PARSEC

(**PAR**allaxes of **S**outhern **E**xtremely **C**ool objects)

I: Targets, Proper Motions and first results

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SCIENTIFIC RATIONALE

• L + T dwarfs: very low-mass stars, cooler than M dwarfs, extremely long life, link between stars and planets

Intricacies:
- complex mass-luminosity-metallicity-age relation
- spectral type change with age

• Need observations to constrain/test theoretical models

Distances: absolute luminosity, large numbers → **LF**

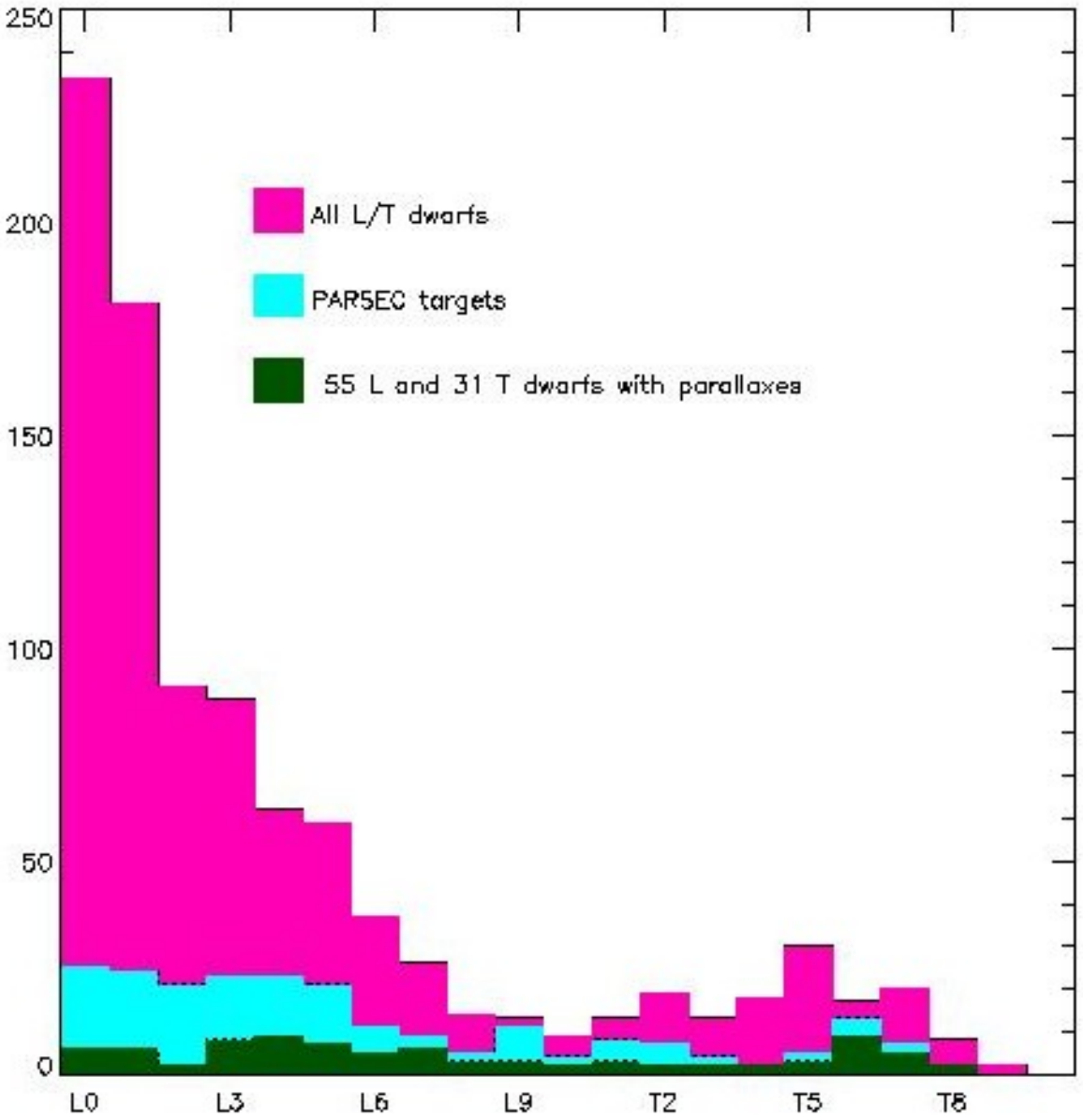
large velocities or low luminosity → **sub-dwarfs**

over luminous → **binarity**

assume a radius → **effective temperature**

Catalogue data from
www.dwarfarchives.org

PARSEC Targets ->



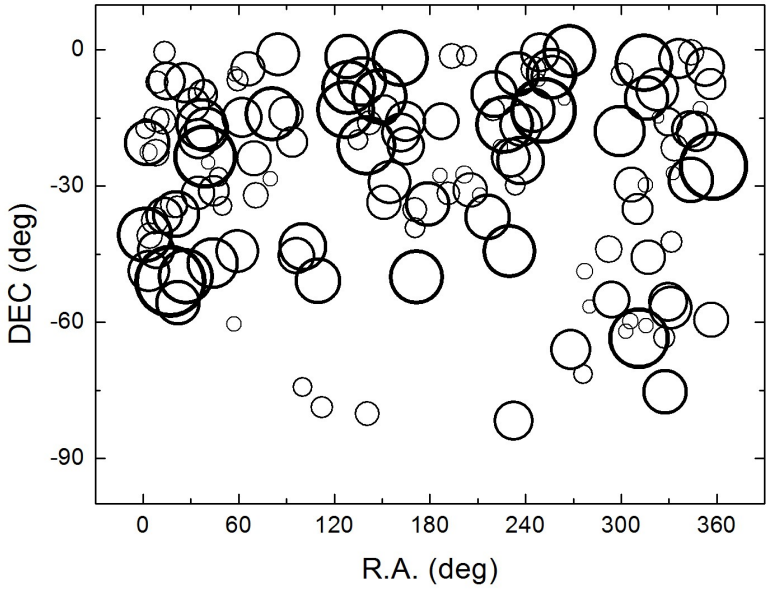
MAIN OUTPUT

- More than 100% increase of L dwarfs w/ parallaxes
- Increment to at least 10 (in conjunction with published results) the # of objects/spectral sub-class up to L9
- Put sensible limits on binarity fraction of brown dwarfs

ADDITIONAL OUTPUT

- Proper motion catalogue of 197,500 anonymous stars on 140 ~0.3 square degrees fields using PARSEC and 2MASS positions

- independent validation of UCAC2
- search for fast-moving objects
- search for stellar companions
- brown dwarf candidate selection tool

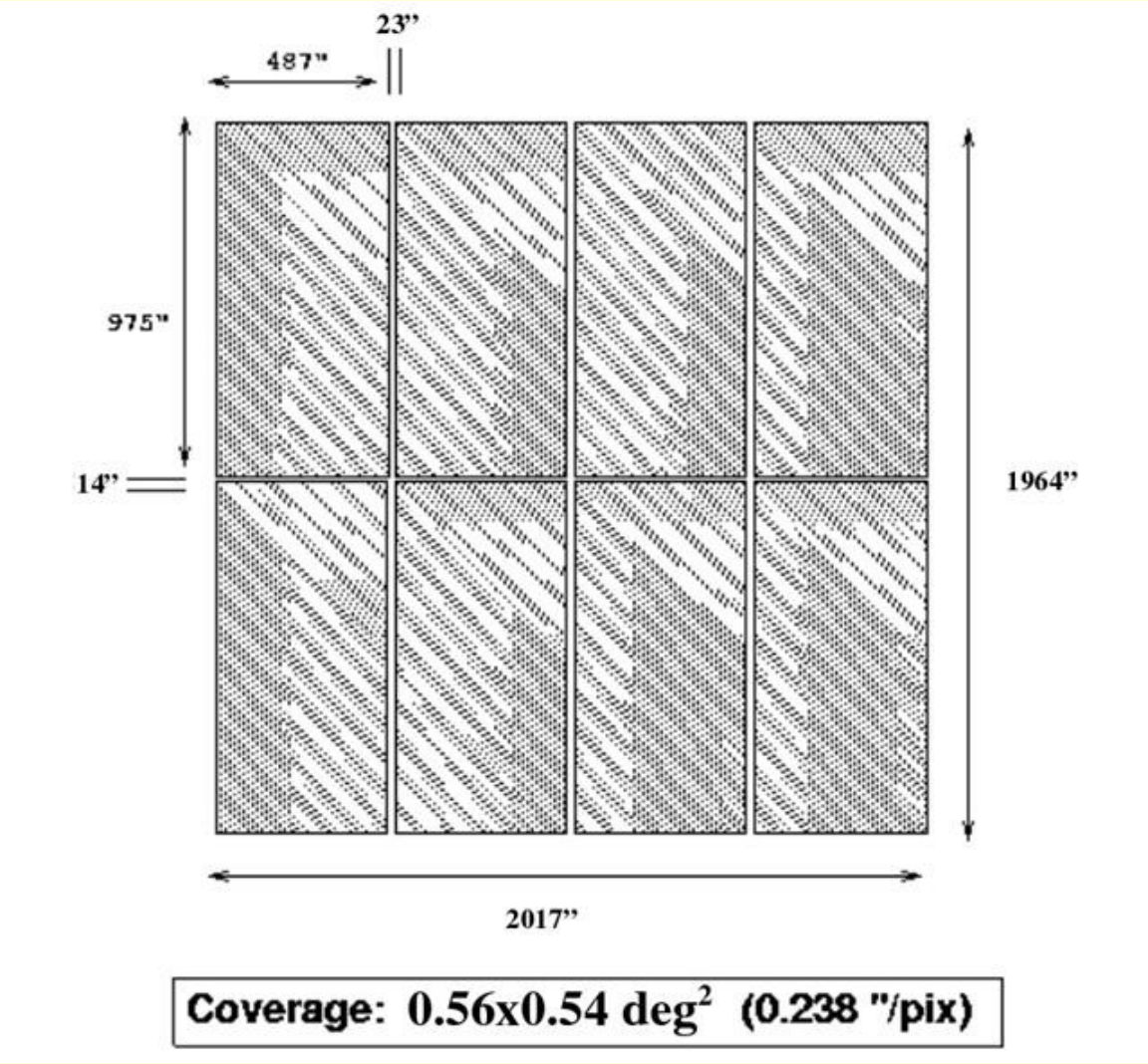


PROGRAM OUTLINE

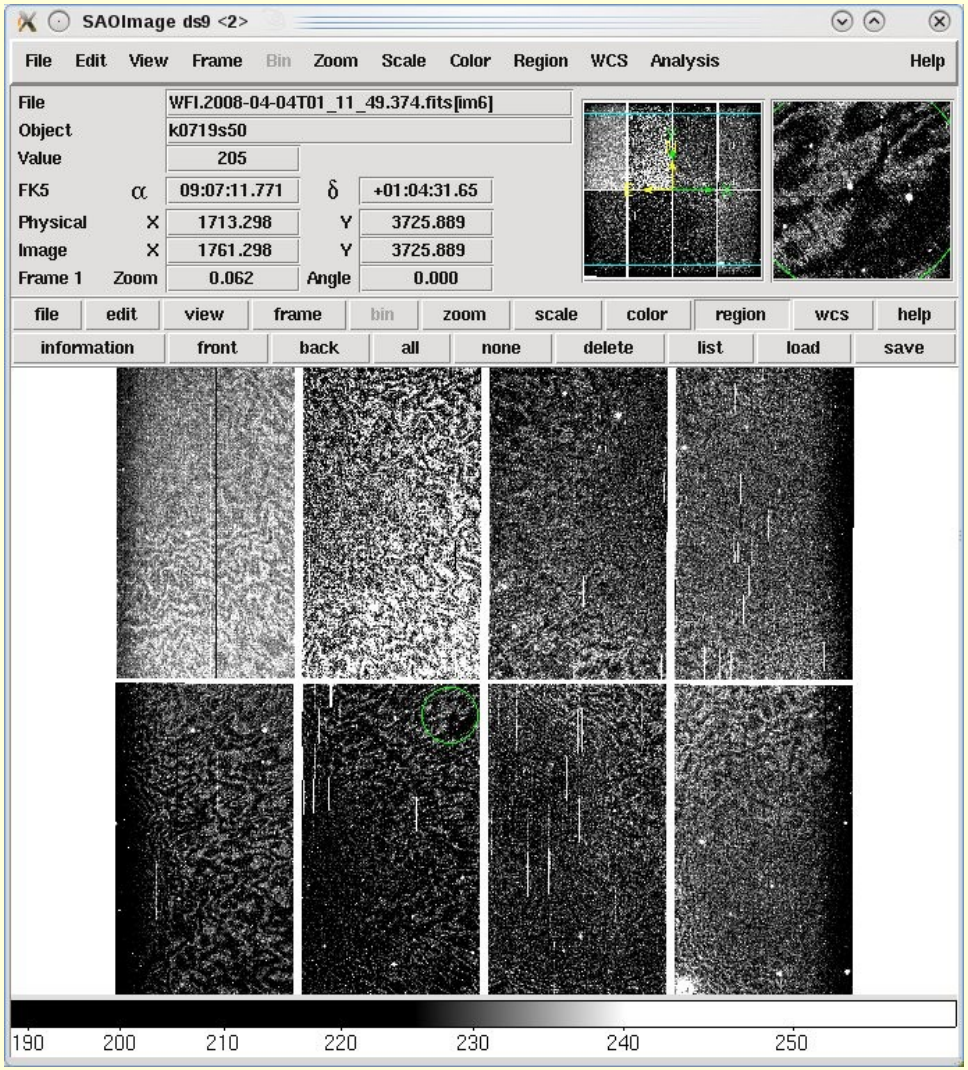
- measure **parallaxes** of 122 L and 28 T dwarfs brighter than *z*=20 in the southern hemisphere
  (most of these objects will not be observed by GAIA)

- using **WFI** on the **ESO 2.2m**, in the z band (compromise between optimal QE in *I* band and target typical brightness *I*-*z*~2)

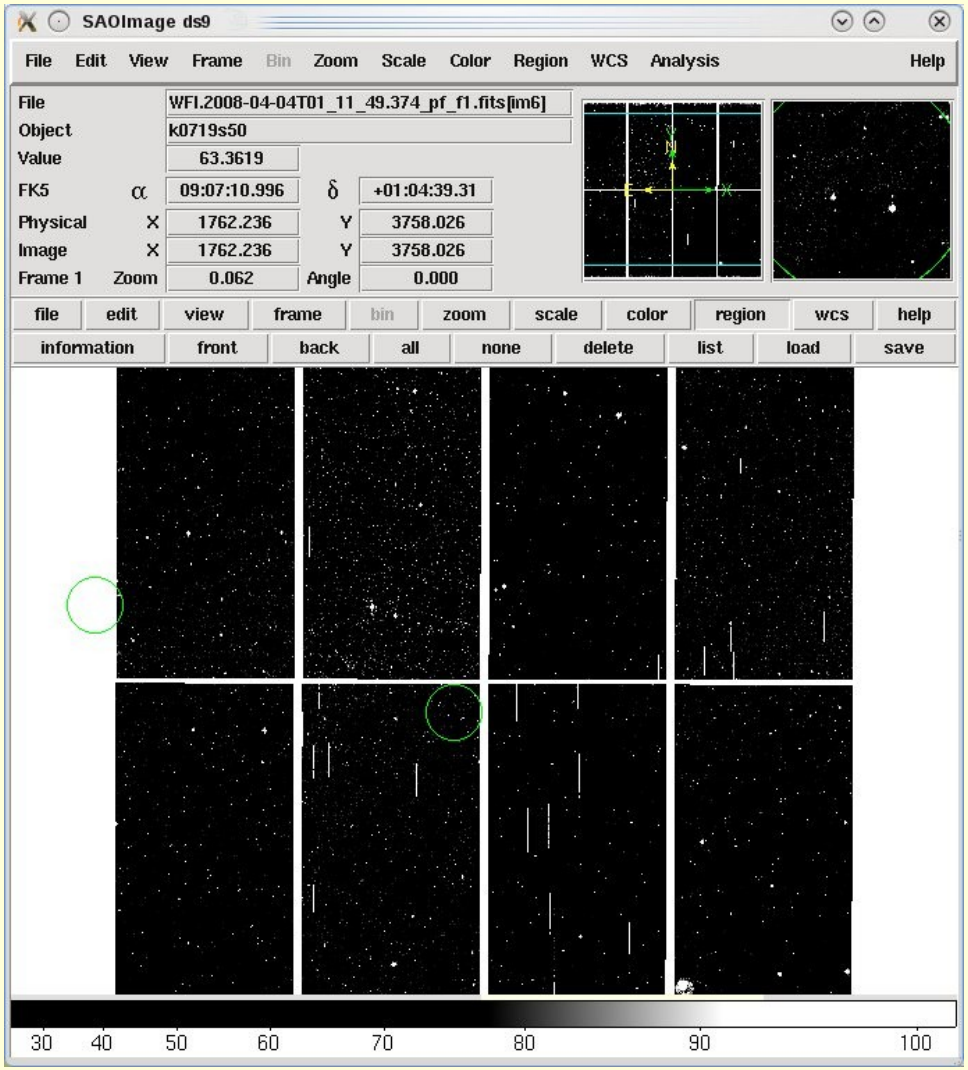
- started in 2007 (2007-2009 on brasilian time), end in early 2011, 4-6 epochs/year



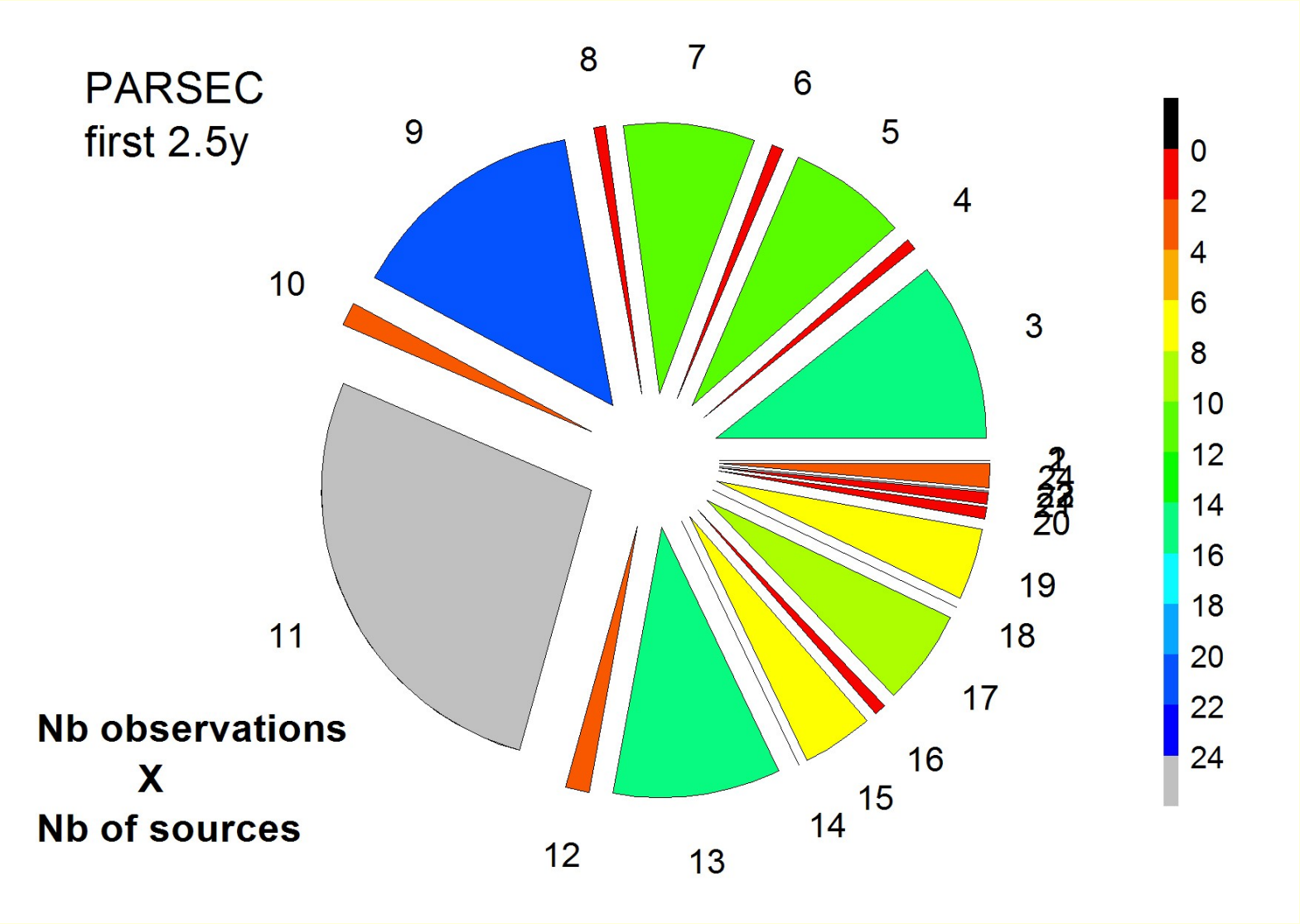
- ESO 2p2 WFI camera geometry, field, and pixel scale. The target always sit in CCD#7, nearby the optical axis.



- Raw image of a typical observation. The target´s spot is highlighted on the upper-left window of CCD#7. Notice the heavy fringe pattern (due to the z-band)



- Corresponding cleaned image. Flat, bias, and a nightly fringe map correction applied. The white dots are real stars, hidden in the noise of the raw image.



- On the edge of the slices are the number of observations; the color scheme indicates the number of sources observed that many times.

PARALLAXES

- WFI has significant astrometric distortions BUT *stability* and *repeatability* only crucial requirements for relative astrometry

Reduction procedure:

- use always top third of CCD#7 (2kx2k 15 μm pixel, 0.23" scale)
- centroiding with 2-D gaussian fit, as in TOPP program (Smart et al. 2007)
- base frame transferred to ξ,η via UCAC2
- all other frames adjusted to base frame with linear transformation
- relative parallaxes and proper motions are derived by fitting observations in the base frame system
- DCR correction is negligible in *z* band (Stone 2002)
- correction to absolute parallaxes using Mendez and Van Altena (1996) Galaxy Model

Rank deficiency in parallax determination

$$X(\mathrm{p}) = -\mathrm{l}$$

System of observation equations
p = unknown "plate" + stellar parameters
l = x,y measurements

$$X = \begin{pmatrix} M & & & -I & -t_1 I & -P_1 I \\ & M & & -I & -t_2 I & -P_2 I \\ & & \ddots & \vdots & \vdots & \vdots \\ & & M & -I & -t_n I & -P_n I \end{pmatrix}$$

The kernel (null space) of *X* is equal to 9 in practice (Eichhorn 1988), but mathematically it reduces to 3.

How to solve the system

- Obtain a *particular* solution by adding *constraint* equations on positions, proper motions, and parallaxes

RISKY

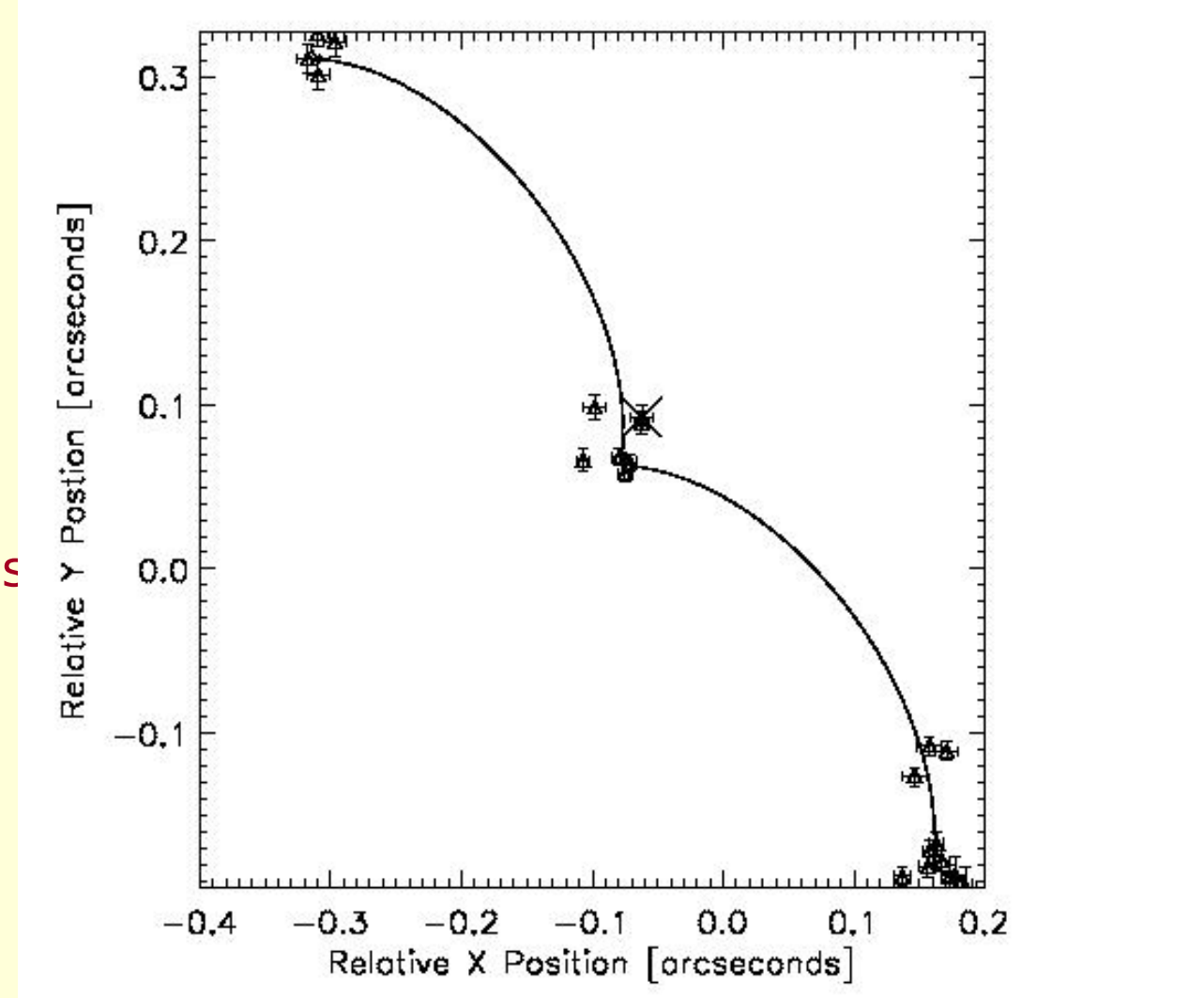
- Obtain a *minimum-norm* solution without adding any constraint equation

PREFERABLE

L0 Dwarf 0719-50 z = 16.5

24-month solution

$\pi = 32.6 \pm 2.4$ mas
$\mu_\alpha = 198.1 \pm 3.2$ mas
$\mu_\delta = -61.4 \pm 3.9$



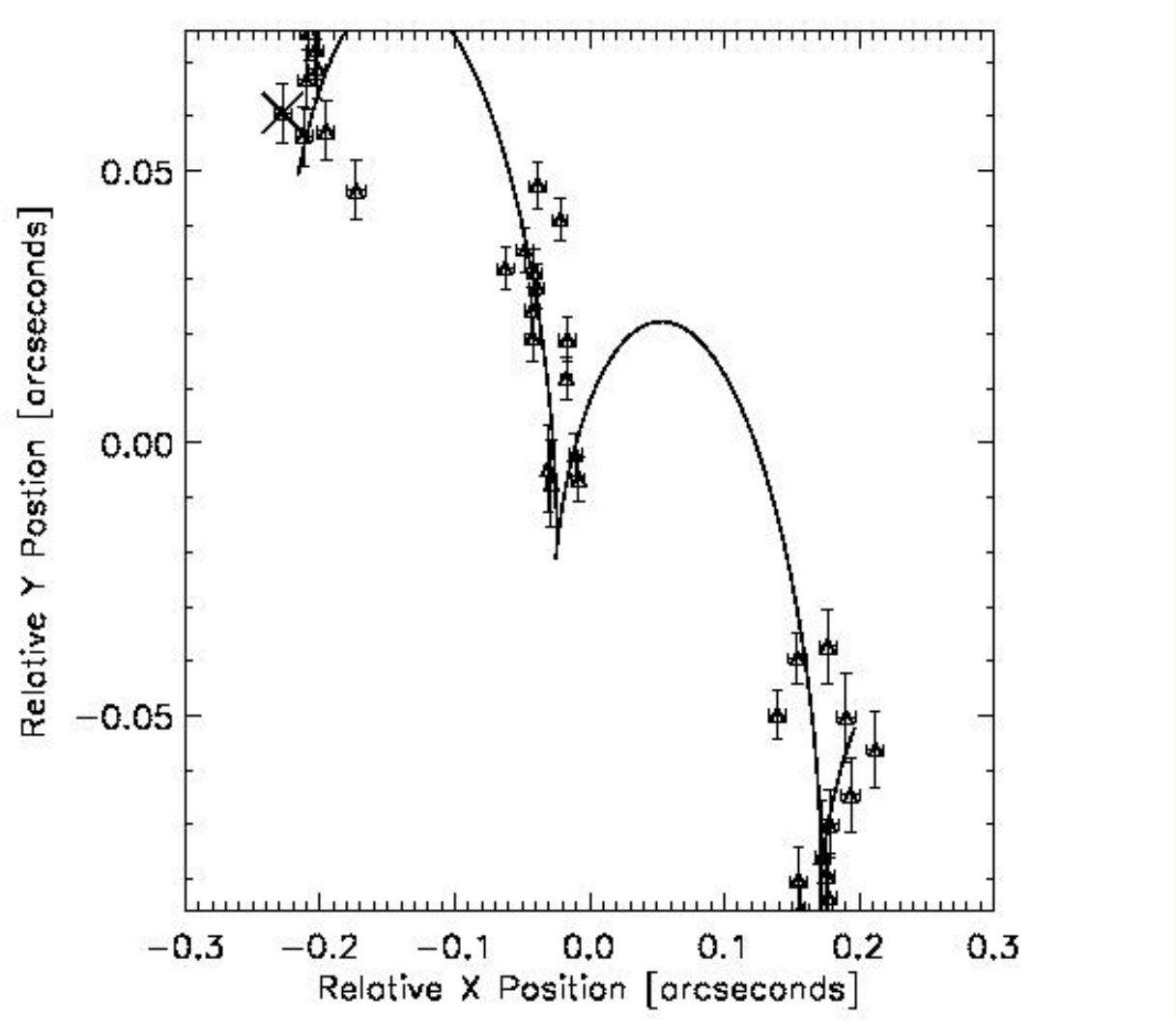
L4 Dwarf 1004-33 z= 17.3

24-month solution

$\pi = 54.8 \pm 5.6$ mas

$\mu_\alpha = 243.5 \pm 4.0$ mas

$\mu_\delta = -253.2 \pm 3.4$



PROPER MOTIONS

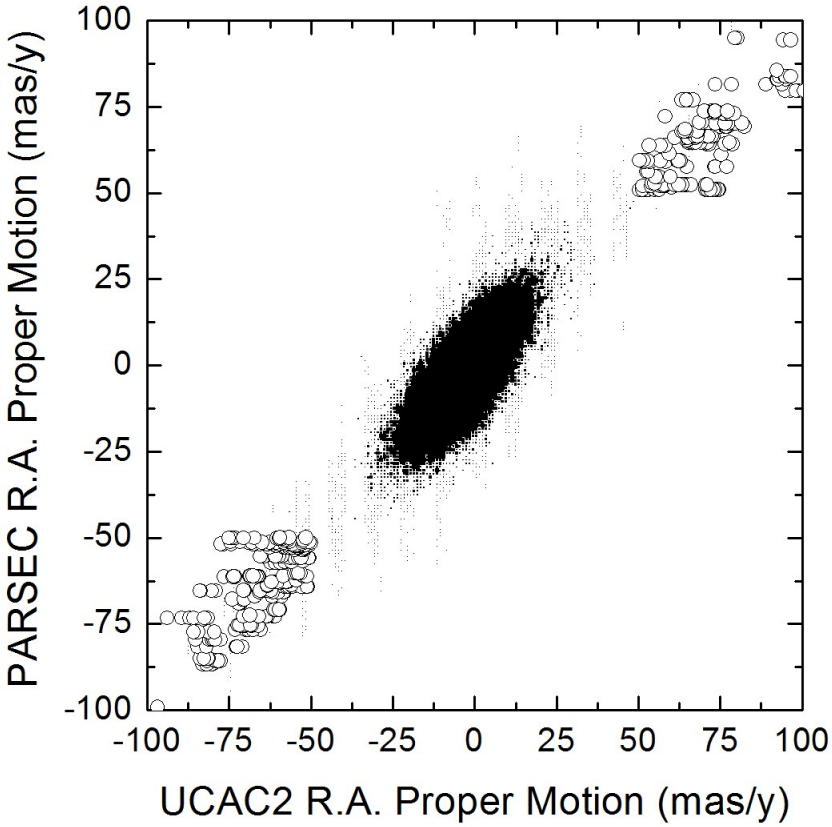
Reduction procedure

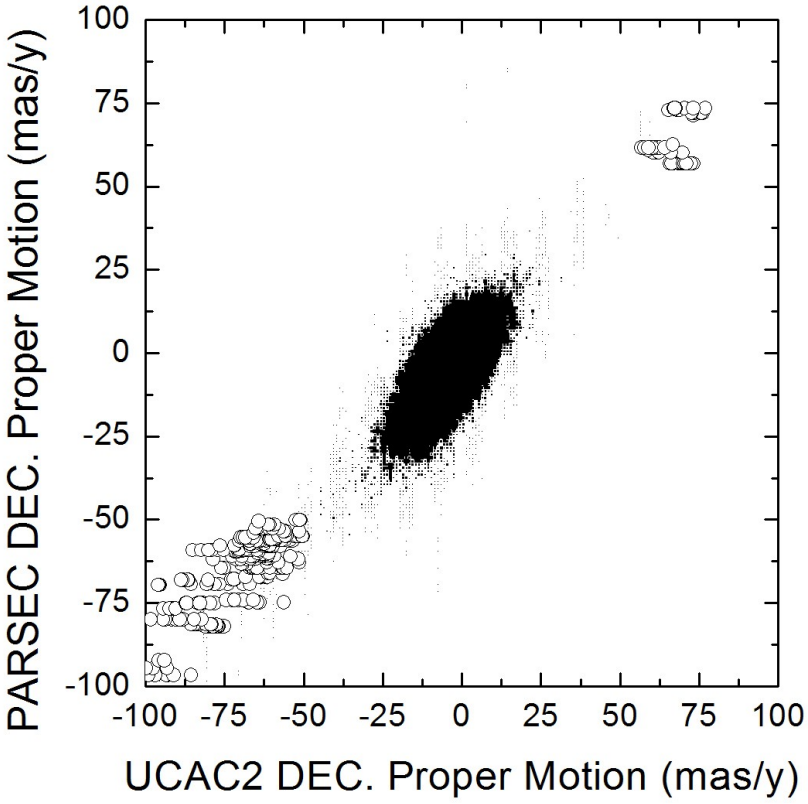
- reduction pipeline applied to entire mosaic of 8 CCDs
- each CCD reduced independently using UCAC2 stars
- nearest- neighbor match with 2MASS point source catalogue
- safety measure: p.m. determined for each observation pair and later averaged while removing deviant values

Results

- median rms error 5 mas/year
- p.m. distribution histograms in agreement w/ UCAC2 data
- more robust algorithm being developed using GSC2.3 positions at different epochs

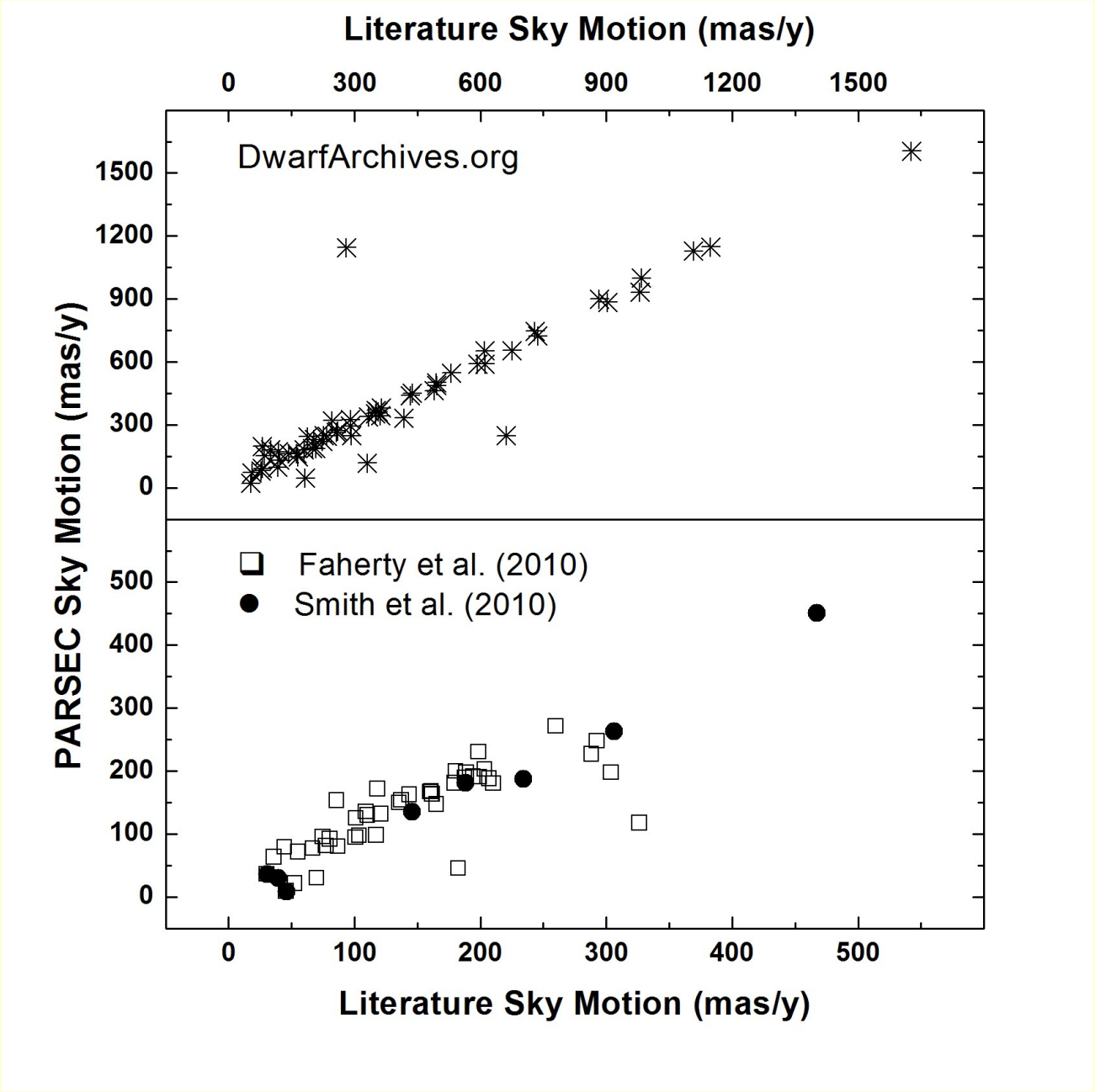
Comparison with UCAC2





$\langle\mu_\alpha\rangle$ = -2.8 mas (UCAC2 -2.7)

$\langle\mu_\delta\rangle$ = -4.0 mas (UCAC2 -3.6)


Literature Sky Motion (mas/y)
0
300
600
900
1200
1500
DwarfArchives.org
PARSEC Sky Motion (mas/y)
Faherty et al. (2010)
Smith et al. (2010)
0
100
200
300
400
500
Literature Sky Motion (mas/y)

RPM diagram of PARSEC Proper Motion catalogue