Internal proper motions of dwarf spheroidal galaxies:

Constraining the density and properties of dark matter

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Context: Draco & Sculptor

- Determination of the mass **density profiles of the dark matter in dwarf galaxies** provides a critical test of dark matter properties and cosmological structure formation.
- Because of the known **mass vs. velocity-anisotropy $\beta(r)$ degeneracy**, and the lack of statistically significant 2-D or 3-D data, our knowledge of this remains hindered.
- With **18 and 20 years of *HST* data baseline**, we construct proper motions (PMs) for the two nearest dwarf spheroidal galaxies: Draco and Scupltor.
- Our *HST* observations enabled us to measure PMs for over 2,300 stars in Draco and over 700 in Sculptor with per-star **uncertainties below the line-of-sight velocity dispersion (σ_{LOS}) of the galaxy**, such that the individual PM accuracies will be more suitable for a robust determination of the $\beta(r)$ for each dSph.
- We will **soon incorporate *JWST* observations** to decrease the uncertainties on our PMs.

Observations: *HST* & *JWST*

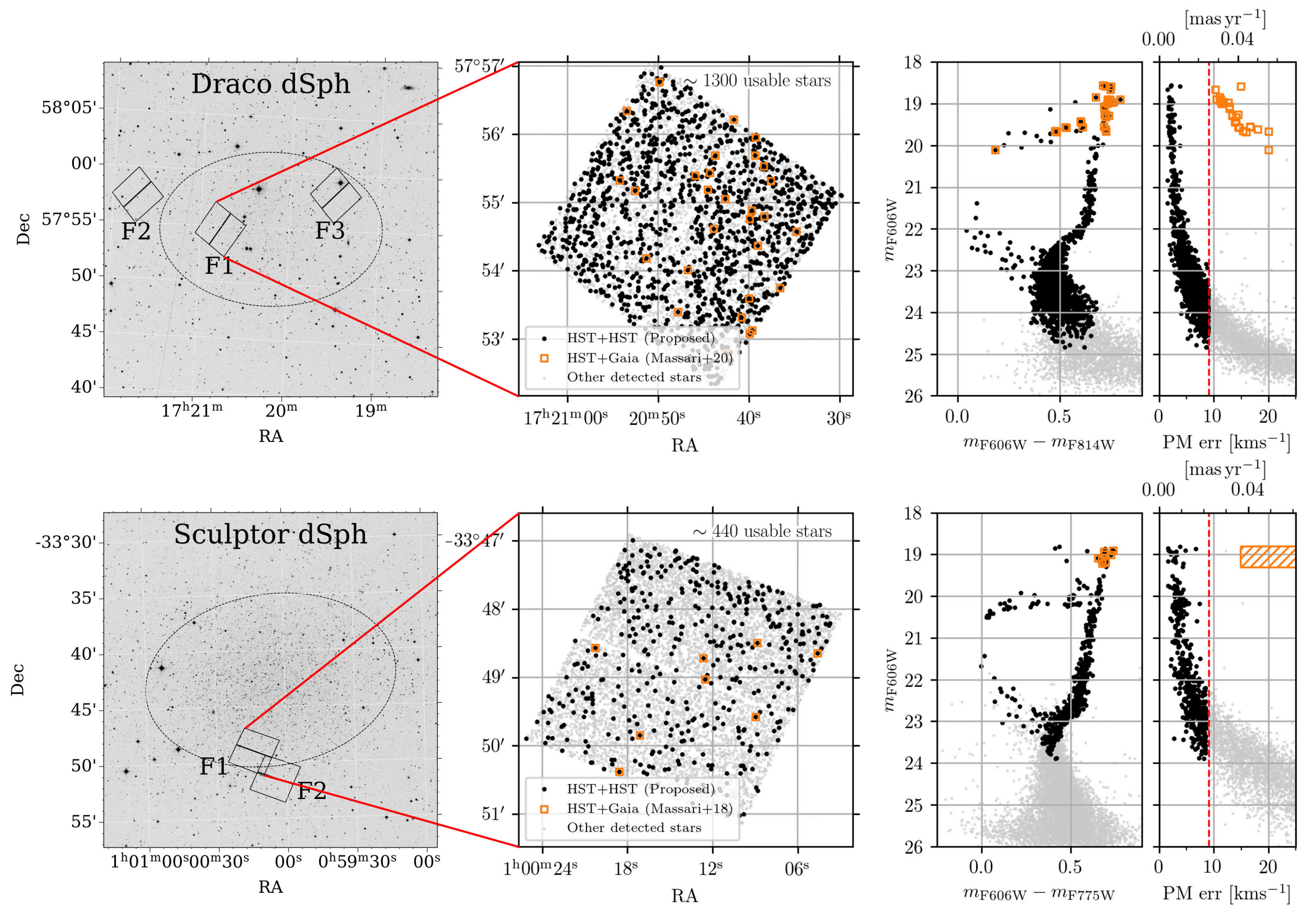

Figure 1: ***HST* programs for Draco and Sculptor** – *Left:* The example target fields show black dots for stars that will have PM accuracies good enough to fulfill our scientific goals. The *HST*+*Gaia* sample used by Massari et al. (2018, 2020) are marked as orange squares, and all other detected stars are in grey. *Right:* CMDs based on *HST* data, using the same symbols as column 2, and the magnitude as a function of PM error. Stars with PM uncertainties lower than the σ_{LOS} of each galaxy ($\sim 9\,\mathrm{km\,s^{-1}}$) are delimited by a *red dashed line.* We show the reported PM uncertainties by Massari et al. (2020) as orange squares for Draco, and the computed PM uncertainty range based on Massari et al. (2018, results for individual stars are not public) as a hatched box for Sculptor.

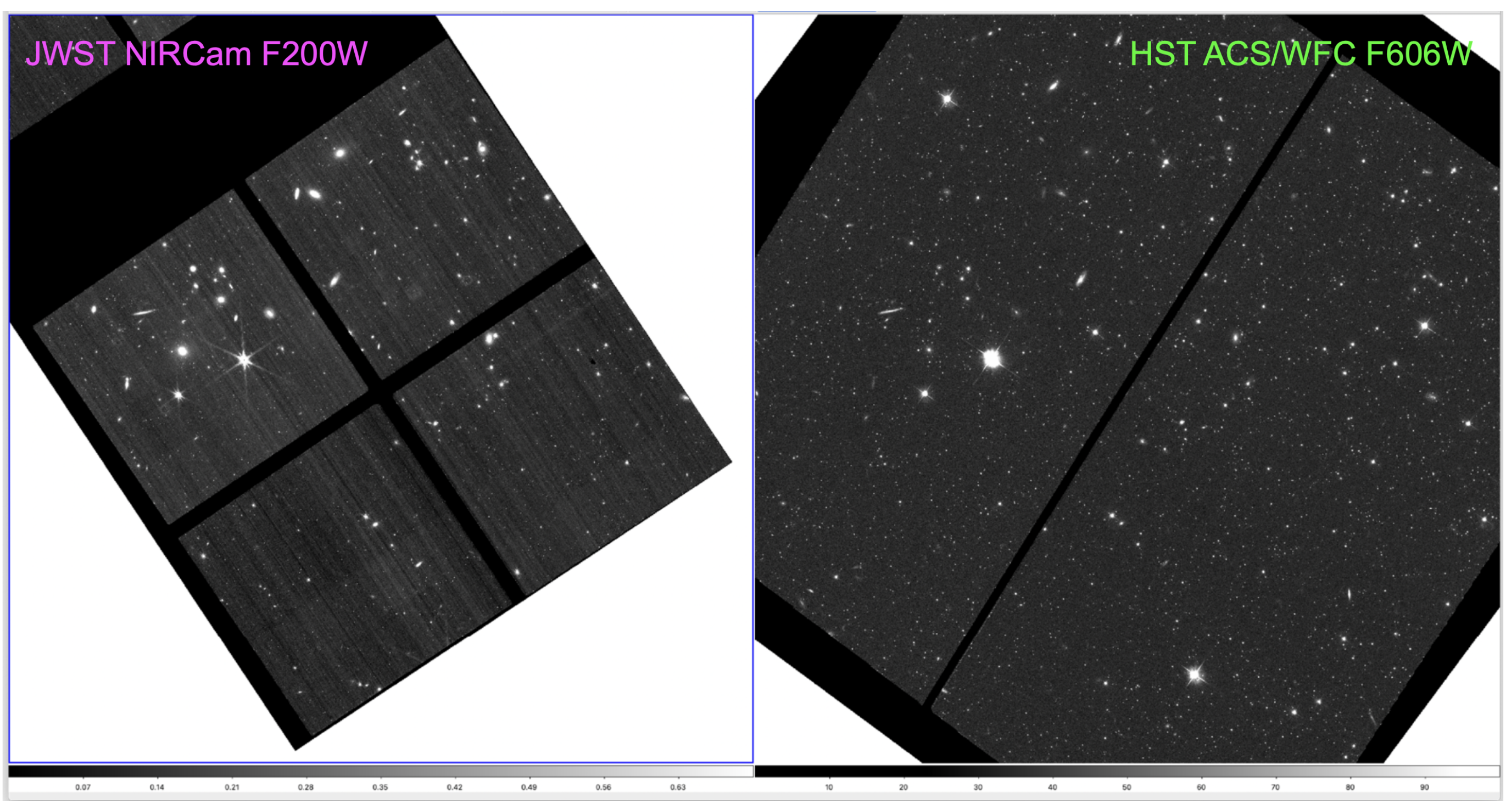

Figure 2: ***JWST* vs. *HST* observations of Draco F1** – We recently acquired extra *JWST* observations of four fields, two of them coinciding with the previous ones, providing a longer baseline.

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Preliminary assessment of Draco–F1: *HST* proper motions

- **We have enough stars to apply a conservative data cleaning**, which in turn yields more reliable results.
- With only one field and without adding our *JWST* observations, we are already able to obtain **much better constraints on the global velocity dispersion than previous works**.

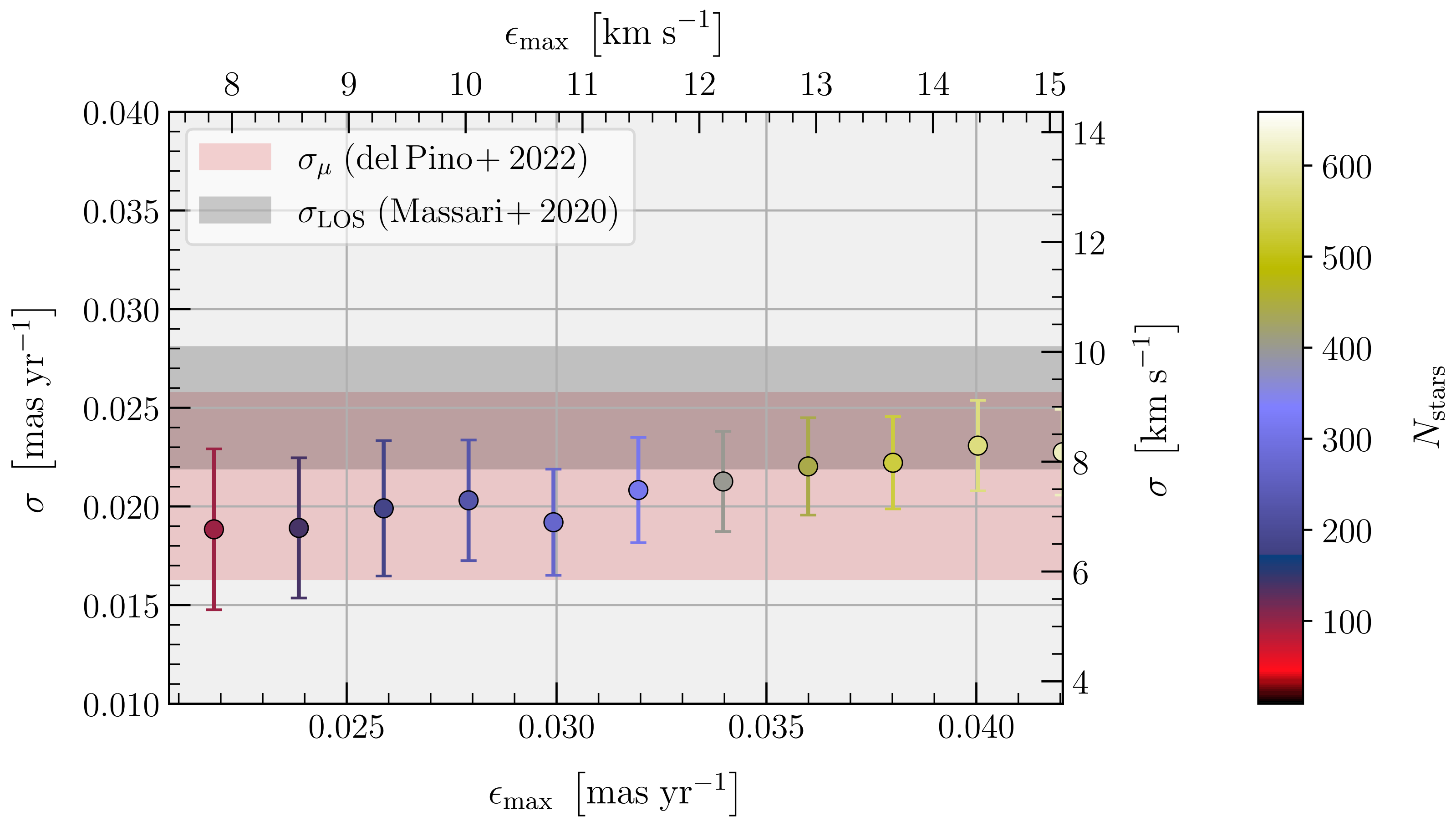

Figure 3: **Low uncertainties** – Computed velocity dispersion of the Draco F1 dataset as a function of the maximum proper motion uncertainty in the data set, colour-coded by the number of stars in each bin. We also display 1-σ estimates of the Draco velocity dispersion in different directions from previous works.

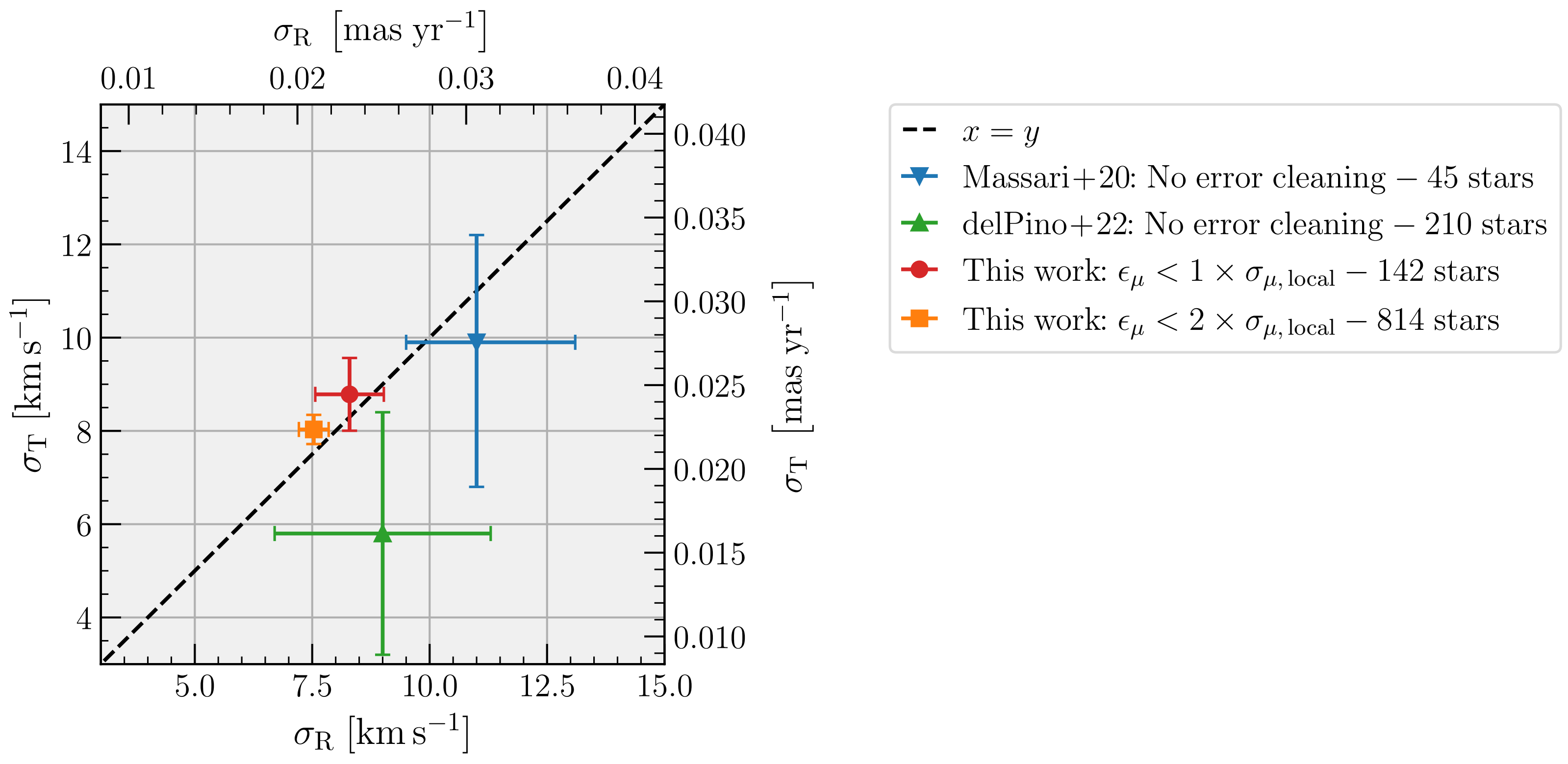

Figure 4: **Projected anisotropy** – We display the velocity dispersions in the plane-of-sky, with the tangential direction in the y-axis and the radial direction in the x-axis. We compare our preliminary assessment of the Draco F1 field (*red circle* and *orange square*) with the works from Massari et al. (2020, *blue upside-down triangle*) and del Pino et al. (2022, *green triangle*). Our new dataset has much better constraints and hints towards a projected tangential anisotropy, differently from the projected radial anisotropy previously measured.

- **Preliminary results** show that the **projected anisotropy seems to be slightly tangential**, in contrast with the radial projected anisotropy estimated in previous works.
- Our **future steps** will be to incorporate the *JWST* data into our measured PMs, and further apply **Jeans modelling techniques to probe the mass and anisotropy profiles** of each dwarf galaxy.

References

del Pino, A., Libralato, M., van der Marel, R. P., Bennet, P., Fardal, M. A., Anderson, J., Bellini, A., Tony Sohn, S., and Watkins, L. L. (2022). GaiaHub: A Method for Combining Data from the Gaia and Hubble Space Telescopes to Derive Improved Proper Motions for Faint Stars. , 933(1):76.

Massari, D., Breddels, M. A., Helmi, A., Posti, L., Brown, A. G. A., and Tolstoy, E. (2018). Three-dimensional motions in the Sculptor dwarf galaxy as a glimpse of a new era. *Nature Astronomy*, 2:156–161.

Massari, D., Helmi, A., Mucciarelli, A., Sales, L. V., Spina, L., and Tolstoy, E. (2020). Stellar 3D kinematics in the Draco dwarf spheroidal galaxy. , 633:A36.

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