New solution for the geometric distorsion in astronomical images.

——Application to Phoebe's observations

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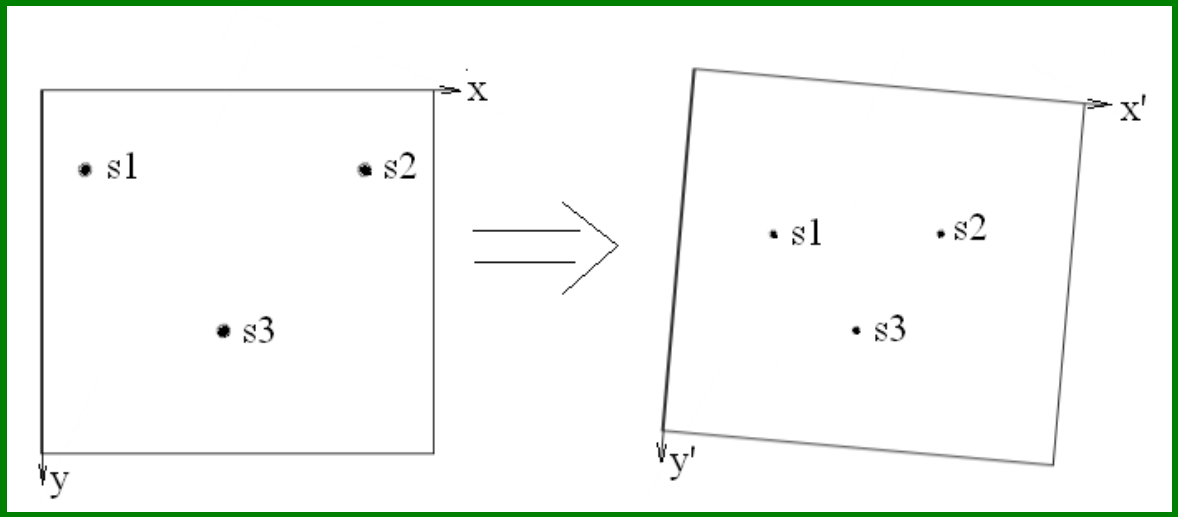
Outlines

1. Definition of Geometric Distortion (GD)
2. Backgrounds of GD
3. A convenient approach to deliver GD
4. Observations of Open Clusters and Phoebe
5. Results
6. Conclusions and prospects

1. Definition of Geometric Distortion (GD)

According to Anderson & King (PASP 2003) for HST

A frame is **distortion-free** if the star positions that define it have been corrected in such a way that the positions of the same stars, measured in any image with a different pointing, but corrected in the same way, can be transformed into those of this frame with nothing more than a displacement, a rotation, and scale factor.➔ **a 4-constant plate model ?**

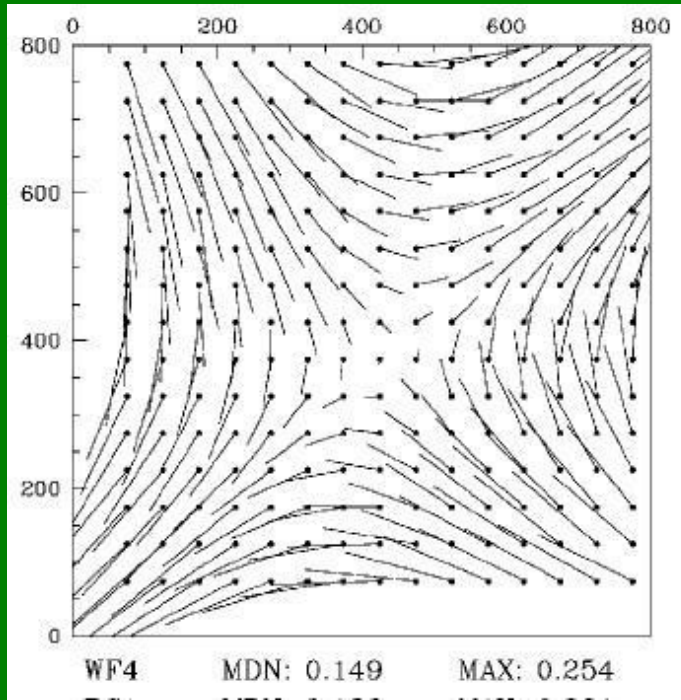


For any star in two frames:

$$x_2 = \rho\cos\varphi \times x_1 - \rho\sin\varphi \times y_1 + \Delta x$$
$$y_2 = \rho\sin\varphi \times x_1 + \rho\cos\varphi \times y_1 + \Delta y$$

Moreover, from a set of overlapping exposures, a single function of position is found that, when applied in exactly the same way to the star positions in all of the images, renders the positions identical except for translation, rotation and scale.

GD = GD(x,y)



➔ **Approach by pixel positions only**

Hubble Space Telescope

2. Backgrounds of GD

1) French et al. (PASP 2006) better precision obs for Saturn's satellites than Poulet & McGhee (A&A 2001) from HST by using the GD correction.

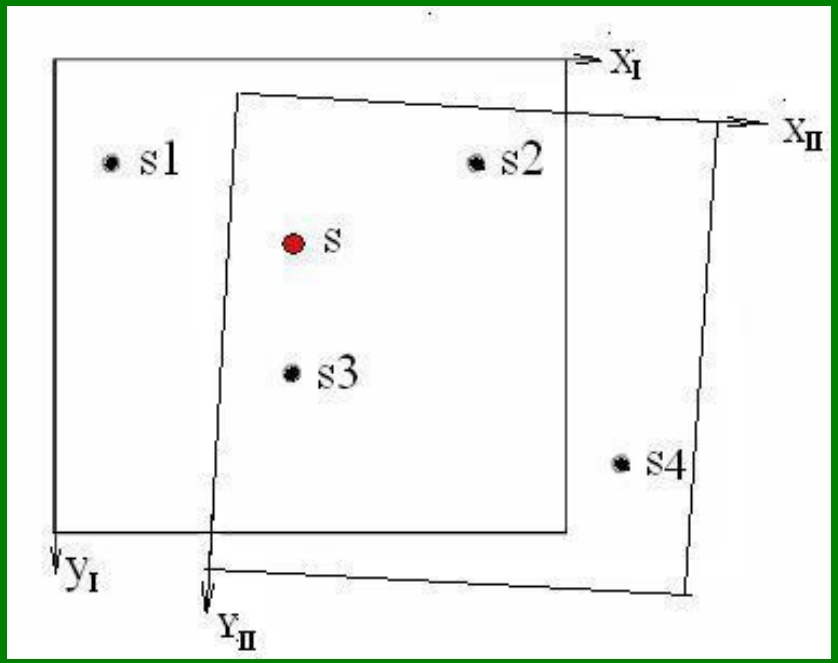
Mallama et al. (Icarus 2004) Galilean satellites' obs from HST?

2) Anderson et al. (A&A 2006) good precision obs for open clusters, by ground-based telescope: 7 mas in each direction after GD correction.

3) Yelda et al. (ApJ 2010) improving Galactic Center Astrometry by Reducing the Effects of Geometric Distortion, from ground-based telescope

→ **Idea: Can we deliver GD by our obs?**

3. A convenient approach to deliver GD



From the frame (X_I,Y_I) by S1, S2, S3 and S

From the frame (X_{II},Y_{II}) by S2, S3, S4 and S

after 4-constant model solution

For the star S ⇓ (O-C) in RA

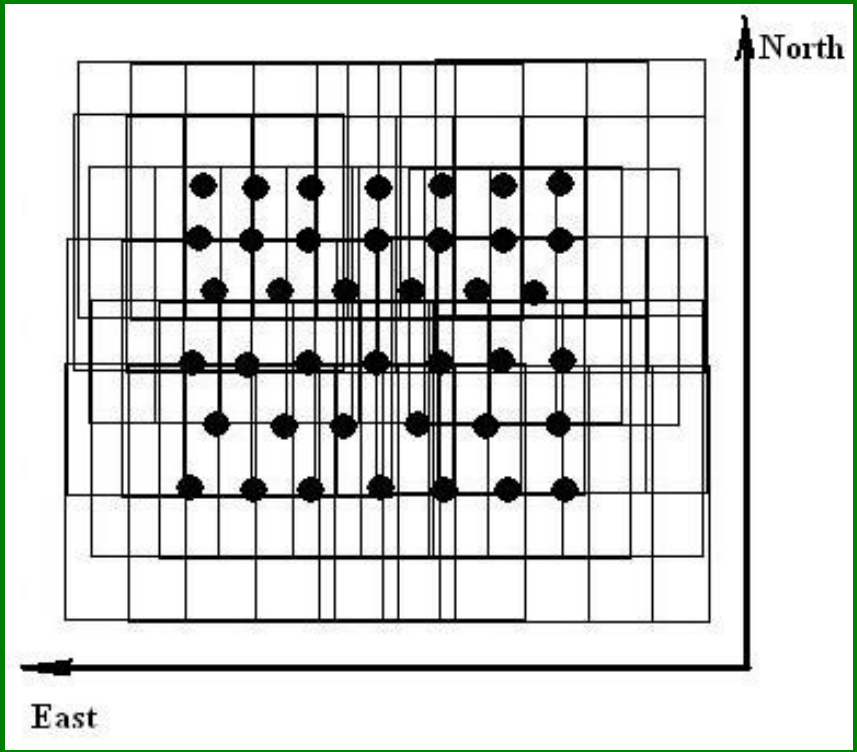
In the frame (X_I,Y_I) ⇒

In the frame (X_{II},Y_{II}) ⇒

$$(\Delta\alpha)_{\mathrm{I}} = \Delta\alpha_0(\alpha,\delta) + \Delta\alpha_{GD}(x_{\mathrm{I}}, y_{\mathrm{I}}) + (v_{x,y}),$$

$$(\Delta\alpha)_{\mathrm{II}} = \Delta\alpha_0(\alpha,\delta) + \Delta\alpha_{GD}(x_{\mathrm{II}}, y_{\mathrm{II}}) + (v_{x,y})$$

Suppose that we have many overlapping CCD images



for each star,

$$(\Delta\alpha)_1 = \Delta\alpha_0(\alpha,\delta) + \Delta\alpha_{GD}(x_1,y_1) + (v_{x,y})_1,$$
$$\vdots$$
$$(\Delta\alpha)_i = \Delta\alpha_0(\alpha,\delta) + \Delta\alpha_{GD}(x_i,y_i) + (v_{x,y})_i$$
$$\vdots$$
$$(\Delta\alpha)_n = \Delta\alpha_0(\alpha,\delta) + \Delta\alpha_{GD}(x_n,y_n) + (v_{x,y})_n$$

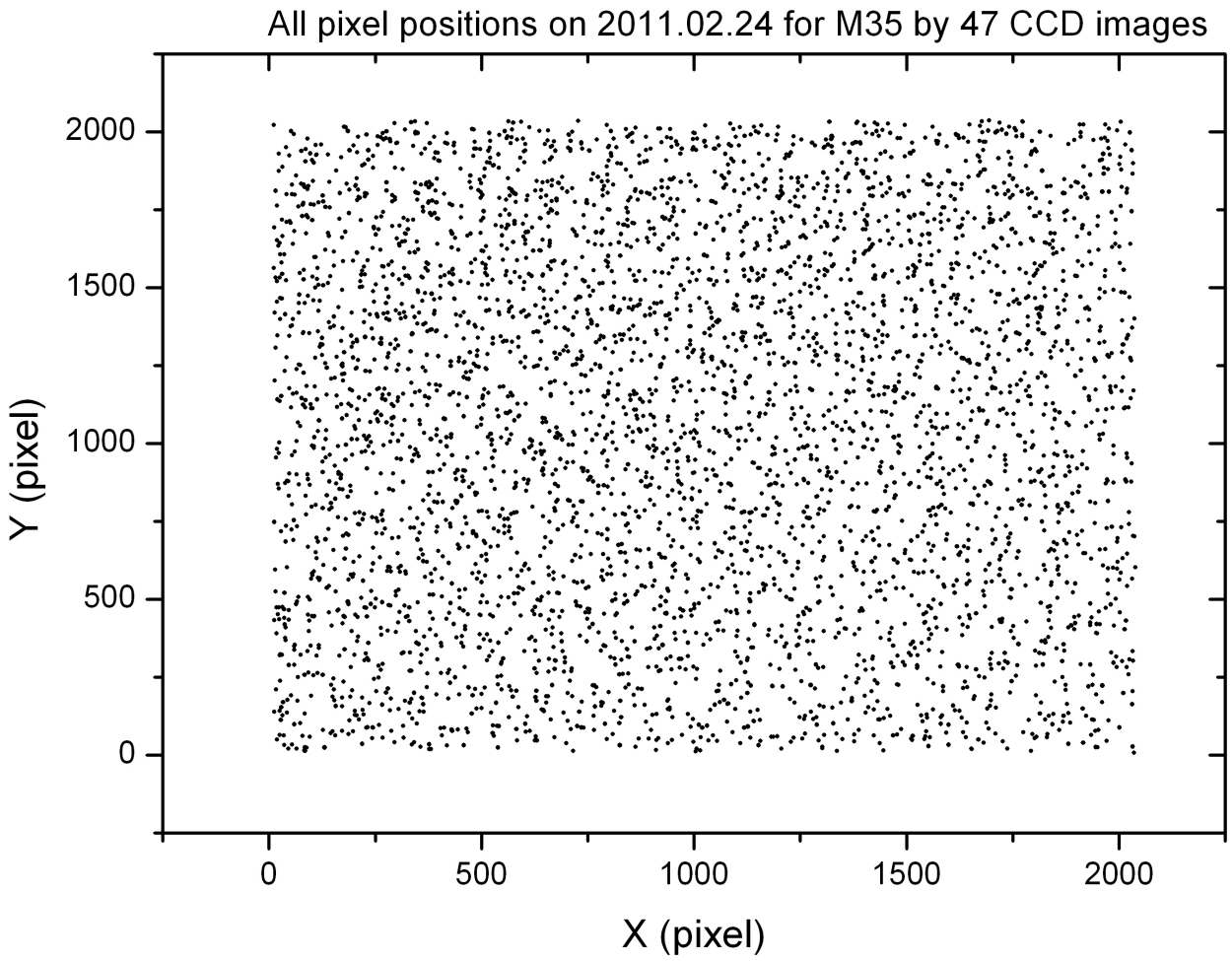
$$(\Delta\alpha)_1 - (\Delta\alpha)_i \approx \Delta\alpha_{GD}(x_1,y_1) - \Delta\alpha_{GD}(x_i,y_i),$$
$$i = 2,3,\ldots,n$$

0

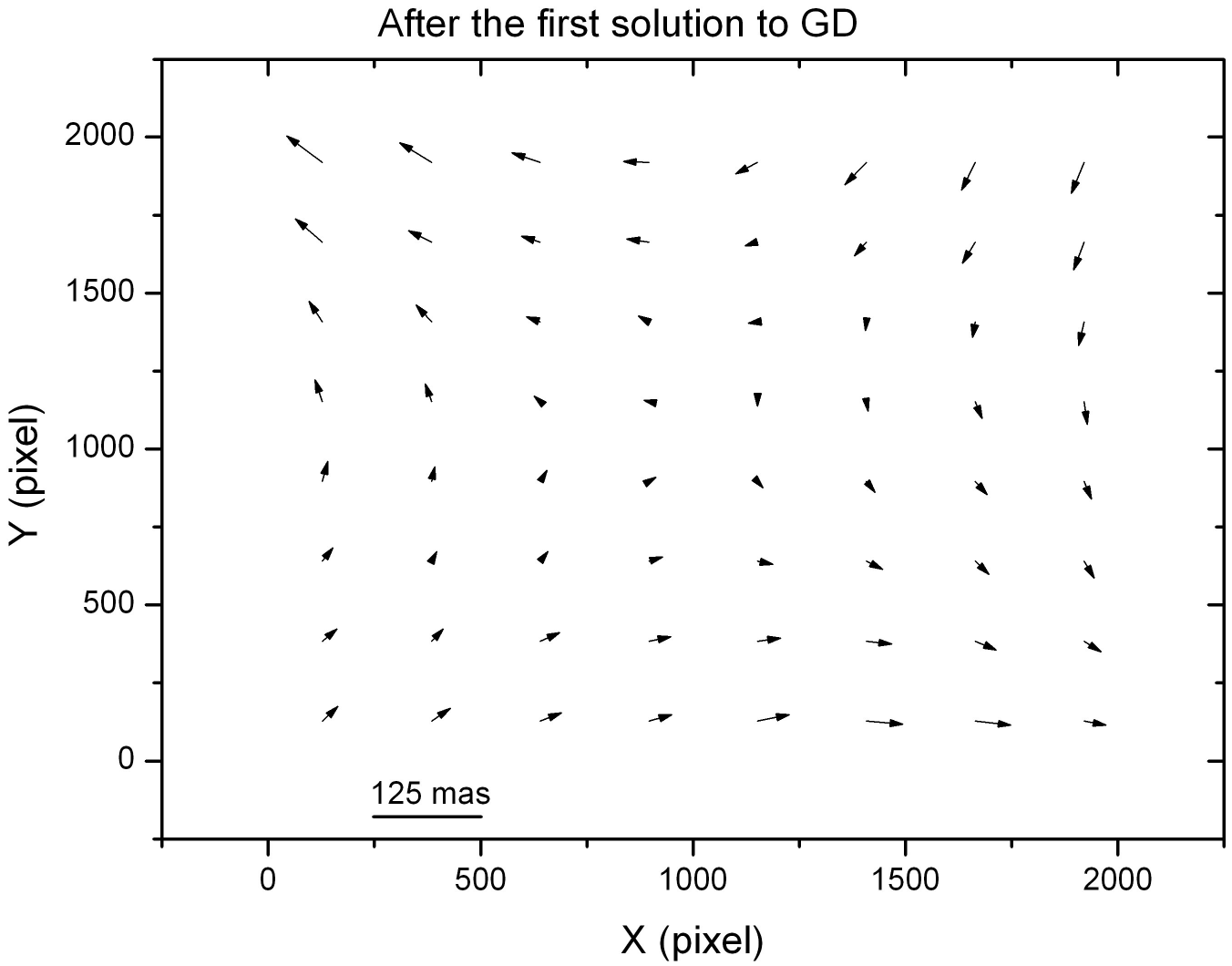
$$\sum_{i=2}^{n}[(\Delta\alpha)_1 - (\Delta\alpha)_i]/(n-1) \approx \Delta\alpha_{GD}(x_1,y_1) - \sum_{i=2}^{n}[\Delta\alpha_{GD}(x_i,y_i)]/(n-1)$$

For example, M35 was overlappingly observed by 47 CCD images. A typical image

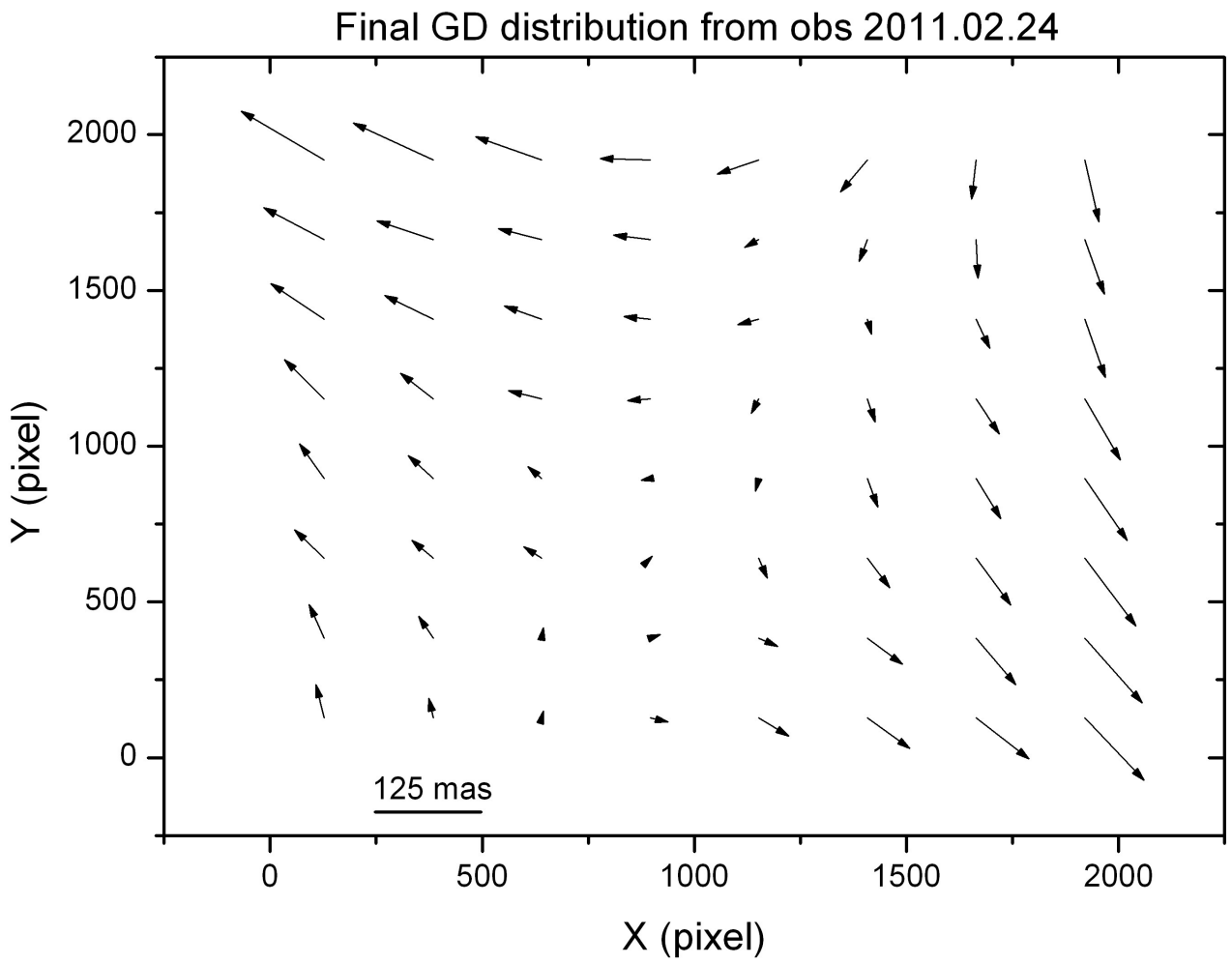
All pixel positions of 47 CCD images were displayed for M35 stars found in UCAC3 catalogue (more than 80,000 positions) in the same frame



Dividing the frame into a grid array of 8 x 8, and each grid supposed to have the same GD, after first solution for GD we have this GD distribution

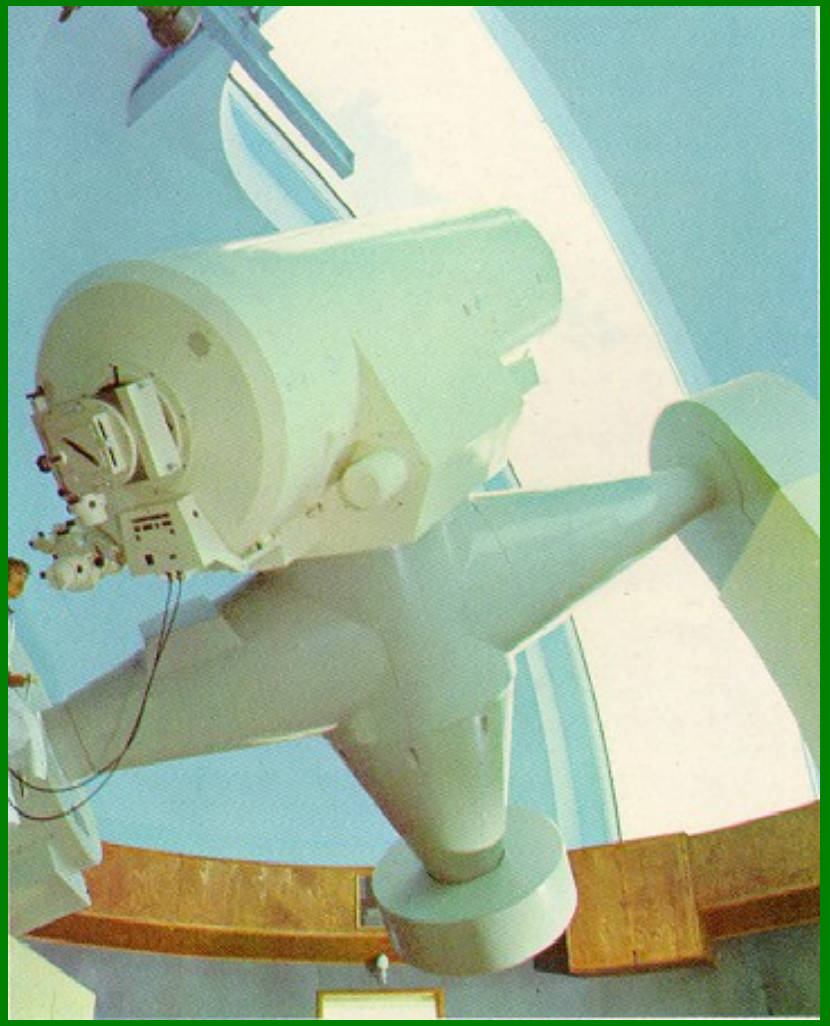


After the first solution to GD, we corrected GD for pixel positions of each star and re-solved the new GD and iterated this step again and again until the residual GD converged in 1-3 mas level.



Specifications for 1 m telescope of Yunnan (Equatorial) .

Main mirror	100 cm
Focal length	1300cm
Res. of CCD	2048 x 2048
Size of pixel	13.5 um x 13.5 um
Field of view	7.’1 x 7.’1
Scale factor	~0.”21/pixel



4. Observations of Open Clusters and Phoebe

In the year 2011, Q. Y. Peng has taken the following obs

(1). M35 by 2.4 m T. on Jan.03 with I-filter

(2). M35 by 1 m T. on Feb.24, Feb.27 with I-filter

(3). NGC2324 by 1 m T. on Feb.26 without filter

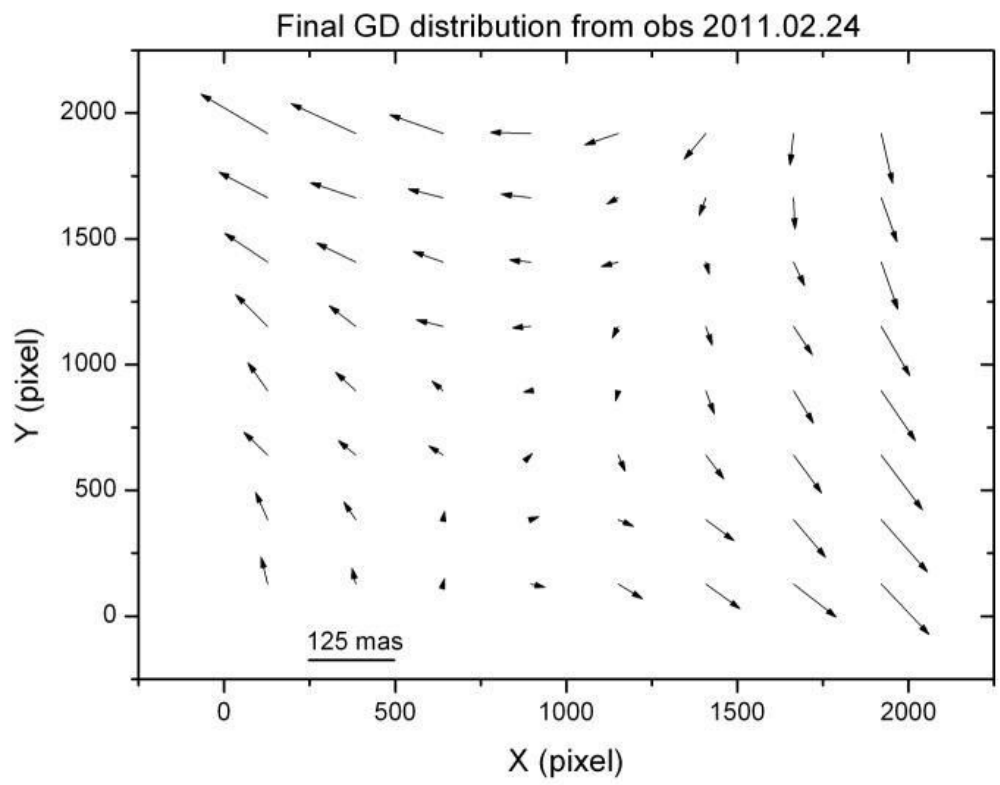
(4). M67 by 1 m T. on Apr. 01 (I), Apr. 02(I+R), Apr.03(I+R) and Apr 04 (I+R).

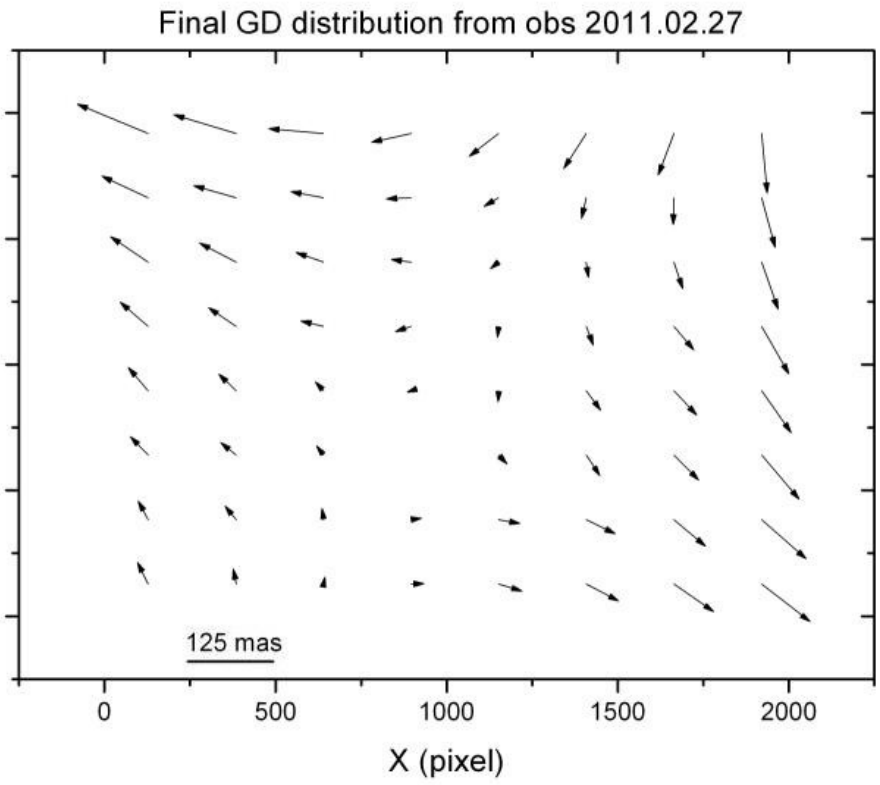
(5). Phoebe (S9) were observed by 1 m T. on the dates:

Feb. 24, 25, 26 and 27 and Apr. 01, 02, 03 and 04

➔ 8 night obs in total

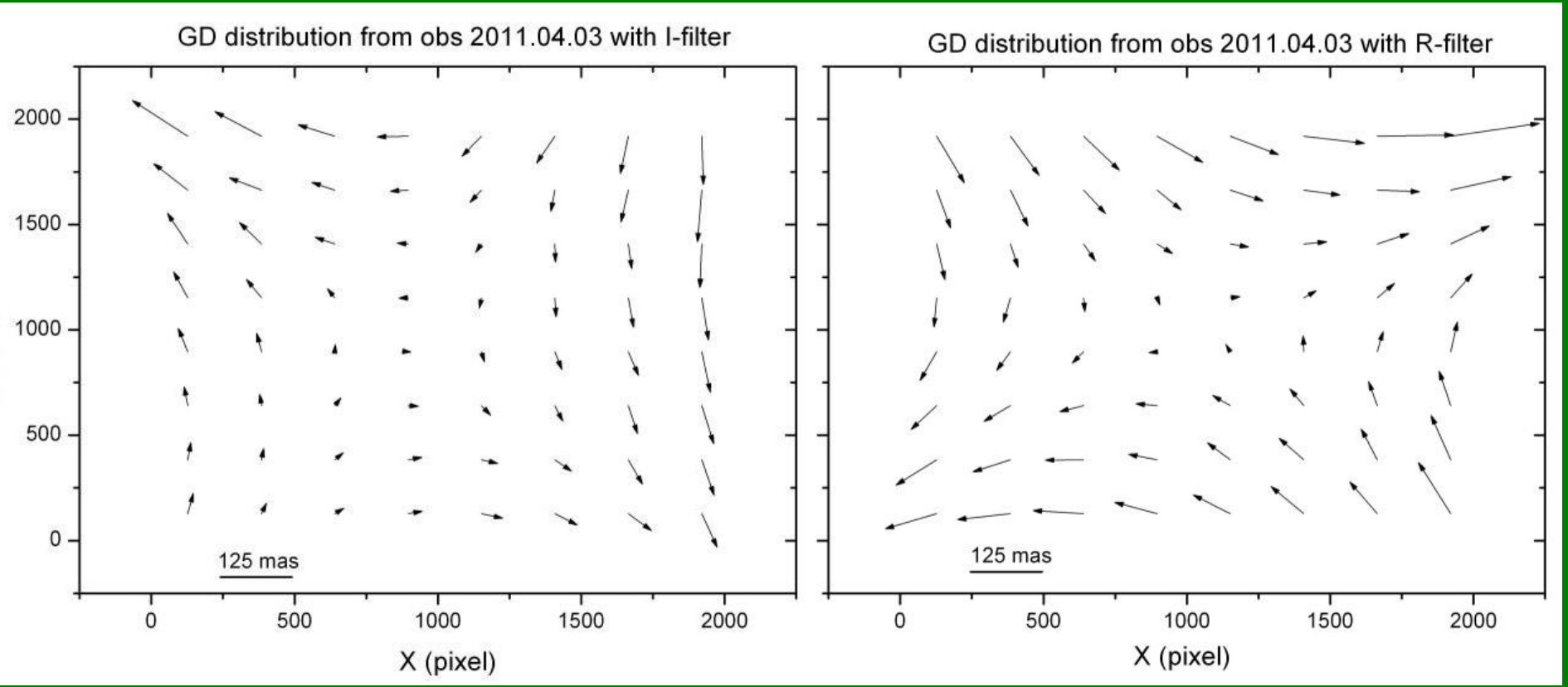
5. Results





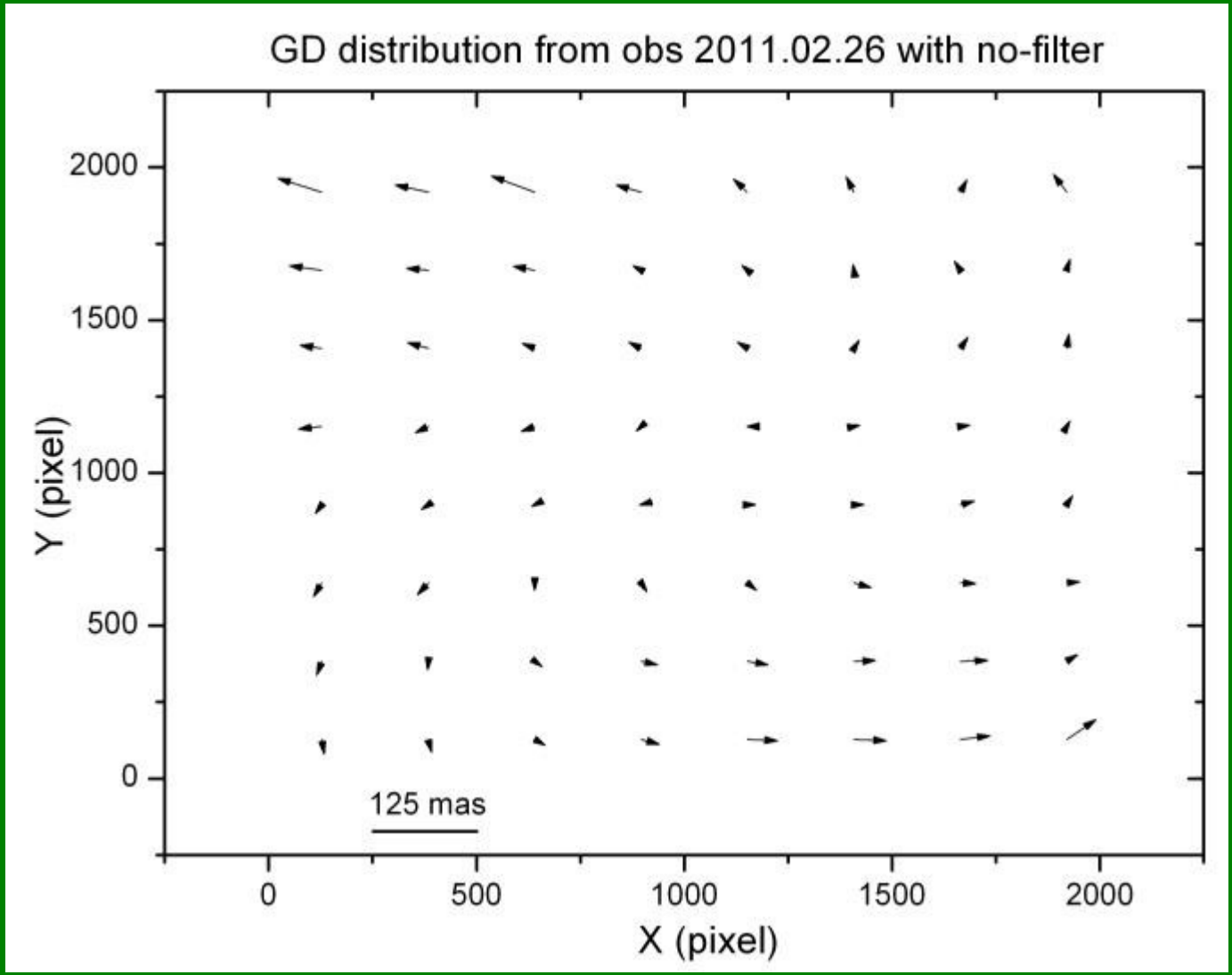
GD is stable in different nights when a same filter is used.

GDs from different filters based on obs on 2011.04.03



GD had great difference when I- and R- filter was respectively used.

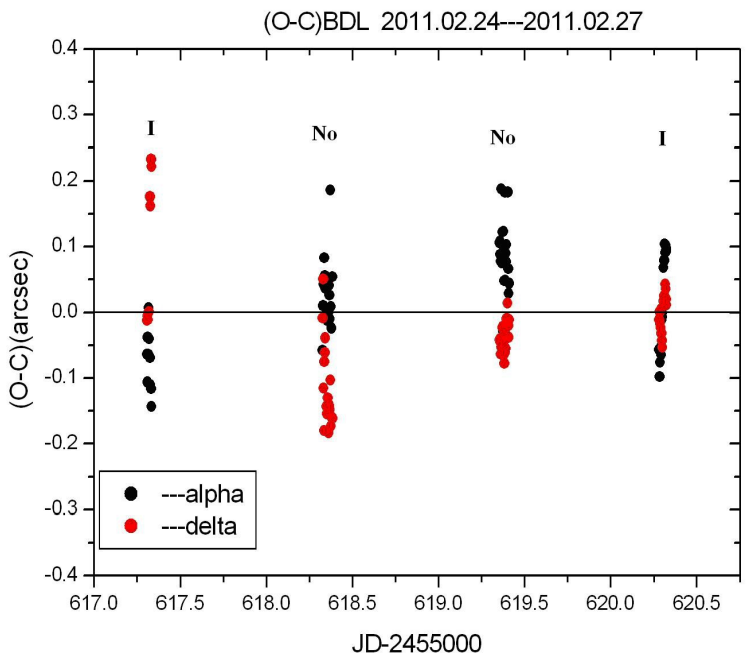
GD from no filter based on obs on 2011.02.26



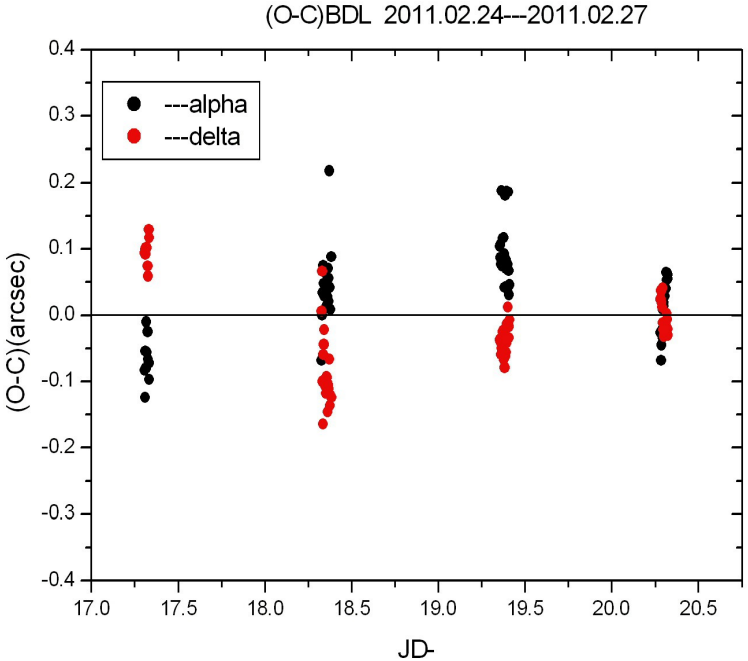
Even without filter, GD has significant effect as big as ~ 50 mas !

(3) (O-C)s for Phoebe (S9) from different filter obs

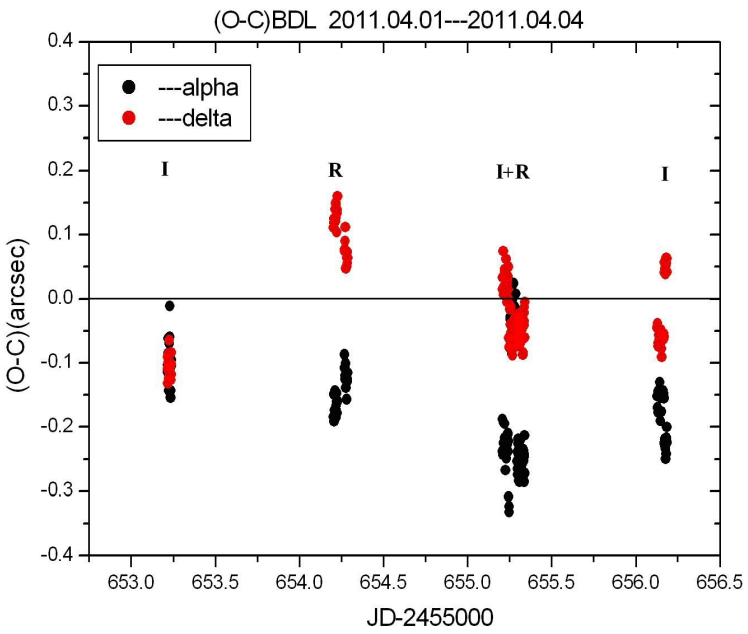
- UCAC2.0 stars are used for reference by a 4-constant plate model
- Ephemerides from IMCCE and JPL are adopted respectively.



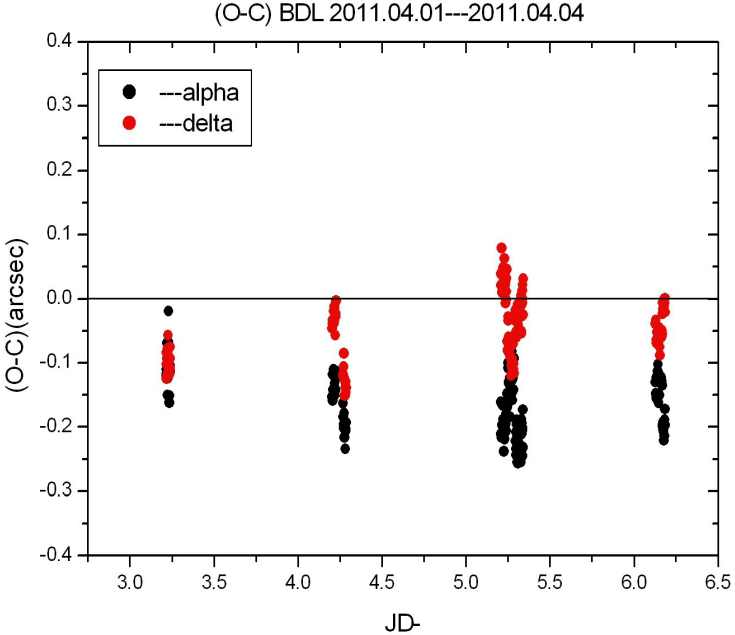
Before GD correction



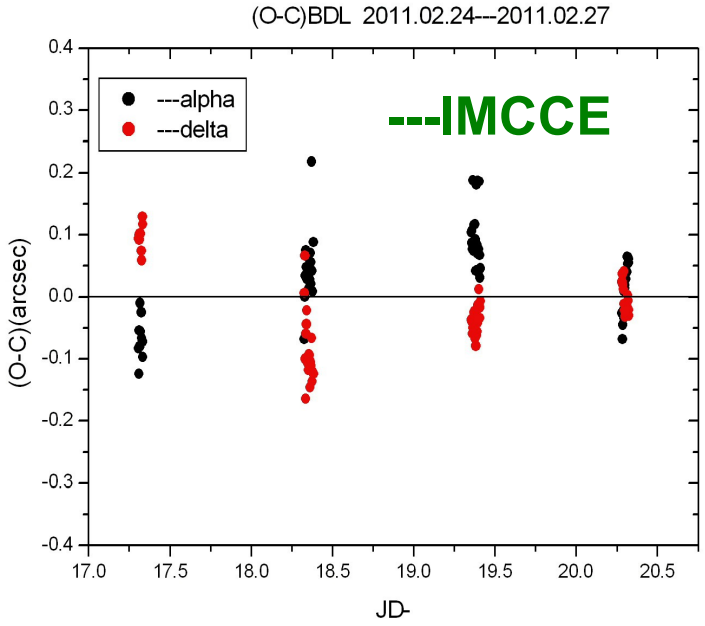
After GD correction

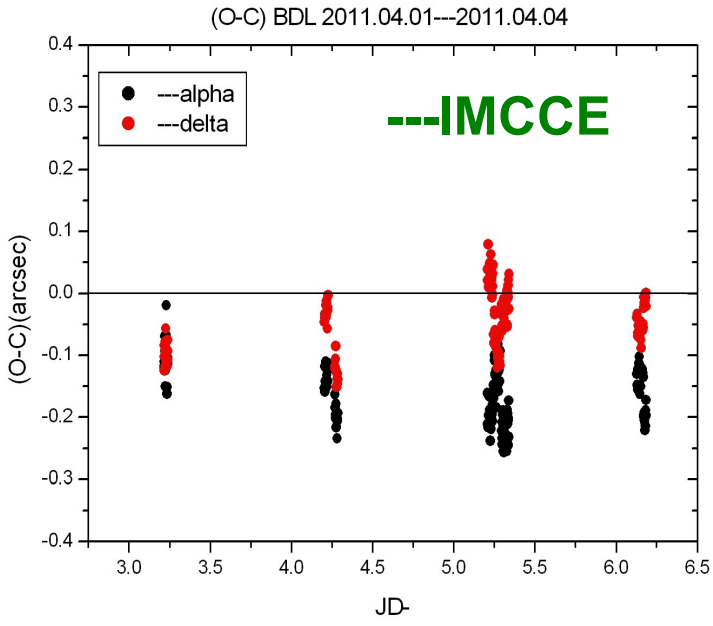


Before GD correction

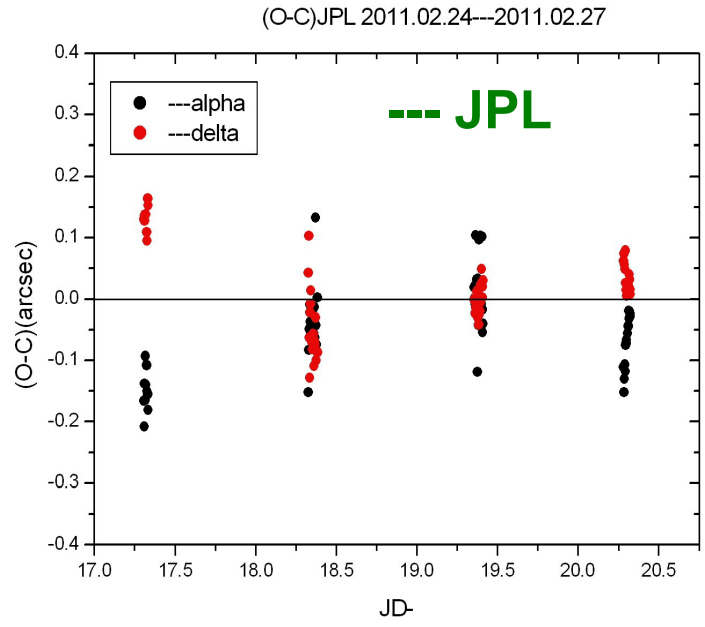


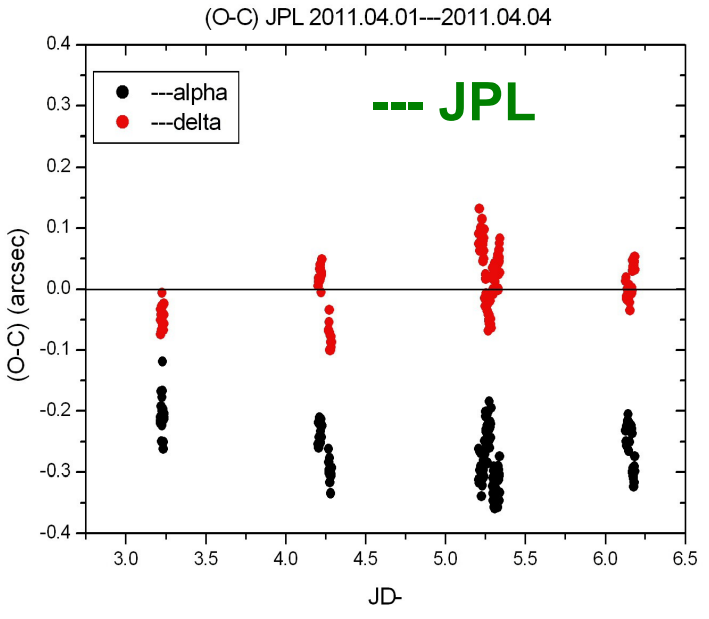
After GD correction





GD is corrected





6. Conclusions and prospects

Conclusions:

- GD can be solved conveniently by many overlapping CCD images from comparison of theoretical positions and pixel positions.
- Different filters have different GDs.
- GD exists significantly even without filter
- Astrometric observations for natural satellites such as Galilean satellites and Saturnian satellites are recommended to correct GD.

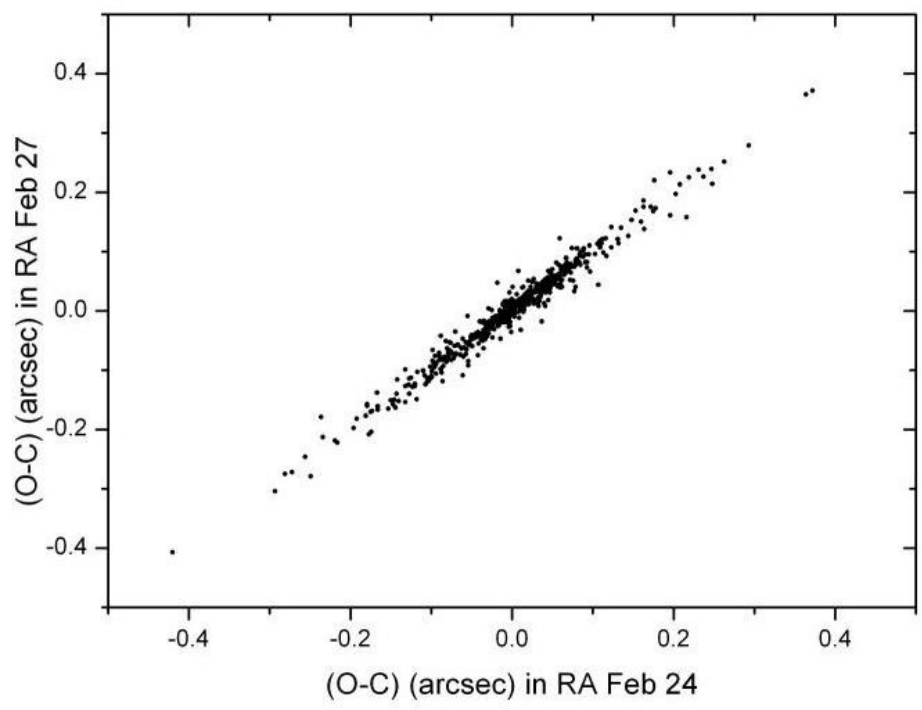
Prospects:

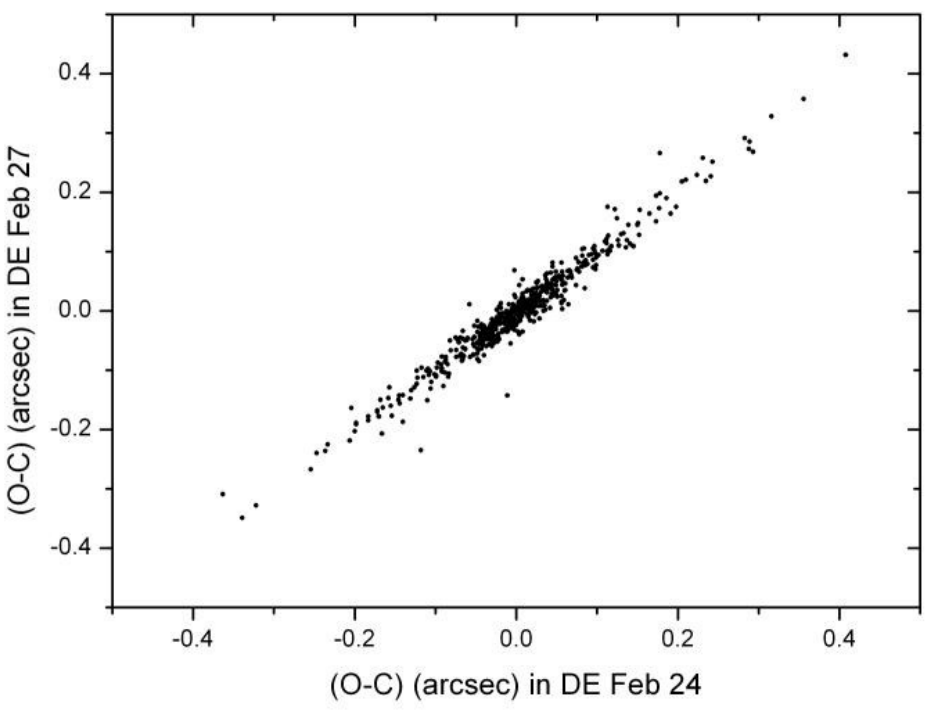
- Study the rules of GD with different filters, in different nights, and in different other conditions.
- Reduce the observations of satellites of Jupiter and Saturn of Yunnan Observatory

Thank you for your attention!

Observatories in the main land of China

(O-C)s derived from M35 on dates 2011.02.24 and 2011.02.27





Here, PPMXL is referenced.

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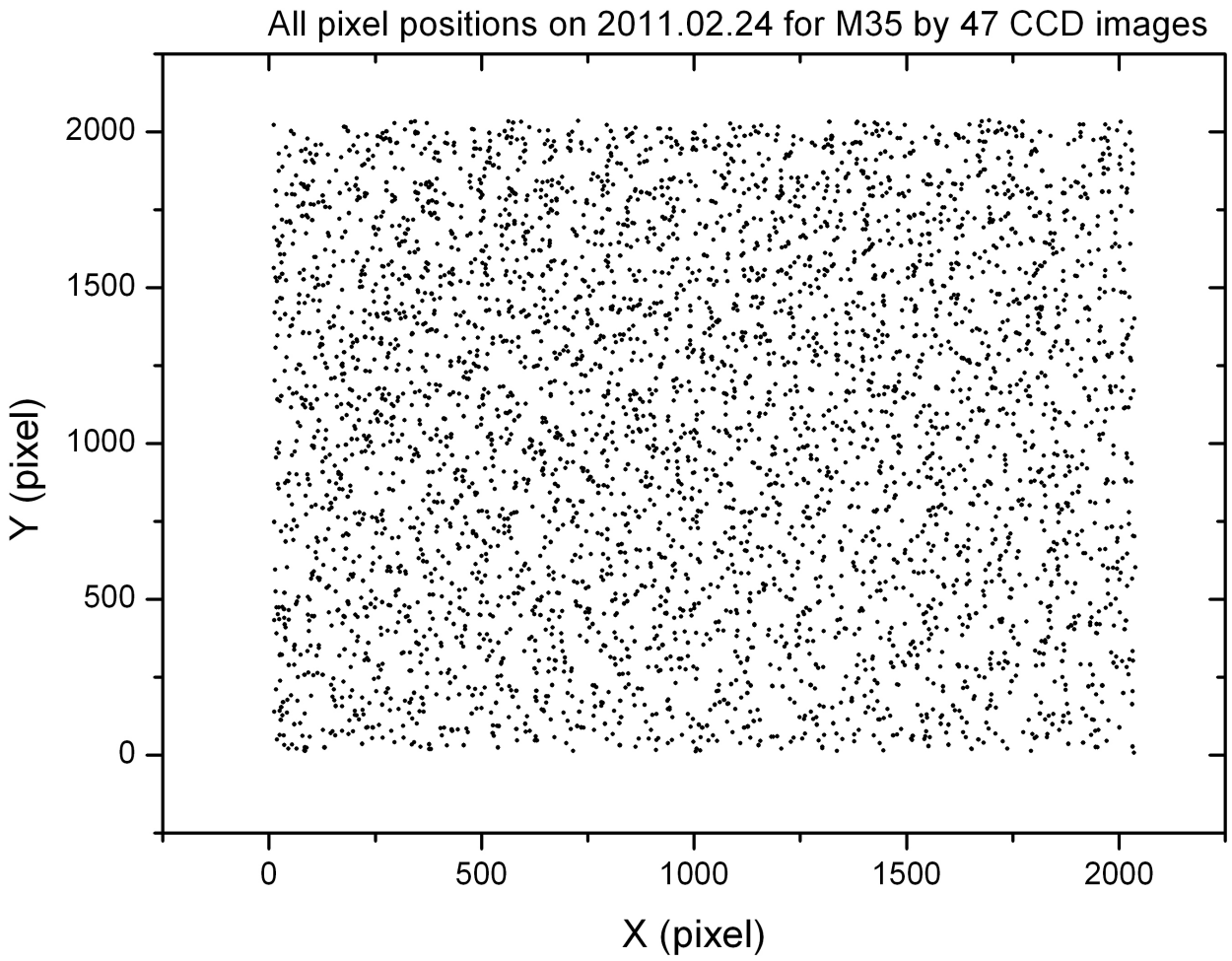

SD for (O-C) is greatly improved after GD is corrected.