00:46.560
Aaron Roodman: There's a stigmatism. Some of you might have a stigmatic eyes astigmatism is pretty good in this telescope astigmatism is changes in the instead of having a circular spot having an elliptical spot. So if you if you get bigger in one dimension than the other answer stigmatism coma.

382
01:00:48.180 --> 01:00:51.150
Aaron Roodman: It's called coma, because the astronomers I guess if the

383
01:00:54.480 --> 01:01:11.400
Aaron Roodman: 18th century looking for comments and but they notice if they looked at the edge of their field of view in their little telescopes that stars often at a shape a little like a comment, and that was caused by aberrations, the coma.

384
01:01:12.420 --> 01:01:24.810
Aaron Roodman: There's a little bit of common saying these what happens in common is that different parts of the aperture different parts of the Save the mirror hit different parts of the

385
01:01:27.480 --> 01:01:39.600
Aaron Roodman: Different parts of the focal point. And those I'm actually going to have some fun. It's raw. It's dry so como would look like this and maybe again, you know,

386
01:01:42.450 --> 01:01:44.070
Aaron Roodman: We used to have a way comma

387
01:01:45.420 --> 01:01:51.270
Aaron Roodman: Would look like one circle and then another circle and another, and it kind of spreads down

388
01:01:52.950 --> 01:01:56.910
Aaron Roodman: And then there's truffle oil to sort of a triangular shape that you can see

389
01:02:00.540 --> 01:02:01.140
Richard Partridge: OK.

390
01:02:03.390 --> 01:02:12.060
Richard Partridge: The next question. It's on slide 12. Why is this doing faster when the telescope and primary mirror or the same time.

391
01:02:14.370 --> 01:02:16.200
Aaron Roodman: Why is this thing.

392
01:02:17.700 --> 01:02:19.680
Aaron Roodman: Oh. Oh, OK.

393
01:02:20.820 --> 01:02:25.860
Aaron Roodman: OK, so maybe I left out a piece. So you could move a

394
01:02:26.880 --> 01:02:39.090
Aaron Roodman: longer and skinnier telescope, just as fast, but it wouldn't settle quickly. So it's not enough just to move the telescope. Let's go back to the now maybe

395

01:02:42.690 --> 01:03:04.050
Aaron Roodman: So it's not enough to move it fast. But when you're done moving to a new spot. The thing has to be stable because if it's if the camera is vibrating that will smear out or images and we want the vibrations be less than I think the number is point oh five arc seconds.

396
01:03:06.570 --> 01:03:21.600
Aaron Roodman: At the end of the slew and you want to reach that level before you start taking the next exposure. So if you had a long skinny telescope and more typical telescope design. There's no way you would be able to achieve that stability after such a short period.

397
01:03:22.830 --> 01:03:35.130
Aaron Roodman: So it's it's it's really the stability. That's the key and having a squat design helps that law. That's also why the camera has to be relatively light it's too heavy. Never get this structure to stabilize

398
01:03:37.590 --> 01:03:38.100
Richard Partridge: Okay.

399
01:03:39.210 --> 01:03:42.300
Richard Partridge: The next question is on also assign

400
01:03:44.340 --> 01:03:47.700
Richard Partridge: This mean that in each picture. There's a hole in the field of view.

401
01:03:50.040 --> 01:03:57.690
Aaron Roodman: Okay, so it's important to understand something about telescopes, there's no hope. There's no. Okay, so there's a hole.

402
01:03:59.550 --> 01:04:01.080
Aaron Roodman: In the pupil.

403
01:04:02.340 --> 01:04:04.620
Aaron Roodman: So the, the pupil is

404
01:04:05.700 --> 01:04:06.330
Aaron Roodman: What

405
01:04:07.620 --> 01:04:18.030
Aaron Roodman: What the bundle of rays looks like far from focus and the pupil is an annual basis. There's a big hole in it because there's a big hole in the primary mirror

406
01:04:18.780 --> 01:04:23.820
Aaron Roodman: But once you're in focus all the light is in the same spot. You don't see the whole

407
01:04:24.720 --> 01:04:34.230
Aaron Roodman: The whole does not appear in the field of view, the field of view corresponds to light coming in from different angles. So what's shown here.

408
01:04:34.680 --> 01:04:50.130
Aaron Roodman: Coming in normally is the center of the field of view. And if you hit the edge of the field of view, the light is coming in at three and a half degrees or well I guess 1.75 degrees from normal, but there's no hole in the, in the field of you.

409
01:04:51.390 --> 01:04:54.300
Aaron Roodman: Those are conjugate surfaces, the people on the focal point.

410
01:04:56.190 --> 01:04:57.600
Aaron Roodman: If you, if you doubt that

411
01:04:58.650 --> 01:04:59.700
Aaron Roodman: Well, yeah.

412
01:05:01.050 --> 01:05:11.310
Aaron Roodman: That's the way it works. So you you could imagine some simple ways of showing that one way, actually, is if you focus if you focus a camera or your eyes and infinity.

413
01:05:12.690 --> 01:05:16.440
Aaron Roodman: And then look through a screen, you don't see the screen.

414
01:05:18.360 --> 01:05:19.650
Aaron Roodman: It's, it's for the same reason.

415
01:05:21.810 --> 01:05:23.520
Richard Partridge: Okay, thank you.

416
01:05:25.110 --> 01:05:30.000
Richard Partridge: Next question is, what's involved in calibrating an amplifier.

417
01:05:31.500 --> 01:05:32.640
Aaron Roodman: Oh, good question.

418
01:05:34.140 --> 01:05:35.760
Aaron Roodman: Let's go, let's go to this.

419
01:05:37.110 --> 01:05:38.160
Aaron Roodman: Okay, so

420
01:05:40.500 --> 01:05:49.170
Aaron Roodman: Number one, you have to know where the zero is what signal from the amplifier corresponds no charge.

421
01:05:50.430 --> 01:06:00.900
Aaron Roodman: That's one calibration. The other is the game what electronic signal, do you see for each electron absorbed.

422
01:06:03.570 --> 01:06:10.800
Aaron Roodman: Then there's also non linearity is the response that goes through your amplifier through digitized.

423
01:06:11.940 --> 01:06:23.490
Aaron Roodman: Linear so you we convert the voltage here to a digital number with a an ADC analog to digital converter and so

424
01:06:25.710 --> 01:06:36.540
Aaron Roodman: Is the risk is that response linear, it's not going to be perfectly linear will be some non linearity, which may have some complicated shape. You have to map that shape out for every amplifier.

425
01:06:38.040 --> 01:06:39.360
Aaron Roodman: There are other issues.

426
01:06:40.470 --> 01:06:51.600
Aaron Roodman: At in some cases at a small level. This process is in perfect. And so when you do your bucket brigade each time you transfer

427
01:06:52.170 --> 01:07:01.980
Aaron Roodman: Maybe not all the charge transfers. Now, for us, our devices, the parallel direction is excellent. You have a few devices that had some issues in the cereal direction.

428
01:07:02.490 --> 01:07:12.240
Aaron Roodman: So the idea is, when you move charge from here to here, not all of it makes it a little bit, maybe 10 to the minus five is left behind.

429
01:07:13.320 --> 01:07:14.520
Aaron Roodman: And you have to correct for that.

430
01:07:18.000 --> 01:07:22.770
Aaron Roodman: So doing that on 3000 channels is hard doing it on 3 billion, I would want to touch.

431
01:07:24.060 --> 01:07:24.600
Richard Partridge: Okay.

432
01:07:26.130 --> 01:07:32.250
Richard Partridge: Next question. How does changing the CCD thickness impact the wavelength of light you can detect

433
01:07:32.910 --> 01:07:35.160
Aaron Roodman: Open question. So the

434
01:07:37.290 --> 01:07:47.190
Aaron Roodman: So the end. So first, the band gap silicon. It is an energy that's equivalent to light at about

435
01:07:49.230 --> 01:08:04.050
Aaron Roodman: 1050 nanometers. So that means that light whose wavelength is longer than 10 1500 meters cannot ionized the silicon and cannot the feathers photons cannot ionized so can not

436
01:08:05.040 --> 01:08:24.000
Aaron Roodman: Make an electron. So you don't see them. So, you know, infrared light is trans silicon CC. These are transparent white above that wavelength now below that wavelength. So there's there's an issue at in the in the UV

437
01:08:25.080 --> 01:08:32.610
Aaron Roodman: Deeper into the UV the photons can't penetrate into the bulk of the silicon. So we don't see them either.

438
01:08:33.420 --> 01:08:44.730

Aaron Roodman: Now silicon has the feature that it's absorption length is highly wavelength dependent. So at 1000 nanometers. The absorption length is around 100 micron.

439
01:08:45.480 --> 01:08:52.230
Aaron Roodman: So if your CDs are only 10 or 15 microns thick and that's how the previous generation of CC. These were

440
01:08:53.100 --> 01:09:03.840
Aaron Roodman: The devices in your cell phone or also thin devices typically most digital cameras or thin devices. So they can't see light passed around

441
01:09:04.440 --> 01:09:20.310
Aaron Roodman: Or can't see efficiently white pastor on 800 nanometers, because the absorption length is too long. And there's a good probability the photon will go all the way through it without being absorbed. So the thickness matters because the absorption length is every wavelength of it.

442
01:09:23.190 --> 01:09:27.150
Richard Partridge: Okay. And the next question.

443
01:09:28.590 --> 01:09:34.110
Richard Partridge: Why does the Hubble constant decrease before increasing in the Hubble Daisy diagram.

444
01:09:34.770 --> 01:09:35.760
Oh, okay.

445
01:09:37.050 --> 01:09:37.650
Aaron Roodman: Oh,

446
01:09:40.530 --> 01:09:55.470
Aaron Roodman: Well, so, you know, the Hubble so often, if people are being more careful we're called the Hubble parameter. It's a constant today, but over cosmic time so I'm sure, Richard. It's not constant and

447
01:09:57.810 --> 01:10:09.840
Aaron Roodman: It sort of basic cosmology that it varies in some way as we look back in time and that variation depends on the makeup of the universe. So how much matter how much dark

448
01:10:11.010 --> 01:10:13.380

Aaron Roodman: Energy, how much radiation is pressing

449
01:10:15.540 --> 01:10:23.520
Aaron Roodman: I think Daniel brewing covered that a little bit acre that something is first two lectures. But yeah, the Hubble it the humble.

450
01:10:24.750 --> 01:10:28.980
Aaron Roodman: This possible value as a parameter depending on customer

451
01:10:32.490 --> 01:10:35.880
Richard Partridge: Okay that's set of her Q AMP a time

452
01:10:38.700 --> 01:10:39.060
Aaron Roodman: Okay.

453
01:10:39.330 --> 01:10:40.080
Aaron Roodman: Terrific. Thanks.

454
01:10:41.160 --> 01:10:45.210
thomas rizzo: Rich think. Thanks, Aaron. I'm going to stop the recording now.