Milky Way Satellite Galaxy Kinematics and Scaling Relations for Dark Matter Searches

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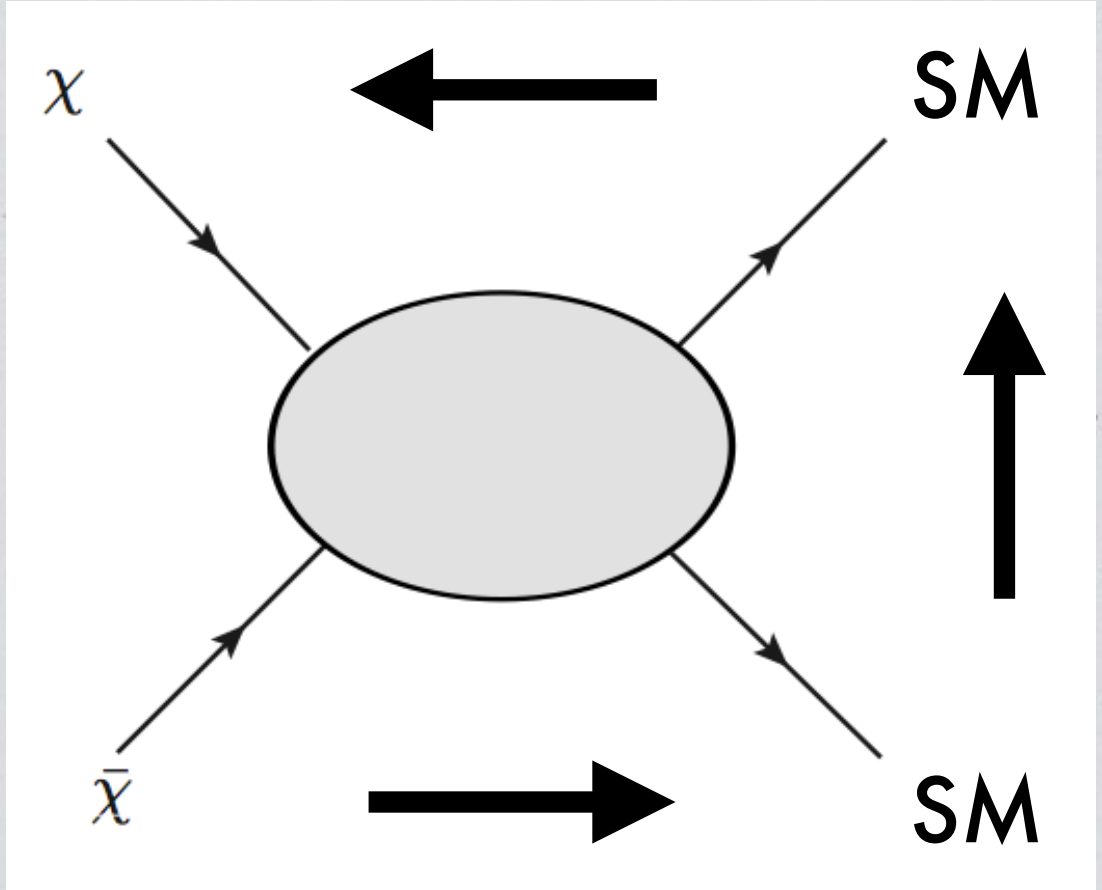
Identifying the Particle Nature of Dark Matter

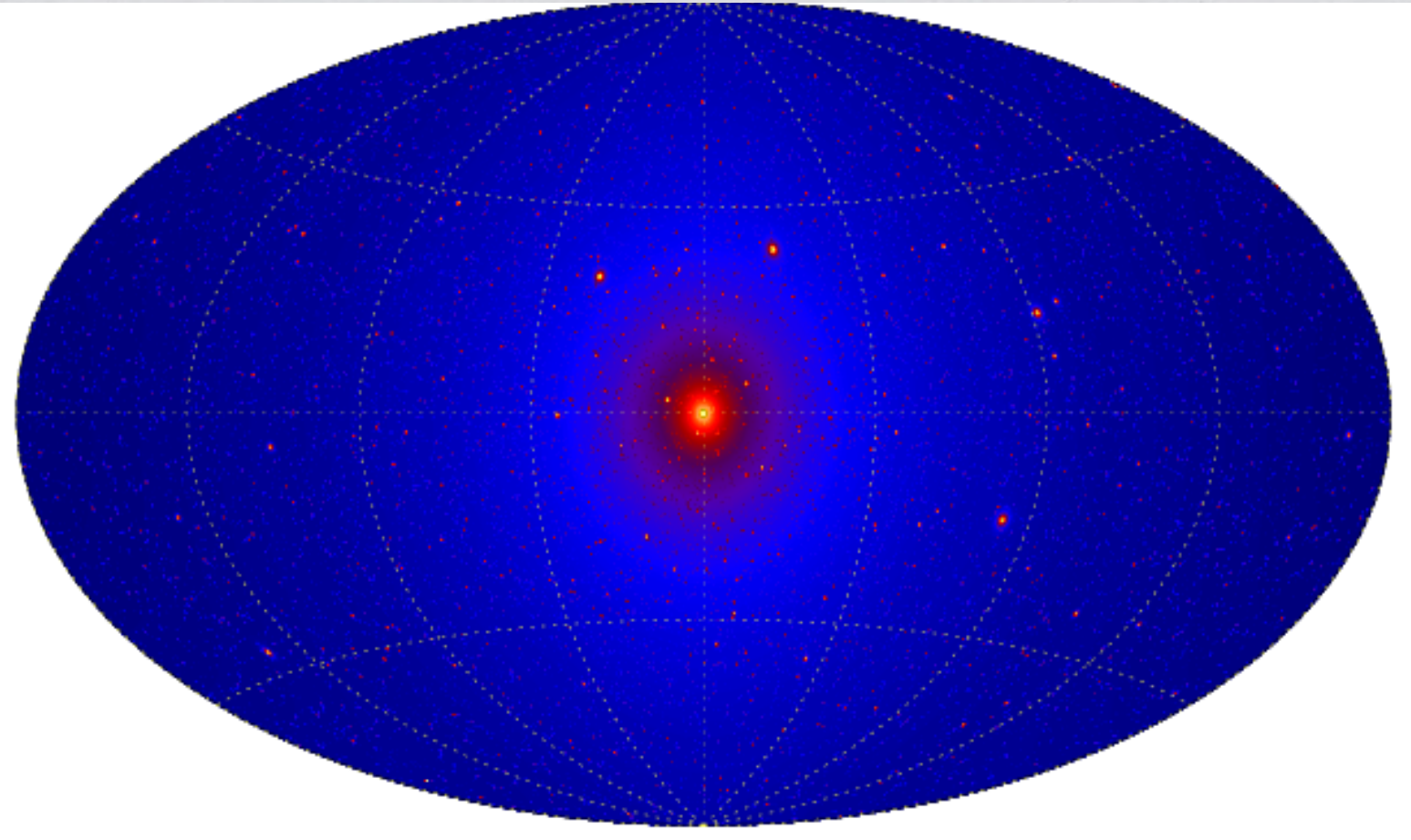
Production via Collider



Direct Detection

Indirect Direction

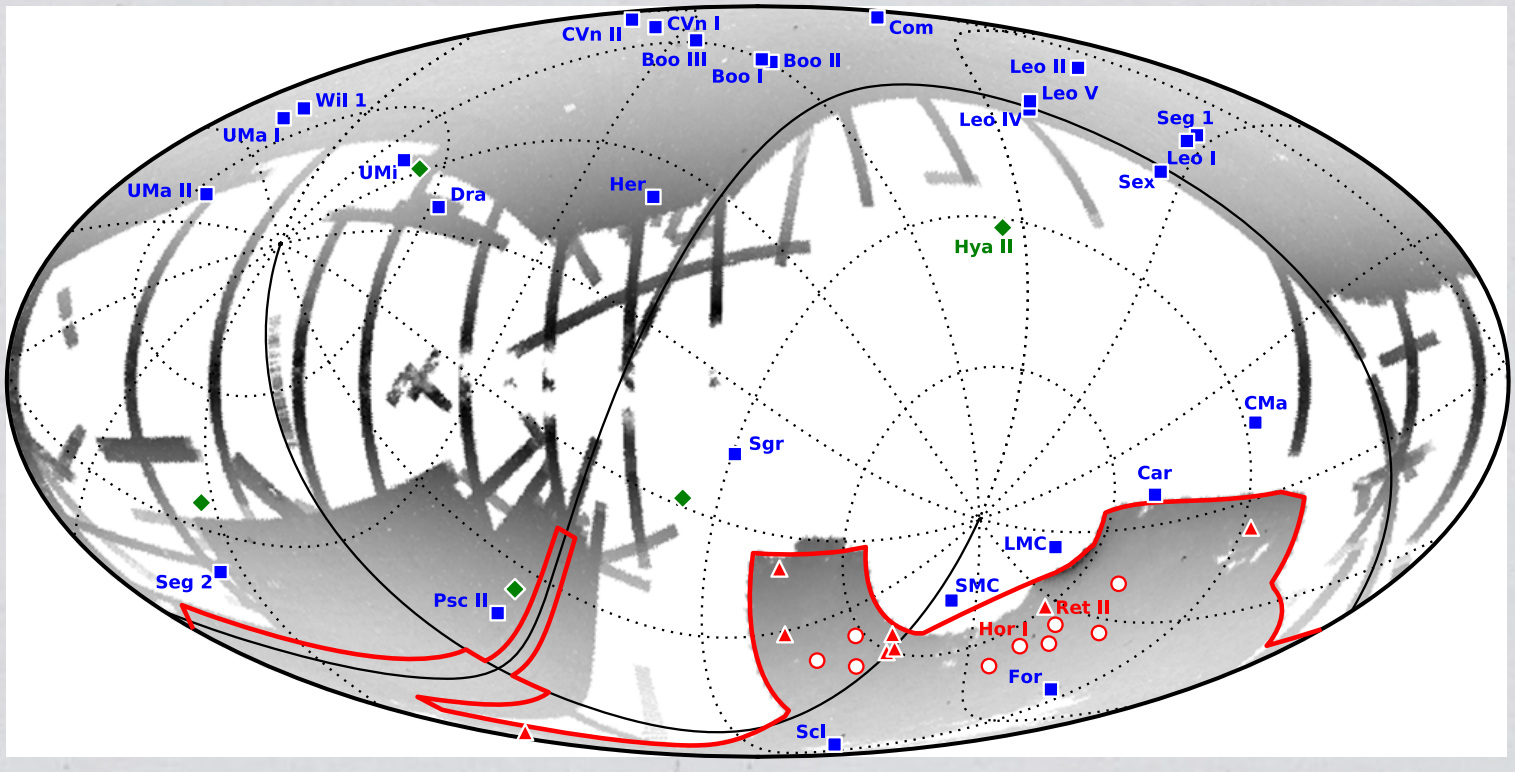
Dark Matter Gamma Ray Sky



Pieri+ 2009

Dark Matter Gamma Ray Sky: Targets

MW Satellite galaxies (dSph)



Drlica-Wagner+ 2015

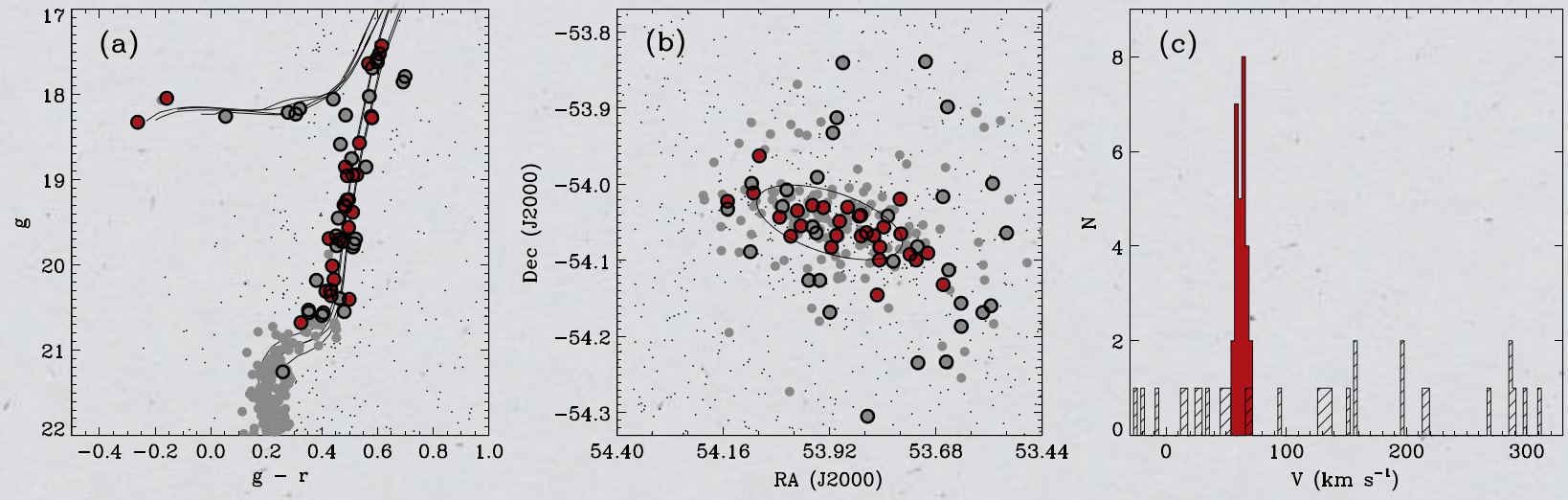
Dark Matter "Flux"

$$\phi(\Delta\Omega, E_{\rm min}, E_{\rm max}) = \underbrace{\frac{1}{4\pi}\frac{\langle\sigma v\rangle}{2m_{\rm DM}^2}\int_{E_{\rm min}}^{E_{\rm max}}\frac{dN_\gamma}{dE_\gamma}{\rm d}E_\gamma}_{\text{particle physics}}$$

$$\times \underbrace{\int_{E_{\rm min}}\int_{\Delta\Omega}\int_{\rm l.o.s.}\rho_{\rm DM}^2(\boldsymbol{r}(l))\,dl\,d\Omega}_{J\,\text{factor}},$$

➡Astrophysics: determine dark matter profile

Dark Matter Profiles in dSph Galaxies



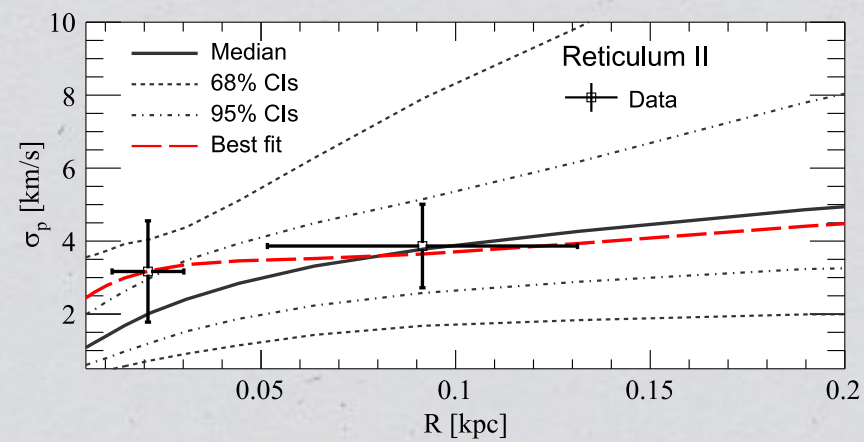
Ret II
Simon+ 2015

Spherical Jeans Equations

$$\frac{1}{\nu}\frac{\mathrm{d}}{\mathrm{d}r}(\nu\bar{v_r^2}) + 2\frac{\beta_{\rm ani}(r)\bar{v_r^2}}{r} = -\frac{GM(r)}{r^2},$$

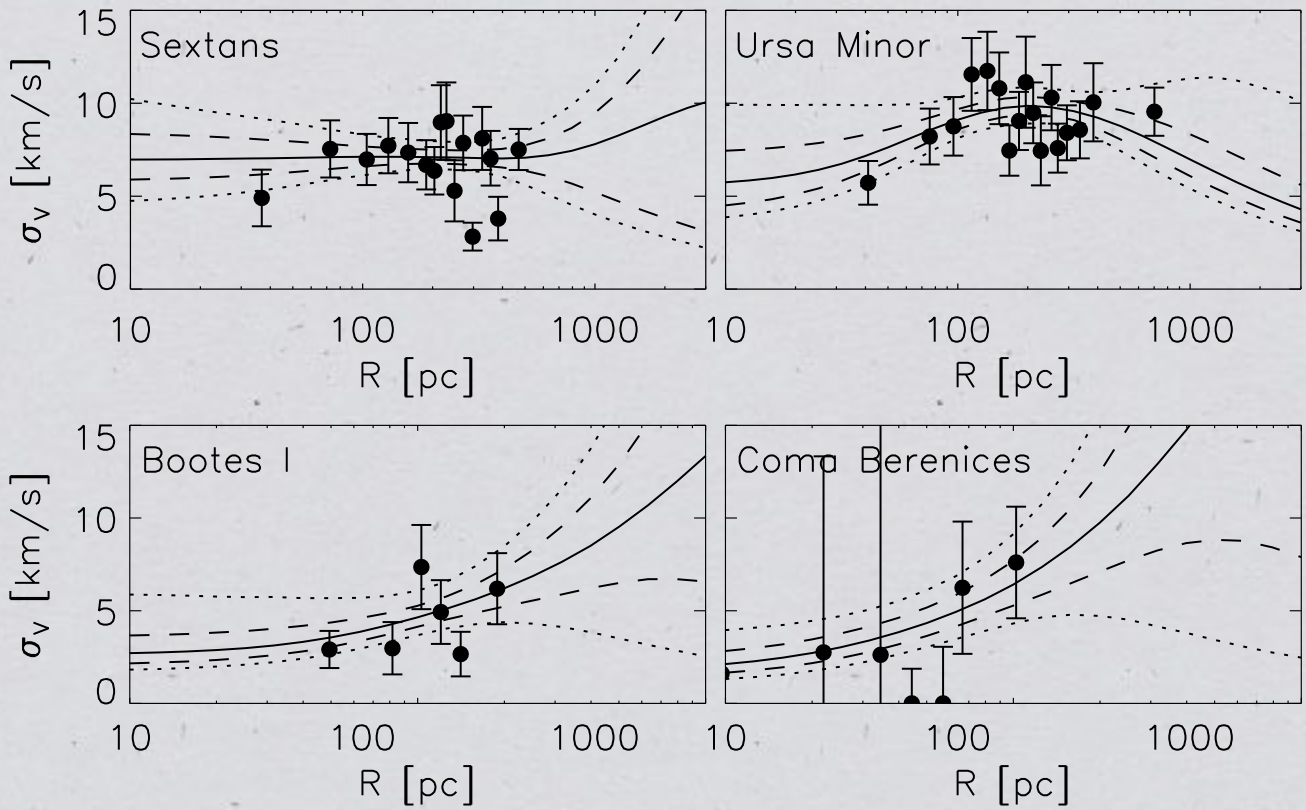
Compare With Stellar Velocities

$$\mathcal{L}^{\rm unbin} = \prod_{i=1}^{N_{\rm stars}} \frac{(2\pi)^{-1/2}}{\sqrt{\sigma_{\rm p}^2(R_i)+\Delta_{v_i}^2}} \exp\left[-\frac{1}{2}\left(\frac{(v_{\rm i}-\bar{v})^2}{\sigma_{\rm p}^2(R_i)+\Delta_{v_i}^2}\right)\right].$$



Bonnivard+ 2015

Dark Matter Profiles in dSph Galaxies

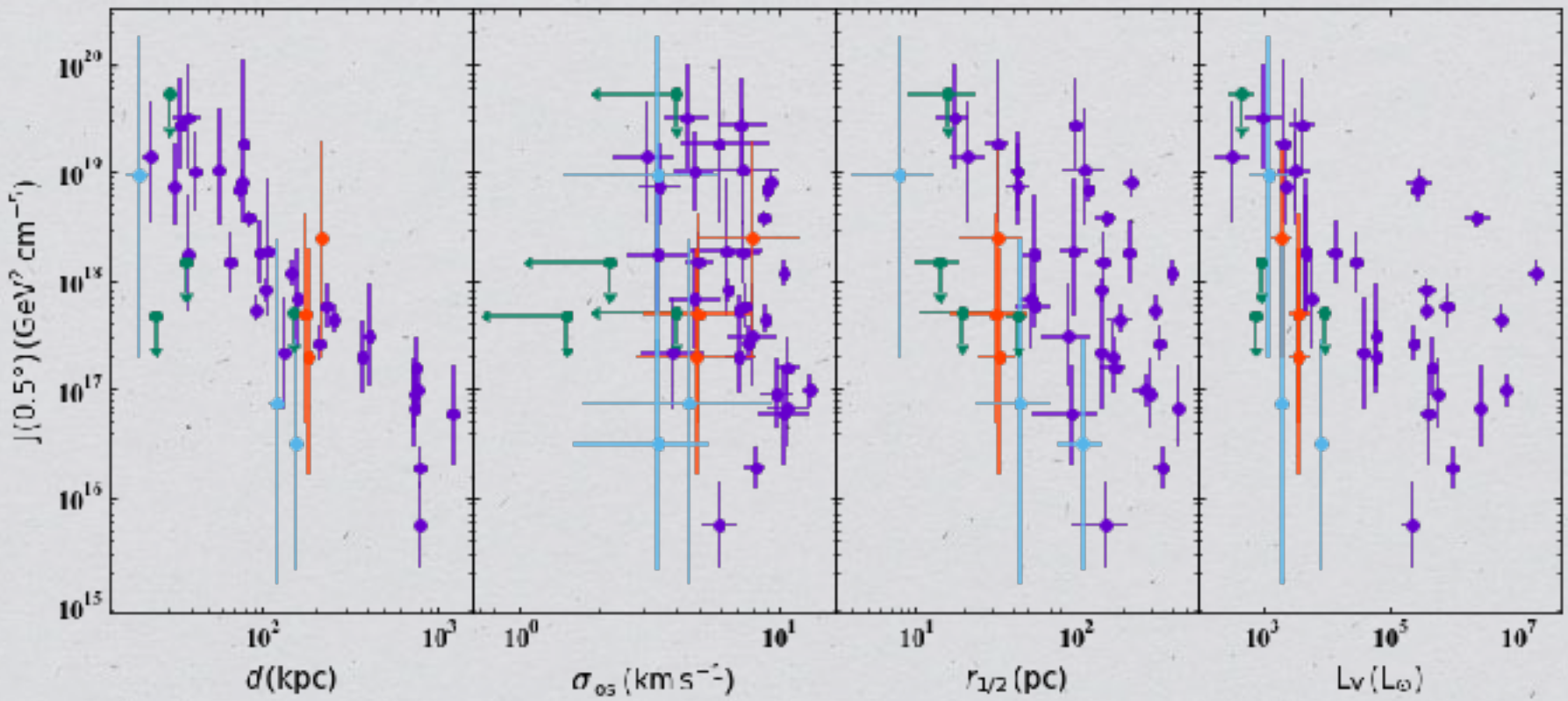


Classical
hundreds of stars

Ultra-Faint
tens of stars

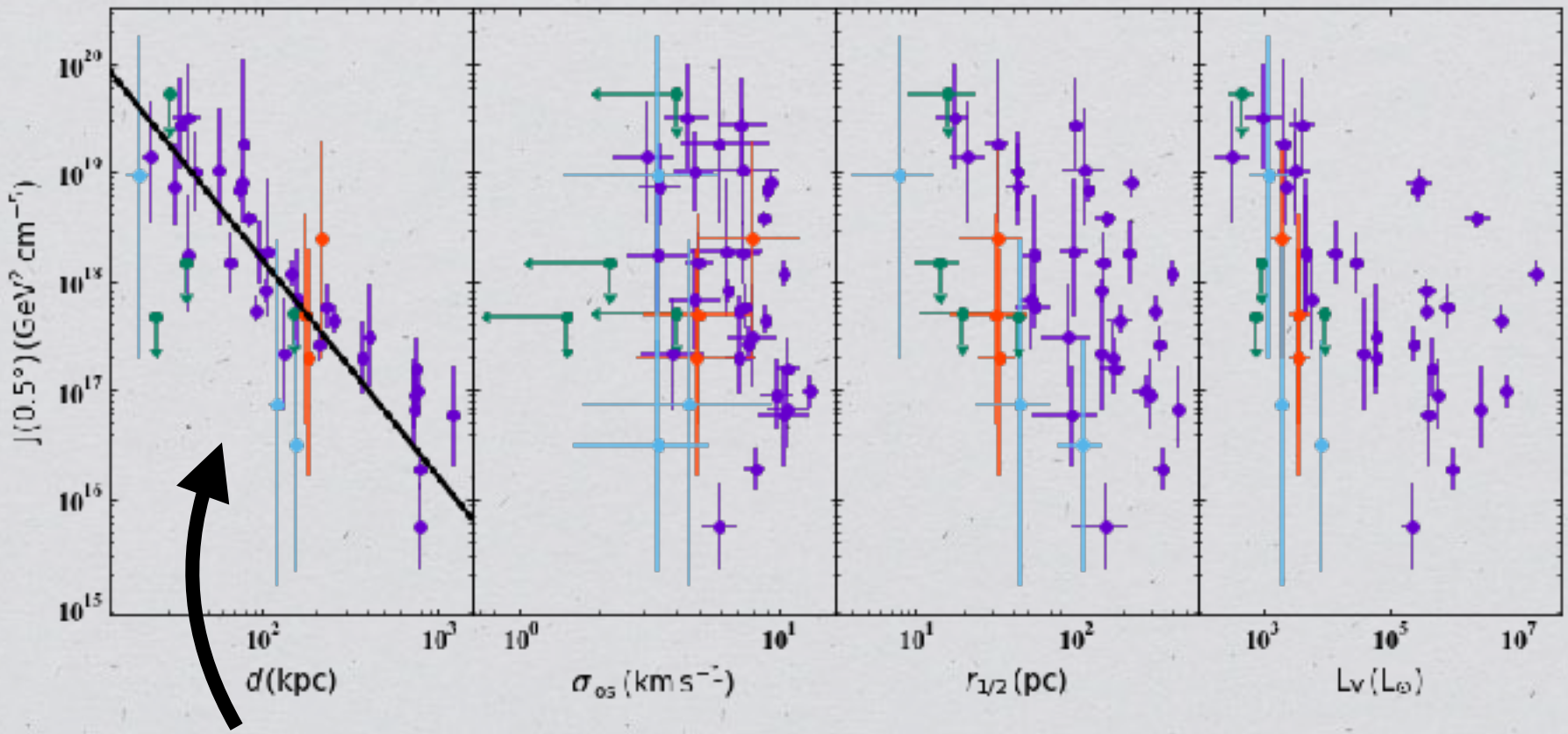
Geringer-Sameth + 2015

J-Factor of Classical and Ultra-Faints



Pace and Strigari 2018

J-Factor of Classical and Ultra-Faints



1/d^2

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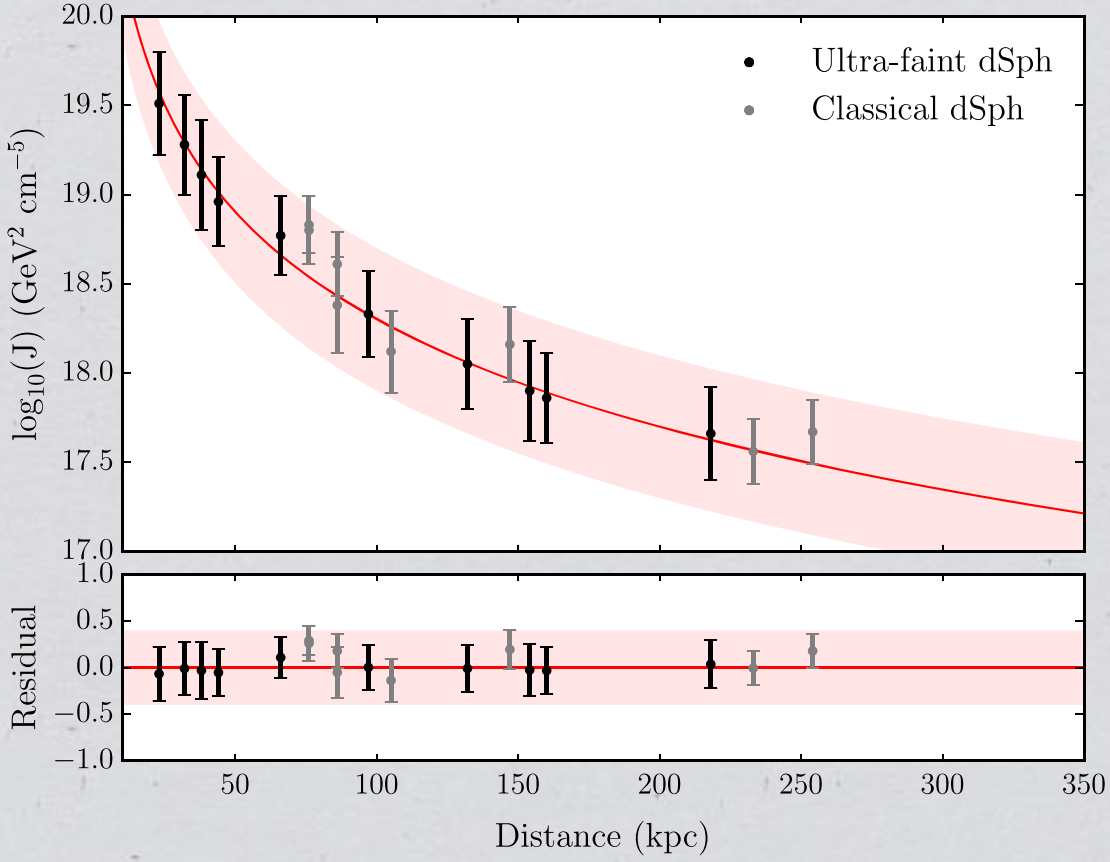
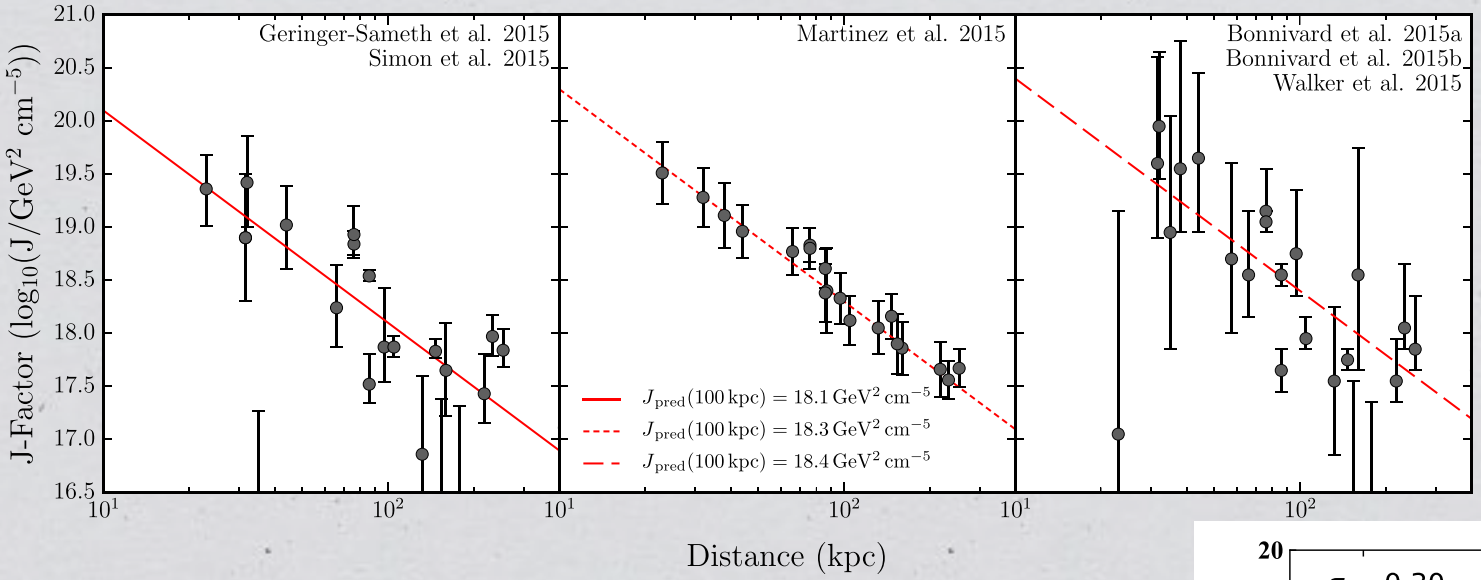
J-Factors for Satellites without Dynamical Modeling



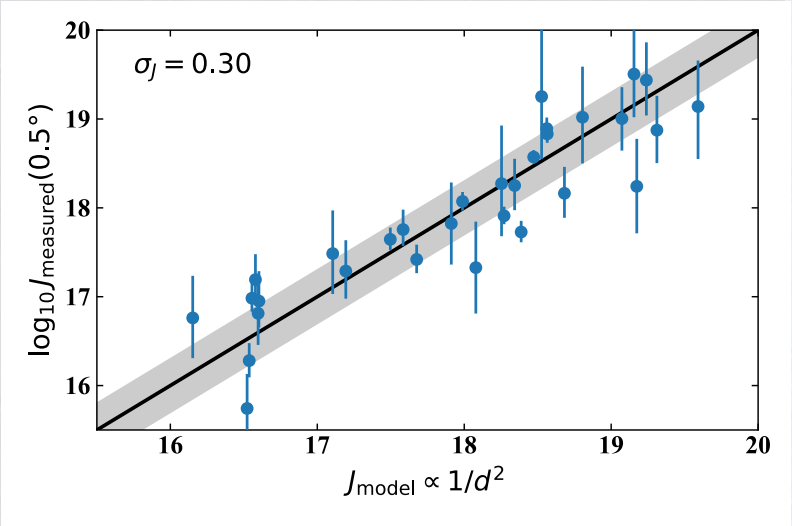
$$\log_{10}\left(\frac{J_{\rm pred}}{J_0}\right) = -2\log_{10}\left(\frac{D}{100\ {\rm kpc}}\right),$$

Drilica-Wagner + 2015, Albert + 2017

J-Factors for Satellites without Dynamical Modeling



Drilica-Wagner + 2015, Albert + 2017



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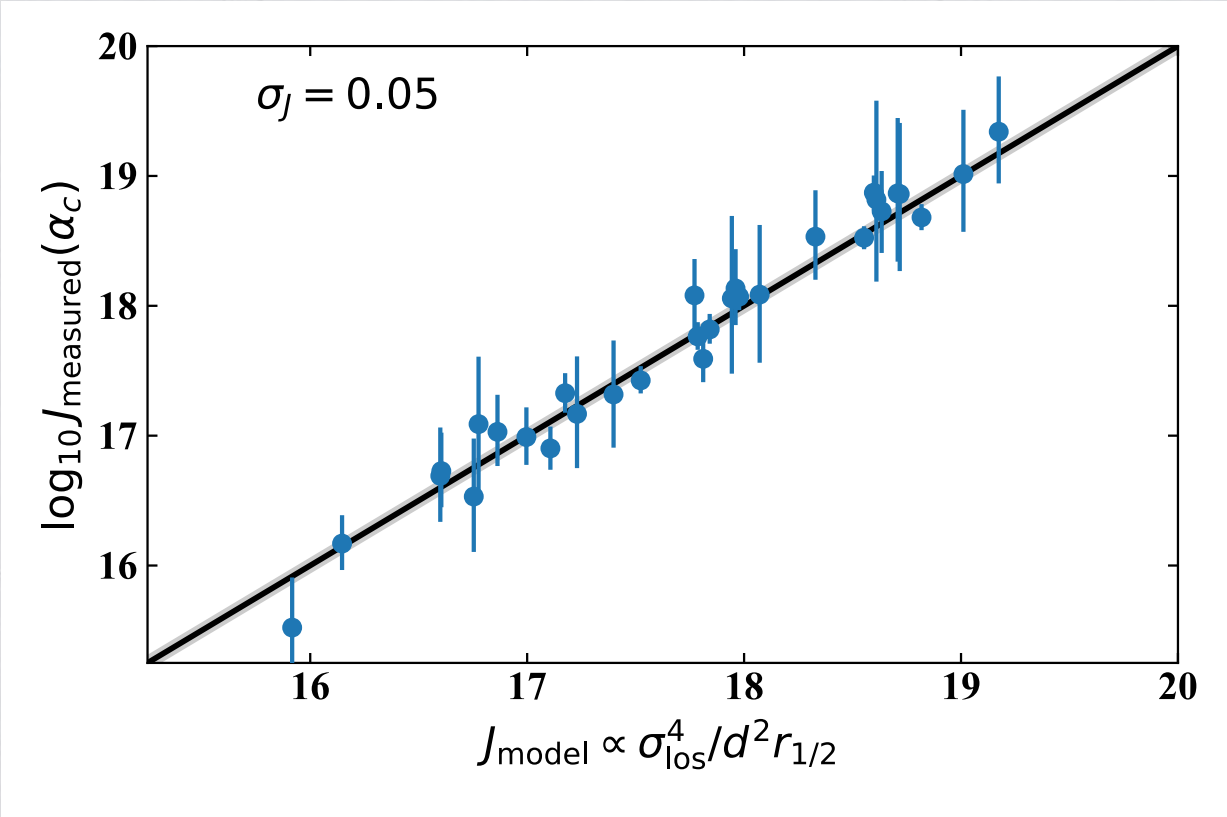
J-Factor Scaling with Dynamics

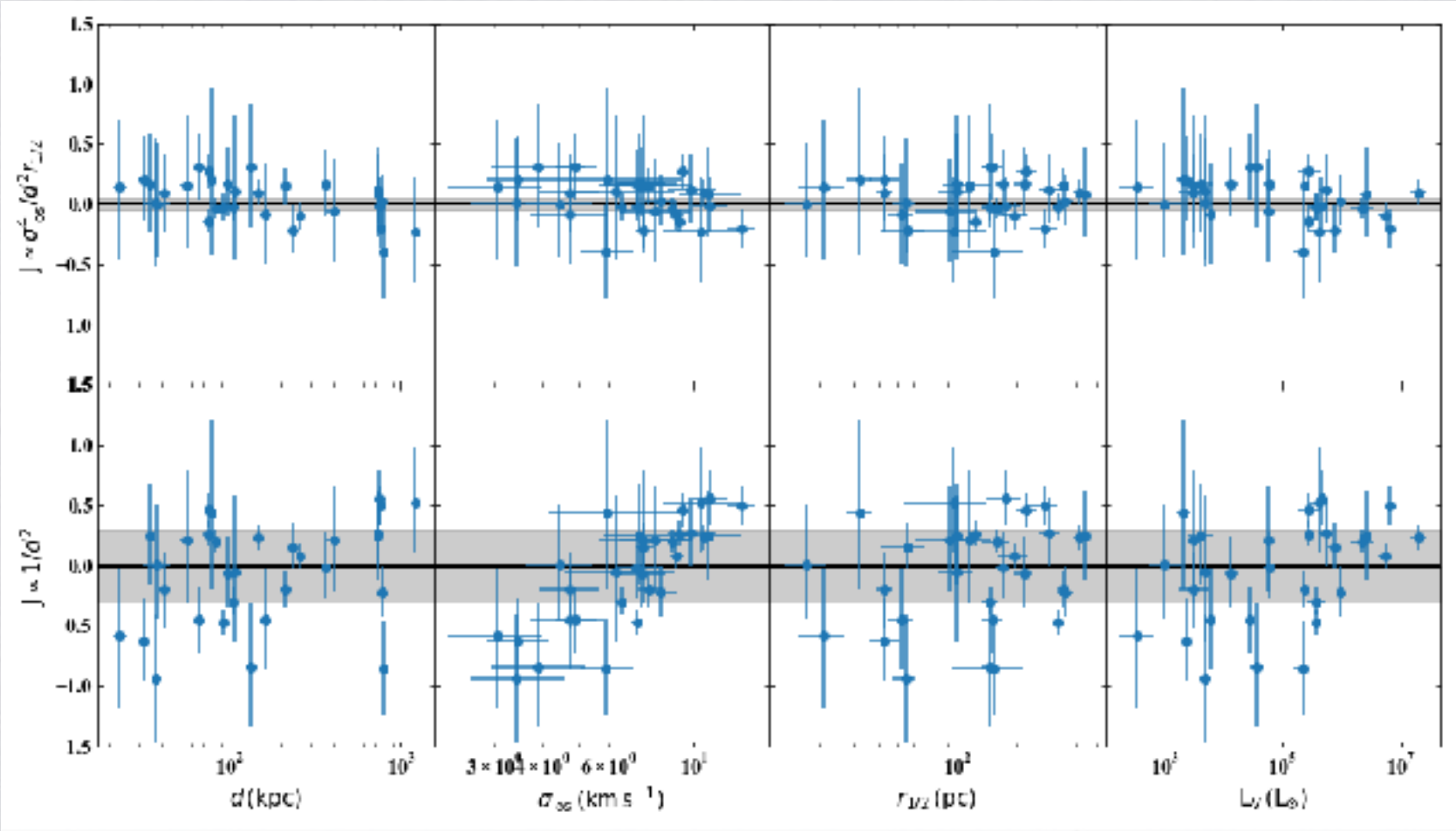


$$\frac{J(0.5^\circ)}{\mathrm{GeV}^2\,\mathrm{cm}^{-5}} \approx 10^{17.72}\left(\frac{\sigma_{\rm los}}{5\,\mathrm{km\,s}^{-1}}\right)^4\left(\frac{d}{100\,\mathrm{kpc}}\right)^{-2}\left(\frac{r_{1/2}}{100\,\mathrm{pc}}\right)^{-1}$$

Pace and Strigari 2018

J-Factor Scaling with Dynamics

Residuals



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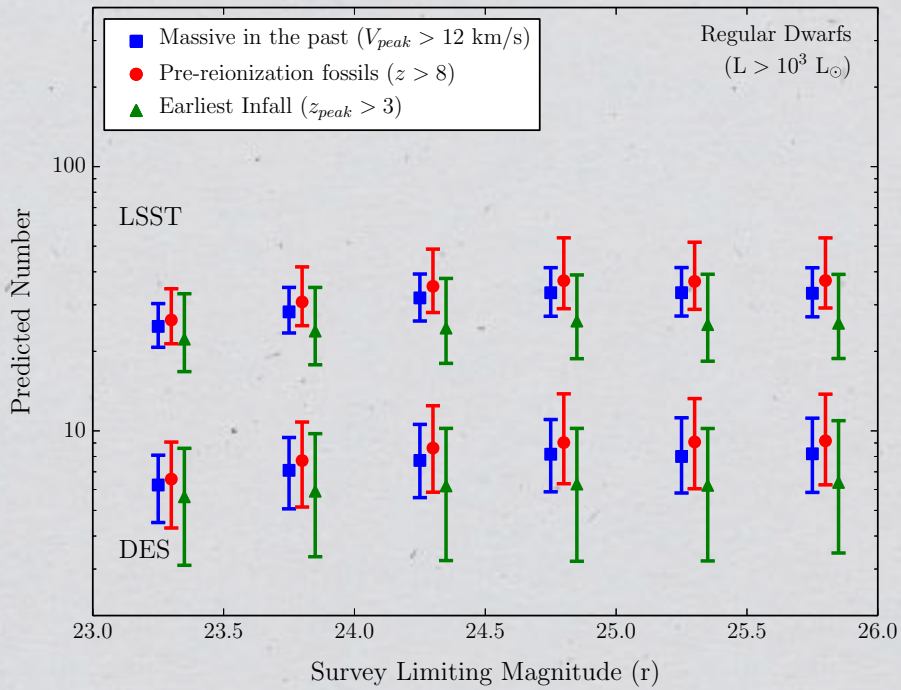
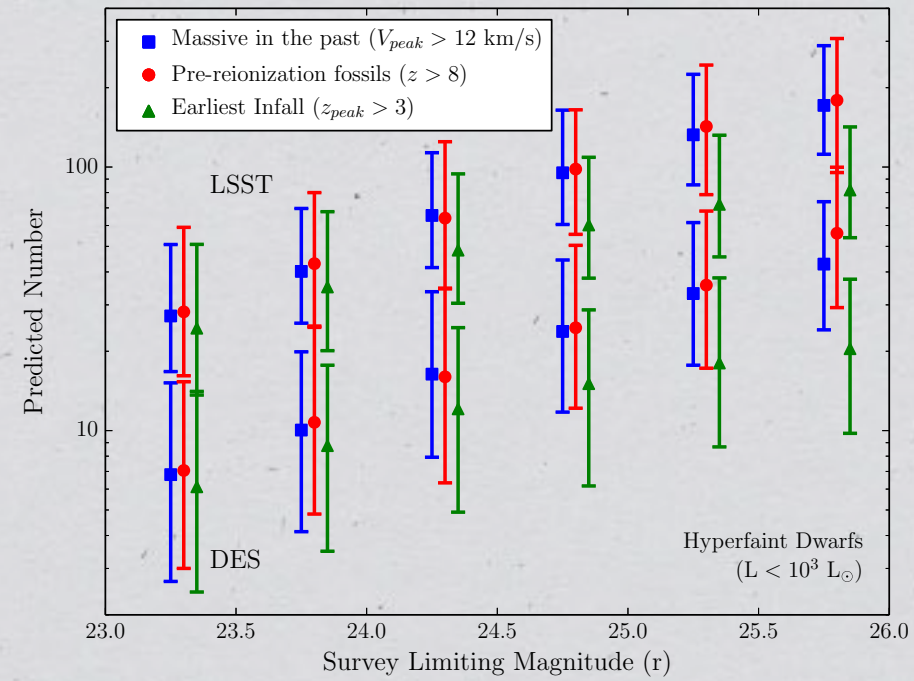
dSphs/J-Factors in the LSST era

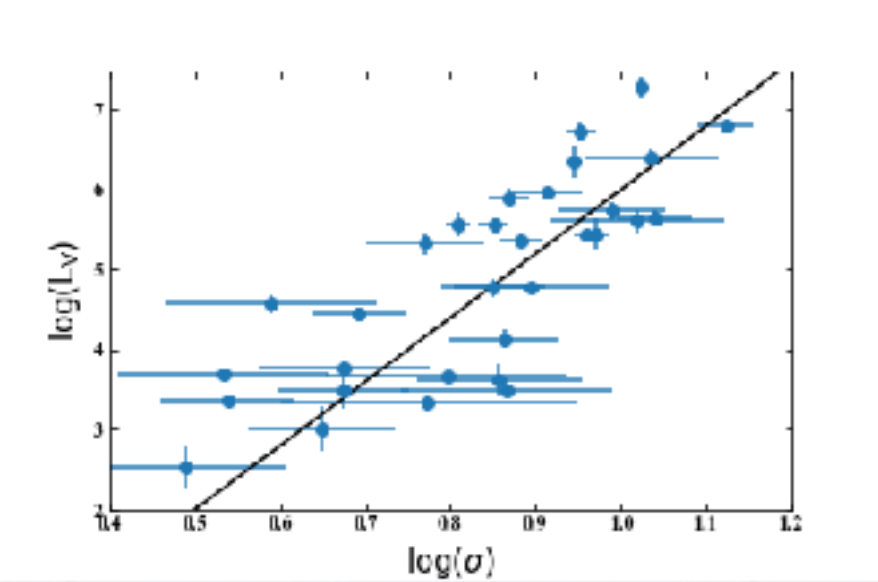




Hargis + 2014

J-Factors for Satellites without Dynamical Modeling

Can we do better than just distance?



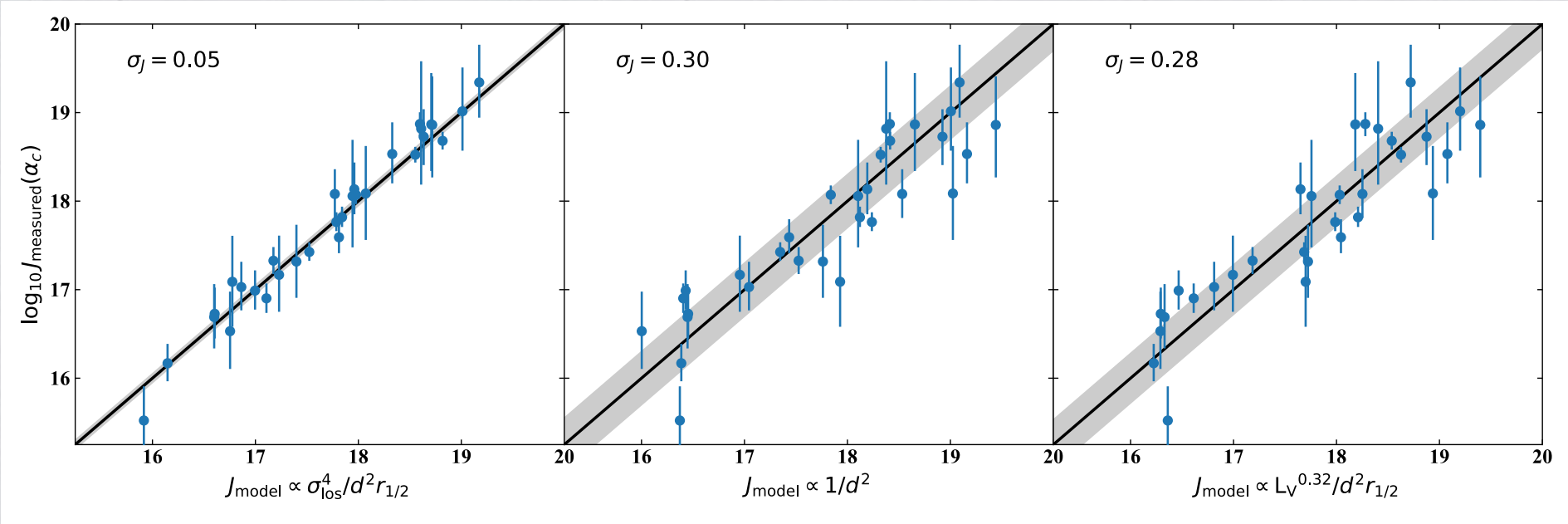
Replacing velocity dispersion with luminosity

$$\frac{J(0.5^\circ)}{\mathrm{GeV}^2\,\mathrm{cm}^{-5}} \approx 10^{17.93}\left(\frac{\mathrm{L_V}}{10^4 L_\odot}\right)^{0.32}\left(\frac{d}{100\,\mathrm{kpc}}\right)^{-2}\left(\frac{r_{1/2}}{100\,\mathrm{pc}}\right)^{-1}.$$

Pace and Strigari 2018

J-Factors for Satellites without Dynamical Modeling

Can we do better than just distance?



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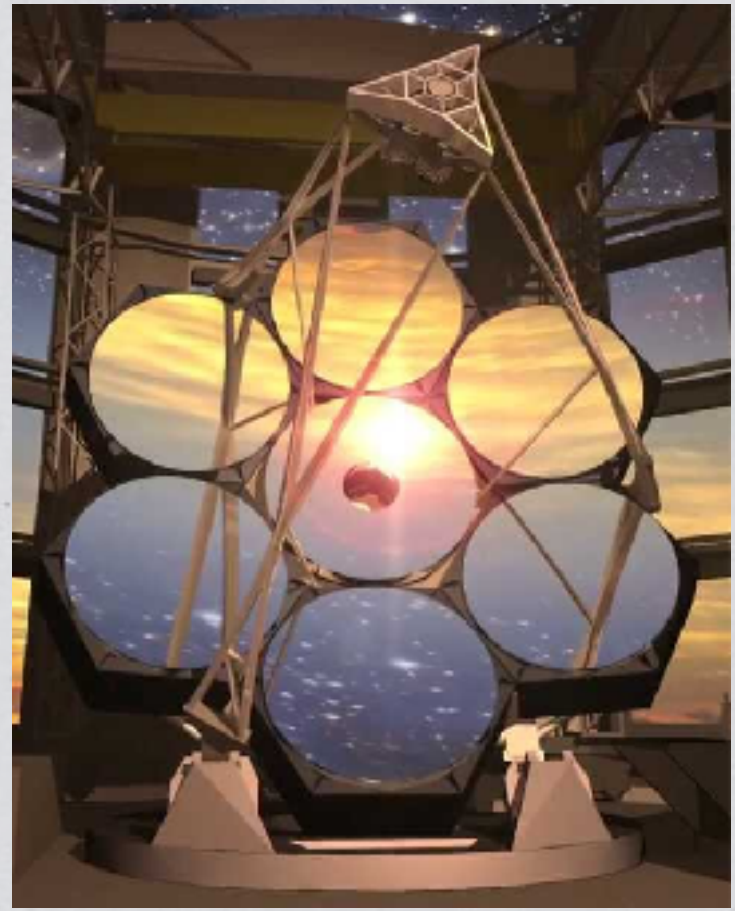
dSphs/J-Factors in the LSST era

Giant Magellan Telscope/GMACS



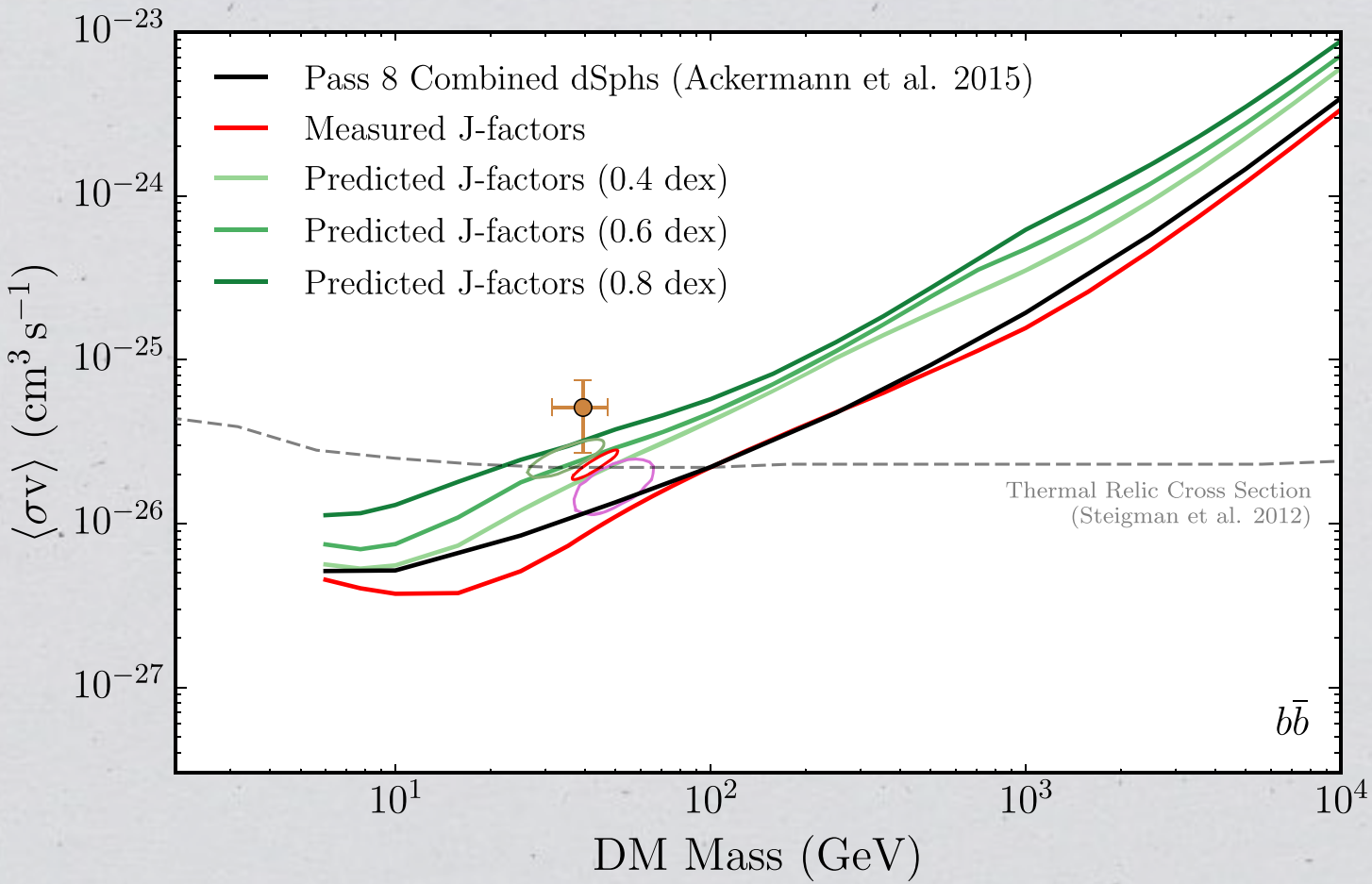
Conclusions

- dSphs are excellent targets for the indirect detection of dark matter.
- Astrophysical J-Factors are required to compute the dark matter "flux".
- There is a simple relationship to estimate the J-Factor with dynamical modeling:

$$\frac{J(0.5^\circ)}{\mathrm{GeV}^2\,\mathrm{cm}^{-5}} \approx 10^{17.72}\left(\frac{\sigma_{\mathrm{los}}}{5\,\mathrm{km\,s}^{-1}}\right)^4\left(\frac{d}{100\,\mathrm{kpc}}\right)^{-2}\left(\frac{r_{1/2}}{100\,\mathrm{pc}}\right)^{-1}$$

- We will discover many satellites in the LSST "era and their follow-up requires the next generation of telescopes.

Dark Matter Gamma Ray Sky: Limits



Albert + 2017