WEBVTT

1
00:00:00.179 --> 00:00:00.480
Malena Rice: All right.

2
00:00:03.090 --> 00:00:04.680
Morgan Elowe MacLeod: Wonderful Thank you so much.

3
00:00:05.580 --> 00:00:09.690
Malena Rice: All right, thank you, Morgan for the introduction and Thank you everyone for being here today.

4
00:00:10.230 --> 00:00:13.620
Malena Rice: My name is Molina rice and i'm a fourth year PhD candidate.

5
00:00:13.679 --> 00:00:22.500
Malena Rice: In the yellow astronomy department working primarily on the dynamics of planetary system so for me that includes both the solar system, as well as extra solar systems.

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00:00:23.070 --> 00:00:34.890
Malena Rice: And today i'll be sharing with you a really fun project, I think, putting together and all sky survey of the distant solar system by shifting and stacking data from the transiting exoplanet survey satellite, which is also known as test.

7
00:00:35.550 --> 00:00:48.120
Malena Rice: The focus of this survey is specifically on solar system objects that are magnitudes below the test single frame detection limit so many objects, need to be stopped in order to actually pull out the signals of these objects.

8
00:00:48.720 --> 00:00:57.120
Malena Rice: So some of this presentation will be based on a proof of concept that I published in 2020 but i'll also dedicate a fair bit of time to update since that paper.

9
00:00:57.420 --> 00:01:06.900
Malena Rice: And a couple of new directions, towards the end of the talk, so this is ongoing work and i'm really excited for the discussion and to hear everyone's input and other ideas that you might have.

10
00:01:07.740 --> 00:01:22.170

Malena Rice: So of course i'd like to start off by acknowledging that this project was actually inspired by two papers, led by scientists here at the CFA so it's really exciting to be here to share my workout the same place where some of that foundational groundwork was laid.

11
00:01:23.820 --> 00:01:35.010
Malena Rice: Alright, so to motivate this project, I wanted to also just begin with an overview of the parameter space, but has spanned by known objects in the Trans neptunian solar system so shown here.

12
00:01:35.280 --> 00:01:45.630
Malena Rice: Is a map of the known objects and semi major access versus eccentricities space, including delineation into a few different populations, so that includes the scattered.

13
00:01:46.200 --> 00:01:57.750
Malena Rice: disk the classical belt the centaurs on the detached pipe rebel objects, something you might notice is that, as we move towards increasingly larger Somebody needs to access, there are fewer objects that are no.

14
00:01:58.410 --> 00:02:07.830
Malena Rice: Specifically at the lower eccentricities and that's just an observational bias that just is showing that with current surveys, we can only see the most eccentric objects in these populations.

15
00:02:07.890 --> 00:02:13.230
Malena Rice: As they reach perihelion bringing them relatively close to the sun so within about 100 a year or so.

16
00:02:15.060 --> 00:02:22.440
Malena Rice: Of these distant objects, there are only about a handful that can that orbit entirely exterior to neptune's orbit, so this is.

17
00:02:22.740 --> 00:02:28.500
Malena Rice: Just a few objects that can't be directly scattered or dynamically interact with the solar system planet.

18
00:02:28.800 --> 00:02:39.210
Malena Rice: And these are the detached hyperbolic objects they've been the subject of a lot of debate over the past few years, and so, because of this they're also the primary population that we're targeting within the survey.

19
00:02:40.800 --> 00:02:51.060

Malena Rice: In 2014 shepherd entry to found that the arguments of perihelion of the long term, stable detached pepper bell objects appear to be clustered in one particular direction on the sky.

20
00:02:51.450 --> 00:02:58.200
Malena Rice: And this is not expected, because the orbits of these objects should process over time at different rates that would cause them to spread out.

21
00:02:58.620 --> 00:03:06.480
Malena Rice: Across the sky over a timescale about billion years so nothing in the solar system is actually in a nice pretty to body system.

22
00:03:06.960 --> 00:03:14.640
Malena Rice: We have deviations from a kepler and potential, particularly due to the outer giant planets in the solar system which we can approximate.

23
00:03:15.330 --> 00:03:30.150
Malena Rice: By summing over the perturbations induced by those giant planets and the secular approximation shown here and that deviation means that the orbits of your objects don't perfectly close and they should spread out but they appear to be clustered on one side of the sky.

24
00:03:31.350 --> 00:03:36.930
Malena Rice: And then similarly fatigue and brown in 2016 showed that the longitude of ascending note.

25
00:03:37.230 --> 00:03:45.030
Malena Rice: which tells us the relative plane and which each of the orbits lies also was found to be unexpectedly clustered and we wouldn't expect to see that, for the same reasons.

26
00:03:45.780 --> 00:03:57.720
Malena Rice: So, if this observed clustering is actually real and it's not an observational bias, it might suggest the influence of another body that can provide a restoring torque that prevents these orbits from spreading out.

27
00:03:58.290 --> 00:04:05.400
Malena Rice: And that proposed body is known as planet nine i'll note that it's sort of contested, whether or not this is real and that's actually a big.

28
00:04:05.820 --> 00:04:16.380

Malena Rice: Part of the survey where we're trying to figure out, you know we're not just looking for planet nine we're also looking for these trans neptunian objects and seeing are we able to put better constraints, with one survey.

29
00:04:16.650 --> 00:04:24.450
Malena Rice: on whether or not this is an actual effect or is just an observational bias from trying to combine multiple surveys that have different systematics.

30
00:04:25.800 --> 00:04:36.510
Malena Rice: So if planet nine does exist, then the the appeal of it is that it would be capable of restoring this, it would be capable of providing this restoring torque.

31
00:04:37.230 --> 00:04:47.730
Malena Rice: That would be able to prevent the procession of these extreme present journey and objects, and it would also be able to provide a mechanism to create detach type rebel objects.

32
00:04:48.030 --> 00:04:55.320
Malena Rice: To create high inclination orbits of objects, such as centers that are a little bit more difficult to explain, with some of our current dynamical models.

33
00:04:55.890 --> 00:05:01.110
Malena Rice: The most up to date parameter ranges for planet nine are shown on the bottom right here.

34
00:05:01.560 --> 00:05:10.170
Malena Rice: And so it would be a super sized planet, it would be really exciting if it did exist because that would allow, for instance, you observations potentially have a super Earth.

35
00:05:10.680 --> 00:05:17.070
Malena Rice: So it's sort of worth pursuing to see if it does exist because it would teach us a lot if it was out there, and if we found it.

36
00:05:18.390 --> 00:05:24.660
Malena Rice: So this is just a slightly more visual depiction of what planet nines orbit might look like, so what those orbital elements actually mean.

37
00:05:26.340 --> 00:05:34.680

Malena Rice: A few different groups have been searching for this planet in a variety of ways, since it was proposed, so the first method you can use is dynamical analyses to narrow down.

38
00:05:34.950 --> 00:05:38.610
Malena Rice: Where the planet could be based on how it would interact with various solar system.

39
00:05:39.150 --> 00:05:46.710
Malena Rice: Minor planet population, so this is just showing the level curves of a hamiltonian that I brought it up for a couple of different locations of.

40
00:05:47.040 --> 00:05:54.810
Malena Rice: pianos for a fight crucial planet now and let's just the middle values that you would expect, for from the initial proposals of what planet nine would look like.

41
00:05:55.500 --> 00:06:08.010
Malena Rice: I mean you can see that, for certain certain locations of these pianos you would get libration in the orbital angles, of the objects and so that means you would get a clustering of objects with.

42
00:06:08.940 --> 00:06:15.660
Malena Rice: This Omega angle in one particular direction of the sky that's the same APP Seidel alignment that we saw in the earlier slide.

43
00:06:16.320 --> 00:06:23.310
Malena Rice: Whereas the objects that are a little bit closer in in the solar system so at 150 or 250 you would not show that same clustering.

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00:06:23.820 --> 00:06:29.280
Malena Rice: So this is sort of the type of argument you can use, you can say we're going to put planet nine in a simulation.

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00:06:29.550 --> 00:06:38.580
Malena Rice: And we're just going to see what type of planet would produce the same dynamics that we observe in the outer solar system and try to narrow down the region of parameters space that it would fit in.

46
00:06:39.900 --> 00:06:48.840
Malena Rice: Another way is you can use gravitational probes so we can narrow down, where a planet can be based on the locations of objects, with a known solar system if amorous.

47
00:06:49.200 --> 00:06:58.890
Malena Rice: The United States tracks, the locations of its spacecraft using radio telescopes and the deep space network, which can pinpoint the locations of the spacecraft in the one D line of sight direction.

48
00:06:59.130 --> 00:07:08.670
Malena Rice: To within just a few meters so, for example, the Cassini radio raging data was used by the end got all 2016 and holman and pain 2016 be.

49
00:07:09.360 --> 00:07:16.770
Malena Rice: To suggest likely regions of forever space for this planet and an issue here is that it can be pretty easy to mistake.

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00:07:17.700 --> 00:07:24.900
Malena Rice: signals from undiscovered capable maps, with a signal from planet nine, there is a lot less material in the kuiper belt, but it's also.

51
00:07:25.230 --> 00:07:34.860
Malena Rice: A lot closer to us, and so the magnitude of the signal that you would get from the kuiper belt, which we don't actually know where all the material is because it's in a lot of very small bodies.

52
00:07:35.400 --> 00:07:43.170
Malena Rice: would produce a larger signal, then planet nine would, so this is a problem that can be mitigated that I did explore and password.

53
00:07:43.500 --> 00:07:58.110
Malena Rice: So I showed in 2019 paper that it would be possible to use a network of small telescopes to pinpoint the locations of many solar system asteroids using occultation which would provide the necessary precision to find or substantially.

54
00:07:58.590 --> 00:08:07.470
Malena Rice: narrow down the region of parameters baseboard planet and the idea here is that objects passing through the solar system will sometimes occult background stars.

55
00:08:07.890 --> 00:08:11.040
Malena Rice: And if we can measure those organizations, then we can figure out.

56
00:08:11.790 --> 00:08:19.830

Malena Rice: exactly where those asteroids are in space to the same precision as where the background stars are, which is now much better because of the guy emission.

57
00:08:20.460 --> 00:08:29.190
Malena Rice: um so with many of these precise positional measurements taken across many objects, this is sort of like having a lot of different Cassini spacecraft and being able to.

58
00:08:29.550 --> 00:08:34.710
Malena Rice: say more definitively with a lot of different probes if you see a statistical.

59
00:08:35.610 --> 00:08:46.230
Malena Rice: perturbation in one particular direction that might correspond to planet nine, so this is a way that you'd be able to use actually just what exists in the solar system already in order to pinpoint where planet nine could be.

60
00:08:46.860 --> 00:08:55.110
Malena Rice: And this is just showing to scale jovian Trojan asteroid Patrick list mendacious probably pronounced that wrong passing over the United States.

61
00:08:55.410 --> 00:08:58.590
Malena Rice: And so you can see, the size of its shadow as it passes over.

62
00:08:58.890 --> 00:09:09.660
Malena Rice: And all the different telescopes that it would cover up, and so there, there are a lot of asteroids that you'd be able to follow up it's, the problem is that you would need to follow up each individual asteroid.

63
00:09:10.380 --> 00:09:23.040
Malena Rice: Several times and so it'd be quite expensive to just fly around the world to try to do this, and the idea, there was that if you had a robotic networks that was just continually observing it would be possible to actually accomplish this.

64
00:09:24.480 --> 00:09:34.980
Malena Rice: These would be relatively small telescopes 16 inch or so, but that's still not terribly inexpensive to implement and so that brings us to direct reflected light searches.

65

00:09:35.550 --> 00:09:51.420
Malena Rice: This is also not always it's not always easy to implement it's kind of expensive as well, but fortunately there was all ready a spacecraft that was completing an all sky optical survey, that is, the transiting exit survey satellite or test that I mentioned at the beginning of the talk.

66
00:09:53.070 --> 00:10:01.110
Malena Rice: So this is just a video that's showing what exactly it is that test observes, it has four different CDs and you'll see it sweep around the sky observing.

67
00:10:01.410 --> 00:10:05.730
Malena Rice: different regions of the sky and eventually it gets around pretty much the entire sky.

68
00:10:06.390 --> 00:10:16.620
Malena Rice: test is an earth orbiting satellites, it was designed to search for transiting exoplanets around right nearby stars and while this isn't actually the missions primary cases actually.

69
00:10:16.950 --> 00:10:24.840
Malena Rice: Really, ideally suited to search for these distant objects that are dim and slow moving in the outer solar system so.

70
00:10:25.440 --> 00:10:38.490
Malena Rice: test observes each region of the sky for about a month at a time, collecting a huge number of photons from each individual object and the frame especially these really dim objects that are moving very slowly and stay in the frame for the entire 27 days.

71
00:10:39.600 --> 00:10:47.310
Malena Rice: Here you can see there's a gap in between the northern and southern surveys and that's actually where the solar system lies, so this is the ecliptic plane.

72
00:10:47.670 --> 00:10:56.850
Malena Rice: And testers observing all of the higher inclination space, which is where we would expect planet nine might potentially exist, it should be on a relatively high inclination orbit.

73
00:10:57.570 --> 00:11:12.570
Malena Rice: testers cameras are actually very conveniently aligned parallel to the ecliptic plane, which means that distance solar system objects that move within the plane or somewhat close to the plane they cover only a small orbital Arc.

74
00:11:13.620 --> 00:11:22.230
Malena Rice: Over the span of the technician the the objects that were interested in that are very far away, and they should just be moving effectively from left to right.

75
00:11:22.590 --> 00:11:29.280
Malena Rice: And the reason for this is we're just seeing the earth's care looks motion as the Earth is moving past these objects that are very far away.

76
00:11:29.610 --> 00:11:33.570
Malena Rice: And so the fact that test hazards cameras align parallels we booked It means that.

77
00:11:33.960 --> 00:11:45.930
Malena Rice: A ships on a ship stalking search really only needs to look at a certain region of parameters face it just needs to look at how's that are moving mostly from left to right because we're just looking at the earth moving past these objects.

78
00:11:48.000 --> 00:11:55.350
Malena Rice: So the two initial feasibility studies on this top have demonstrated that known transcript tuning and objects can be recovered by ship stocking.

79
00:11:55.620 --> 00:12:02.130
Malena Rice: And they stated that it should be possible to actually discover up to hundreds of new objects by searching a lot all possible orbital pads.

80
00:12:02.550 --> 00:12:15.630
Malena Rice: This is a really cool opportunity actually to use a space faced all sky survey to search for high inclination solar system objects that are rare, but are also really dynamically interesting and can tell us a lot about the history of the solar system.

81
00:12:16.890 --> 00:12:26.880
Malena Rice: So to realize this idea we developed a shift stocking pipeline that's designed to process tests full frame images and search for the signals of DEM outer solar system objects below the tests.

82
00:12:27.360 --> 00:12:35.070

Malena Rice: single frame detection limit and this pipeline involves first masking out the brightest pixels so we're just reducing noise from stars in the frames.

83
00:12:35.640 --> 00:12:43.080
Malena Rice: Then we subtract away the baseline for flux of every pixel, we need to do that because we're looking for systematic increases of.

84
00:12:43.500 --> 00:12:51.900
Malena Rice: Above the baseline flux that occur along a path and then Lastly, we shift and stock the frames alone all possible paths in order to search for these new objects.

85
00:12:52.620 --> 00:12:57.000
Malena Rice: So a little bit more concretely we can consider the example of sedna which is.

86
00:12:57.540 --> 00:13:08.490
Malena Rice: The about 20.6 extreme trans neptunian objects sedna is in the pixel with a black Star and the test screen to the left and it's in the pixel with a red dot and the test for into the right.

87
00:13:08.760 --> 00:13:19.620
Malena Rice: So you can't really see any obvious changes in flux from justice photometer because it's so dim and so what what we do is, we take the full time series we just.

88
00:13:20.730 --> 00:13:26.130
Malena Rice: Ignore sort of these data downlinks that occur at the beginning middle and end of each sector.

89
00:13:26.610 --> 00:13:36.480
Malena Rice: And then we fit some model to each side of each pixels like curve subtracted away until we get effectively noise and then we end up with just this Nice.

90
00:13:37.290 --> 00:13:45.840
Malena Rice: Noise image and well that's great because what we're looking for is actually just tiny deviations above that noise so you're not going to be able to see any of this by.

91
00:13:46.530 --> 00:13:53.790
Malena Rice: Once we've done that we can then look for objects that are actually moving across the frame that are extremely dim so if you're looking for.

92
00:13:54.120 --> 00:14:02.220
Malena Rice: An object that moves across the frame like this, then you could equivalent Lee follow the frame of the object instead and slide the image past.

93
00:14:02.520 --> 00:14:12.000
Malena Rice: And so that's sort of the idea of shift stacking where you're sliding the images path to follow the path to follow the frame of reference of the object that you're looking for.

94
00:14:12.510 --> 00:14:19.770
Malena Rice: And this is a, this is an example video that's just showing how we shift stock to recover sadness.

95
00:14:20.520 --> 00:14:27.570
Malena Rice: flux and so what you see here is in the Left frame we've maxed out all of the foreground stars.

96
00:14:27.990 --> 00:14:32.850
Malena Rice: Are all the background stars, and so what you end up seeing is foreground asteroids that are just passing through the frame.

97
00:14:33.450 --> 00:14:41.850
Malena Rice: So once we've gotten rid of all of the other all the extremely bright things in the frame, then you end up with the slightly less bright things that are just asteroids passing through.

98
00:14:42.480 --> 00:14:48.480
Malena Rice: And then on the right side, we are showing the recovery of said no overtime and So here we.

99
00:14:48.840 --> 00:14:59.910
Malena Rice: Are sequentially summing the images, as they show up on the left and we start off with this big gap on the left side of the right frame that ends up being filled in over time, as we shift and stop to get this Nice.

100
00:15:00.840 --> 00:15:11.460
Malena Rice: Little dot that is that enough, and so this is sort of how we are able to extract the signals of individual objects that we know of already using shift stacking.

101
00:15:12.810 --> 00:15:15.810

Malena Rice: And that's to summarize by the first three slides that are shown here.

102
00:15:16.770 --> 00:15:25.350
Malena Rice: And this, this is sort of showing how we can extract the already known objects, but we want to take this a step further and also find undiscovered objects.

103
00:15:25.800 --> 00:15:32.880
Malena Rice: And so what we do, there is, we create something that we call a best ever frame which is an aggregate frame that retains the highest flux.

104
00:15:33.180 --> 00:15:38.130
Malena Rice: From all of the tested shift stocks a given pixel so in order to create this frame we check.

105
00:15:38.460 --> 00:15:44.310
Malena Rice: All the different pods of interest that and find the highest some flux, that is attained along all pads.

106
00:15:44.640 --> 00:15:50.580
Malena Rice: And this ends up, leading to a final data product that looks kind of similar to an image, but it's a little bit different it's actually.

107
00:15:50.880 --> 00:16:00.060
Malena Rice: Information dense aggregate that condenses all the information from all your ships docs into one image and then you can pick out what looks like real signals.

108
00:16:00.390 --> 00:16:15.030
Malena Rice: conduct the standards ships Doc so just do what we did on the previous frame and see if you get a signal that looks like a realistic object, so this is kind of a way to pull out the most promising signals and look at all of your ship stocks at the same time.

109
00:16:16.590 --> 00:16:27.210
Malena Rice: So we demonstrated our object to recover objects are three different objects that are below the testing over in detection limit here, so these are three different trans neptunian objects sedna.

110
00:16:31.500 --> 00:16:36.450
Malena Rice: And these are the three rows that are shown in descending order of magnitude.

111
00:16:36.990 --> 00:16:44.310
Malena Rice: And in the first column, we just shipped in stock the frames along the objects known orbital pads, so this is like the video that I showed earlier.

112
00:16:44.700 --> 00:16:56.250
Malena Rice: But in the second and the third columns here the recovery is actually incorporate no prior knowledge of the objects orbits so here we're shifting and stacking along all possible orbital pads assuming.

113
00:16:56.580 --> 00:17:06.360
Malena Rice: linear paths that are dominated by the earth's motion between 35 and 808 and we end up having nice signals of sedna and BP 519.

114
00:17:07.380 --> 00:17:13.830
Malena Rice: tg for 22 was not recovered with this blind search and that's probably because of a combination of two factors.

115
00:17:14.160 --> 00:17:19.830
Malena Rice: The first is that we think this is about what our detection limit is and might be slightly below our detection limit with the search.

116
00:17:20.340 --> 00:17:31.620
Malena Rice: In terms of magnitude, so this is the dentist of the three objects and the other reason is that tj for 22 is the most nearby of these three objects so it's out of distance of about 37 a you from.

117
00:17:32.100 --> 00:17:43.650
Malena Rice: 37 eight away from the earth, and what that ends up meaning is it has a more non linear path because you get a larger contribution in the test rain from the objects actual motion, instead of just the earth's parallax.

118
00:17:44.040 --> 00:17:49.260
Malena Rice: And so, because you have the object that's actually moving on a larger part of its orbital Arc.

119
00:17:49.740 --> 00:18:01.440
Malena Rice: you're not going to be able to capture the entire Arc in a linear shift stalking search and so because of that it's sort of challenging in two different ways, because it's relatively nearby as well as because of its magnitude.

120

00:18:02.940 --> 00:18:11.190
Malena Rice: We used induction recovery tests to understand the completeness or detection limits using two different baselines subtraction methods that we applied in our blind search.

121
00:18:11.460 --> 00:18:19.410
Malena Rice: So we selected a random cut out region from each of the tests, the CDS specifically looking at a region along the galactic plane.

122
00:18:19.710 --> 00:18:25.890
Malena Rice: With the motivation that we want to understand what our detection limits are in the most challenging region of the sky before we then.

123
00:18:26.400 --> 00:18:36.120
Malena Rice: Go for a full sky survey that that will then perform better in the cleaner parts of the sky, but we want to know how well we can perform and the really tough parts of the sky as well.

124
00:18:37.110 --> 00:18:43.740
Malena Rice: Here we injected a grid of 24 signals at each magnitude and extra into each of these frames an extra gift is.

125
00:18:44.070 --> 00:18:55.980
Malena Rice: A proxy for distance because this just quantifies the rate at which the signal moves across the sky, so this is the number of pixels that it spans over a test sector, then we ran our pipeline that.

126
00:18:57.120 --> 00:19:06.390
Malena Rice: We ran our pipeline using two different baseline subtraction methods so we used a polynomial fit where we just fit simple polynomials to the baseline of that pixel.

127
00:19:06.900 --> 00:19:14.700
Malena Rice: We also use a principal component analysis baseline subtraction where we were looking at surrounding pixels in order to determine the baseline of that individual one.

128
00:19:15.120 --> 00:19:30.480
Malena Rice: And we find that first of all our survey is mostly complete for objects to about 21st magnitude and around 150 au so that's about 25 to 30 pixel shift, and so you can see, we have mostly blue to purple diamonds that are in that region.

129
00:19:31.560 --> 00:19:36.450

Malena Rice: And that's in the galactic plane, specifically the performance would be a little bit better outside of the galactic plane.

130
00:19:37.110 --> 00:19:45.120
Malena Rice: And our PCA baseline subtraction method also performs generally better than our polynomial method and that's because we don't get as much self subtraction.

131
00:19:45.660 --> 00:19:57.990
Malena Rice: So we're looking at other pixels in order to determine the pace baseline of a given pixel and that's going to be really important for these really slow moving objects like planet nine because they stay on one pixel for a really long time.

132
00:19:58.320 --> 00:20:08.790
Malena Rice: And so it's very easy to just subtract away the signal the object if you're just fitting to the baseline of that pixel itself, because it will stay in one pixel for most of the time that it's being observed.

133
00:20:10.290 --> 00:20:22.020
Malena Rice: We also quantified our detection limits, specifically for more planet nine like objects on where we found that we're sensitive out to about 20th magnitude or so in the galactic plane, using the PCA subtraction.

134
00:20:22.920 --> 00:20:34.680
Malena Rice: But I would like to emphasize that this first paper was really intended as a proof of concept so since then we've done further work to refine our methods before extending to the all sky survey and so.

135
00:20:35.490 --> 00:20:42.870
Malena Rice: Here you can see our published best ever frame recovery of sedna, this is the initial recovery that we showed a couple of slides back, and if we.

136
00:20:43.590 --> 00:20:50.610
Malena Rice: mask out the foreground asteroids, then we can refine that return signal and just get rid of a lot of the streets that showed up.

137
00:20:51.030 --> 00:20:59.610
Malena Rice: And then, with a couple more adjustments to the pipeline so more careful stellar masking maximizing the number of data frames that we preserve within our recovery.

138

00:21:00.240 --> 00:21:06.990
Malena Rice: we're able to extract the signal, and this is again a best ever frame, so this is searching over every possible path in that.

139
00:21:07.260 --> 00:21:15.060
Malena Rice: region of the test frame and you really just get a signal from said now you're not seeing really any substantial systematics in this frame.

140
00:21:15.600 --> 00:21:20.310
Malena Rice: And this is what we're trying to get all of our signals to look like, before we do, and also, I search.

141
00:21:20.850 --> 00:21:30.180
Malena Rice: Because we want to make sure that our limits are not in our methods and then it's really a limit of the data set so we want to hit the magnitude limit that is possible to hit with tests.

142
00:21:30.690 --> 00:21:34.500
Malena Rice: By being as careful as we can with all of our pre processing methods.

143
00:21:35.190 --> 00:21:43.860
Malena Rice: And so the primary goal of this work is to extend this project to and all sky survey that is incorporating neural networks, so it is quite a lot of data.

144
00:21:44.370 --> 00:21:54.450
Malena Rice: To go through all the tests primary mission, but then test is actually also continuing to observe, so you can just continually run all of the sectors through this type of search.

145
00:21:55.260 --> 00:22:02.550
Malena Rice: This would streamline the candidate identification process, but it would also help us to better understand what our false positive rate is going to be.

146
00:22:02.760 --> 00:22:10.410
Malena Rice: So we inject signals into our data set and better understand what types of ground or what region of parameter space we're actually sensitive to.

147
00:22:12.000 --> 00:22:19.410

Malena Rice: Throughout this talk i've also been really focused on the very distant solar system objects, but it's also possible to extend to other populations so.

148
00:22:19.650 --> 00:22:24.450
Malena Rice: On this map alone there are a lot of different populations that could be explored with the same methods.

149
00:22:24.750 --> 00:22:35.160
Malena Rice: test surveys, the entire high inclination sky and will also be looking within the solar system so it's going to be filling in a lot of the space that it didn't observe before over the coming years.

150
00:22:35.610 --> 00:22:43.320
Malena Rice: And so there's a lot that is there to be mined and that hasn't really been explored so much for the purposes of studying the solar system just yet.

151
00:22:44.580 --> 00:22:52.470
Malena Rice: One example population of potential interest is the interstellar objects and that comes to mind because test is observing the high inclination sky.

152
00:22:52.800 --> 00:23:03.360
Malena Rice: interstellar objects generally come from very high inclinations and you can see the orbits of the two that have been observed, so far, within this simulation here the.

153
00:23:04.470 --> 00:23:12.300
Malena Rice: In particular, something really interesting about this is that those two objects both came from the same direction in the sky they came from.

154
00:23:12.660 --> 00:23:18.120
Malena Rice: The solar apex, which is the direction that the sun travels in the galaxy relative to the local standard oppressed.

155
00:23:18.450 --> 00:23:27.270
Malena Rice: And that's not actually too far off from the test continuous viewing zone, which is where test takes 350 days of continuous observations.

156
00:23:27.510 --> 00:23:35.880

Malena Rice: So this could actually be a really good place to search to understand occurrence, or to place constraints on interstellar object occurrence rates.

157
00:23:36.450 --> 00:23:45.750
Malena Rice: And previous studies that are have extrapolated from the observations of the first one to two interstellar objects so that's a big asterisk because we actually haven't seen that many.

158
00:23:46.320 --> 00:23:52.290
Malena Rice: But extrapolating from that it, it seems like there might be a lot of these objects out there.

159
00:23:52.740 --> 00:24:03.300
Malena Rice: And so it might be possible for testified individual objects, but even if not, it could be used to place limits on what should have been detectable and it could be a really good survey to accomplish that.

160
00:24:04.800 --> 00:24:15.510
Malena Rice: shift stalking search for dim nearby objects like interstellar objects, is going to require nonlinear shift stalking so you can't just do a linear search the way that we have been in this initial survey.

161
00:24:16.230 --> 00:24:26.700
Malena Rice: This is something that I have been actually working on developed a program that converts directly from orbital elements to the sky projected locations of objects as viewed by this test spacecraft.

162
00:24:27.120 --> 00:24:30.900
Malena Rice: So these are just a couple of sample tracks and the top left here.

163
00:24:31.500 --> 00:24:41.130
Malena Rice: And with that we're now injecting signals on randomly sampled orbits into our data frames to better understand what kinds of signals are extracted by our neural network.

164
00:24:41.490 --> 00:24:51.150
Malena Rice: And to delineate that parameter space and to better understand, should we be doing a nonlinear ship stocks should be continued doing linear shifts docs just in particular regions of parameter space.

165

00:24:51.480 --> 00:24:56.100
Malena Rice: And to figure out what we would expect to be able to accomplish with each of those approaches.

166
00:24:56.760 --> 00:25:04.140
Malena Rice: And I also want to note that the location of these objects as viewed by tests as a little bit different from.

167
00:25:04.800 --> 00:25:12.450
Malena Rice: As viewed from the earth, as shown in the bottom left here so test is on a really highly eccentric orbit and you need to start taking that into consideration for.

168
00:25:12.660 --> 00:25:24.810
Malena Rice: objects that are a little bit closer in so our first search was just focusing on the objects like 78 you are farther from the earth you don't really have this problem, but once you get start getting a little bit closer and you really do need to take it into account.

169
00:25:26.100 --> 00:25:35.130
Malena Rice: And then, a last fun thing that I tried recently actually based on a suggestion by Mike Alexander sent here at the CFA is sequential summing to see if we can.

170
00:25:35.490 --> 00:25:45.720
Malena Rice: extrapolate any information about the shapes and rotational properties of the observed objects so for Center we don't really see any particularly obvious trends from this.

171
00:25:46.170 --> 00:25:49.050
Malena Rice: image in the top right, and I think that's actually expected because.

172
00:25:49.320 --> 00:26:00.840
Malena Rice: Suddenly was just about large enough for gravitational forces to overcome rigid forces and so Center should have actually potentially be an hydrostatic equilibrium and would this be round, so you wouldn't really see anything.

173
00:26:01.110 --> 00:26:14.490
Malena Rice: But for moral blade objects, this could be really interesting to better understand the shapes the distribution of these objects, including for known objects, potentially, but also for these objects that were searching for that have not yet been discovered.

174

00:26:15.720 --> 00:26:22.830
Malena Rice: So I will leave you with my conclusions Thank you again all for being here and i'm excited to chat more about this.

175
00:26:26.580 --> 00:26:29.790
Morgan Elowe MacLeod: Thank you so much million a year, the, but you can only hear me clap thanks.

176
00:26:31.110 --> 00:26:36.450
Morgan Elowe MacLeod: really appreciate it, and I think that it's really exciting stuff here as we think about.

177
00:26:39.000 --> 00:26:47.370
Morgan Elowe MacLeod: Well, I don't know, on a personal level, I get really excited about work like this, because it takes an instrument that we already have like capability that we already have.

178
00:26:47.790 --> 00:27:00.780
Morgan Elowe MacLeod: And we're kind of imagining what a totally different science application could be, then the like original design and and we also don't have to wait a decade to start doing that science, so I think that's incredibly exciting.

179
00:27:01.800 --> 00:27:03.930
Morgan Elowe MacLeod: So as a logistical reminder.

180
00:27:05.550 --> 00:27:13.980
Morgan Elowe MacLeod: People who have questions go ahead and text me in the private chat just a word or two about the the topic of your.

181
00:27:15.300 --> 00:27:18.420
Morgan Elowe MacLeod: Question and and we can start a conversation there.

182
00:27:19.920 --> 00:27:26.880
Morgan Elowe MacLeod: So i'll go ahead and as go first question, I am curious about.

183
00:27:32.310 --> 00:27:34.260
Morgan Elowe MacLeod: I guess about your.

184
00:27:35.820 --> 00:27:39.960
Morgan Elowe MacLeod: outlook on or, if you could talk a tiny bit more about like.

185
00:27:41.070 --> 00:27:50.250
Morgan Elowe MacLeod: Expanding into the faster moving or the nonlinear emotion that that you were referencing, how do we.

186
00:27:53.520 --> 00:28:05.400
Morgan Elowe MacLeod: Do do you envision that happening in a way that is essentially like totally blind or totally algorithmic in the sense of like just like letting.

187
00:28:06.870 --> 00:28:19.020
Morgan Elowe MacLeod: A neural network try to handle that or do you envision that happening in terms of like we encode you know the capillary and motion and then like a search in a more targeted way.

188
00:28:20.580 --> 00:28:21.120
Malena Rice: yeah.

189
00:28:21.210 --> 00:28:23.040
Morgan Elowe MacLeod: And if there are things that i'm missing, please.

190
00:28:23.070 --> 00:28:25.650
Morgan Elowe MacLeod: Go ahead and speak more broadly to that.

191
00:28:26.250 --> 00:28:29.850
Malena Rice: um yeah so in a nonlinear ship stock.

192
00:28:31.260 --> 00:28:33.510
Malena Rice: i've actually just been working on this, so I can pull up.

193
00:28:34.350 --> 00:28:34.950
amazing.

194
00:28:36.090 --> 00:28:49.650
Malena Rice: So I i've been working on developing a library of just all of the So this is the plot that you saw earlier of all of the possible orbital paths that you can get and there was an interesting work by.

195
00:28:50.550 --> 00:29:01.530
Malena Rice: Robbie burkhardt magazine, and someone else a couple of years ago that was they were they were finding the minimum number of these orbits that you can find that.

196

00:29:03.000 --> 00:29:09.420
Malena Rice: Are overlapping little enough that you would expect to find the the full range of.

197
00:29:10.560 --> 00:29:12.420
Malena Rice: orbits that you're interested in and so.

198
00:29:12.990 --> 00:29:24.750
Malena Rice: The idea, there is you randomly sample lots and lots of orbits over the entire parameter space so that's what i've been doing i'm specifically right now focusing on objects from about 50 to 200 a year because that's the.

199
00:29:25.410 --> 00:29:29.040
Malena Rice: region of these extreme trans neptunian objects, where there's a lot of debate.

200
00:29:29.490 --> 00:29:42.330
Malena Rice: And so i've been working on just developing a library of lots and lots of orbits and then, once we have that, then we can actually narrow down and first of all understand what what types of orbits create.

201
00:29:42.990 --> 00:29:45.990
Malena Rice: Or what types of orbits create what kinds of paths, you can.

202
00:29:46.410 --> 00:29:57.600
Malena Rice: just get a better sense of like if we only look at the pro great orbits then they look like this, as opposed to this initial group or if we just look at the lower eccentricity orbits then and narrows it down a little bit.

203
00:29:58.170 --> 00:30:04.710
Malena Rice: And so what i'd like to do there is just first of all consider for all of the possible orbits.

204
00:30:05.160 --> 00:30:15.900
Malena Rice: How many pods would you actually need to search and then, if you want to narrow down to fewer orbits so if that might be sort of computationally intractable if that's too many paths.

205
00:30:16.230 --> 00:30:25.710
Malena Rice: To actually search with this algorithm, then you can also narrow it down and just say i'm only going to look for pro grade objects that are at this range of eccentricities.

206
00:30:26.280 --> 00:30:31.950
Malena Rice: That also helps to reduce noise and these best ever frames, because the more pads you search the more noise, you get.

207
00:30:32.400 --> 00:30:39.180
Malena Rice: And so that's one of the main concerns that I have is that I don't want to search too many paths such that the real signal gets drowned out.

208
00:30:40.050 --> 00:30:45.210
Malena Rice: And yeah so I guess the direction that I see that going is coming up with a library of the.

209
00:30:45.660 --> 00:30:51.930
Malena Rice: minimum number of paths that you can search to expect to actually recover all the objects in your expected parameter space.

210
00:30:52.230 --> 00:31:02.460
Malena Rice: And then actually just shift and stock along those pads and developing the library is actually the more computationally expensive part because shift stocking is just like a ray operation so it's.

211
00:31:02.460 --> 00:31:03.450
Morgan Elowe MacLeod: very expensive.

212
00:31:03.480 --> 00:31:05.550
Morgan Elowe MacLeod: right with these 2d arrays.

213
00:31:06.600 --> 00:31:06.810
Malena Rice: yeah.

214
00:31:06.870 --> 00:31:08.820
Morgan Elowe MacLeod: that's really interesting and i'm.

215
00:31:10.500 --> 00:31:16.140
Morgan Elowe MacLeod: Along those lines, does that relate to some of your comments on completeness, because, like you can understand whether.

216
00:31:17.820 --> 00:31:32.580
Morgan Elowe MacLeod: i'm making this up, because I don't know but, like a very eccentric orbit would produce a path that's harder to detect or something like that, like does that relate to what types of orbits are easiest to find.

217
00:31:33.750 --> 00:31:35.910
Malena Rice: yeah so this tells us more about.

218
00:31:37.470 --> 00:31:41.490
Malena Rice: What types of orbits you can find with a linear ship stacking so.

219
00:31:41.490 --> 00:31:42.420
Morgan Elowe MacLeod: Good and.

220
00:31:42.450 --> 00:31:43.080
Malena Rice: So if.

221
00:31:43.170 --> 00:31:48.870
Malena Rice: If the line is straight, then you can find it and if it's not straight, then you probably can't find is effectively what's that saying.

222
00:31:49.680 --> 00:31:59.070
Malena Rice: You can again extend to a nonlinear shifts document research is just extends the parameter space, so that you might get more false positives and so you have to be a lot more careful.

223
00:31:59.370 --> 00:32:05.130
Malena Rice: About actually interpreting your results, once you do that so it's something we've been actively thinking about how to do.

224
00:32:06.360 --> 00:32:09.840
Morgan Elowe MacLeod: Interesting brad do you want to go ahead and continue along these lines.

225
00:32:11.640 --> 00:32:15.090
Brad Wargelin: Oh no I think that's all been covered thanks.

226
00:32:17.610 --> 00:32:19.410
Morgan Elowe MacLeod: matt had a question also.

227
00:32:22.770 --> 00:32:31.470
Matthew Holman: yeah nice talk more that really it's really great to see this, I have a few questions about some of them have already been answered but.

228
00:32:32.190 --> 00:32:42.150
Matthew Holman: So this is mostly about the sort of the details of the backgrounds of traction so it's really interesting to see you know your approach of fitting the individual pixels.

229
00:32:43.020 --> 00:32:52.470
Matthew Holman: And I mean I guess what you're also doing some PCA so did you do examine options for kind of more conventional image subtraction.

230
00:32:53.820 --> 00:32:57.690
Matthew Holman: Is that that was what really what I had kind of imagined anybody would do.

231
00:32:58.500 --> 00:33:05.190
Malena Rice: yeah do you mean just subtracting out the median from the test data set for.

232
00:33:05.820 --> 00:33:14.820
Matthew Holman: Or you know, there are a bunch of different approaches, where you're maybe not subtracting the median, but you have some transformation from.

233
00:33:15.930 --> 00:33:19.140
Matthew Holman: Each individual exposure to a template exposure.

234
00:33:20.220 --> 00:33:28.260
Matthew Holman: That you know, and I know that's really challenging for the case of a test because it's under sampled somewhat and because there are.

235
00:33:28.770 --> 00:33:41.100
Matthew Holman: distortions that have to do with the velocity of the spacecraft but i've just it was interesting to see that you, you, you took them or local approach that seems to be pretty effective and i'm mostly interested in how you arrived at that.

236
00:33:42.180 --> 00:33:53.910
Malena Rice: yeah so in in the more recent iteration that came or blitzes this image, I actually did do a median subtraction before then implementing these other methods, but I found that when I used.

237
00:33:54.240 --> 00:34:04.290

Malena Rice: Just the media and subtraction I ended up with a little bit too much noise, where you couldn't really extract the signal as nicely, and I think it's just that.

238
00:34:05.610 --> 00:34:17.100
Malena Rice: Different pixels are maybe affected more or less by locally what exists around them within the frame so maybe if they are a little bit closer to a nearby star or something else.

239
00:34:17.700 --> 00:34:24.690
Malena Rice: So the media and subtraction, I guess, first of all doesn't really get rid of the signals from surrounding star so that was kind of the motivation for.

240
00:34:24.930 --> 00:34:33.540
Malena Rice: Just a direct polynomial fit, because then, you know that if this pixel is a little bit closer to the star than another pixel you're still subtracting the baseline and the same way.

241
00:34:34.020 --> 00:34:50.160
Malena Rice: yeah the the PCA method we found worked better and what we're doing there as we consider a given pixel we have masked out the region within five pixels of that particular pixel and we consider the.

242
00:34:50.700 --> 00:35:03.480
Malena Rice: end the number of surrounding pixels outside of that opportunity that we then use to determine the baseline subtraction, so this is something that is implemented in the light or package, it exists from the test team itself.

243
00:35:03.810 --> 00:35:04.530
Matthew Holman: Okay okay.

244
00:35:04.710 --> 00:35:15.870
Malena Rice: So that's that's something that we have used that we found more effective, I think, because it captures those local effects, a little bit better, but it also doesn't consider flux associated with the objects that you're interested in.

245
00:35:16.410 --> 00:35:28.200
Malena Rice: I know that there are other kind of more detailed methods that do this as well, where they specifically look for just the regions that are farther from the stars and are a lot more careful about exactly what.

246

00:35:28.620 --> 00:35:40.320
Malena Rice: pixels they use in the baseline subtraction and this that's really the most important part in how how well, you can extract your signal is really very, very directly based on how good your baseline subtraction is.

247
00:35:40.950 --> 00:35:41.250
Matthew Holman: yeah.

248
00:35:41.700 --> 00:35:46.560
Malena Rice: I know, Dan foreman mackey who i'm working with on this as a student who has been working on that, but.

249
00:35:47.010 --> 00:35:54.150
Malena Rice: He also mentioned that it's pretty computationally expensive and so everything that i've been doing best bar runs within.

250
00:35:54.810 --> 00:35:59.940
Malena Rice: A day for a sector, so it doesn't take very long to run and i'm a little bit hesitant to make it.

251
00:36:00.360 --> 00:36:11.700
Malena Rice: Very computationally expensive but yeah i'll see if it works much better because it might be worth doing if it takes a few days versus a day just kind of slows down the timeline a little bit.

252
00:36:12.600 --> 00:36:17.850
Matthew Holman: yeah and I saw a question related to that as your best driver frame.

253
00:36:18.900 --> 00:36:19.530
Matthew Holman: So.

254
00:36:20.730 --> 00:36:30.930
Matthew Holman: I guess I don't really understand what and I Maybe I should just look at the paper to see you know how are you kind of compressing all the results into one frame and you kind of alluded to.

255
00:36:31.650 --> 00:36:33.480
Matthew Holman: The noise from different solutions.

256
00:36:33.510 --> 00:36:34.290
interfering.

257
00:36:36.030 --> 00:36:38.700
Matthew Holman: Of course I know how shift and stack works, but.

258
00:36:40.140 --> 00:36:47.340
Malena Rice: yeah so I skipped over this because I didn't have enough time to go over everything in detail, but.

259
00:36:48.000 --> 00:36:55.290
Malena Rice: What we're doing in the best evergreens is we're basically starting with a 2d array of zeros we put our baseline subtracting image in it.

260
00:36:55.710 --> 00:37:10.200
Malena Rice: And then we shift and stock along some path, and then we every pixel that has been covered here check if the flux is higher than it has ever been before so for the first just stack every positive value is retained.

261
00:37:10.740 --> 00:37:19.260
Malena Rice: And then we keep that image and conduct another ship stock along another path and do the same thing so then we compare with all of the other.

262
00:37:20.340 --> 00:37:31.050
Malena Rice: pixels that exist or we compare with the previous values of those pixels and just retain the highest blocks, and this is going to sort of add some noise.

263
00:37:32.340 --> 00:37:43.080
Malena Rice: But it also creates a slightly more intuitive wait for me at least to understand what the highest signal to noise results are in a given frame because each.

264
00:37:44.250 --> 00:37:52.890
Malena Rice: Because then you're able to maintain that the highest flux, that you get from every possible shift starts within just one image and so you can compare.

265
00:37:53.280 --> 00:38:06.000
Malena Rice: All of the signals and false positives in a given image together all at the same time as opposed to having lots and lots of different images that you have to check for individual potential signals.

266
00:38:07.410 --> 00:38:25.830

Morgan Elowe MacLeod: Say can I follow up on your comments on adding noise, so does it have the effect of like say you have a pixel, which is particularly high background level like doesn't that smear it in every direction so that your background is like equivalent to whatever your worst.

267
00:38:27.090 --> 00:38:28.800
Morgan Elowe MacLeod: deviation upward is.

268
00:38:30.600 --> 00:38:32.640
Morgan Elowe MacLeod: Or, or like.

269
00:38:33.120 --> 00:38:43.740
Malena Rice: yeah, so I think that would end up leading to effectively what you're seeing from these asteroids where you would get sort of a streak in the frame, so we have roots here.

270
00:38:44.190 --> 00:38:57.240
Malena Rice: And so that that also helps to if you just had an individual ship stack that you might just see this as a bright point but with the best ever frame than the signal sort of get smeared across the frame or.

271
00:38:57.930 --> 00:39:16.050
Malena Rice: you end up with what doesn't look like a real signal and what i'm calling a real signal is one that has a High Flux peak of the very Center so that corresponds to the best match in terms of the ship's docking path, so the linear path best overlaps with that particular.

272
00:39:17.790 --> 00:39:25.290
Malena Rice: With that particular path and then you get the highest FLEX and then you get a tapering around it and those are pods that are.

273
00:39:25.560 --> 00:39:31.770
Malena Rice: close to the right path, but don't overlap entirely so they overlap partially with the path of the object, but not fully.

274
00:39:32.220 --> 00:39:40.590
Malena Rice: And you end up with this nice sort of tapering off, and you can kind of distinguish that from like this does not look like that, so you know that that's probably something else.

275
00:39:40.890 --> 00:39:51.420
Malena Rice: Sometimes it's a little tricky with the stars, but usually they're kind of a little bit more uniformly a bright region as opposed to having a bright Center that tapers off.

276
00:39:52.920 --> 00:39:53.520
Malena Rice: make sense.

277
00:39:54.090 --> 00:39:54.570
yeah.

278
00:39:55.830 --> 00:40:10.440
Morgan Elowe MacLeod: And, Madam sorry to derail things does that does that, like taper that sort of it is that, like can I think of that as like a density of states or like a density of pads like so that pss is not like.

279
00:40:11.970 --> 00:40:15.030
Morgan Elowe MacLeod: Point spread function in the traditional sense but it's like a.

280
00:40:16.710 --> 00:40:21.720
Morgan Elowe MacLeod: related to the relative density of possible paths or something like that.

281
00:40:22.080 --> 00:40:23.670
Morgan Elowe MacLeod: Can you explain that to me a little.

282
00:40:25.260 --> 00:40:26.190
Morgan Elowe MacLeod: That I just did.

283
00:40:26.880 --> 00:40:27.810
Malena Rice: yeah, so I think.

284
00:40:29.220 --> 00:40:37.650
Malena Rice: let's see if I can try to explain this with maybe So these are some actual paths that you might have across the dreams, that they were trying to recover this particular object.

285
00:40:38.010 --> 00:40:45.870
Malena Rice: there'll be a linear path that best overlaps with this, you can also have a linear path that sort of overlaps with the beginning part and then it.

286
00:40:46.320 --> 00:40:57.870

Malena Rice: tapers off and doesn't overlap with any of the rest of the signal, or that goes like this, and so you would still end up with some books accumulation from that little part of the path that you overlapped.

287
00:40:58.710 --> 00:41:20.220
Malena Rice: But you wouldn't get the maximum overlap, and so what you're seeing is the maximum overlap occurs at the Center and then you have a tapering off that corresponds to decreasingly overlapping pods and you can sort of see this also in these images so.

288
00:41:21.330 --> 00:41:22.860
Malena Rice: A an injection.

289
00:41:24.150 --> 00:41:37.110
Malena Rice: A given best ever brain corresponds to this ingredient and extracts and why shifts if it's a bright signal, where this the Center here that that corresponds to this bright point is going to be the.

290
00:41:37.500 --> 00:41:46.470
Malena Rice: True signal, or the path that best overlaps with the real path and this injection and then all of these other shifts are going to be sort of.

291
00:41:47.010 --> 00:41:56.430
Malena Rice: Gradually approaching that but are a little bit different so maybe a path only overlaps with some portion or it is.

292
00:41:56.910 --> 00:42:07.680
Malena Rice: like an object that moves just a little bit slower than your real object and so it'll lag behind it a little bit you'll catch a little bit of the outer region of the objects real pss but you're not going to be at the Center of the objects.

293
00:42:08.700 --> 00:42:09.600
Malena Rice: And so you end up with.

294
00:42:09.630 --> 00:42:27.840
Malena Rice: A gradient like this, where the true signal is at the Center and then you have these extra X and y shifts that are close but not exactly the right path and it's going to look a little bit less nice, but Mr nonlinear cars, but this was for a linear injection interesting.

295
00:42:28.530 --> 00:42:29.670
Morgan Elowe MacLeod: that's super interesting.

296
00:42:31.800 --> 00:42:34.260
Malena Rice: yeah so it also provides a little bit more information for.

297
00:42:34.260 --> 00:42:38.670
Malena Rice: The neural networks to work off of to have the best ever friends, instead of the individual.

298
00:42:40.080 --> 00:42:40.800
Malena Rice: injected.

299
00:42:42.570 --> 00:42:46.470
Malena Rice: or yeah, I guess, instead of just the ship stocking image by itself so we're.

300
00:42:47.160 --> 00:43:01.440
Malena Rice: Trying to see if that helps us to reduce the false positives and if the neural network can use this information which, if it's as clear as this certainly should be able to it's just a question of for the more nonlinear pods if that might end up confusing the network in some way.

301
00:43:05.040 --> 00:43:07.110
Morgan Elowe MacLeod: Man back right back to you i'm sorry.

302
00:43:08.970 --> 00:43:16.410
Matthew Holman: No that's fine um, I guess, I might have a number of comments that are probably just better offline I mean but.

303
00:43:17.160 --> 00:43:24.720
Matthew Holman: My I would point out that I think in terms of doing a complete search of the non linear paths so that's something that.

304
00:43:25.110 --> 00:43:33.120
Matthew Holman: That matt painter and I kind of laid out in our proof of concept and that that's something that it comes from a paper that was led by Gary bernstein where we.

305
00:43:33.570 --> 00:43:41.250
Matthew Holman: Use HST to look for very faint to you knows, I know, in the case of HST is it's going around the earth every every 90 minutes.

306
00:43:41.730 --> 00:43:49.620

Matthew Holman: And the parallax of the HST at 48 was completely resolved so you know, we had to kind of lay out a way to do.

307
00:43:50.130 --> 00:44:03.990
Matthew Holman: A complete search where you know the parameters are really about, you know they're the really the standards are parallax parameters like what's the distance one of the distance to the object and that kind of thing and and you know I could be wrong, but I think that.

308
00:44:05.220 --> 00:44:10.650
Matthew Holman: That where, if you grid in that space you end up naturally getting a complete search.

309
00:44:13.080 --> 00:44:13.470
Malena Rice: yeah.

310
00:44:14.430 --> 00:44:21.750
Matthew Holman: And i'm happy to talk with you about that offline because I, you know I know people have explored different ways, but I think that that basis is.

311
00:44:22.230 --> 00:44:31.170
Matthew Holman: it's linear orthogonal and you know basically it's linear in the parameters and you know takes you know separates out the.

312
00:44:32.070 --> 00:44:41.160
Matthew Holman: The motion of the earth, and then the object itself is just you know the the elements don't really matter, because all these objects are more or less going on a straight line.

313
00:44:42.270 --> 00:44:49.020
Matthew Holman: In an original space, and that is a little bit of curvature, but the main curvature you're seeing you pointed out that's that's the earth's curvature.

314
00:44:49.620 --> 00:44:58.050
Matthew Holman: right and it anyway, I just so I think that that's something that I i'm happy to to help you with.

315
00:44:58.830 --> 00:45:09.120
Matthew Holman: Like punch you in different directions, I think I think it would you would at least be able to me that was part of our calculation in the paper that matter I did it like how many calculate how many competitions, would you have to do.

316
00:45:09.690 --> 00:45:13.200
Matthew Holman: To be complete and we use that basis, just because it's tractable.

317
00:45:15.690 --> 00:45:16.020
Malena Rice: yeah.

318
00:45:17.400 --> 00:45:25.740
Malena Rice: Okay yeah so the nonlinear part we just started implementing More recently, because we were really focused on.

319
00:45:25.920 --> 00:45:26.280
Yes.

320
00:45:27.540 --> 00:45:31.470
Matthew Holman: Exactly and you don't have to do the larger pointed out, you for the distance stuff you don't have to do.

321
00:45:32.490 --> 00:45:32.940
Matthew Holman: This.

322
00:45:32.970 --> 00:45:35.310
Matthew Holman: linear on the sky is really what you're going to see first.

323
00:45:35.790 --> 00:45:41.040
Malena Rice: that's really helpful because we, we do want to extend and where it's through at least 58 because.

324
00:45:41.310 --> 00:45:45.300
Malena Rice: That yeah so into there and so that'd be really helpful.

325
00:45:45.600 --> 00:45:50.430
Matthew Holman: Sure, I mean all of the you find out that all the computation is on the stuff closest to the earth.

326
00:45:51.630 --> 00:45:53.850
Matthew Holman: All the hard work is on the inner edge.

327
00:45:54.870 --> 00:45:58.830
Matthew Holman: So you know you're doing the right thing to proceed from outward inward.

328
00:45:59.850 --> 00:46:00.180
yeah.

329
00:46:01.410 --> 00:46:14.100
Morgan Elowe MacLeod: Yes, good sort of broad question that's related to that so at say this isn't a well defined question, but like at 50 au or 100 a you are 208 you.

330
00:46:14.790 --> 00:46:33.000
Morgan Elowe MacLeod: were doing an experiment like this in like a patch like the test field, give us a sense of like I don't have a sense of like how complete our census is of the objects as a function of distance and and maybe you do and also like.

331
00:46:34.440 --> 00:46:44.790
Morgan Elowe MacLeod: Can you do kind of like almost like a counting exercise in like how many objects you discover in a test pointing versus how many you knew about or like.

332
00:46:46.800 --> 00:46:47.280
Malena Rice: i'm.

333
00:46:47.310 --> 00:46:57.840
Morgan Elowe MacLeod: So find out how much is there that is unexpected as a function of you know, maybe magnitude or something like that, because obviously there's more little stuff than big stuff but.

334
00:46:58.740 --> 00:47:08.310
Malena Rice: yeah sort of I think it just depends on what population you're looking at so for the very distant objects these red dots are the pretty much the only ones that are known.

335
00:47:09.480 --> 00:47:18.810
Malena Rice: And so there aren't very many and it's difficult to do a survey where you're trying to delineate how many there are as a function of magnitude just because there are so few of them.

336
00:47:19.680 --> 00:47:26.820
Malena Rice: But with That said, we really are so I think that this gap here is the galactic plane and the.

337
00:47:27.570 --> 00:47:35.700

Malena Rice: The point of this survey is really to try to figure out whether this gap is actually there, or if it's just that nobody is really looked there.

338
00:47:36.630 --> 00:47:48.990
Malena Rice: And so we're hoping that, especially with the shift stocking survey, you might be able to better figure out whether objects in the galactic plane or signals in the galactic plane or stars vs real objects because.

339
00:47:49.320 --> 00:47:55.680
Malena Rice: If you see something that's moving and the galactic plane then that's a little more compelling than a bright.at the galactic plane.

340
00:47:57.180 --> 00:47:57.690
Malena Rice: And so.

341
00:47:59.010 --> 00:48:09.690
Malena Rice: that's that's kind of what we're trying to do where we want to see if we can find anything here, or if we don't find anything there that would also be really interesting that would be maybe reinforcing that the.

342
00:48:10.230 --> 00:48:26.040
Malena Rice: alignment actually exists, but then we would have to be really careful about what do we actually expect to have seen and so that's why we're being so meticulous about these injections and making sure that they're as realistic as they possibly can be.

343
00:48:27.510 --> 00:48:28.830
Morgan Elowe MacLeod: and truly interesting.

344
00:48:29.250 --> 00:48:38.130
Malena Rice: yeah so the the first project that we, the first paper that we published was actually just looking at sectors 18 and 19 which are along the galactic plane.

345
00:48:38.910 --> 00:48:48.360
Malena Rice: But we do ultimately want to extend this, but our focus really still is on trying to figure out if there is something that's lost just within the galactic plane.

346
00:48:49.020 --> 00:49:01.710
Malena Rice: We do have actually a list of 17 candidates that we found in that initial survey, but our methods have been refined a lot since then

we don't expect all 17 of those to be real, because these objects are just so rare that.

347
00:49:02.040 --> 00:49:05.520
Malena Rice: You know if a couple of them were real and and that would be great, but we, it would be.

348
00:49:06.390 --> 00:49:12.450
Malena Rice: Very strange to have such an over density in that particular region of the sky, and so we don't expect them to all be real.

349
00:49:12.930 --> 00:49:28.650
Malena Rice: So we're hoping with these improved methods we can, first of all narrow down which of those candidates are really worthwhile to follow up and then also extend to other regions of the sky, because the tests data set so this is this is sectors 18 and 19 shown here.

350
00:49:29.850 --> 00:49:37.530
Malena Rice: The the test data set also a sectors through this part of the galactic plane this part this part so there's actually a lot there that can be explored.

351
00:49:38.670 --> 00:49:41.010
Malena Rice: And we we just looked at a small portion so far.

352
00:49:42.480 --> 00:49:42.930
Malena Rice: yeah.

353
00:49:43.200 --> 00:49:46.350
Morgan Elowe MacLeod: Let me step back even further, and this reflects my.

354
00:49:46.440 --> 00:49:56.670
Morgan Elowe MacLeod: Ignorance is the rarity of those objects like that they're surely rare or are there more that we don't know about, or is that.

355
00:49:57.810 --> 00:49:58.140
Morgan Elowe MacLeod: Like.

356
00:49:58.800 --> 00:50:03.930
Morgan Elowe MacLeod: I don't have a sense of I had always thought that there were more of those objects.

357
00:50:04.110 --> 00:50:17.910
Morgan Elowe MacLeod: We just are incomplete, but I could be completely wrong, so that I think I was just wondering that also like do we have an expectation of the number that is truly there.

358
00:50:18.630 --> 00:50:32.010
Malena Rice: um so if there is no actual upside alignment and if this isn't observational bias, then there should be more objects that are there that we just haven't seen that would be about the same magnitude.

359
00:50:32.670 --> 00:50:53.220
Malena Rice: or ish orbits that are very highly eccentric and objects that are sort of near perihelion if that upside alignment is actually real than maybe there isn't anything there and so it's that's The big question is that we actually don't have a definitive answer to that yet.

360
00:50:53.250 --> 00:50:54.540
Morgan Elowe MacLeod: Okay we're trying to.

361
00:50:54.660 --> 00:50:56.130
Morgan Elowe MacLeod: yeah thanks for bearing with me.

362
00:50:56.760 --> 00:50:57.450
Malena Rice: No, no problem.

363
00:51:02.790 --> 00:51:06.990
Morgan Elowe MacLeod: Well, on that note, I think we have a couple minutes left like we've talked.

364
00:51:08.520 --> 00:51:12.930
Morgan Elowe MacLeod: Just now, some about like where you see that going, and then the next steps.

365
00:51:14.100 --> 00:51:18.120
Morgan Elowe MacLeod: But if you want to offer us any other sort of final word.

366
00:51:20.100 --> 00:51:32.610
Malena Rice: yeah I think it'll be really exciting to try to understand this region of parameter space, I have not thought as much about going further in in the solar system, but I think that's going to be also a really.

367

00:51:32.970 --> 00:51:50.220
Malena Rice: fruitful place to look once especially once test actually observes the inner or observes within the plane of the ecliptic and so that's that's something that is sort of ongoing in the back of my mind, but because test hasn't observing it hasn't been quite a priority.

368
00:51:51.960 --> 00:51:52.500
Malena Rice: and

369
00:51:53.100 --> 00:51:58.590
Malena Rice: yeah i'd be interested if anyone has thoughts on like if there are particular.

370
00:51:59.460 --> 00:52:08.790
Malena Rice: categories of objects that would be really interesting to actually see if we can find like signatures of politeness or something else within them.

371
00:52:09.750 --> 00:52:24.540
Malena Rice: But otherwise I think they're they're just a lot of interesting directions that this could go both with tests and also extending this type of search to other data sets, so this is something you can do with any data set that returns to the same region of the sky a few times.

372
00:52:26.130 --> 00:52:28.560
Malena Rice: every couple of days, maybe or.

373
00:52:29.850 --> 00:52:34.470
Malena Rice: With some cadence that will allow you to actually link the same object to itself.

374
00:52:36.000 --> 00:52:40.020
Malena Rice: And so yeah it's further extensions to other surveys are also something.

375
00:52:40.020 --> 00:52:51.930
Morgan Elowe MacLeod: That becomes pretty straightforward, especially when the objects themselves are so distant right like these things, as you said, are moving really slowly across the sky so like a three day cadence or something.

376
00:52:52.560 --> 00:52:57.990
Morgan Elowe MacLeod: yeah is totally Okay, and the outer solar system is that right yeah that's.

377
00:52:58.230 --> 00:53:02.640
Morgan Elowe MacLeod: Interesting so like doing this from the ground is.

378
00:53:03.060 --> 00:53:04.650
Morgan Elowe MacLeod: is plausible as well, like.

379
00:53:05.220 --> 00:53:05.700
Morgan Elowe MacLeod: You know.

380
00:53:05.790 --> 00:53:07.230
Morgan Elowe MacLeod: With like an ssd type.

381
00:53:07.770 --> 00:53:08.640
Malena Rice: yeah yeah.

382
00:53:08.970 --> 00:53:15.600
Malena Rice: This is definitely something you could do with sst analysis team will be releasing its full frame images.

383
00:53:16.590 --> 00:53:26.460
Malena Rice: talking to a couple of Members of the team and it's not yet known exactly how or in what format, but it will happen at some point during the mission, and so this is something that.

384
00:53:27.120 --> 00:53:33.600
Malena Rice: That team has been sort of thinking about implementing a ship stacking search as well, it will be a lot more computationally expensive with.

385
00:53:34.500 --> 00:53:46.350
Malena Rice: So here we're working on the scale of terabytes for tests and for else's T, it will be petabytes like maybe more so it does get very computationally expensive.

386
00:53:47.520 --> 00:53:51.300
Malena Rice: But it's doable you just need to have a very large computer or multiple.

387
00:53:55.680 --> 00:53:57.000
Morgan Elowe MacLeod: Is a amazing.

388

00:54:00.000 --> 00:54:12.390
Morgan Elowe MacLeod: Well, I think, maybe on that note, we should stop there, I think there's also some interesting questions about how we do that on the computational level, but we can we can stop there, thank you Melinda for a really wonderful talk, thank you.

389
00:54:13.290 --> 00:54:19.920
Morgan Elowe MacLeod: For for educating us, and it was really a delight to have this conversation, so thank you all for joining.

390
00:54:22.470 --> 00:54:22.800
adrianna: Thank you.