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The pure astrometric microlensing channel: First direct mass of a single white dwarf and prospects for Roman

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Plan

- First direct mass of a single white dwarf

McGill et al (2023)

with Jay Anderson, Stefano Casertano, Kailash C Sahu, Pierre Bergeron, Simon Blouin, Patrick Dufour, Leigh C Smith, N Wyn Evans, Vasily Belokurov, Richard L Smart, Andrea Bellini, Annalisa Calamida, Martin Dominik, Noé Kains, Jonas Klüter, Martin Bo Nielsen, Joachim Wambsganss

- Pure astrometric PBH prospects for Roman

Fardeen et al (2023) - Astrometric Microlensing by Primordial Black Holes with The Roman Space Telescope in review

With James Fardeen, Scott E. Perkins, William A. Dawson, Natasha S. Abrams, Jessica R. Lu, Ming-Feng Ho, Simeon Bird

Finding microlensing events

“It seems safe to conclude that passages observable from the Earth occur rather frequently. The problem is to find where and when the passages take place. By comparing photographs of the sky taken at different times, the angular velocity of a great number of stars can be determined, and passages may be predicted.”

Refsdal (1964)

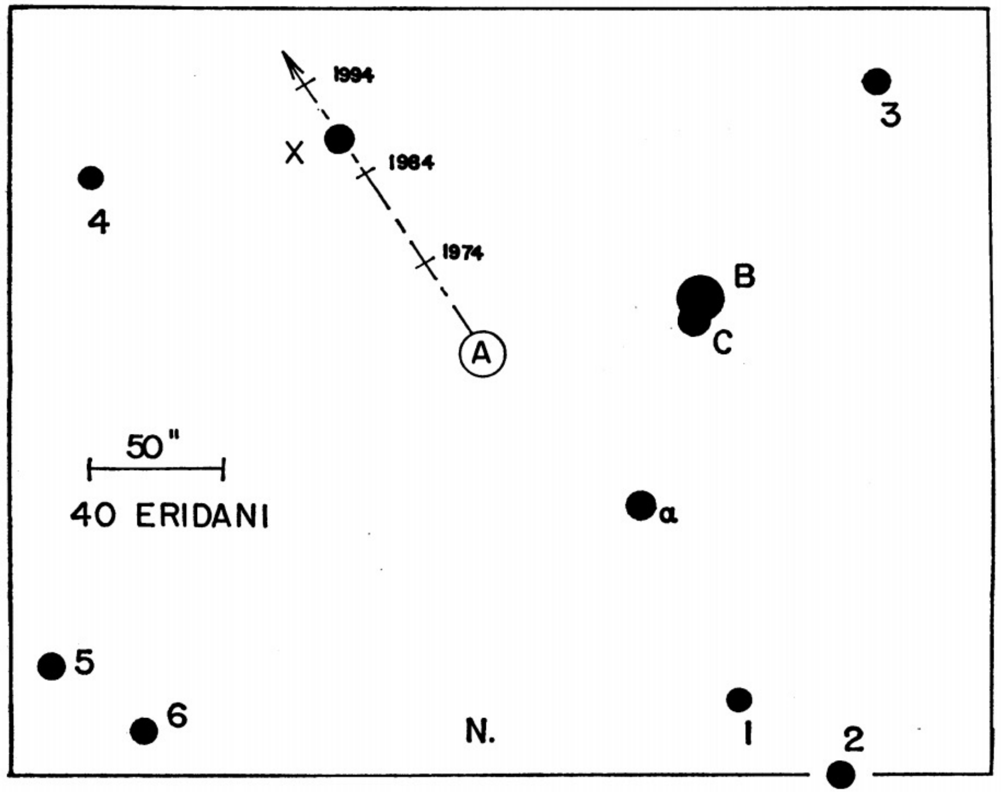
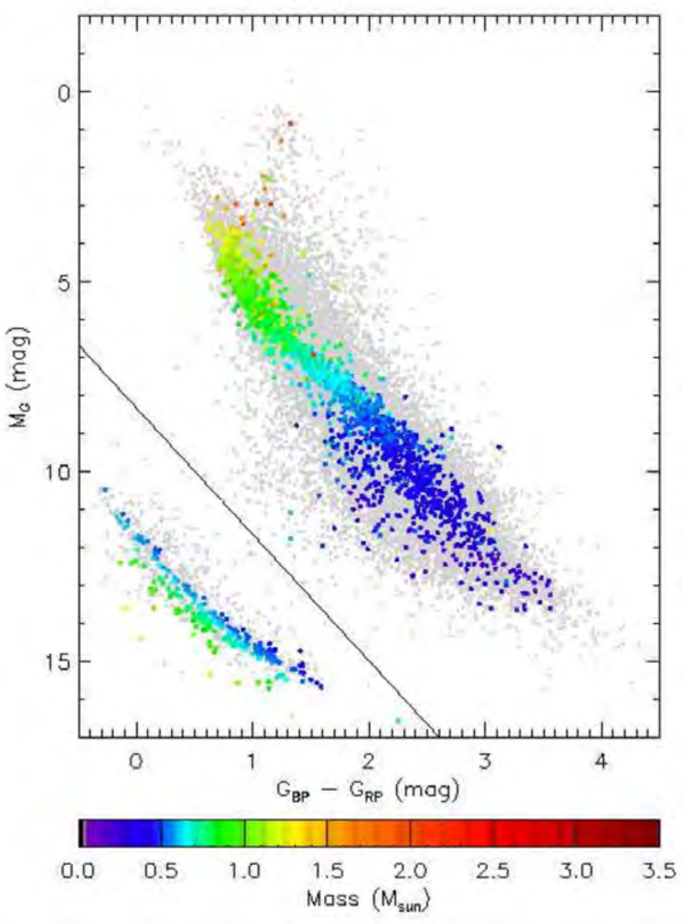


Fig. 1. Region of 40 Eridani. The arrow indicates proper motion of 40 Eridani-A from 1964 to 1994, crossing star X in 1988. Notation of stars A, B, C, and a is that of the Aitken double-star catalog (*7*); the other stars are not listed in the catalog.

Image credit: Feibelman (1966, 1986)

The Gaia Revolution



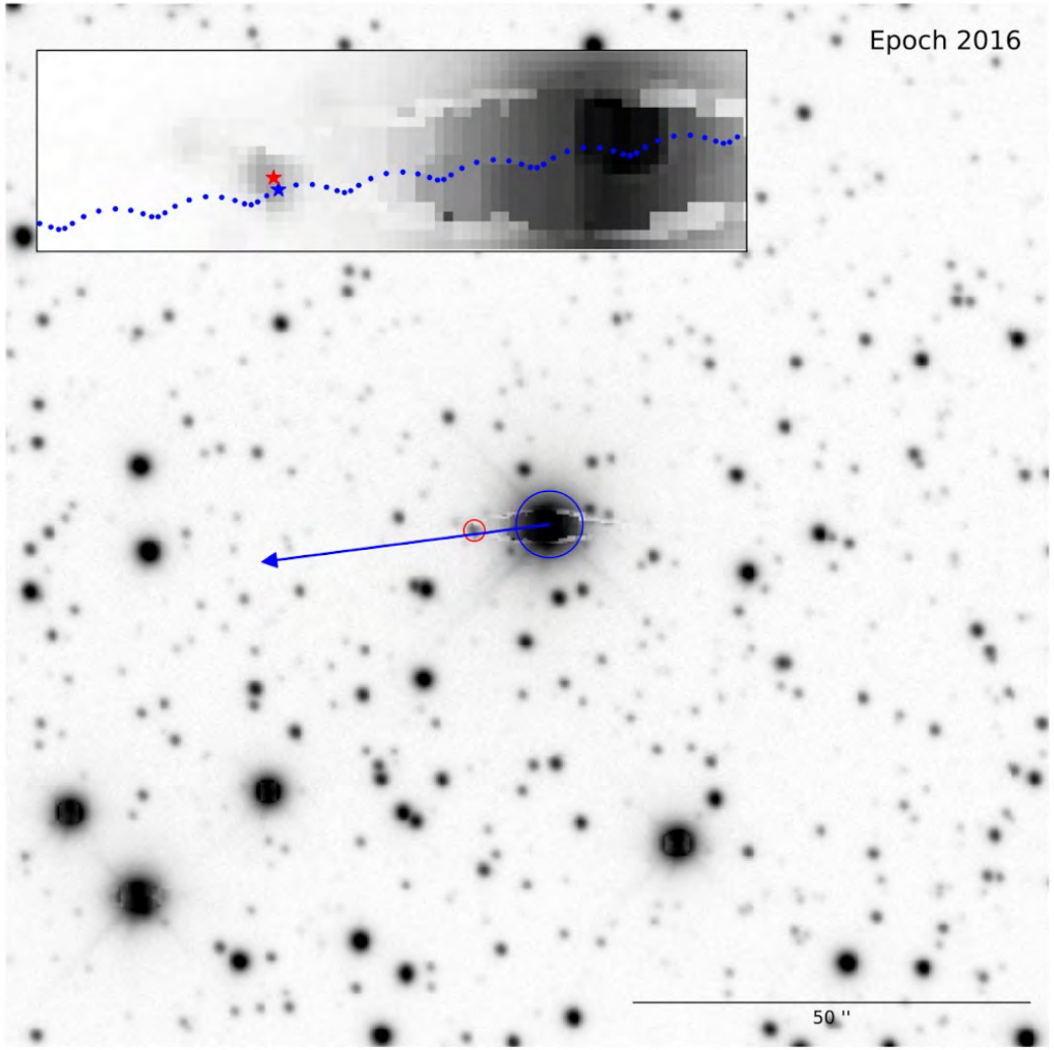
- Gaia DR2 provided precision astrometry for > 1 billion objects 2 orders of magnitude more precise and for 4 orders of magnitudes more objects

Can predict microlensing events with time of maximum with uncertainty of **~ hours to days** peak astrometric shift with uncertainty of ~ **1-10%**

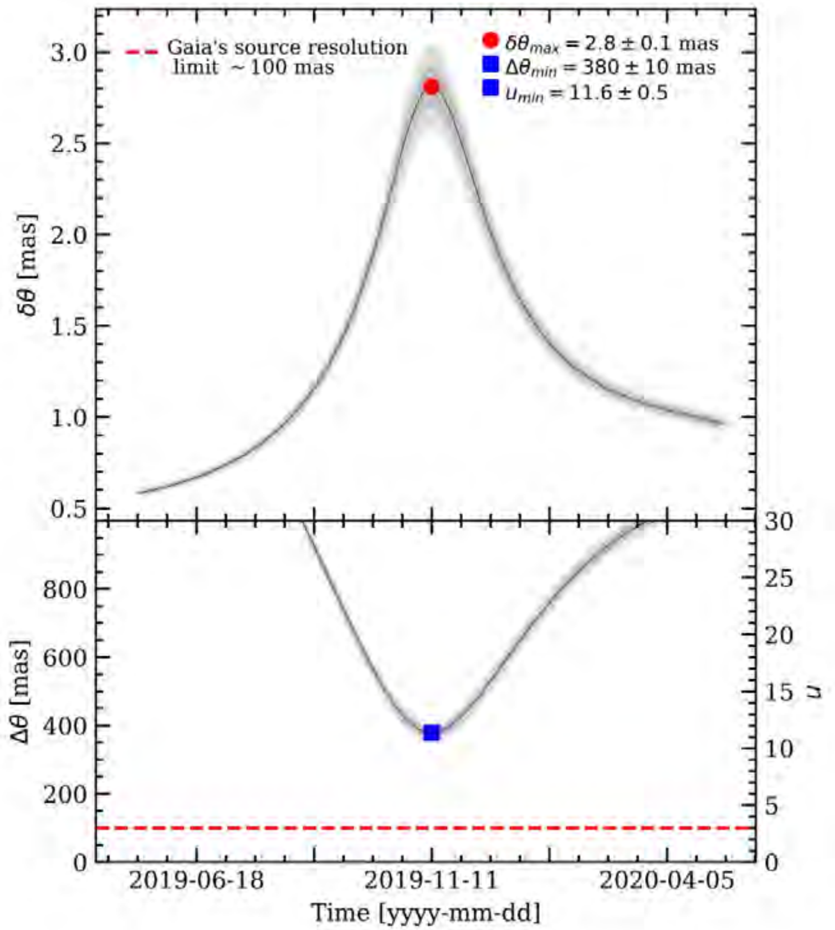
- ~ 5000 events predicted with Gaia DR2, ~ steady stream of ~10 high astrometric signal events over the next century.
- Known lens and source astrometry breaks all degeneracies, follow-up leads to direct lens masses.

Bramich (2018) Bramich 18, McGill+18,19a,b,Bramich+18,Mustill+18, Neilsen+18,Klueter+18a,b, Mustill+18, Ofek18.

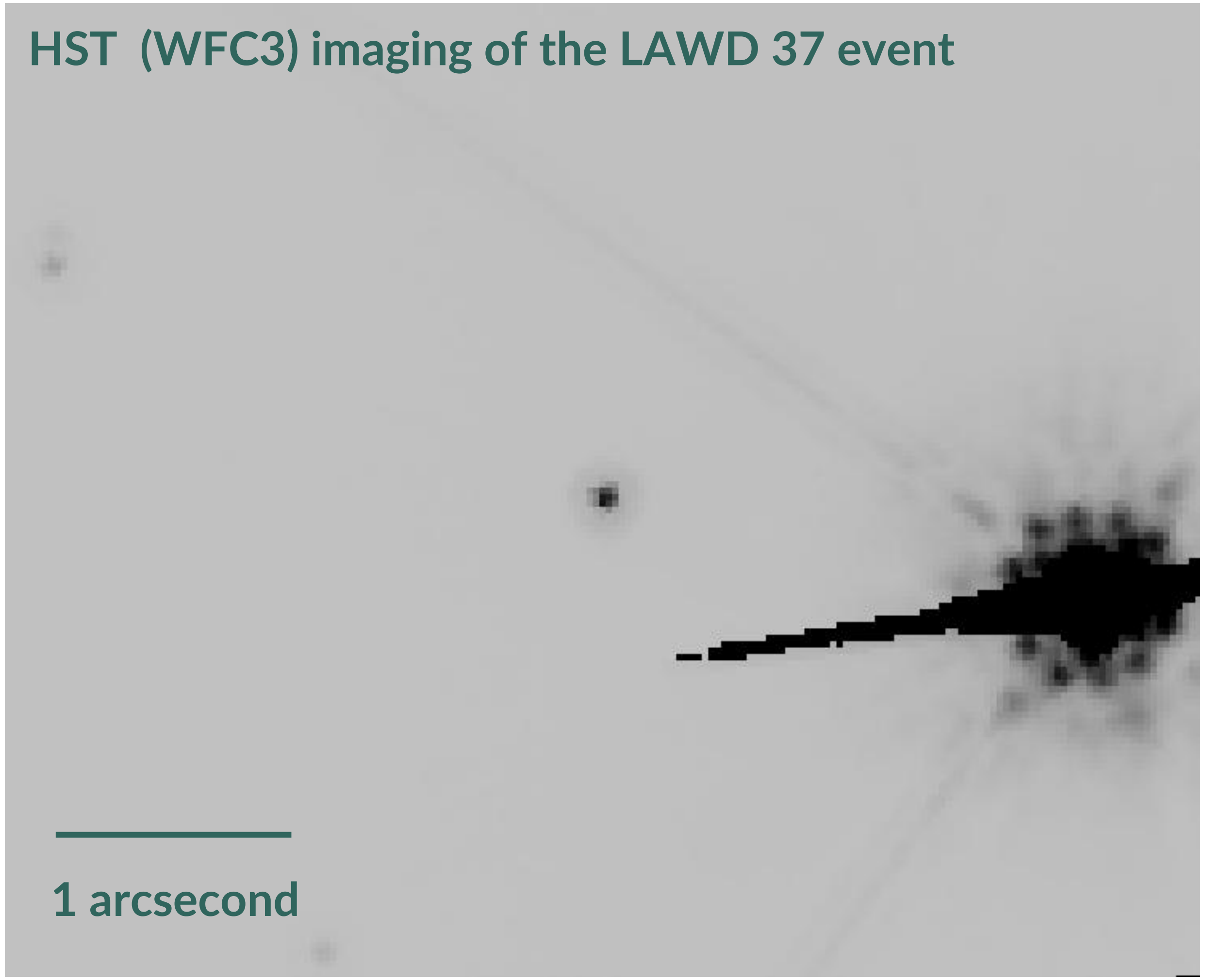
Lensing by white dwarf LAWD 37 - 4.6 pc

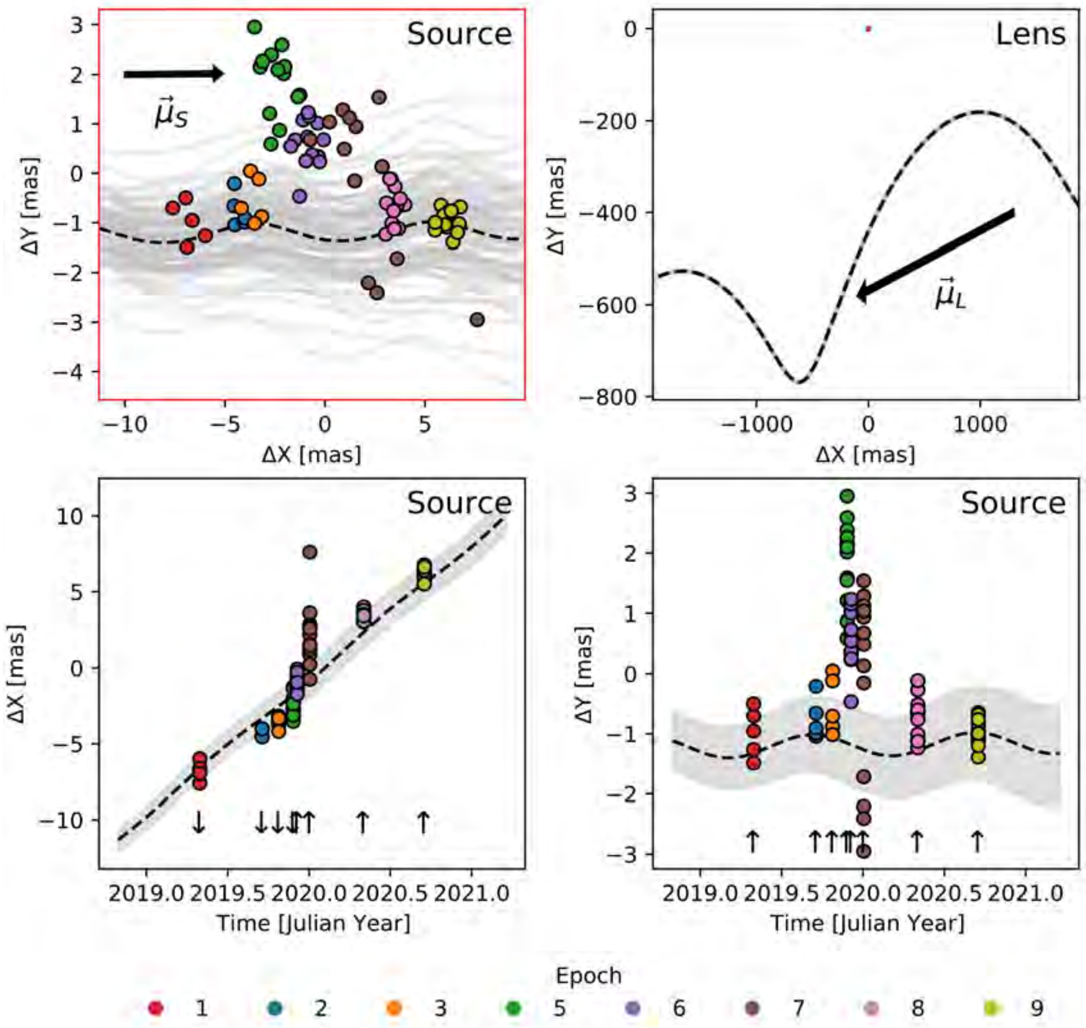


McGill et al (2018)



HST Follow-up





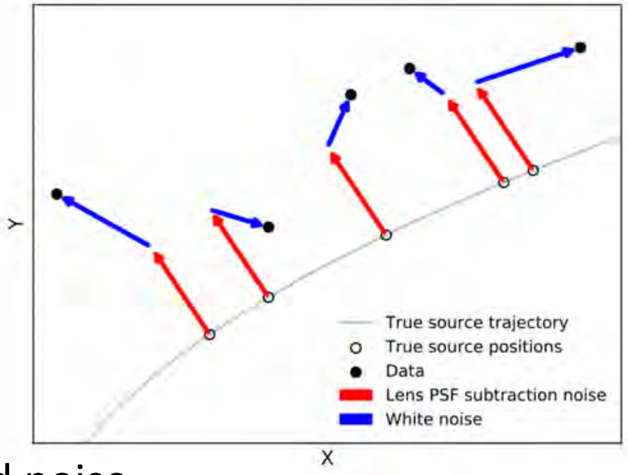
Event Modeling Challenge

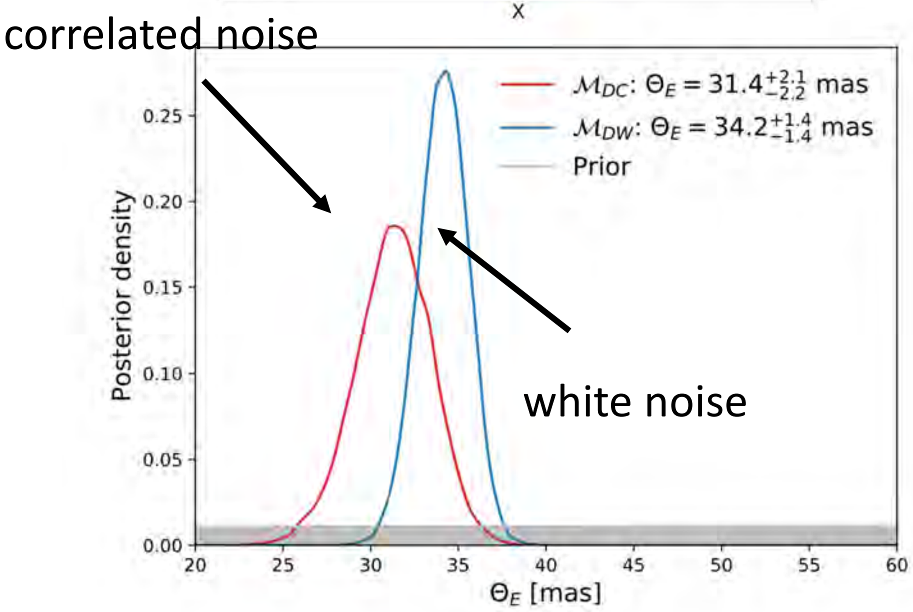
- Combine prior information from Gaia with HST follow-up - Bayesian inference problem

- The noise introduced by the lens PSF subtraction looks like an astrometric lensing signal

- Inclusion of correlated noise in the likelihood does change the mass inference for the lens

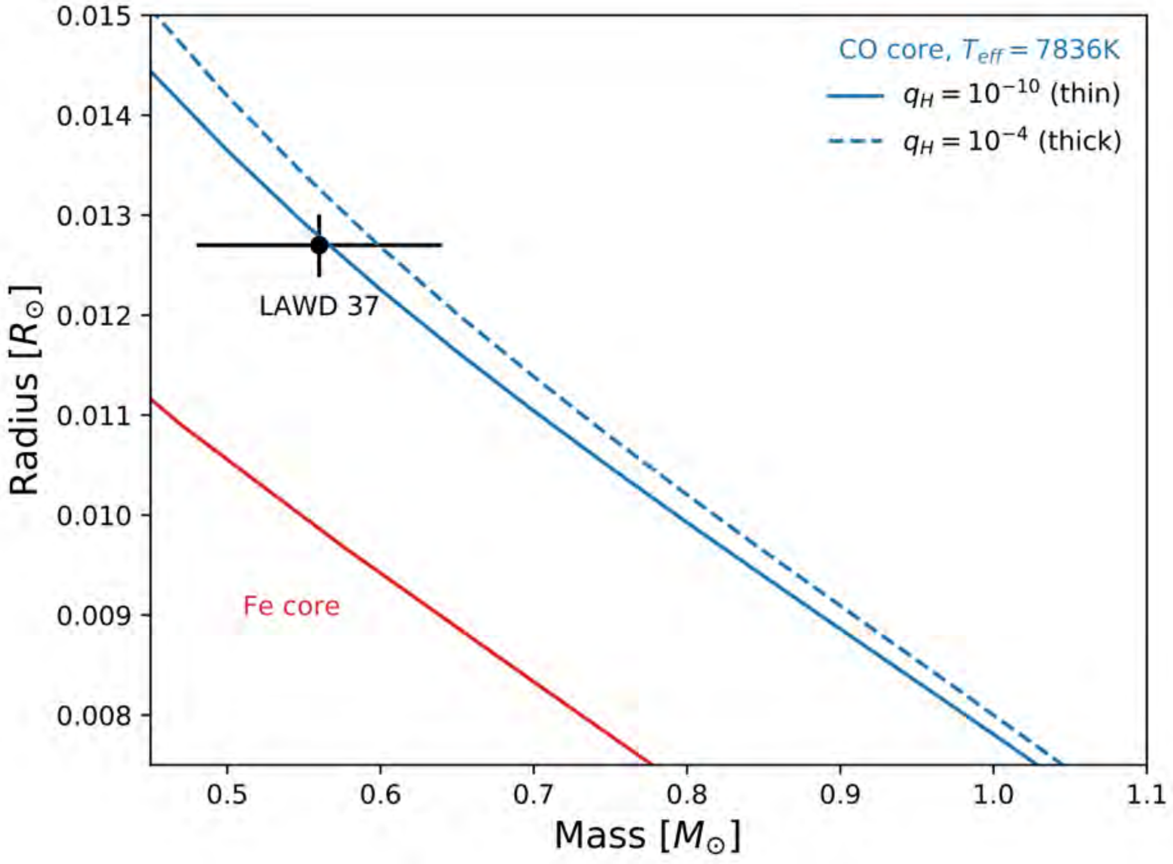
- We found the correlated noise model provided the best explanation of the data





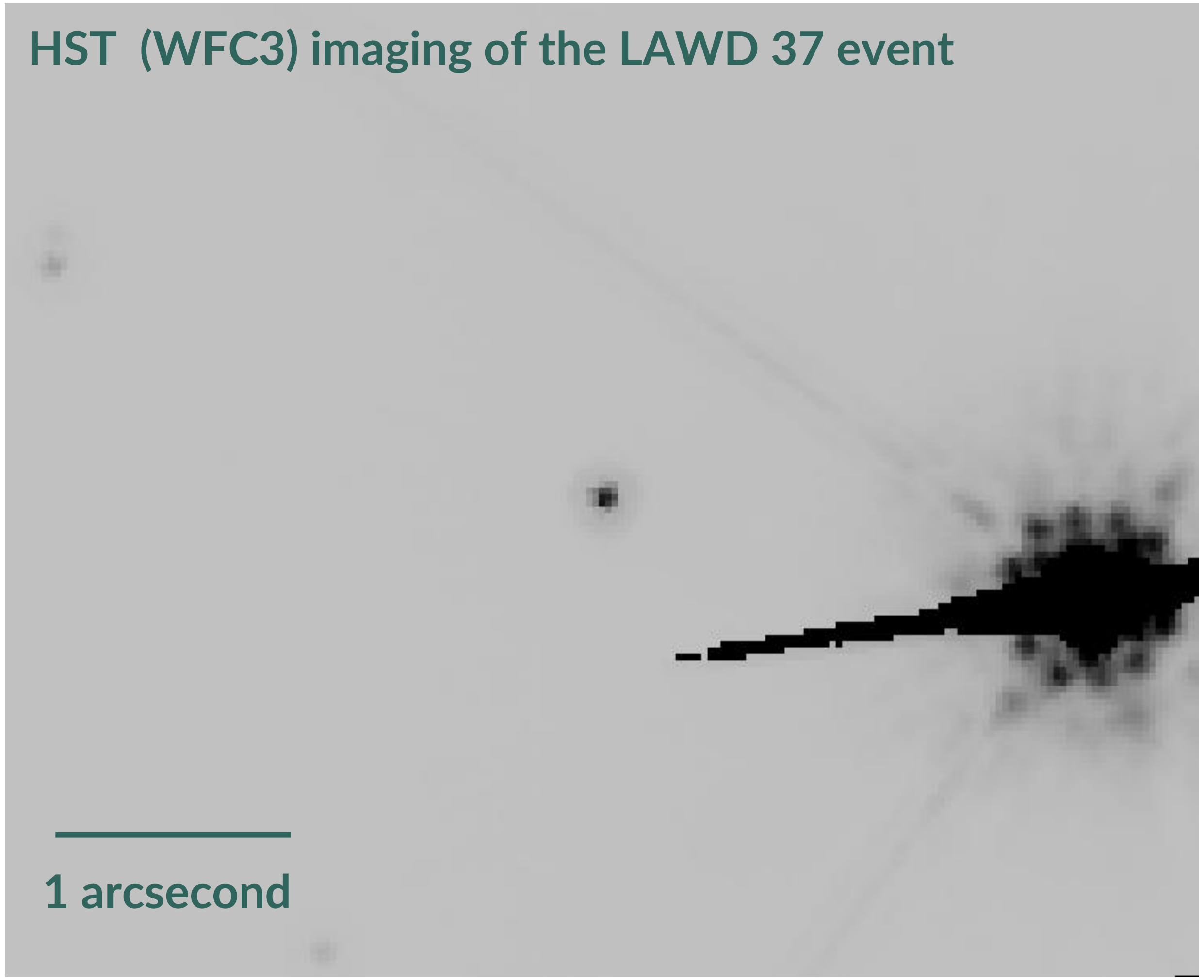
Testing the white dwarf mass-radius relationship

- LAWD 37 is an isolated DQ type white dwarf - mainly made of degenerate matter
- It should follow a strict mass radius relationship - hard to test
- Current mass radius relationships tests require strong modeling assumptions on the interior of white dwarf
- First event direct mass determination of an isolated and single white dwarf
- LAWD 37 will cause more events giving an opportunity to compress the error bars



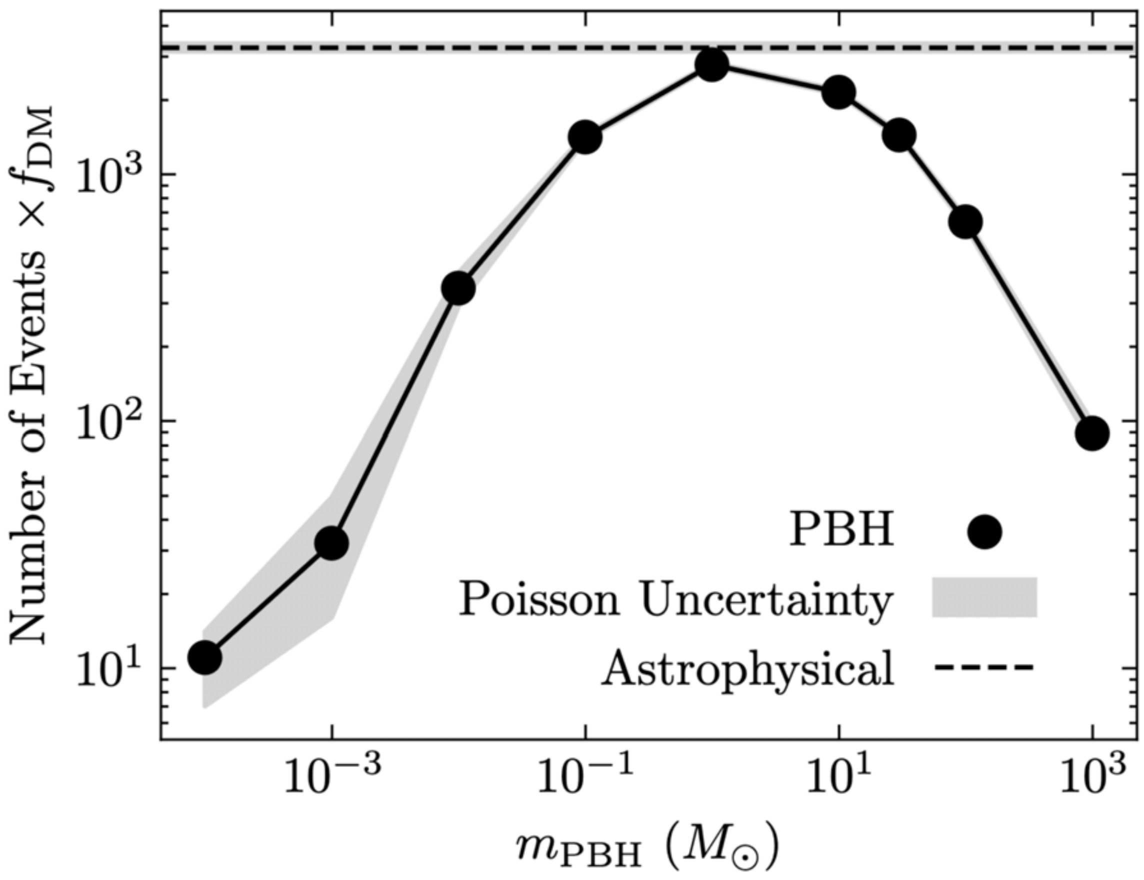
Lessons Learned

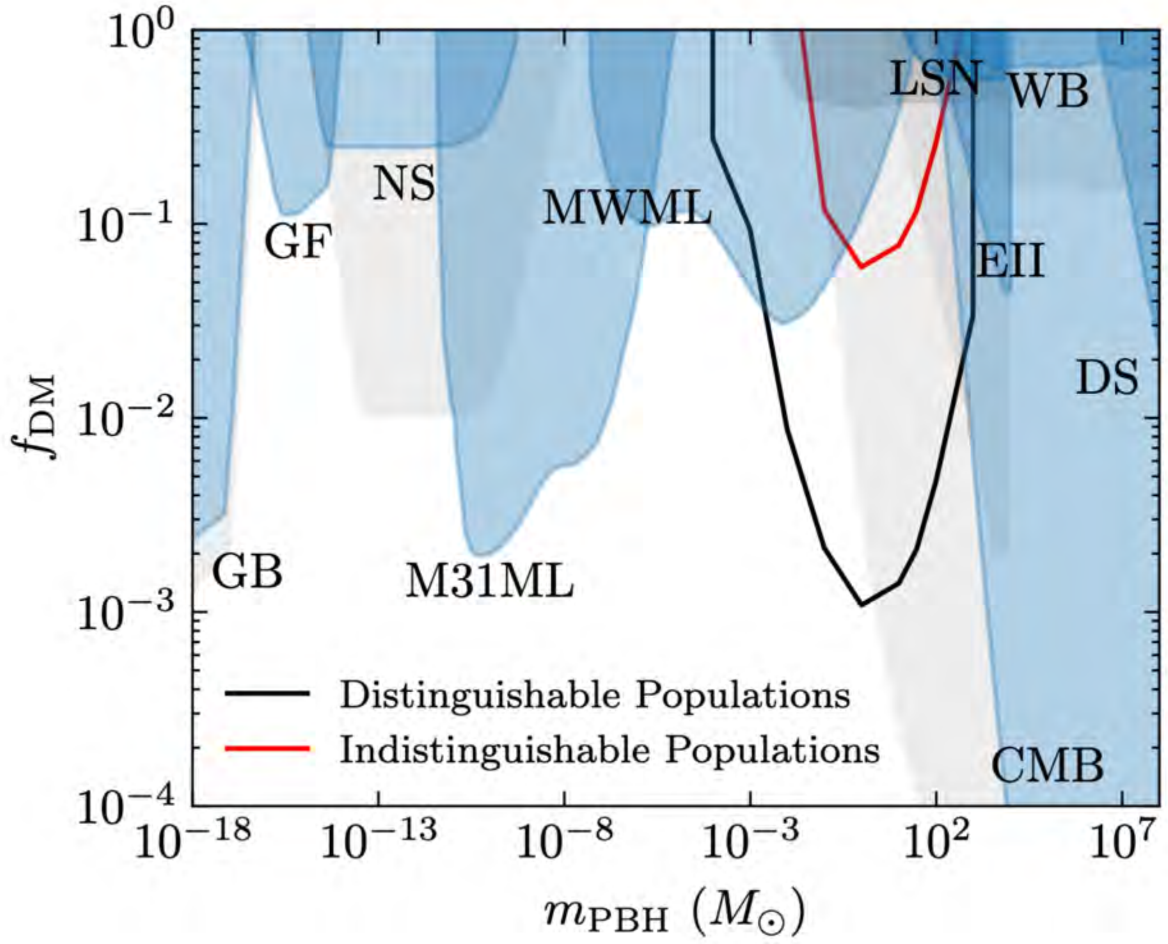
- Taking data clustered around the peak was not the optimal strategy for LAWD 37 - that's where the correlated noise was the highest!
- Tails of the event, where the correlated noise was small ended up being much more powerful
- For a given event, when should we take data to get best lens mass constraint?



Pure Astrometric Microlensing with Roman

Simulated Galactic Bulge Time Domain Survey, u0 > 2 (~astrometric only), m_F146 < 22 (AB)





Summary

- Gaia has revealed a stream of ~10 predicted astrometric events per year for the next 100 years. New reliable detection channel in microlensing!
- Main challenge is astrometry of faint sources in the presence of bright lenses
- Characterisation of the events will likely lead to precision mass determinations of a rich variety of stars
- Opportunity for fine-grade follow-up planning for predicted events
- Roman will detect a significant number of purely (u0>2) astrometric events for all lens types which will be missed by photometric only processing
- Potential for novel PBH constraints
- Length of the survey is a limiting factor for ~> 10 solar mass lenses

References

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