暗黒物質間接検出と PFSによる矮小楕円体銀河の暗黒物質密度分布推定

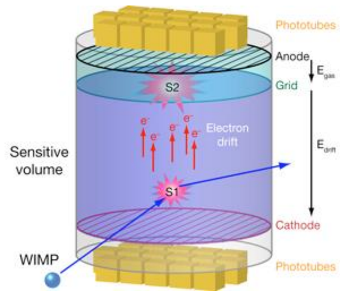
Koji Ichikawa

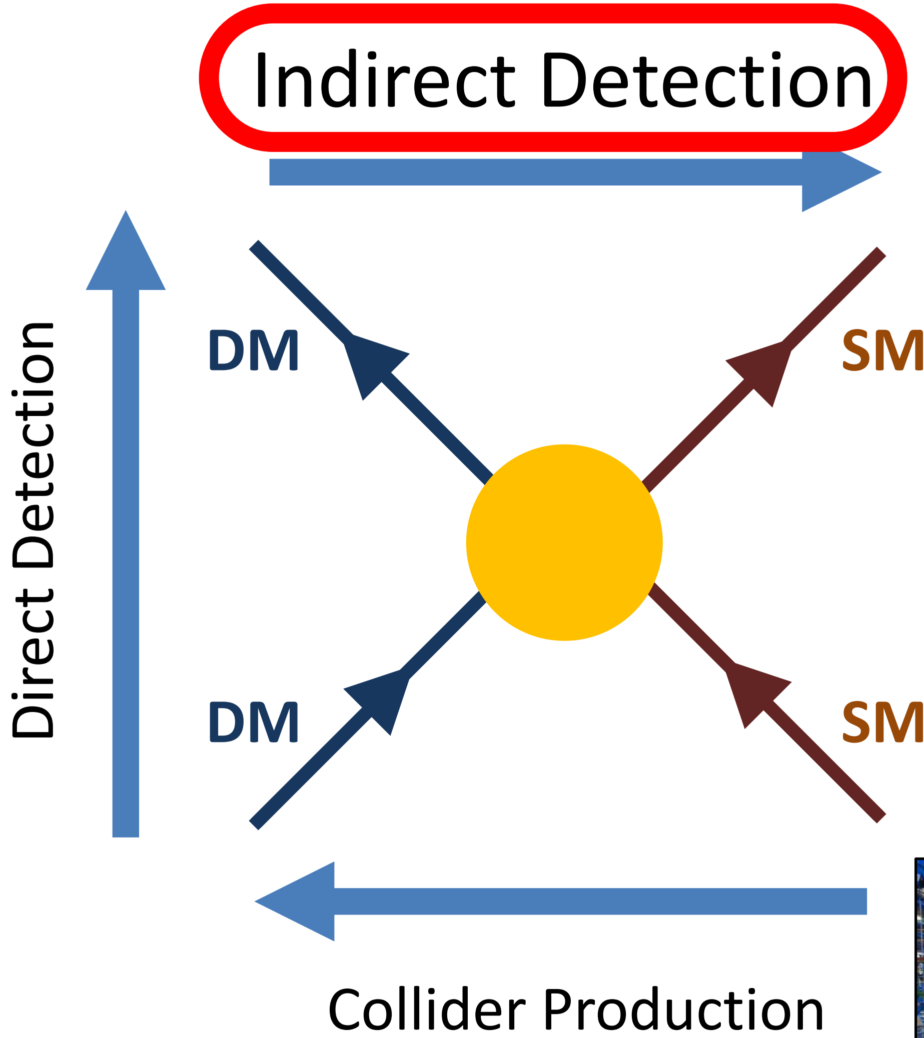
In collaboration with
Kohei Hayashi , Masahiro Ibe, Miho N. Ishigaki,
Shigeki Matsumoto and Hajime Sugai.

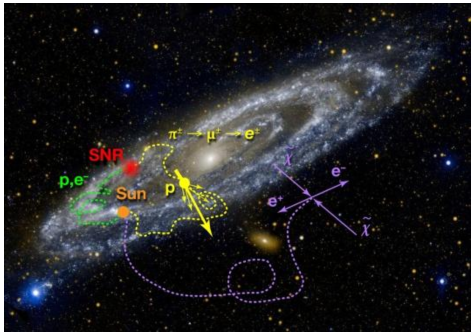
KAVLI IPMU

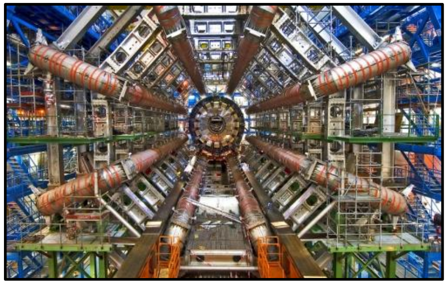
PFS Workshop, July 9-11, 2015

Dark Matter Search

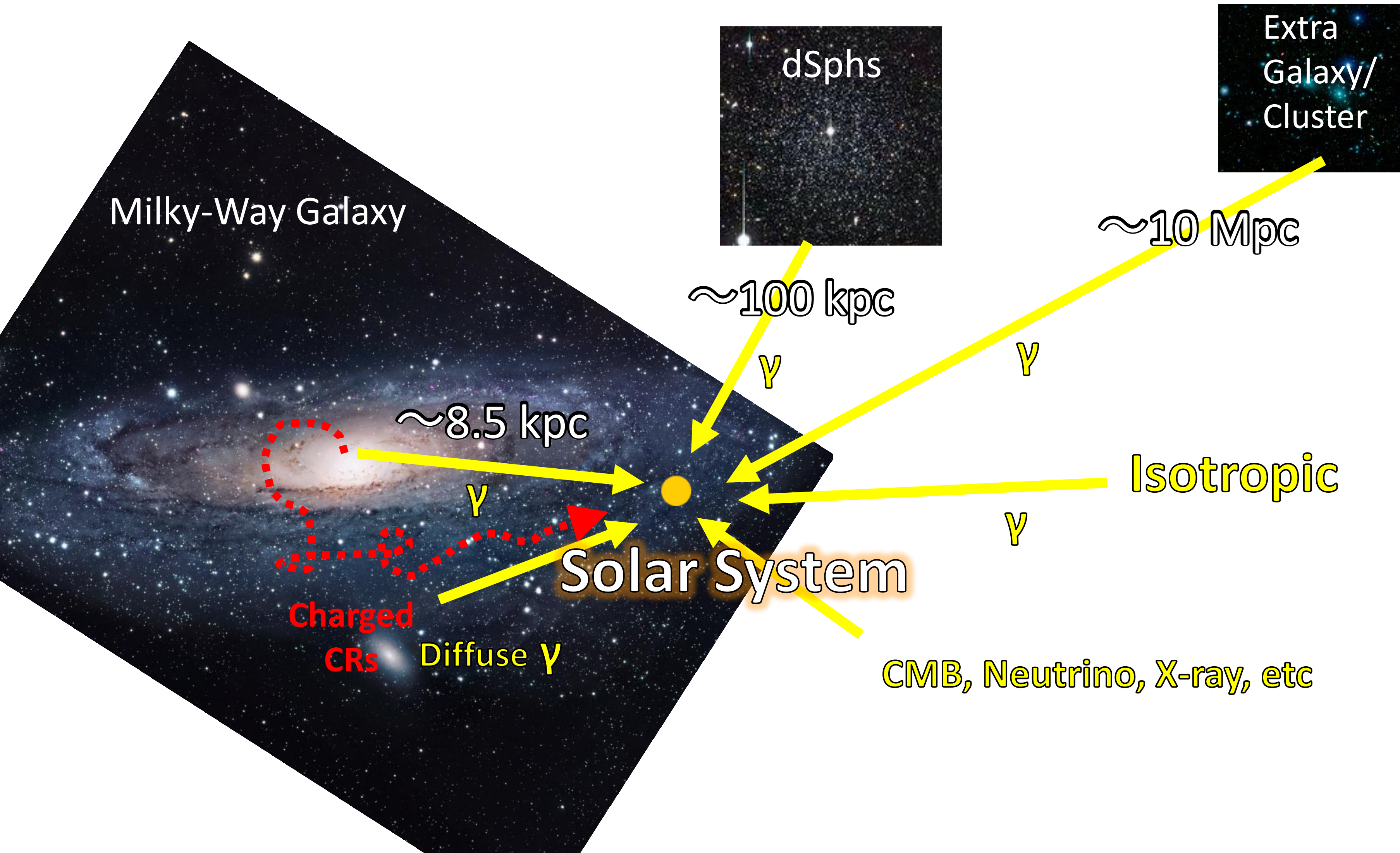




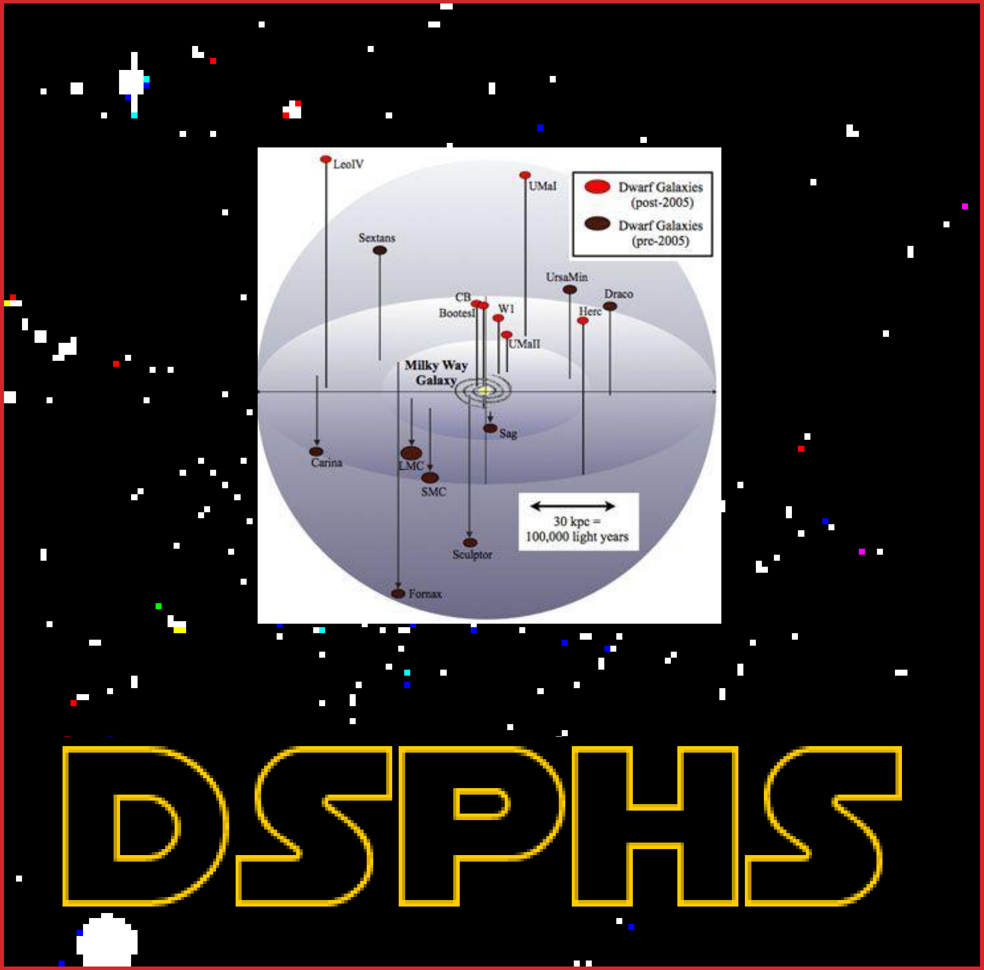


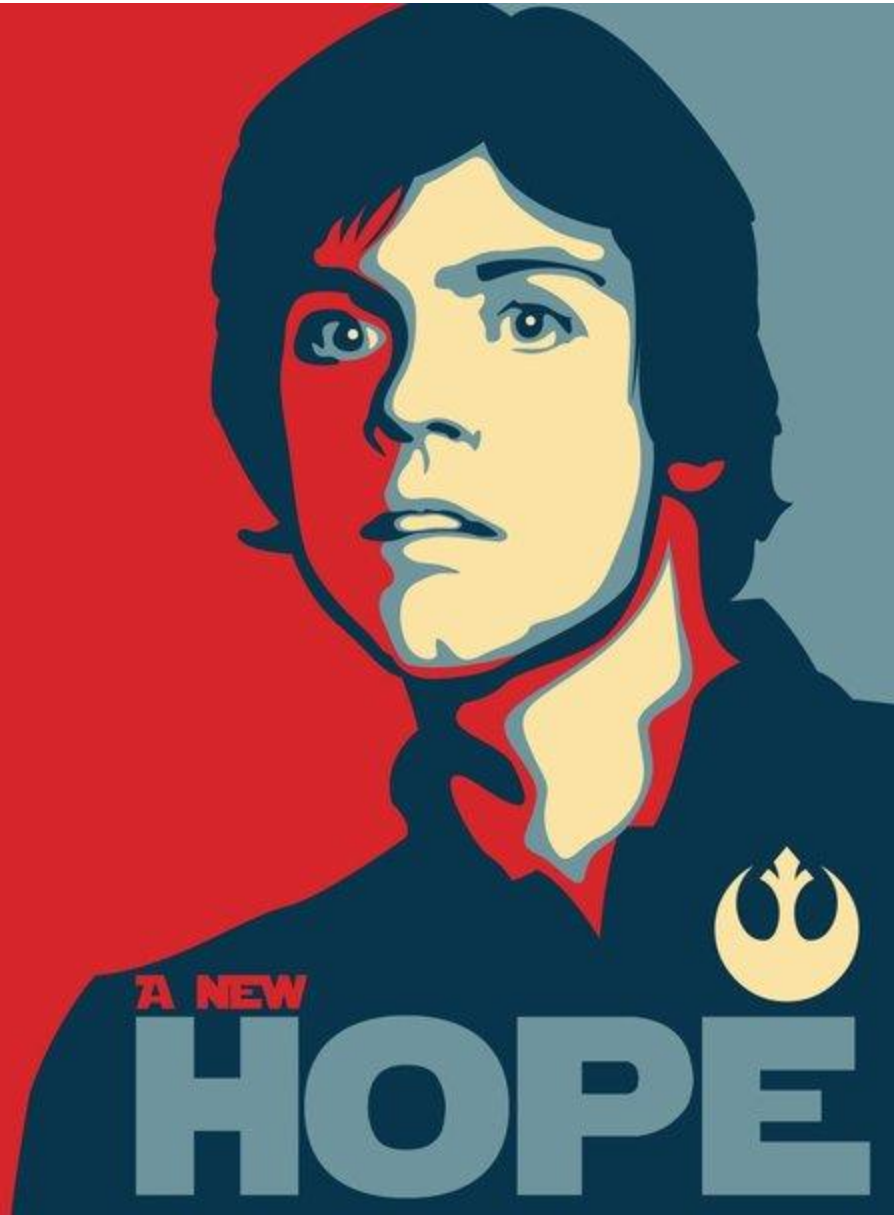


Signal Target



Current observational limit

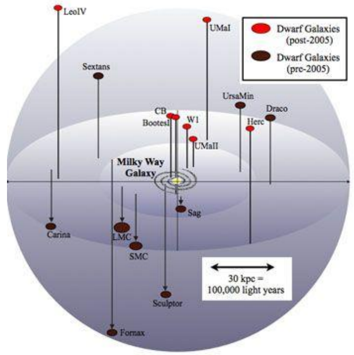




Dwarf spheroidal galaxies

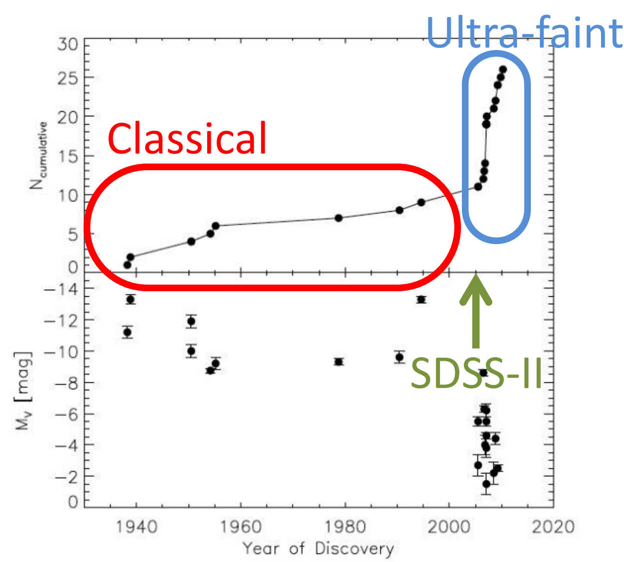
dSphs:

1. **Neighbor** galaxies: 10~100kpc
2. Large Mass to Luminosity ratio = **DM rich**
3. Fewer gas containment



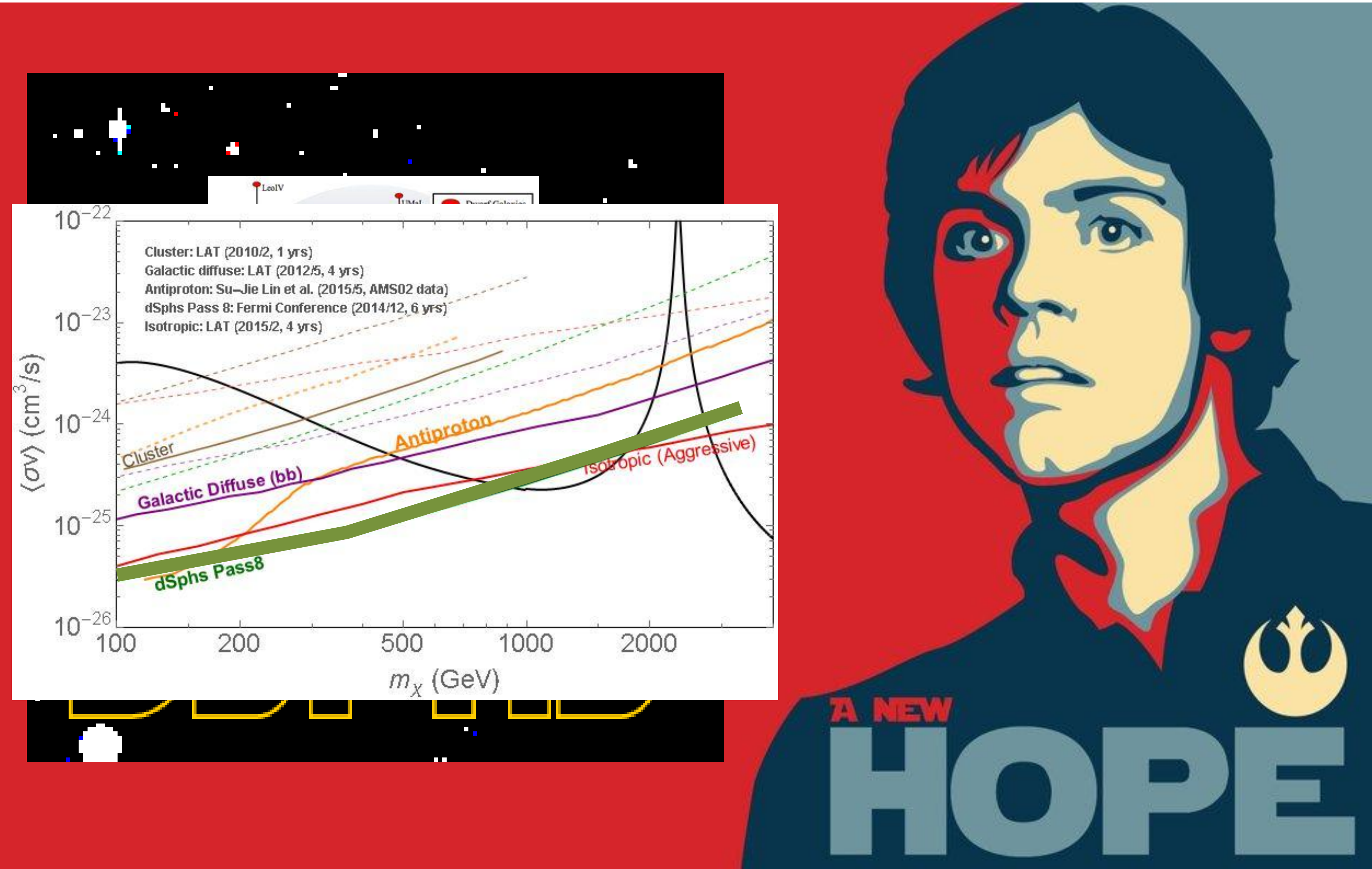
	Classical	Ultra-faint
#dSphs	8	>20
M/L ($M_\odot/L_\odot$)	10-100	100-1000
Distance (kpc)	60-250	10-60
#Obs Stars	150-2500	20-100
Characteristics	Brighter, farther	Darker, closer

See, e.g. Wolf et al (2010)



arXiv:0908.2995v6 [astro-ph.CO]

Current observational limit



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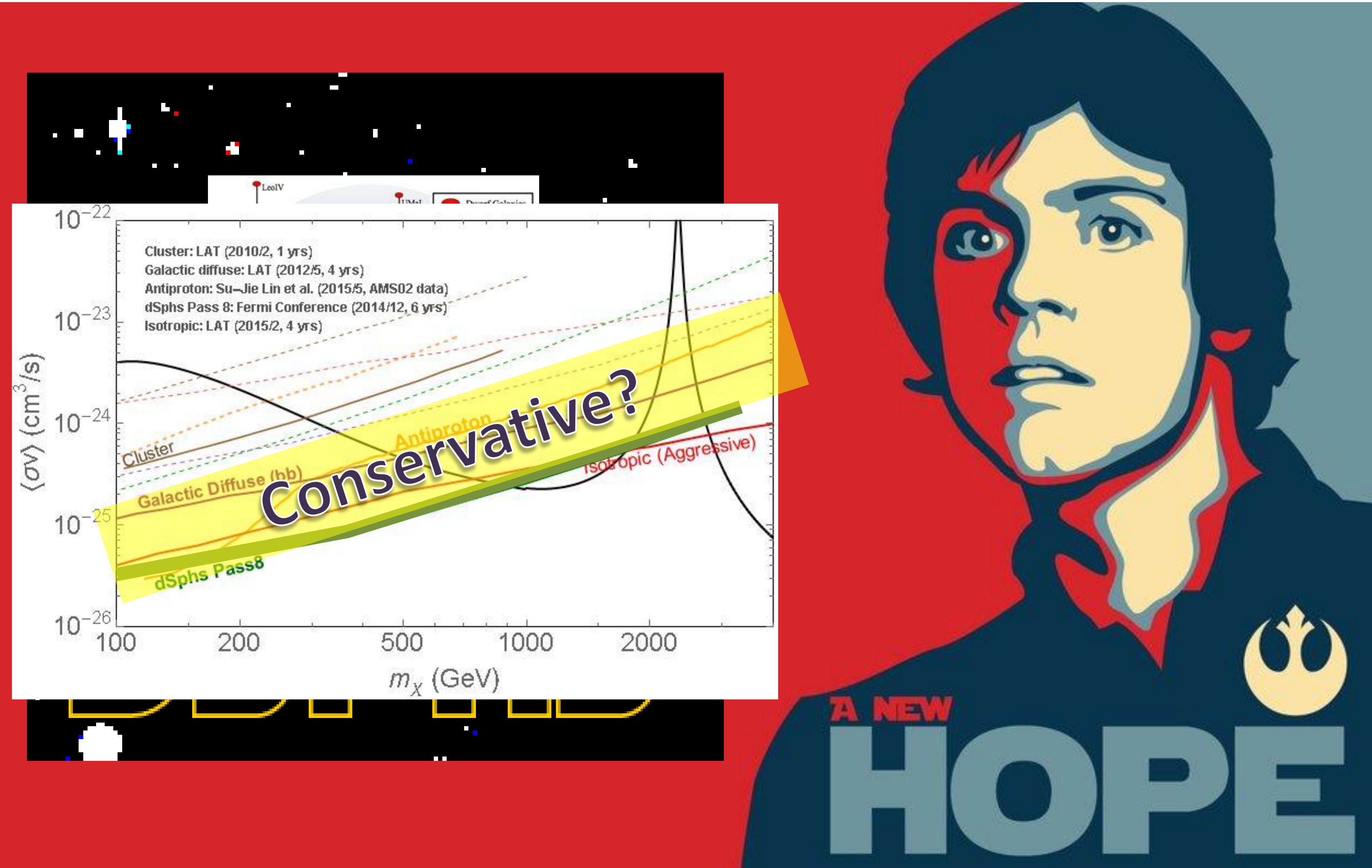


Astrophysical Factor

DM Density profile

$$\rho(r) = \rho_s \left(r/r_s\right)^{-\gamma} \left[1 + \left(r/r_s\right)^{\alpha}\right]^{(\gamma-\beta)/\alpha}$$

$\rho_s (r/r_s)^{-1}(1+r/r_s)^{-2}$ Cusp

$\rho_s (1+r/r_s)^{-1}(1+r/r_s)^{-2}$ Cored

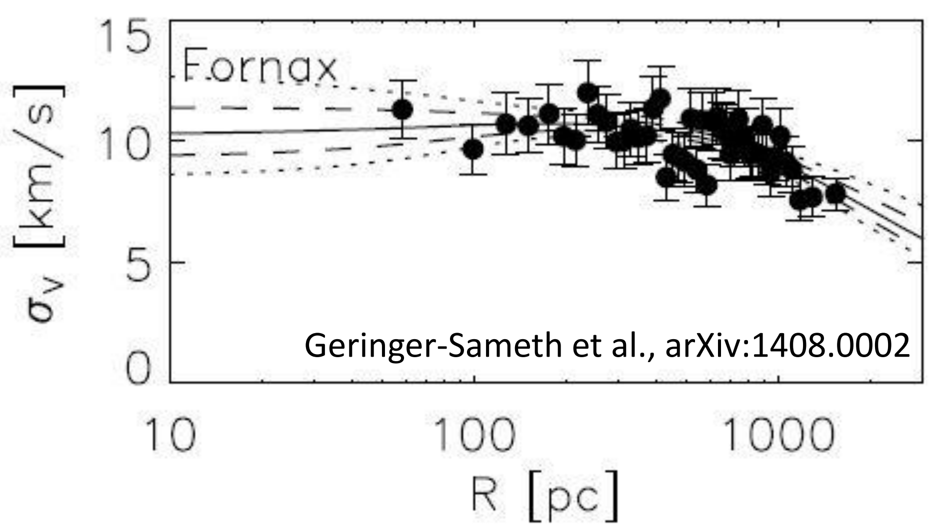
Stellar Density Profile: ν(r)

Jeans equation for stars

$$\frac{1}{\nu}\frac{d}{dr}(\nu \bar{v_r^2}) + 2\frac{\beta(r)\bar{v_r^2}}{r} = -\frac{GM(r)}{r^2}$$

$\sigma^{2\,(\mathrm{Theory})}_{\mathrm{l.o.s}} \longleftrightarrow \sigma^{2\,(\mathrm{obs})}_{\mathrm{l.o.s}}$

Fit



Geringer-Sameth et al., arXiv:1408.0002

$$P(\theta|D) \propto P(D|\theta)P(\theta)$$

$$\sim \prod_i^{\mathrm{samples}} \exp\left[-\frac{(\sigma^2_{\mathrm{obs}}(r_i) - \sigma^2_{\mathrm{theory}}(r_i,\theta))^2}{2\delta^2}\right]$$

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$\sigma_{\mathrm{l.o.s}}^{2\,(\mathrm{Theory})}$ ⟷ $\sigma_{\mathrm{l.o.s}}^{2\,(\mathrm{obs})}$

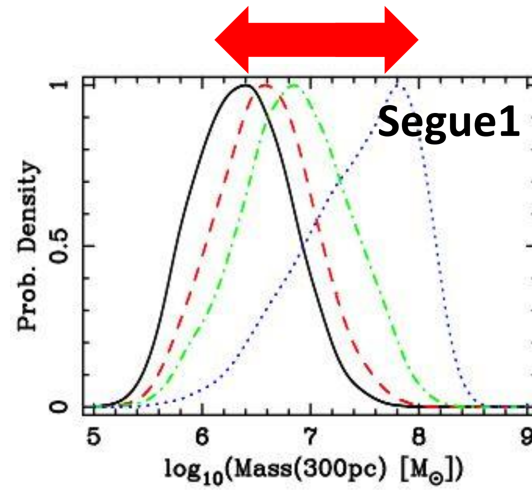
Fit

		long. (deg.)	lat. (deg.)	dist. (kpc)	α_s (deg.)	$\log_{10}[J(0.5°)/(\mathrm{GeV^2 cm^{-5} sr})]$
Classical: Well-determined	Draco	86.4	34.7	76	$0.25^{+0.15}_{-0.09}$	18.8 ± 0.16
	Ursa Min.	105.0	44.8	76	$0.32^{+0.18}_{-0.12}$	18.8 ± 0.19
	Sculptor	287.5	-83.2	86	$0.25^{+0.25}_{-0.13}$	18.6 ± 0.18
	Sextans	243.5	42.3	86	$0.13^{+0.07}_{-0.05}$	18.4 ± 0.27
Ultra-faint: Not well-determined. Prior dependence	Segue 1	220.5	50.4	23	$0.40^{+0.86}_{-0.27}$	*19.5 ± 0.29*
	Ursa Maj. II	152.5	37.4	32	$0.32^{+0.48}_{-0.19}$	*19.3 ± 0.28*
	Willman 1	158.6	56.8	38	$0.25^{+0.54}_{-0.17}$	*19.1 ± 0.31*
	Coma B.	241.9	83.6	44	$0.25^{+0.54}_{-0.17}$	*19.0 ± 0.25*

Large ambiguity?

Hidden Systematics…

- Prior Bias?



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$$\sim \prod_i^{\mathrm{samples}} \exp\left[-\frac{(\sigma^2_{\mathrm{obs}}(r_i) - \sigma^2_{\mathrm{theory}}(r_i,\theta))^2}{2\delta^2}\right]$$

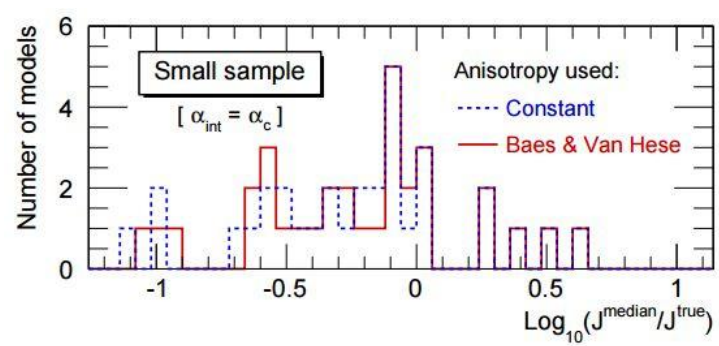
ex: $P(v_{\max}) \propto v_{\max}^{-n} dv_{\max}$

Martinez et al., arXiv: 0902.4715

- Non Spherical? => Hayashi-san's talk

Hayashi and Chiba., arXiv: 1206.3888

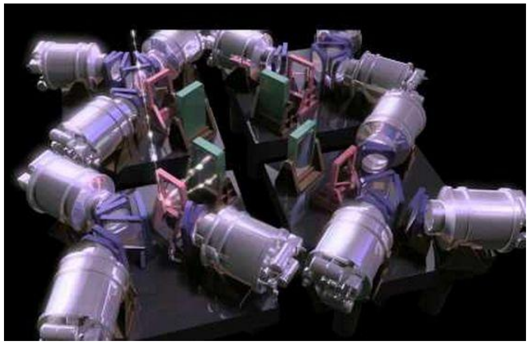
- Sampling Bias?

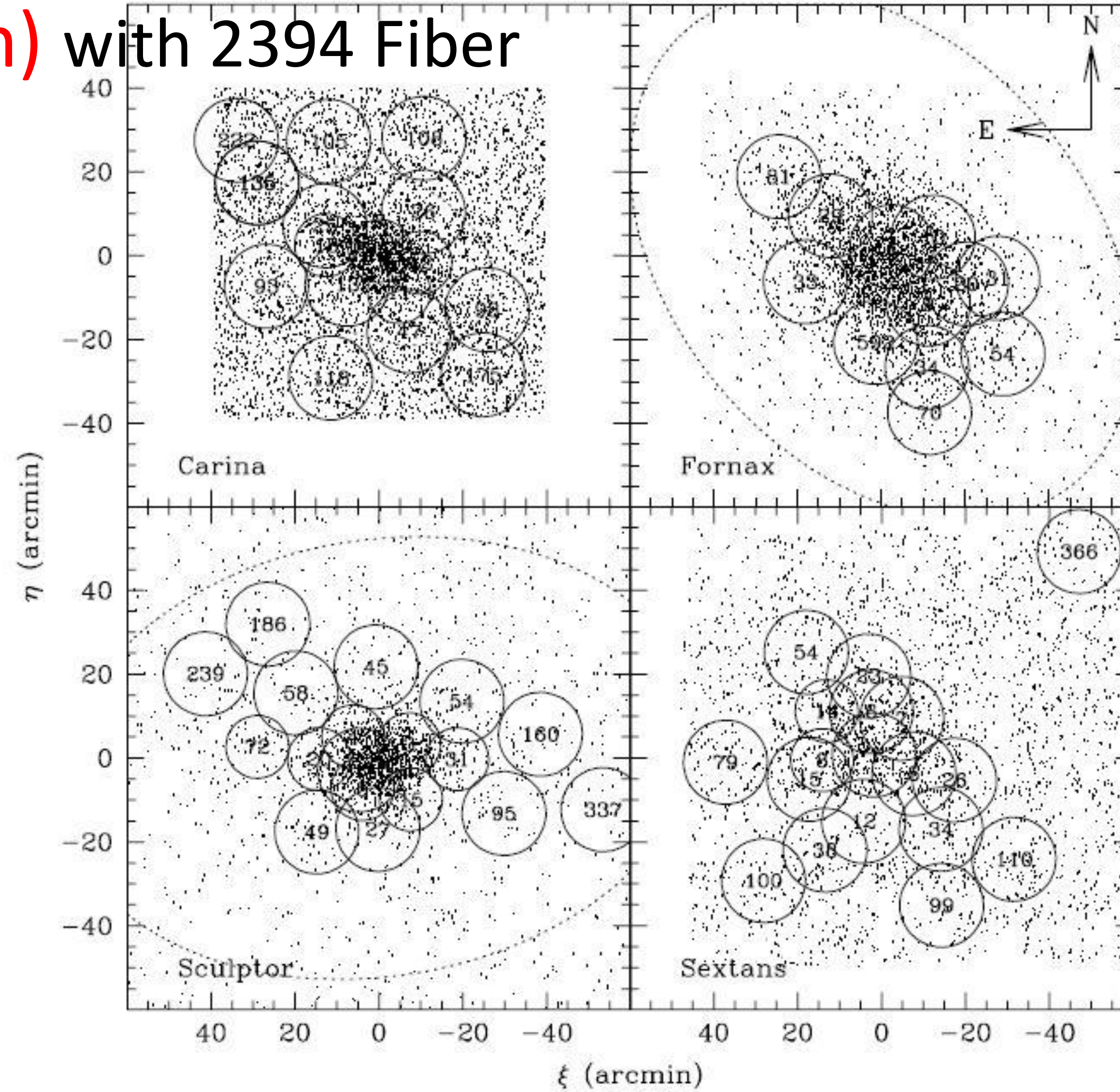


Bonnivard et al., arXiv: 1407.7822

Prime Focus Spectroscopy

FoV 1.3 deg (diam) with 2394 Fiber





MMFS (M. G. Walker et al,. (2007))

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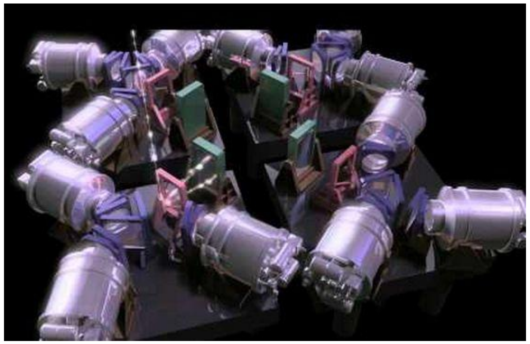

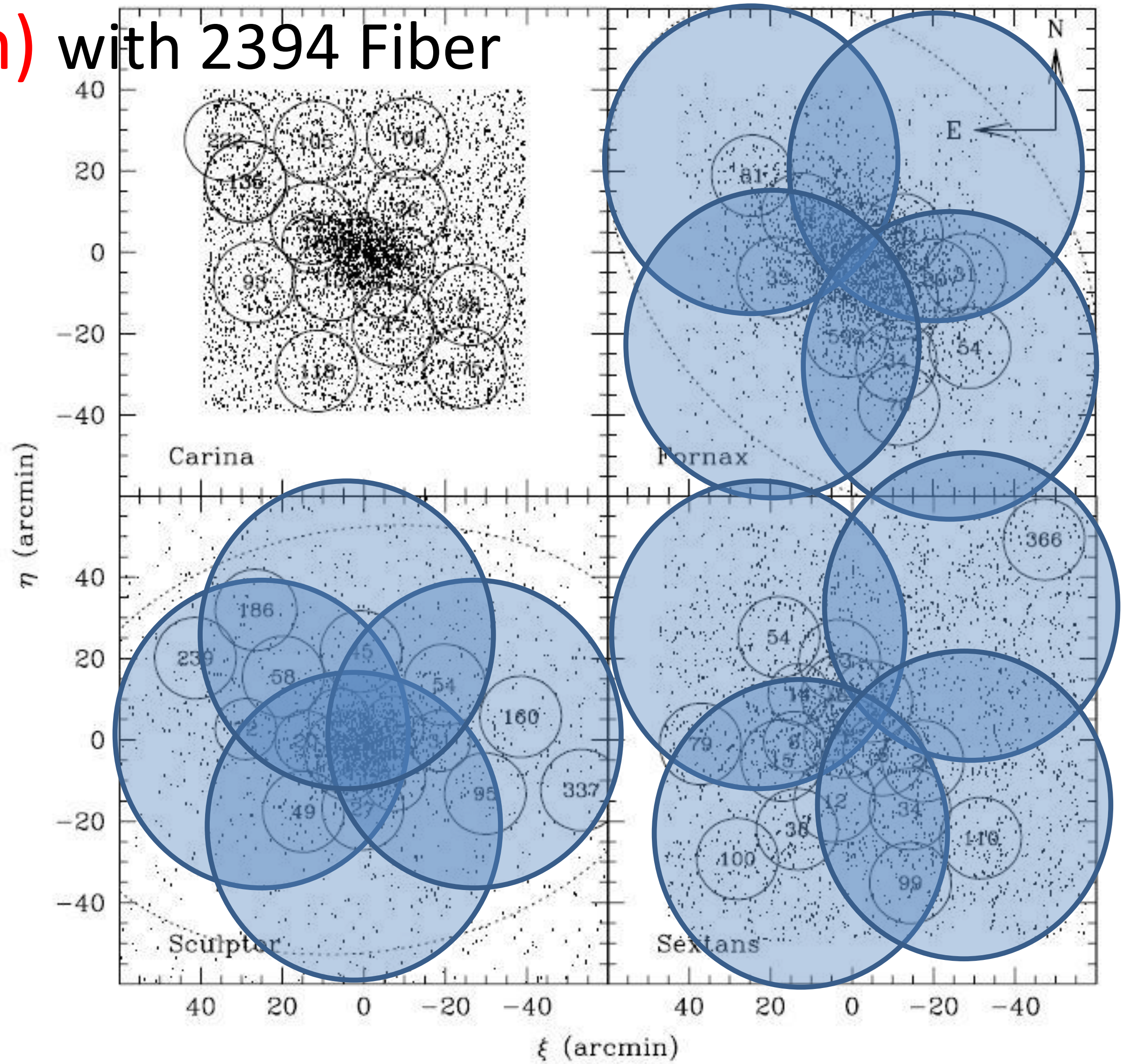

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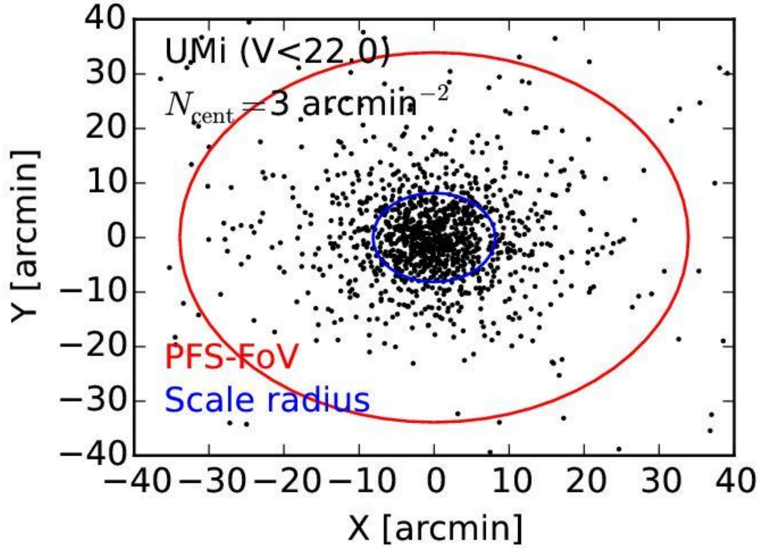
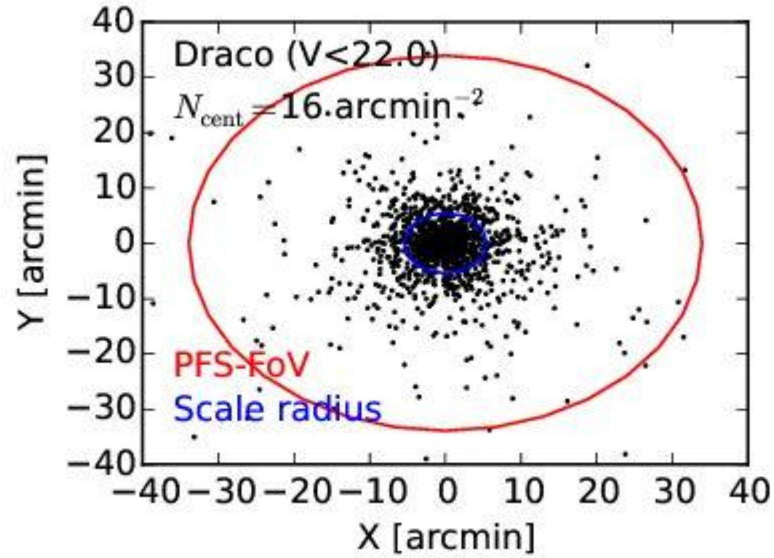
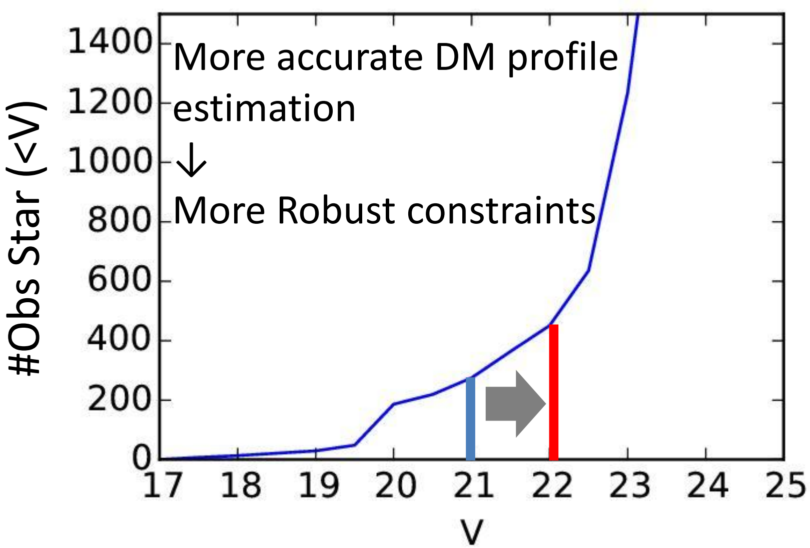
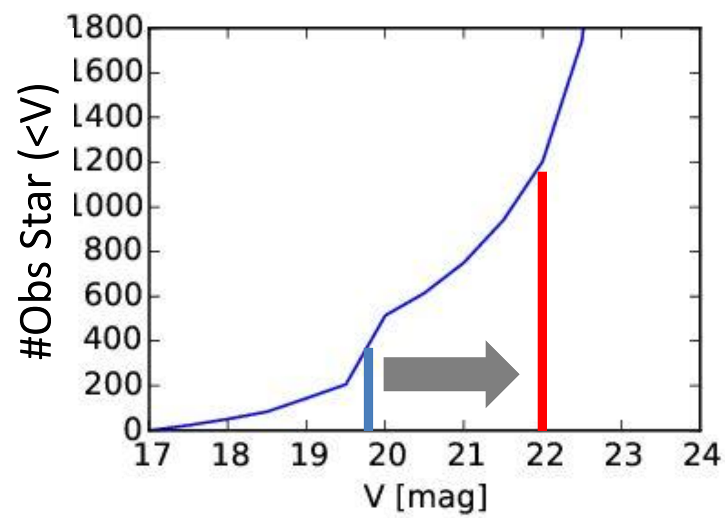








gaki-san

Strategy

<u>1. Mock Observable:</u>

(R, v, Metalicity, Luminosity)

= dSph Stellar + Foreground

dSph Stellar Mock

$\Rightarrow$Boltzmann Equation under DM profile

Foreground Mock

$\Rightarrow$Besancon Model (Robin+ (2003))

<u>2. Detector Convolution:</u>

$\Rightarrow$1. fix: dv = 3.0km/s

$\Rightarrow$2. Luminosity dependence for each stars

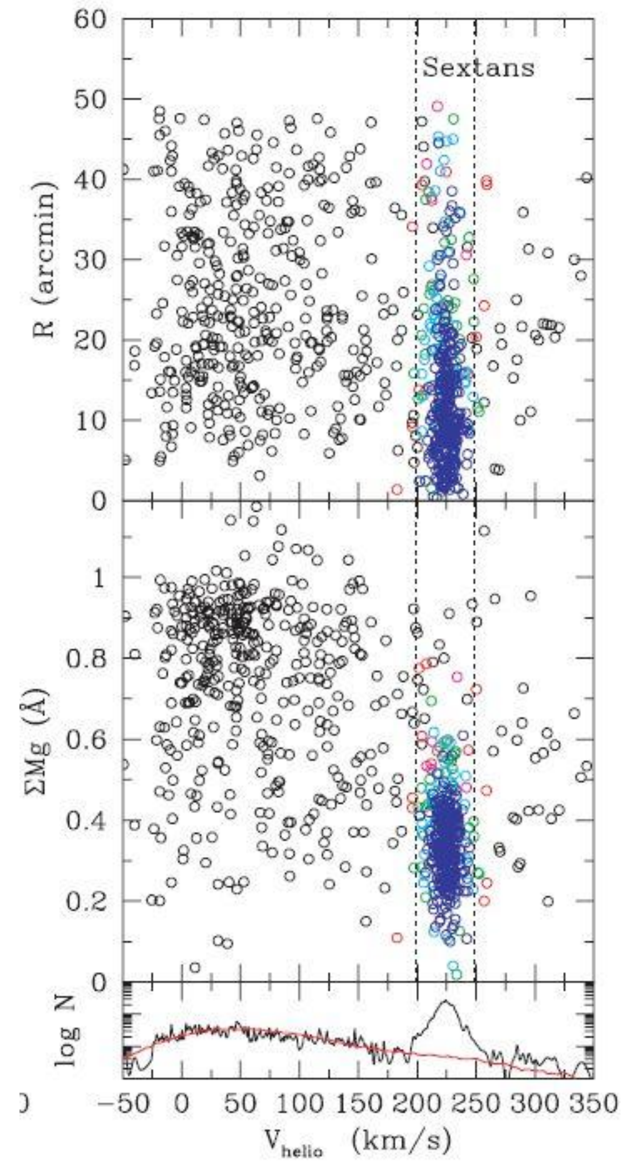
<u>3. Fit:</u>

(DM profile, anisotropy, dSph stellar profile, dSph v, foreground norm + metalicity)

$\Rightarrow$Fit to (v, r) probability density.

<u>4. Implication:</u>

Fermi 10 yr Exp



Walker+, AJ 137 (2009)

Stra

1. Moc

(R, v, N

= dSph S

dSph Stell

⇒Boltz

Foregroun

⇒Besa

2. Dete

⇒1. fix: dv

⇒2. Lumi

3. Fit:

(DM prof

dSph v, f

⇒Fit to

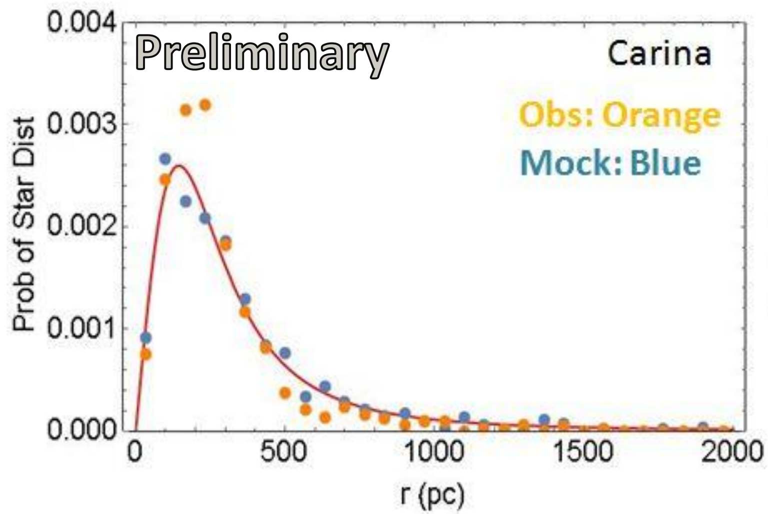
4. Impli

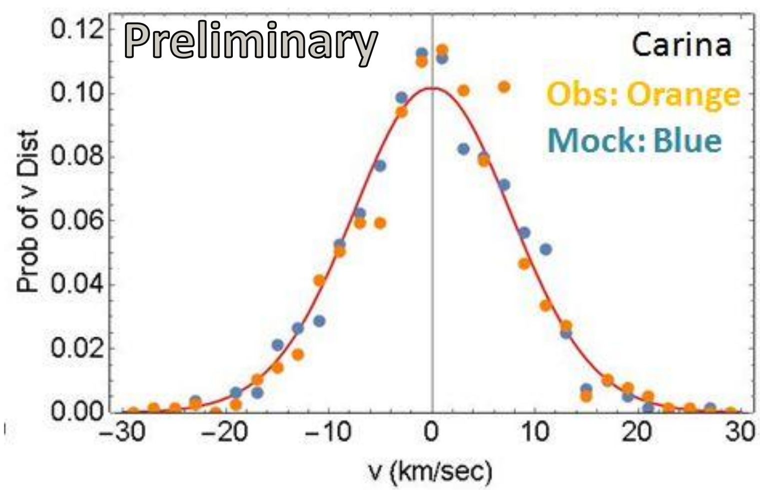
Fermi 1

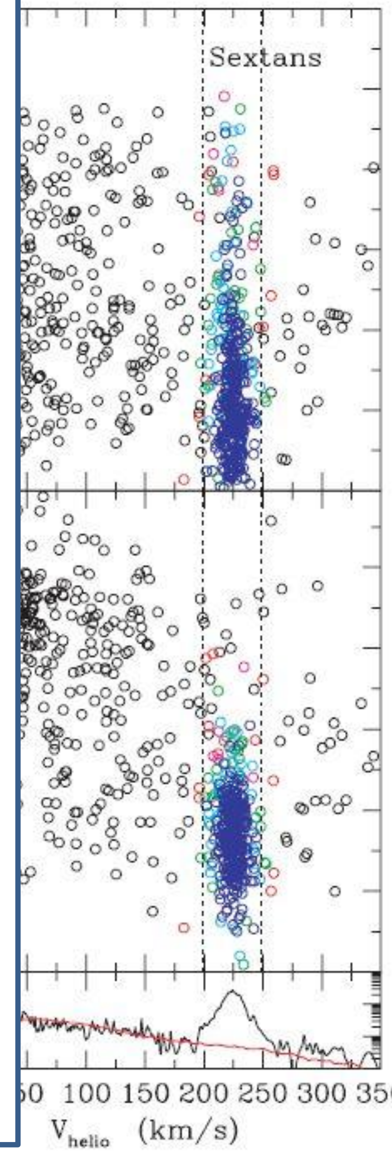
1. Mock Samples

$\rho_{DM}(r)$, $v_{star}(r)$ => $f(r,v)$

Osipkov & Merrit
Cuddeford (1991)







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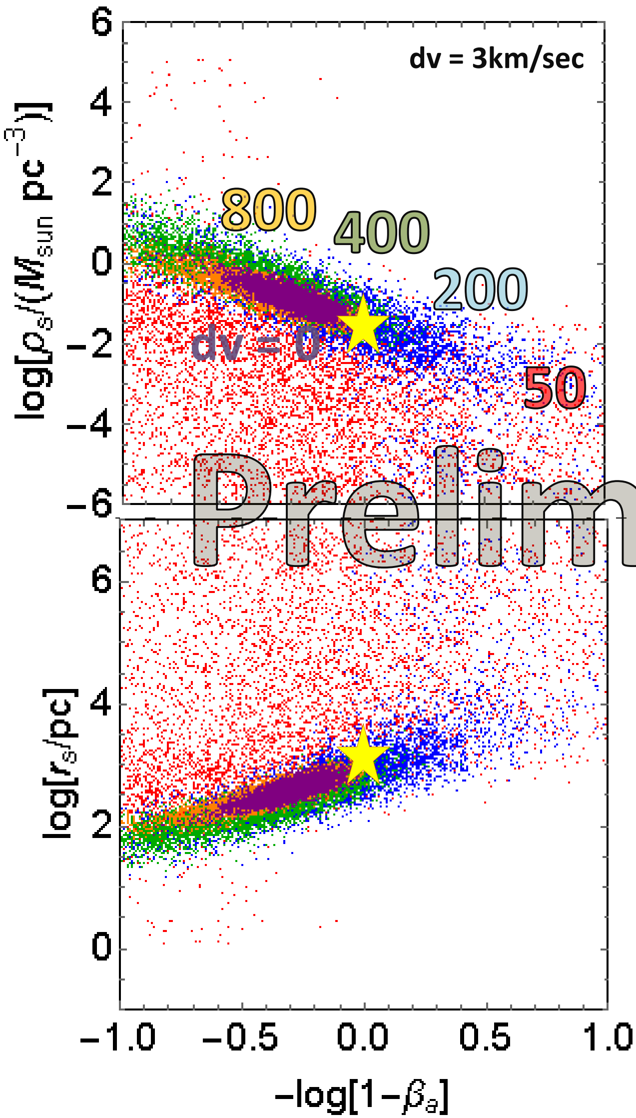
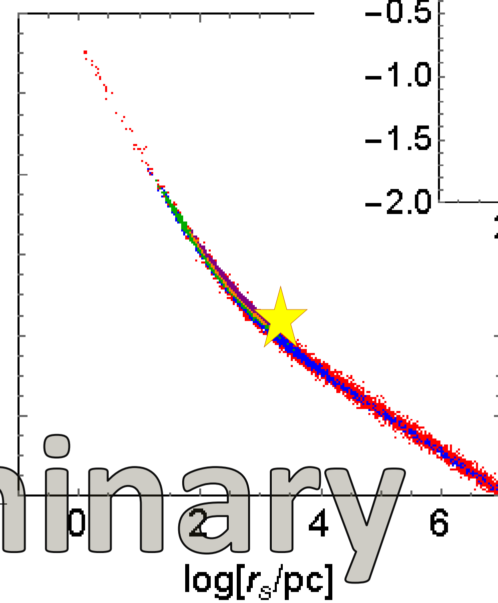
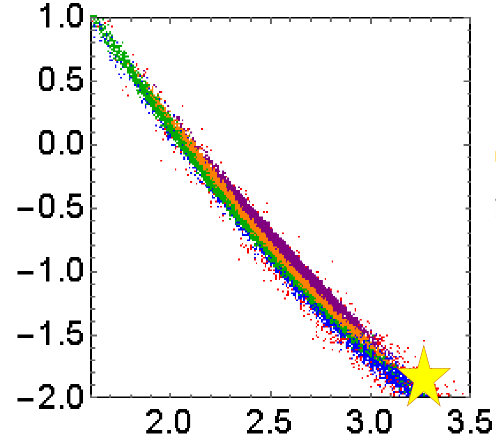
4. Impli

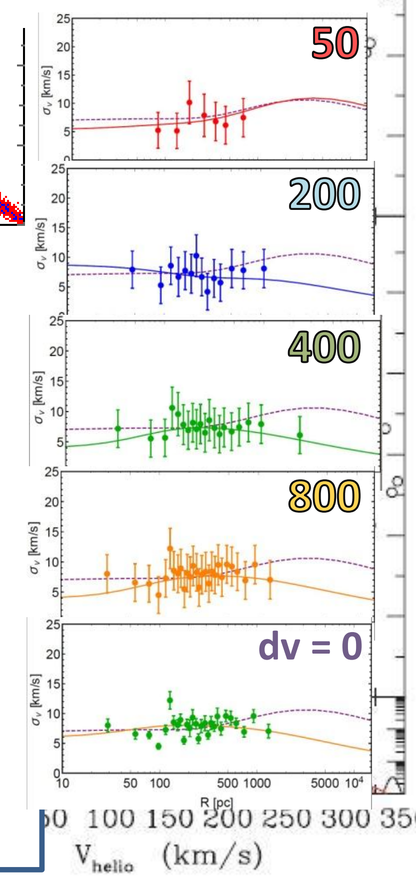
Fermi 1

3. Fit (MCMC Posterior)









Profile Shape Dep.?

Physical Cut?

Outer Star Effect?

Sampling Fluctuation?

Fiber vs #Star?

Time vs Depths?

Walker+, AJ 137 (2009)

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Coming Soon!

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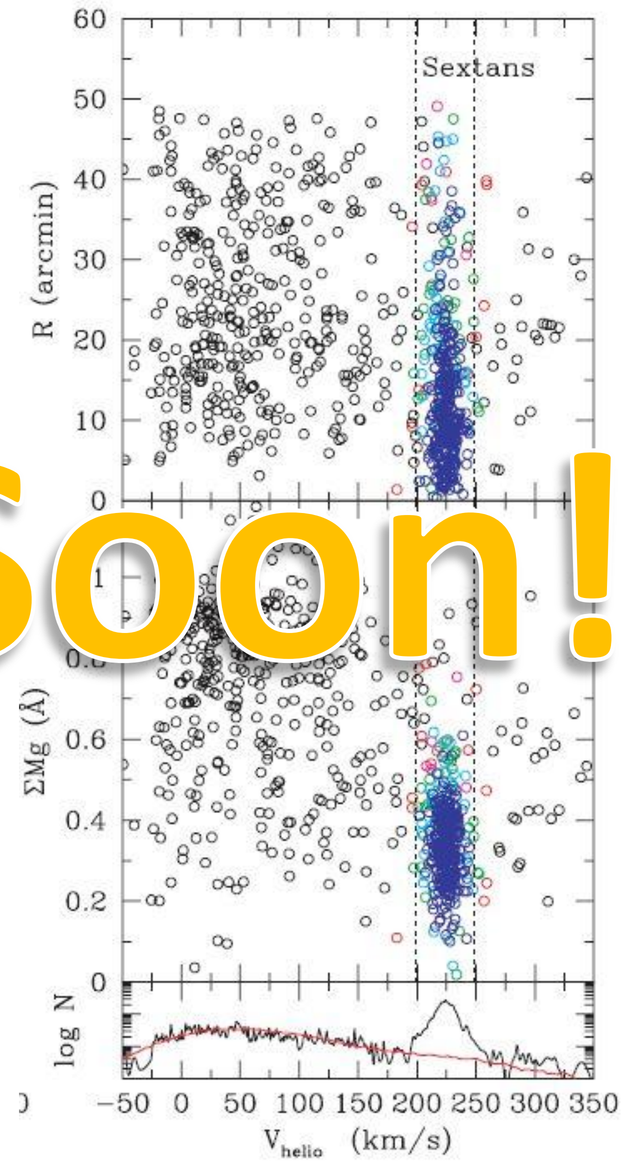

Walker+, AJ 137 (2009)

Summary

- Indirect detection is essential for DM search.
- Gamma-ray observation of dSph can give robust constraints on the DM annihilation cross section.
- Investigation of stellar kinematics is important.
- PFS will play a crucial role.

Thank You !

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