Stellar Wakes from Dark Matter Subhalos

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Malte Buschmann
Dark Matter Halos

Galaxy Cluster

Spiral Galaxy

Dwarf Galaxy

Empty
Empty
Empty
Empty

Not shown to scale!

10^7 - 10^8 M_☉
Jethwa et al 2017
Dark Matter Subhalos

- Spectrum of DM subhalos predicted by ΛCDM
- Drastic deviations between different models (in particular warm/fuzzy/self-interacting DM)
- Invaluable targets for indirect DM searches

But:
How to find something that is dark?
Perturbing Stellar Streams

Method 1: Subhalo is passing through a stellar stream

NASA/JPL-Caltech/R. Hurt (SSC/Caltech)
Perturbing Stellar Streams

Gaps in the Pal 5 stream might be due to DM subhalos:

Erkal et al. 2017
Perturbing the MW disk

Subhalos can also leave a trace in the vertical velocity of disk stars:

Feldmann et al. 2014
Perturbing MW Halo Stars $\rightarrow$ Stellar Wakes

This work: Perturbation to the luminous MW halo

Big advantage: We can tell exactly where the subhalo is $\rightarrow$ follow-up studies possible!
Perturbing MW Halo Stars → Stellar Wakes
Perturbing MW Halo Stars $\rightarrow$ Stellar Wakes

Look for patterns in the stars 6-D phase space!

**Gaia** measures this right now!
Perturbing MW Halo Stars → Stellar Wakes

**Strategy:**

- Define test statistic: \( TS = 2 \left[ \max_\theta \log p(\theta) - \max_\theta \log p(\theta) \bigg| M_{sh}=0 \right] \)

- Likelihood product over stars PS: \( p(\theta) = e^{-N_{\text{star}}} \prod_{k=1}^{N_{\text{star}}} f_k \)

- Phase-space: \( f = f_0 + f_1 \) (\( f_0 = \) Maxwell-Boltzmann, \( f_1 = \) perturbation)

- Solve Boltzmann Eq. for \( f_1 \): \( f_1 = \int_0^\infty \frac{du}{u^2} \nabla_y \Phi(\vec{y}) \cdot \nabla_v f_0(\vec{v}) \bigg|_{\vec{y} = \vec{x} - \vec{v}/u} \)

Here, \( \Phi \) subhalo potential, e.g. \( \Phi(r) = -\frac{GM_{sh}}{\sqrt{r^2 + r_s^2}} \)
Conclusion:
Dark matter subhalos might be found by looking at the perturbation of Milky Way halo stars!
Perturbing MW Halo Stars $\rightarrow$ Stellar Wakes

blue: $\delta v_x > 0$, red $\delta v_x < 0$
Perturbing MW Halo Stars → Stellar Wakes

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Perturbing MW Halo Stars $\rightarrow$ Stellar Wakes

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