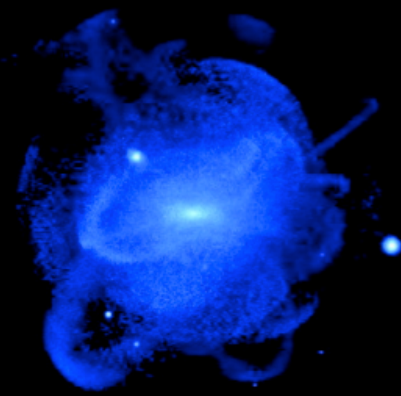


Probing the Galactic Halo with WFIRST Proper Motions of Streams

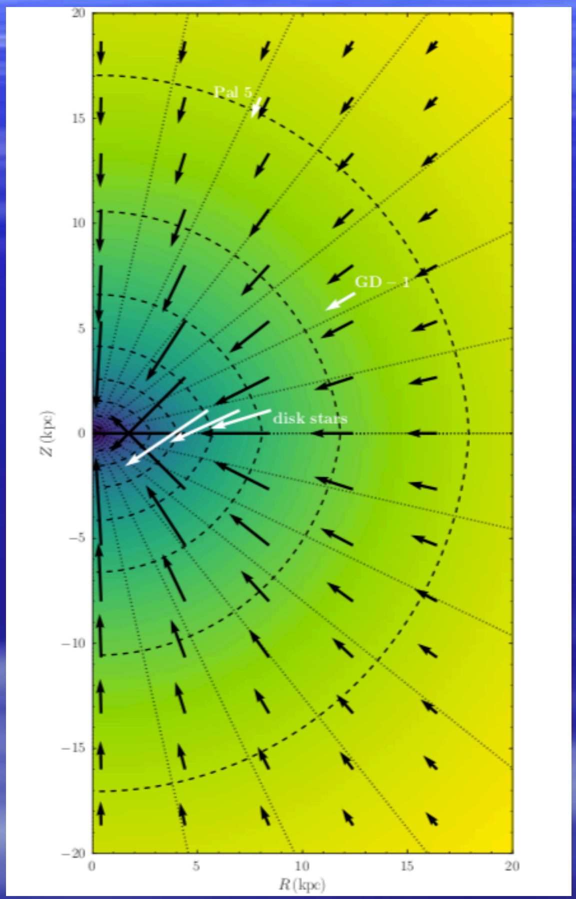
Carl J. Grillmair

19 June, 2019

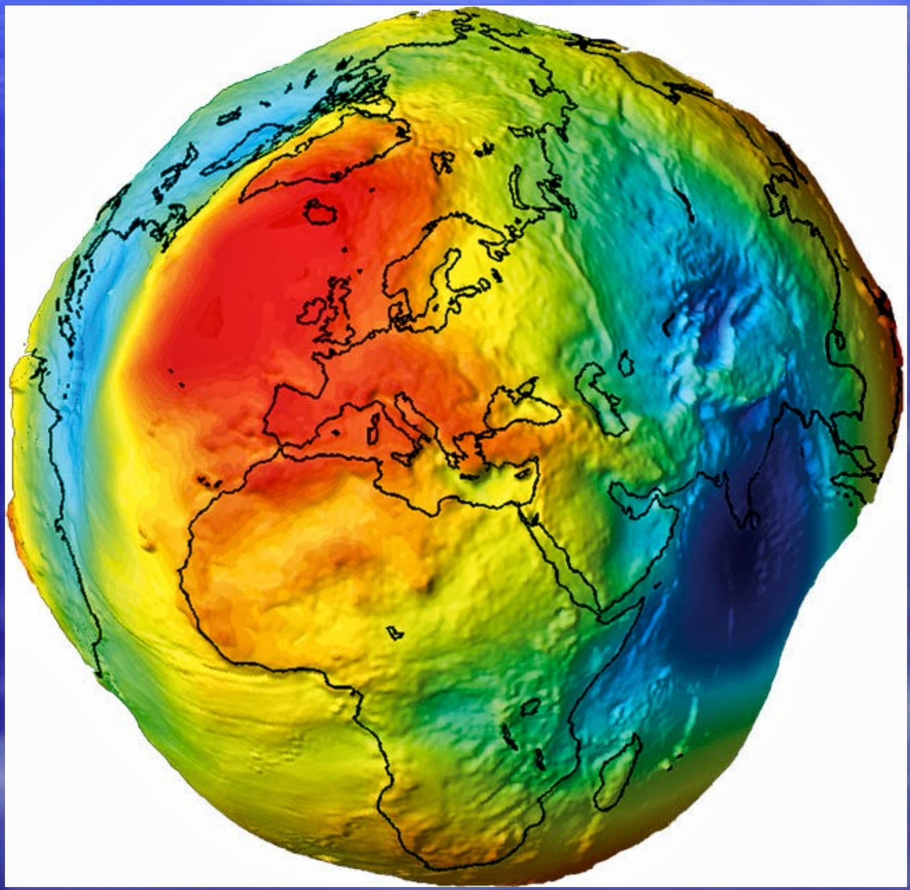
Why Stream Proper Motions?

- Motions of distant streams will be critical for direct and independent estimates of $d\Phi/dR$ and the mass of the Galaxy.
  - Many streams in many quadrants should eventually give us a non-parametric view of the distribution of mass in the halo.
- The motions of streams can tell us about the present day evolution of the Galactic potential and put limits on different types of dark matter.
- Streams and substructures can tell us about the assembly history of the Galaxy.
- Dwarf galaxy streams should tell us more about the presence and distribution of dark matter in these galaxies.
- Nearby cold streams will be critical for cold dark matter subhalo and dark matter stream detection.

Galactoid?



Bovy et al. 2016



GRACE Geoid

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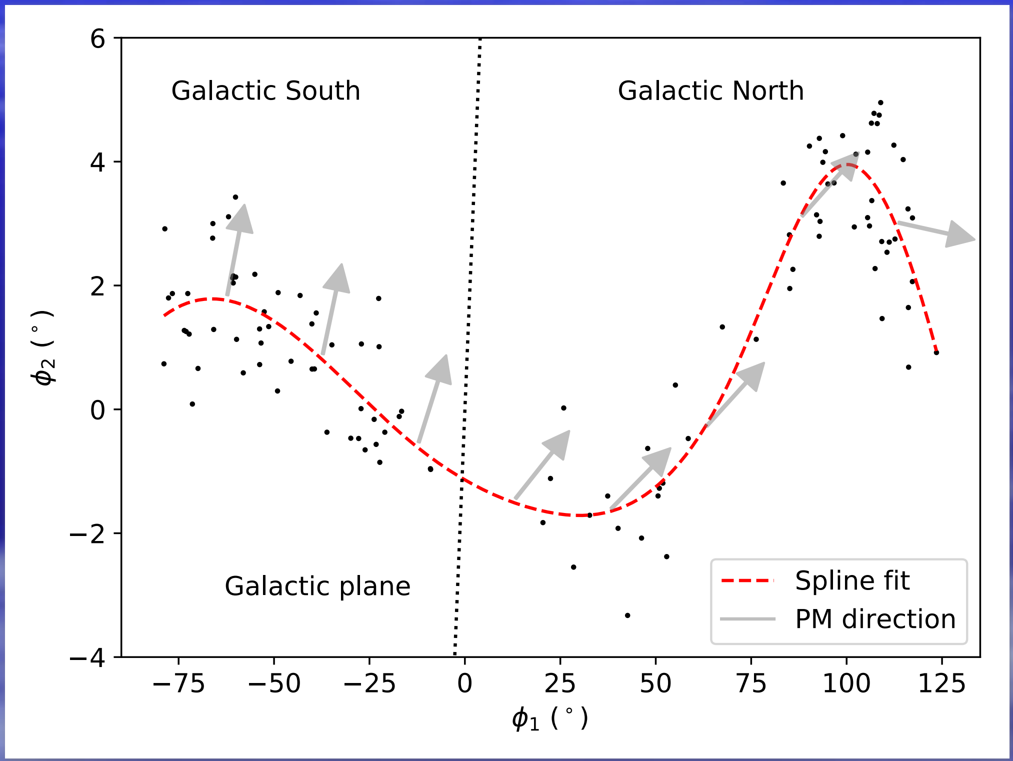
Orphan Stream in RR Lyrae



Erkal et al. 2019

⇒ LMC mass ~ 1.4 x 10^{11} $M_\odot$

⇒ significant current halo distortion

- Possible limits to cross section of self-interacting dark matter (Carlberg 2019)

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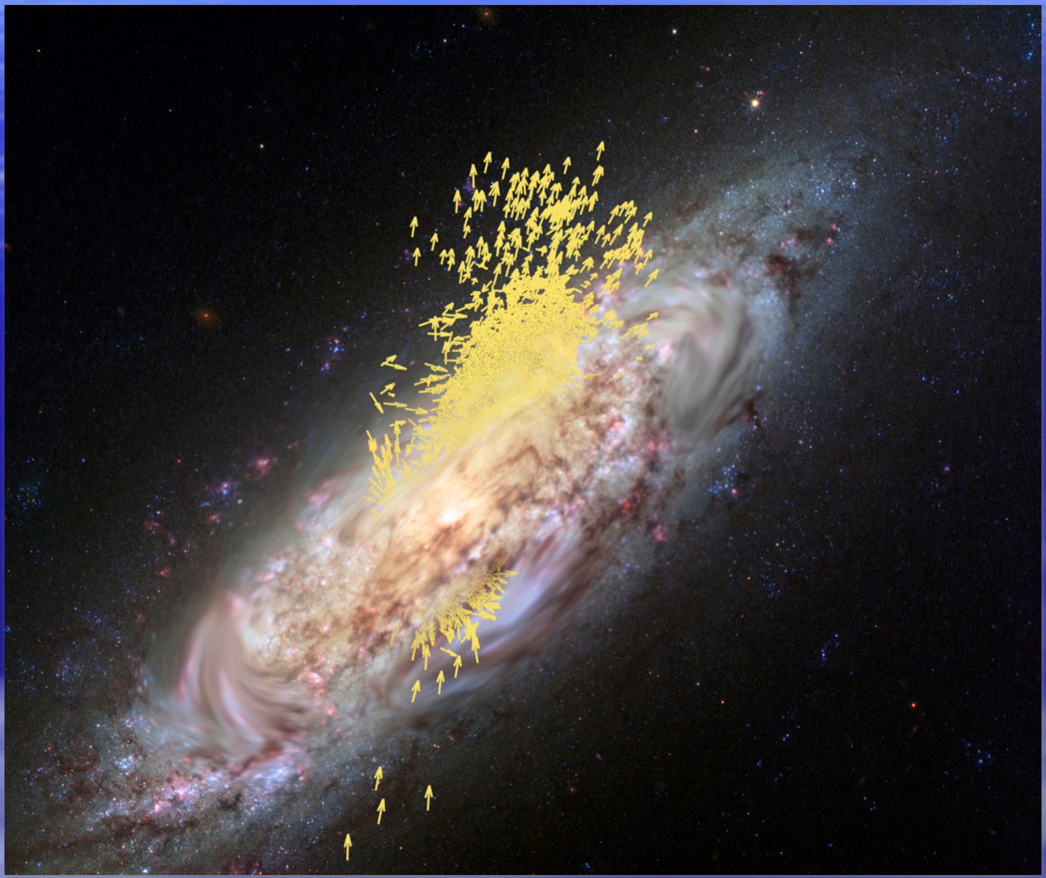
Gaia-Enceladus/ The Sausage



Helmi et al. 2018, Belokurov et al. 2018

>20% of halo is accounted for by the Sagittarius stream.

Other major events are becoming evident.

The halo is almost certainly just a junkyard.

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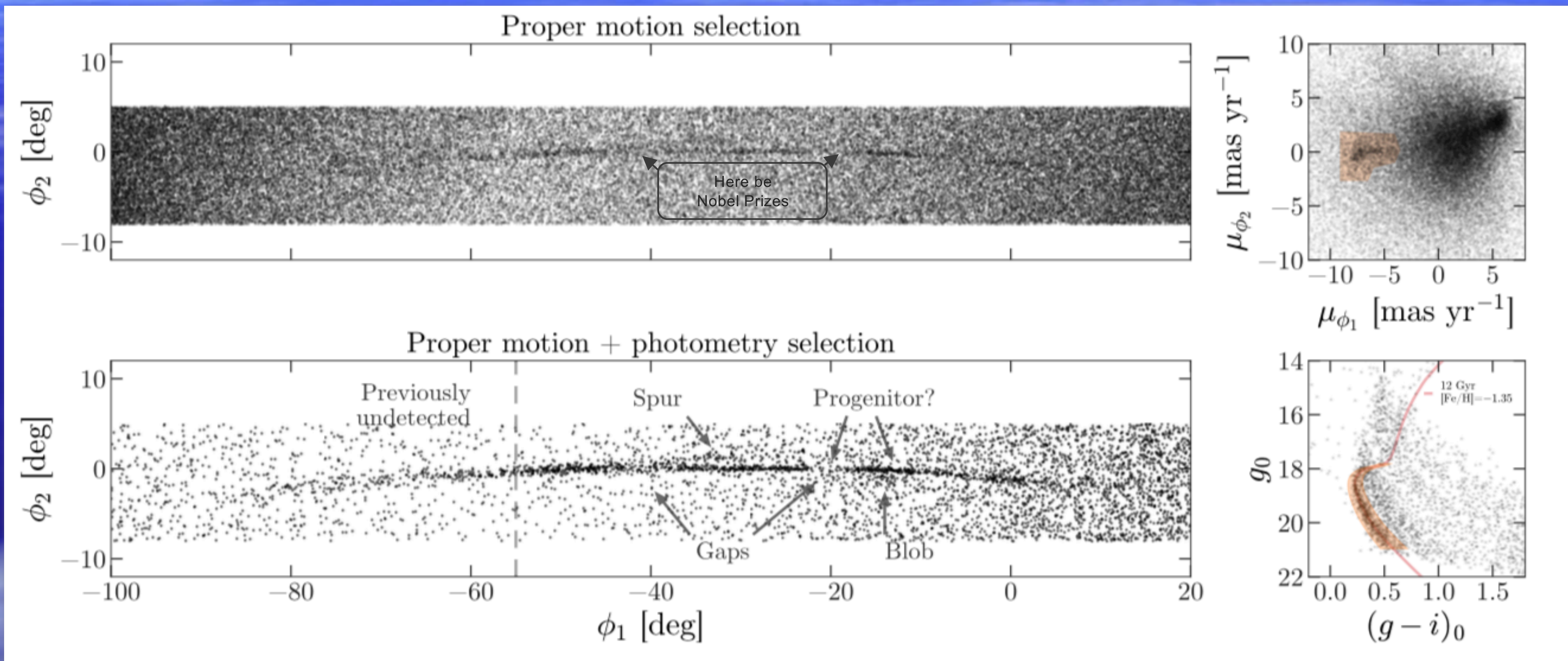
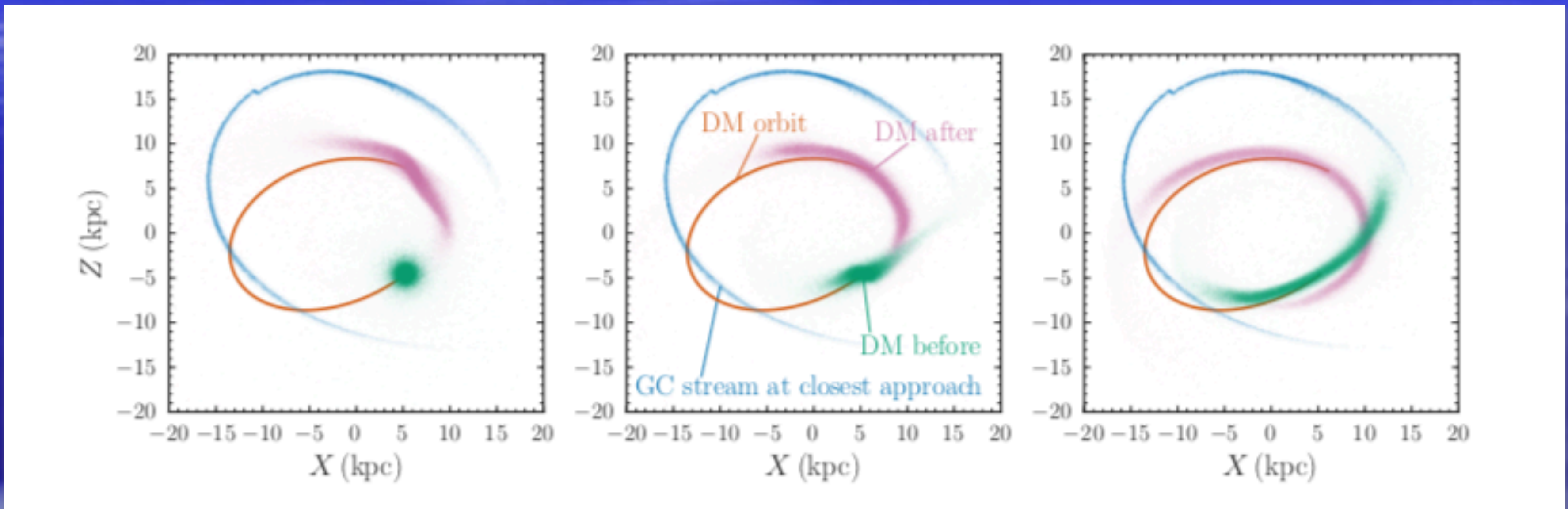
GD-1



Price-Whelan & Bonaca 2018

<10 μasec/yr required proper motions may be possible for brightest giant branch stars with Gaia + 15 years of WFIRST scanning (Spergel 2016).

Mapping Dark Matter Streams



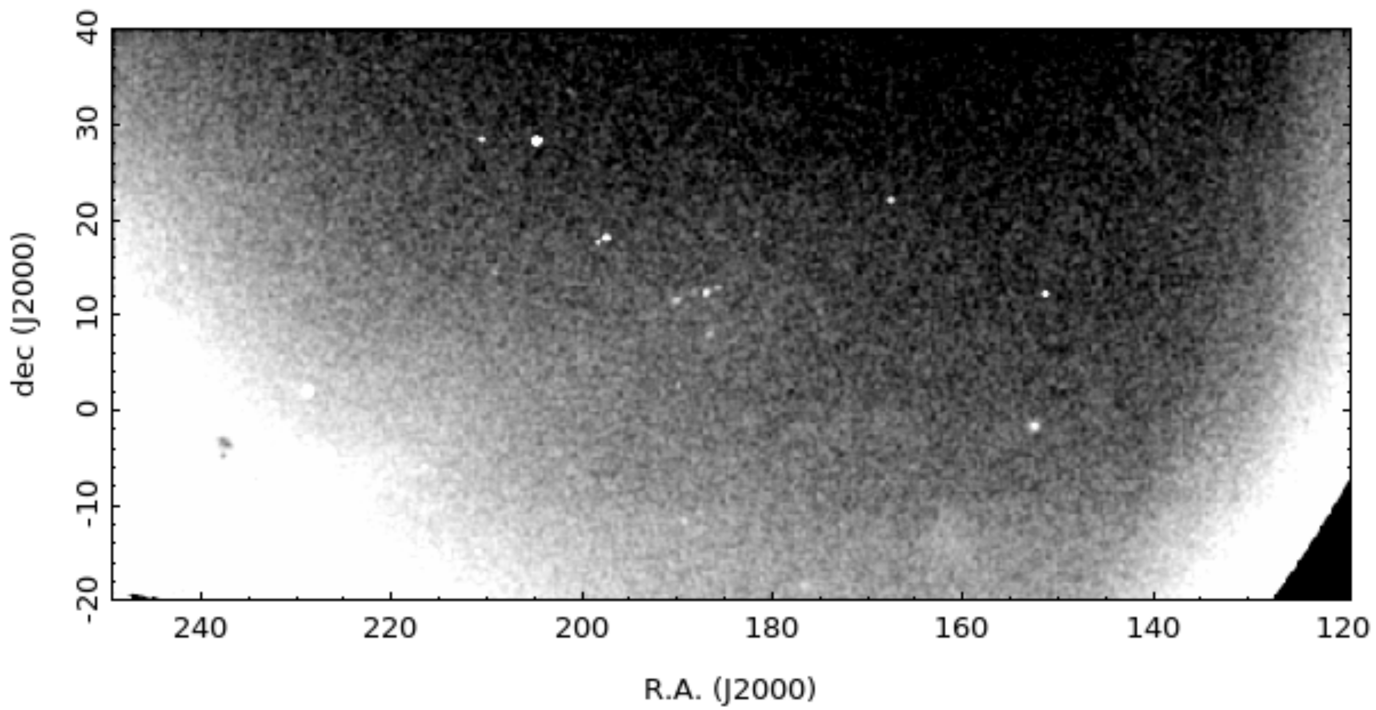
Bovy 2016

- Dark matter streams can also create gaps in cold stellar streams.
- Gap morphologies would be subtly different, reflecting a more diffuse potential.

Finding Streams with WFIRST

- Signal to noise ratio is simply $N_{stream}/\sqrt{N_{foreground}}$
- For nearby cold streams, deep WFIRST photometry can increase N_{stream} by at least an order of magnitude. (LF + mass segregation)
- With proper motions better than ~1 mas/yr (26th mag) we can reduce $N_{foreground}$ by an order of magnitude.
- For distant streams, 1 mas/yr proper motions can more than compensate for increase in $N_{foreground}$ at $\mu_\alpha, \mu_\delta = 0$.

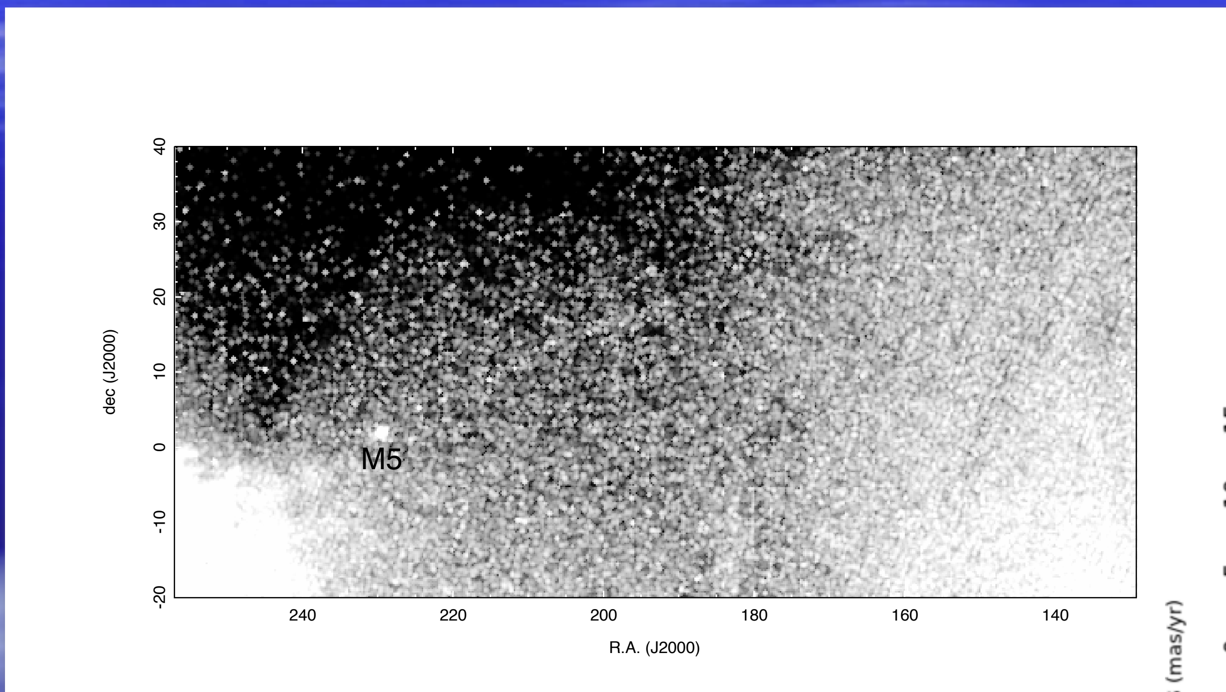
M5 Trailing Tidal Tail

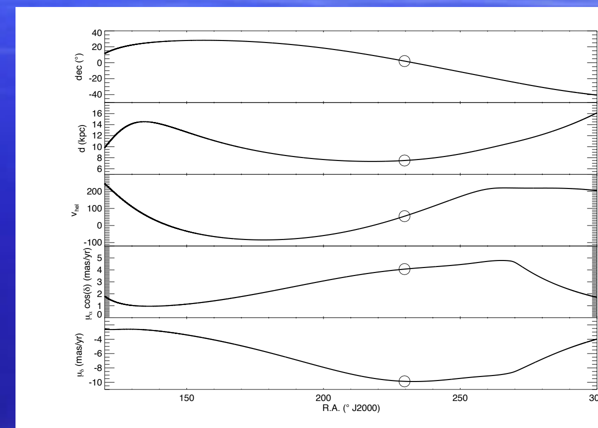


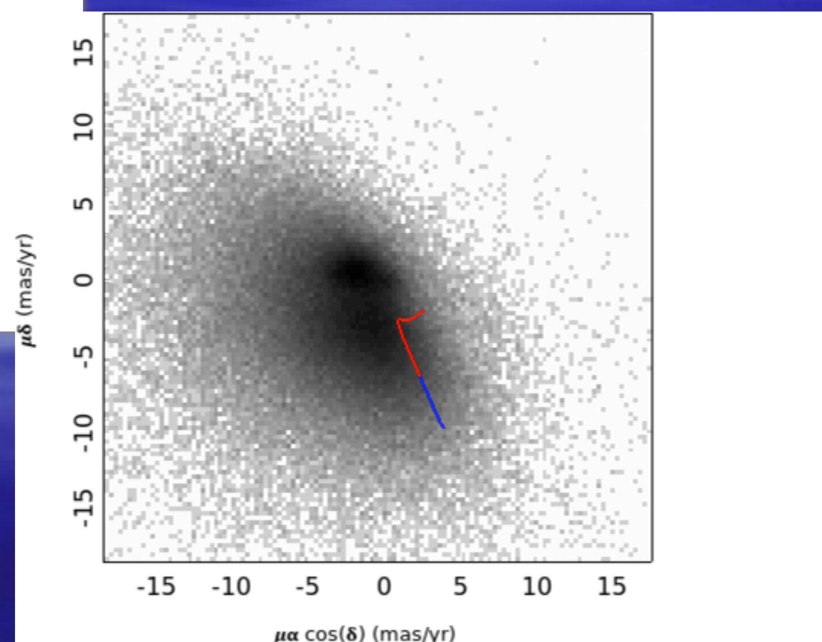
Pan-STARRs photometry to g = 21.7
Optimally Filtered for d = 7.5 kpc

M5 Trailing Tidal Tail

50º to 80º long, 1.5 star per square degree (~35 mag/arcsec^2)







Gaia photometry + astrometry (G_{lim} = 20)
Grillmair 2019

Reduced signal by 2.5x, but background by 100x.

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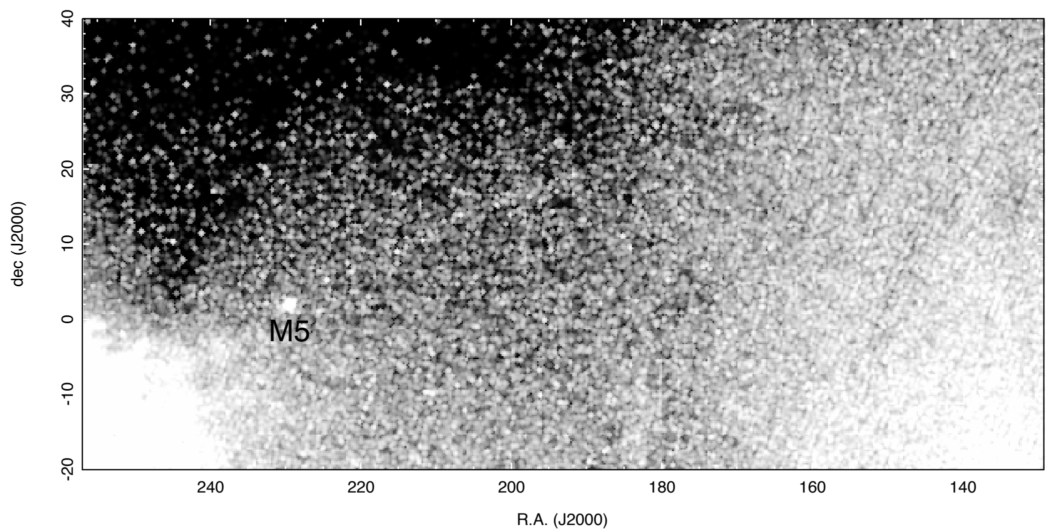

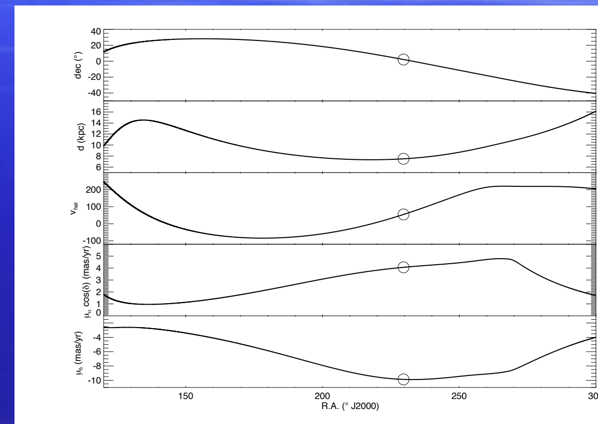

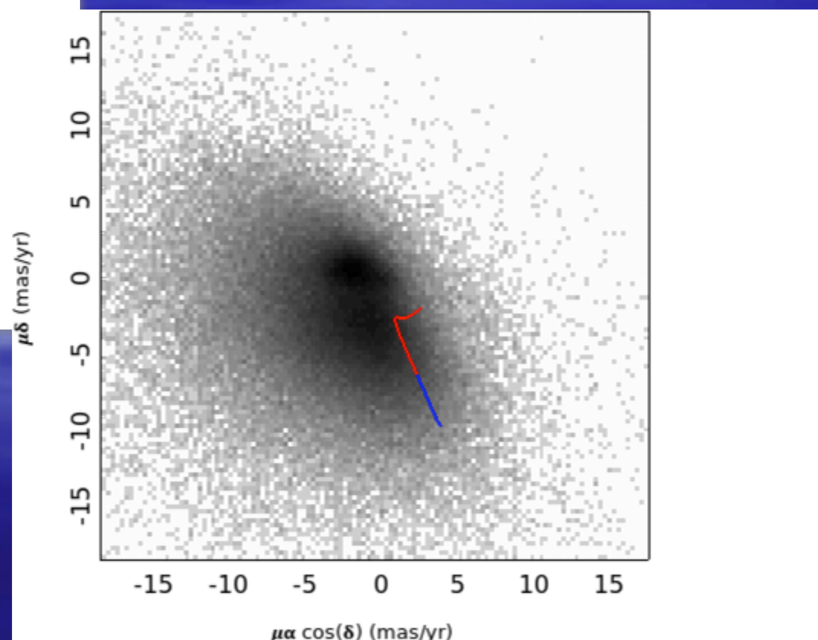

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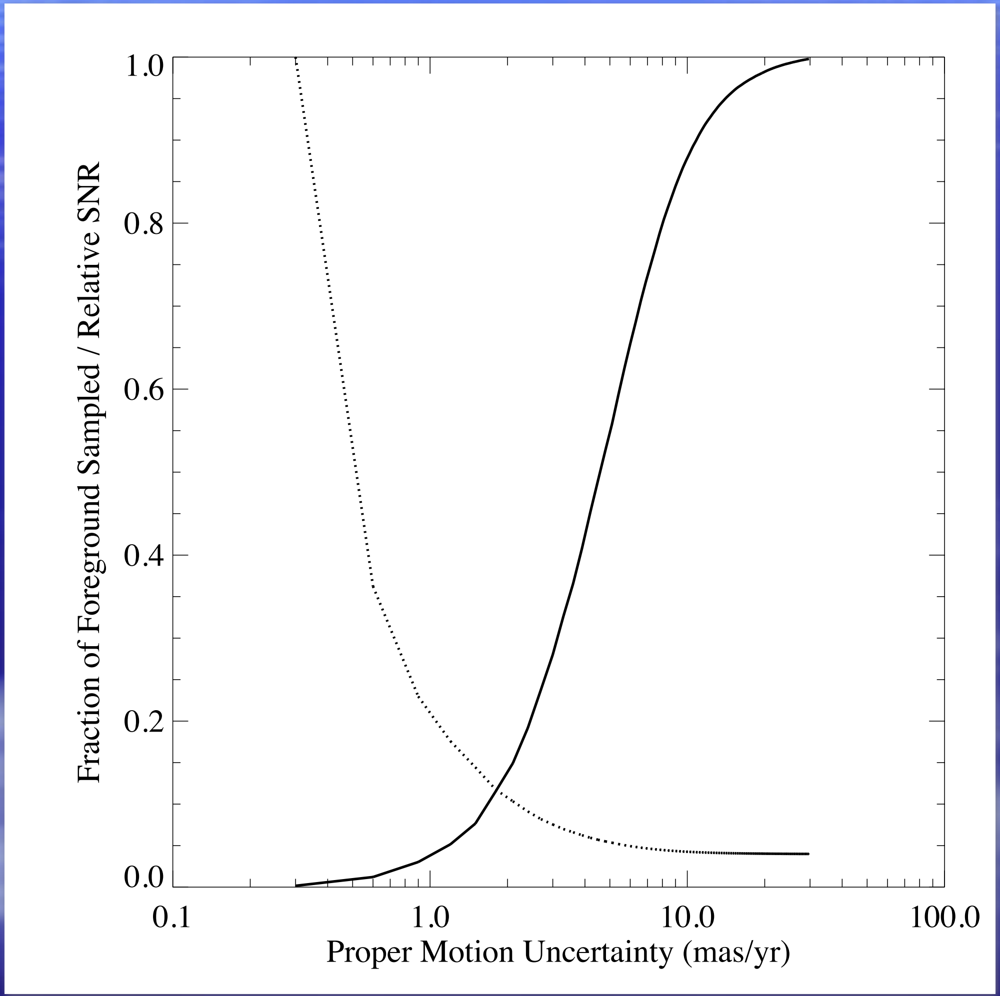
Finding Distant Streams with WFIRST



~1 mas/yr proper motion uncertainties (at ~26th mag in HLS*) reduce field star contamination by ~20x, increasing SNR by factor of 4.

~300 micro arcsec/yr (~130 exposures over 15 years) would improve SNR by another factor of 5.

* 26th mag corresponds to ~1 magnitude below the main sequence turn off for a 13 Gyr-old stellar population at 200 kpc.