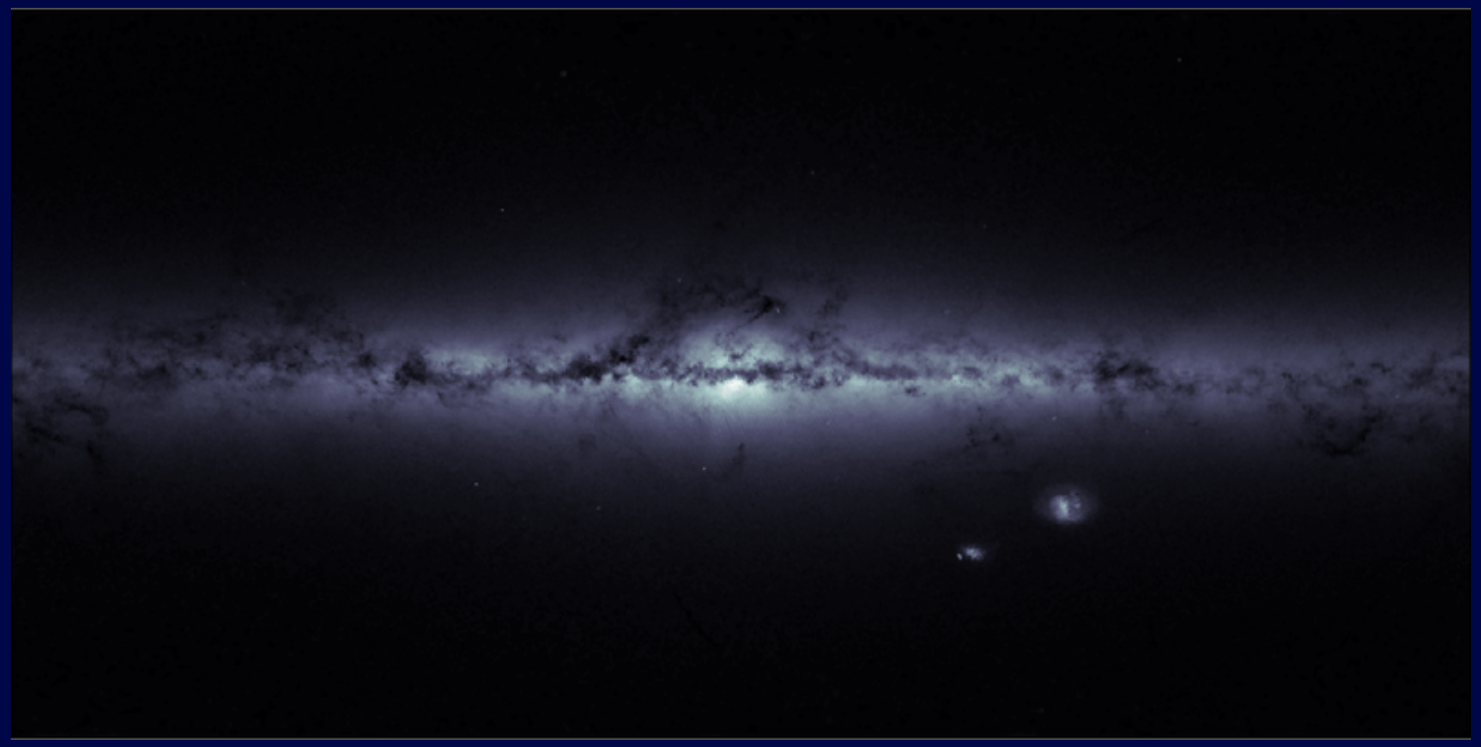
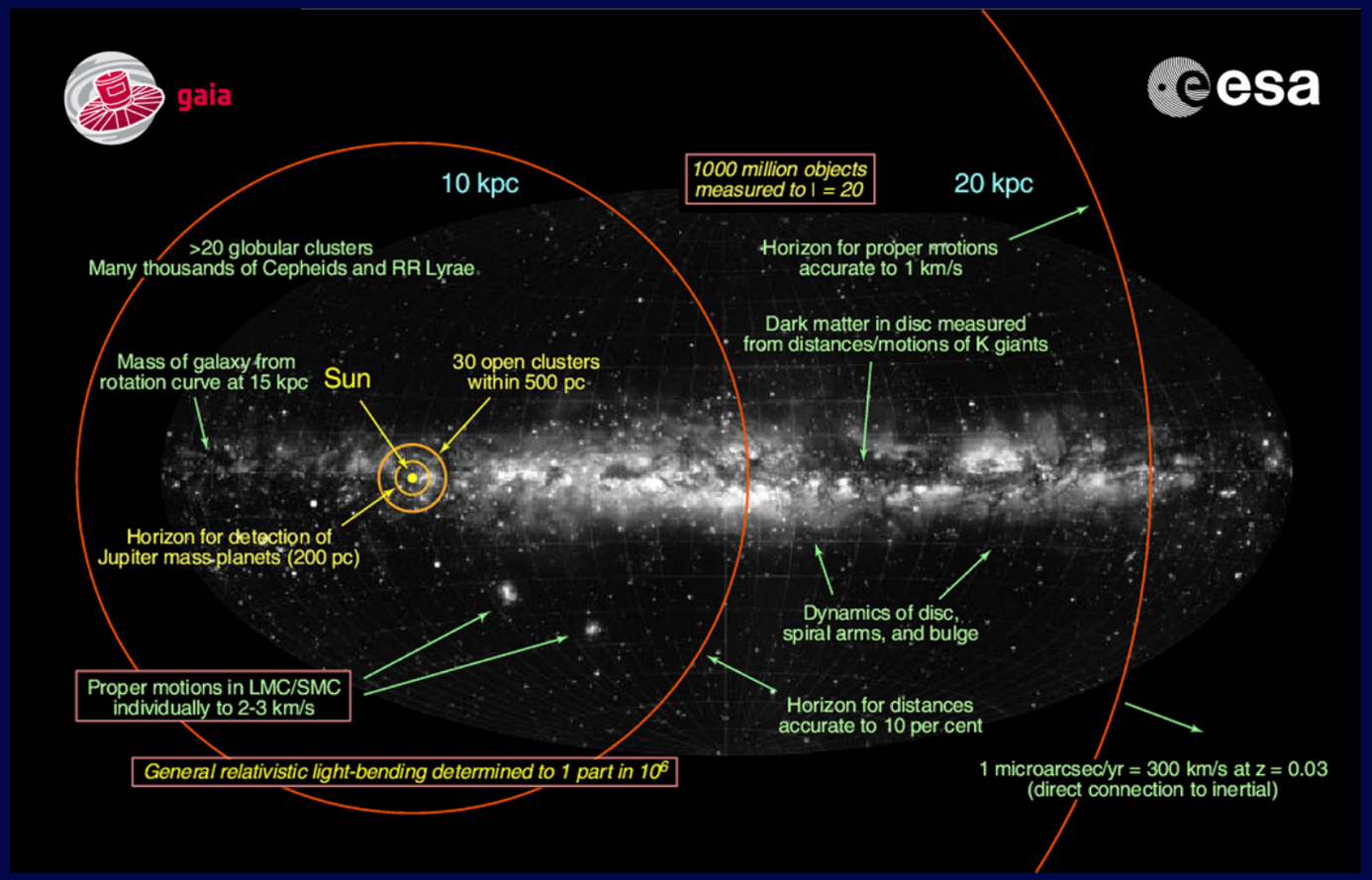
Can we better constrain the nature of Dark Matter with new observations?

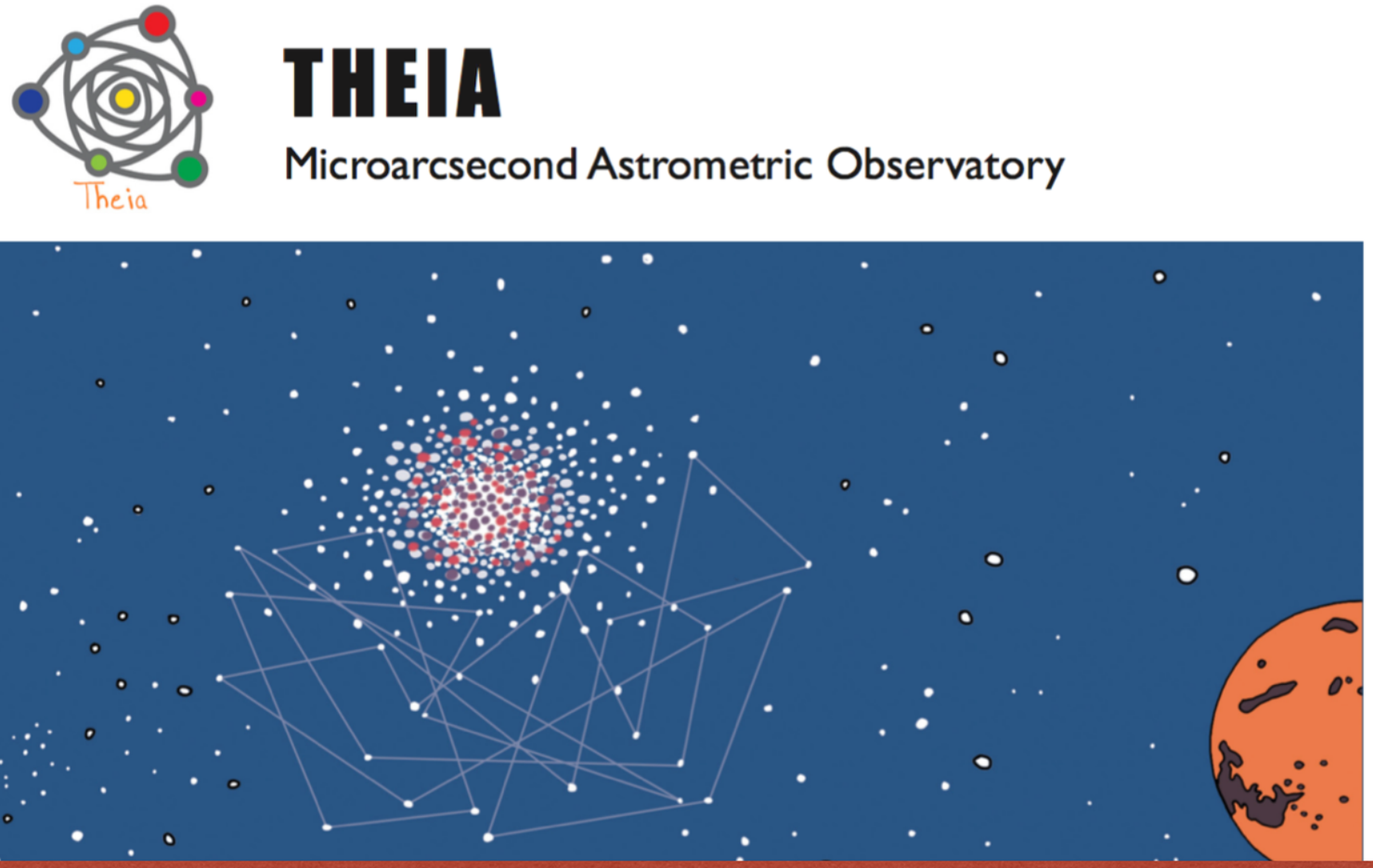
Possible issues with Cold Dark Matter

- Cusps in galaxy centers
- Numerous subhalos
- Prolate halos

Gaia




gaia
esa
10 kpc
1000 million objects measured to I = 20
20 kpc
>20 globular clusters
Many thousands of Cepheids and RR Lyrae
Horizon for proper motions accurate to 1 km/s
Dark matter in disc measured from distances/motions of K giants
Mass of galaxy from rotation curve at 15 kpc
Sun
30 open clusters within 500 pc
Horizon for detection of Jupiter mass planets (200 pc)
Dynamics of disc, spiral arms, and bulge
Proper motions in LMC/SMC individually to 2-3 km/s
Horizon for distances accurate to 10 per cent
General relativistic light-bending determined to 1 part in 10^6
1 microarcsec/yr = 300 km/s at z = 0.03
(direct connection to inertial)



Astrometric satellite with 100x Gaia's accuracy

PI: Céline Bohm (Durham)
Co-PI: Alberto Krone-Martins (Lisbon)

Faint objects in motion : the new astrometry frontier

Proposal for a medium size mission opportunity in ESA's science programme (M5) mission

Astrometric mission: 30x Gaia's accuracy

	Gaia post-launch	Theia	improvement
Telescope Aperture	1.45 x 0.5 = 0.73 m^2	0.8 m → 0.40 m^2	**0.55**
Field of view		0.6 deg	
Coverage	Survey	Pointed	
Astrometry	Global	Differential	
Exposure time per field	76 x 9 (CCD) x 4.4 sec	20 x 50 hr = 1000 hr	**1200**

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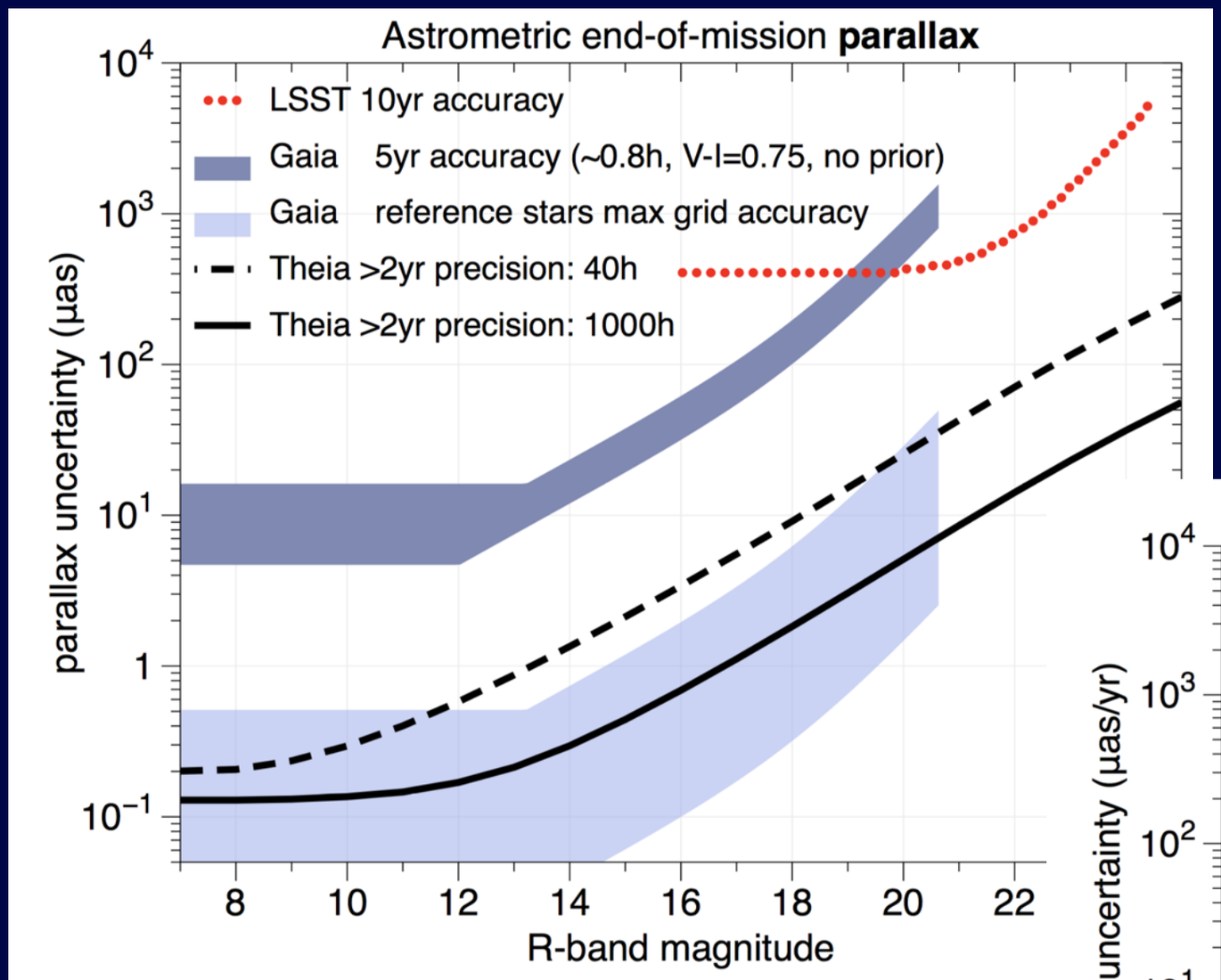
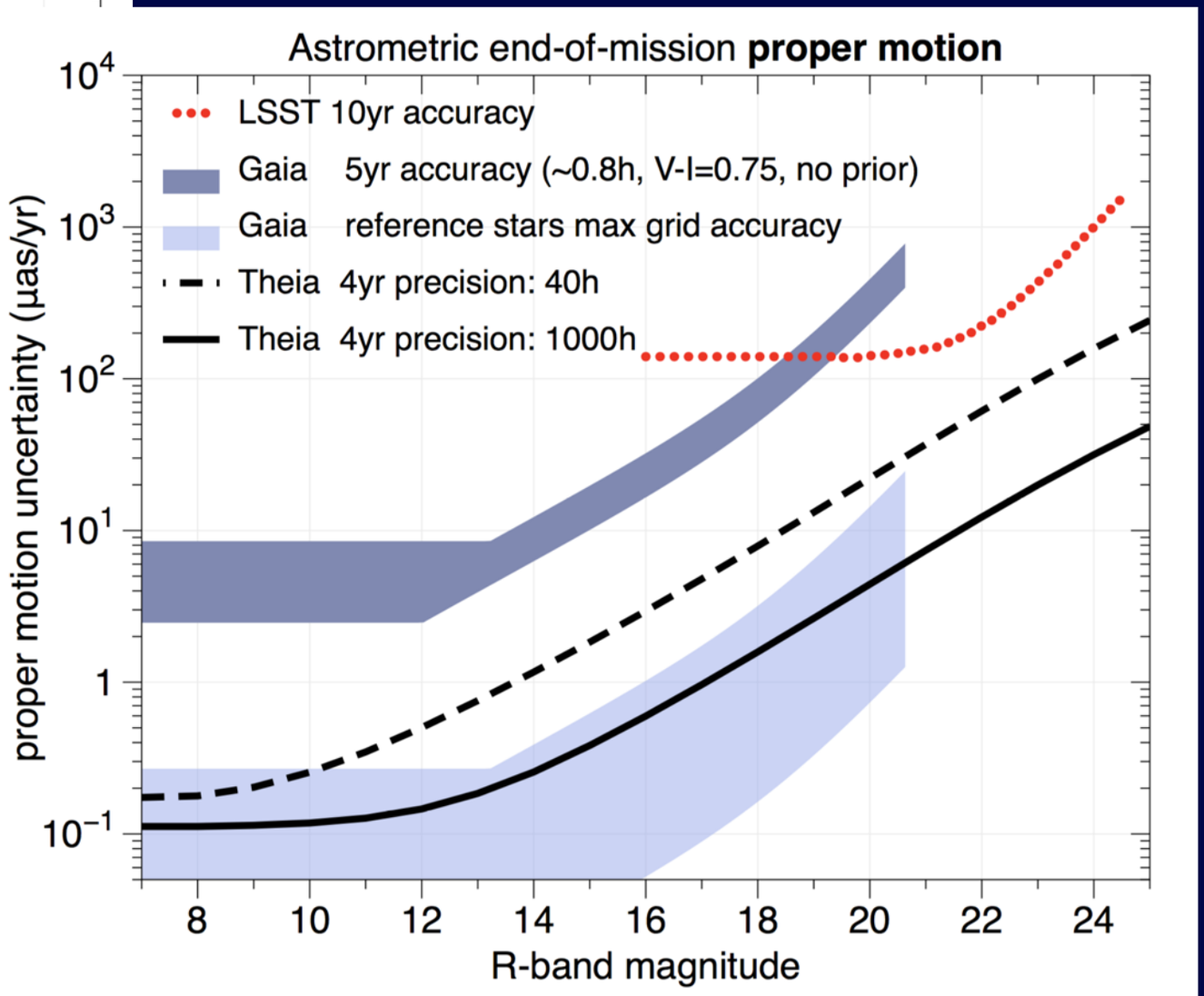
Additional factors	2D vs 1D astrometry: 1.4, Gaia Stray light: 1.9, non-uniform sampling: 1.6		
Proper motion accuracy *G*=10 star	3.5 μas/yr	0.03 μas/yr	119
Proper motion accuracy *G*=15 star	14 μas/yr	0.23 μas/yr	60
Proper motion accuracy *G*=20 star	330 μas/yr	2.8 μas/yr	118

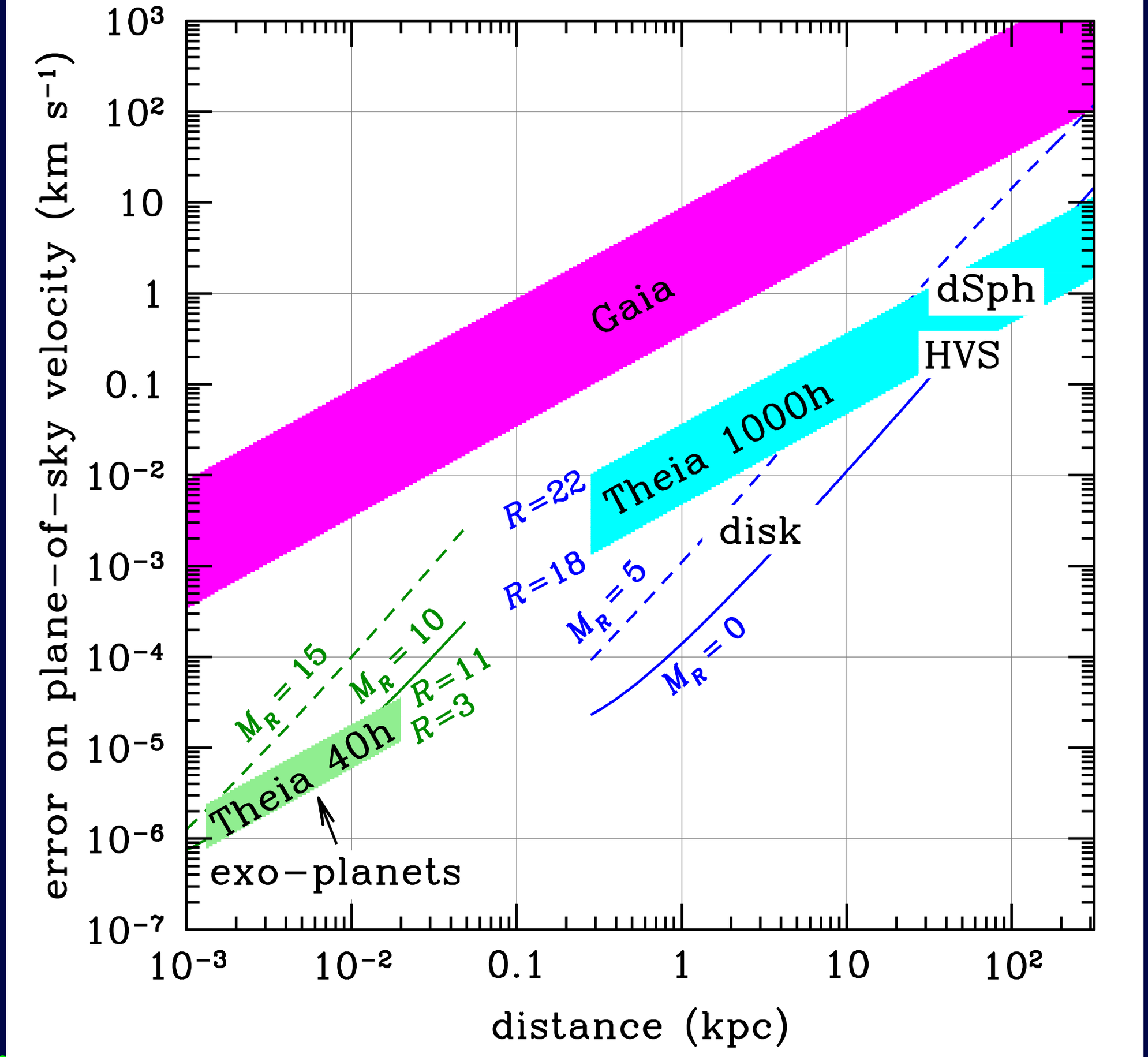
naïve global gain = $(0.55 \times 1200)^{1/2} = 26$ ➜ **110** after additional factors

Precision vs. magnitude

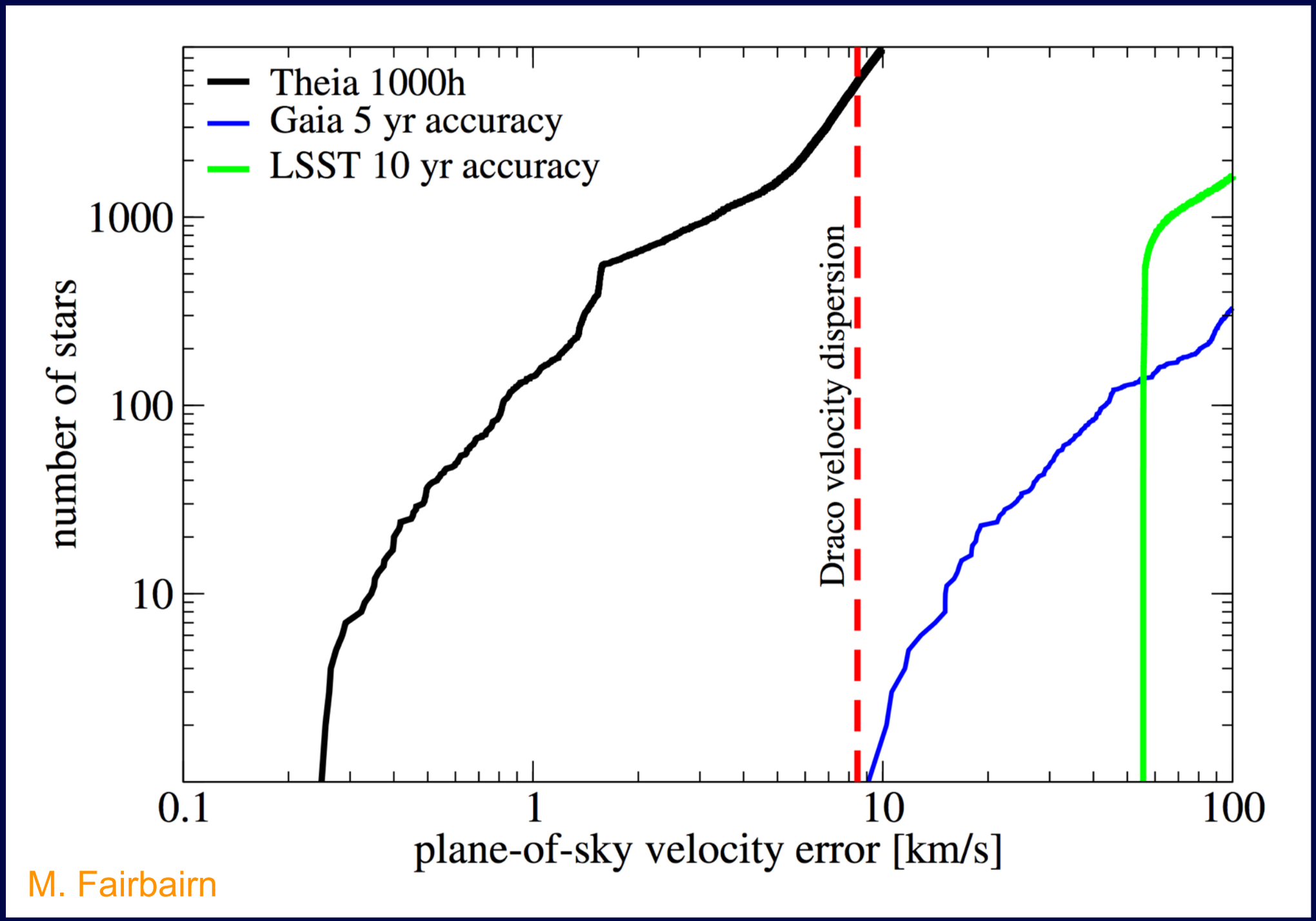




what science?

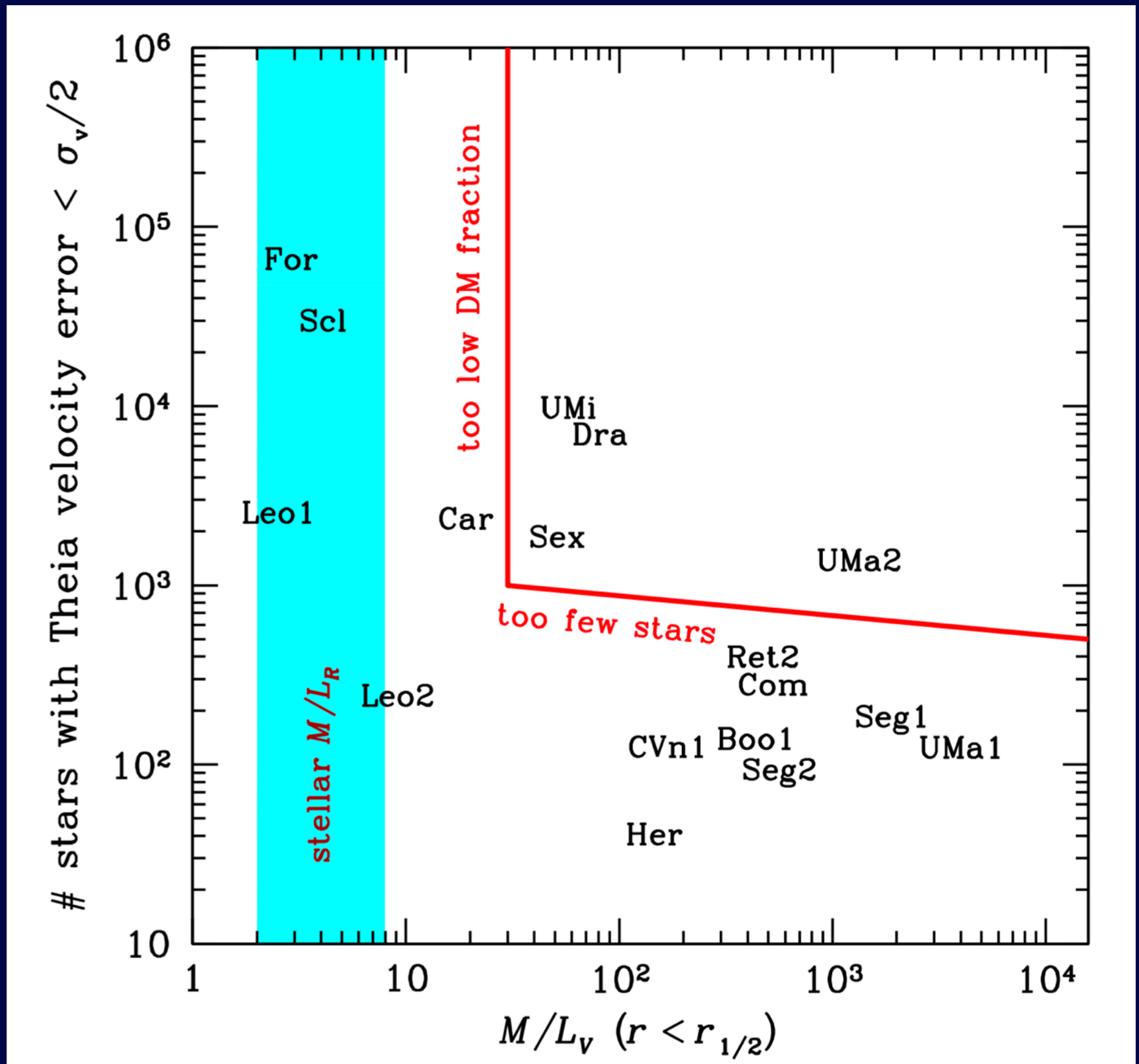


dwarf spheroidal galaxies: numbers of stars for Draco



M. Fairbairn

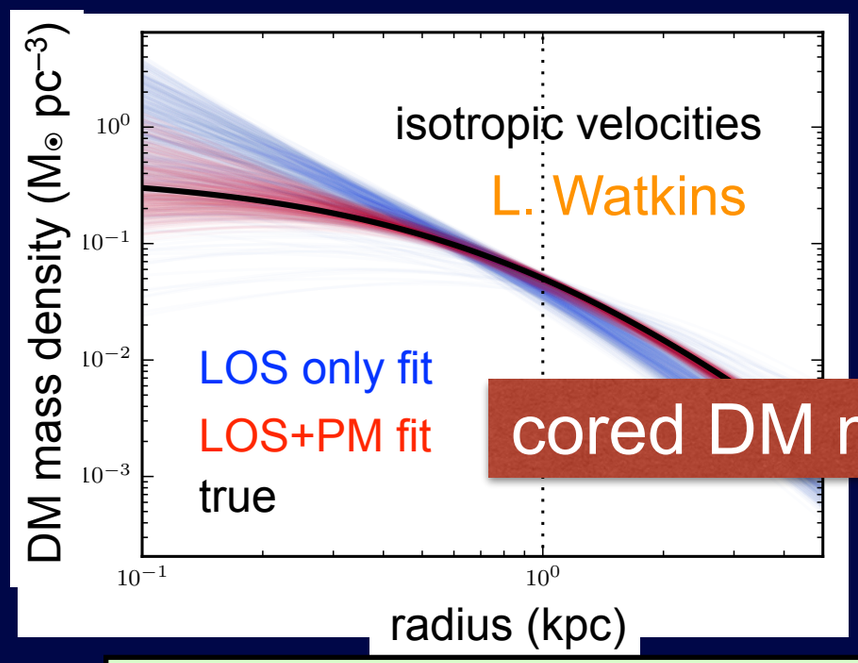
numbers of stars per dSph



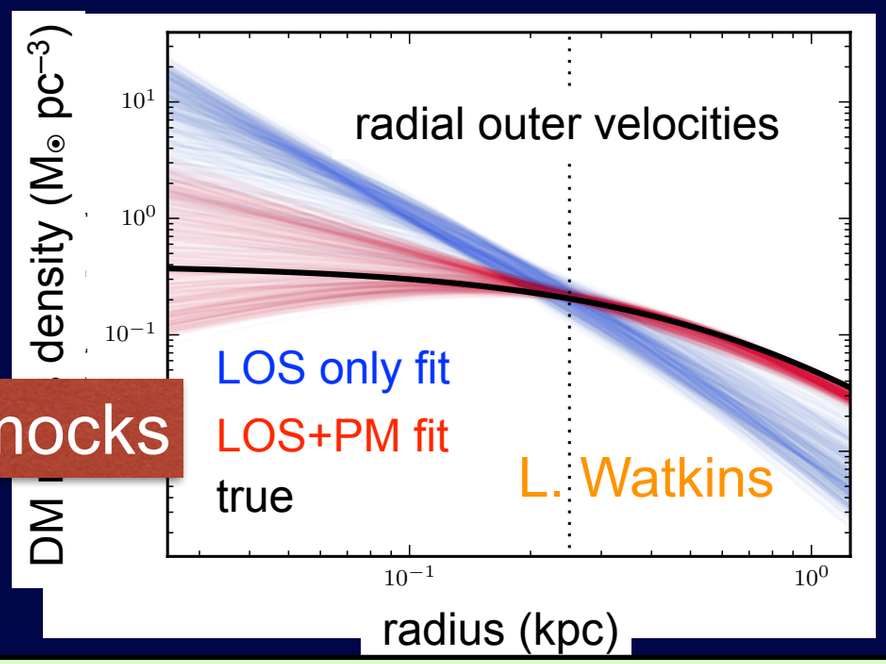
Dark Matter (DM) in mock dwarf Spheroidal galaxies without & with proper motions

Gaia Challenge: mocks from M. Walker; with J. Read & L. Watkins

Mass-orbit modeling (Jeans equation) of mock dSph galaxies → DM density profiles



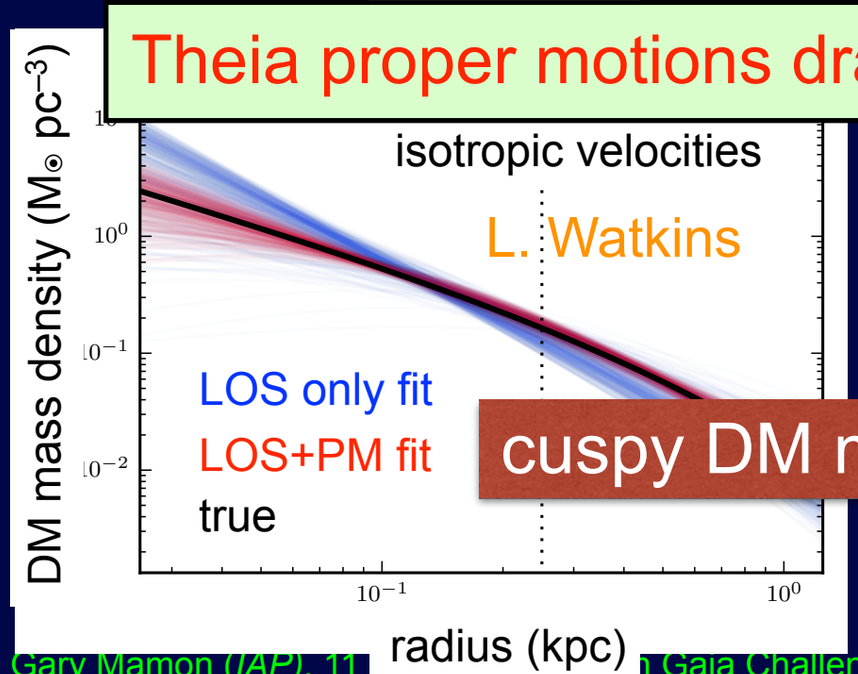
cored DM mocks



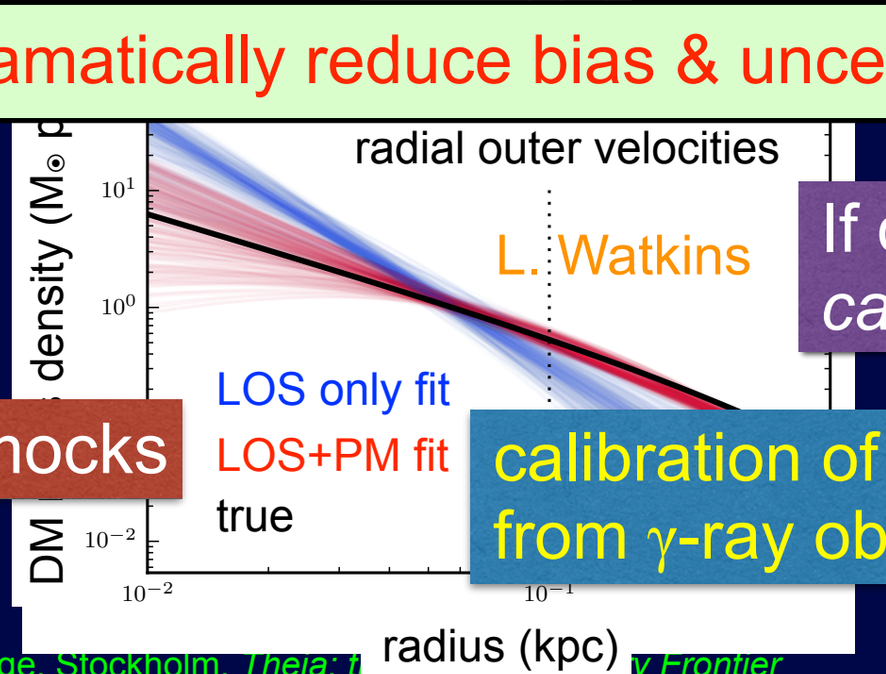
dSph = DM-dominated velocity dispersion: $\sigma_v \approx 10$ km/s

Theia proper motions → $\Delta v = 3$ km/s

Theia proper motions dramatically reduce bias & uncertainty on inner DM slope!



cuspy DM mocks

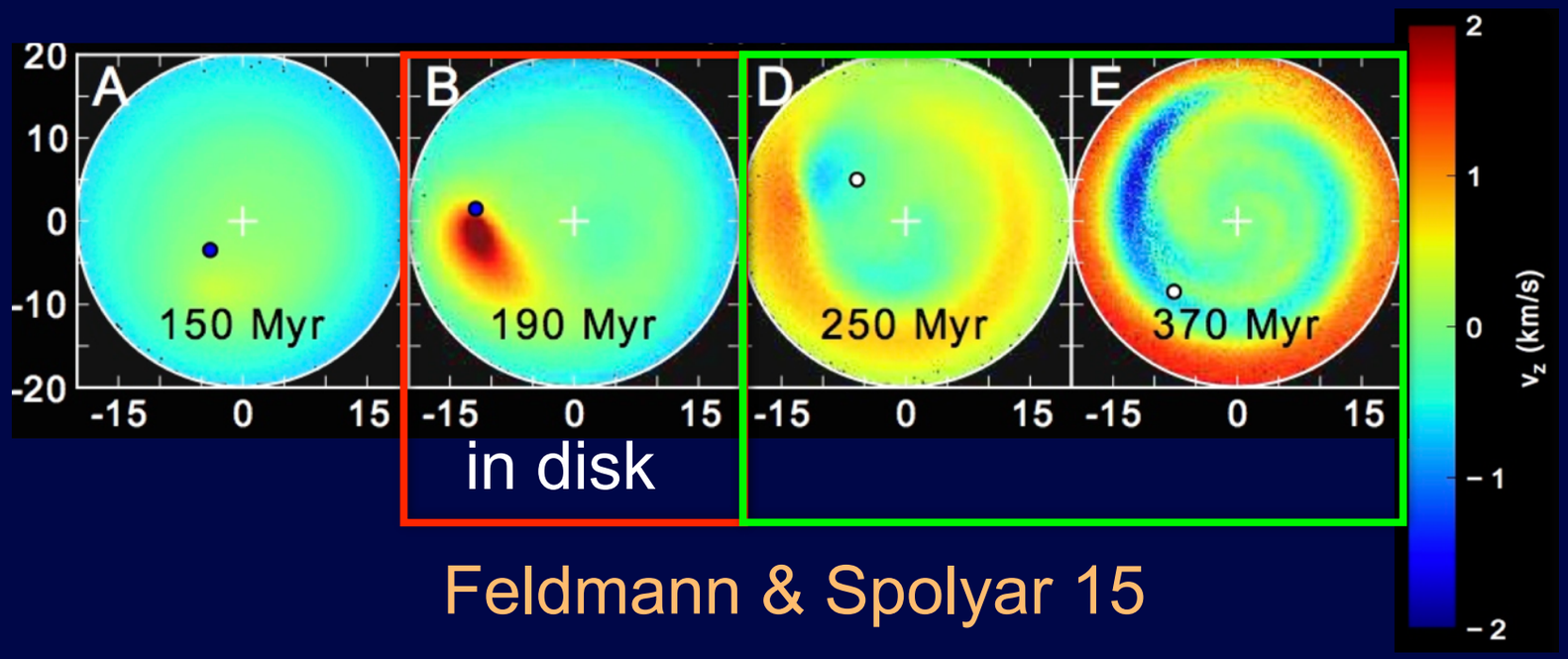


If cores found in ~all dSphs: *case for interacting DM*

calibration of DM annihilation x-section from γ-ray obs of dSph galaxies

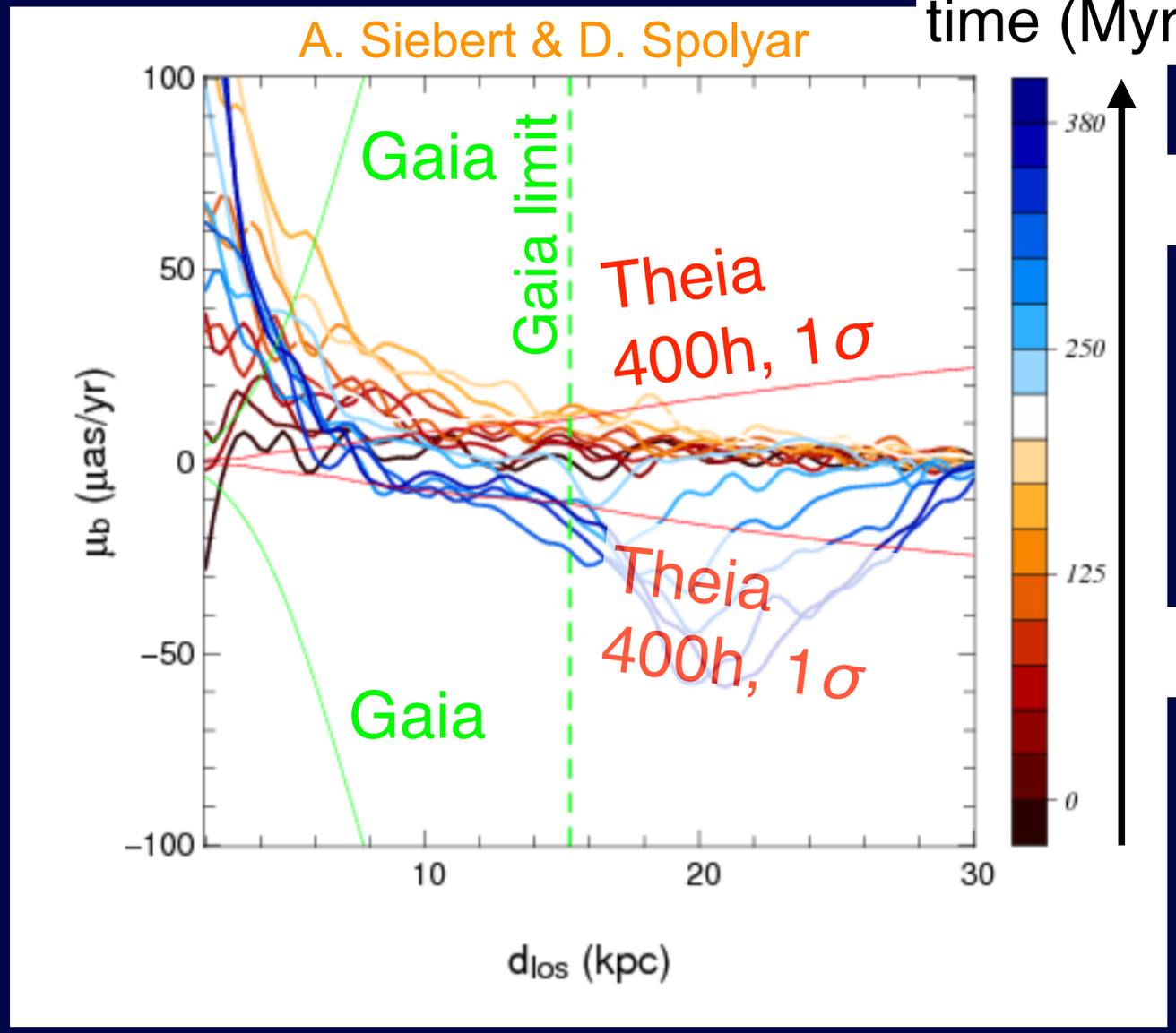
Detecting subhalos in Milky Way

Largest effect when subhalo passes through disk | still visible after 1st passage



Feldmann & Spolyar 15

Detecting subhalos in Milky Way



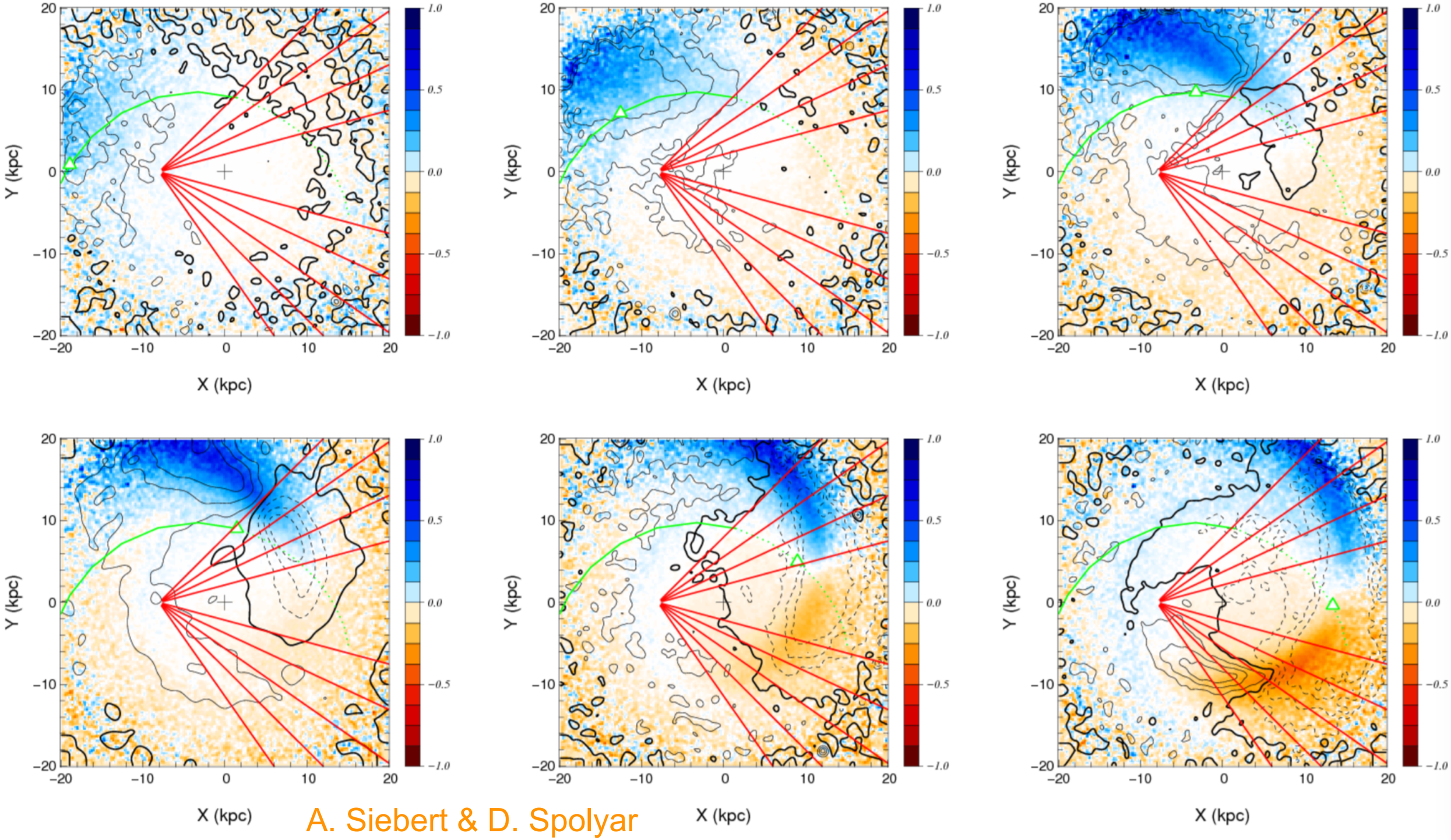
after disk crossing

before disk crossing

Gaia can detect log M = 8 subhalos (rare: closest at 3 kpc)
Theia (20 LOS in 2 yr) can unambiguously detect log M = 6.7 subhalos
→ avoid confusion with other perturbers

If no subhalos found: *case for Warm Dark Matter*

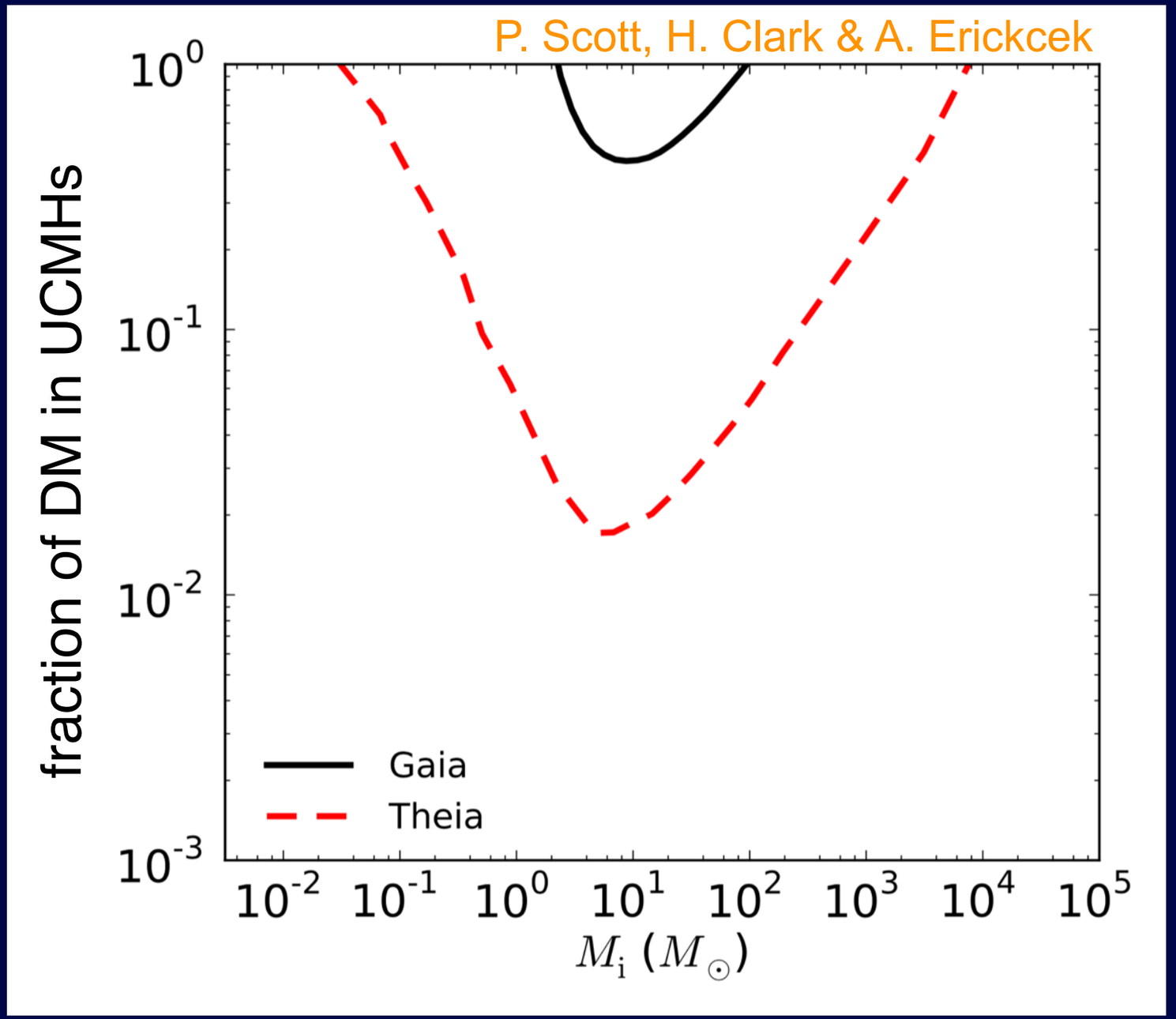
tomography of halo substructure



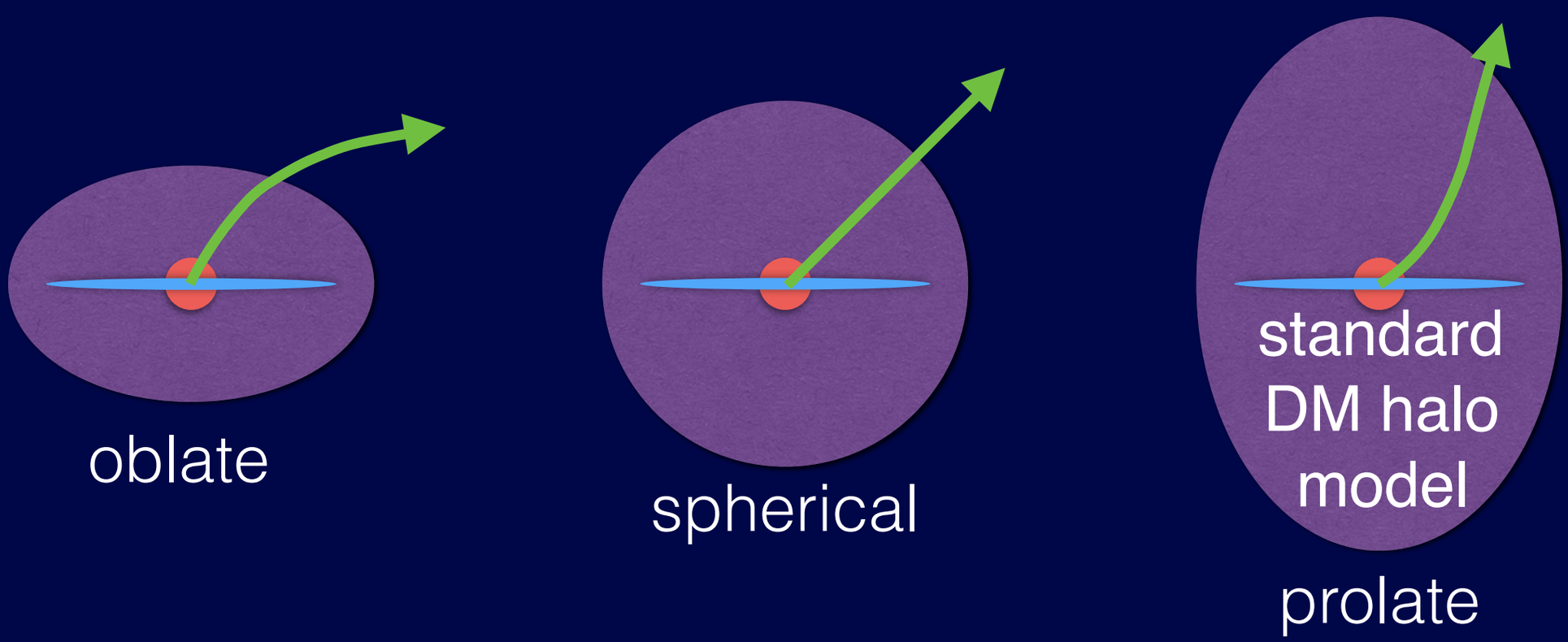
A. Siebert & D. Spolyar

Detecting Ultra-Compact Minihalos in Milky Way

by micro-lensing



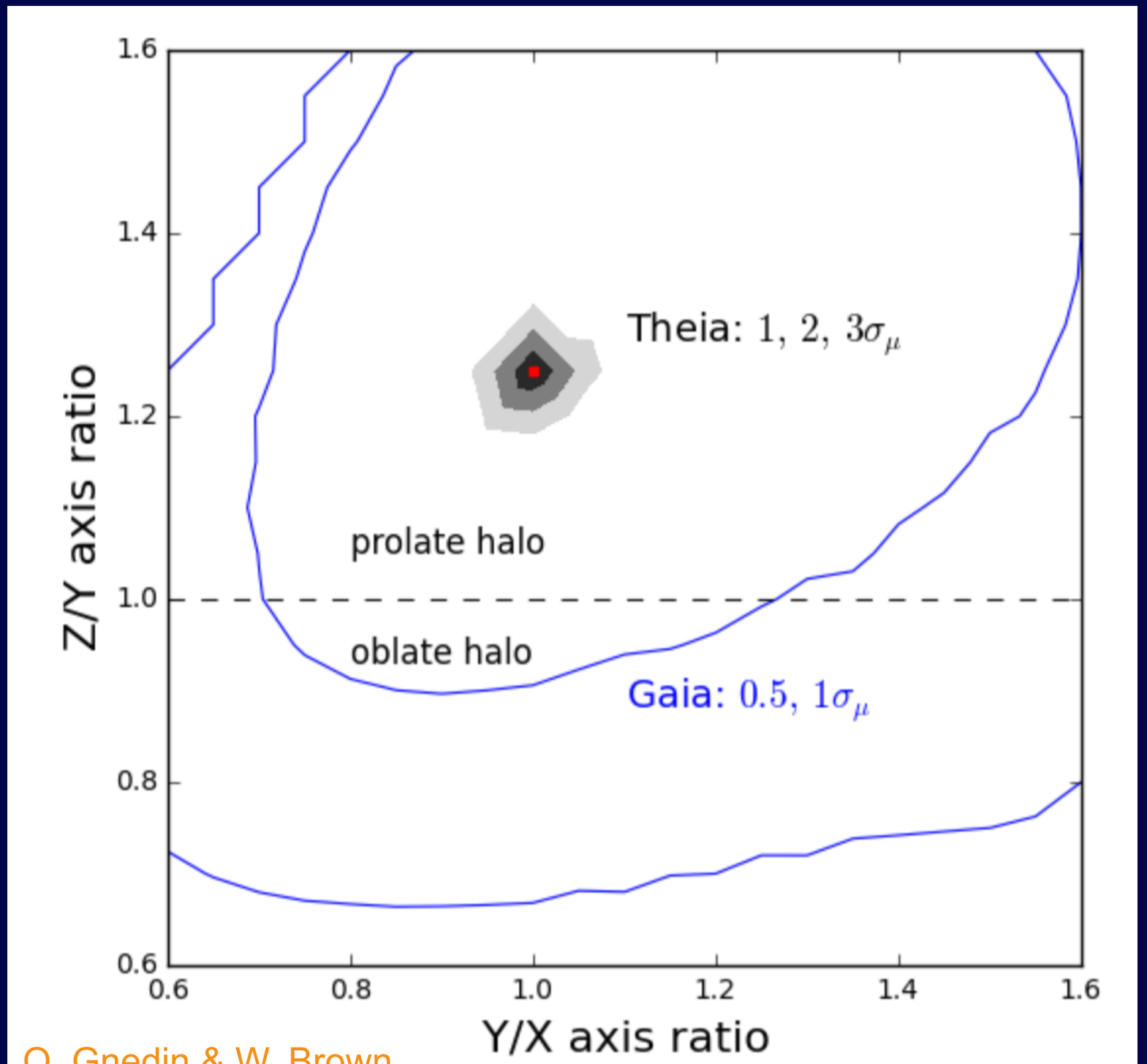
Shape of outer Dark Matter halo of Milky Way using Hypervelocity stars



10 μas/yr accuracy required Gnedin+05

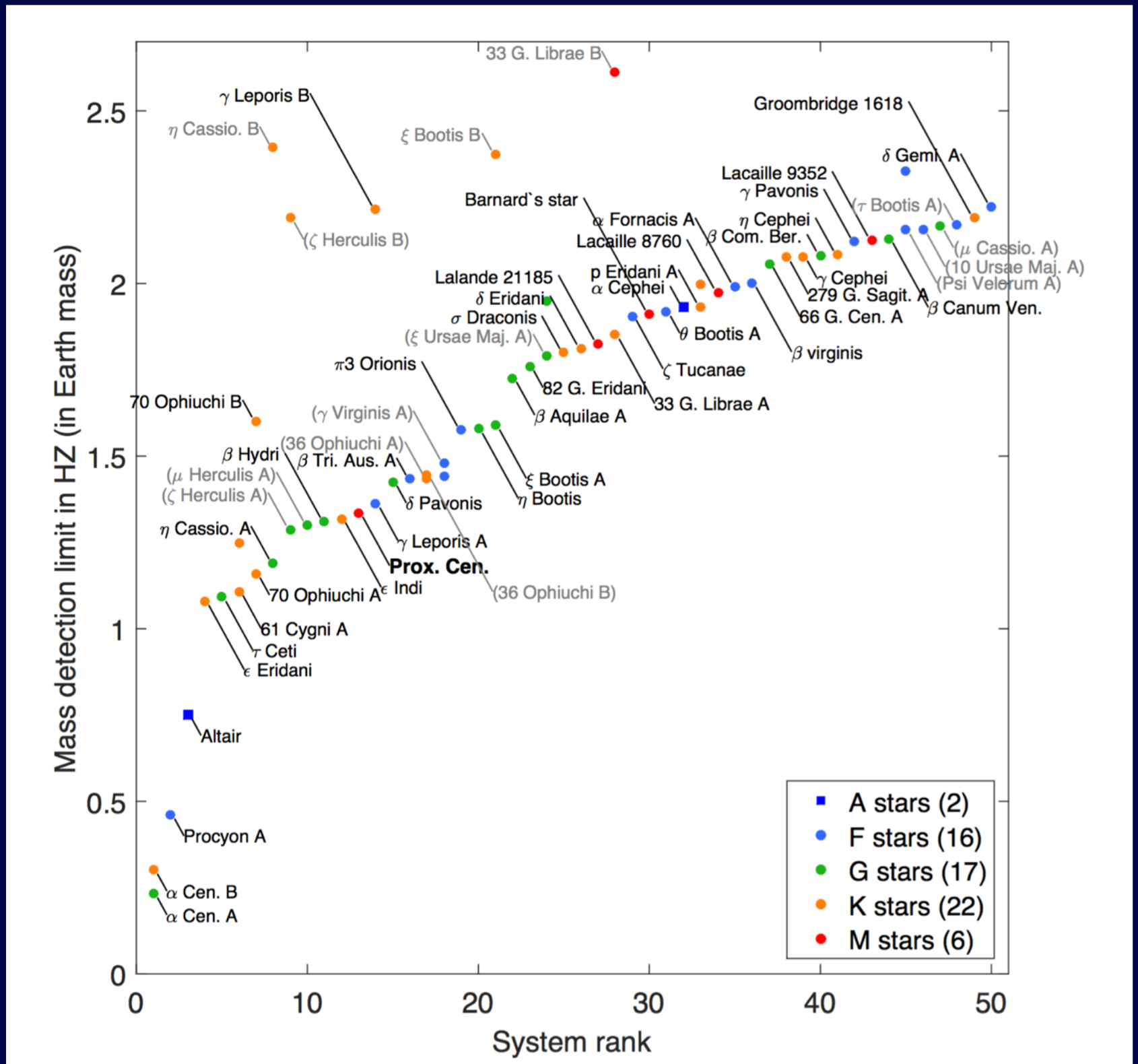
> 20 Hyper-Velocity Stars known (v_{LOS} > 500 km/s)
Brown+05,…,15

Shape of outer Dark Matter halo of Milky Way using Hypervelocity stars

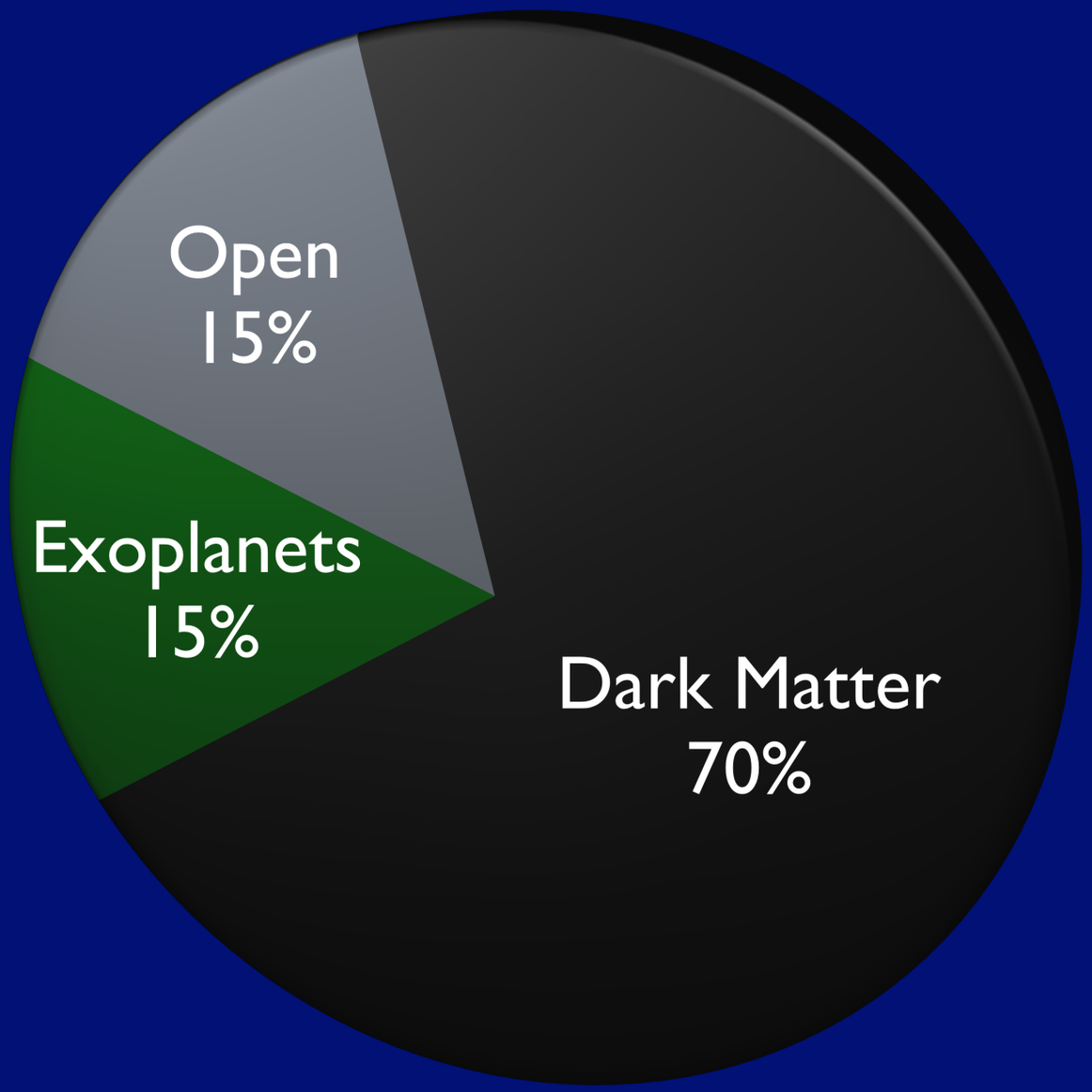


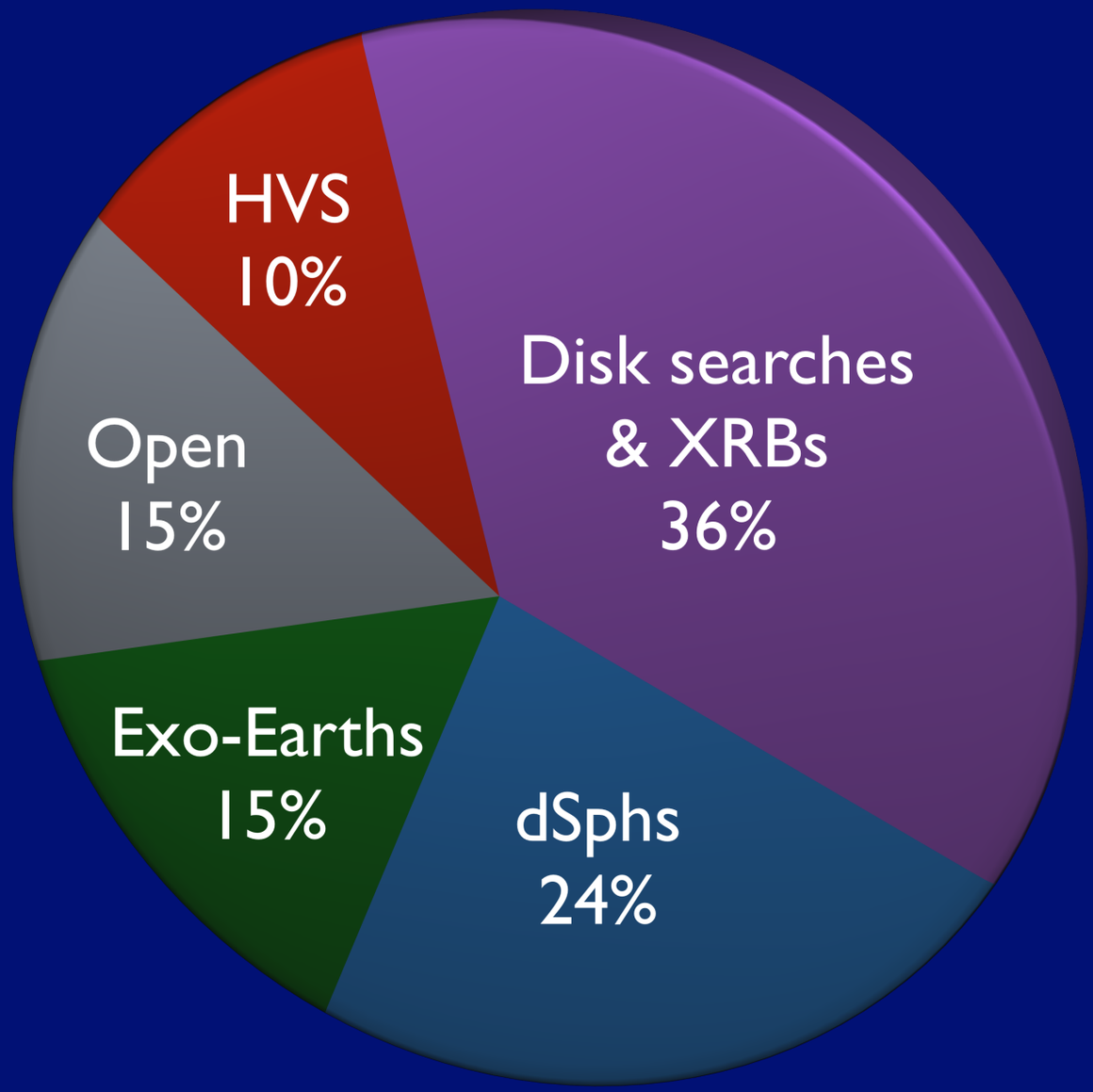
O. Gnedin & W. Brown

Habitable exo-Earths



Strategy


Open
15%
Exoplanets
15%
Dark Matter
70%

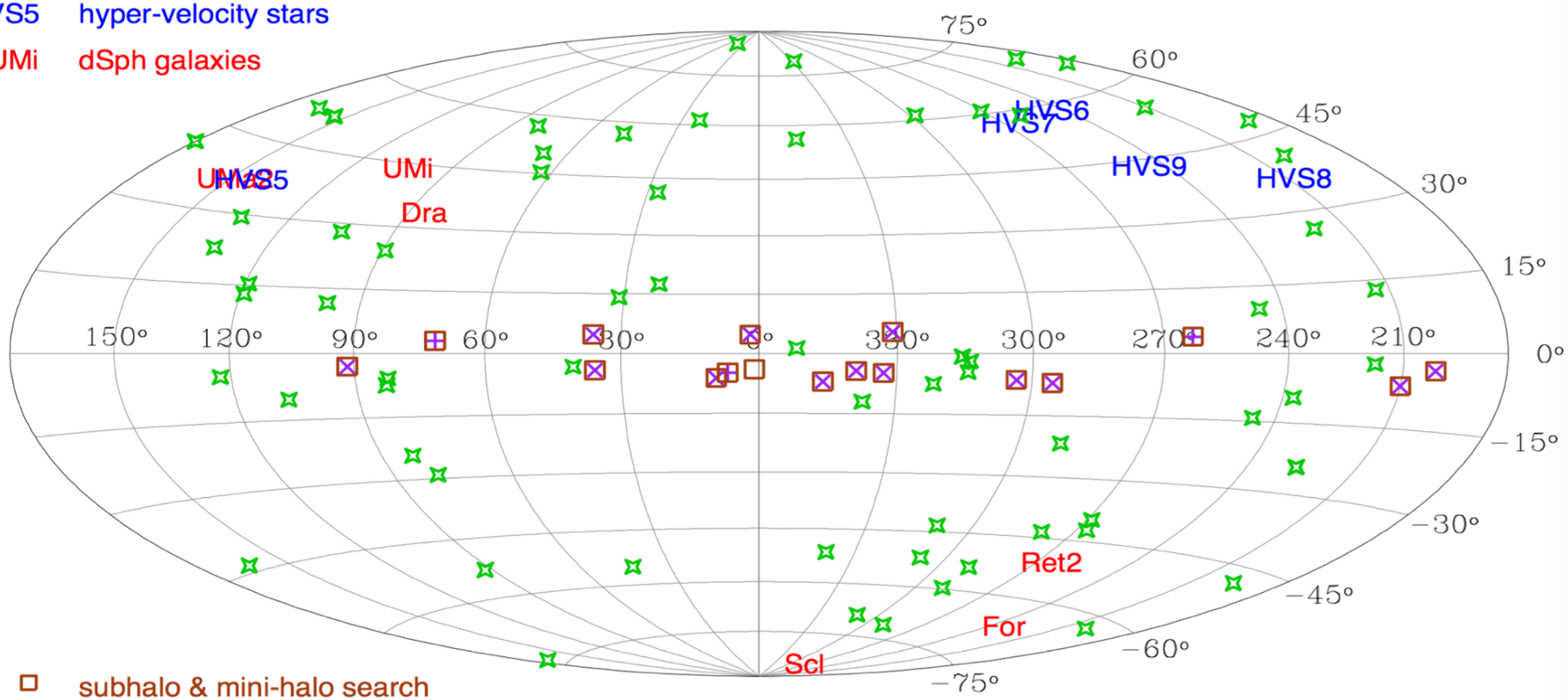

HVS
10%
Disk searches
& XRBs
36%
Open
15%
Exo-Earths
15%
dSphs
24%

Targets

nearest stars for exo-planets

HVS5 hyper-velocity stars

UMi dSph galaxies



subhalo & mini-halo search

× X-ray binaries: distances

\+ X-ray binaries: orbital proper motions

Theia = unique microarcsec telescope

- 1st to probe Dark Matter on small scales
  - ➡ Nature of Dark Matter, discriminate among models

- 1st to directly probe shape of Milky Way Dark Matter halo
  - ➡ should see transition from oblate to prolate

- 1st to detect habitable exo-Earths with high mass accuracy
  - ➡ input for biosphere search followups

- open time (15%) & serendipitous discoveries