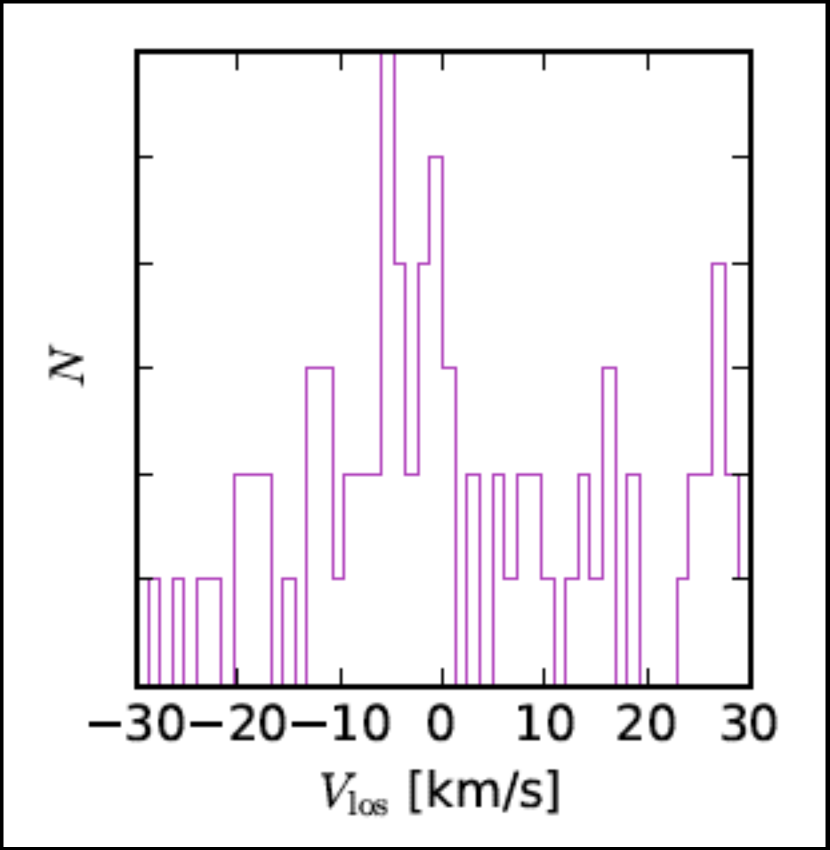
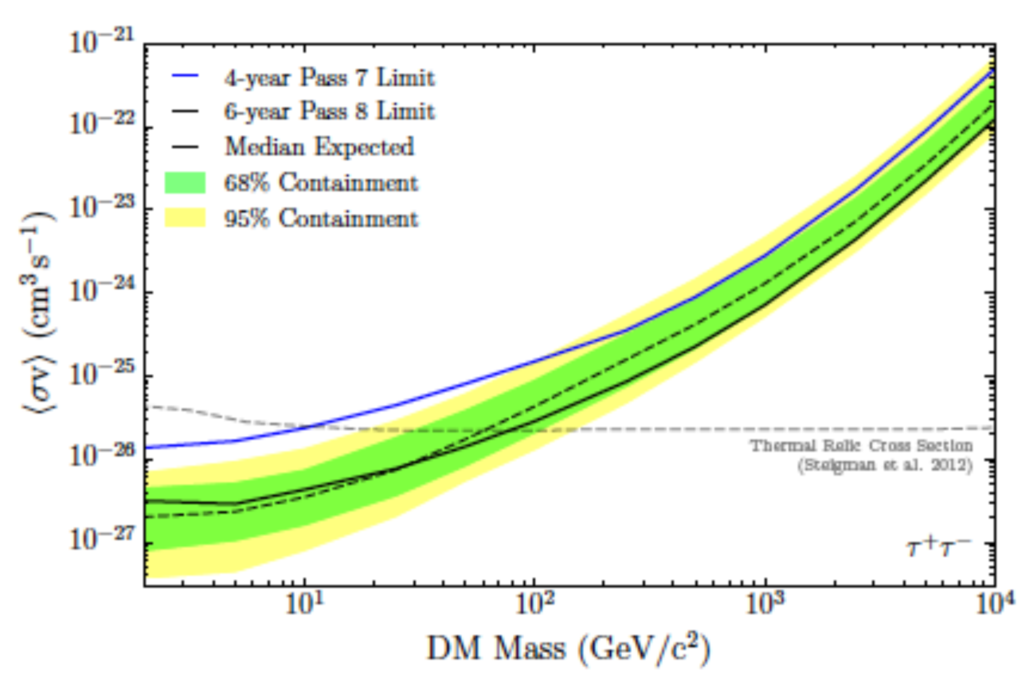
Kinematics and Velocity Dispersion Measurements



Matthew G. Walker
Carnegie Mellon University

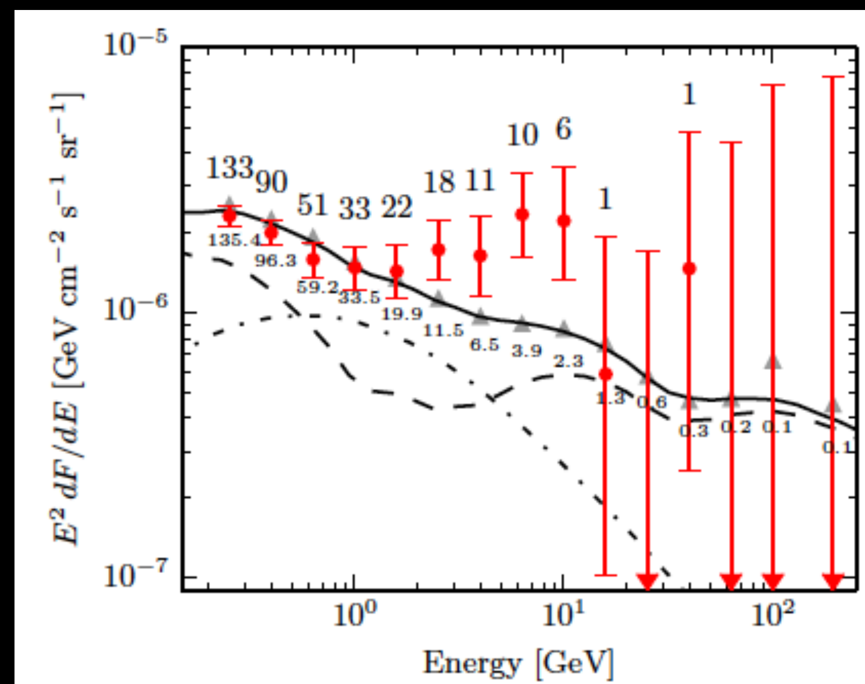
Barolo
4 Sep 2017



Geringer-Sameth et al. (2015)

Fermi-LAT (Ackerman et al. 2015)
(also Geringer-Sameth etal 2015)

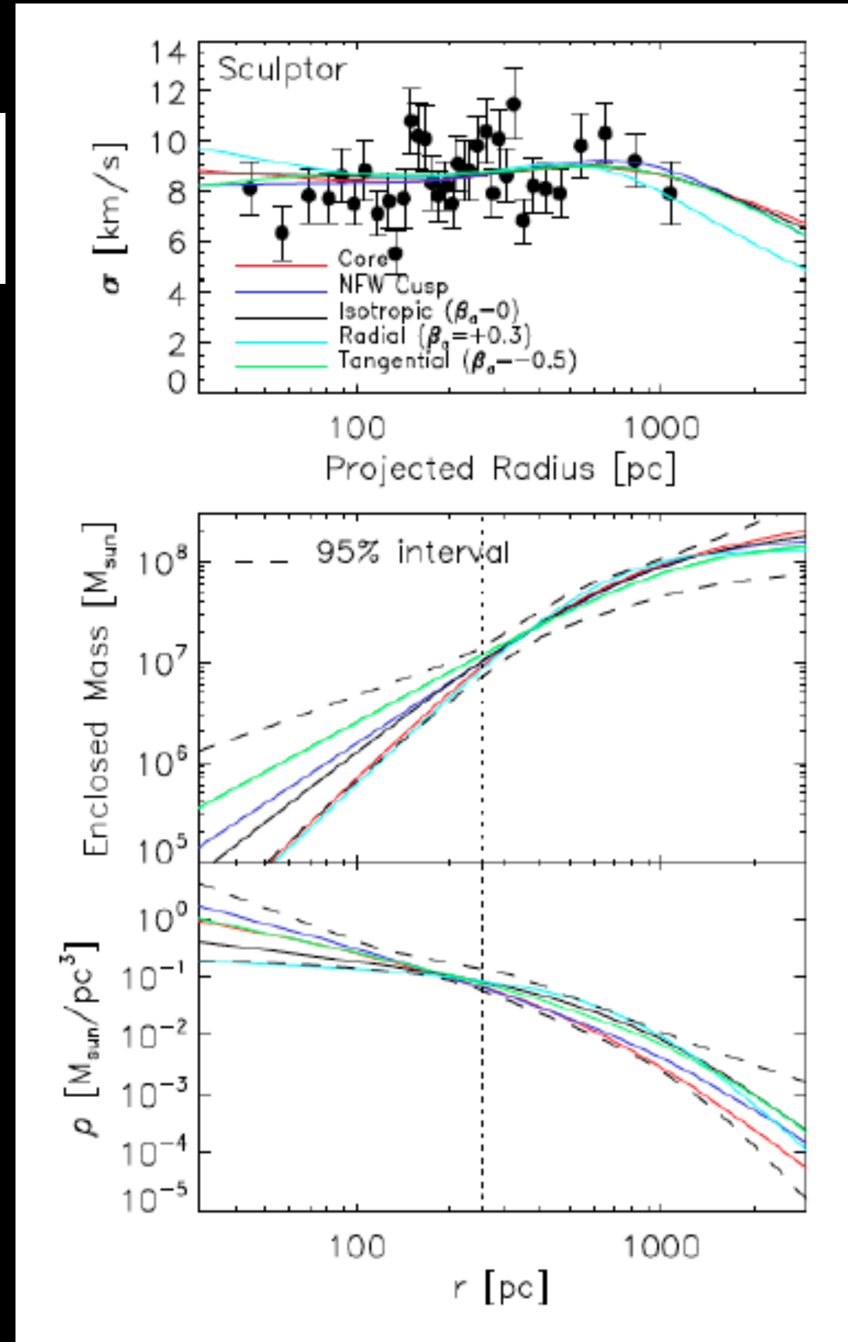
$$\frac{dF(E,\hat{\mathbf{n}})}{dE\,d\Omega} = \frac{\langle \sigma v \rangle}{8\pi M^2}\frac{dN_\gamma(E)}{dE}\int d\ell\, \rho^2(\ell\hat{\mathbf{n}})$$



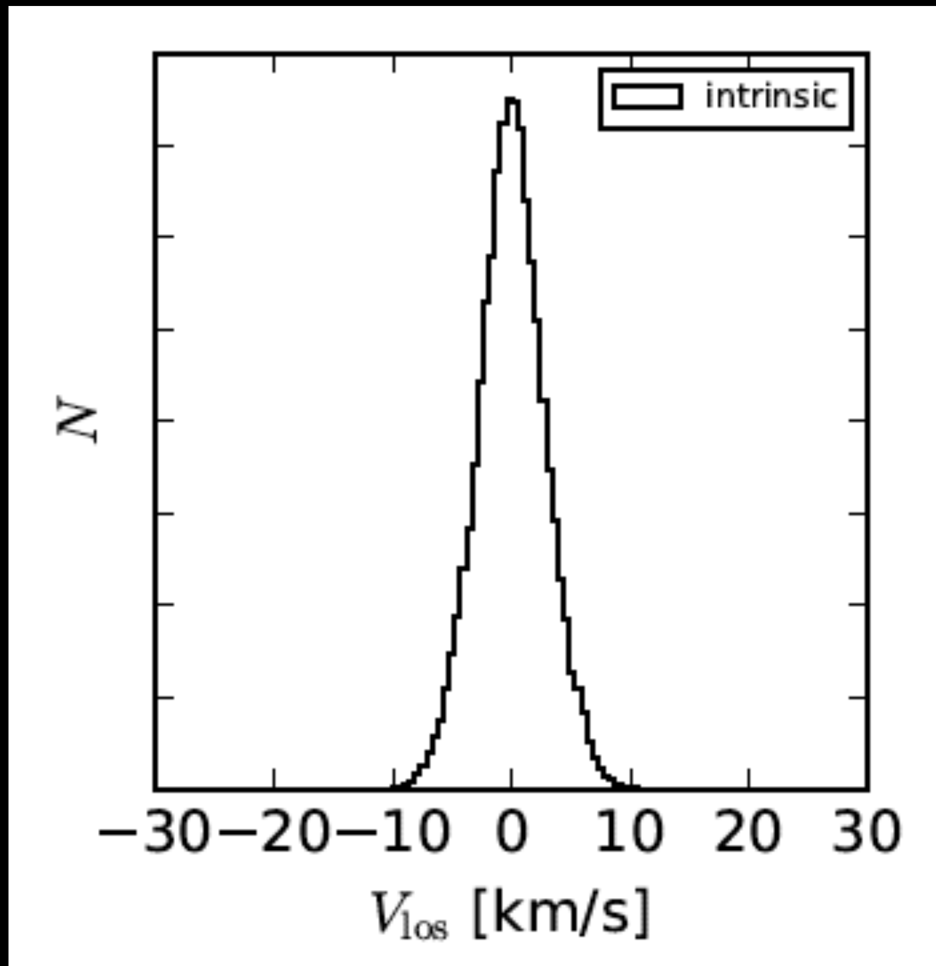
$$\sigma_{\rm p}^2(R)\Sigma(R) = 2\int_R^\infty \left(1-\beta(r)\frac{R^2}{r^2}\right)\frac{\nu(r)\overline{v_r^2}(r)\,r}{\sqrt{r^2-R^2}}\,{\rm d}r$$

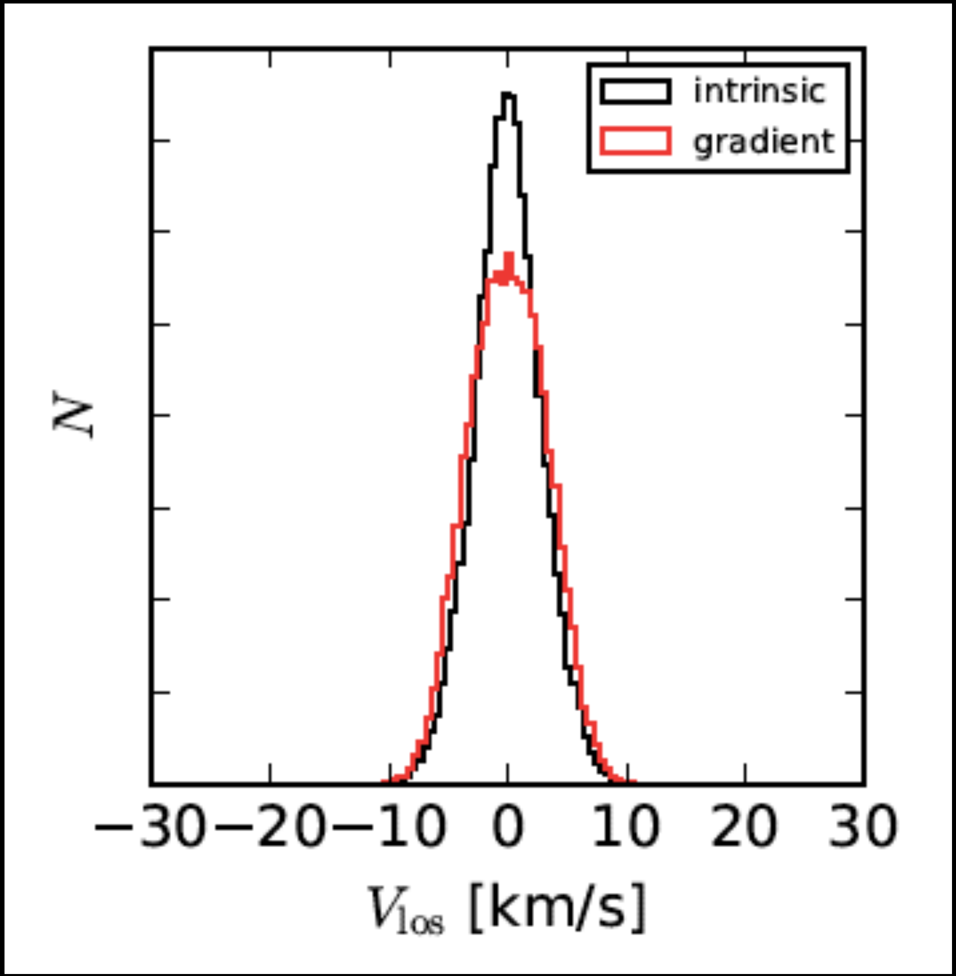
observed

not observed

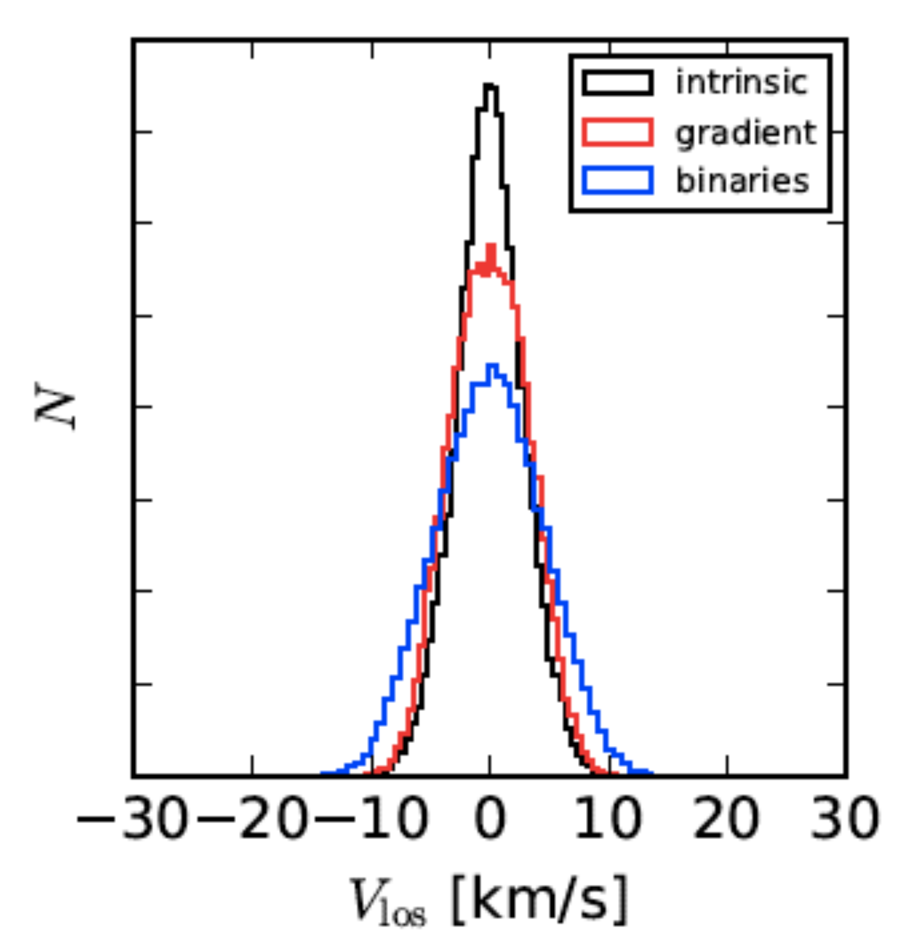


$$\frac{dF(E,\hat{\mathbf{n}})}{dE\,d\Omega} = \frac{\langle\sigma v\rangle}{8\pi M^2}\frac{dN_\gamma(E)}{dE}\int d\ell\,\rho^2(\ell\hat{\mathbf{n}})$$

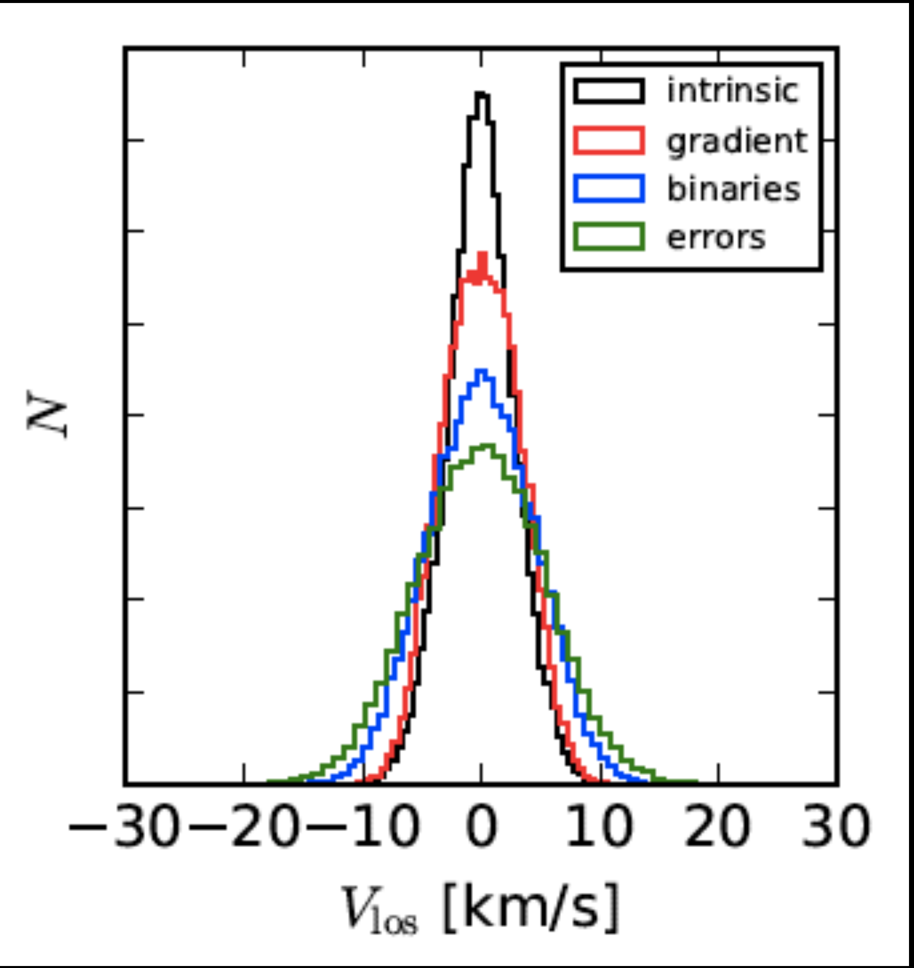

intrinsic
N
−30
−20
−10
0
10
20
30
$V_{\rm los}$ [km/s]



intrinsic
gradient
N
−30
−20
−10
0
10
20
30
$V_{\rm los}$ [km/s]



intrinsic
gradient
binaries
N
−30
−20
−10
0
10
20
30
$V_{\rm los}$ [km/s]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gradient
binaries
errors
N
−30
−20
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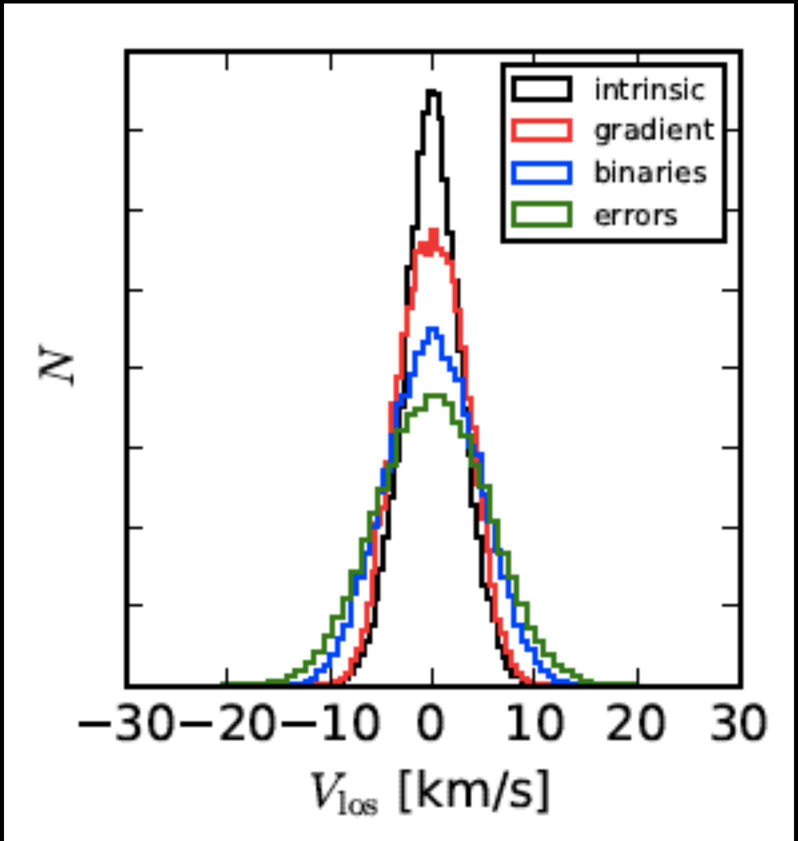
0
10
20
30
$V_{\rm los}$ [km/s]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N
−30
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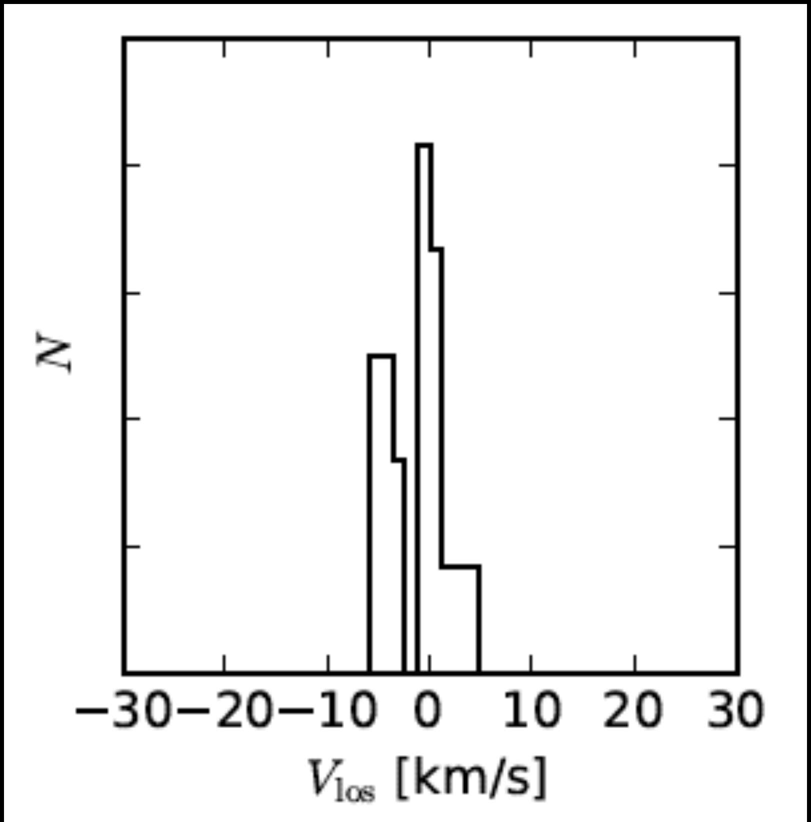
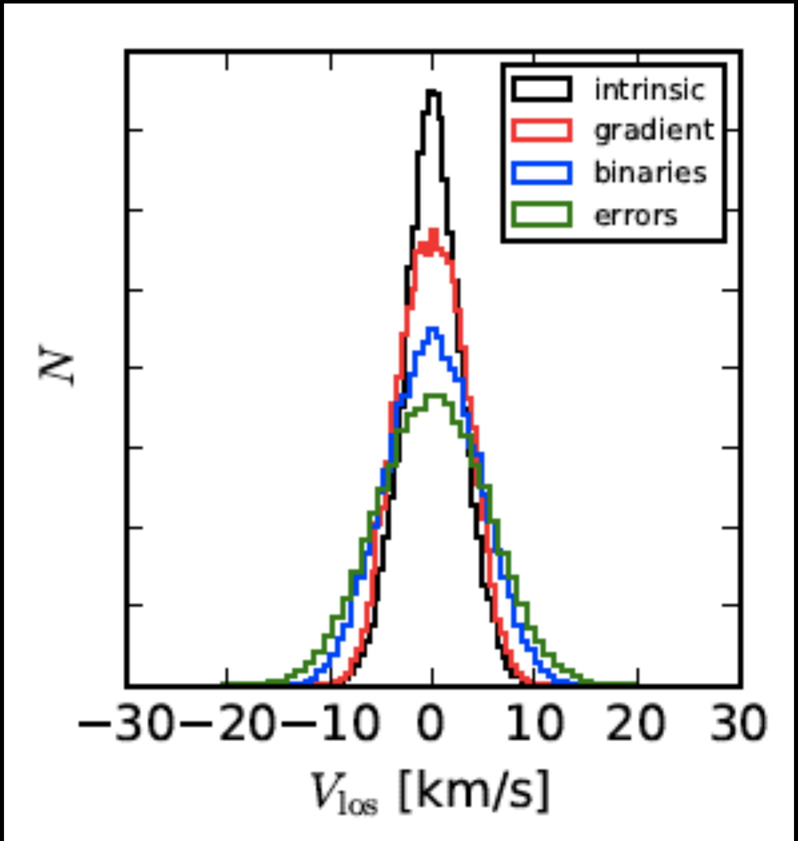
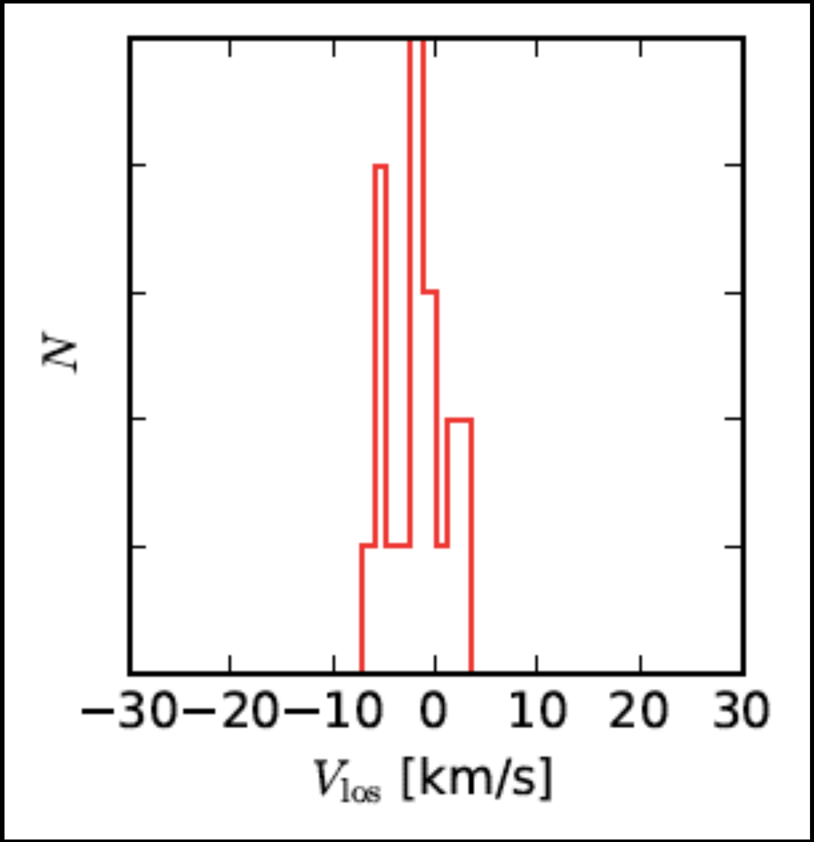
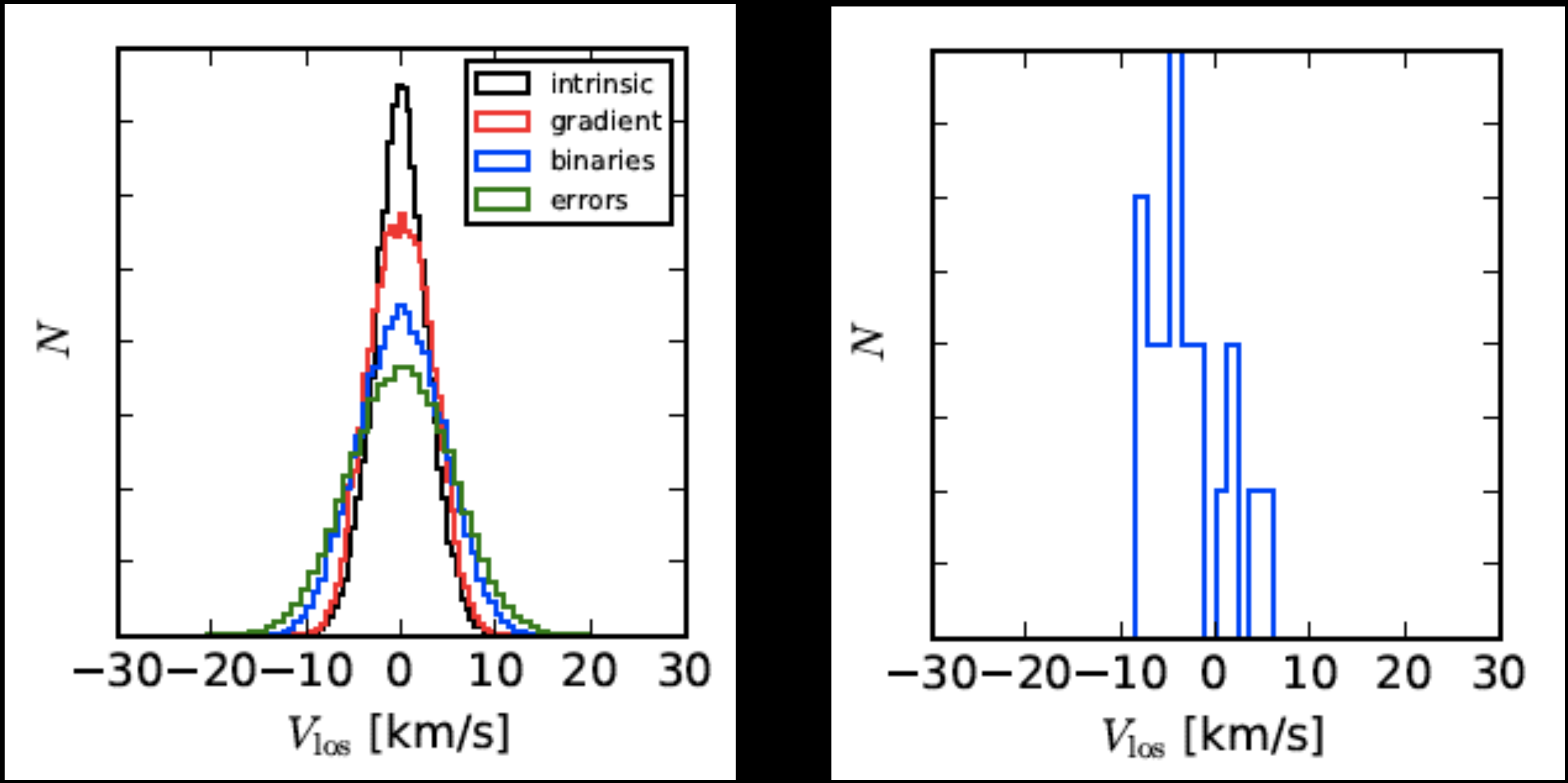
10
20
30
$V_{\rm los}$ [km/s]


N
−30
−20
−10
0
10
20
30
$V_{\rm los}$ [km/s]


intrinsic
gradient
binaries
errors
N
−30 −20 −10 0 10 20 30
$V_{\rm los}$ [km/s]


N
−30 −20 −10 0 10 20 30
$V_{\rm los}$ [km/s]



intrinsic
gradient
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errors
N
−30
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30
$V_{\rm los}$ [km/s]
N
−30
−20
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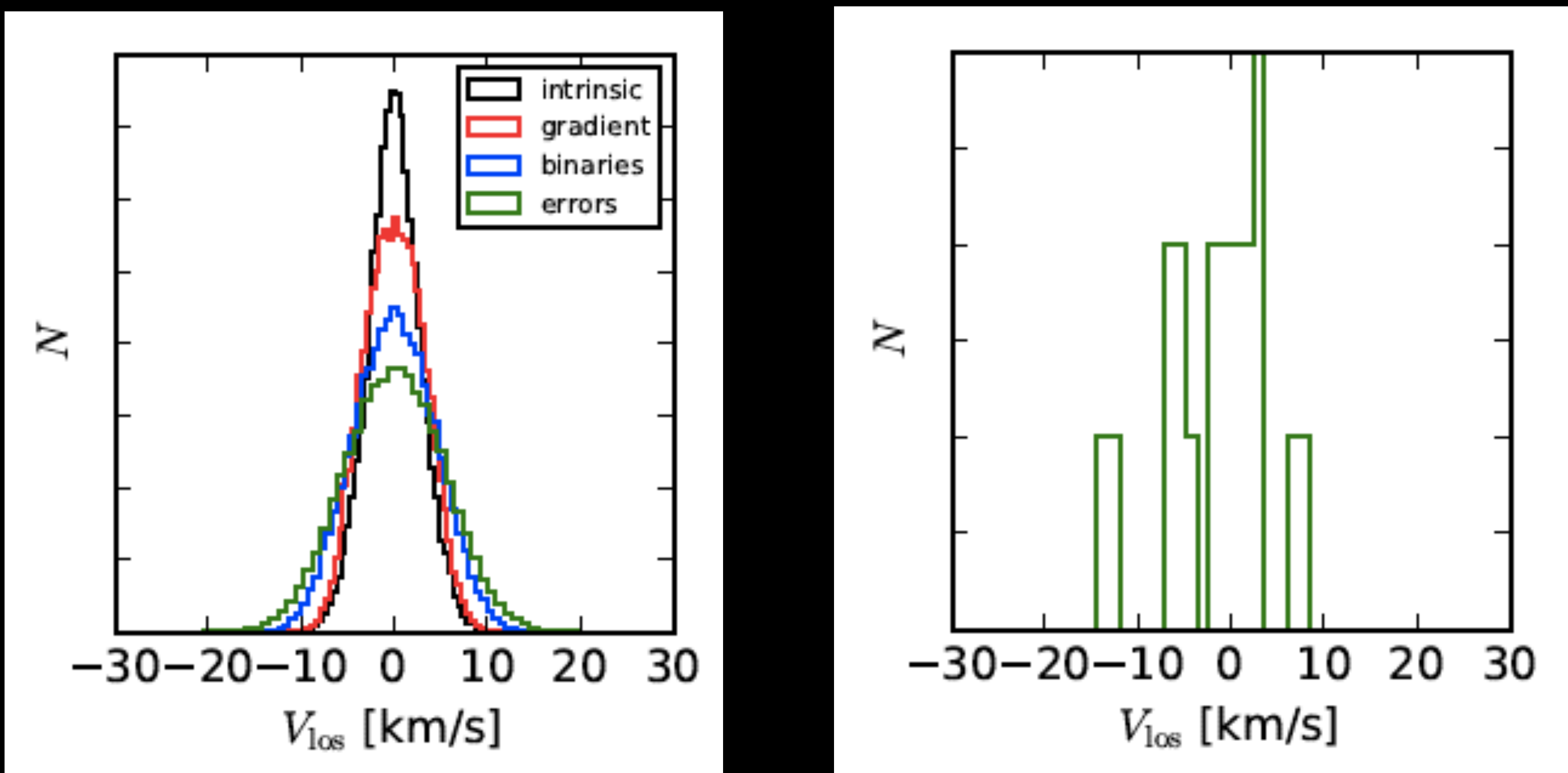
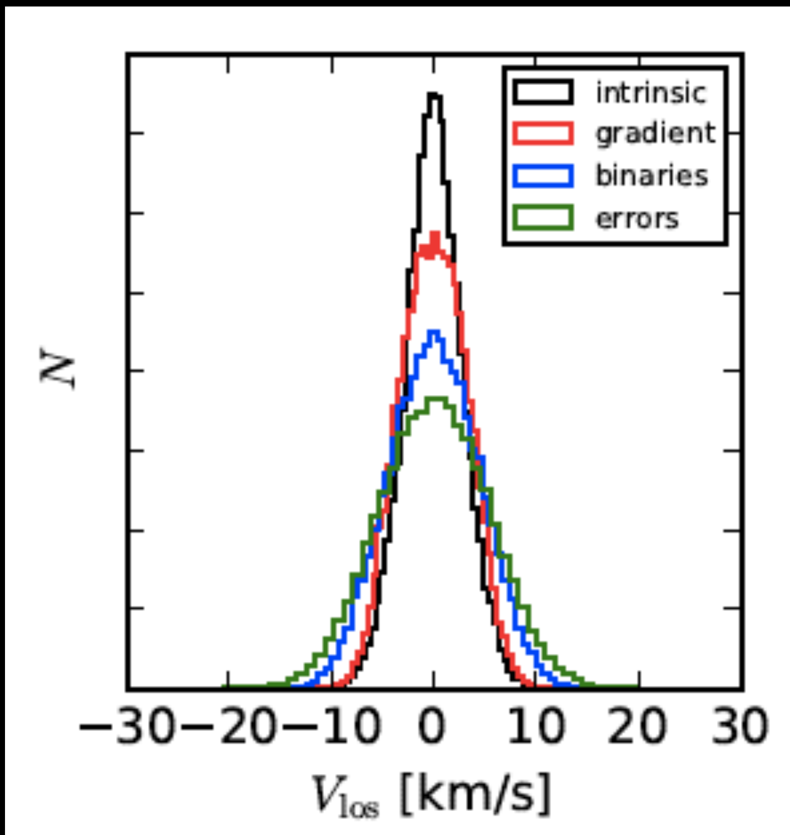
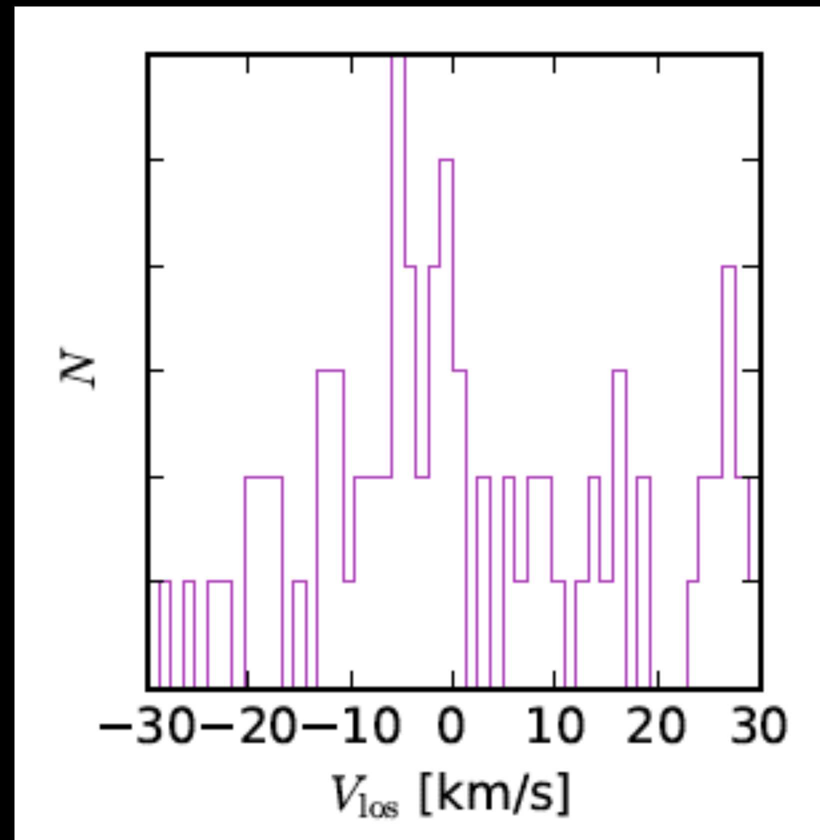
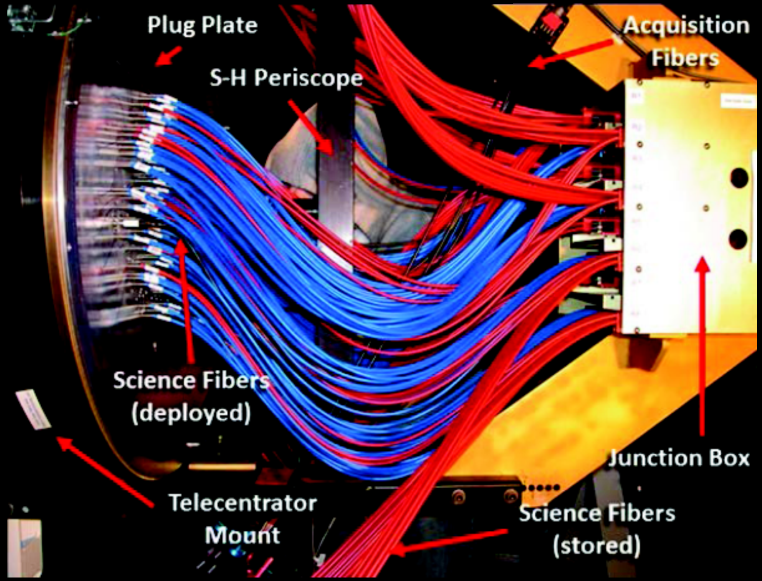
0
10
20
30
$V_{\rm los}$ [km/s]

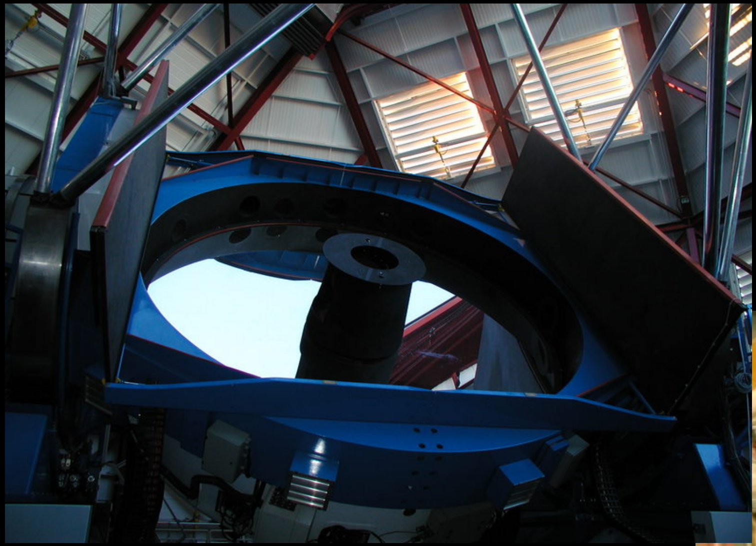

intrinsic
gradient
binaries
errors
N
−30 −20 −10 0 10 20 30
$V_{\rm los}$ [km/s]
N
−30 −20 −10 0 10 20 30
$V_{\rm los}$ [km/s]

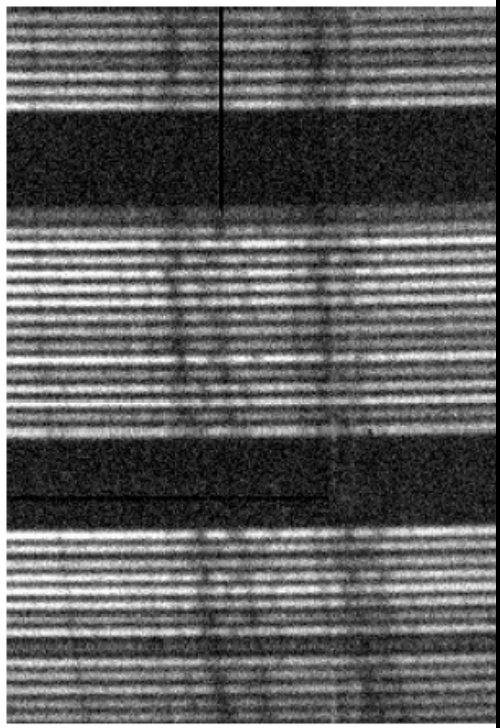

intrinsic
gradient
binaries
errors
N
−30 −20 −10 0 10 20 30
V_los [km/s]

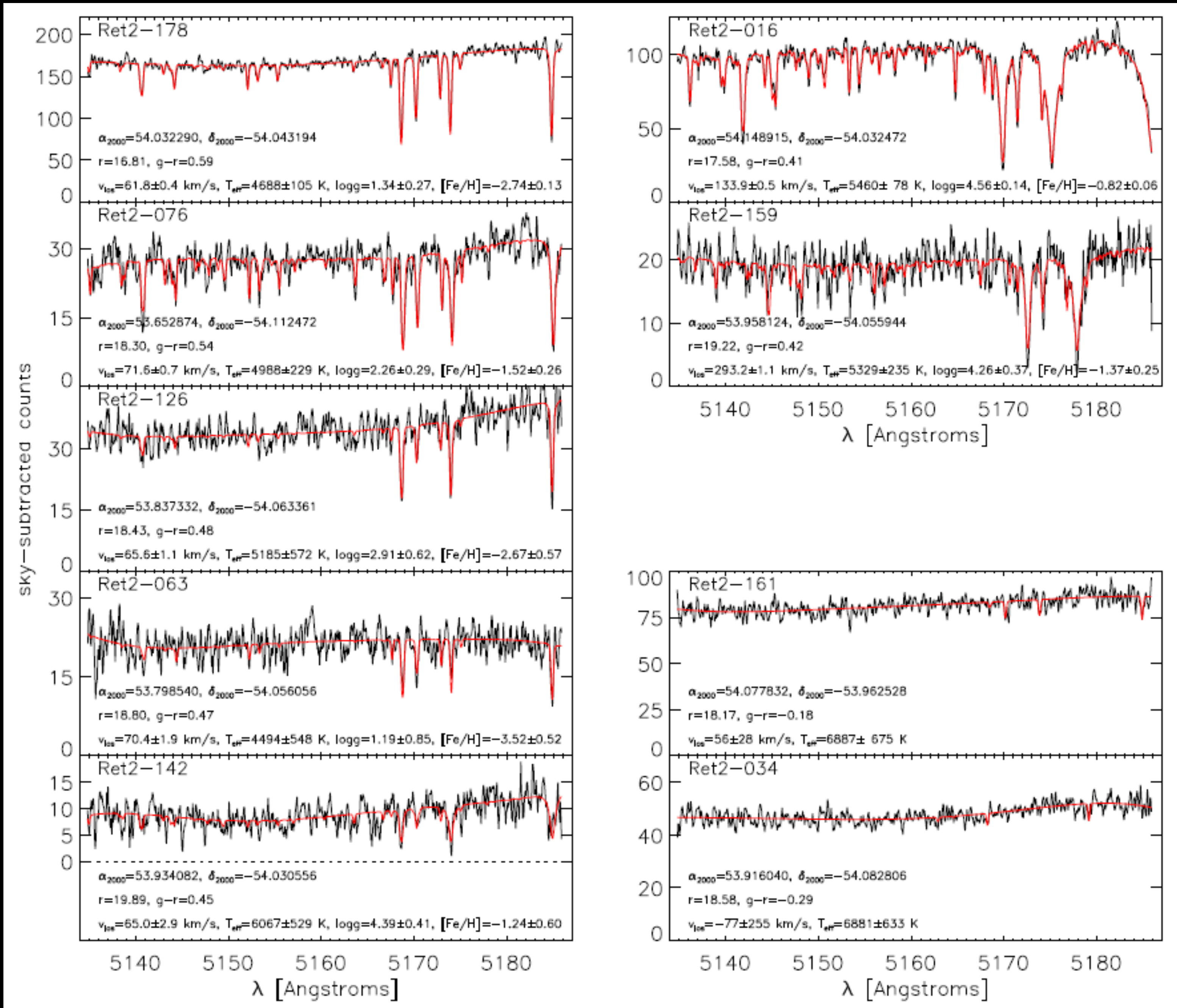

N
−30 −20 −10 0 10 20 30
V_los [km/s]

Magellan/M2FS spectroscopy with Mario Mateo, Ed Olszewski, Nelson Caldwell

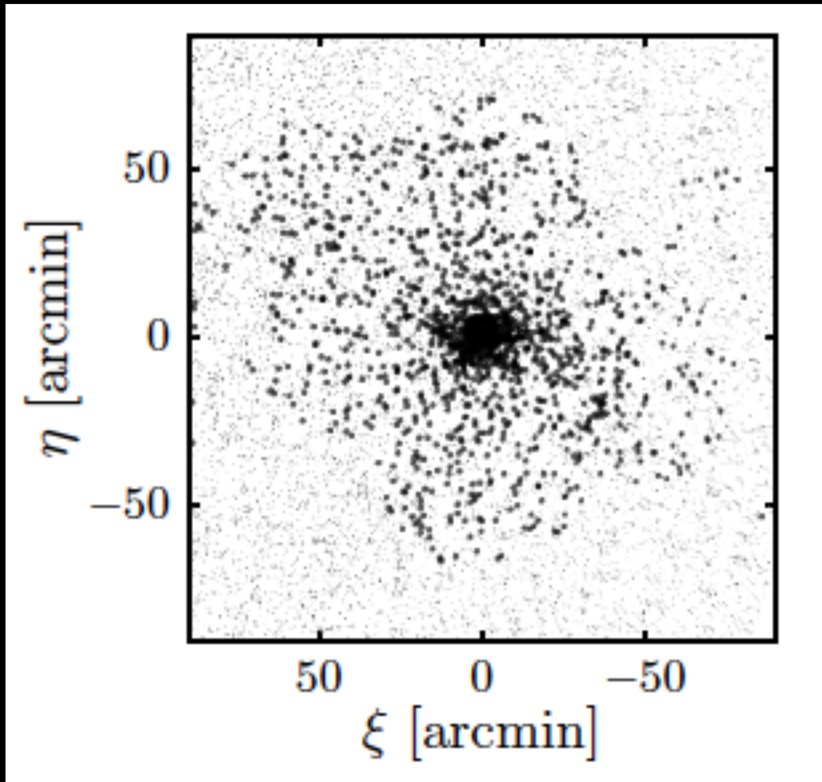


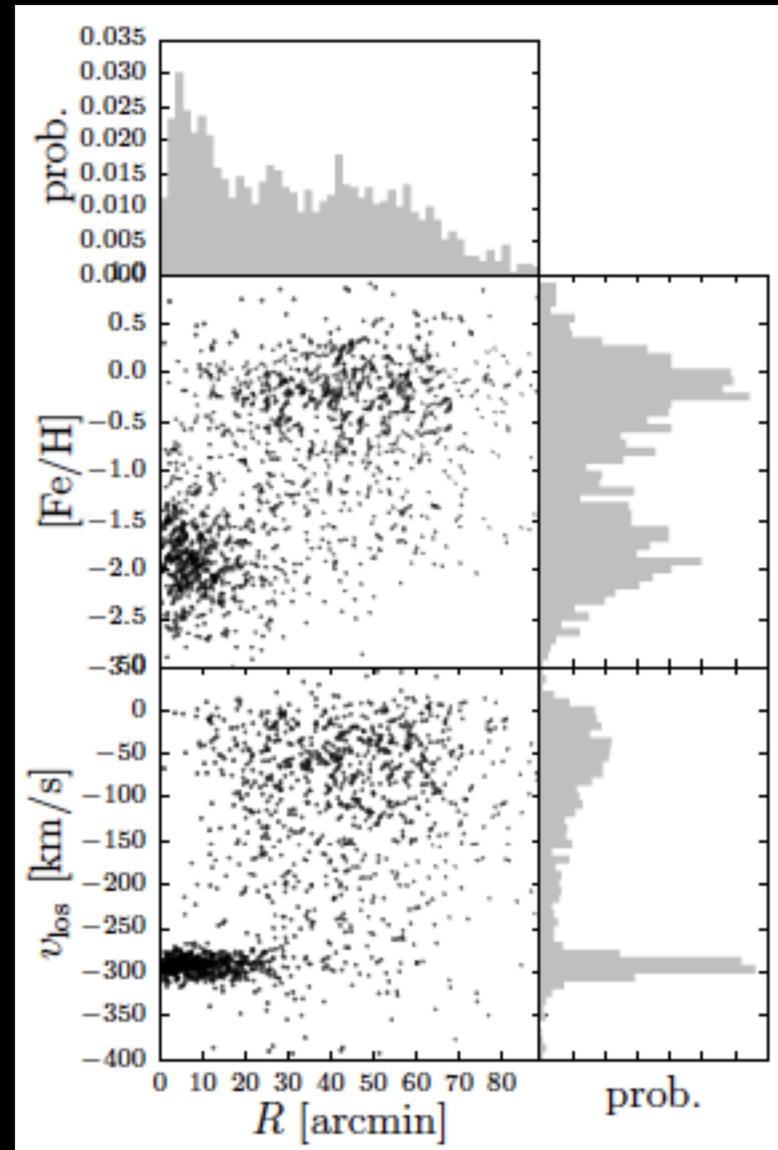


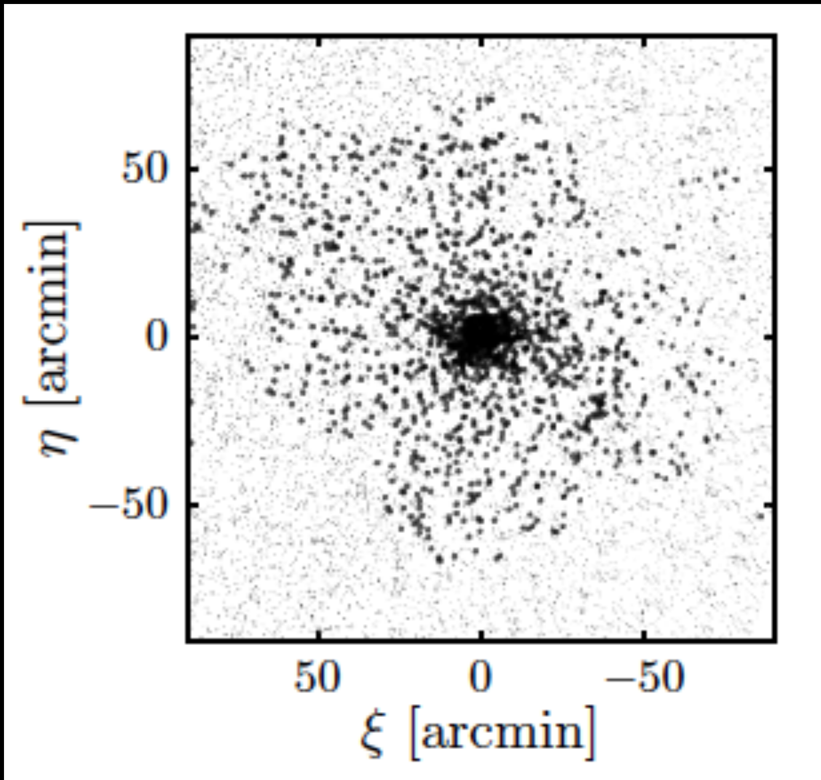


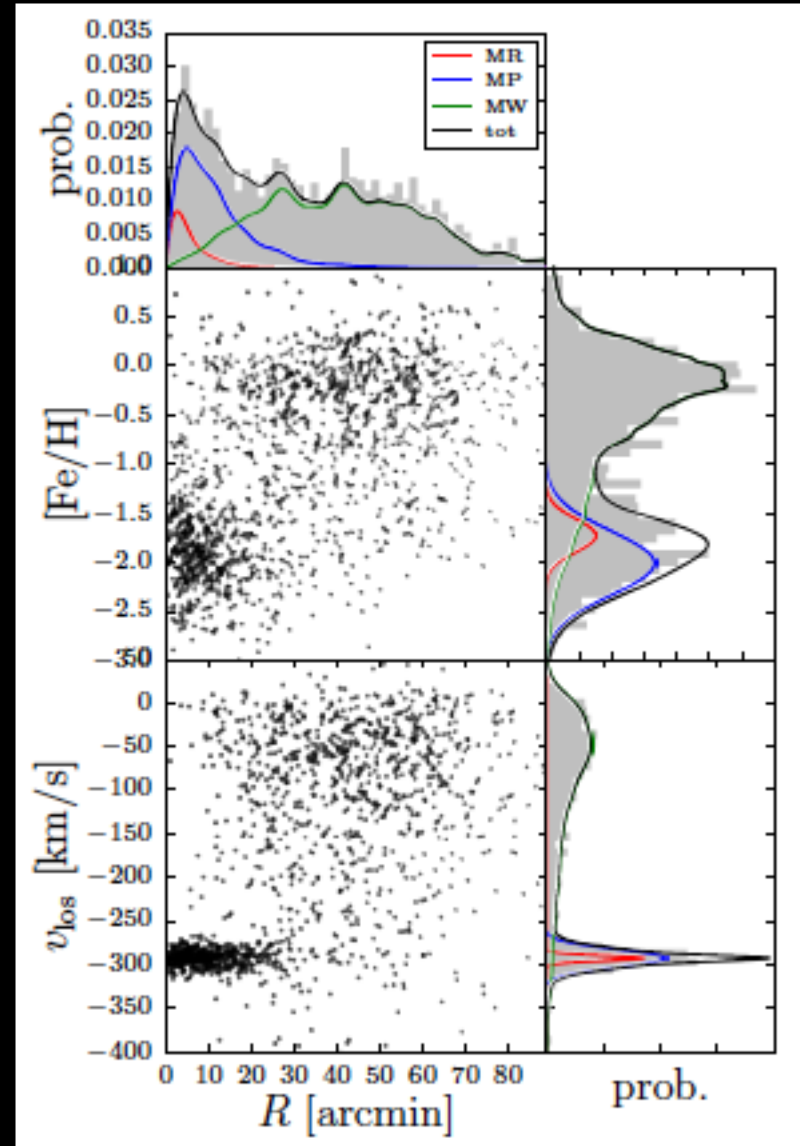


MGW et al. (2015)


η [arcmin]
ξ [arcmin]
50
0
−50
50
0
−50


prob.
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
[Fe/H]
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
v_los [km/s]
0
−50
−100
−150
−200
−250
−300
−350
−400
0
10
20
30
40
50
60
70
80
R [arcmin]
prob.





$$
\begin{aligned}
P(R,V,Z|\text{model}) &\propto \sum_{M=1}^{N_{\rm pop}} P(R,V,Z,M|\text{model}) \\
&\propto \sum_{M=1}^{N_{\rm pop}} P(M|\text{model})P(R|M,\text{model})P(V,Z|R,M,\text{model}) \\
&\propto \frac{2\pi R}{N_{\rm tot}} \sum_{M=1}^{N_{\rm pop}} I_M(R)P(V,Z|R,M,\text{model})
\end{aligned}
$$

REVISITING THE INFLUENCE OF UNIDENTIFIED BINARIES ON VELOCITY DISPERSION MEASUREMENTS IN ULTRA-FAINT STELLAR SYSTEMS

Alan W. McConnachie and Patrick Côté
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Received 2010 March 30; accepted 2010 September 21; published 2010 October 1

ABSTRACT

Velocity dispersion measurements of recently discovered Milky Way satellites with $M_V \gtrsim -7$ imply that they posses high mass-to-light ratios. The expected velocity dispersions due to their baryonic mass are $\sim$0.2 km s^{-1}, but values $\gtrsim$3 km s^{-1} are measured. We perform Monte Carlo simulations of mock radial velocity measurements of these systems assuming that they have mass-to-light ratios similar to globular clusters and posses an unidentified binary star population, to determine if these stars could boost the velocity dispersion to the observed values. We find that this hypothesis is unlikely to produce dispersions much in excess of $\sim$4.5 km s^{-1}, in agreement with previous work. However, for the systems with the potentially smallest velocity dispersions, values consistent with observations are produced in 5%–40% of our simulations for binary fractions in excess of $f_{\rm bin}(P \leqslant 10\,{\rm yr}) \sim 5\%$. This sample includes the dwarf galaxy candidates that lie closest to classical globular clusters in $M_V - r_h$ space. Considered as a population, it is unlikely that all of these dwarf galaxy candidates have mass-to-light ratios typical of globular clusters, but boosting of the observed dispersion by binaries from near-zero values cannot be ruled out at high confidence for several individual dwarf galaxy candidates. Given the importance of obtaining accurate velocity dispersions and dynamical masses for the faintest satellites, it is clearly desirable to directly exclude the possible effect of binaries on these systems. This requires multi-epoch radial velocity measurements with individual uncertainties of $\lesssim$1 km s^{-1} to identify spectroscopic binaries with orbital velocities of the order of the observed velocity dispersion.

BINARY POPULATIONS IN MILKY WAY SATELLITE GALAXIES: CONSTRAINTS FROM MULTI-EPOCH DATA IN THE CARINA, FORNAX, SCULPTOR, AND SEXTANS DWARF SPHEROIDAL GALAXIES

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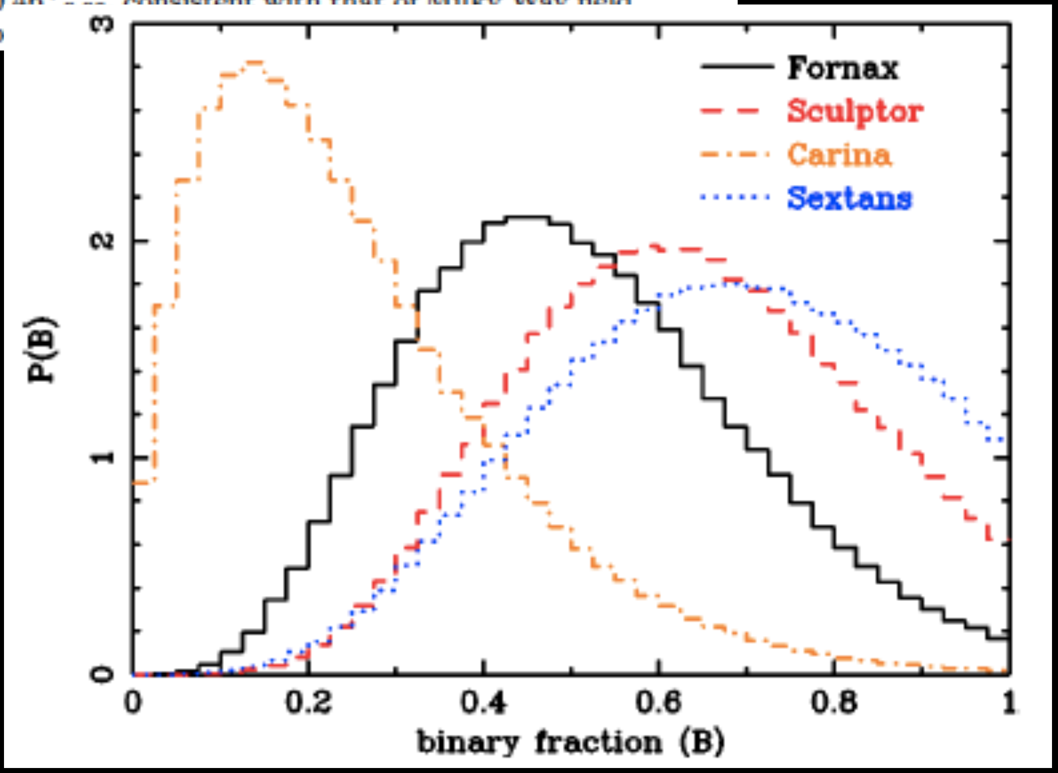
Submitted to ApJ 2013-05-25; accepted 2013-11-06

ABSTRACT

We introduce a likelihood analysis of multi-epoch stellar line-of-sight velocities to constrain the binary fractions and binary period distributions of dwarf spheroidal galaxies. This method is applied to multi-epoch data from the Magellan/MMFS survey of the Carina, Fornax, Sculptor and Sextans dSph galaxies, after applying a model for the measurement errors that accounts for binary orbital motion. We find that the Fornax, Sculptor, and Sextans dSphs are consistent with having binary populations similar to that of Milky Way field binaries to within 68% confidence limits, whereas the Carina dSph is remarkably deficient in binaries with periods less than ~10 years. If Carina is assumed to have a period distribution identical to that of the Milky Way field, its best-fit binary fraction is $0.14^{+0.28}_{-0.05}$, and is constrained to be less than 0.5 at the 90% confidence level; thus it is unlikely to host a binary population identical to that of the Milky Way field. By contrast, the best-fit binary fraction of the combined sample of all four galaxies is $0.46^{+0.13}$ consistent with that of Milky Way field binaries. More generally, we infer probability distrib

Minor (2013),
also Spencer et al. (2017)



ACCURATE STELLAR KINEMATICS AT FAINT MAGNITUDES: APPLICATION TO THE BOÖTES I DWAR SPHEROIDAL GALAXY

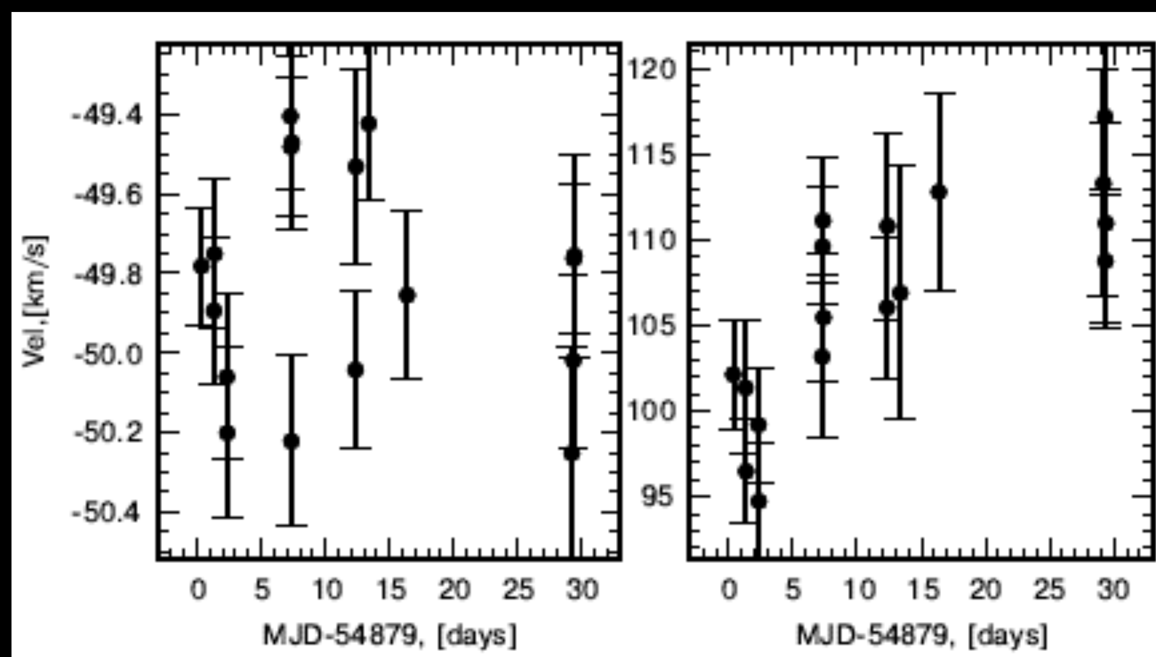
SERGEY E. KOPOSOV[1,2], G. GILMORE[1], M. G. WALKER[1,3], V. BELOKUROV[1], N.WYN EVANS[1], M. FELLHAUER[4], W. GIEREN[4], D. GEISLER[4], L. MONACO[4,5], J.E. NORRIS[6], S. OKAMOTO[1], J. PEÑARRUBIA[1], M. WILKINSON[7], R.F.G. WYSE[8] D.B. ZUCKER[9,10]

Draft version May 23, 2011

ABSTRACT

We develop, implement and characterise an enhanced data reduction approach which delivers precise, accurate, radial velocities from moderate resolution spectroscopy with the fibre-fed VLT/FLAMES+GIRAFFE facility. This facility, with appropriate care, delivers radial velocities adequate to resolve the intrinsic velocity dispersions of the very faint dSph dwarf galaxies. Importantly, repeated measurements let us reliably calibrate our individual velocity errors ($0.2 \le \delta_V \le 5$ km s^{-1}) and directly detect stars with variable radial velocities. We show, by application to the Boötes I dwarf spheroidal, that the intrinsic velocity dispersion of this system is significantly below 6.5 km/s reported by previous studies. Our data favor a two-population model of Boötes I, consisting of a majority 'cold' stellar component, with velocity dispersion $2.4^{+0.9}_{-0.5}$ km/s, and a minority 'hot' stellar component, with velocity dispersion ~ 9 km/s, although we can not completely rule out a single component distribution with velocity dispersion $4.6^{0.8}_{-0.6}$ km/s. We speculate this complex velocity distribution actually reflects the distribution of velocity anisotropy in Boötes I, which is a measure of its formation processes.

Koposov et al. (2011)



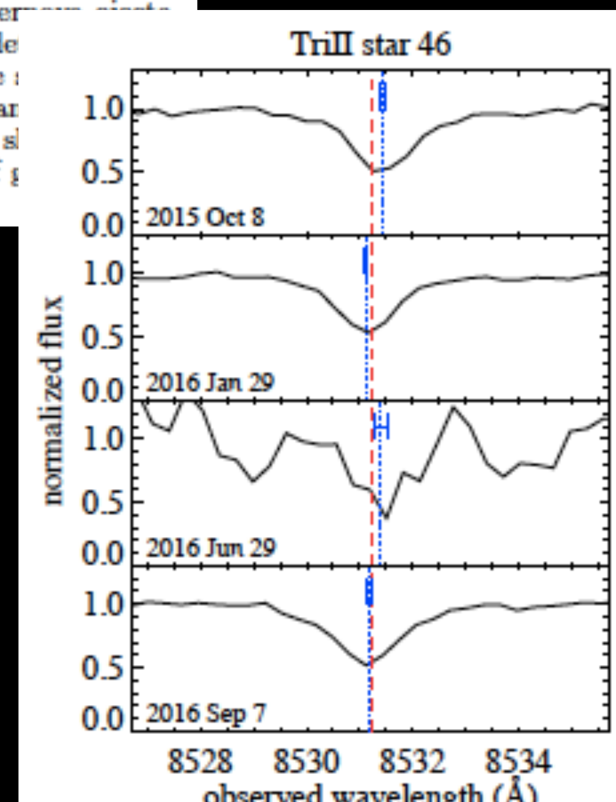
TRIANGULUM II: NOT ESPECIALLY DENSE AFTER ALL

EVAN N. KIRBY[1], JUDITH G. COHEN[1], JOSHUA D. SIMON[2], PURAGRA GUHATHAKURTA[3], ANDERS O. THYGESEN[1]
GINA E. DUGGAN[1]

Accepted to ApJ on 2017 March 8

ABSTRACT

Among the Milky Way satellites discovered in the past three years, Triangulum II has presented the most difficulty in revealing its dynamical status. Kirby et al. (2015a) identified it as the most dark matter-dominated galaxy known, with a mass-to-light ratio within the half-light radius of $3600^{+3500}_{-2100}\ M_\odot\ L_\odot^{-1}$. On the other hand, Martin et al. (2016) measured an outer velocity dispersion that is 3.5 ± 2.1 times larger than the central velocity dispersion, suggesting that the system might not be in equilibrium. From new multi-epoch Keck/DEIMOS measurements of 13 member stars in Triangulum II, we constrain the velocity dispersion to be $\sigma_v < 3.4$ km s^{-1} (90% C.L.). Our previous measurement of σ_v, based on six stars, was inflated by the presence of a binary star with variable radial velocity. We find no evidence that the velocity dispersion increases with radius. The stars display a wide range of metallicities, indicating that Triangulum II retained super[…]
and therefore possesses or once possessed a massive dark matter halo. However, the de[…]
metallicity dispersion hinges on the membership of the two most metal-rich stars. The […]
is lower than galaxies of similar mean stellar metallicity, which might indicate that Trian[…]
either a star cluster or a tidally stripped dwarf galaxy. Detailed abundances of one star s[…]
depressed neutron-capture abundances, similar to stars in most other ultra-faint dwarf […]
unlike stars in globular clusters.



Kirby et al. (2017)

A COMPLETE SPECTROSCOPIC SURVEY OF THE MILKY WAY SATELLITE SEGUE 1: DARK MATTER CONTENT, STELLAR MEMBERSHIP AND BINARY PROPERTIES FROM A BAYESIAN ANALYSIS

GREGORY D. MARTINEZ, QUINN E. MINOR, JAMES BULLOCK, MANOJ KAPLINGHAT
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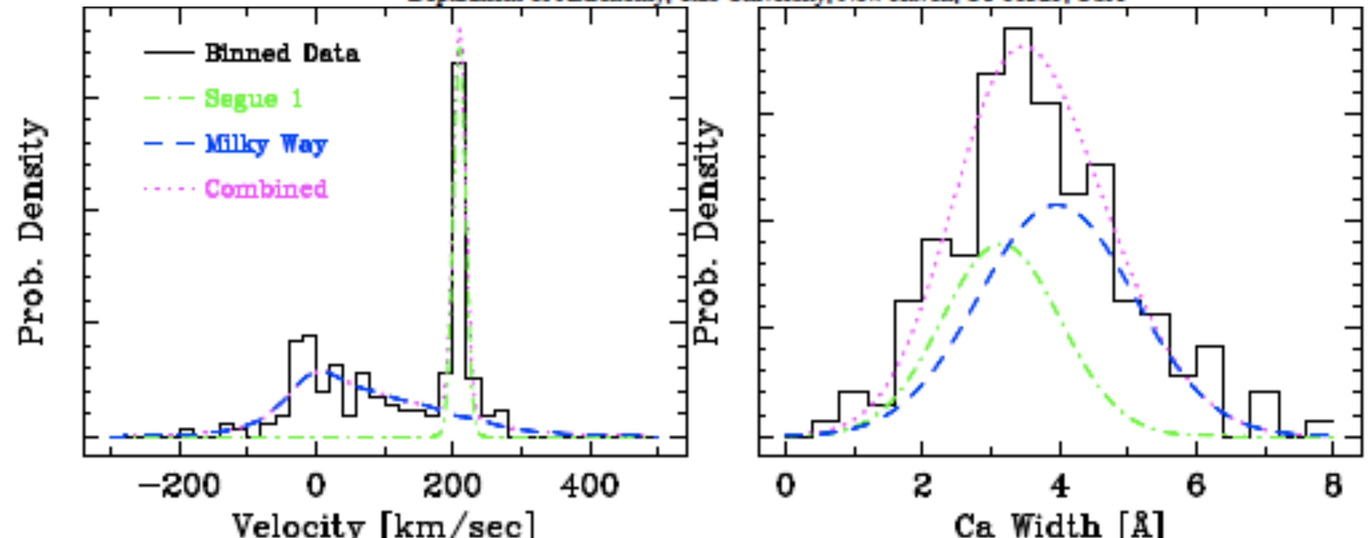
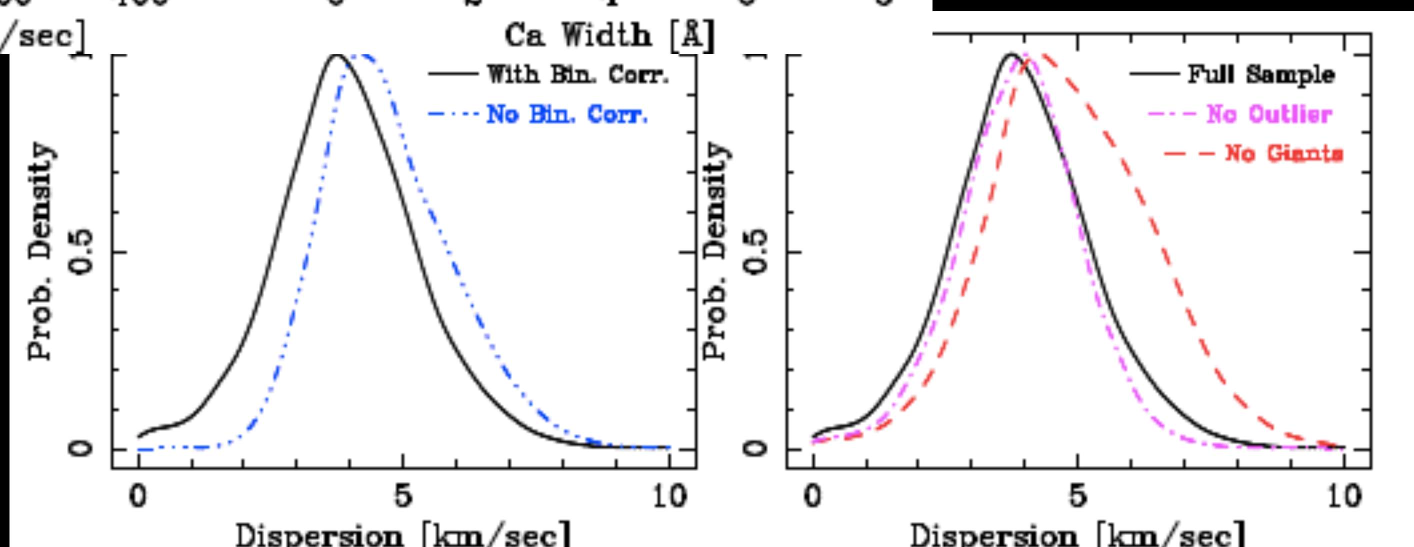
JOSHUA D. SIMON
Observatories of the Carnegie Institution of Washington, 813 Santa Barbara St., Pasadena CA 91101, USA

MARLA GEHA
Department of Astronomy, Yale University, New Haven, CT 06520, USA





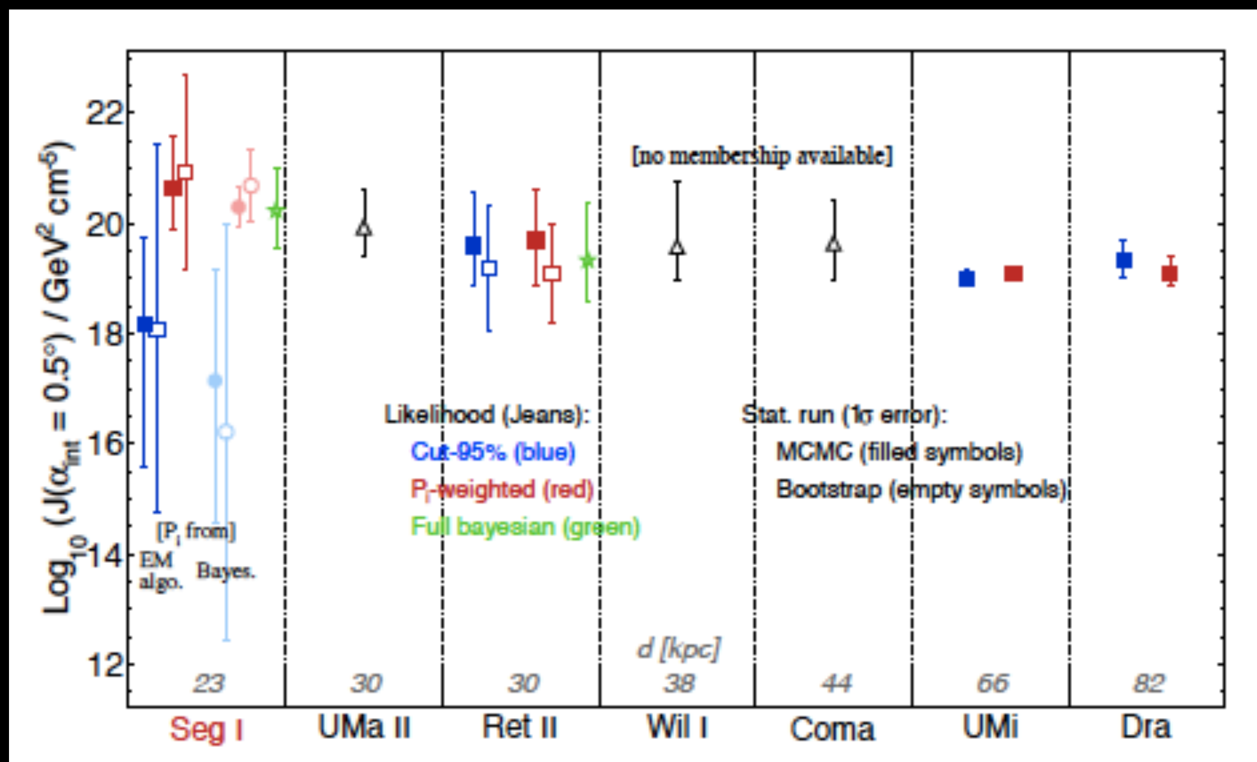
Contamination of stellar-kinematic samples and uncertainty about dark matter annihilation profiles in ultrafaint dwarf galaxies: the example of Segue I

V. Bonnivard[1]*, D. Maurin[1], M. G. Walker[2,3]

[1]*LPSC, Université Grenoble-Alpes, CNRS/IN2P3, 53 avenue des Martyrs, 38026 Grenoble, France*

[2]*Department of Physics, Carnegie Mellon University, Pittsburgh, PA 15213, USA*

[3]*McWilliams Center for Cosmology, 5000 Forbes Avenue Pittsburgh, PA 15213, USA*

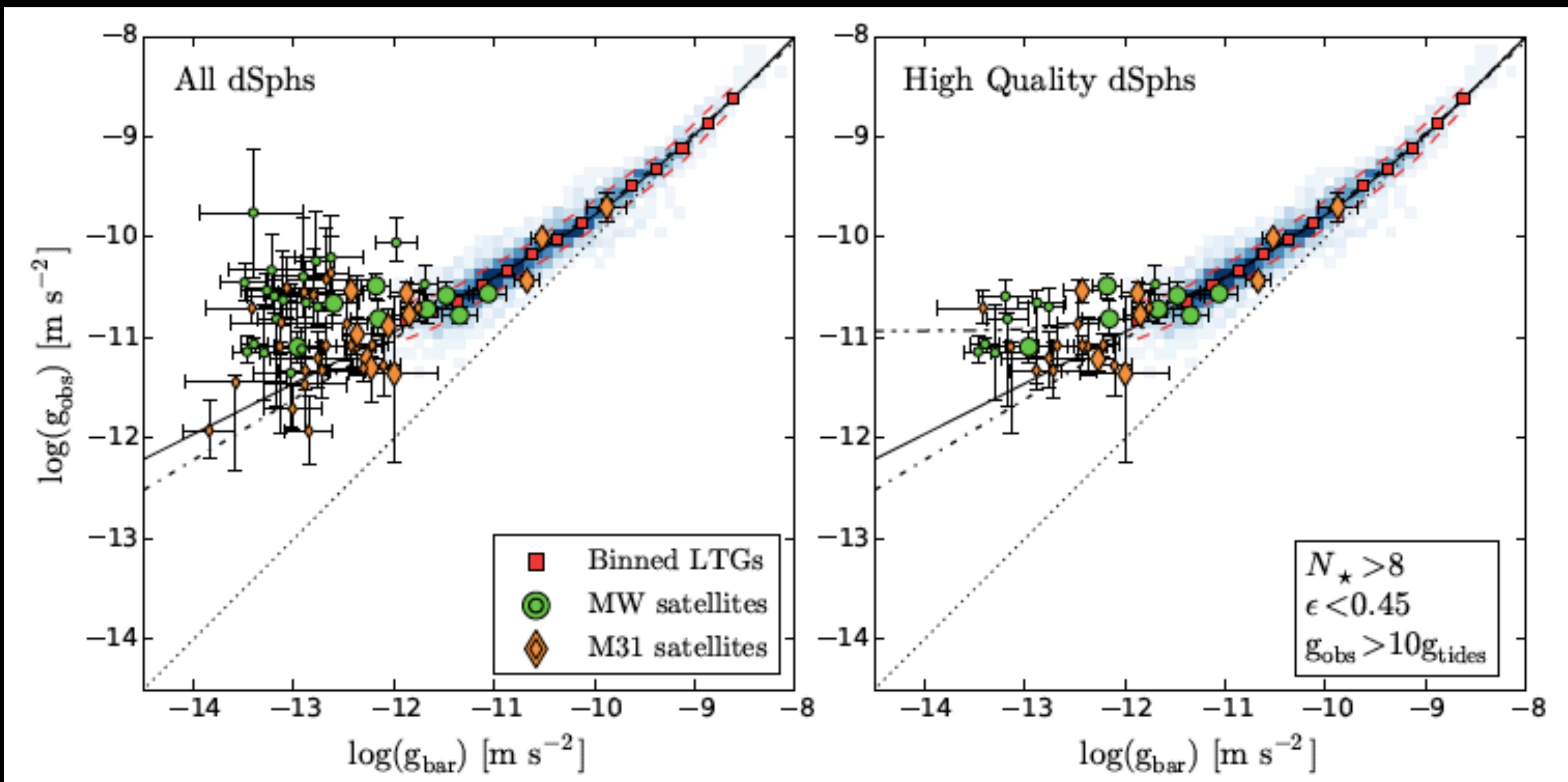


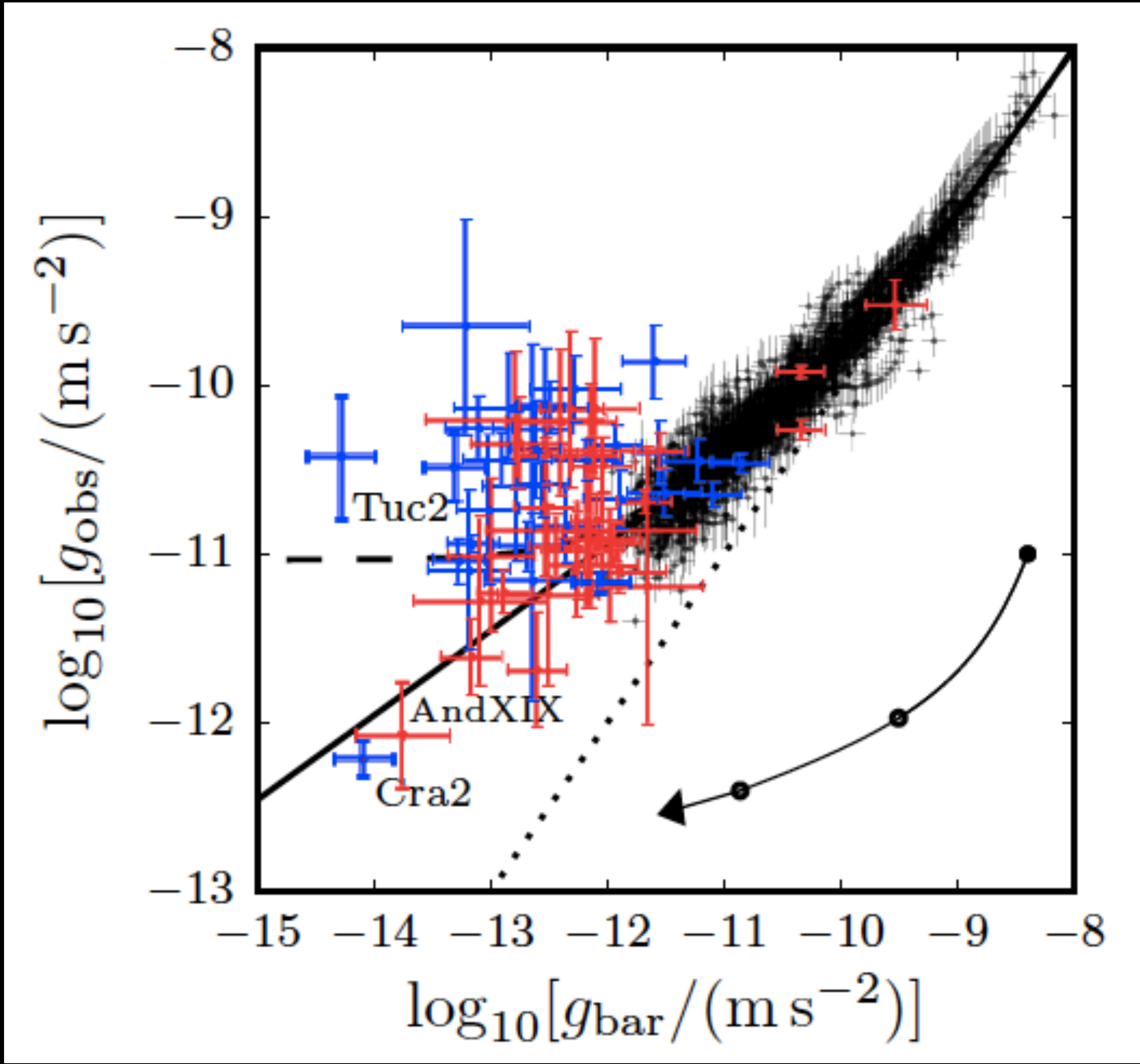
ONE LAW TO RULE THEM ALL: THE RADIAL ACCELERATION RELATION OF GALAXIES

Federico Lelli[1,2,⋆], Stacy S. McGaugh[1], James M. Schombert[3], and Marcel S. Pawlowski[1,4,†]
[1]Department of Astronomy, Case Western Reserve University, Cleveland, OH 44106, USA
[2]European Southern Observatory, Karl-Schwarzschild-Strasse 2, D-85748, Garching, Germany
[3]Department of Physics, University of Oregon, Eugene, OR 97403, USA
[4]Department of Physics and Astronomy, University of California, Irvine, CA 92697, USA

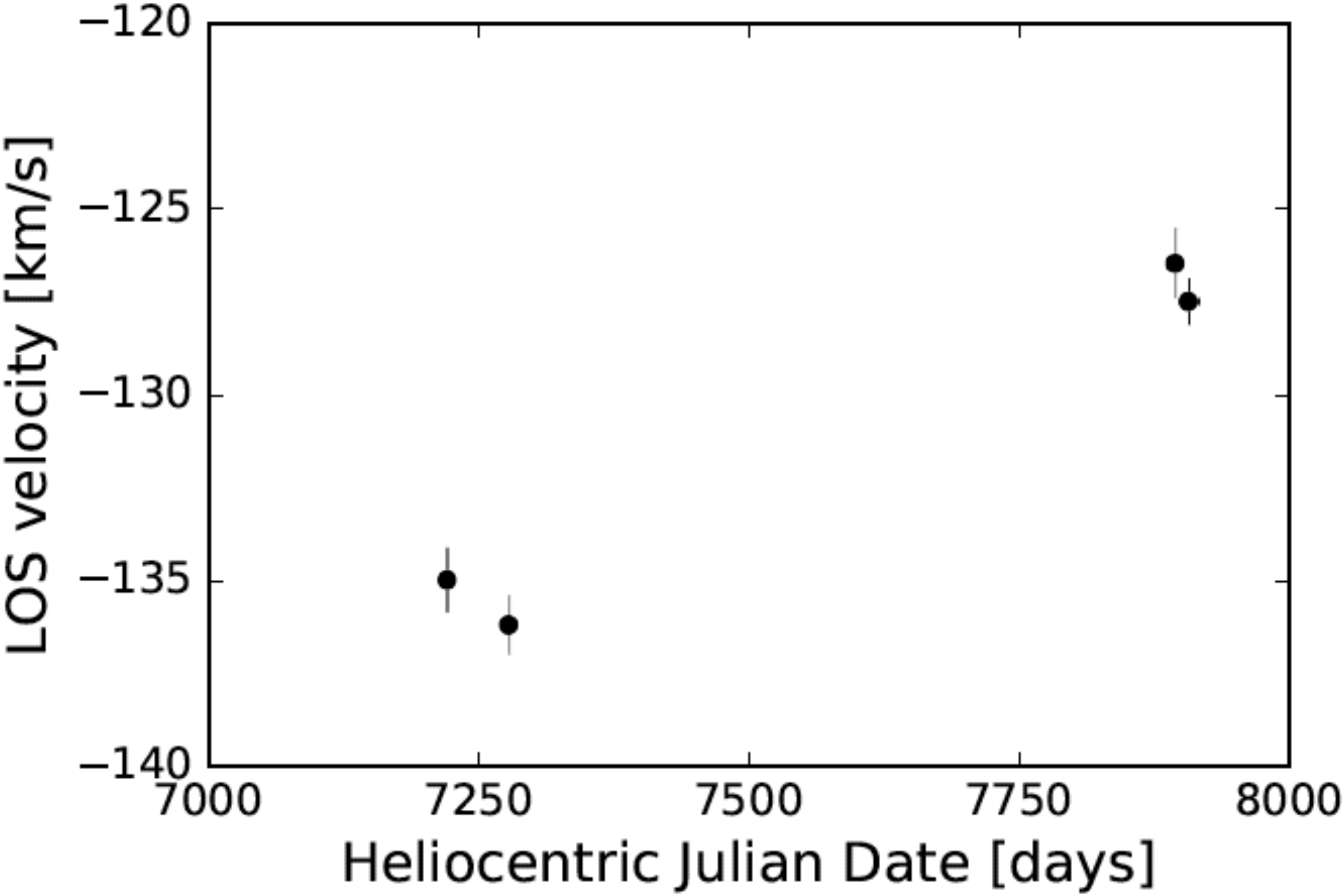
Draft version January 25, 2017

arXiv:1610.08981v2

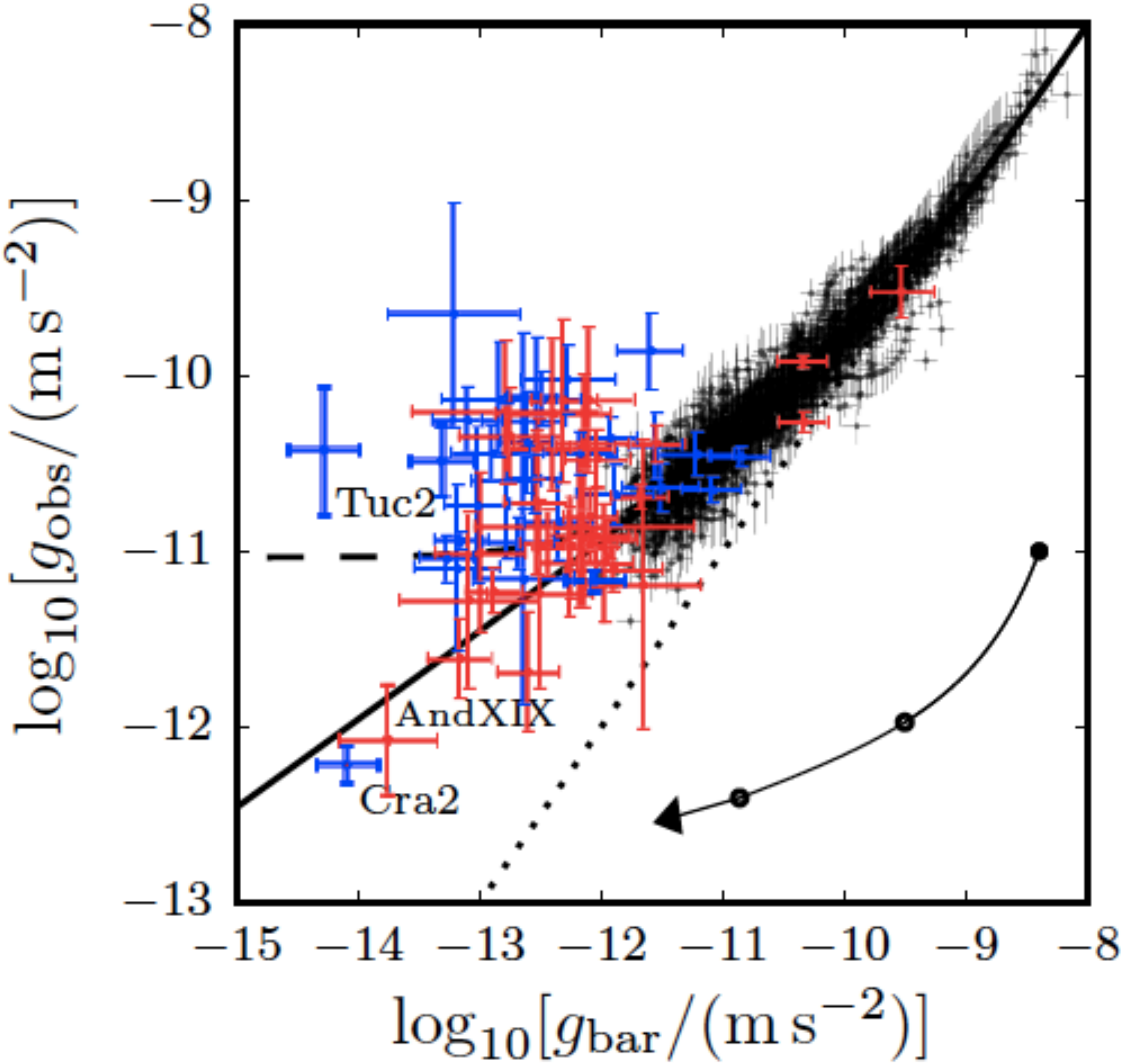




−8
−9
−10
−11
−12
−13
−15
−14
−13
−12
−11
−10
−9
−8
$\log_{10}[g_{\rm obs}/({\rm m\,s^{-2}})]$
$\log_{10}[g_{\rm bar}/({\rm m\,s^{-2}})]$
Tuc2
AndXIX
Cra2



−120
−125
−130
−135
−140
LOS velocity [km/s]
7000
7250
7500
7750
8000
Heliocentric Julian Date [days]



Tuc2
AndXIX
Cra2
$\log_{10}[g_{\rm obs}/(\rm m\,s^{-2})]$
$\log_{10}[g_{\rm bar}/(\rm m\,s^{-2})]$
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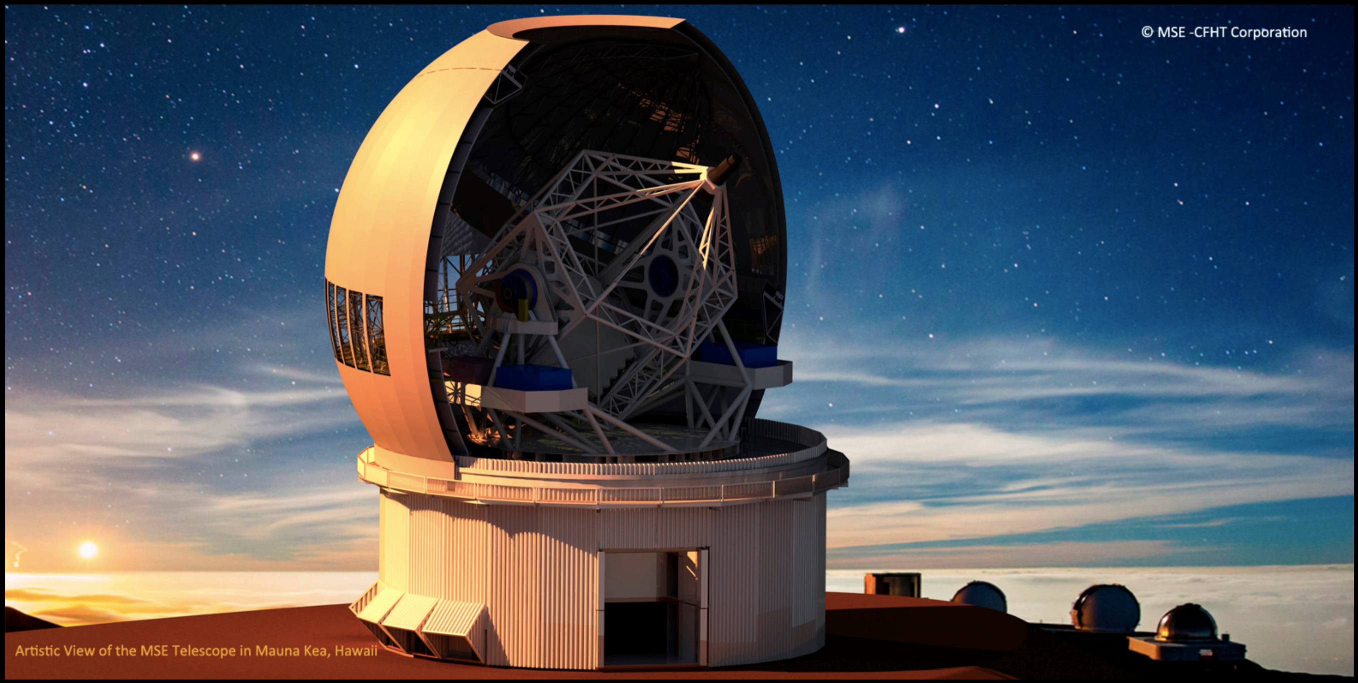
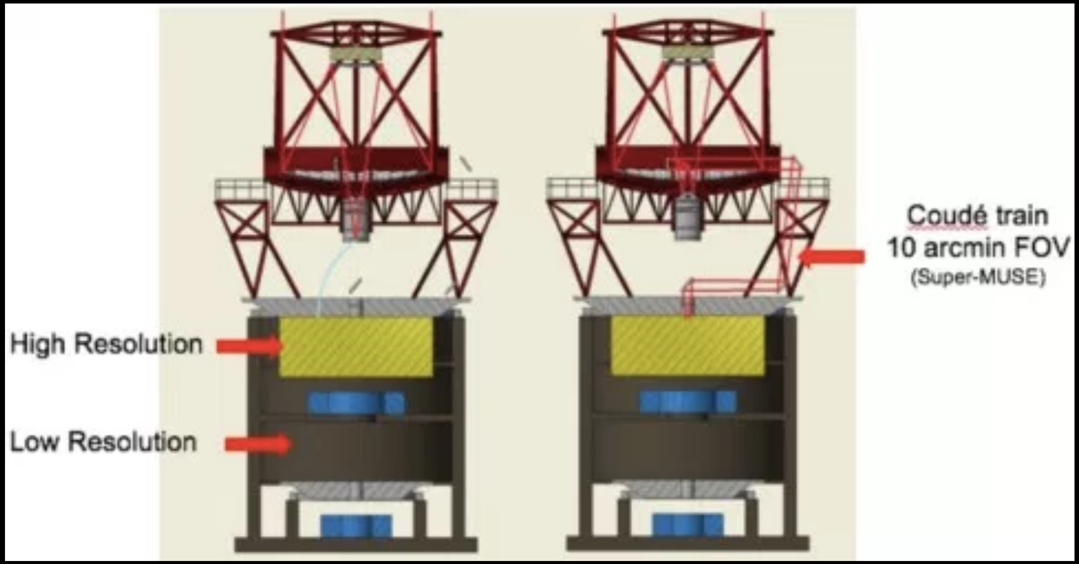
−11
−10
−9
−8



Mauna Kea Spectroscopic Explorer (McConnachie et al. 2016)

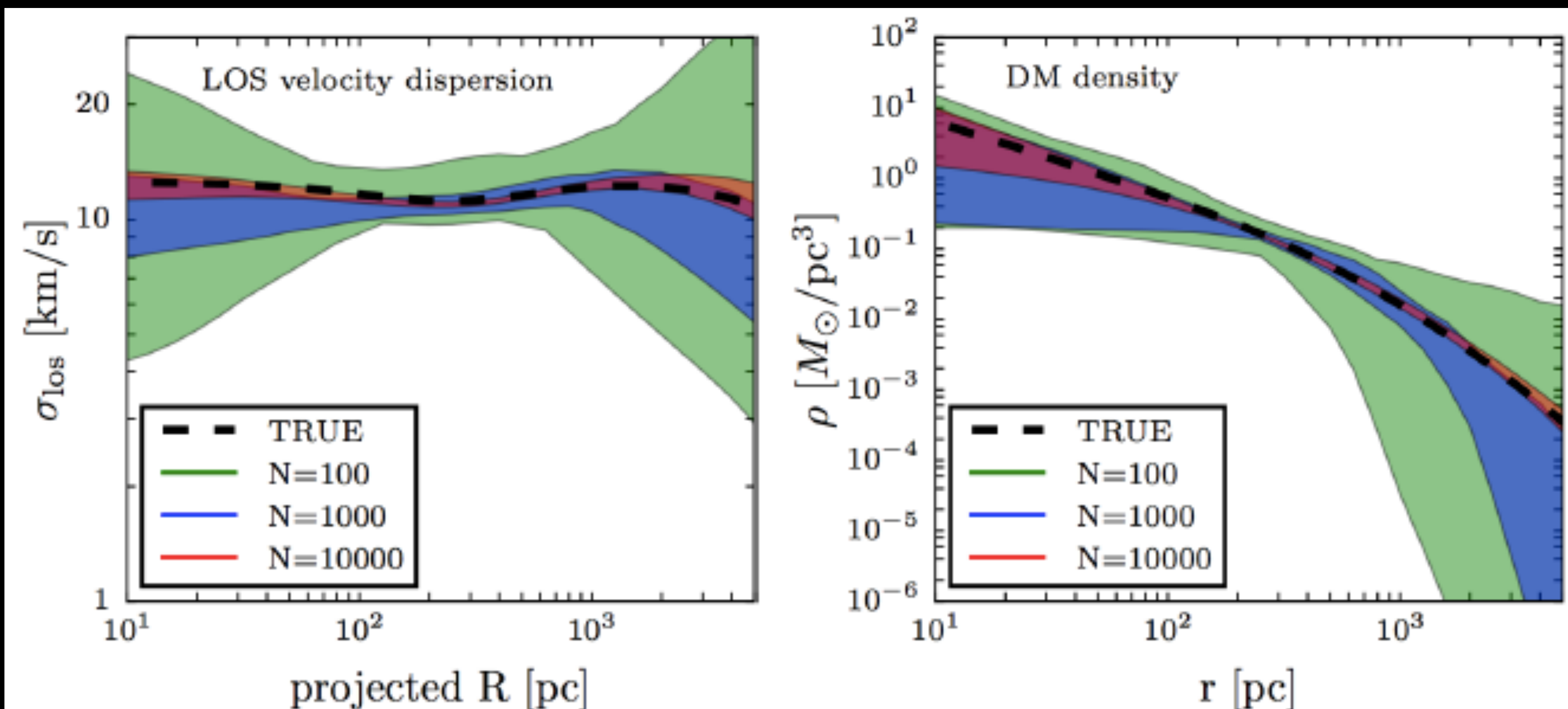
ESO Spectroscopic Facility (Pasquini et al. 2017)

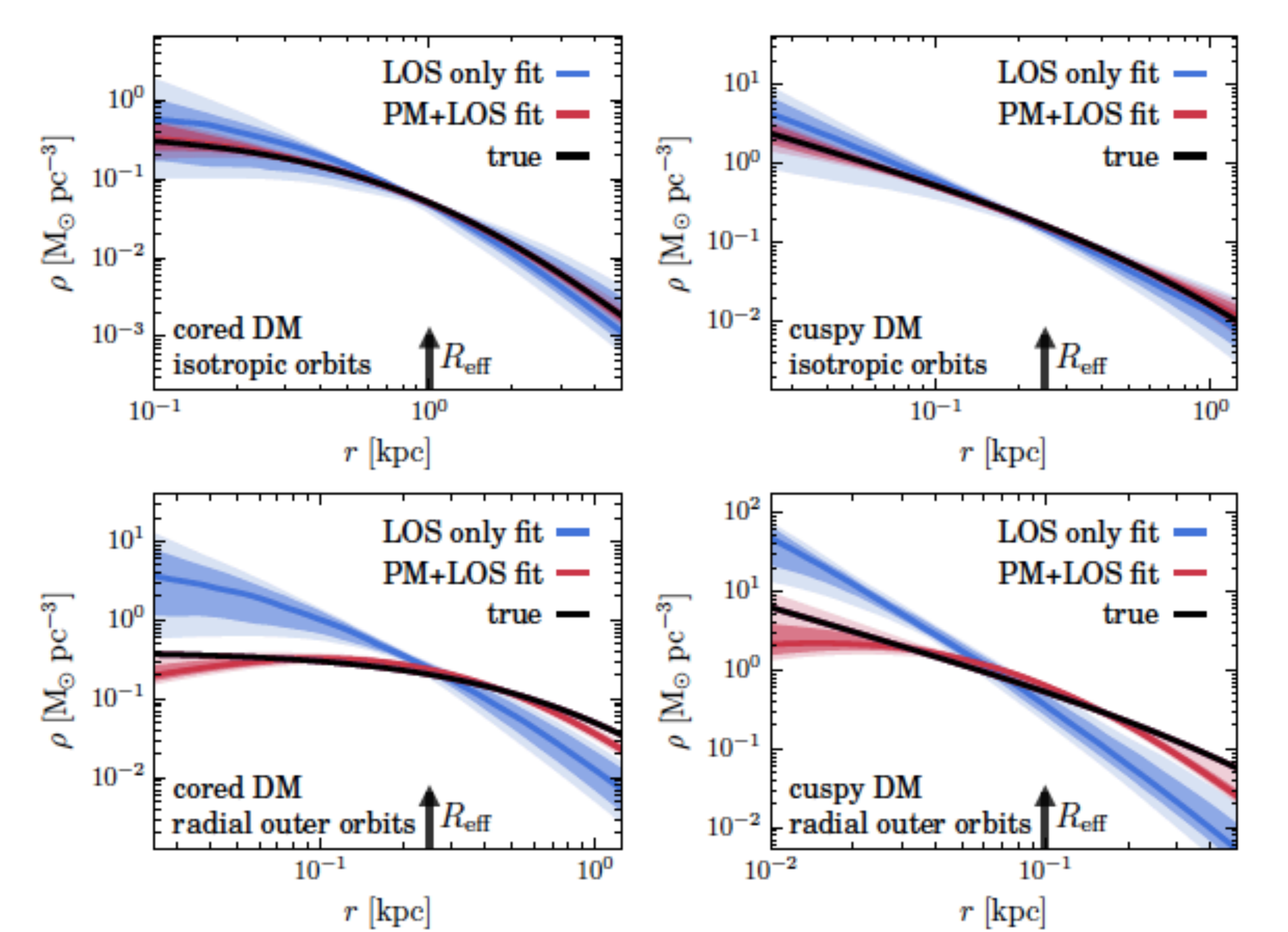


Maunakea Spectroscopic Explorer

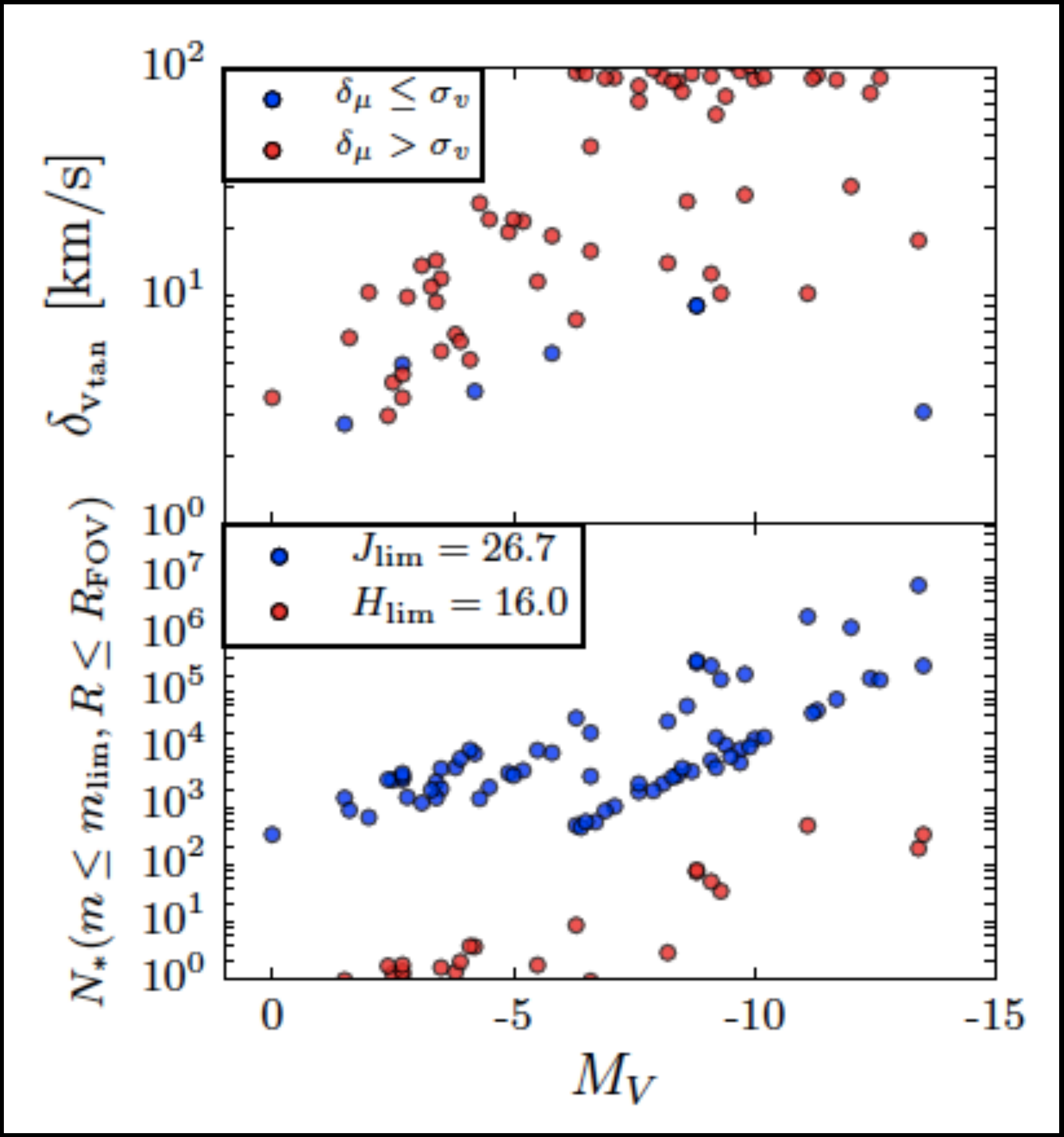
A concise overview of the
Maunakea Spectroscopic Explorer

McConnachie et al. arXiv:106.00060




LOS only fit
PM+LOS fit
true
cored DM
isotropic orbits
$R_{\rm eff}$
ρ [$M_\odot$ pc^{-3}]
r [kpc]
LOS only fit
PM+LOS fit
true
cuspy DM
isotropic orbits
$R_{\rm eff}$
ρ [$M_\odot$ pc^{-3}]
r [kpc]
LOS only fit
PM+LOS fit
true
cored DM
radial outer orbits
$R_{\rm eff}$
ρ [$M_\odot$ pc^{-3}]
r [kpc]
LOS only fit
PM+LOS fit
true
cuspy DM
radial outer orbits
$R_{\rm eff}$
ρ [$M_\odot$ pc^{-3}]
r [kpc]

rough forecast for WFIRST proper motions



assumes precision of 25 uas/yr over 5 years

Summary

» measurement of dSph velocity dispersions is not trivial: systematic and random errors often similar to intrinsic dispersions

» can improve right now with better analysis of multi-epoch data sets

» quantitative and qualitative improvements to come with next generation(s) of telescopes