Parallaxes of Ultra Cool Brown Dwarfs Calibrators

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Outlines

- Introduction : ground-based parallaxes why?
- Our project at the Soar Telescope
- Image treatment : denoising

Detectability of ultra cool BD by Gaia

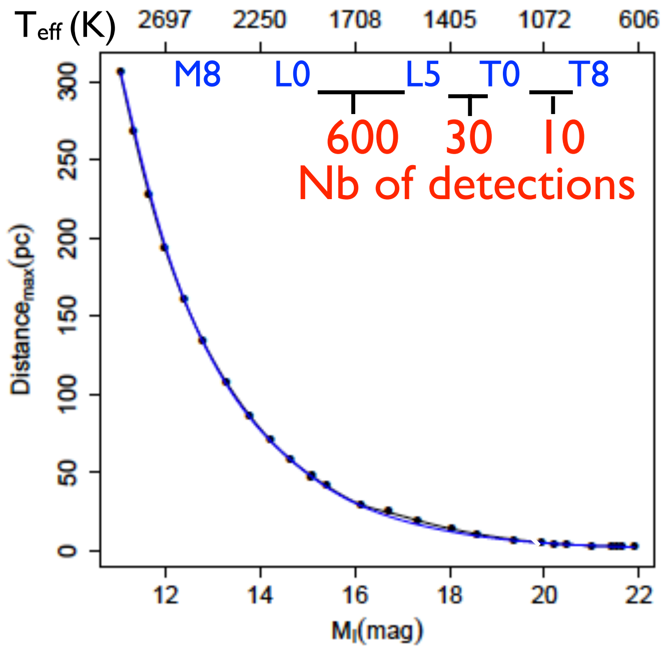


Fig. 3. Maximum distances at which an ultra-cool dwarf can be detected by *Gaia* at the limiting magnitud $G = 20$ as a function of its absolute magnitude in the I band. These have been derived from BT-Settl models (filled circles) and the continuous lines represent the interpolation used in deriving the expected counts per spectral type bin in Table 1. The black continuous line corresponds to $\log(g) = 5.0$ and the blue line to $\log(g) = 3.5$. The top axis shows the effective temperature measured in Kelvin for a $\log(g) = 5.0$ object with the absolute I magnitudes shown in the x axis, according to the BT-Settl models. The $T_{eff} - M_I$ mapping is only bi-valued below 600 K.

L. M. Sarro et al., 2013, A&A 550, A44

- Few UCBD observed by Gaia
- Gaia catalog : 2020
- Need to calibrate atmospheric models in the BD/UCBD regime

Detection of ultra cool BD from ground

- **WISE** in activity since 2009 (entire sky, 4 mid-infrared wavelengths).
- About 200 BD SType > T6

	RA [h:m:s]	DEC [d:m:s]	ST	D(pc)	Parallax	Discovery
WISE	9 43 5,98	+36 7 23,5	T9.5	6,6-12,1	Cushing et al. (2014)	Cushing et al. (2011)
WISE	20 0 50,19	+36 29 50,1	T8	6,4-8,0	Cushing et al. (2014)	Cushing et al. (2011)
WISE	22 9 5,73	+27 11 43,9	Y0	5,2-11,7	Cushing et al. (2014)	Cushing et al. (2011)
WISEP	4 10 22,71	+15 2 48,5	Y0	4,2	Marsh et al. (2013)	Cushing et al. (2011)
WISEPC	14 5 18,40	+55 34 21,5	Y0	3,4	Marsh et al. (2013)	Cushing et al. (2011)
WISE	17 38 35,53	+27 32 59,0	Y0	6,0	Marsh et al. (2013)	Cushing et al. (2011)
WISEPC	20 56 28,90	+14 59 53,3	Y0	7,5	Marsh et al. (2013)	Cushing et al. (2011)
WISEPA	2 54 9,45	+02 23 59,1	T8	4,9	Marsh et al. (2013)	Scholz et al. (2011)
WISEPC	15 6 49,97	+70 27 36,0	T6	3,4	Marsh et al. (2013)	Kirkpatrick et al.(2011)
WISEPA	17 41 24,26	+25 53 19,5	T9	5,8	Marsh et al. (2013)	Kirkpatrick et al.(2011)

• • •

Distance needed now

➡to characterize these objects

➡to constrain the atmospheric models

How to obtain distances ?

Spectroscopic distance

- ➡Relies on a calibrated *Abs. Mag & Spec. Type* relationship
- ➡Interstellar extinction

Photometric distance

- ➡Relies on a calibrated *Color & apparent Mag* relationship

Trigonometric distance

- ➡Relies on no astrophysical assumption
- ➡Time demanding

Table 7
Distance Estimates

Object	SpType	d_{spec} (pc)[a]	d_{π} (pc)[b]	d_{phot} (pc)[c]
UGPS 0722−05	T9	11.1 (10.4–11.1)	3.6–4.7	...
WISEPC J0148−7202	T9.5	14.7 (13.1–14.7)	...	12.1
WISEP J0410+1502	Y0	11.8 (6.3–16.9)	...	9.0
WISEPC J1405+5534	Y0 (pec?)	3.8	...	8.6
WISEP J1541−2250	Y0	8.1 (8.1–8.9)	2.2–4.1	8.2
WISEP J1738+2732	Y0	3.4 (3.4–7.3)	...	10.5
WISEP J1828+2650	>Y0	...	...	<9.4
WISEPC J2056+1459	Y0	3.0 (2.4–6.4)	...	7.7

Notes.
[a] Spectroscopic distance estimates derived as described in Section 4.2.1. The distance corresponding to the best-fitting model is given and the range of distances corresponding to models that are consistent with the data are given in parentheses.
[b] Parallactic distance for UGPS 0722−05 and WISEP J1541−2250 from Lucas et al. (2010) and Kirkpatrick et al. (2011), respectively.
[c] Photometric distance estimates from Kirkpatrick et al. (2011).

Cushing et al. 2011

Trigonometric parallaxes

Constraints :

- ➡Project over a minimum of 2.5 yr time-base
- ➡A unique instrument
- ➡Data mining remains difficult

Is it worth ?

- ➡For locating a 5 pc object : No.
- ➡For statistics : No
- ➡To calibrate the models : Yes
- ➡To characterize objects : Yes, even for close objects

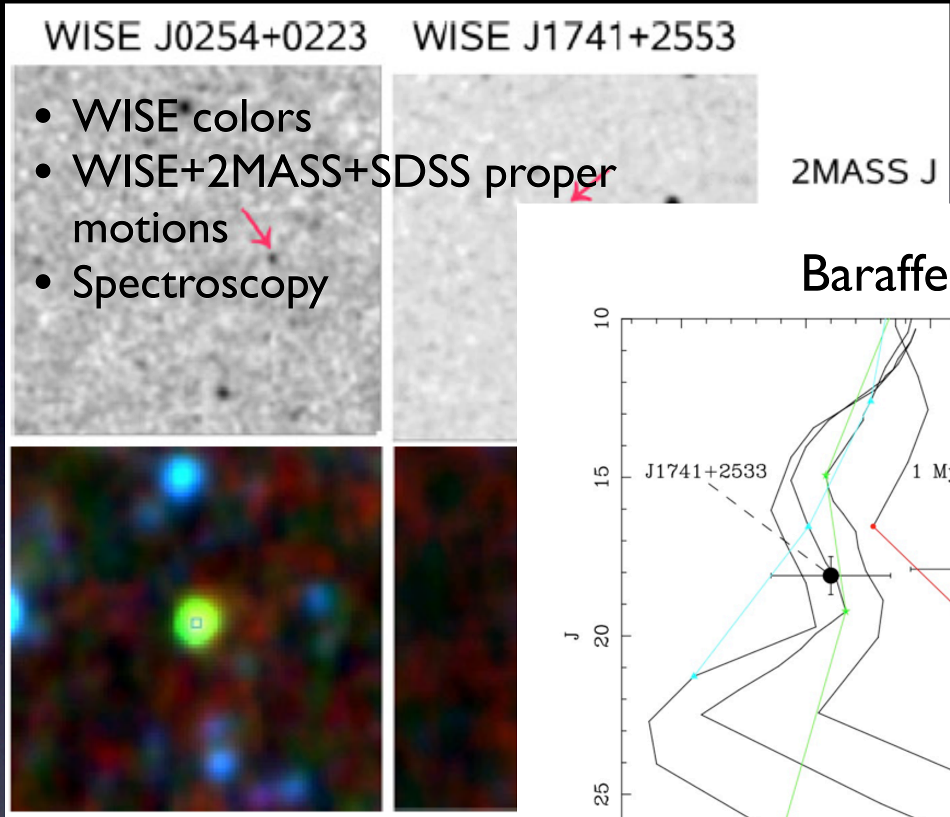
Our parallax program

Distances at 1-5%

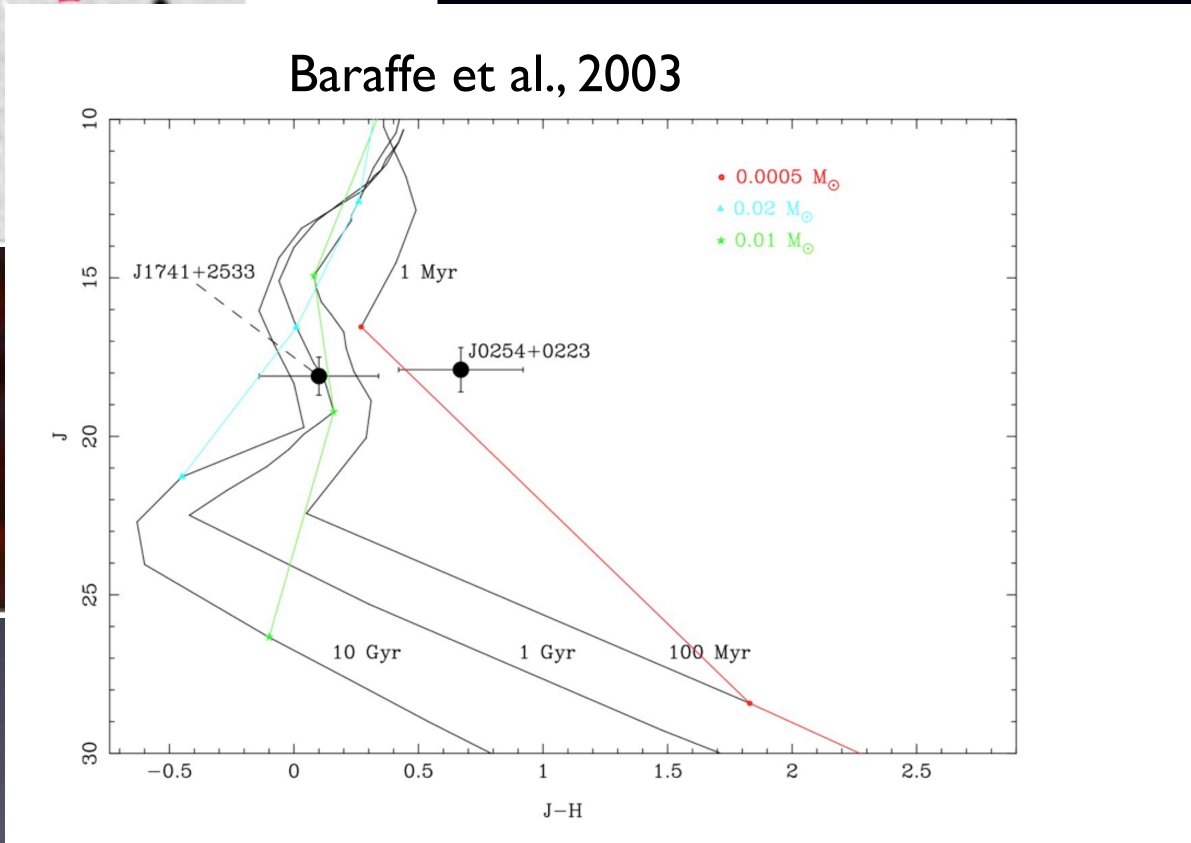
Id	RA	DE	St	J	Note
WISE J0254+0223	02:54:09.00	+02:23:59.00	T8-9	15.8	Very close
WISE J1741+2533	17:41:24.00	+25:53:20.00	T9-10	16.5	Very close
UGPS J0722-0540	07:22:27.00	-05:40:30.00	T9	16.5	
WISE 1541-2250	15:41:00.00	-22:49:55.00	Y0?	21.2	350K?
2M 0041353-562112	00:41:35.39	-56:21:12.77	M7-9	14.7	BD system
Omega centauri	13:26:47,00	-47:28:46,00	Calibration of Spartan		

WISE J0254+0223 **T8** **5.5 +- 2.3 pc photometric**

WISE J1741+2533 **T9-T10** **4.6 +- 1.2 pc photometric** *Scholz et al. 2011*



- WISE colors
- WISE+2MASS+SDSS proper motions
- Spectroscopy



Difficult to conclude on the age : either error on distance underestimated or models imprecise.

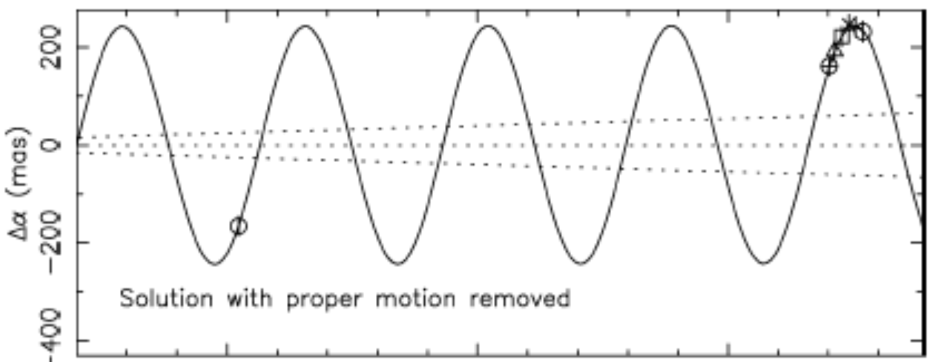
Need for accurate distance

UGPS J0722-0540 T9

Lucas et al., 2010 (UKIRT data)

Pi = 246 +/- 33 mas

T_{eff} = 520 +/- 40 K



WISE 1541-2250 Y0

Cushing et al. 2011 (WISE data)

T_{eff} = 350 +/- ... K

Important calibrators

Need of a precise distance

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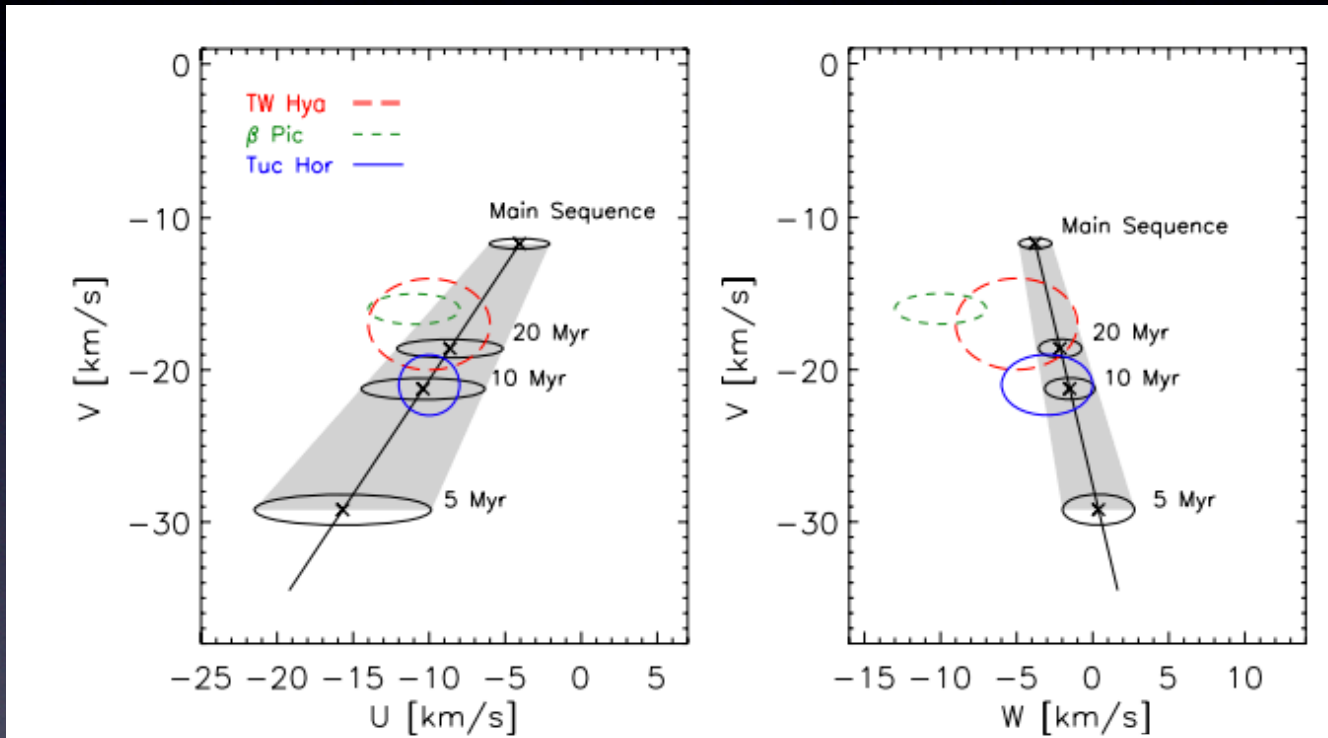
Cushing et al. 2011

2MJ0041353-562112 M7.5 BD system

Reiners et al. 2009

- Signs of accretion : disk, age < 10 Myr
- Kinematics : member of Tuc-Hor association (10-40 Myr)



Reiners et al. 2009

Need of accurate distance to derive **individual masses !**

The Soar telescope

The telescope

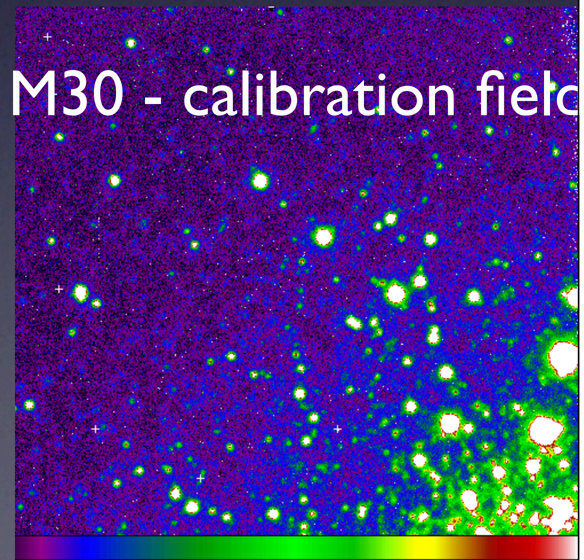
- The Southern Astrophysical Research 4.1 m telescope (SOAR)
- Cerro Pachon (Chile) 2700m

The Spartan camera

➡ IR camera with high spatial resolution.

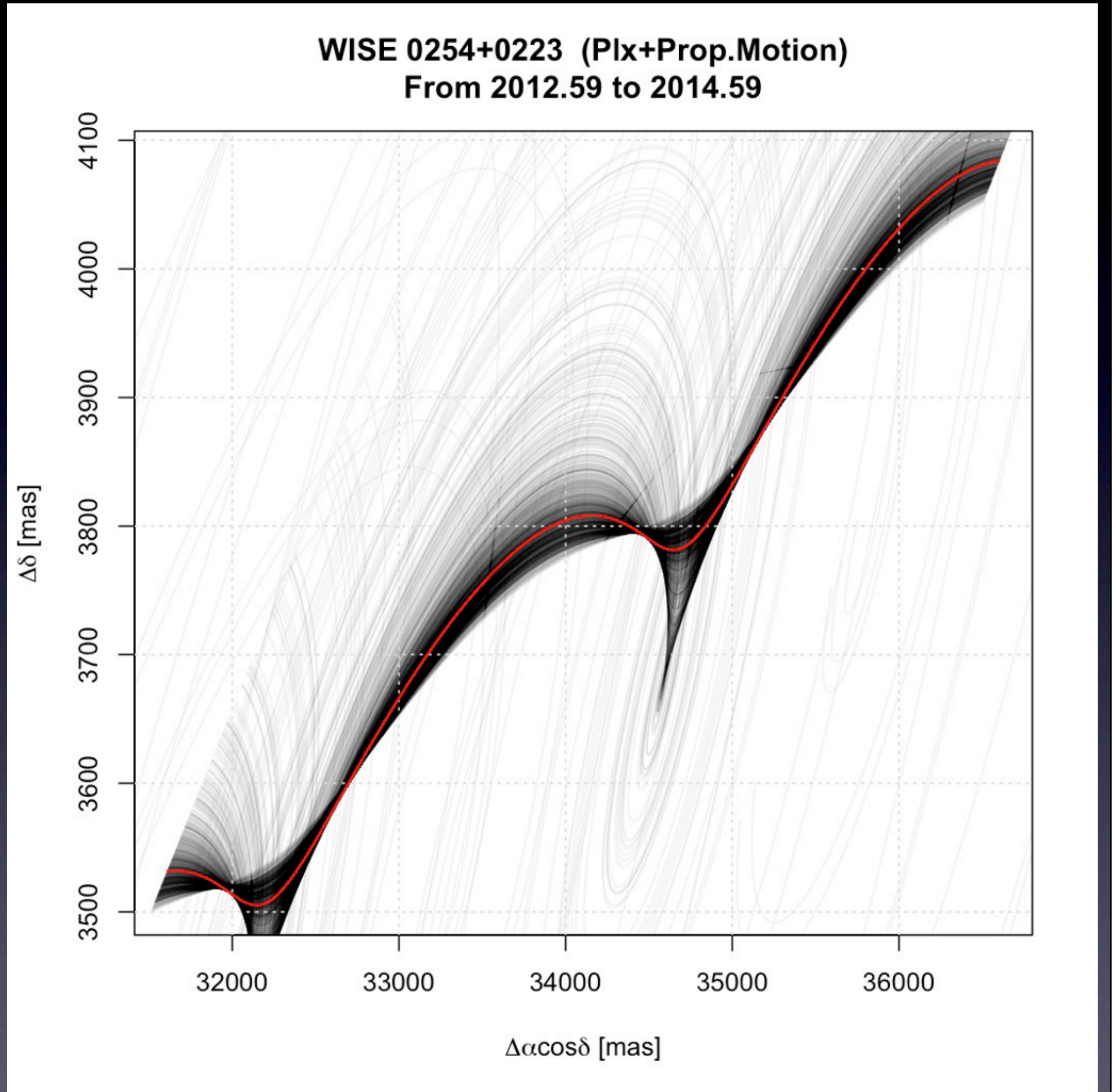
➡ 4 Hawaii-II" 2048 x 2048 pixel HgCdTe detectors

- 66 mas/pixel
- FOV of 5.04' x 5.04'



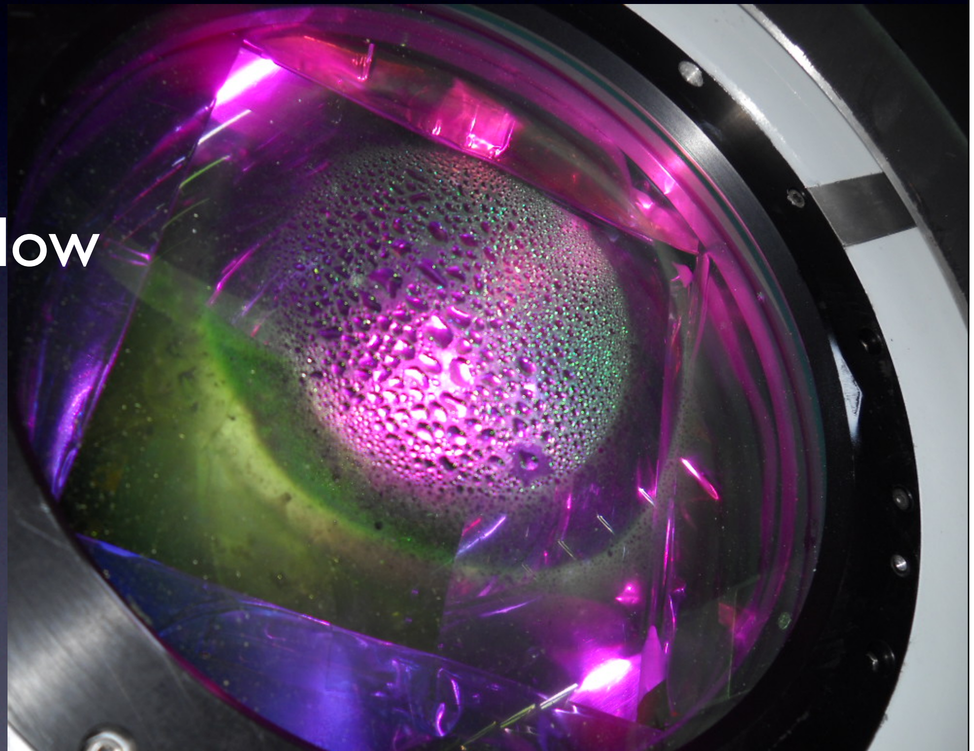
Observations

- 2.5 years project
- J filter, jittered observations
- 8 epochs of observation / year
- 9 hours / epochs
- 6-10 images of each target each year
- Strict observing conditions (HA<1.5h)
- Astrometric calibration of Spartan with omega centauri observations

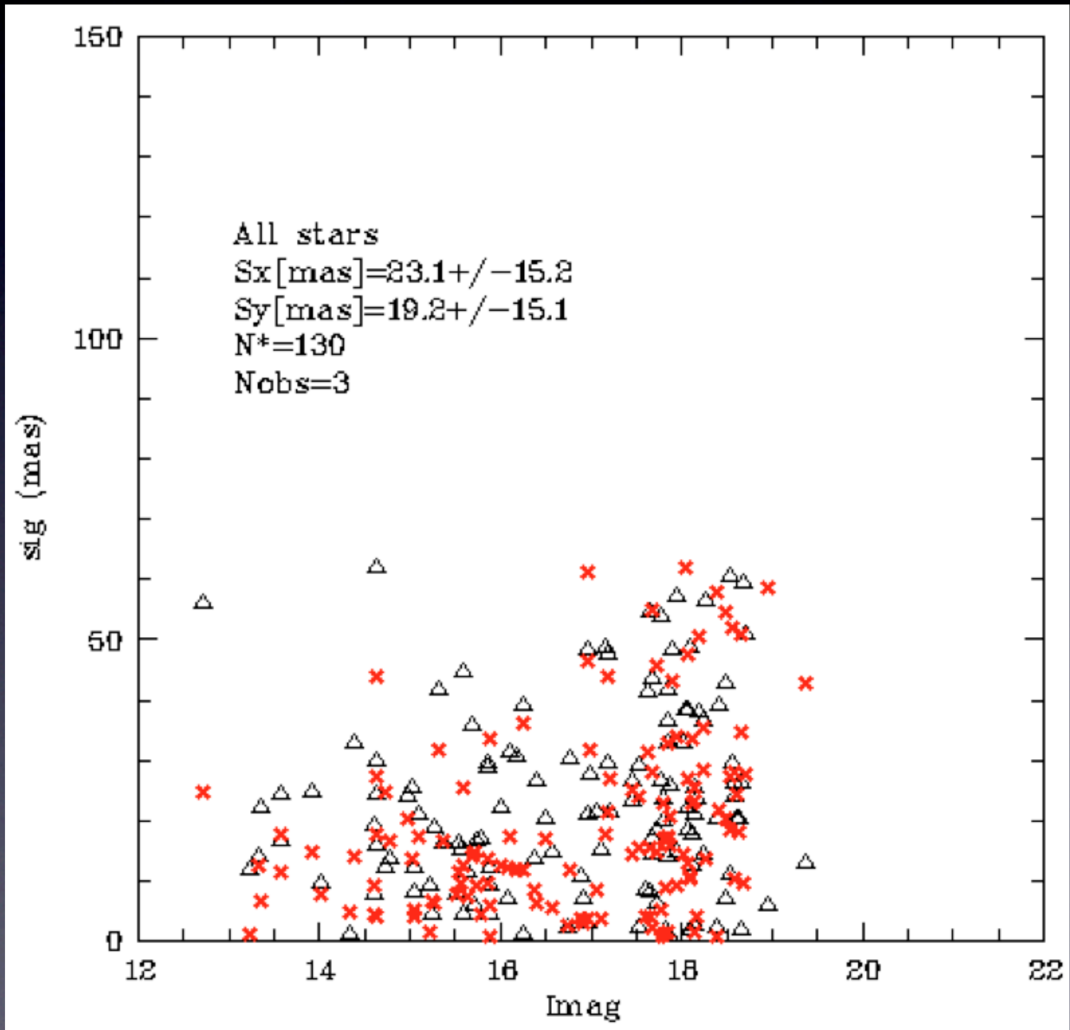


A problem with the Spartan camera

- Motor of wheel filter failed
- Condensation on the dewar window
  ➡3 months delay
- 1 chip dead



Data treatment

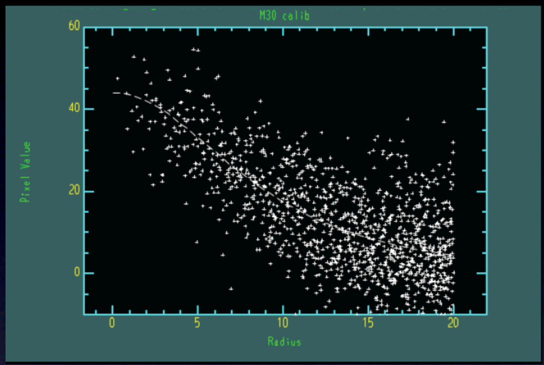


Repeatability < 20 mas

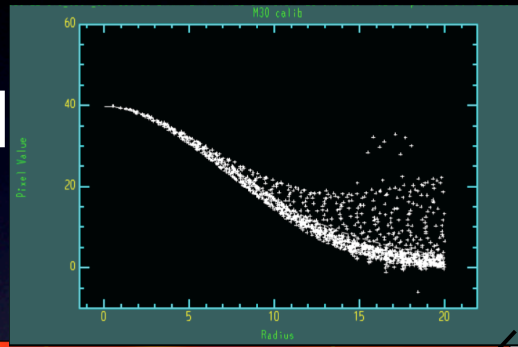
Image Treatment :

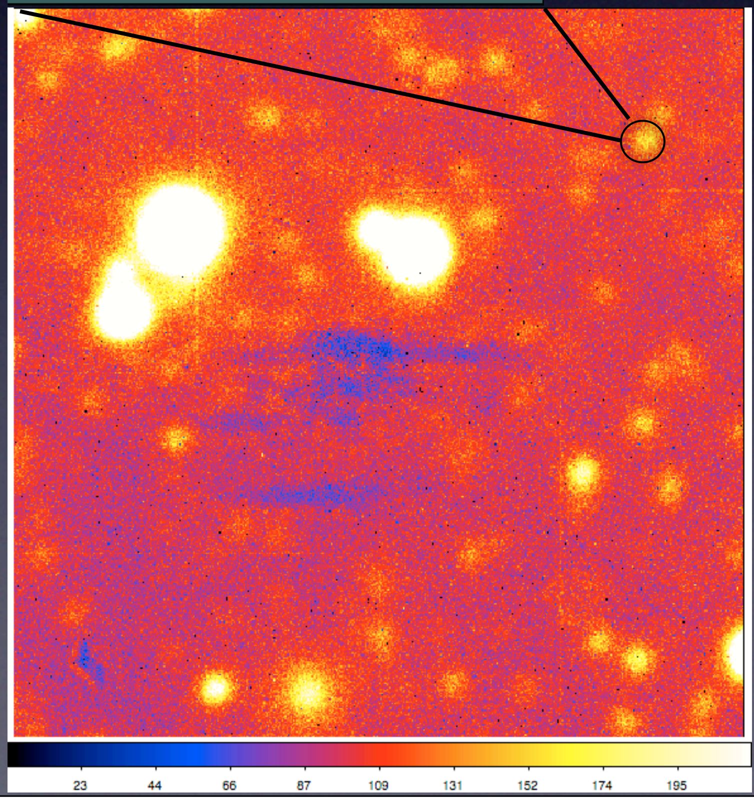
Wavelet and variance stabilizing pre-processing

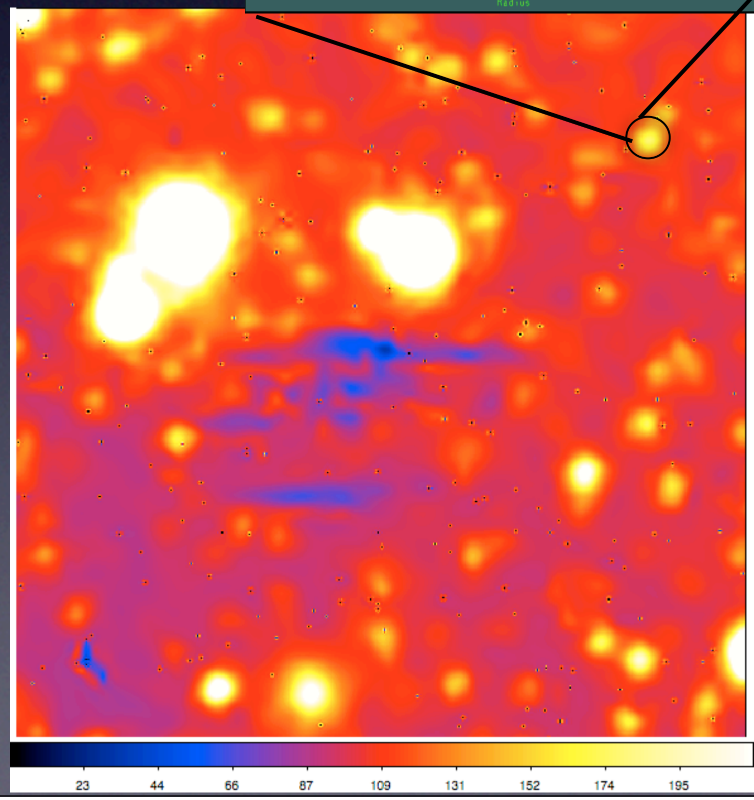
Zhang et al., 2008, IEEE Transactions on image processing, vol 17, 7



Improvement of S/N

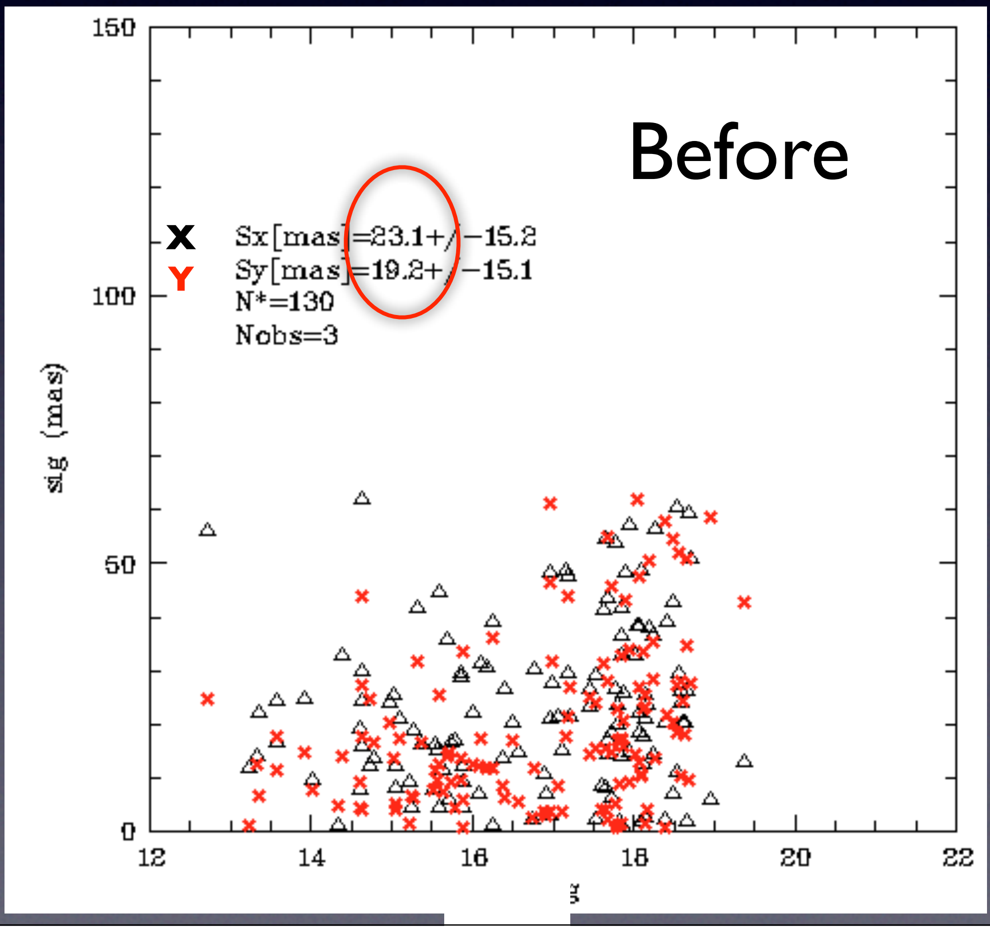


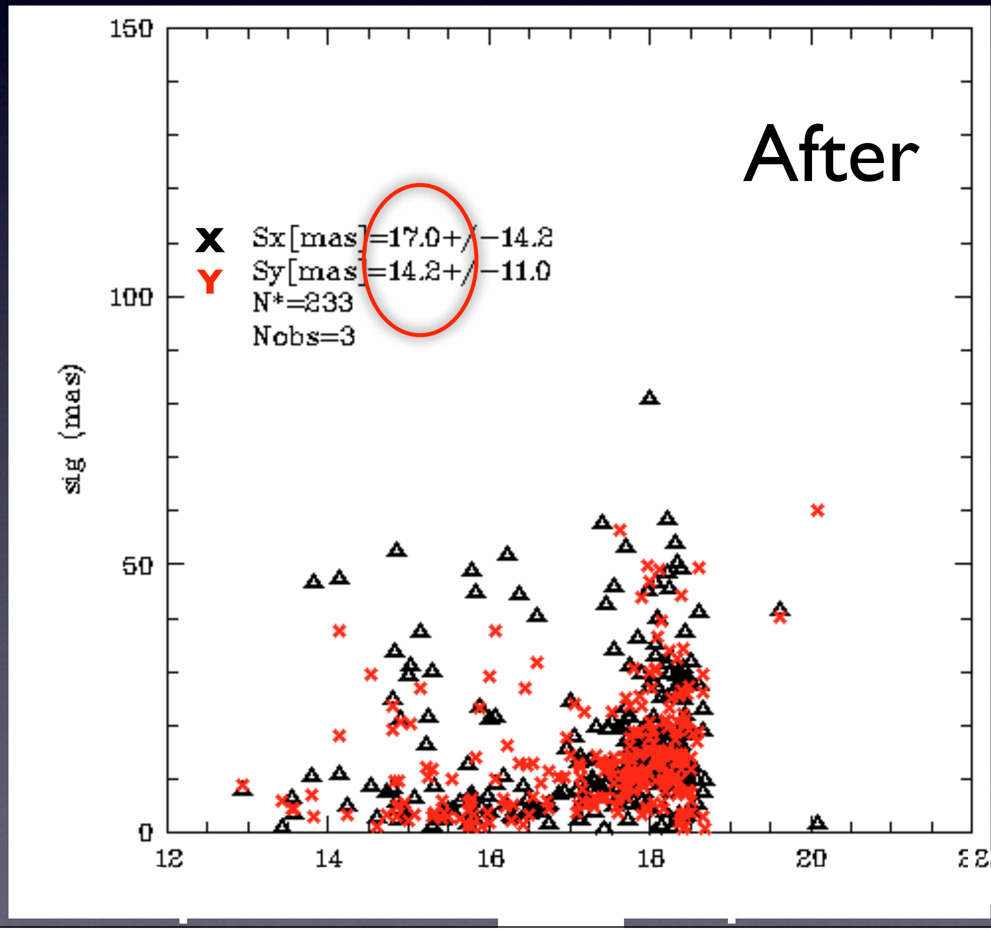




Denoising : improved repeatability

- 3 consecutive Spartan images of the same field
- Cross-id
- Mean and dispersion of (x,y) positions





Denoising : accuracy of positions ?

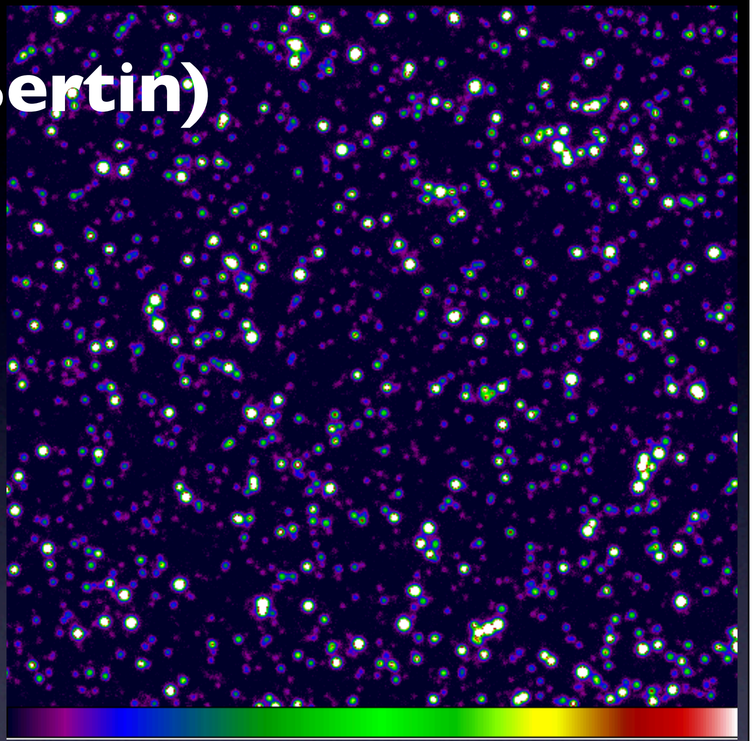


Image simulation SkyMaker (E. Bertin)

➡ *Ideal positions*+mag objects

➡ Simulated noised image

Denoising

➡ Denoised image

Image measurement

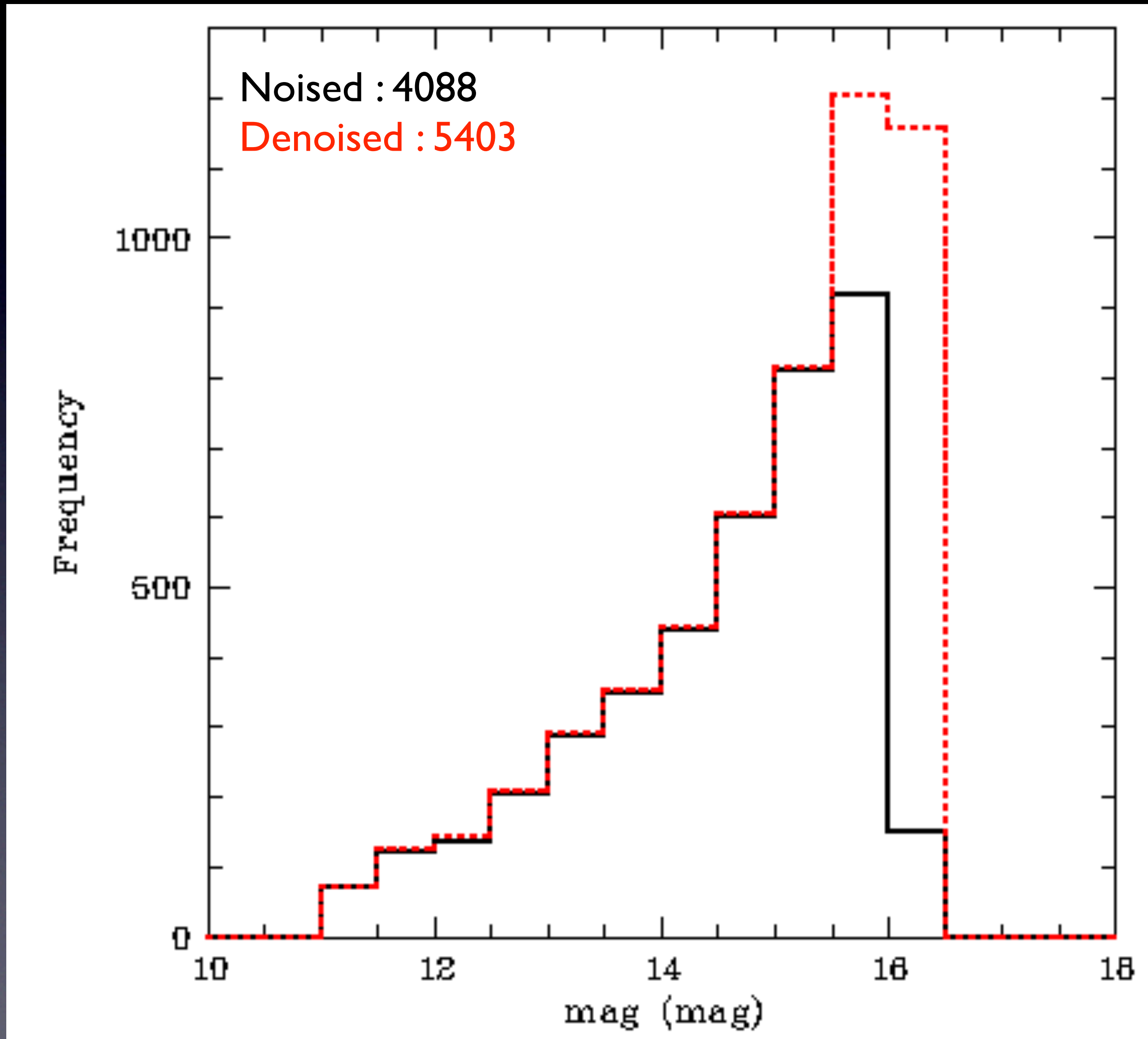
➡ Daophot (...)/Sextractor (E. Bertin)/...

➡ Measured positions/mag objects for

- *Noised image*
- *Denoised image*

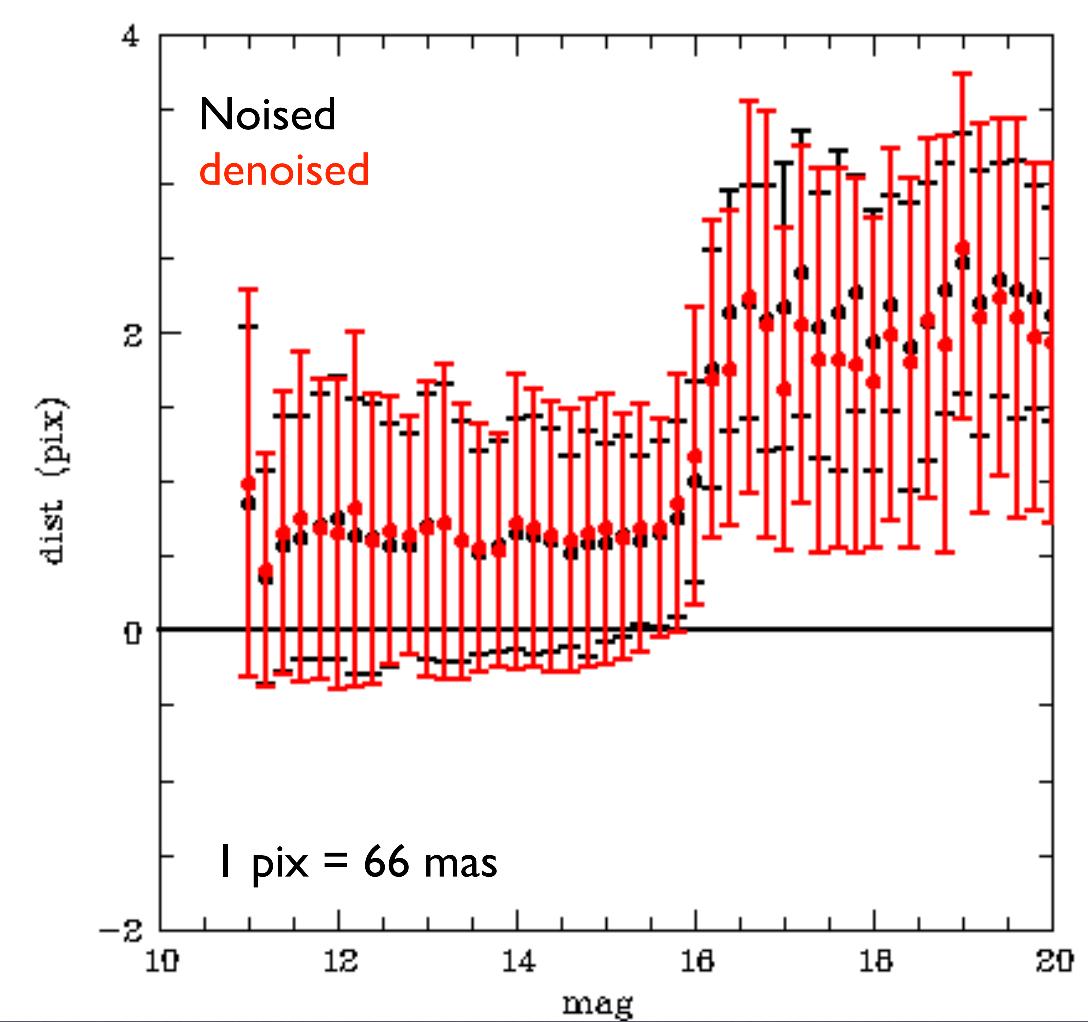
➡ Distance to Ideal positions

Denoising : 20-30% more faint detections



Denoising : accuracy ?

$$dist = \sqrt{(X_{ideal} - X)^2 + (Y_{ideal}) - Y)^2}$$



+ No systematics in position
+ Mean distance between measured and ideal positions equivalent for noised and denoised image.
+ Lower distance for faint objects on denoised images.
- Larger spread of distances with denoised image.

Denoising ?

- More tests to fully understand the impact of denoising onto astrometry.
- If verified correct, denoising processes might allow to measure parallaxes of very faint objects that are not normally within the reach of 4m telescopes using reasonable observing times.
- Compare parallax results with and without denoising.

Conclusions

- ➡ **Parallaxes (1-5% precision) for 5 important calibrators of the BD/UCBD regime by end of 2014.**
- ➡ **Experimenting the denoising --> interesting for faint detections, need to conclude.**