Improvements of astrometry from ground based observatories

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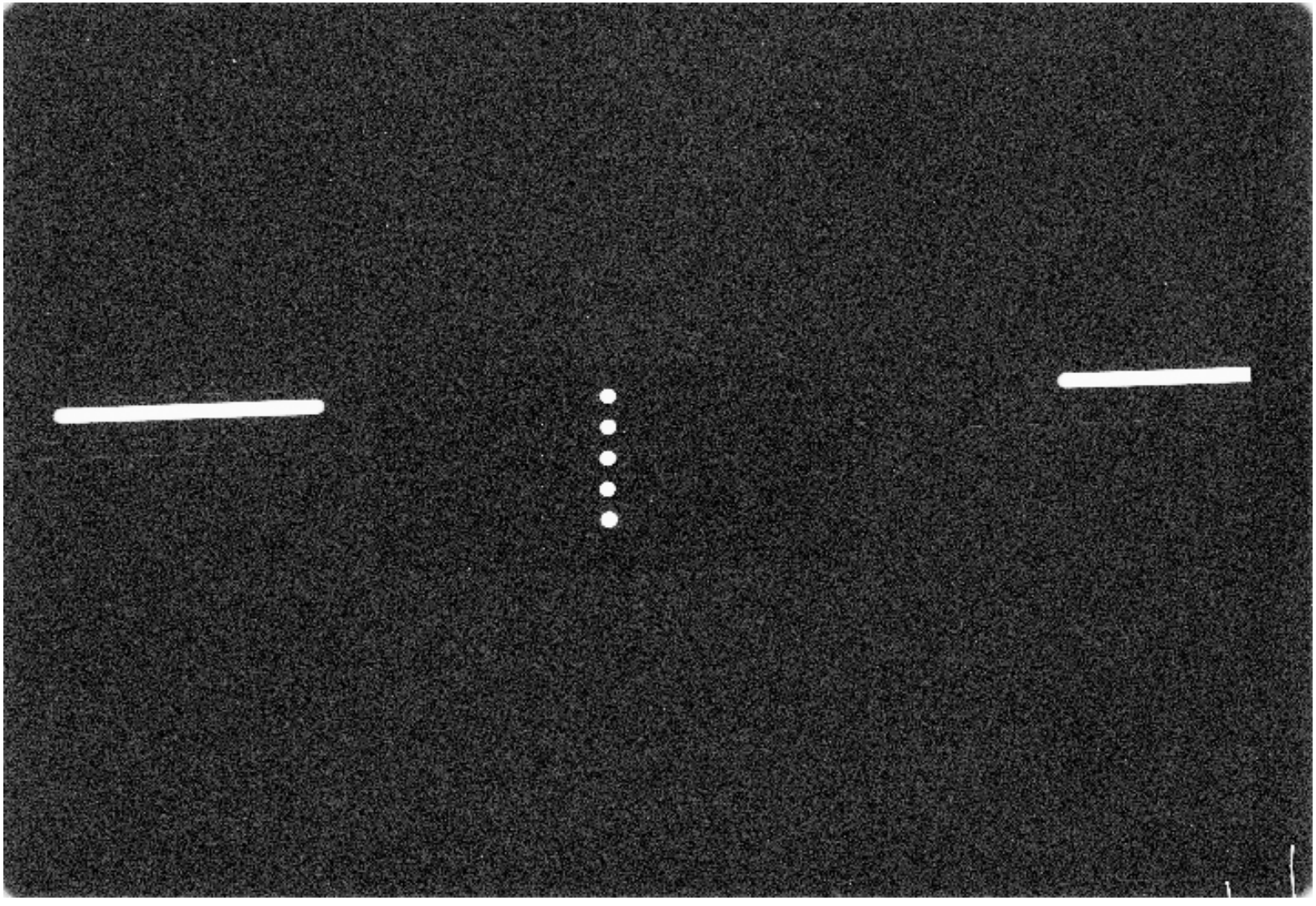
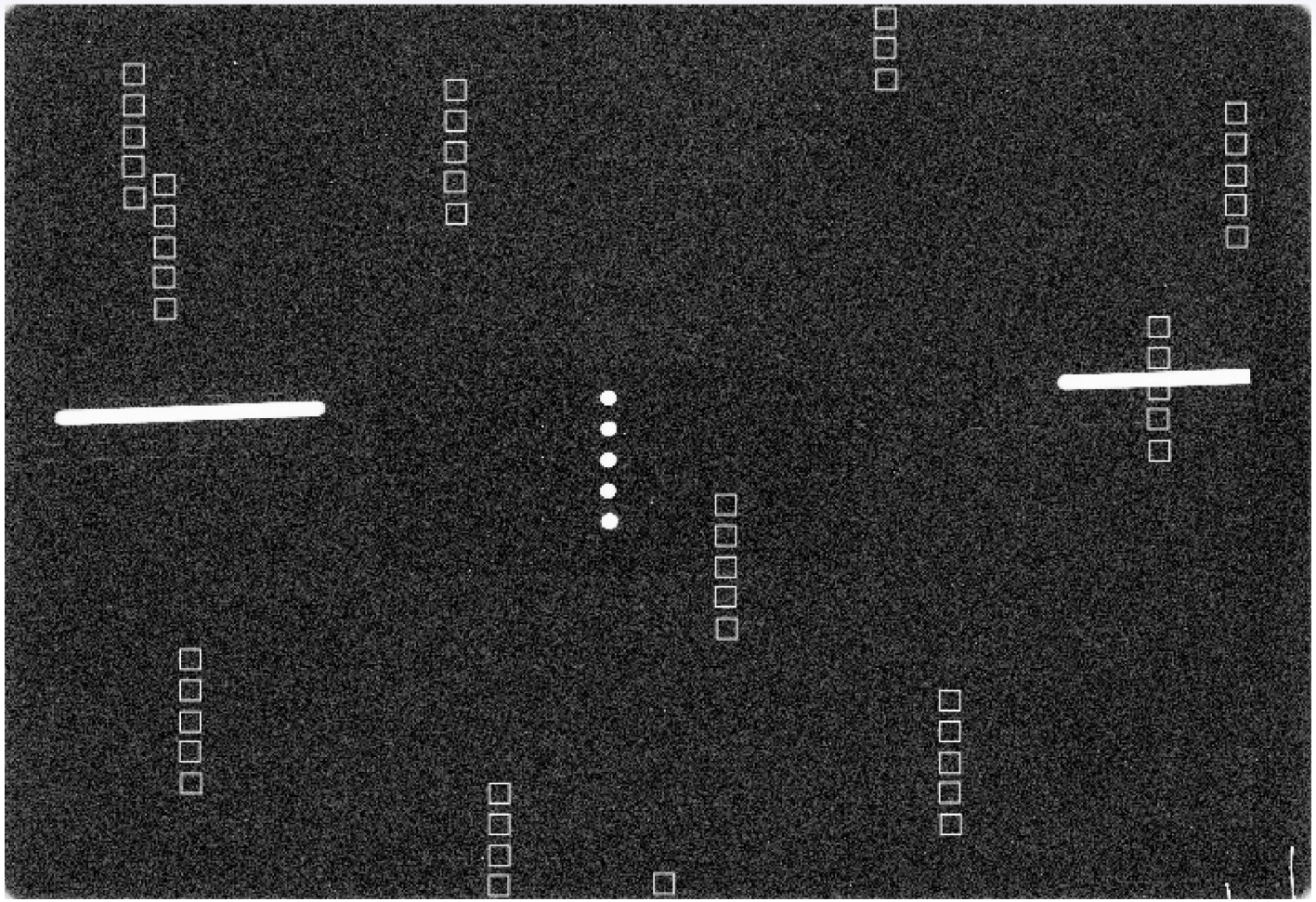
Introduction

- Our first goal was to improve the astrometric reductions for digitized photographic plates in case of too few reference stars and to propose solutions.
- Analysis of past observations with old photographic plates obtained from 1967 to 1998 at the USNO (Pascu, 1977, 1979, 1994).
- Problematic :
  - which effects must be taken into account to reach the best accuracy ?
  - which applications for the position measurements ?



Digitization of the USNO plate n°2114 (positive).

Improvement of the reduction of an image



Object identification method.

Because there are too few stars for a good astrometric reduction, the first solution is to correct for the refraction and the coma-magnitude effects before the reduction.

The star catalogues

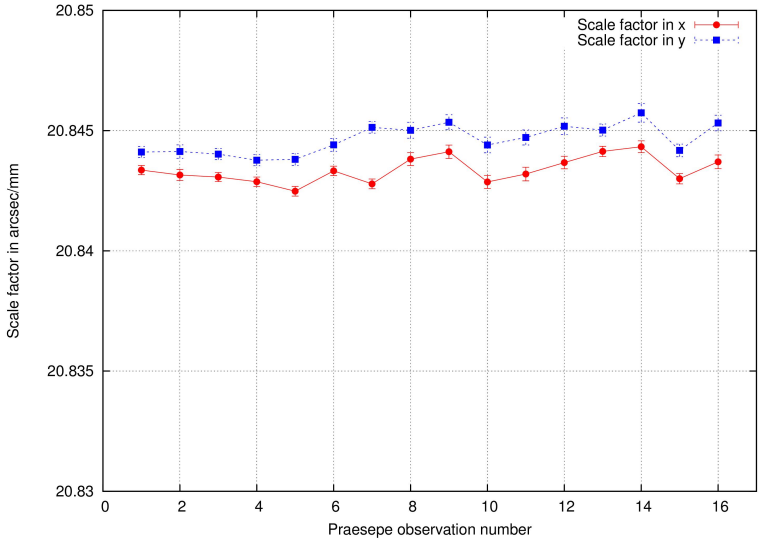
Year	Name	Nb of stars	Mag limit	Accuracy mas	Accuracy pr motions	Origin
1997	Hipparcos	120 000	12.4	< 0.78	< 0.88 m/y	obs. from space
2000	Tycho 2	2 500 000	16	< 60	< 2.5 m/y	from Tycho and 143 sources
1998	USNO A2	526 280 881				
2001	GSC II	19 000 000		360		Schmidt plates
2003	USNO B1	1 billion	21	200		Schmidt plates
2004	UCAC 2	48 000 000	7.5 → 16	20 → 70	1 → 7 m/y	scans
2004	Bright stars	430 000	< 7.5			Hipparcos + Tycho2
2005	Nomad	1 billion				compilation of best entries
2006	Bordeaux	2 970 674	15.4	50 → 70	1.5→6 m/y	$+11° > \delta > +18°$
2003	2MASS	470 000 000	16	60 → 100		Infra red K
2015	GAIA	1 billion	20	< 0.01 mas		obs. from space

In case of few available stars :

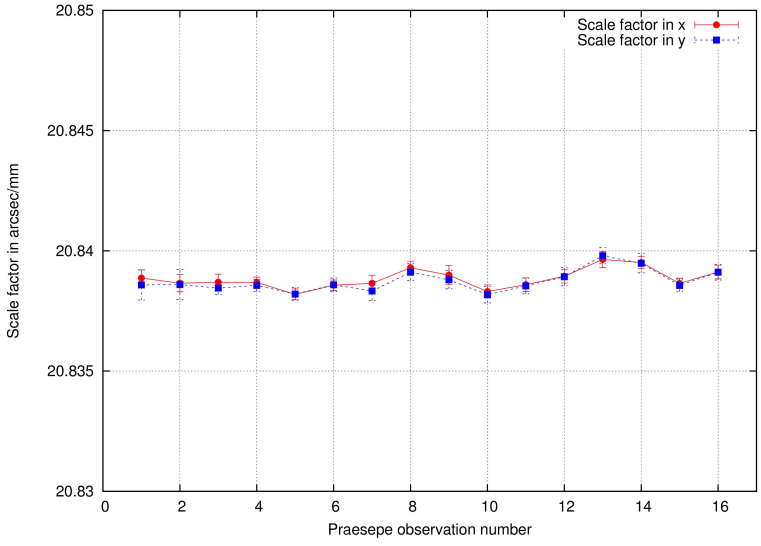
1. the equatorial coordinates are directly corrected for the proper motion, parallax, aberration, relative deflexion and total atmospheric refraction effects ;
2. the measured coordinates are corrected for the digitization and coma-magnitude instrumental effects ;
3. the reference stars only provide position, scale and orientation for the field.

Differences with a common astrometric reduction :

1. the star $(\alpha, \delta)_c$ equatorial coordinates are corrected for the main spherical effects ;
2. the star $(x, y)_m$ measured coordinates are corrected for the evaluated instrumental effects ;
3. the astrometric reduction is realised through the atmosphere so that (α, δ) equatorial coordinates are deduced from apparent (X, Y) tangential coordinates.



Scale in RA and Dec before correction.



Scale in RA and Dec after correction.

Adapted $(x, y)_m \mapsto (X, Y)_{m,a}$ model

$$X_{m,a} = \rho \cos\theta \times x_m - (\rho + \epsilon_1 \sin(\epsilon_2 t_m + \epsilon_3)) \sin\theta \times y_m + \Delta_x + C_x \times x_m \times (m - m_0)$$
$$Y_{m,a} = \rho \sin\theta \times x_m + (\rho + \epsilon_1 \sin(\epsilon_2 t_m + \epsilon_3)) \cos\theta \times y_m + \Delta_y + C_y \times y_m \times (m - m_0)$$

Only 4 parameters are fitted for a minimum of 2 reference stars !

The contribution of each plate constant is now separated !

Accuracy and expected improvements

Exposition		$(O-C)_X$	$(O-C)_Y$
1	(a)	0.060	0.130
	(b)	0.048	0.108
	(c)	0.203	0.188
	(d)	**0.009**	**0.028**
2	(a)	0.059	0.082
	(b)	0.036	0.057
	(c)	0.195	0.139
	(d)	**0.016**	**0.033**
3	(a)	0.096	0.077
	(b)	0.076	0.060
	(c)	0.248	0.125
	(d)	**0.017**	**0.017**
4	(a)	0.098	0.036
	(b)	0.128	0.043
	(c)	0.238	0.066
	(d)	**0.021**	**0.009**

Tangential (O-C)'s in arcsec, with secondary catalog 6 stars order 1 (a), 7 stars order 1 (b), 7 stars order 2 (c), and UCAC2 stars (d).

The astrometric accuracy depends on :

1. the image pixel sampling $\rightarrow$ choice of a pixel size depending on the seeing ;
2. the centroid of image (trailed images) $\rightarrow$ use a gaussian fit for the photocenter of punctual sources ;
3. the object magnitude $\rightarrow$ increasing the S/N signal noise ratio ;
4. the atmospheric refraction $\rightarrow$ improving the model of the atmospheric refraction ;
5. the sky absorption for moving objects $\rightarrow$ taking into account the effect for moving object low on the horizon through a photometric monitoring of the exposure ;
6. the reference stars $\rightarrow$ using an appropriate reference star catalogue ;
7. the correction photocentre-centre of mass $\rightarrow$ better correction photocentre to centre of mass by using a recent modeling of the surface of the object.

Conclusion

Our reductions of digitized photographic plates made necessary to take into account all instrumental errors and all biases.

The corrections made should be applied to modern observations, increasing the astrometric accuracy.

Some observations are difficult to reduce or present some biases. The astrometric positions provided by these observations will not be precise enough in the frame of the Gaia project.

Corrections for instrumental errors, for the atmospheric refraction and for the sky absorption should be made at first. More, when using the Gaia catalogue for future reductions, all biases must be corrected.

Questions