Searching for Planet Nine with WISE

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A ninth planet in the solar system?

A ninth planet of mass $\gtrsim 10\ m_\oplus$ could explain many enigmatic aspects of our solar system, including:
- the existence of Sedna and 2012 VP[113]
- the claimed clustering of extreme trans-Neptunian object (ETNO) perihelia[1]
- the solar obliquity[2]

Plotted at right: top-down view of ETNO orbits. The initial 6 ETNOs are black, and the latest 7 ETNO discoveries are blue.

2015 KG[163]
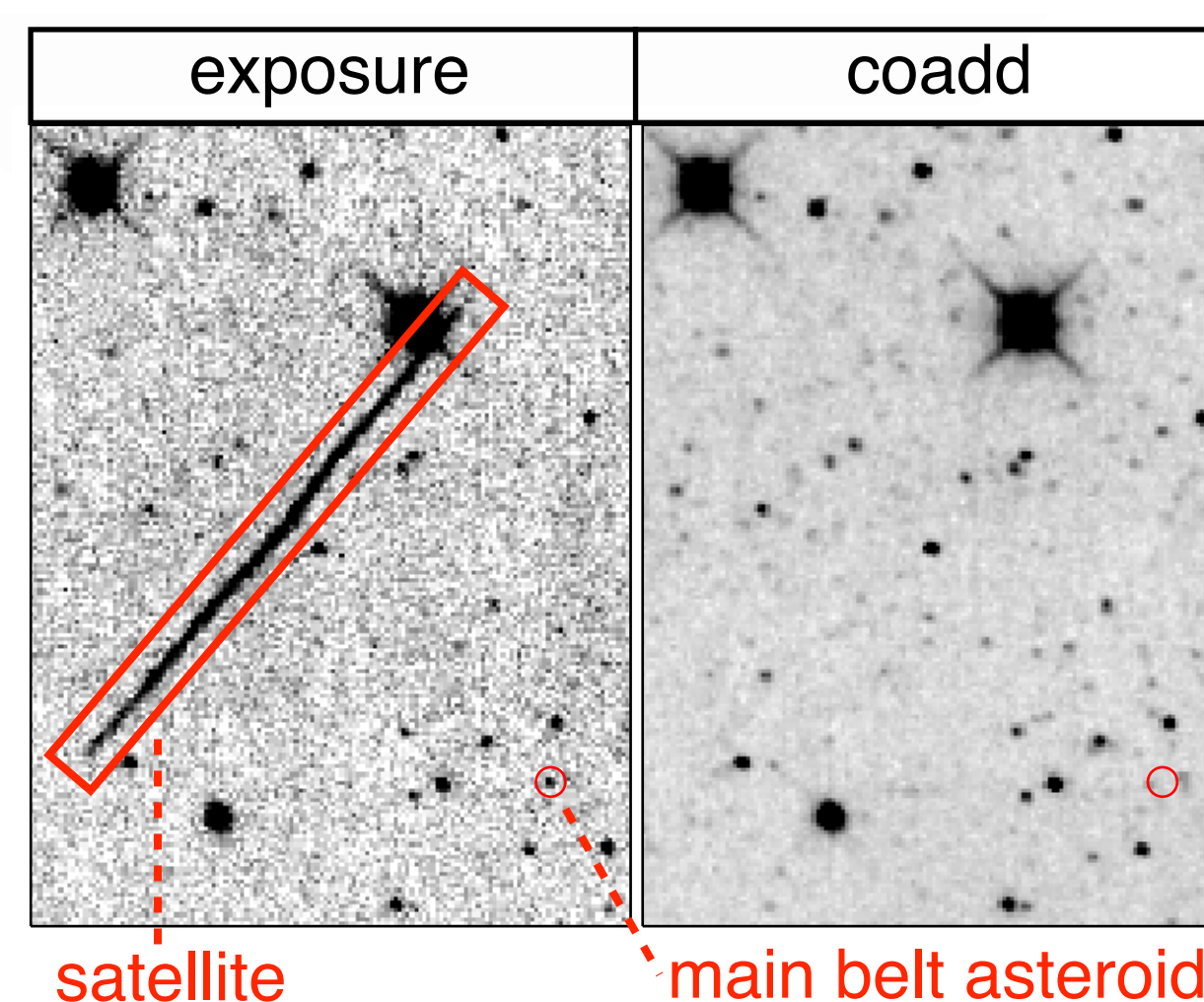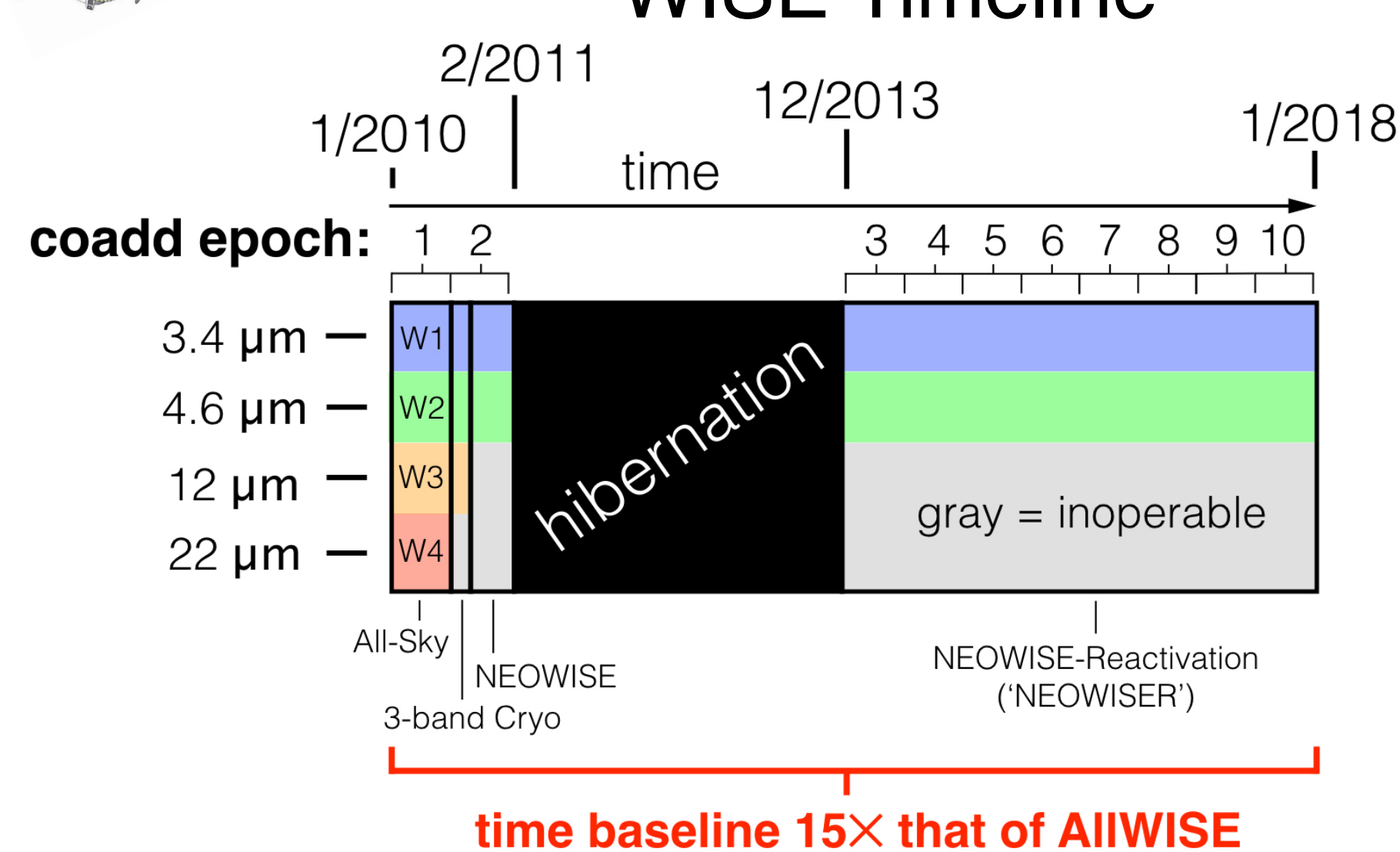2013 FT[28]
Planet Nine?
2015 GT[50]
2013 SY[99]
Sedna
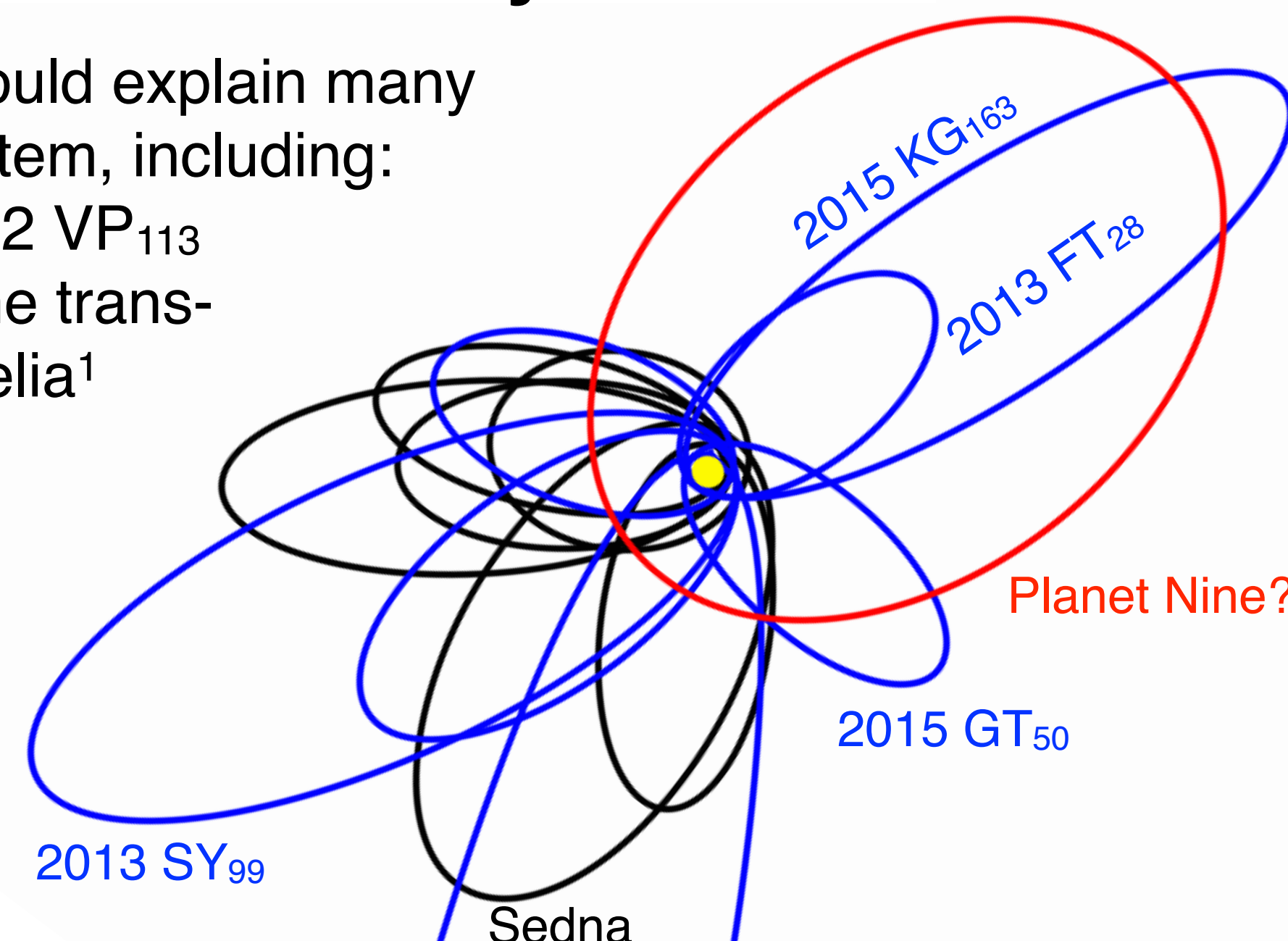
Many wide-area, **archival** data sets can be transformed into serendipitous searches for Planet Nine, for example: Pan-STARRS, DES, and **WISE**.

schematic illustration of WISE Planet Nine search strategy


ref | t_0 | $t_0 + 0.5$ yr | $t_0 + 1$ yr
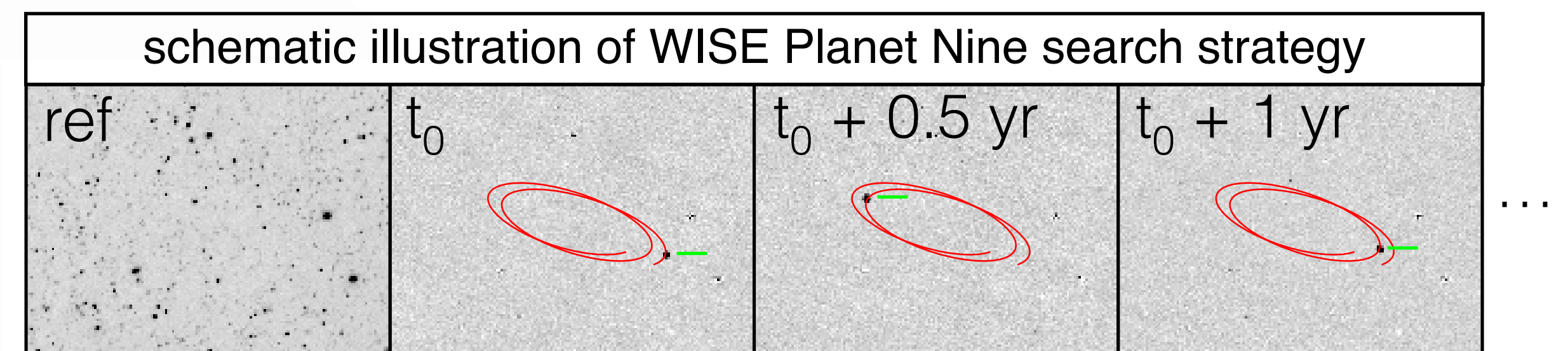
Existing data sets ought to be thoroughly and systematically searched for Planet Nine! Here, we present our search covering >3/4 of the sky in the WISE 3.4 micron (W1) channel[3,4].

Time-resolved WISE coadds: enabling deep mid-infrared motion searches

WISE: Wide-field Infrared Survey Explorer

WISE Timeline

2/2011 · 1/2010 · 12/2013 · 1/2018
time
coadd epoch: 1 2 · 3 4 5 6 7 8 9 10
3.4 µm — W1
4.6 µm — W2
12 µm — W3
22 µm — W4
hibernation — gray = inoperable
All-Sky · NEOWISE · 3-band Cryo · NEOWISE-Reactivation ('NEOWISER')

time baseline 15× that of AllWISE
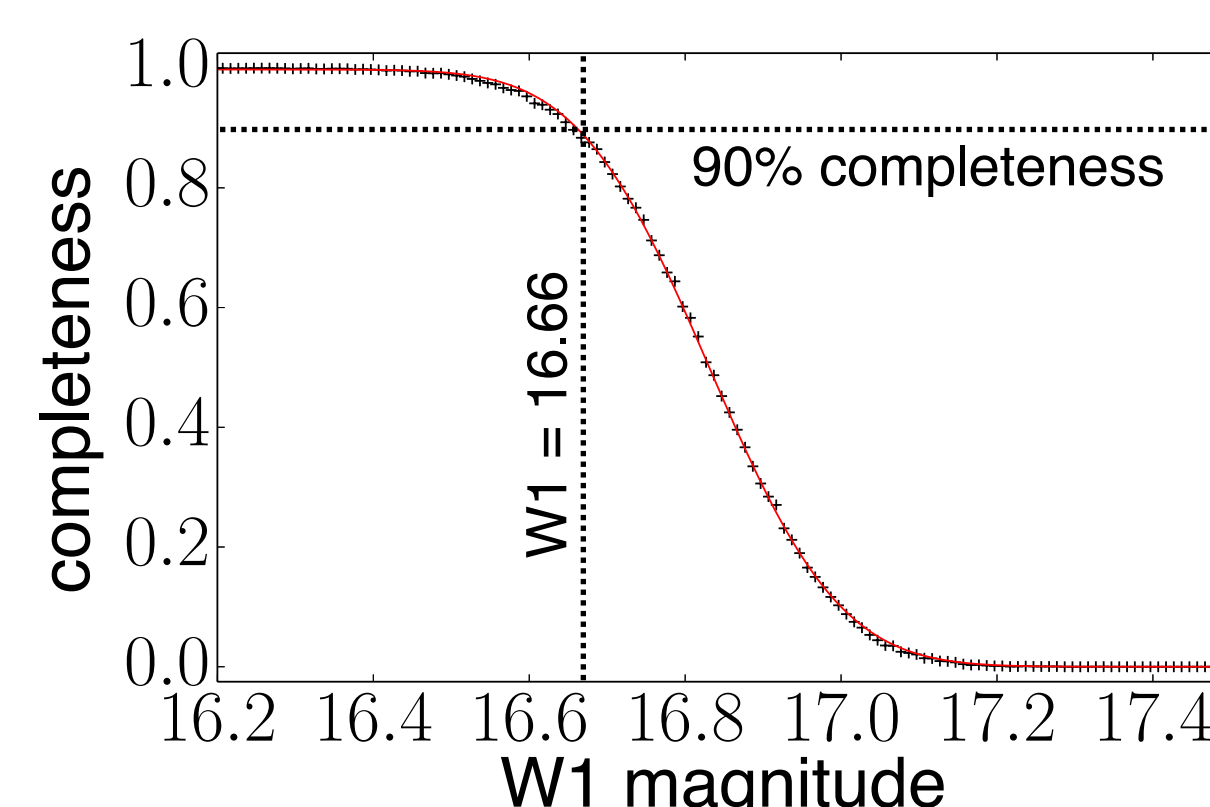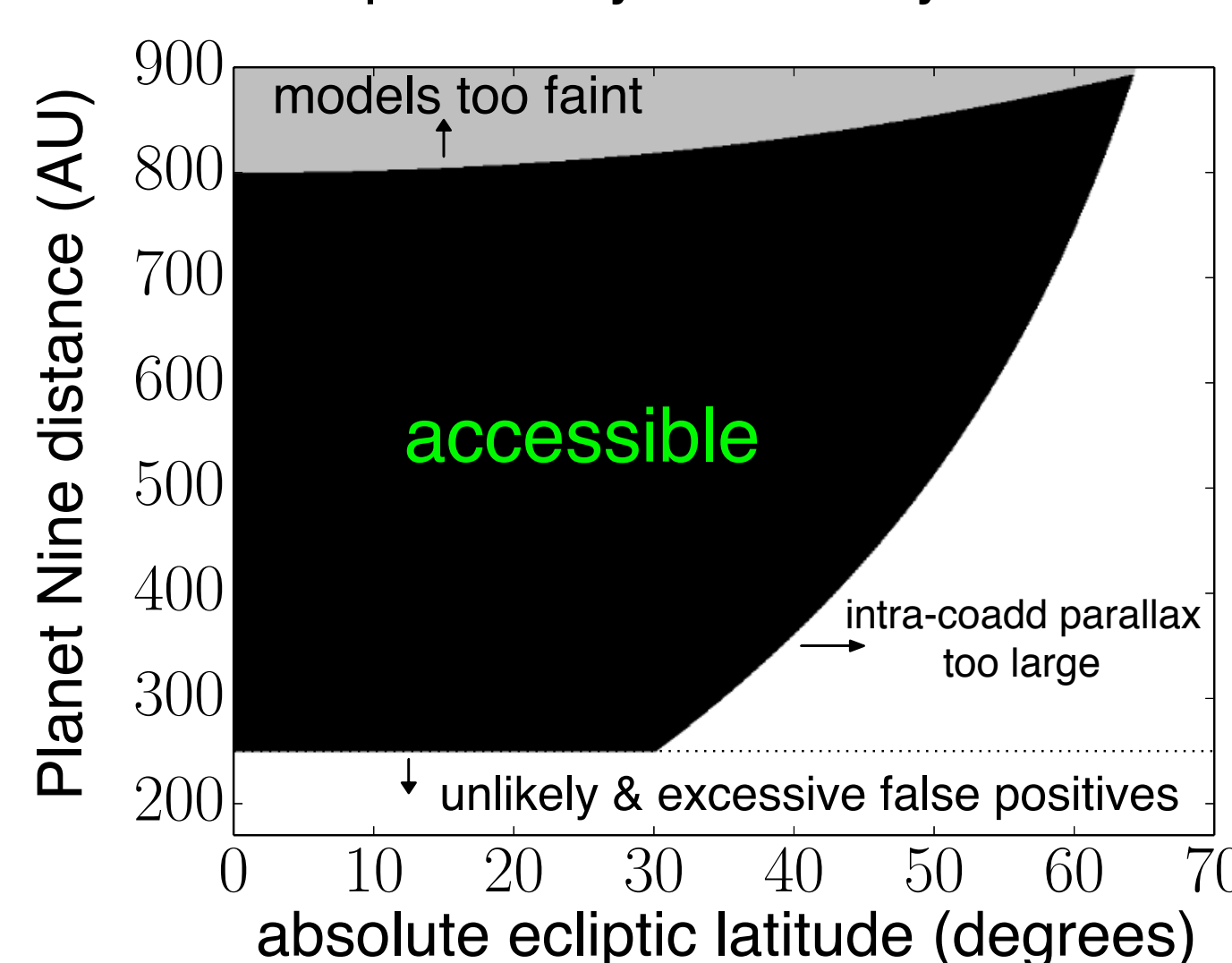
exposure | coadd

satellite | main belt asteroid

- Our coaddition[5] begins with **~140 terabytes** of single-exposure WISE pixels.
- Coadds are **much** deeper and cleaner than single frames, as illustrated above.

Our W1 Planet Nine search typically includes ~9 coadd epochs per sky location. Without incorporating post-hibernation data, we would not have enough coadd epochs to make our search viable.
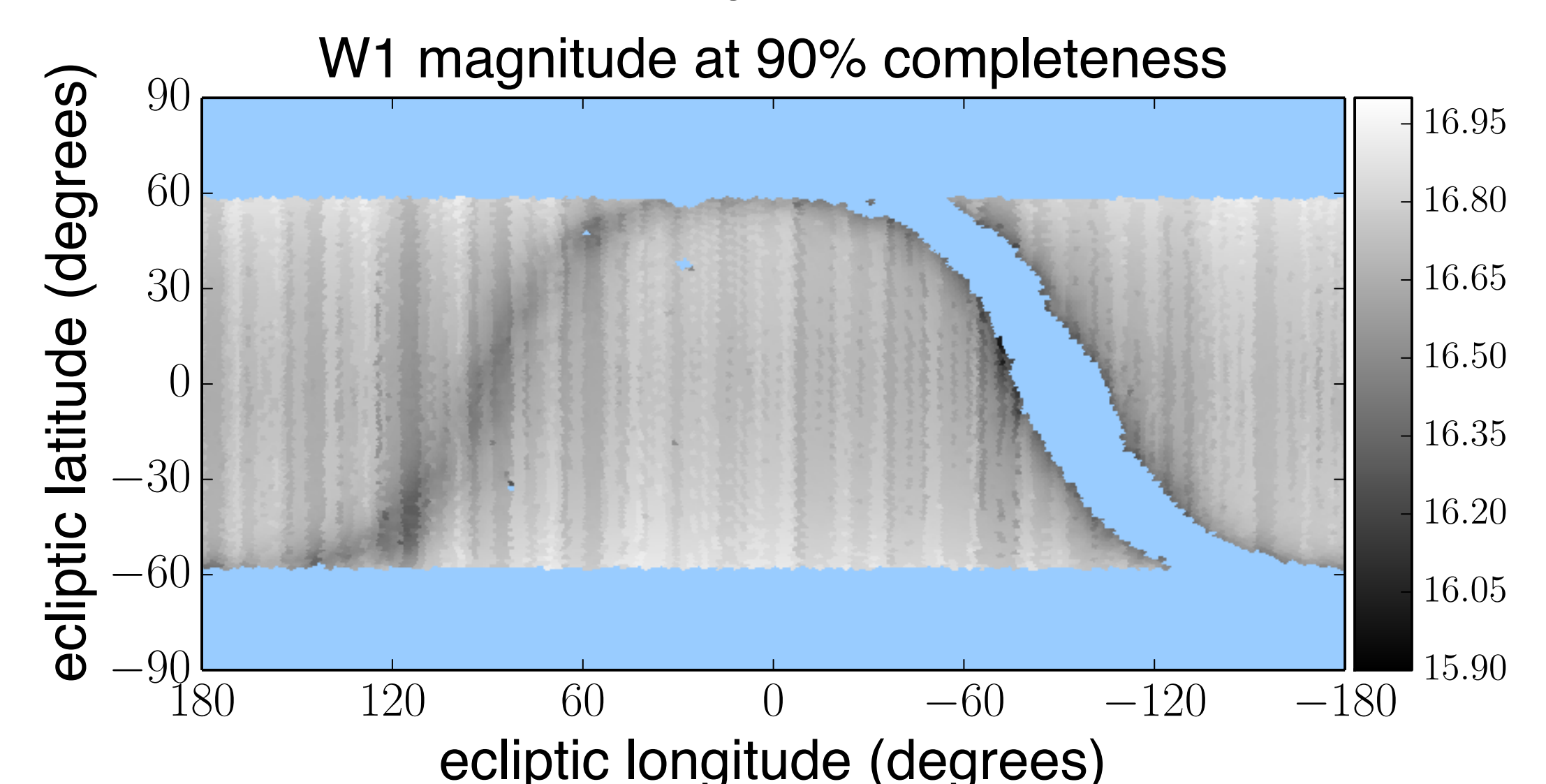
number of coadd epochs
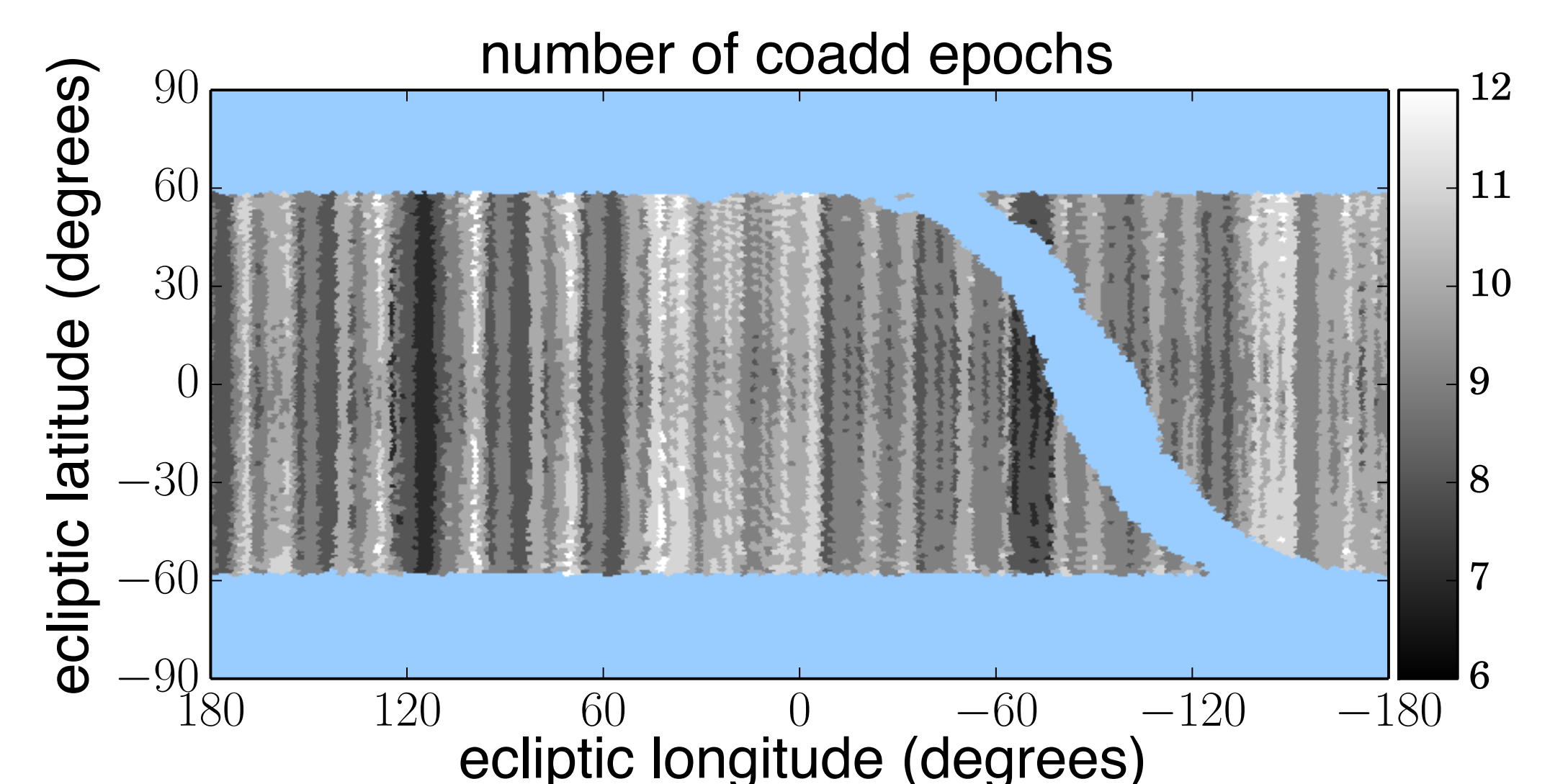
WISE Planet Nine search results and constraints

Coaddition impacts the parameter space accessible to our Planet Nine search. White regions in the plot below are not probed by our survey.
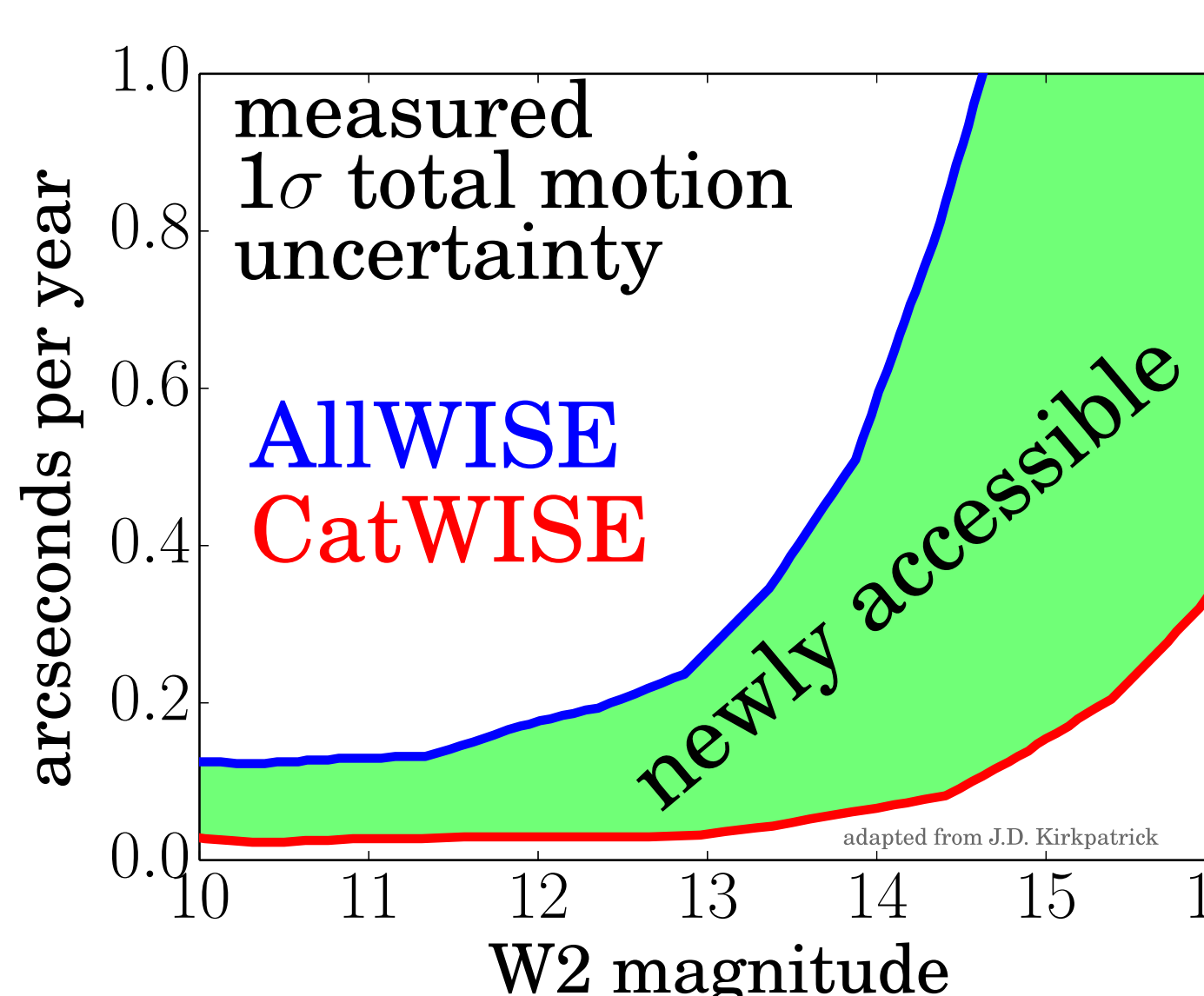

models too faint
accessible
intra-coadd parallax too large
unlikely & excessive false positives

W1 = 16.66
90% completeness

We didn't find Planet Nine, but did obtain the deepest ever WISE-based constraints:
- W1 > 16.7 (90% completeness)
- This corresponds to VR > 22.1 assuming most W1-luminous model[6]

We also mapped the spatial variation of our sensitivity, which results from factors including Galactic and ecliptic latitude.

W1 magnitude at 90% completeness

Ongoing and future extensions

CatWISE: a successor to AllWISE in W1 and W2

measured 1σ total motion uncertainty
AllWISE
CatWISE
newly accessible
adapted from J.D. Kirkpatrick

Using our time-resolved WISE coadds, CatWISE will measure apparent motions for ~1 billion mid-infrared sources, pushing much fainter than AllWISE as illustrated at left. CatWISE will thereby greatly improve the solar neighborhood census of ultra-cool brown dwarfs at the latest spectral types.

Backyard Worlds: Planet 9
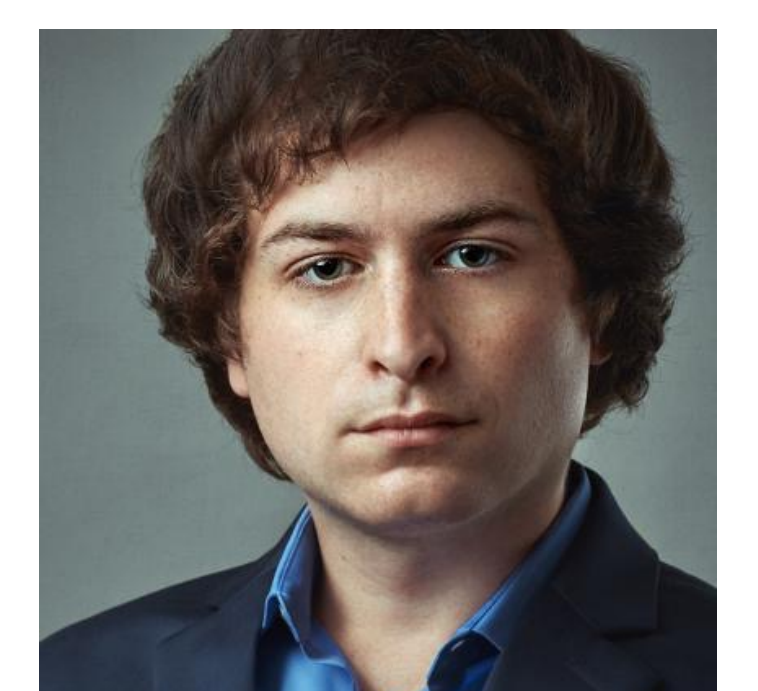discovering nearby brown dwarfs through citizen science

yr = 2010.3 · yr = 2010.8 · yr = 2015.8
Meisner+ 2017c coadd
hibernation
single exposure
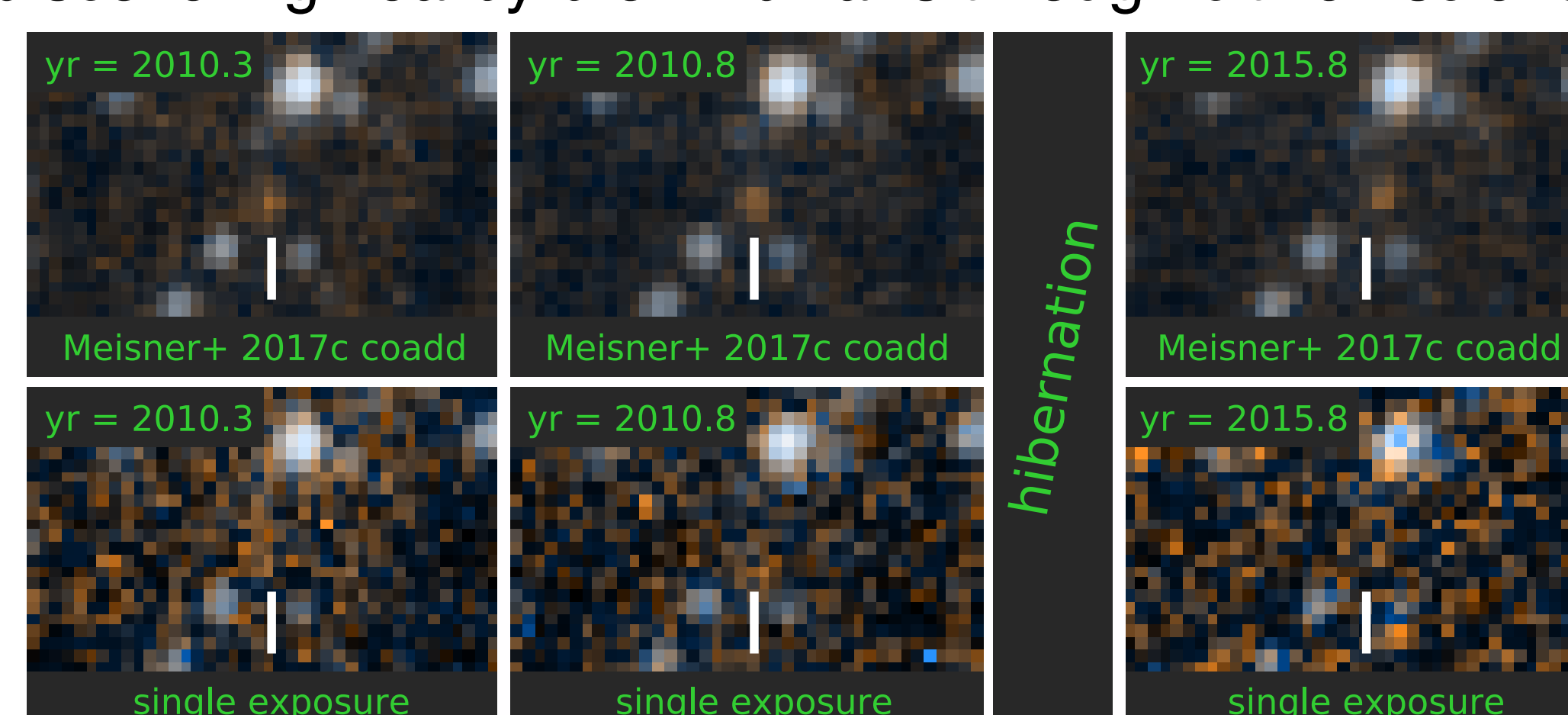
backyardworlds.org

Our time-resolved WISE coadds allow the motions of faint, cold objects to be detected by eye!

References

[1]Batygin & Brown 2016, AJ, 151, 22
[2]Bailey et al. 2016, AJ, 152, 126
[3]Meisner et al. 2017a, AJ, 153, 65
[4]Meisner et al. 2017b, arXiv: 1712.04950
[5]Meisner et al. 2017c, arXiv: 1710.02526
[6]Fortney et al. 2016, ApJL, 824, 25

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