# Astrometry - discussion session

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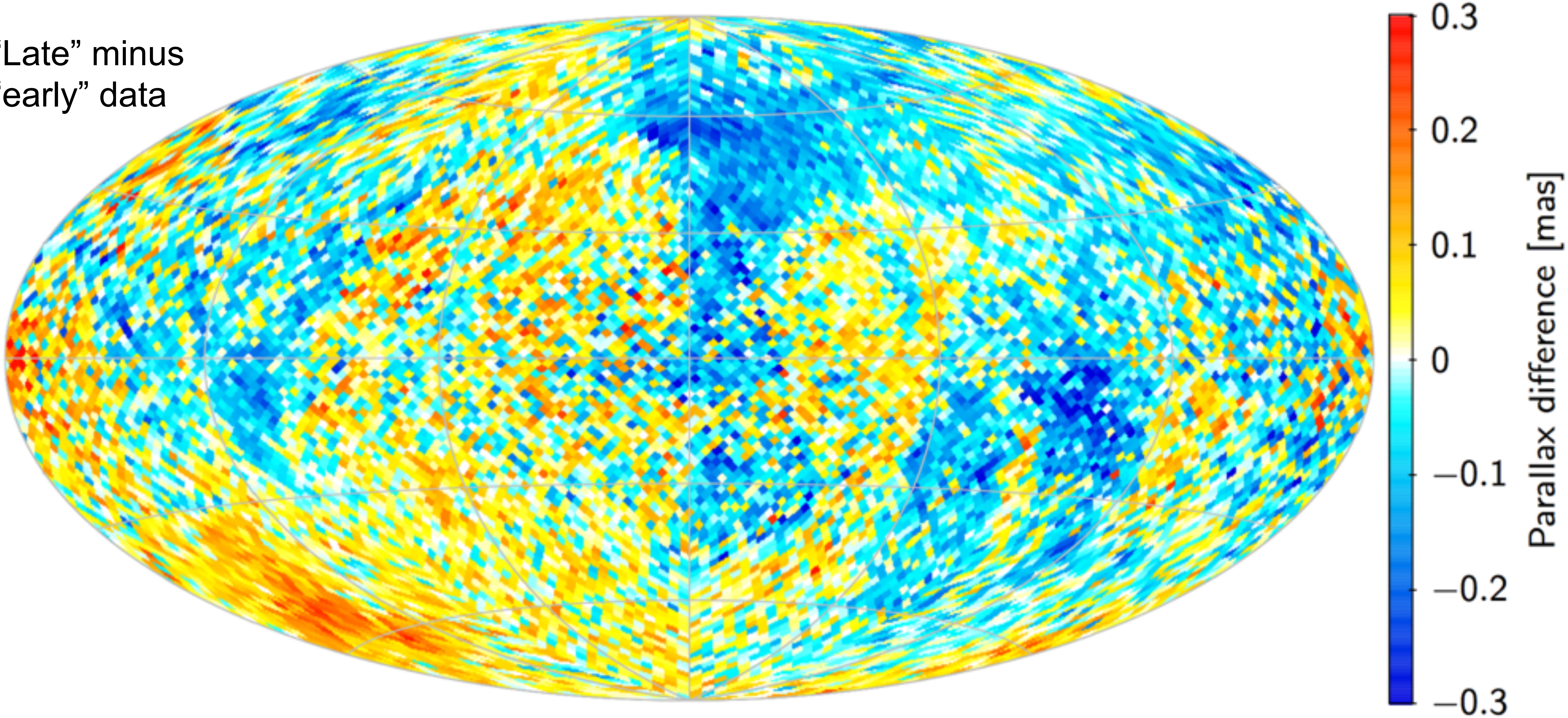
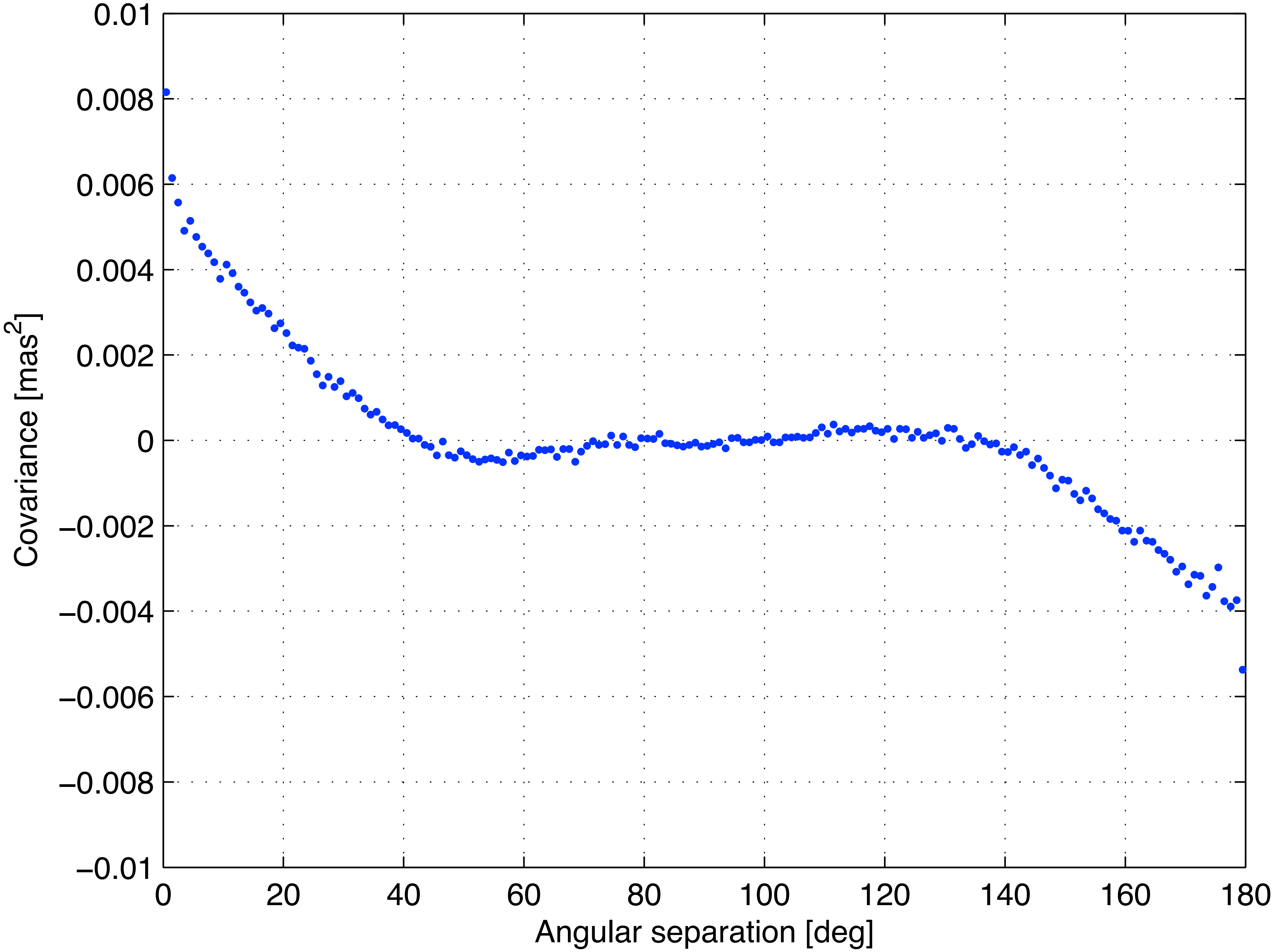
Gaia DR1 Workshop, ESAC
2016 November 3

# Systematic errors (bias) in TGAS parallaxes: Comparing solutions from split FoV

"Late" minus "early" data



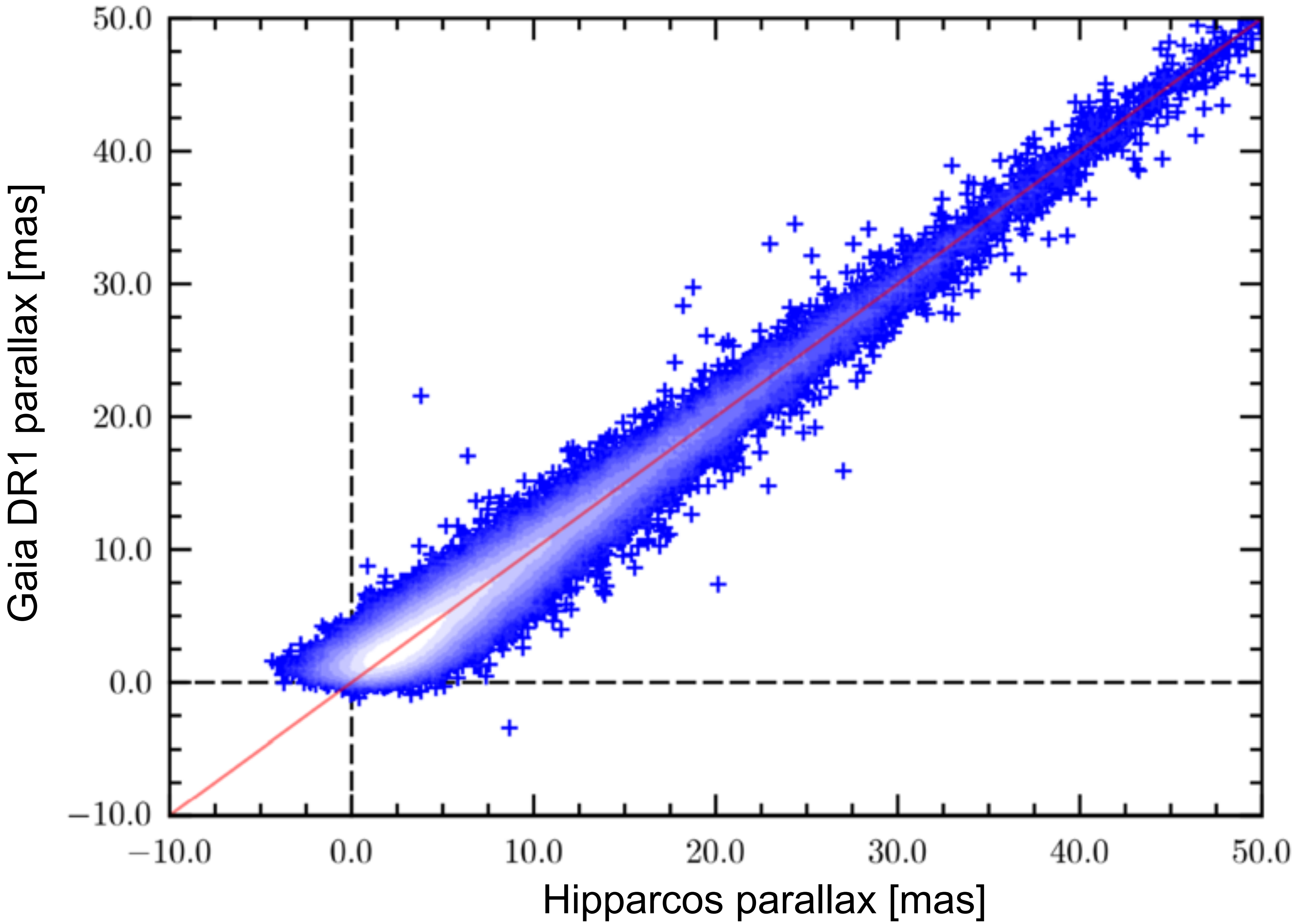
# Covariance of split FoV parallax differences as function of angular separation




Angular scale of correlations ~30 deg

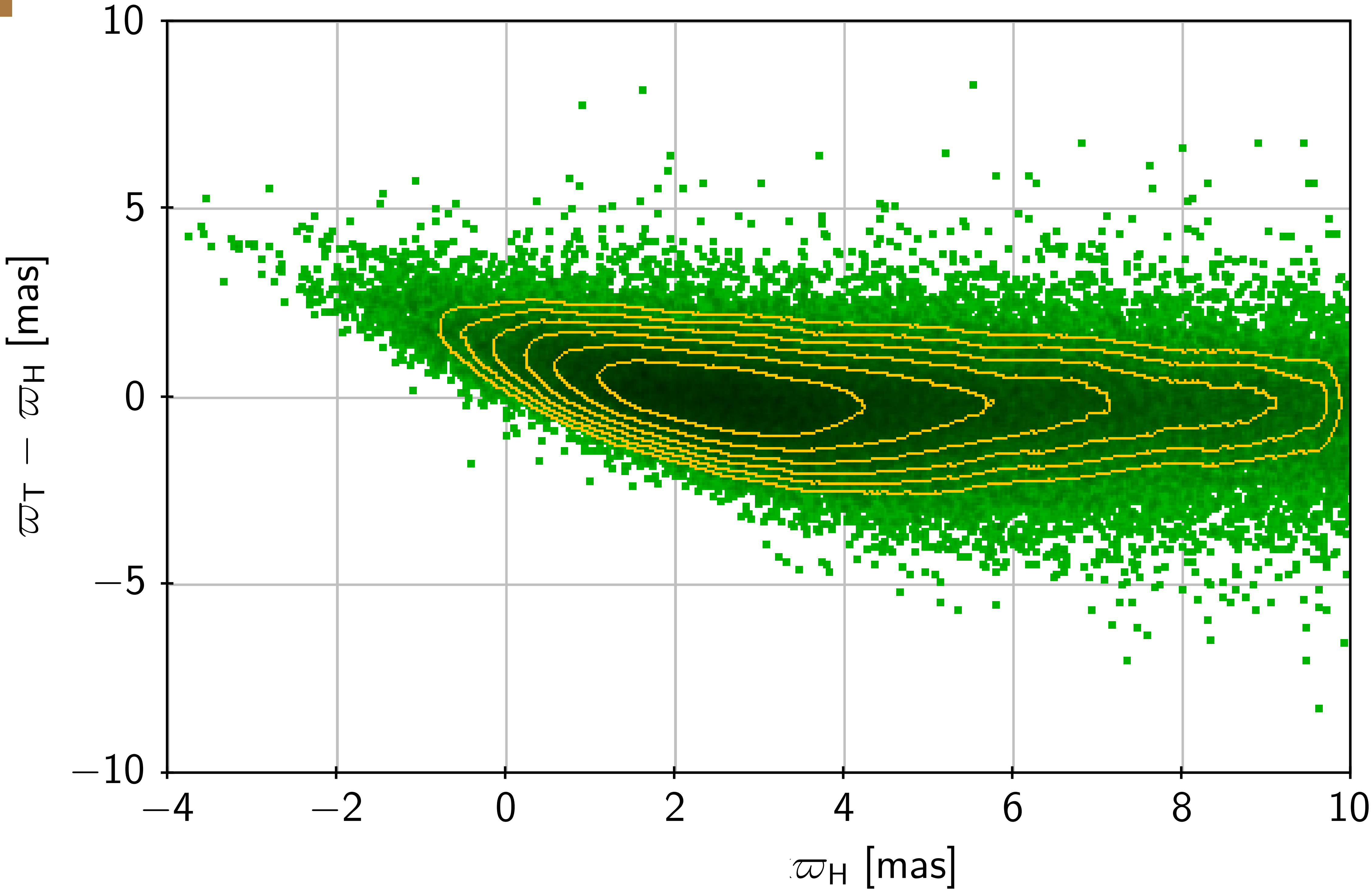
Covariance at separation < 2 deg is 0.006 - 0.008 mas$^2$ (0.08 - 0.09 mas RMS)

# Calibration of TGAS parallax uncertainties through comparison with Hipparcos

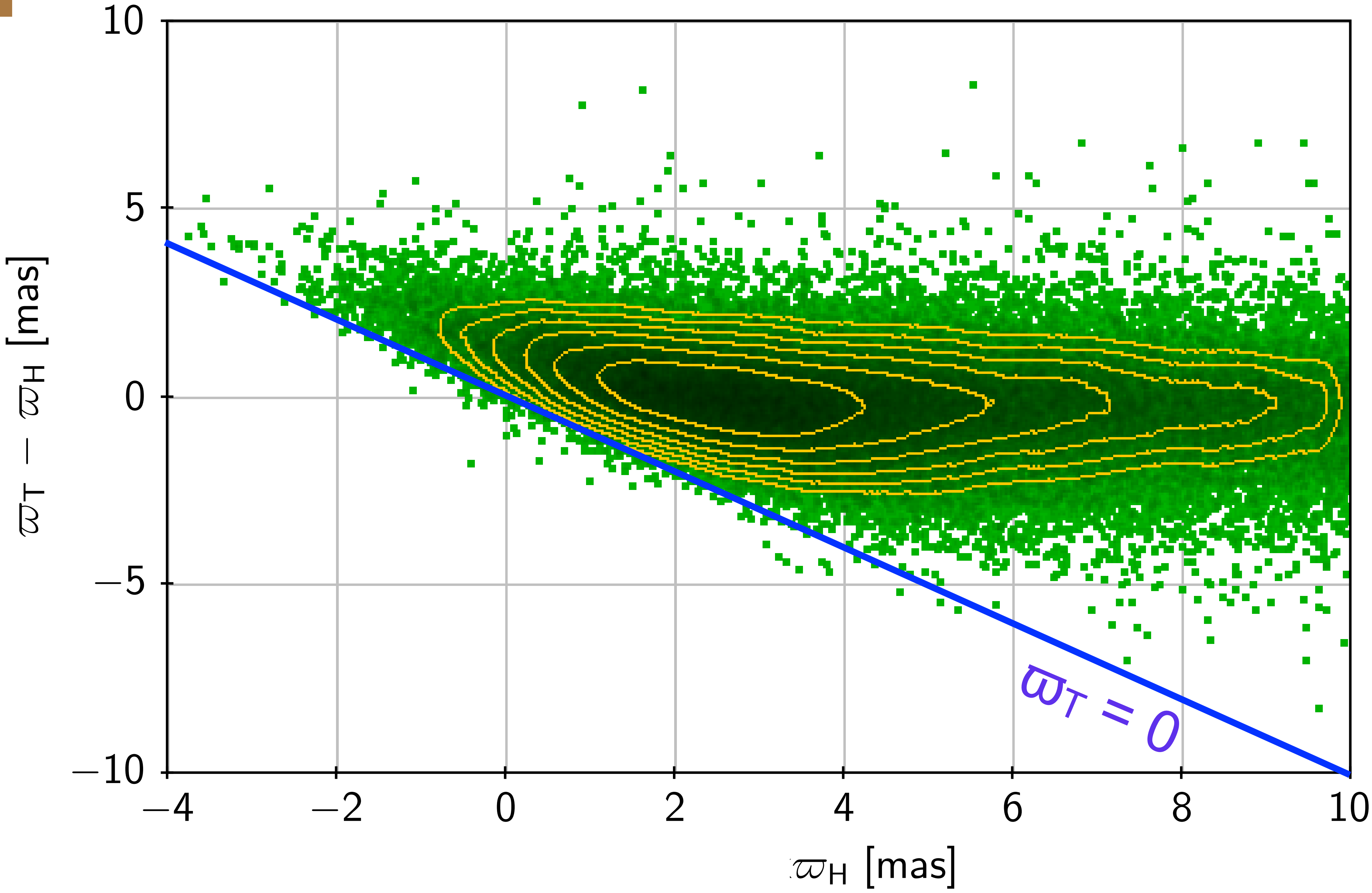



- TGAS and Hipparcos parallaxes are independent!
- Comparison confirms global quality of Hipparcos and Gaia
- Analysis provides realistic error estimates
- Realistic errors are published in Gaia DR1

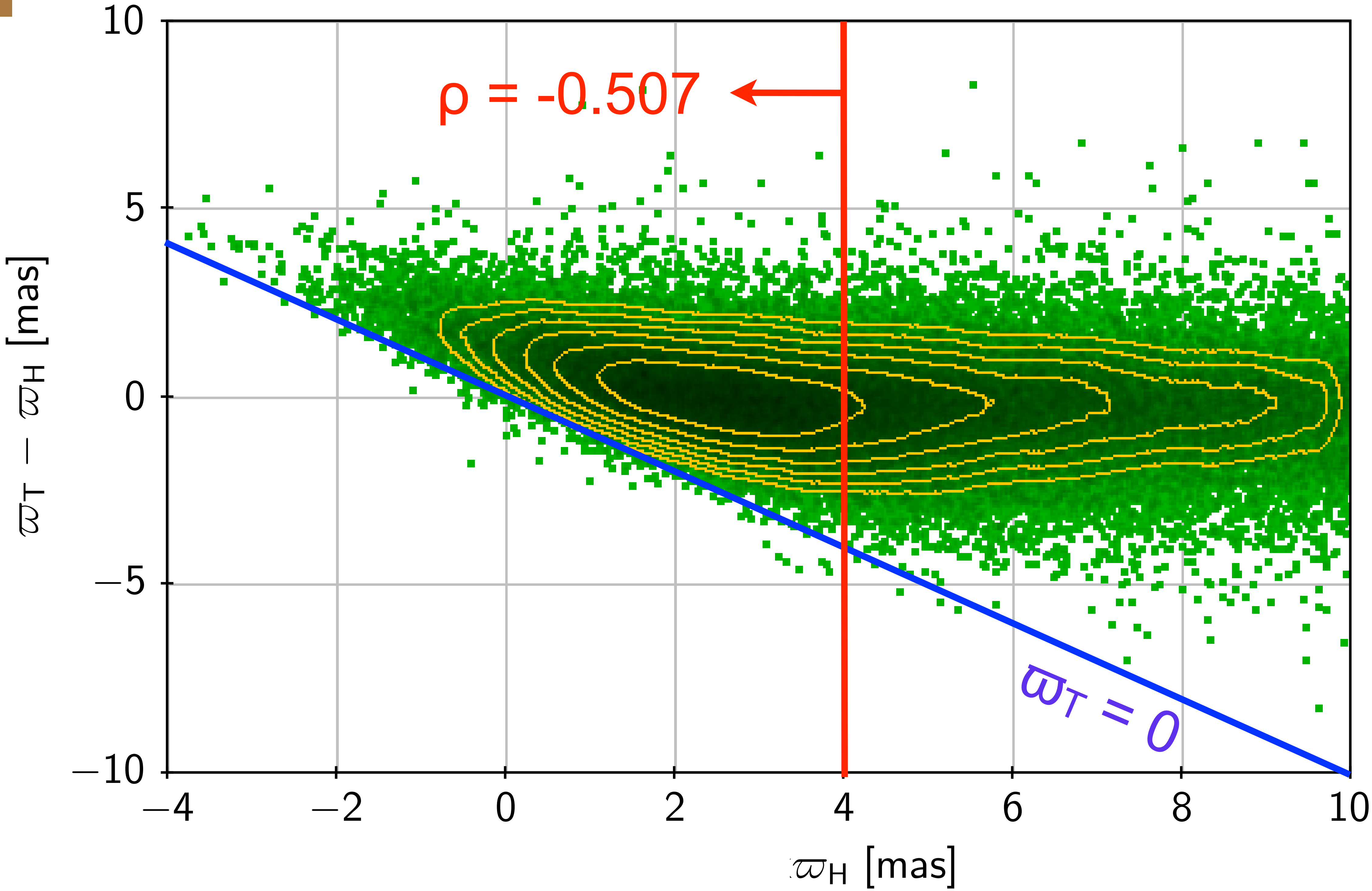
# Calibration of parallax uncertainty - principle



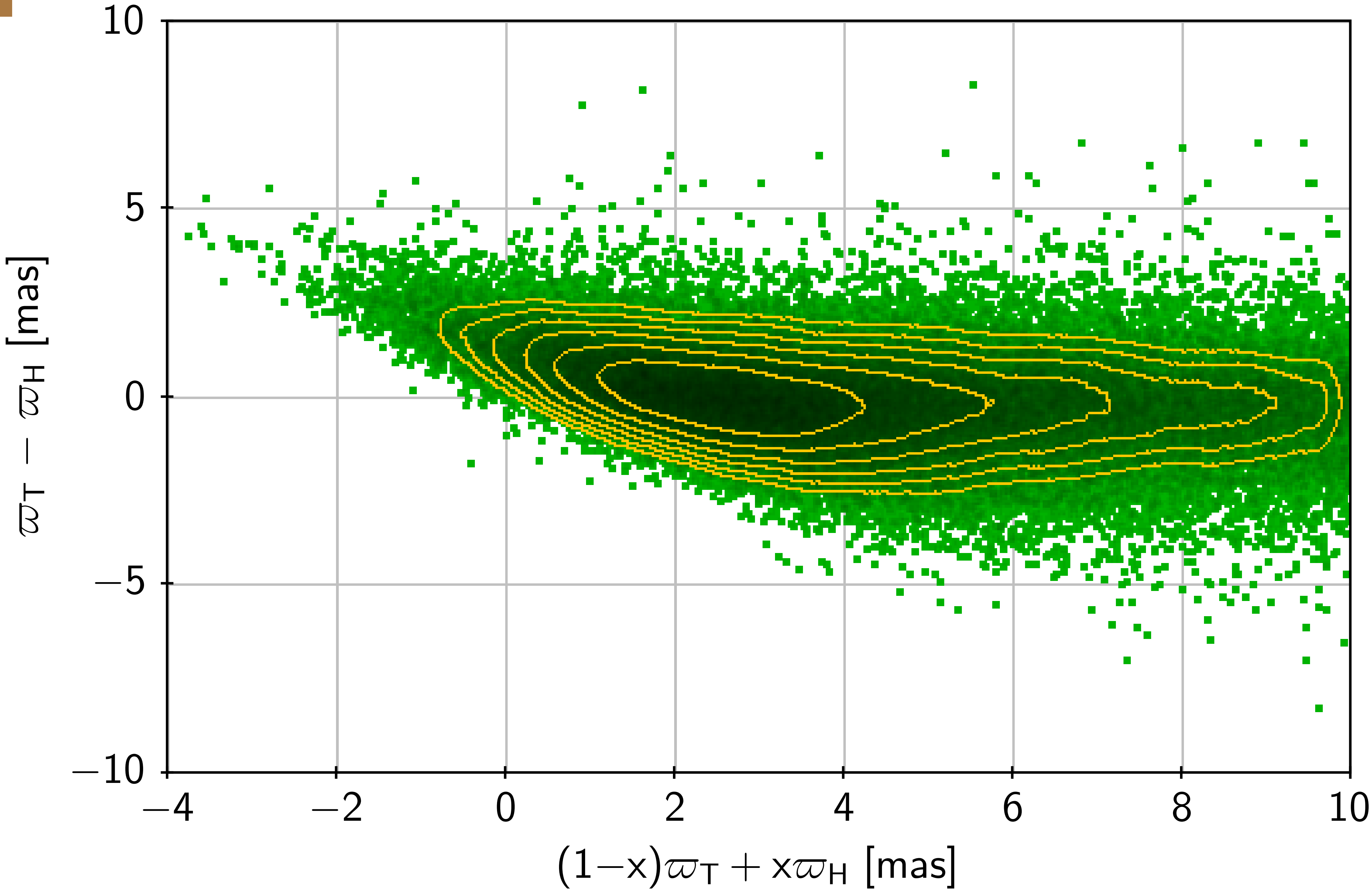
# Calibration of parallax uncertainty - principle



# Calibration of parallax uncertainty - principle



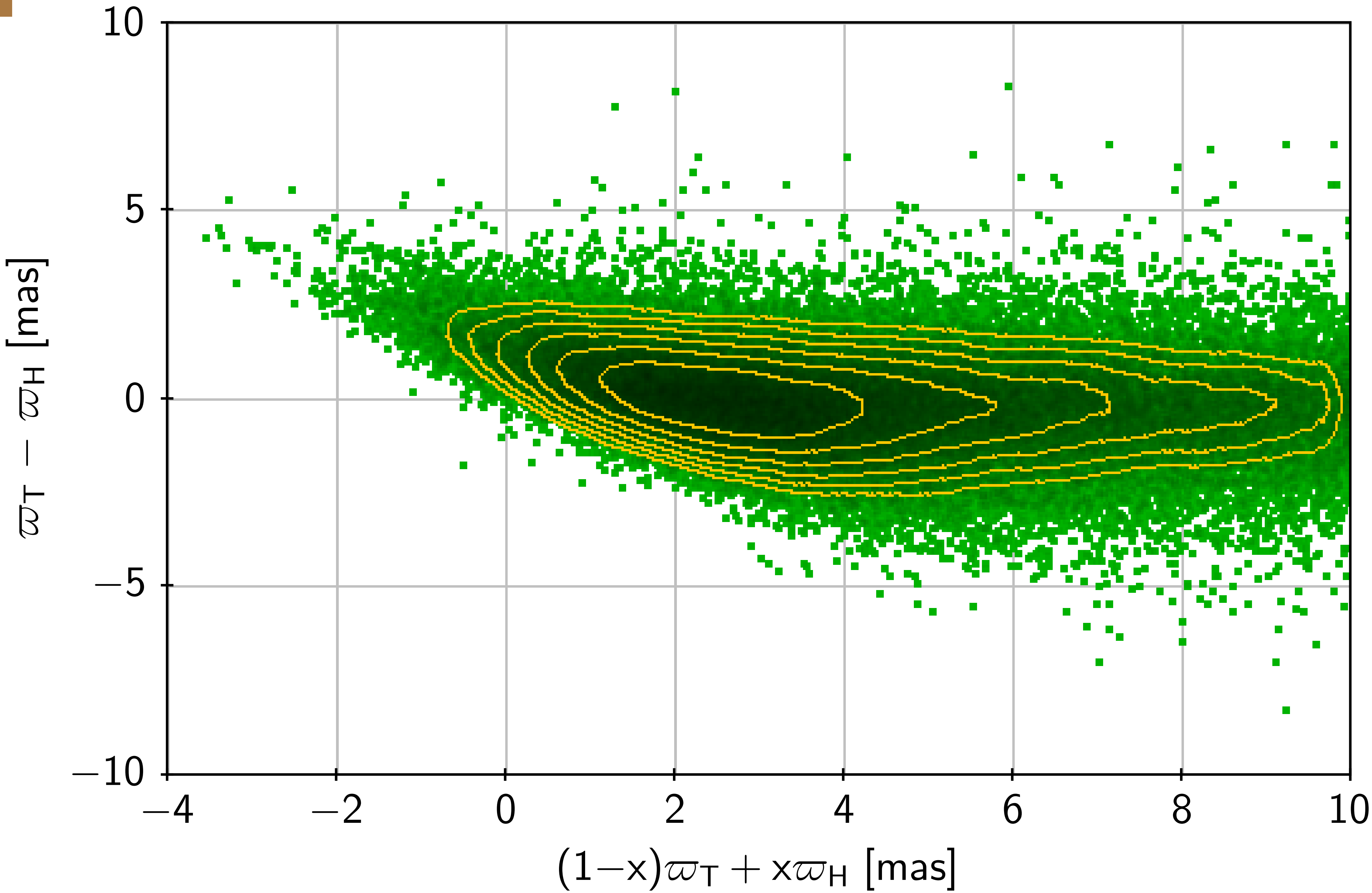
# Parallax difference T−H vs. weighted mean (1-x)*T + x*H




x = 1.00

ρ = -0.507

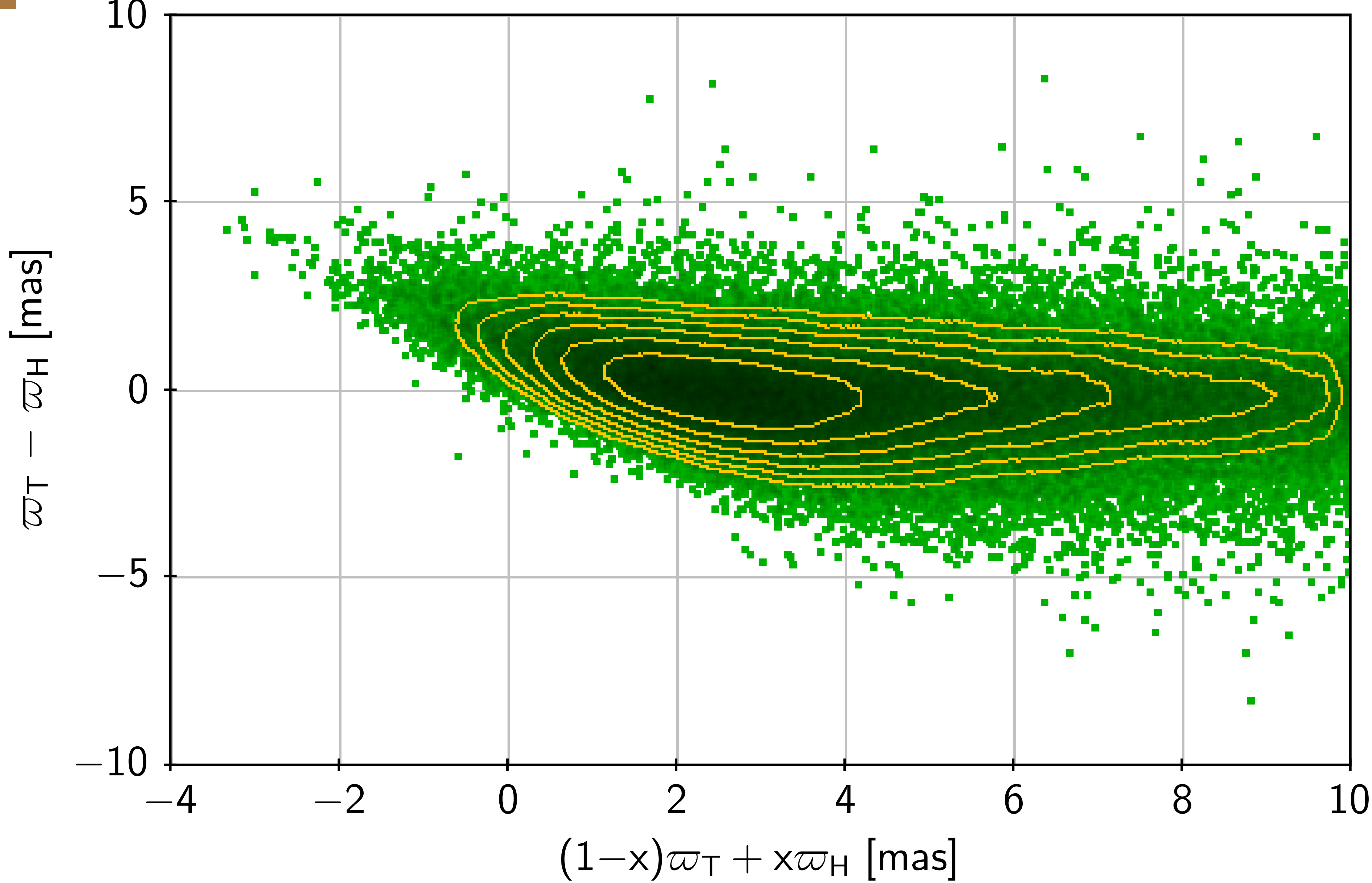
# Parallax difference T−H vs. weighted mean (1-x)*T + x*H




x = 0.95

ρ = -0.492

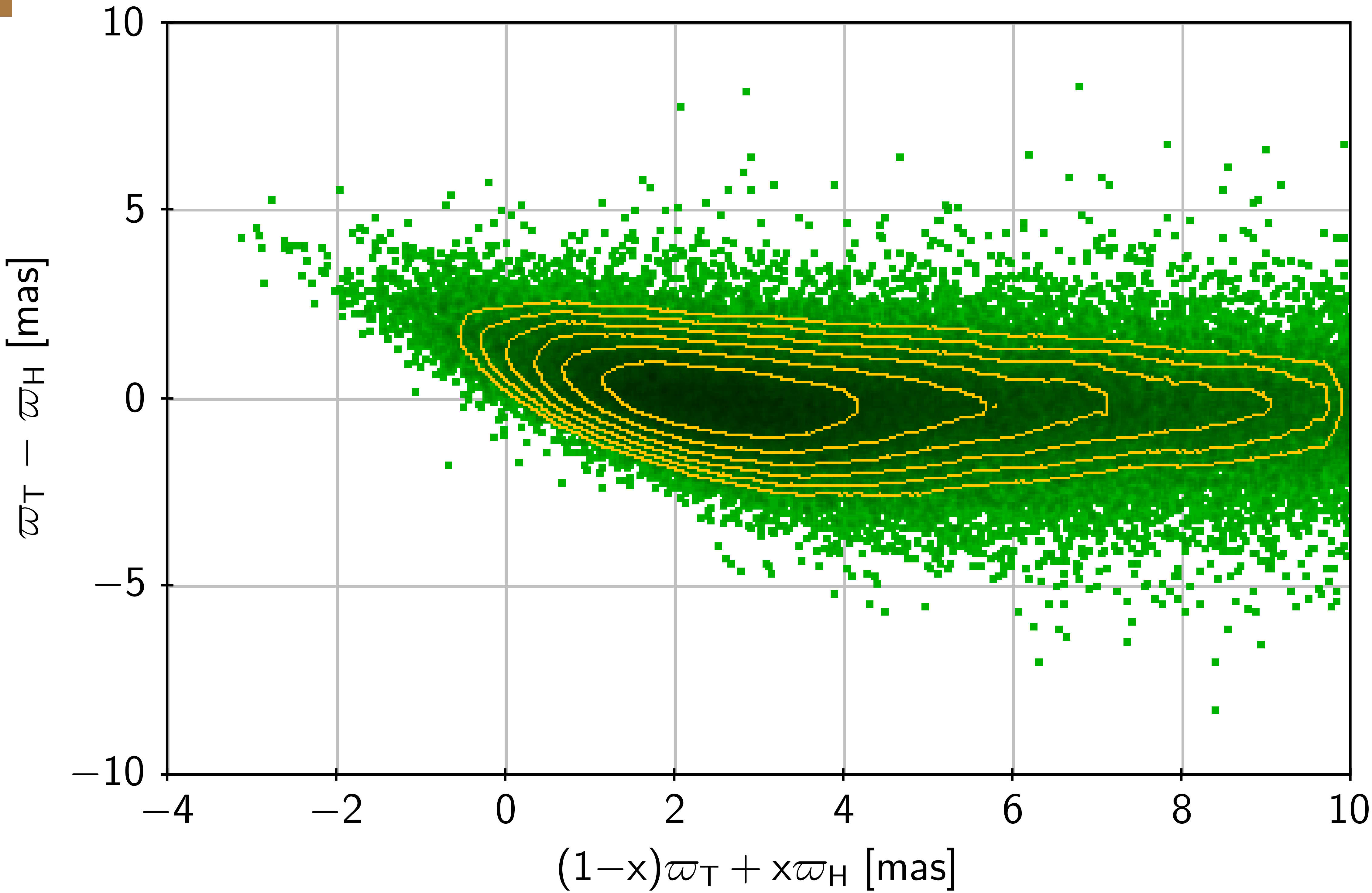
# Parallax difference T−H vs. weighted mean (1-x)*T + x*H




x = 0.90

ρ = -0.474

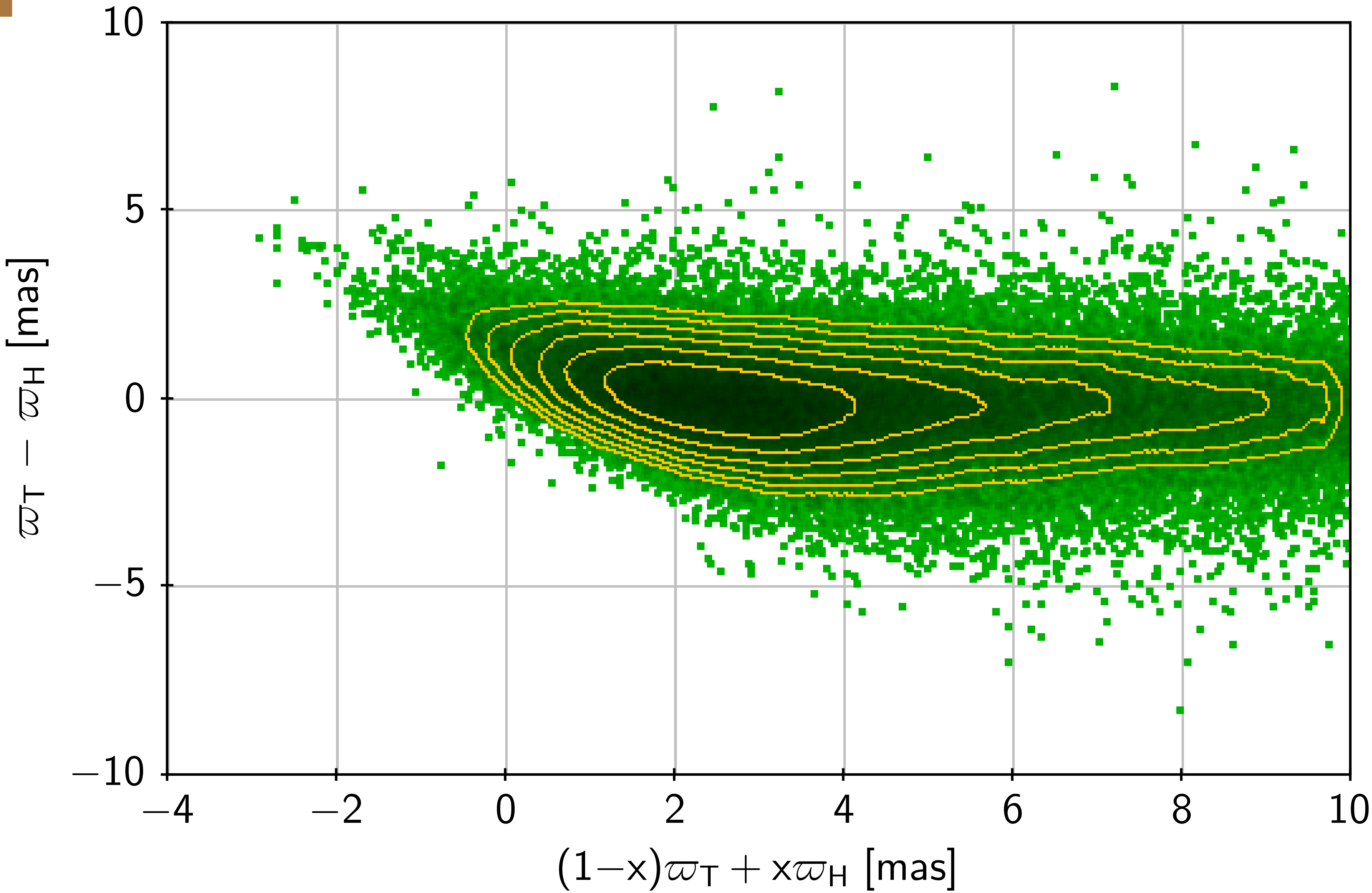
# Parallax difference T−H vs. weighted mean (1-x)*T + x*H




x = 0.85

ρ = -0.455

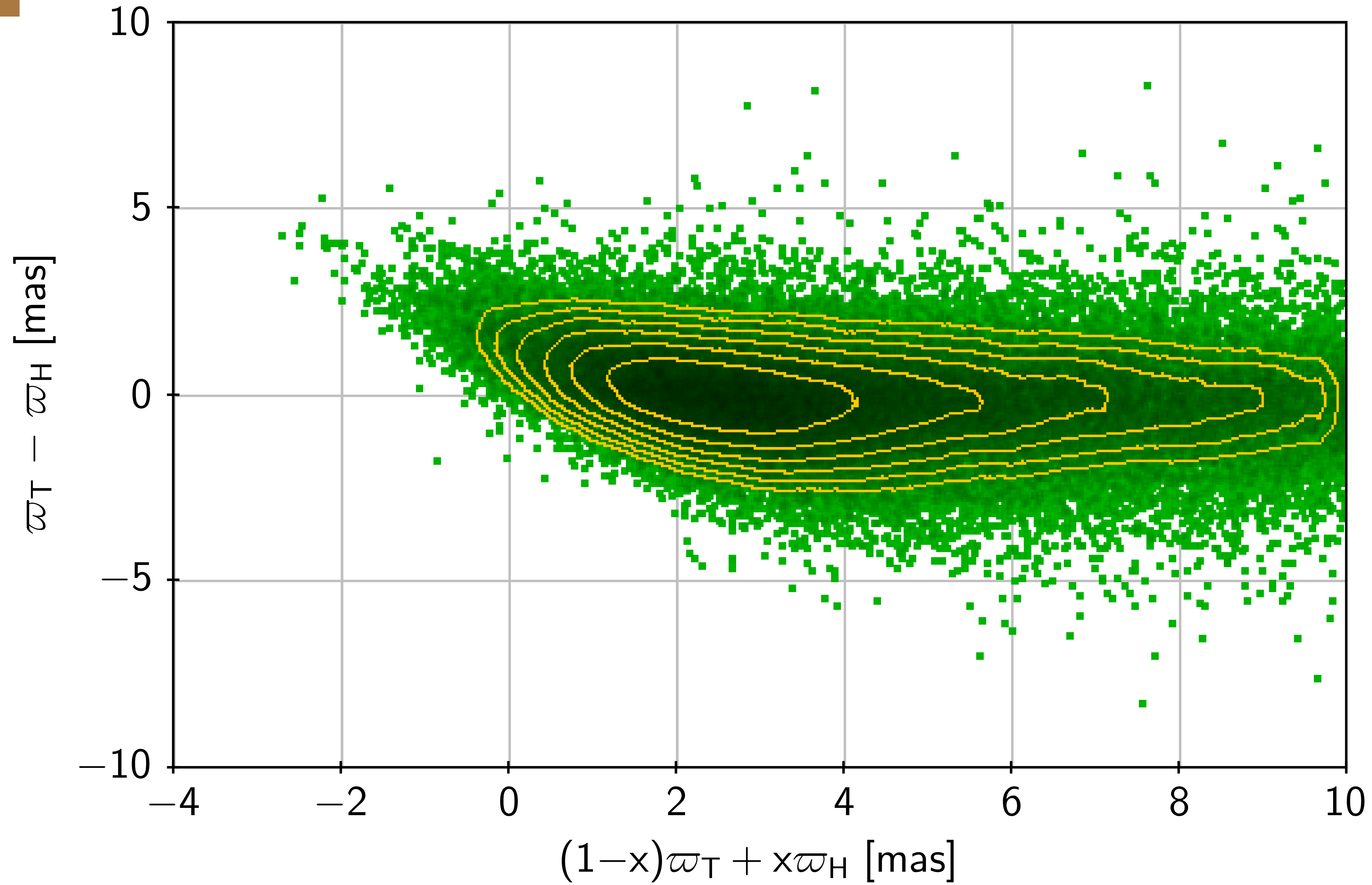
# Parallax difference T−H vs. weighted mean (1-x)*T + x*H




x = 0.80

ρ = -0.436

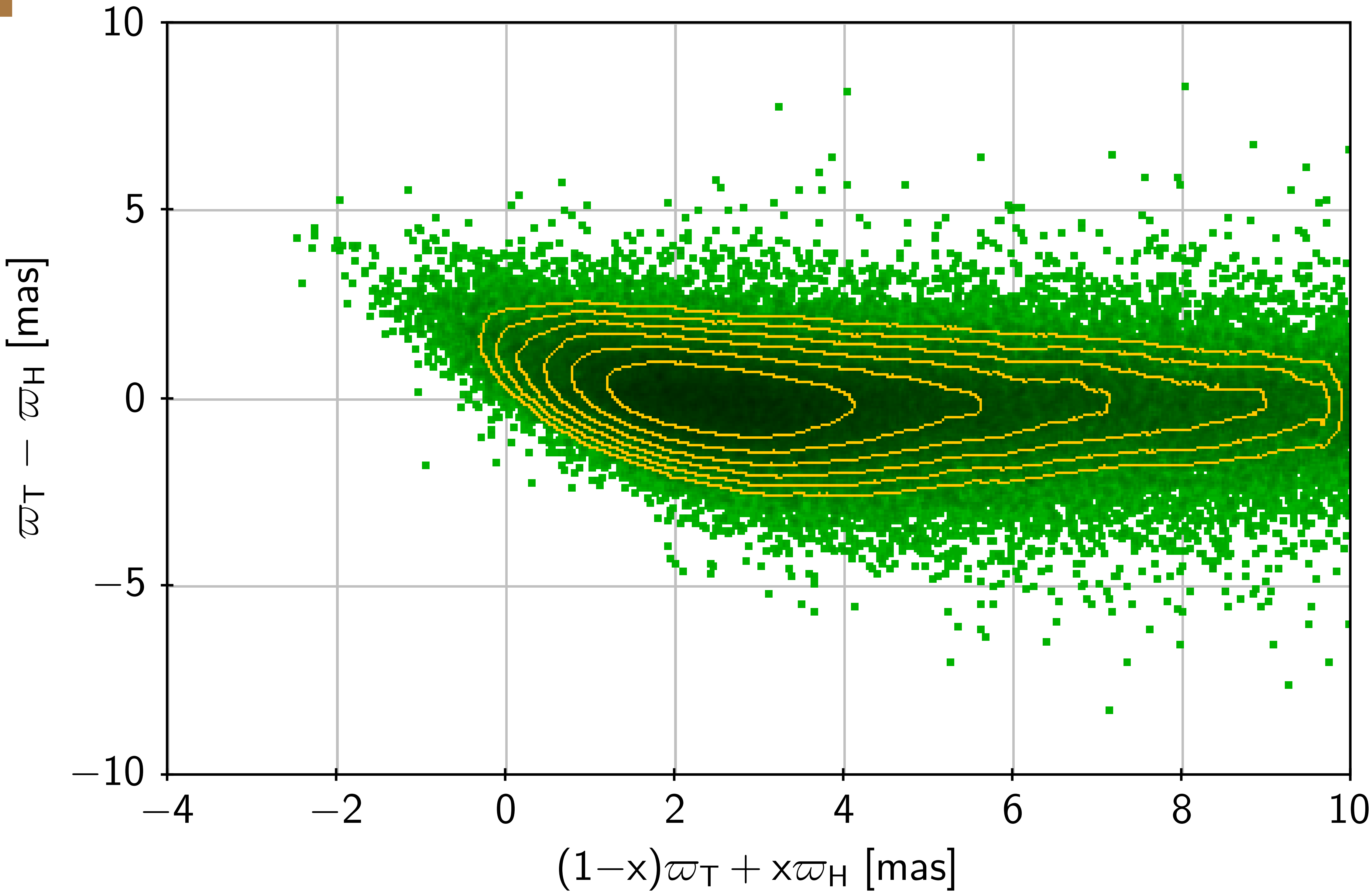
# Parallax difference T−H vs. weighted mean (1-x)*T + x*H




x = 0.75

ρ = -0.414

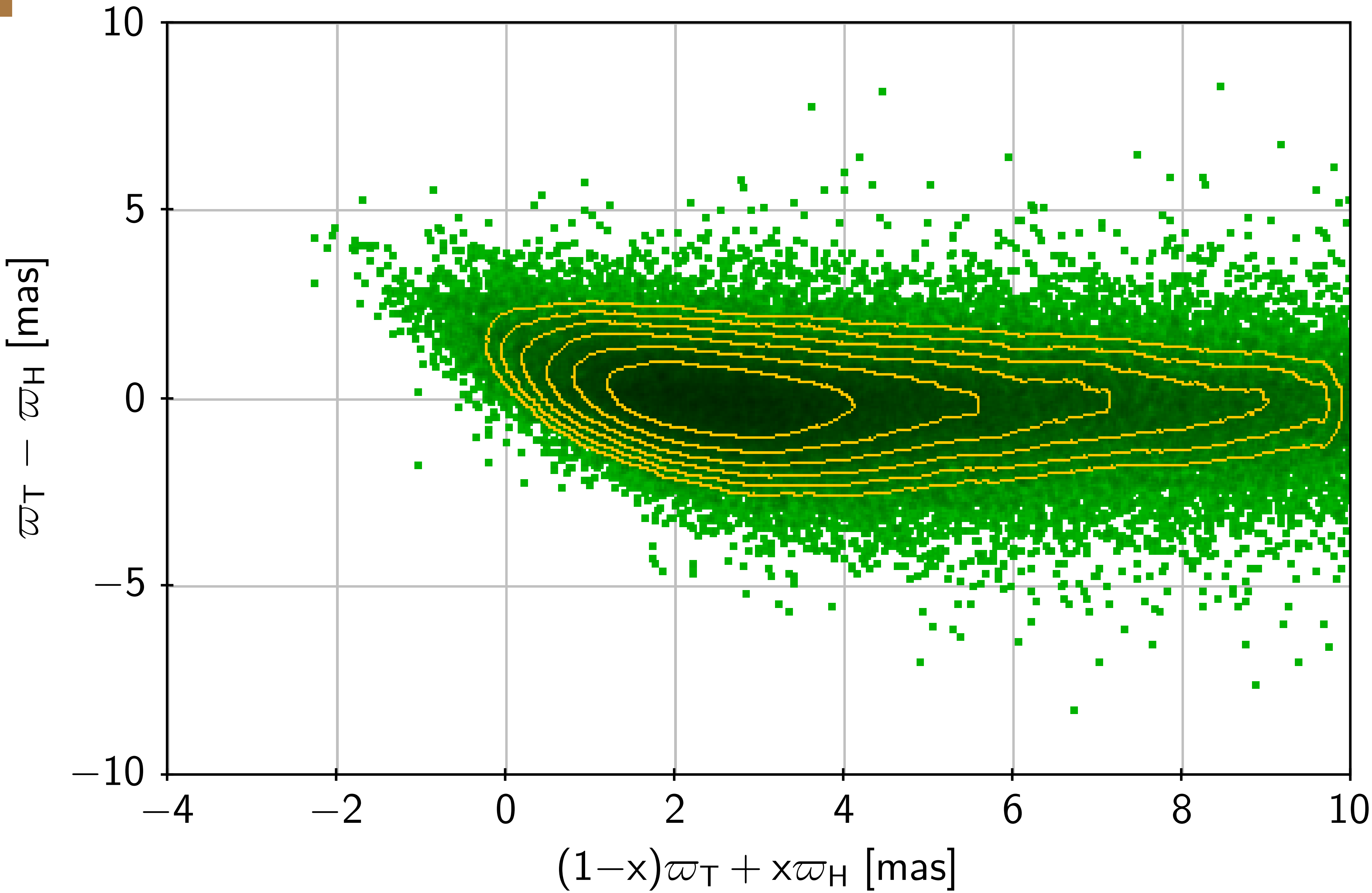
# Parallax difference T–H vs. weighted mean (1-x)*T + x*H




x = 0.70

ρ = -0.392

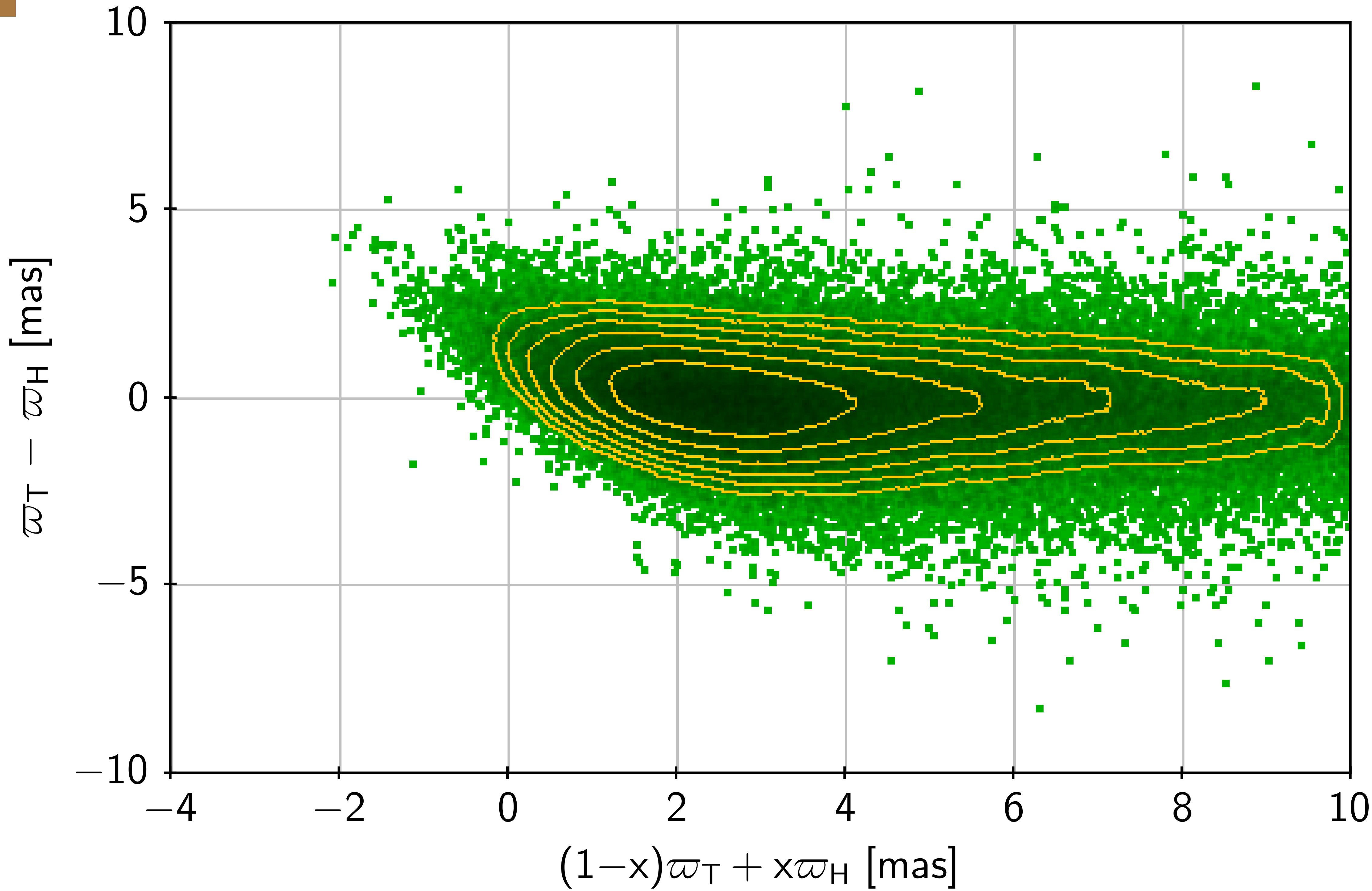
# Parallax difference T−H vs. weighted mean (1-x)*T + x*H




x = 0.65

ρ = -0.366

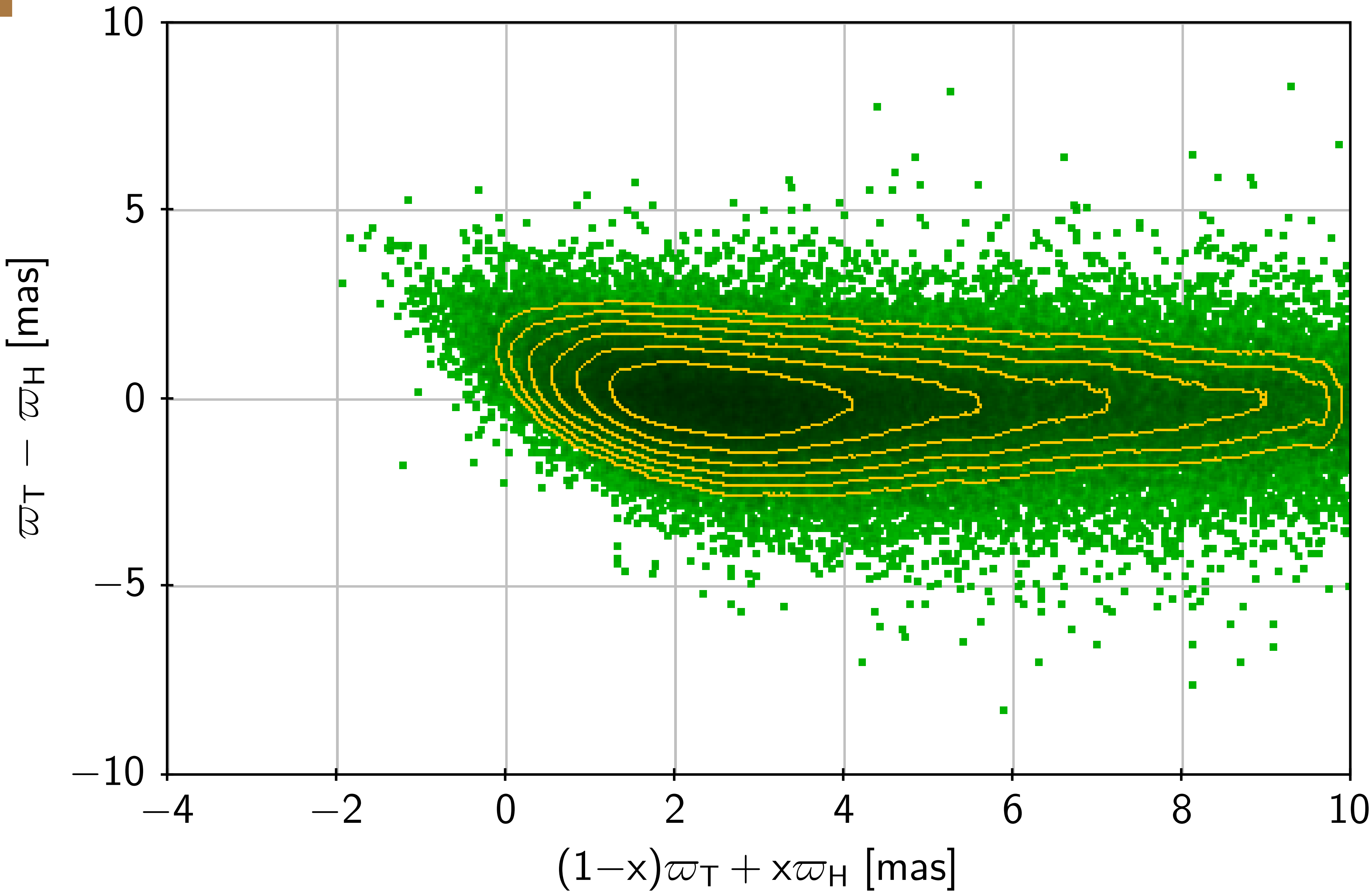
# Parallax difference T−H vs. weighted mean (1-x)*T + x*H




x = 0.60

ρ = -0.339

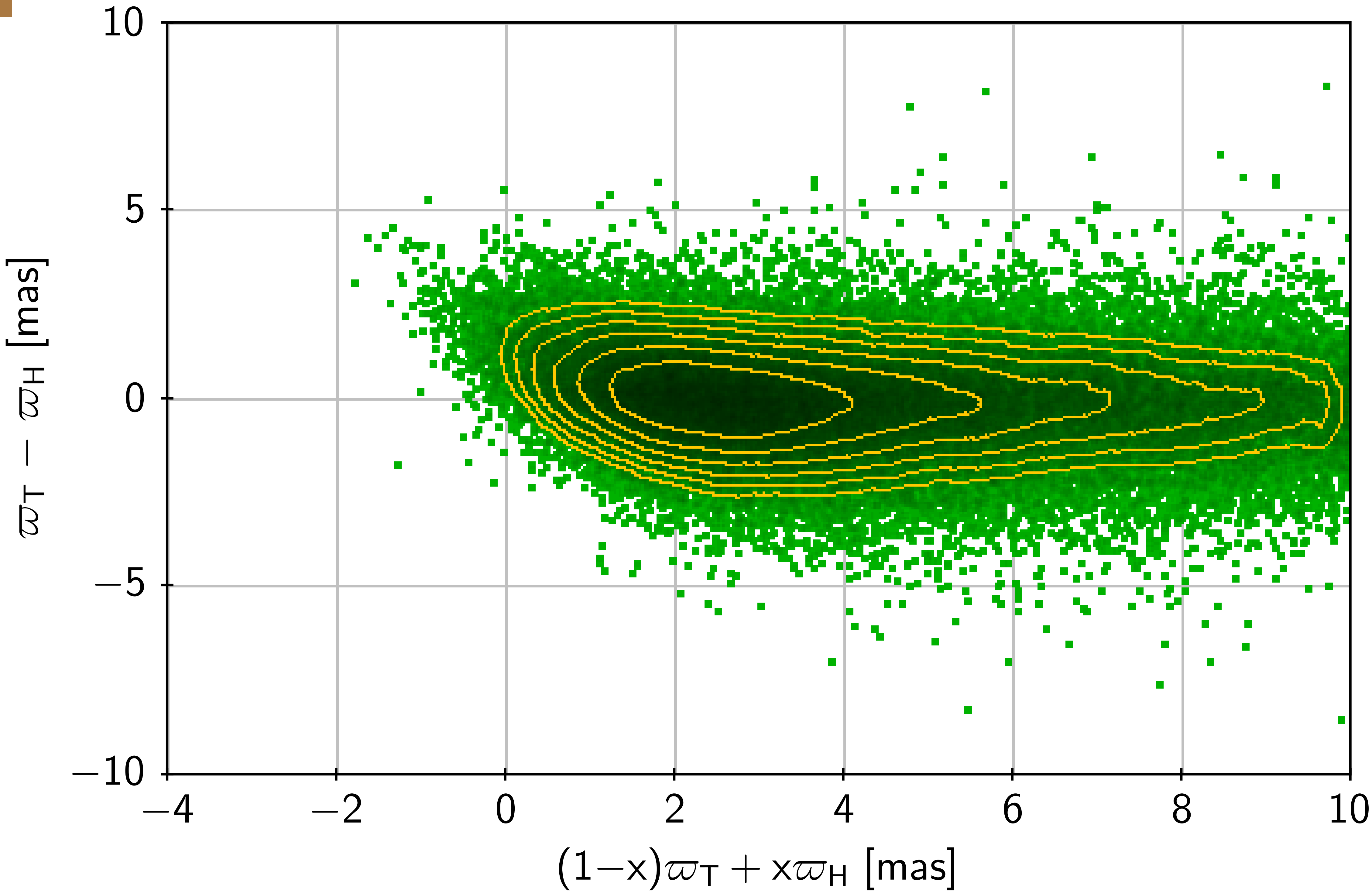
# Parallax difference T−H vs. weighted mean (1-x)*T + x*H




x = 0.55

ρ = -0.312

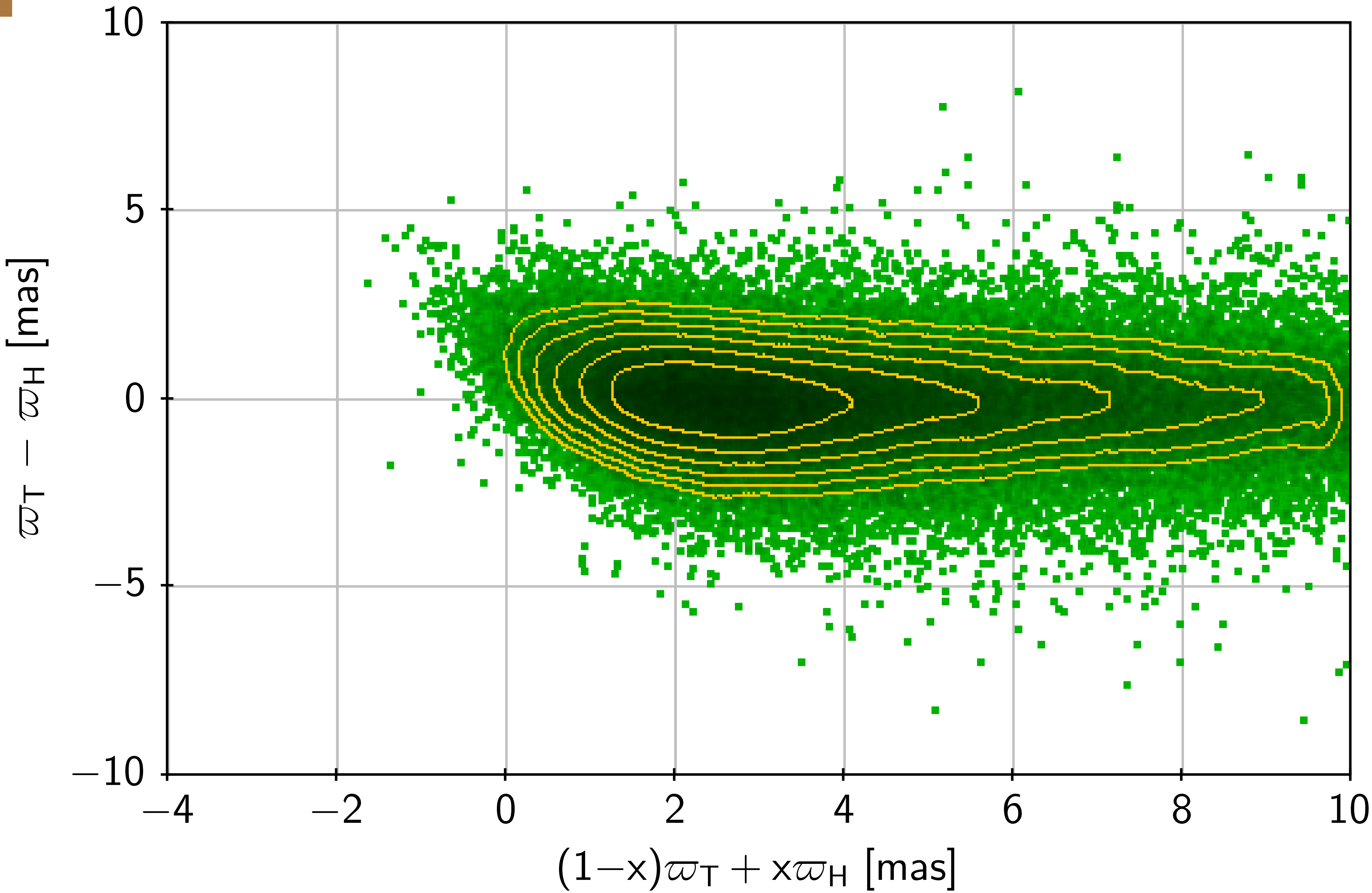
# Parallax difference T−H vs. weighted mean (1-x)*T + x*H




x = 0.50

ρ = -0.285

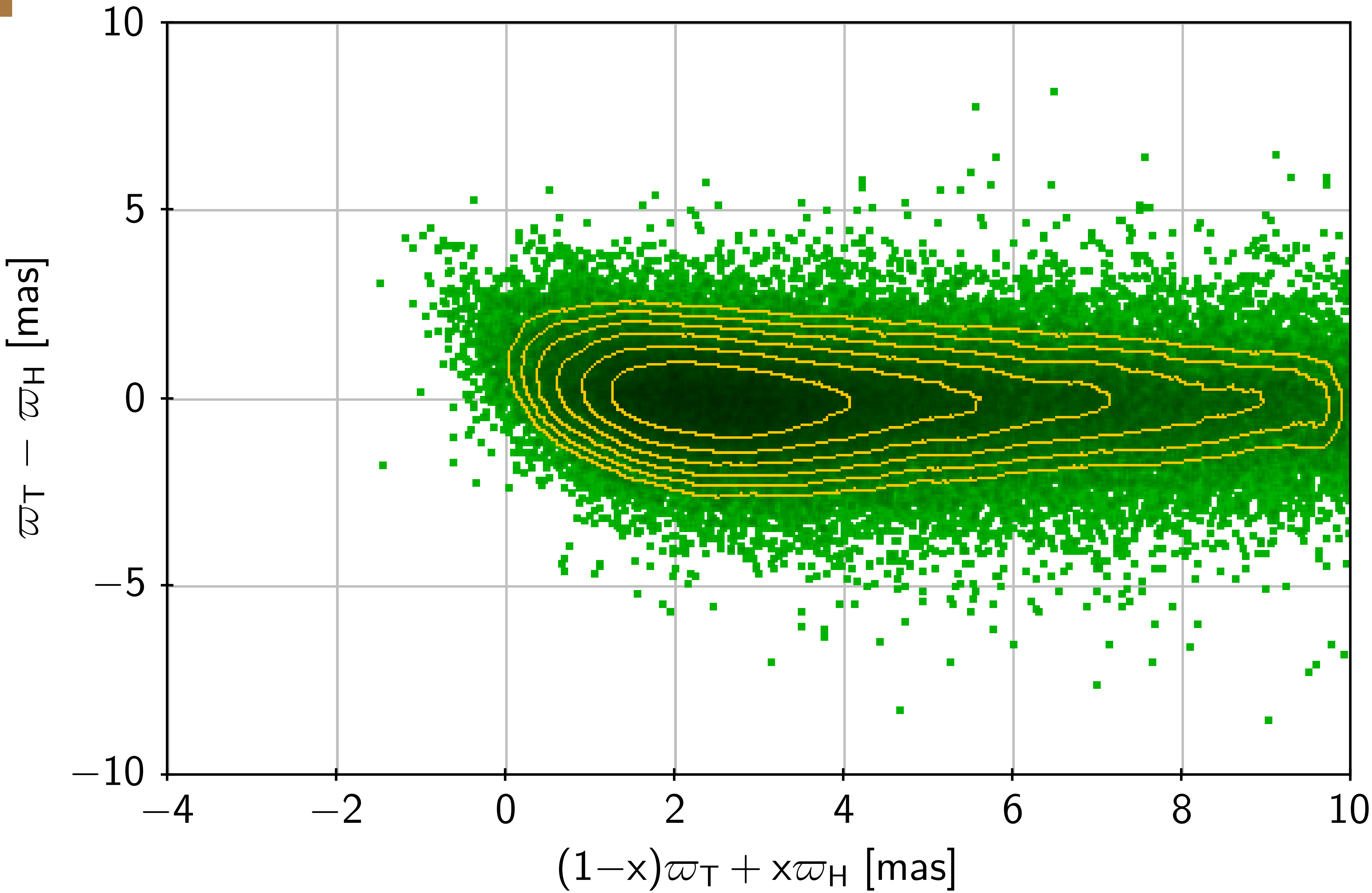
# Parallax difference T−H vs. weighted mean (1-x)*T + x*H




x = 0.45

ρ = -0.256

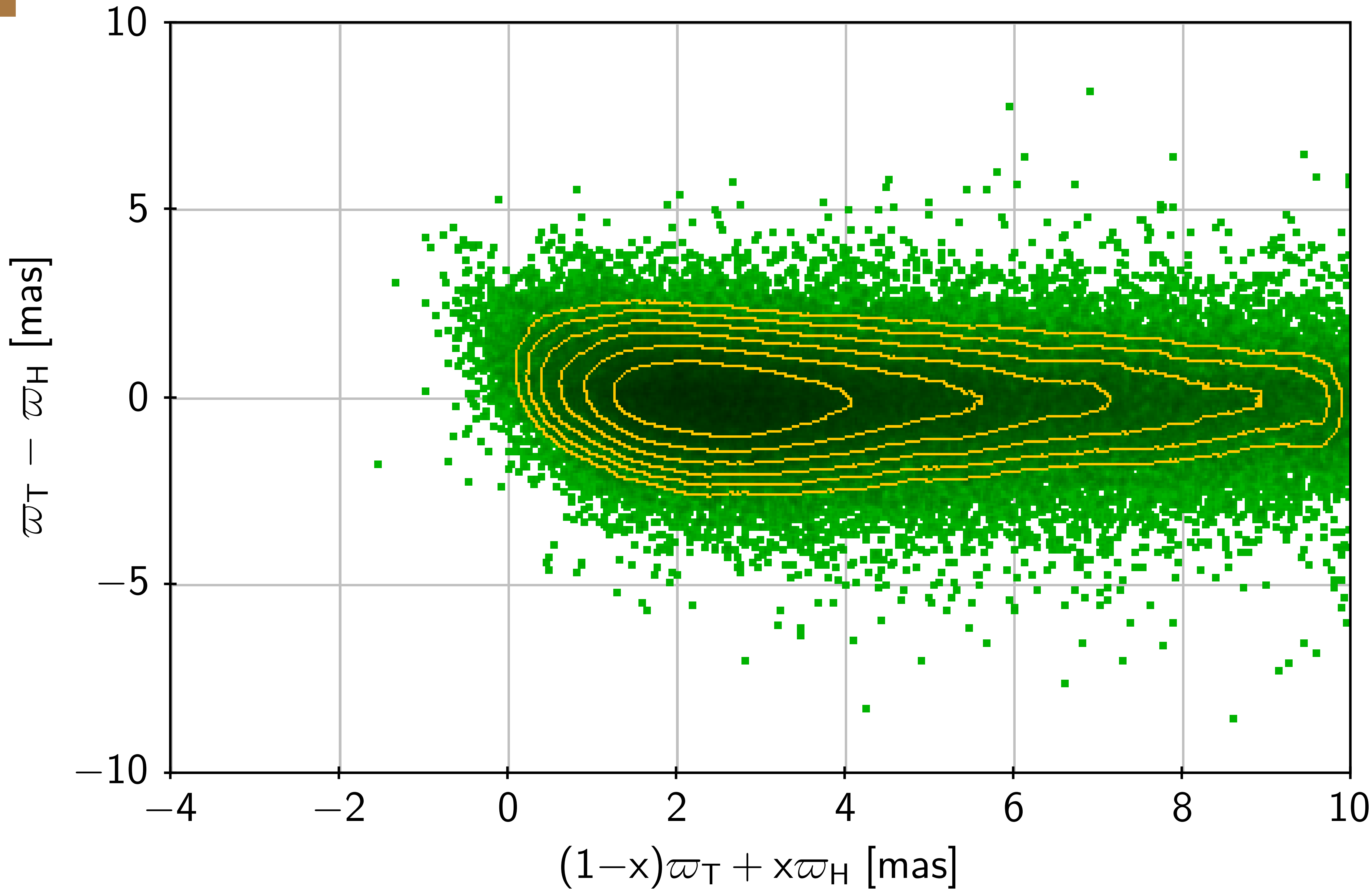
# Parallax difference T−H vs. weighted mean (1-x)*T + x*H




x = 0.40

ρ = -0.224

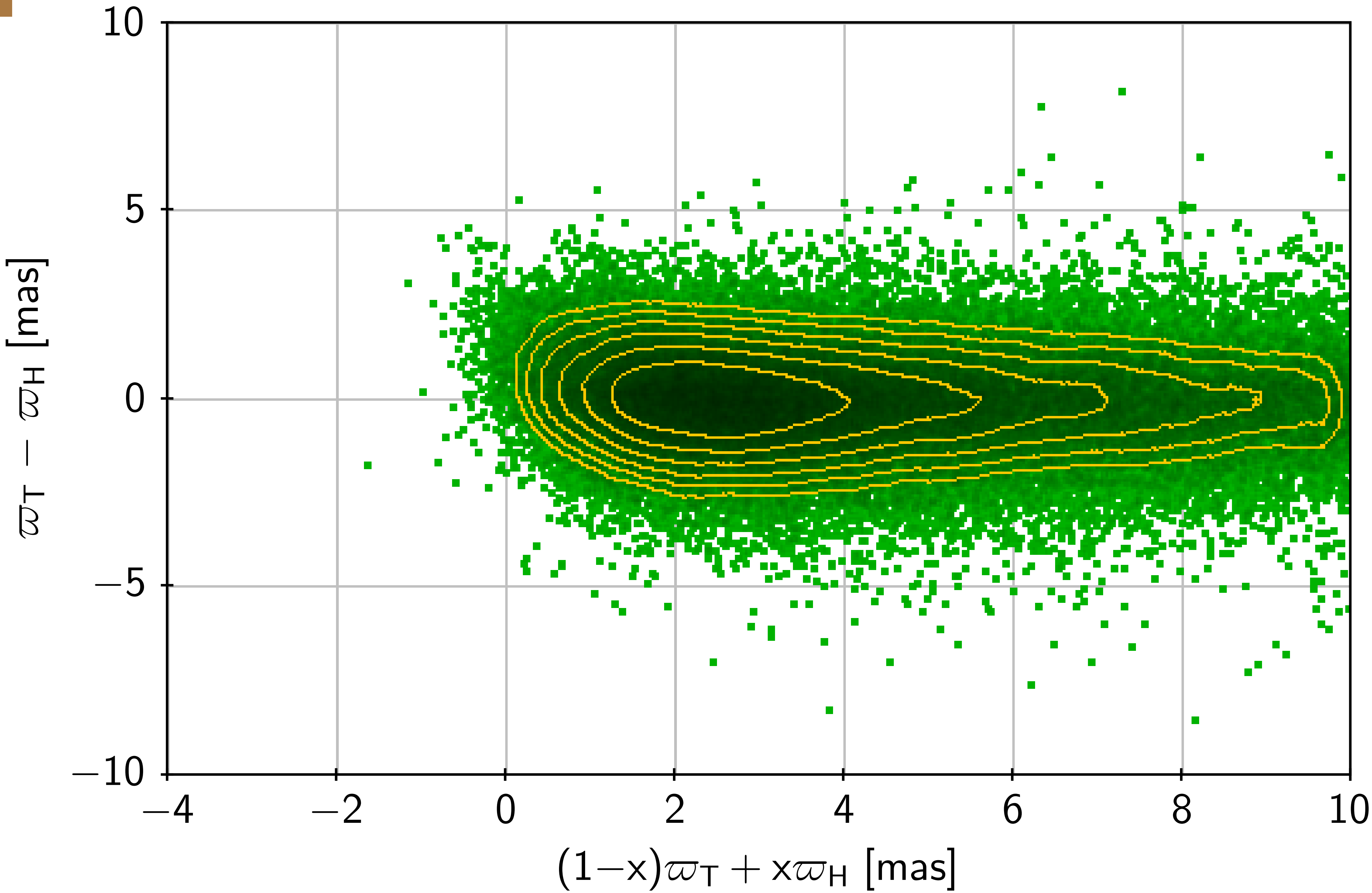
# Parallax difference T−H vs. weighted mean (1-x)*T + x*H




x = 0.35

ρ = -0.190

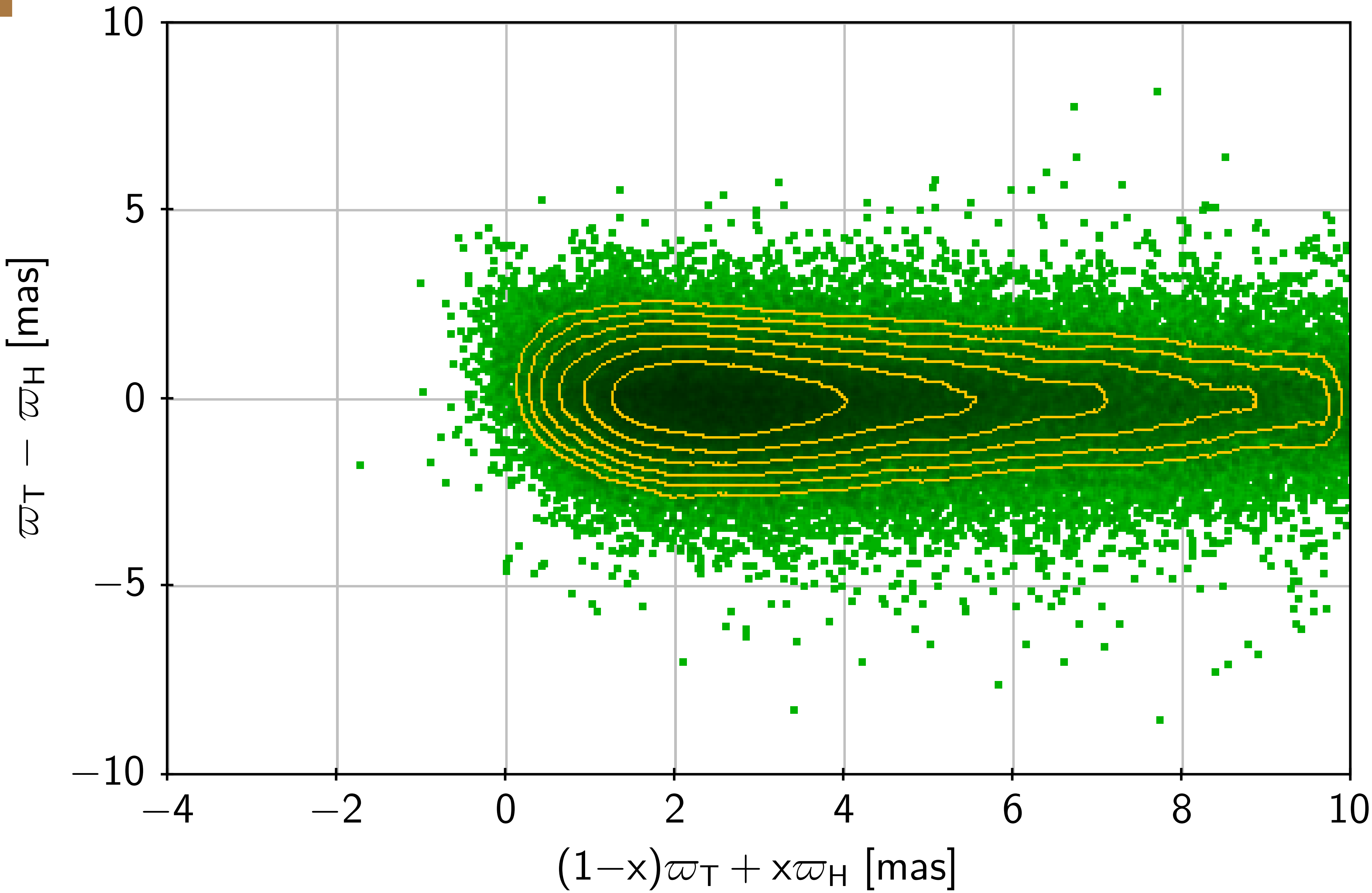
# Parallax difference T−H vs. weighted mean (1-x)*T + x*H




x = 0.30

ρ = -0.154

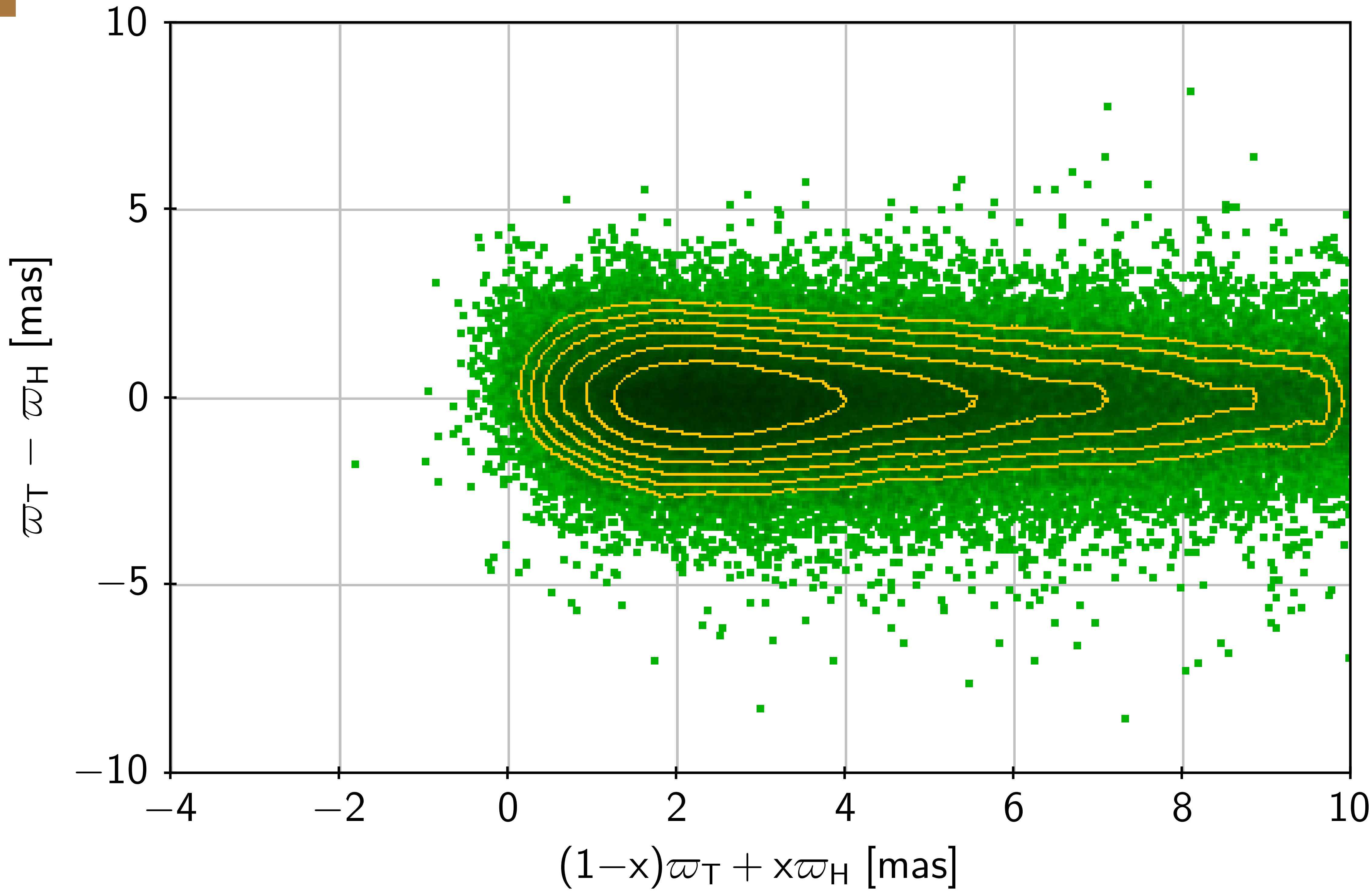
# Parallax difference T−H vs. weighted mean (1-x)*T + x*H




x = 0.25

ρ = -0.119

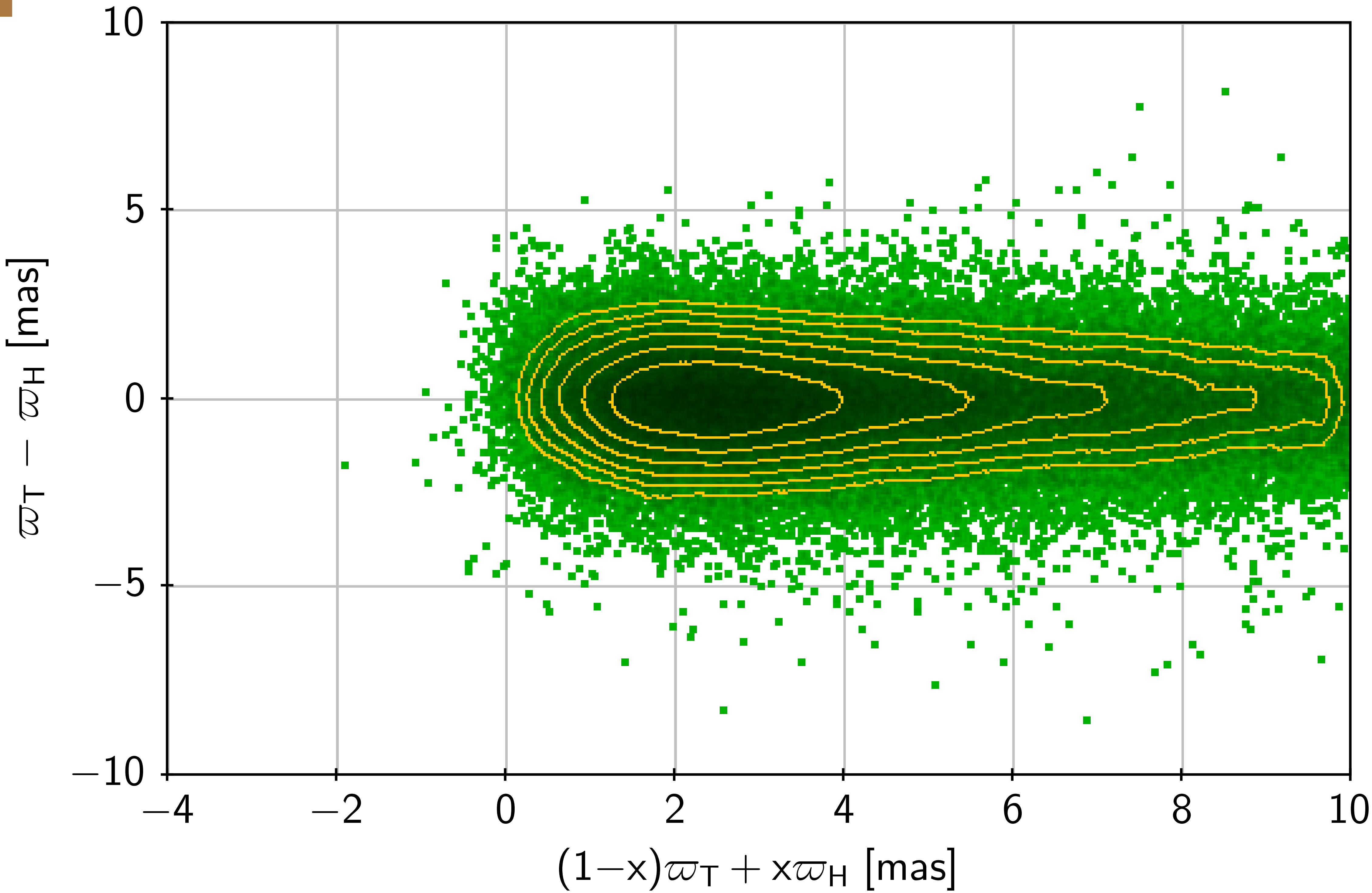
# Parallax difference T−H vs. weighted mean (1-x)*T + x*H




x = 0.20

ρ = -0.081

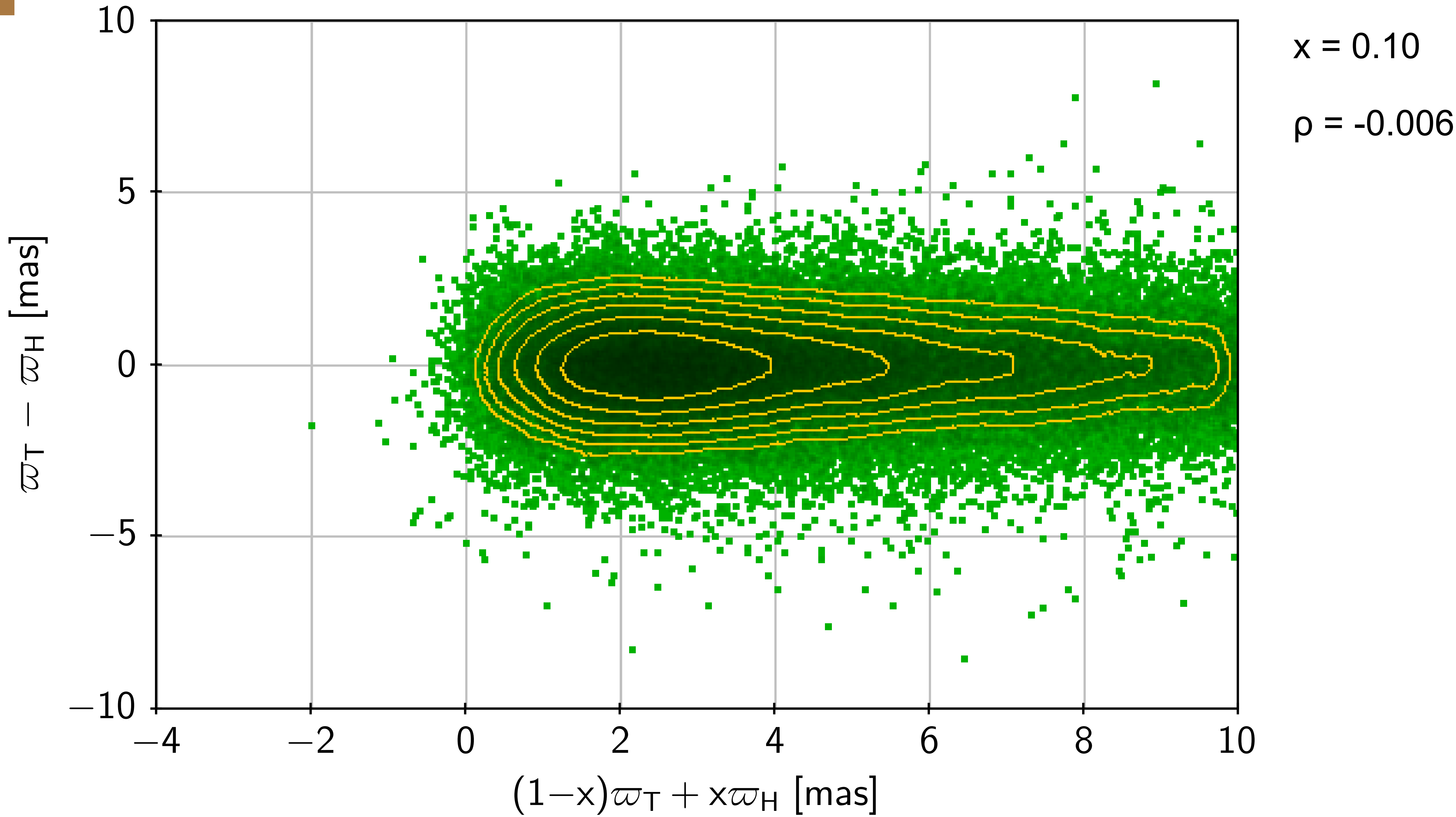
# Parallax difference T−H vs. weighted mean (1-x)*T + x*H



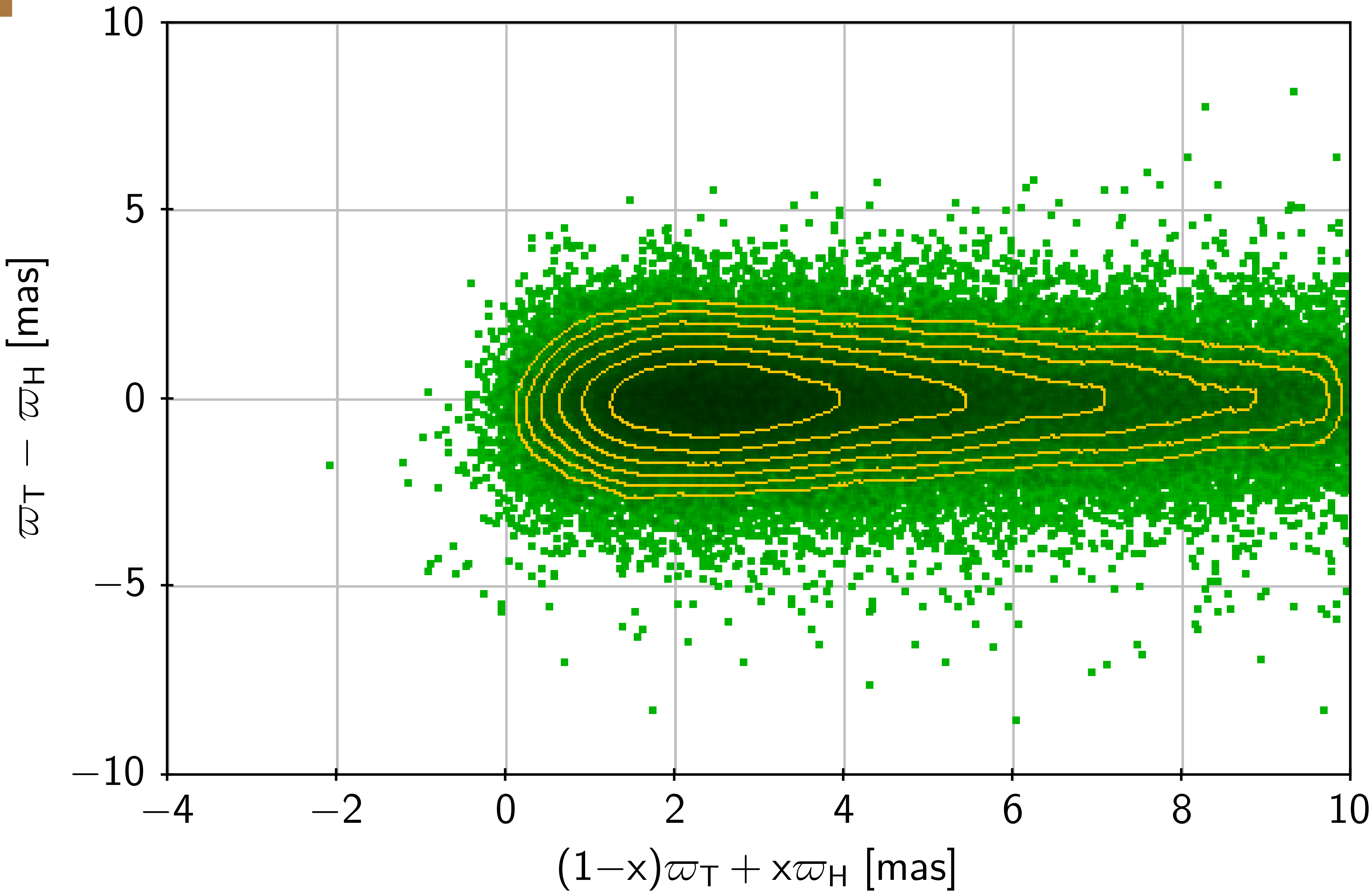

x = 0.15

ρ = -0.044

# Parallax difference T−H vs. weighted mean (1-x)*T + x*H



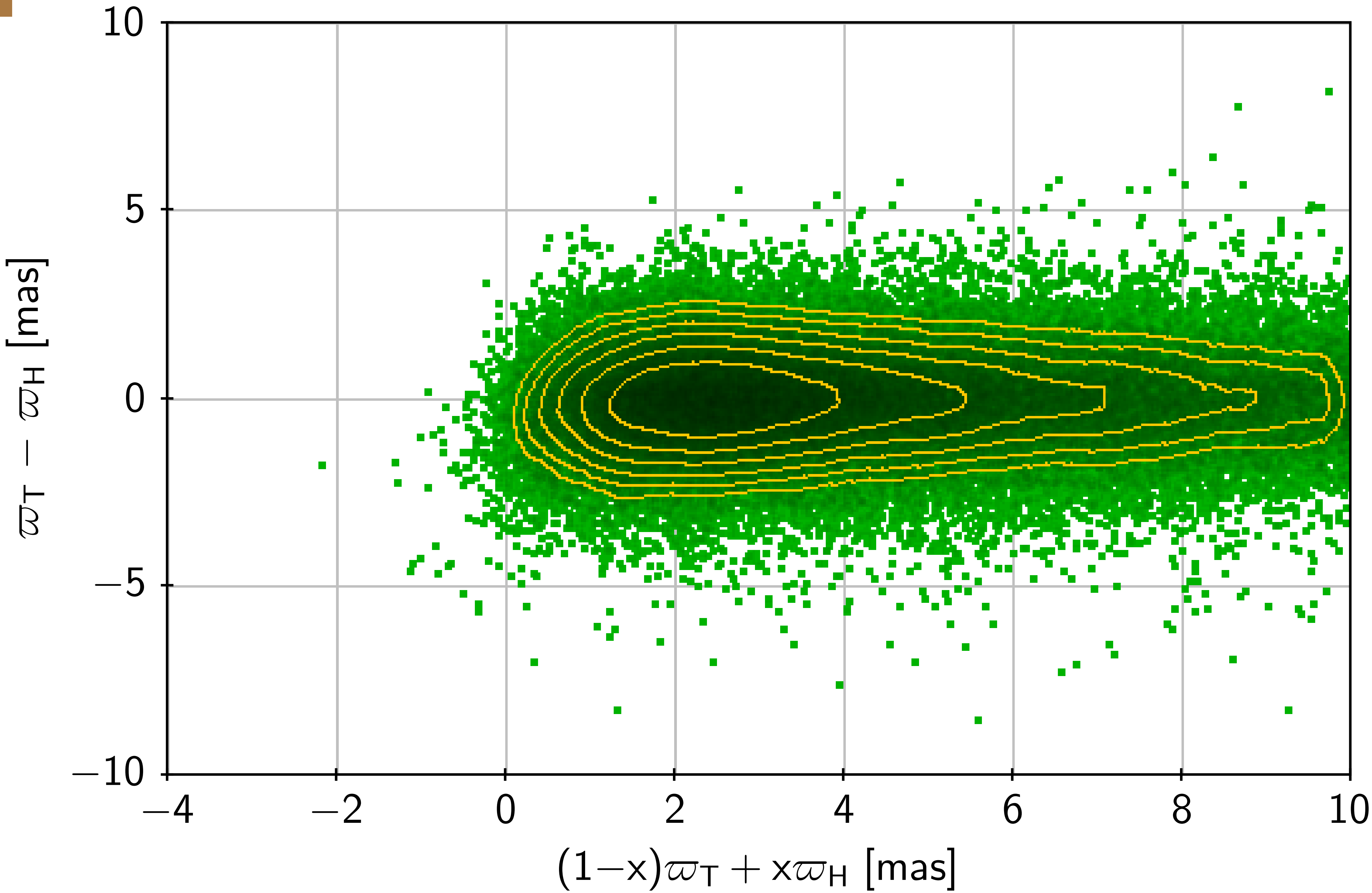
# Parallax difference T−H vs. weighted mean (1-x)*T + x*H




x = 0.05

ρ = +0.034

# Parallax difference T−H vs. weighted mean (1-x)*T + x*H




x = 0.00

ρ = +0.069

# Calibration of parallax uncertainty - theory

$$\Delta\varpi = \varpi_{\mathrm{T}} - \varpi_{\mathrm{H}}$$

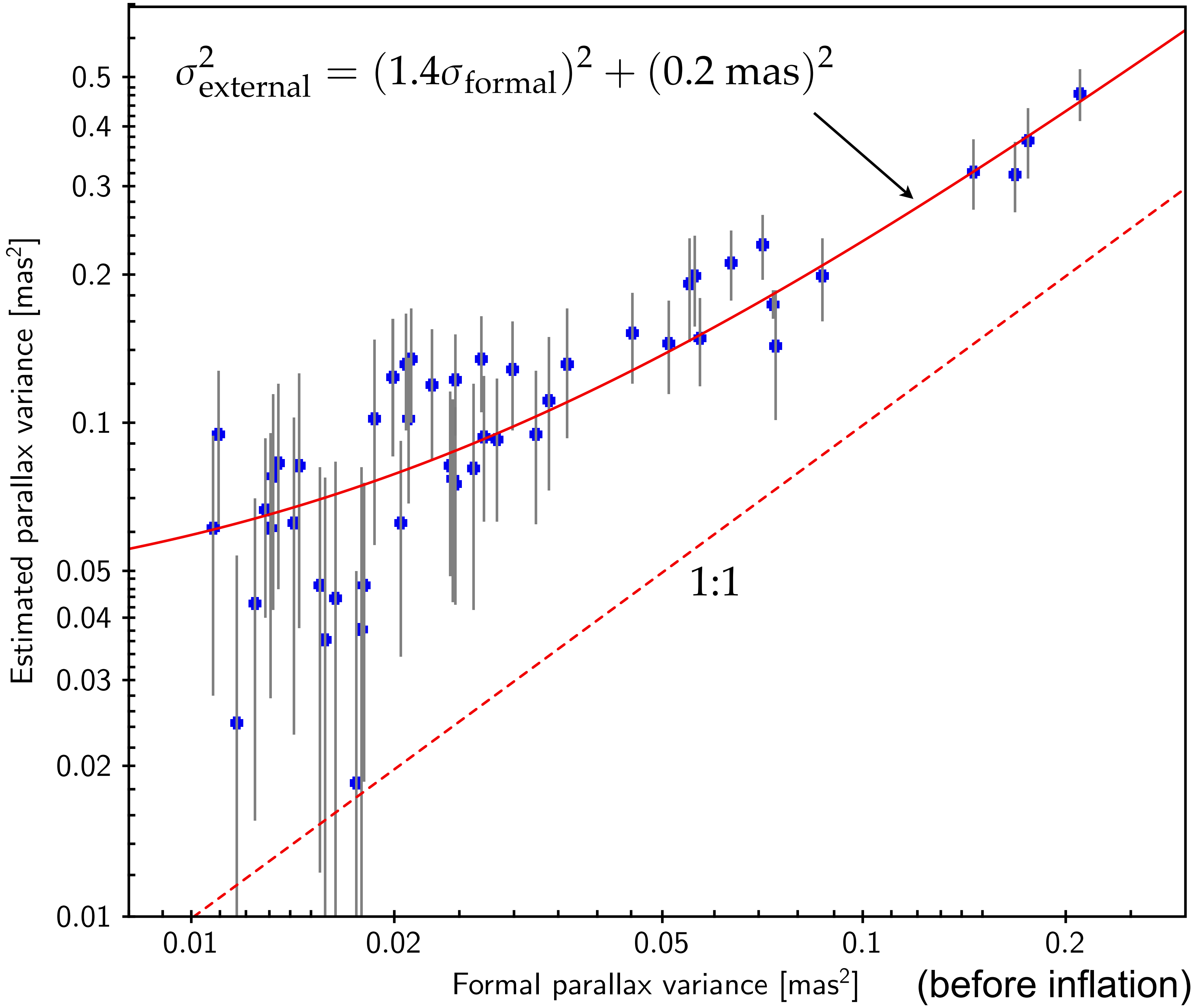
$$\varpi_x = (1 - x)\varpi_{\mathrm{T}} + x\varpi_{\mathrm{H}}$$

If the errors in $\varpi_{\mathrm{T}}$ and $\varpi_{\mathrm{H}}$ are mutually uncorrelated, and uncorrelated with the true parallax, then:

$$\mathrm{Var}(\Delta\varpi) = \mathrm{Var}(\varpi_{\mathrm{T}}) + \mathrm{Var}(\varpi_{\mathrm{H}})$$

$$\mathrm{Cov}(\Delta\varpi, \varpi_x) = 0 \quad \Leftrightarrow \quad \frac{\mathrm{Var}(\varpi_{\mathrm{T}})}{\mathrm{Var}(\varpi_{\mathrm{H}})} = \frac{x}{1 - x}$$

# External precision from TGAS-Hip comparison




(before inflation)

"Inflation":

Empirical correction factor applied to the formal uncertainties of all five astrometric parameters

# ΔQ (only for Hipparcos subset of TGAS)

ΔQ is the discrepancy between Hipparcos and TGAS proper motions, in relation to the combined covariance:

$$\Delta Q = \begin{bmatrix} \Delta\mu_{\alpha*} & \Delta\mu_{\delta} \end{bmatrix} \left( \boldsymbol{C}_{\mathrm{pm,\,T}} + \boldsymbol{C}_{\mathrm{pm,\,H}} \right)^{-1} \begin{bmatrix} \Delta\mu_{\alpha*} \\ \Delta\mu_{\delta} \end{bmatrix}$$

If the kinematic model (uniform motion) and covariances are correct, then ΔQ is expected to follow the chi-squared distribution with 2 d.o.f. (exponential distribution).

ΔQ should be sensitive to astrometric binaries with periods of 10-100 yr.

# ΔQ

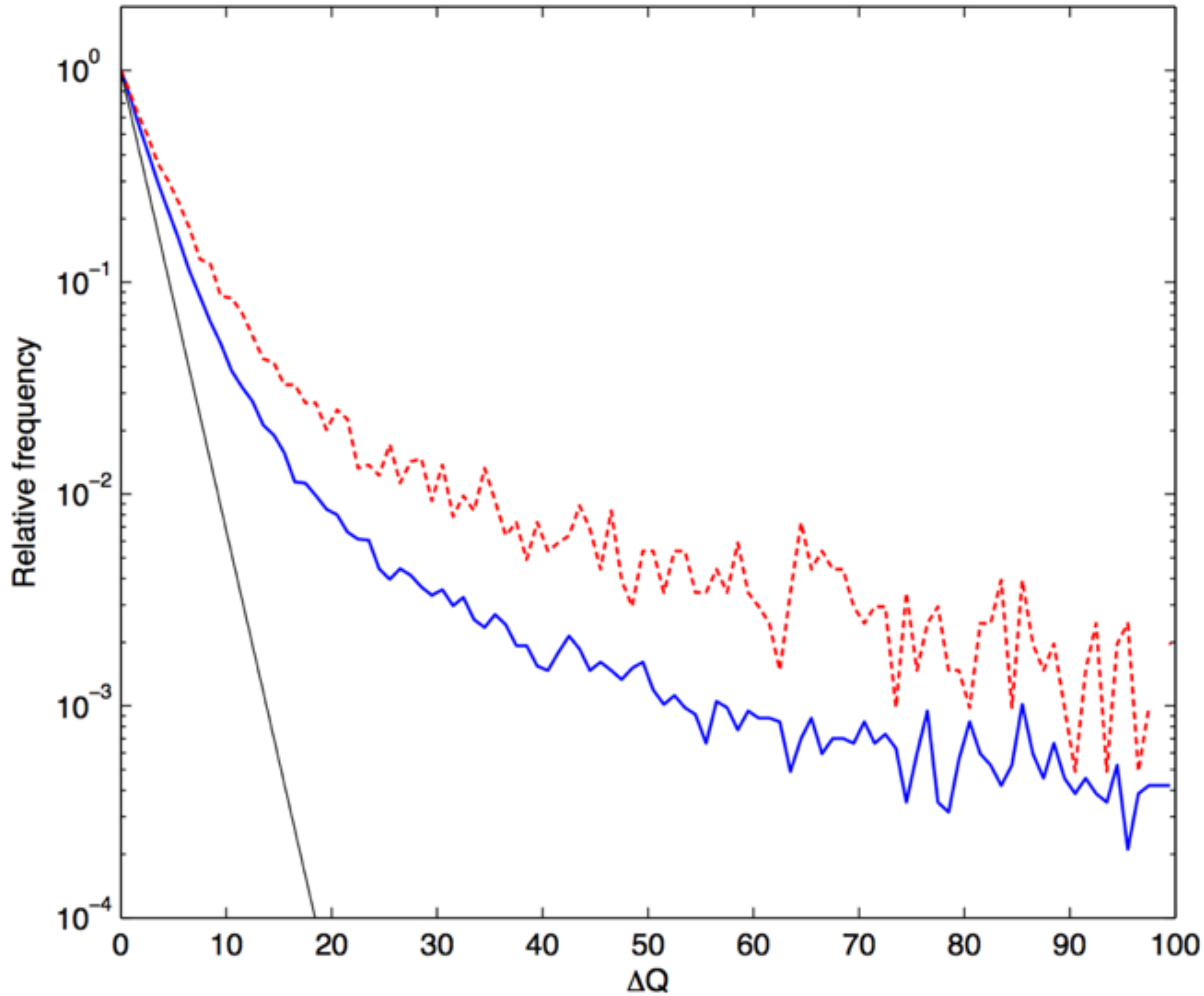
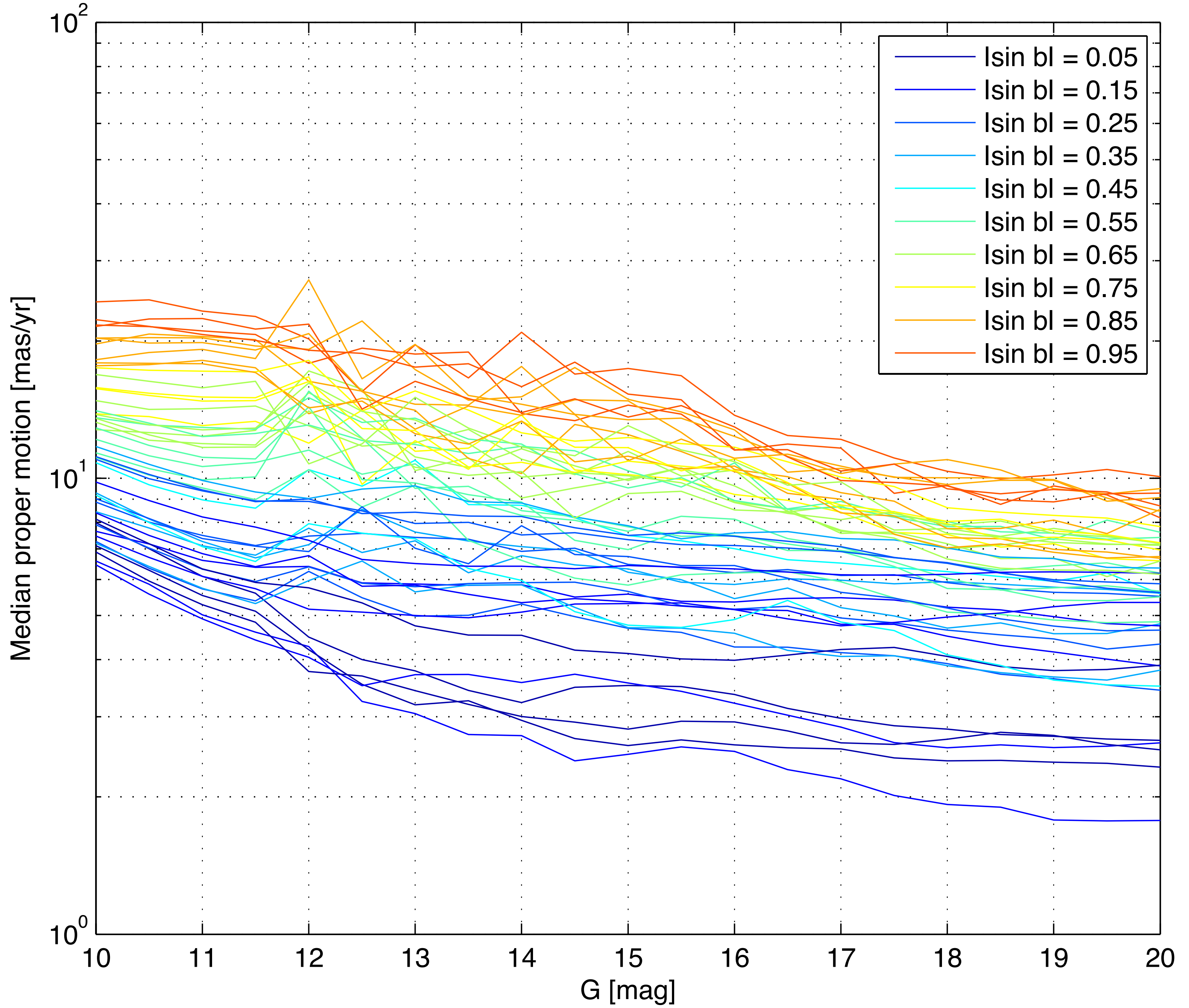



**Fig. C.3.** Relative frequencies of the statistic $\Delta Q$ for two selections of stars in the Hipparcos subset of the primary solution: 91 939 bona fide single stars (solid blue curve) and 9167 other stars (dashed red). The black line is the theoretically expected distribution.

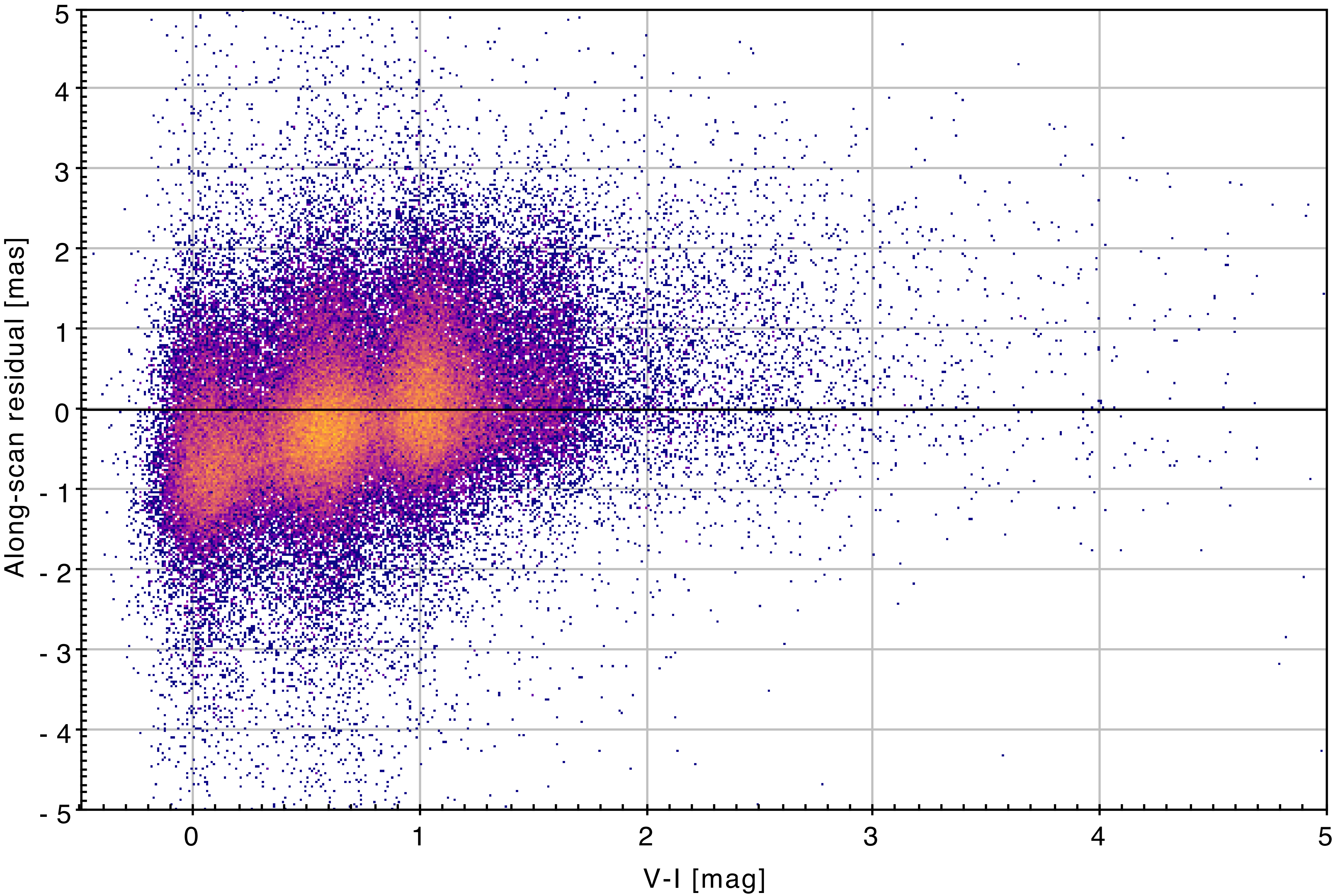
# Secondary solution: For epochs ≠ 2015.0, the position uncertainties increase due to the (unknown) proper motions




The diagram shows the median proper motion as function of magnitude (G) and galactic latitude (b), based on GUM

At G = 15 mag, the median proper motion ranges from 3 mas/yr (at b ~ 0 deg) to 20 mas/yr (b ~ 90 deg)

# Residual statistics: Chromaticity (~1 mas/mag)




Hipp stars, PFoV, AF1, row 1

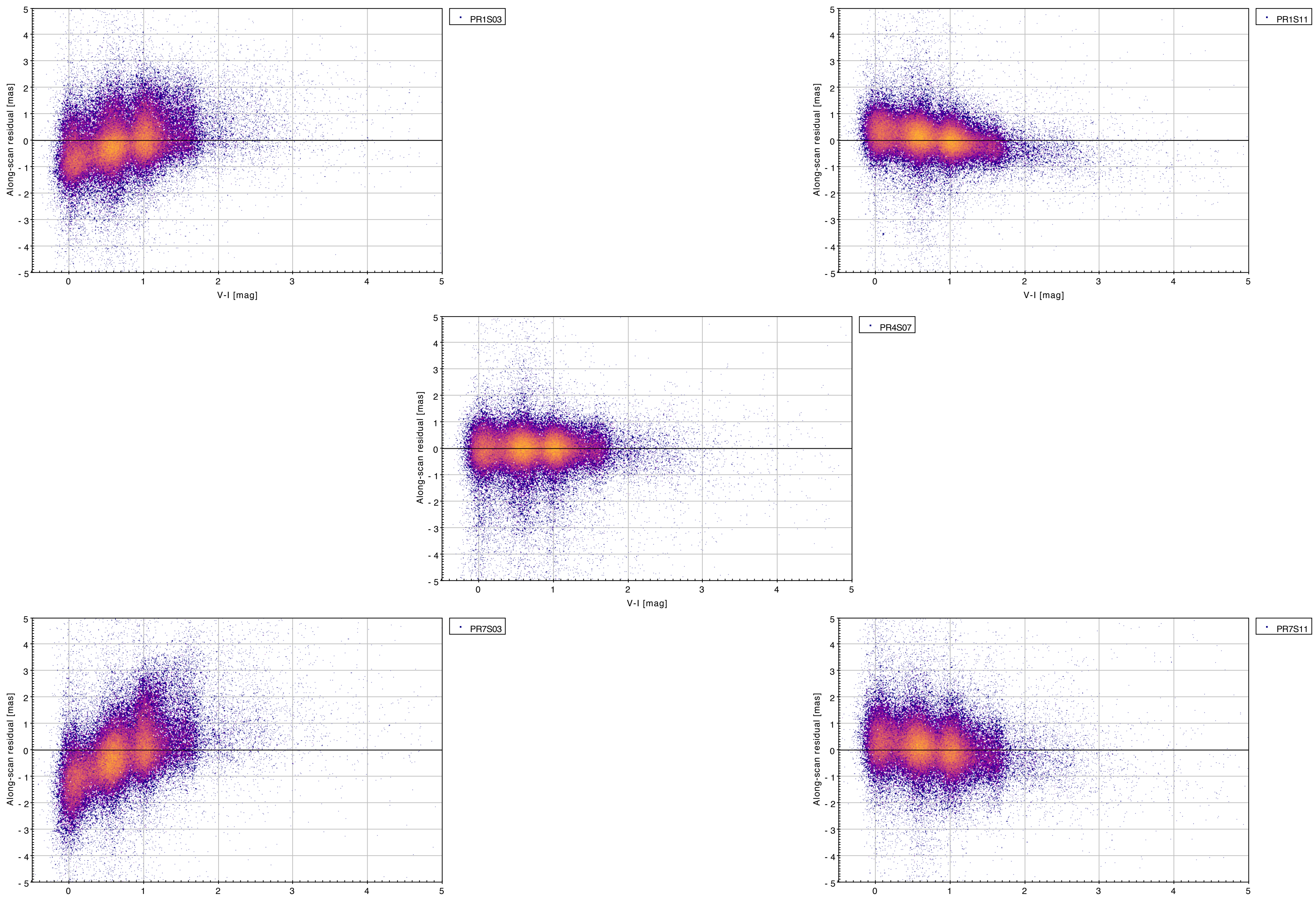
# Residual statistics: Chromaticity

PFoV

Row1

Row4

Row7




AF1 AF5 AF9

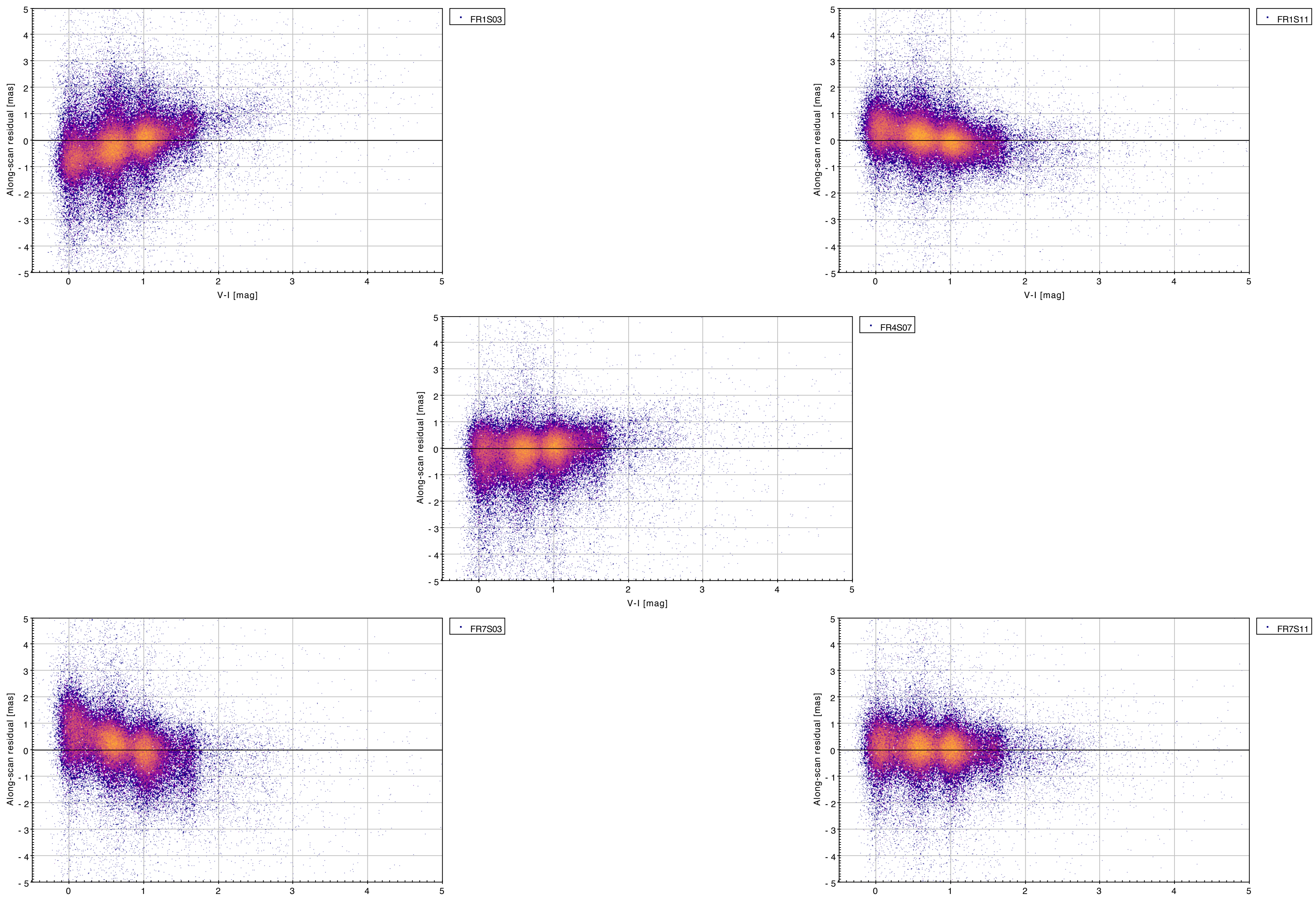
# Residual statistics: Chromaticity

FFoV

Row1

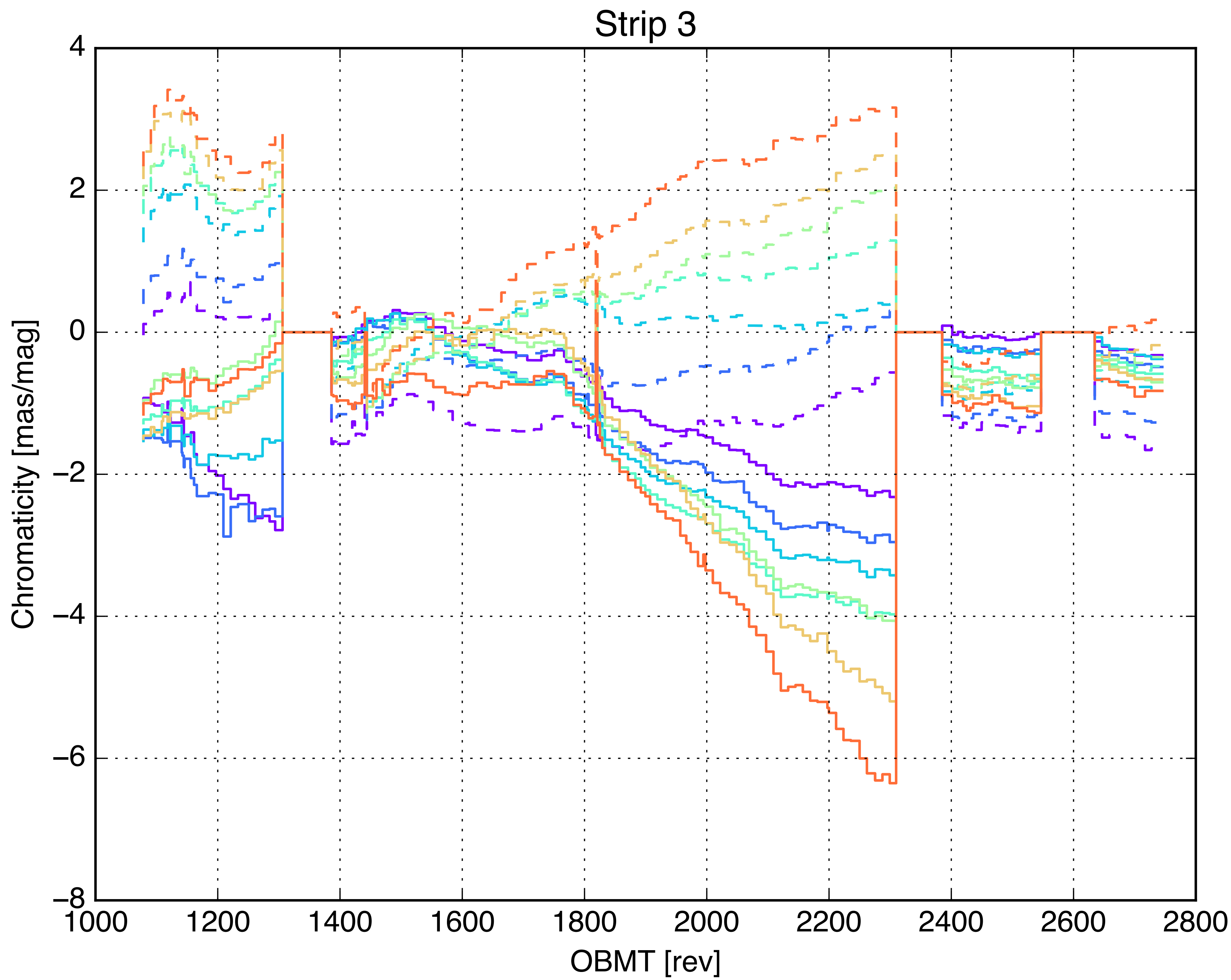
Row4

Row7




AF1 AF5 AF9

# Chromaticity term per CCD vs time (AF1)

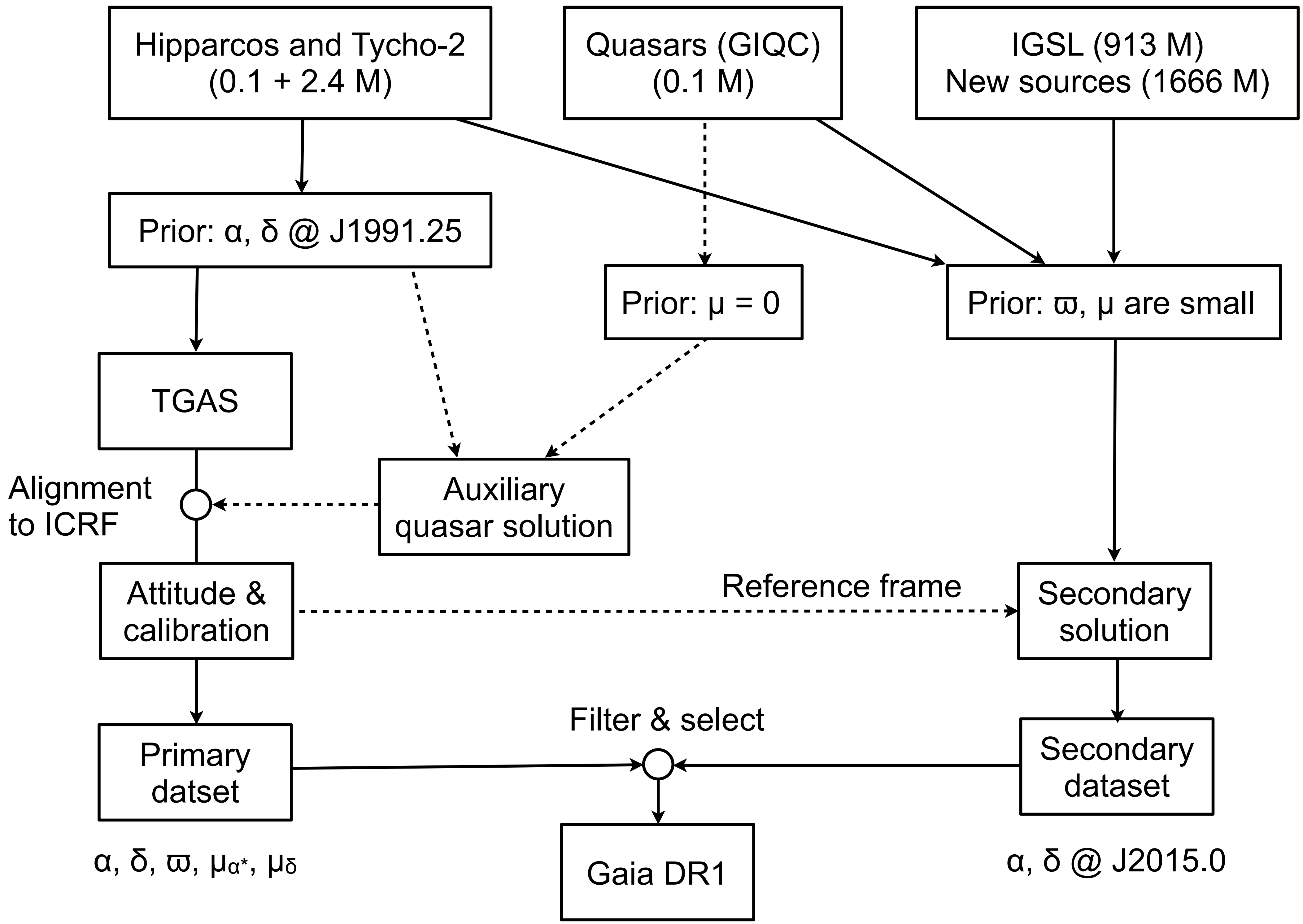



Solid: PFoV
Dashed: FFoV

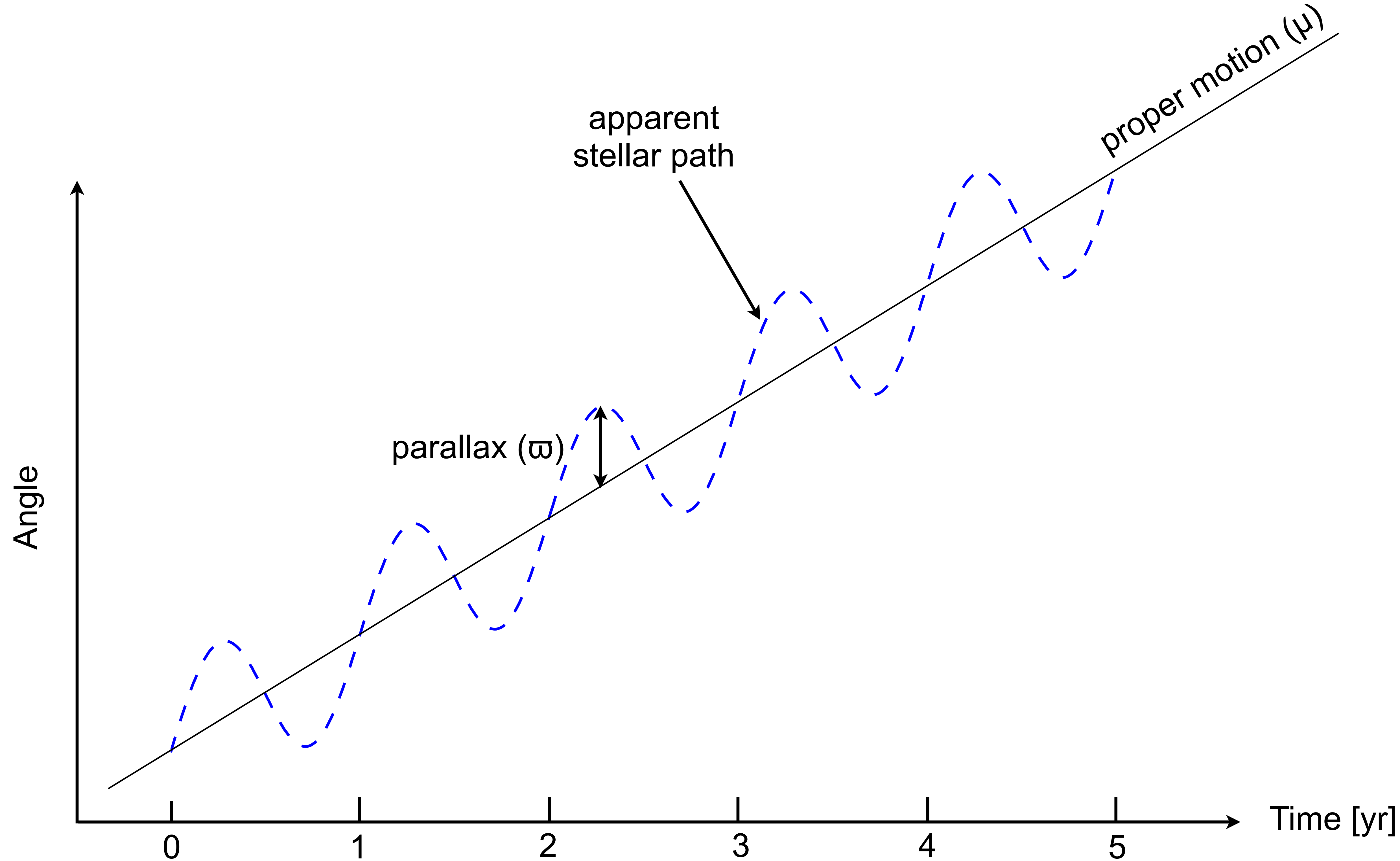
Row 1 - 7:
violet - orange

(A. Bombrun)

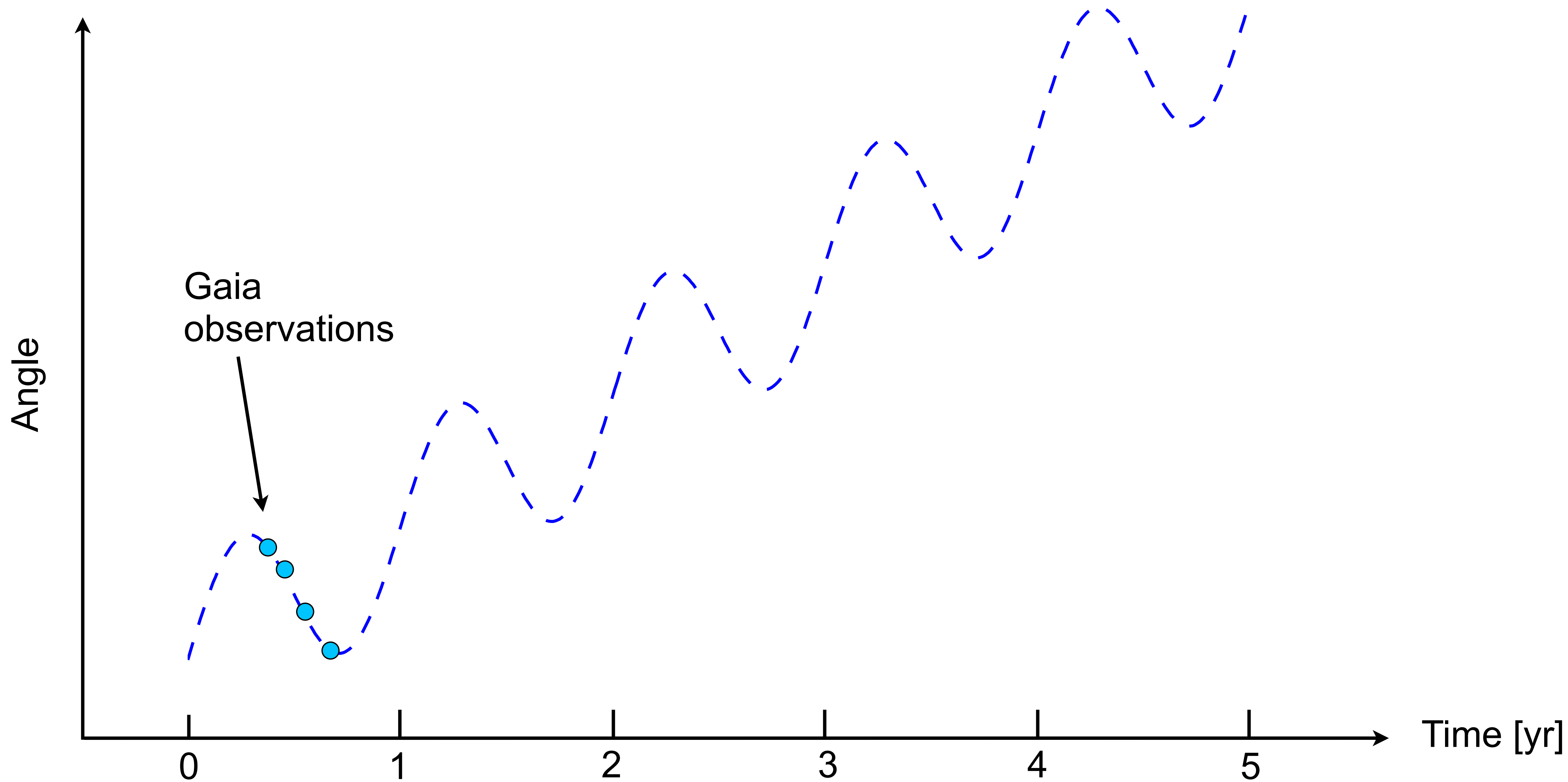
# Gaia DR1 astrometric solution flow logic



# Astrometric parameters for a single star (uniform space motion)



# μ–ϖ degeneracy for < 1 yr of observations



# Lifting the degeneracy: TGAS - Tycho-Gaia Astrometric Solution (Michalik et al. 2015)