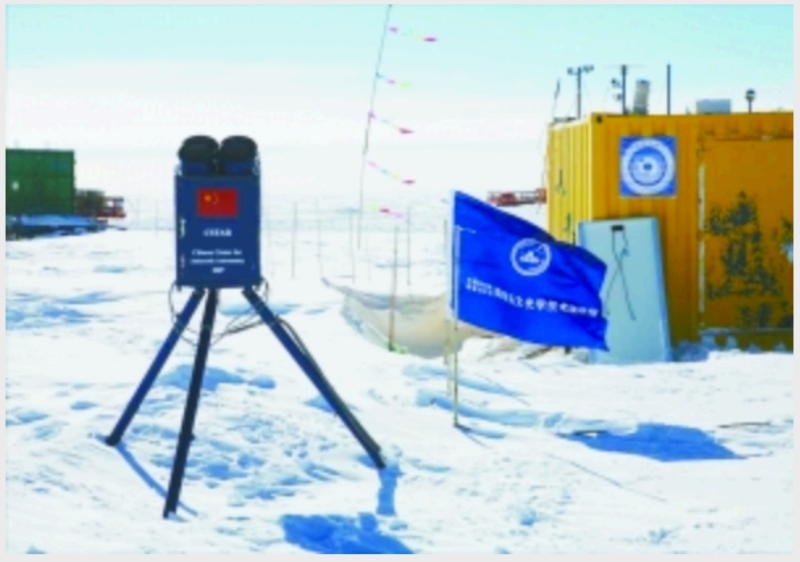
CSTAR Survey Results of Transiting Events

Nanjing University

School of Astronomy and Space Science



Exoplanet Group:

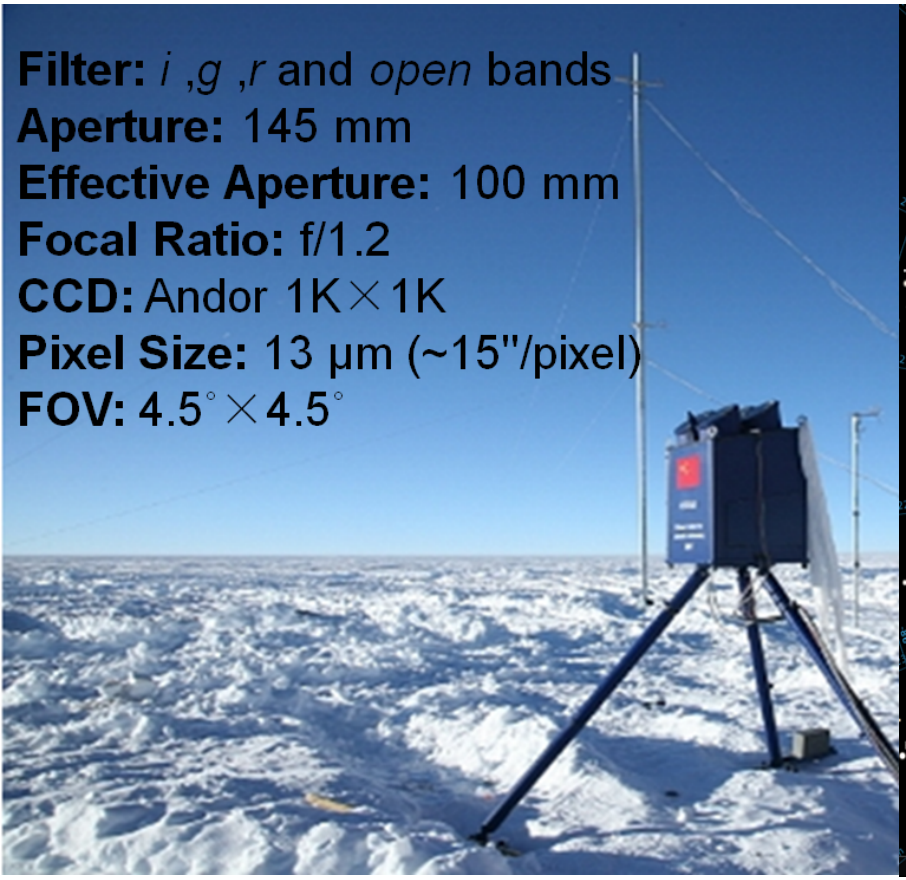
Zhou Ji-Lin, Zhang Hui, Liu Hui-Gen, Wang Songhu, Yang Ming, Meng Zeyang, Liang Ensi, Yu Zhouyi

HongKong University, May,9, 2015

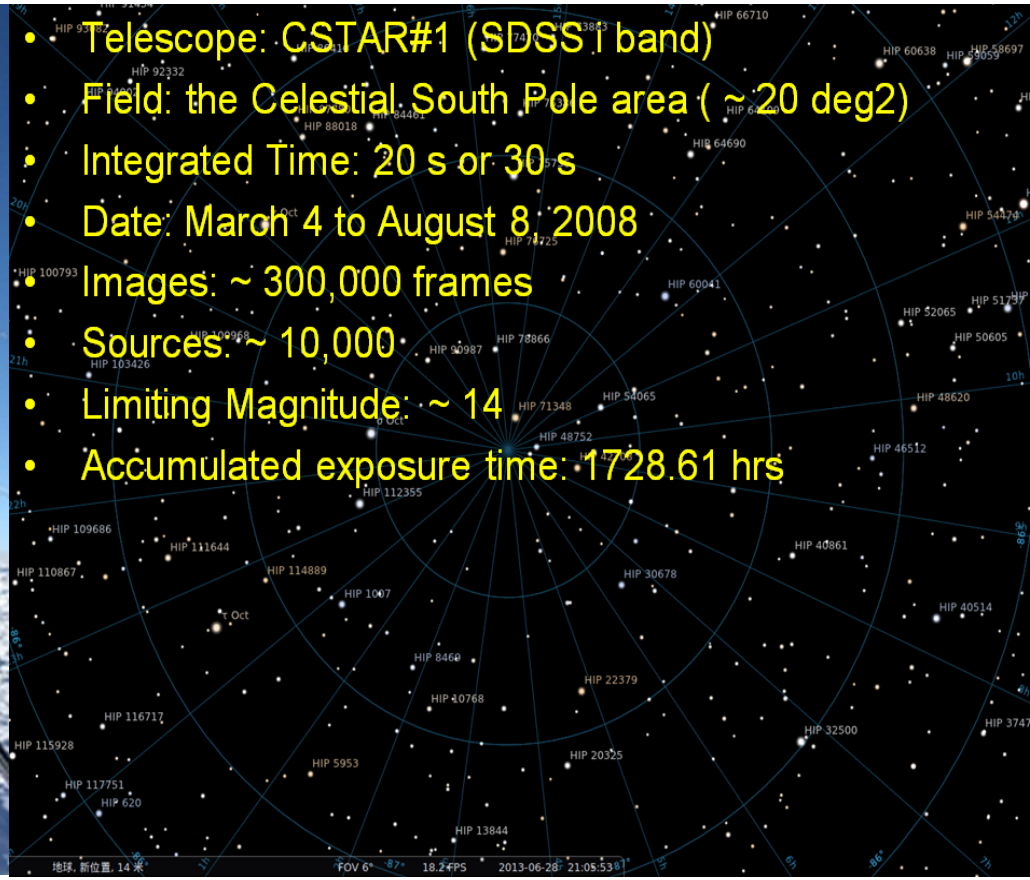
CSTAR Survey

NANJING UNIVERSITY

Instrument



Observational Data



Systematic Error Corrections

Yang et al. 2009

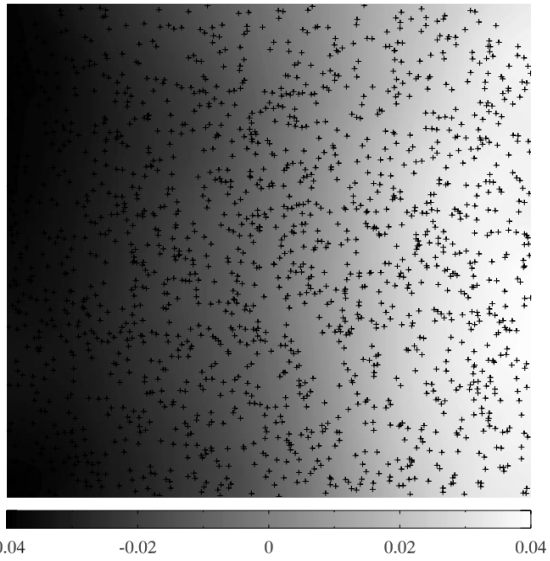
TABLE 1

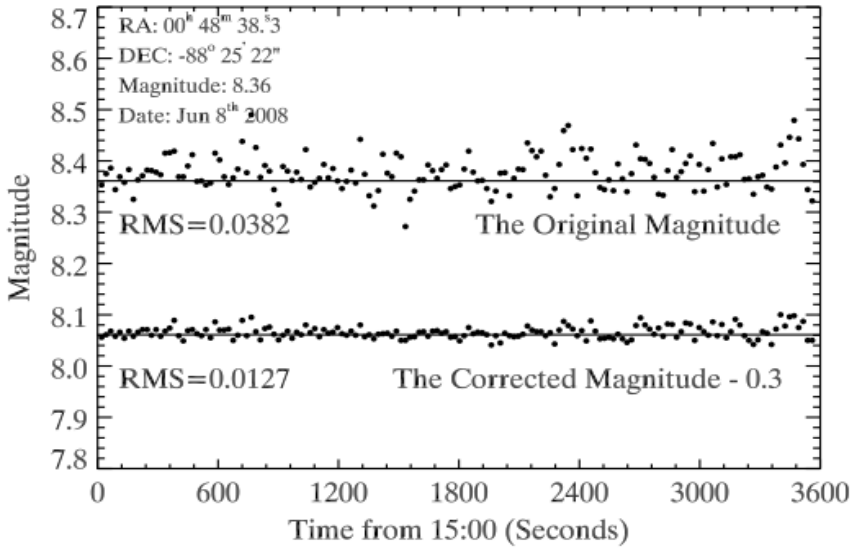
PHOTOMETRY OF SEVERAL SOURCES IN THREE DIFFERENT APERTURES;
CATALOG HEADER: −59 2008 JUNE 02 22:50:42.20 20 i 10398 154.954086

Number	R.A. (J2000)	Declination (J2000)	$M1$ (r = 3 pixel)	$\sigma1$	$M2$ (r = 4 pixels)	$\sigma2$	$M3$ (r = 5 pixels)	$\sigma3$
277	23:23:46.274	−89:25:17.81	11.095	0.022	11.011	0.022	10.838	0.025
278	10:43:24.023	−88:42:00.78	11.099	0.026	11.048	0.022	11.013	0.022
279	16:13:39.187	−87:44:30.11	11.100	0.026	11.030	0.022	11.014	0.022
280	14:09:08.706	−89:07:12.63	11.100	0.026	11.035	0.022	10.987	0.022
281	13:46:15.127	−88:26:01.94	11.100	0.026	11.013	0.022	10.885	0.025
282	17:54:27.175	−89:42:21.70	11.103	0.026	11.065	0.022	11.032	0.022

NOTE.—Catalog header parameters are decoded as: CCD temperature (°C), date, exposure time (in seconds), the number of sources detected in the image, day of the year during 2008. The catalogs can be downloaded from National Astronomical Observatories Science Data Center, Chinese Academy of Science at http://archive.bao.ac.cn/en/cstar.

The first results of photometry catalogues ***Zhou Xu et al. 2010***





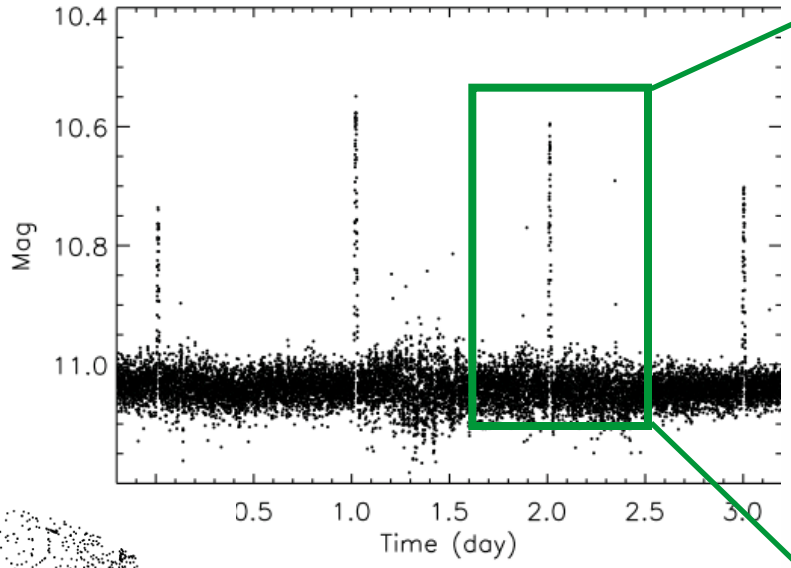
Wang et al. 2012 , Correction: the *inhomogeneous effect of cloud on CSTAR Photometry*

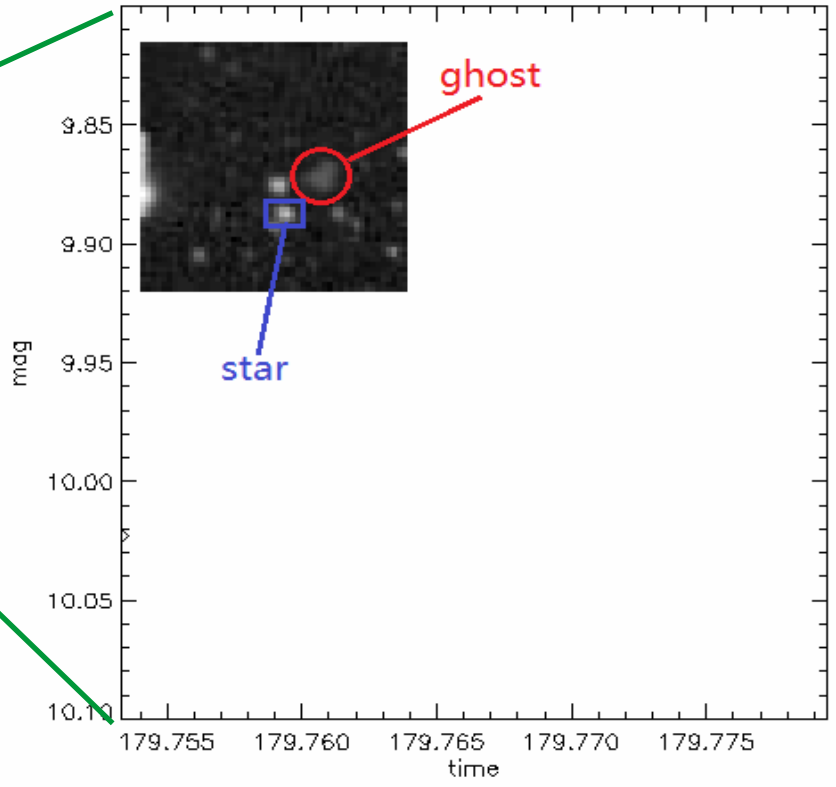
Systematic Error Corrections

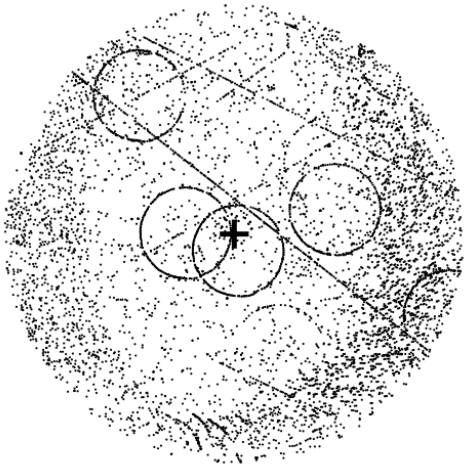
NANJING UNIVERSITY

Highlight:

We develop a standard ghost correction procedure and formulate the impact parameter as a function of star-ghost separation

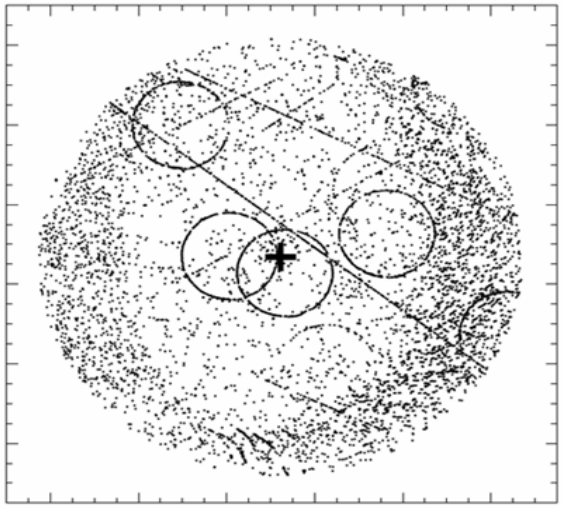


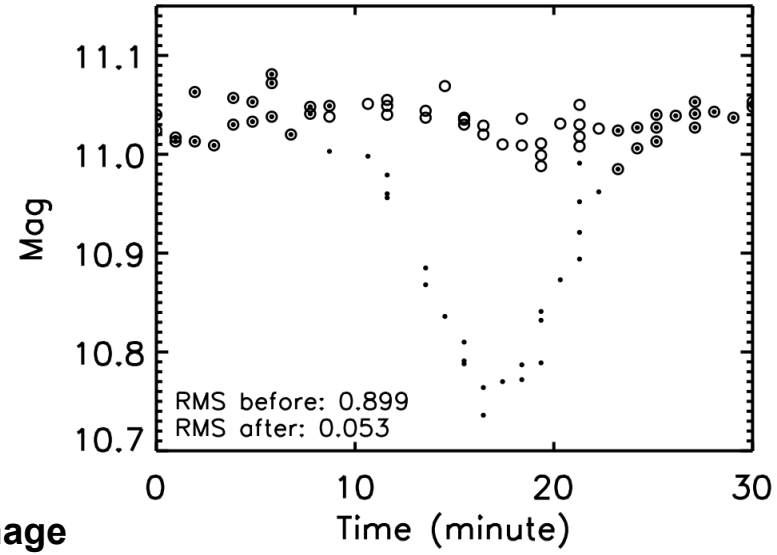




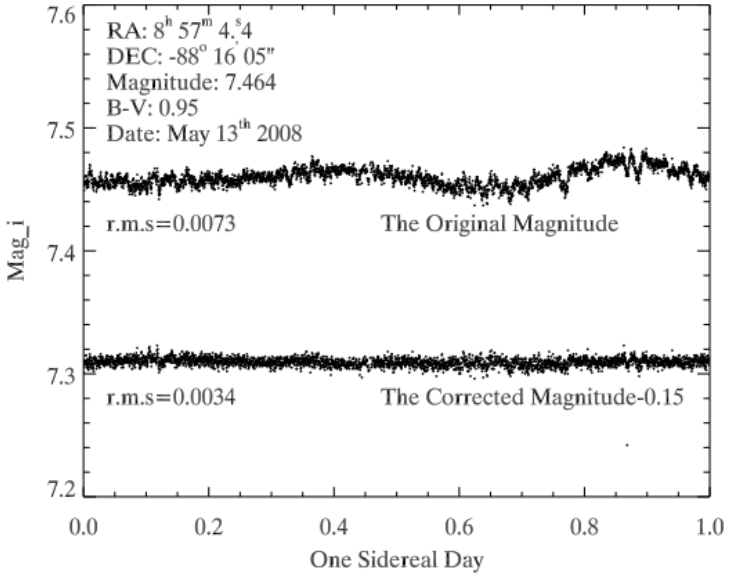
Ghostimage Correction

Systematic Error Corrections





Meng et al. 2013 Correction of ghostimage

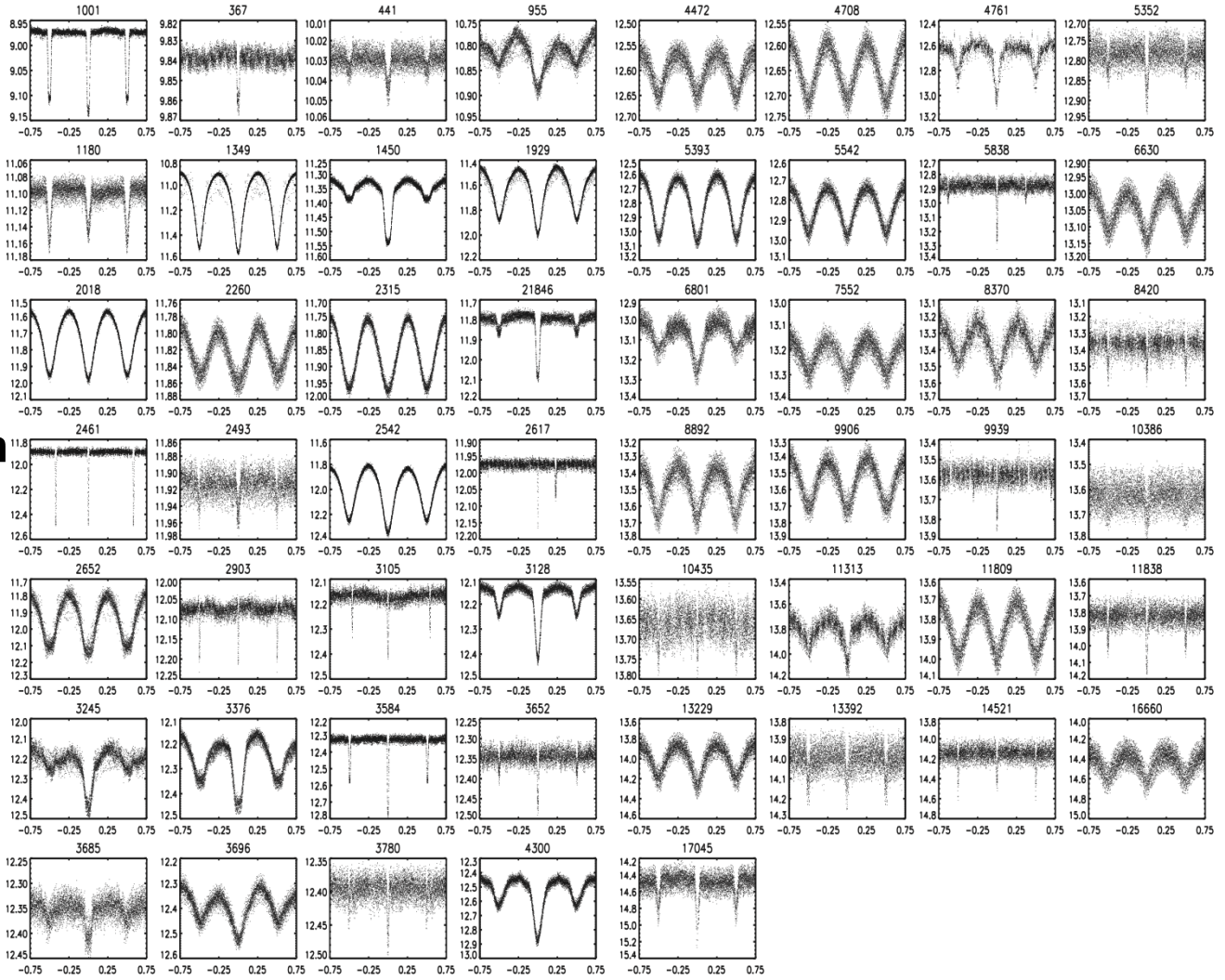


Wang et al. 2014 *Correction of diurnal effects on CSTAR photometry*

Eclipsing binaries from the CSTAR project

NANJING UNIVERSITY

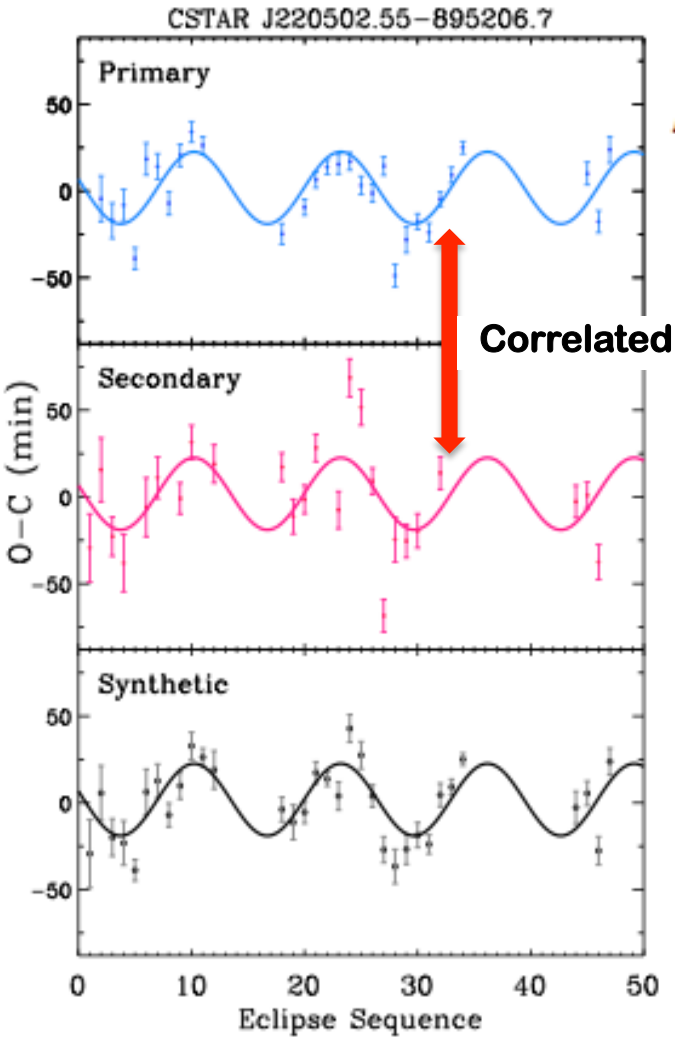
- **Search： 53 binaries**
- **Classification**
  - **24 detached**
  - **8 semi-detached**
  - **18 contact**
  - **3 ellipsoidal**
- **Parameters Solution**
- **Analysis**
  - **ETV (Eclipse timing variation)**
  - **Eccentric systems**
  - **O'Connell effect**



(Ming Yang, Hui Zhang, Ji-Lin Zhou et al. 2015 ApJS accepted)

Phase folded light curves

Eclipse Timing Variations (ETV) analysis



ETV model (Rappaport et al. 2013): triple star systems

$$ETV = A\left[\left(1-e_3^2\right)^{1/2}\sin u_3(t)\cos\omega_3 + (\cos u_3(t) - e_3)\sin\omega_3\right]$$

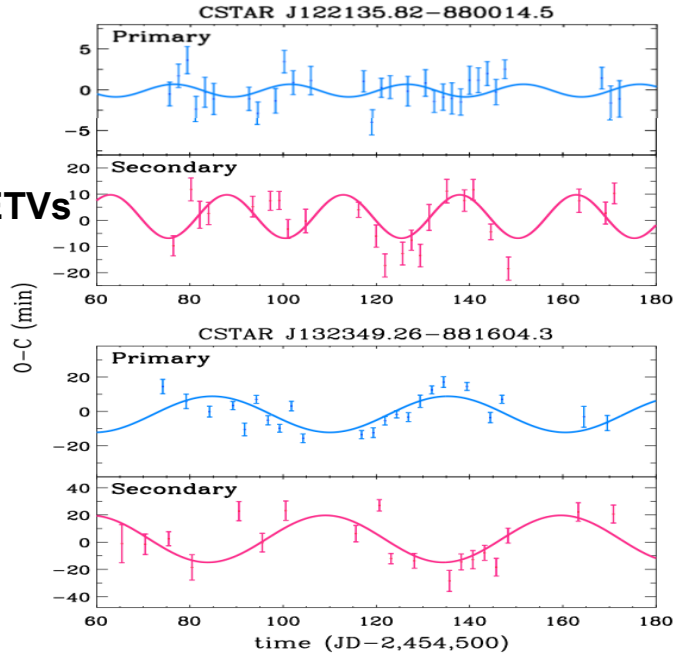
$$u_3(t) = M_3(t) + e_3\sin u_3(t)$$

$$M_3(t) = (t - t_0)\frac{2\pi}{P_3}$$

$$A_{LTTE} = \frac{G^{1/3}}{c(2\pi)^{2/3}}\left[\frac{m_3}{m_{123}^{2/3}}\sin i_3\right]P_3^{2/3}$$

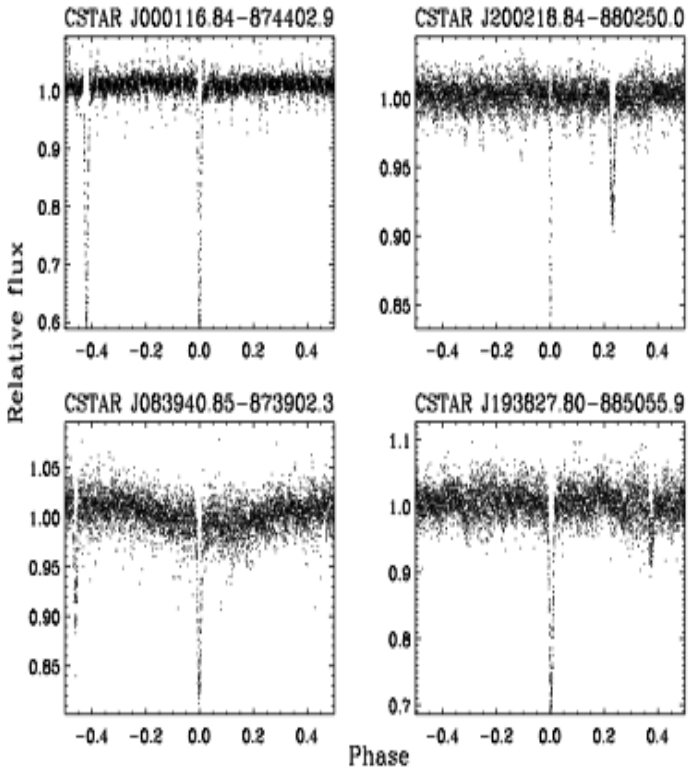
Parameters	Values
Period (days)	25.36(±0.83)
Amplitude (min)	19.27(±4.49)
eccentricity	0.07(±0.02)
w (rad)	3.36(±0.87)
FAP (log)	-3.4

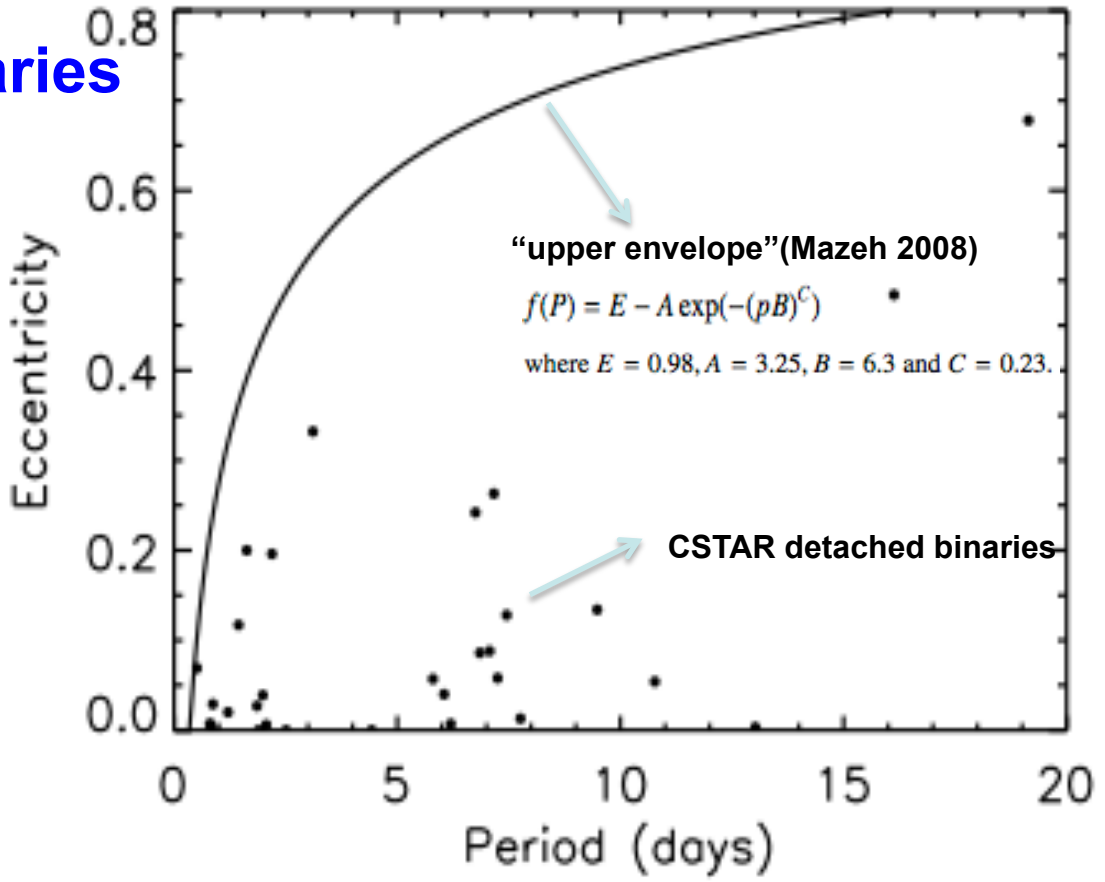
Anti-correlated ETVs



Primary (blue) secondary (red) & synthetic (black) ETV
Synthetic ETV is the half of the sum of primary and secoı

Eccentric detached binaries





O'Connell effect

different maximum in brightness

△m = m2 – m1

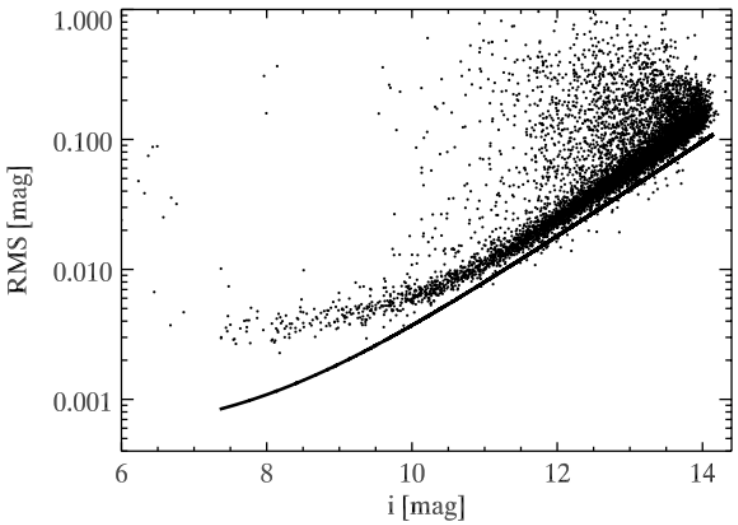
m1: peak magnitude after primary minimum

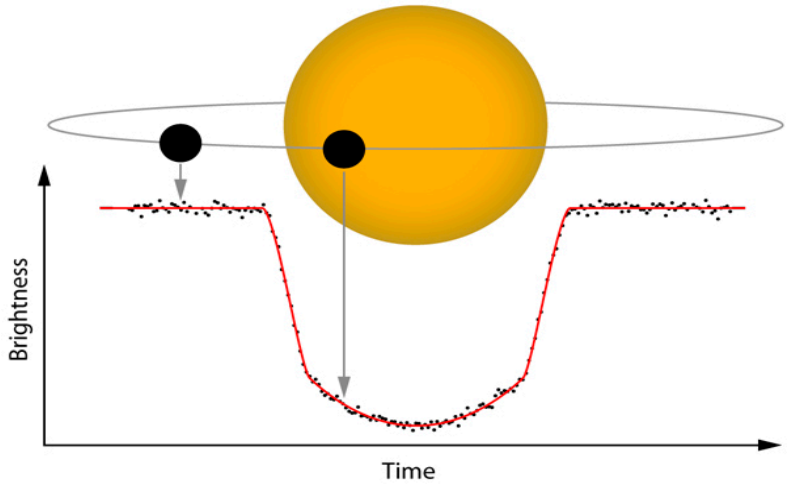
m2: peak magnitude after secondary minimum

Table 7. Contact and semi-detached systems with O'Connell effect

CSTAR ID	Δm (mag)	Type	CSTAR ID	Δm (mag)	Type
CSTAR J031348.84-891511.7	0.015	EC	CSTAR J061954.94-872047.5	0.036	EC
CSTAR J071652.61-872856.4	-0.016	EC	CSTAR J073412.18-874037.3	0.015	EC
CSTAR J084612.64-883342.9	-0.022	EC	CSTAR J124916.22-881117.6	0.015	EC
CSTAR J135318.49-885414.6	0.023	EC	CSTAR J142901.63-873816.2	0.024	EC
CSTAR J181735.42-870602.2	-0.019	EC	CSTAR J223707.30-872849.9	0.017	EC
CSTAR J110803.52-870114.0	0.030	ESD	CSTAR J132349.26-881604.3	0.037	ESD
CSTAR J220502.55-895206.7	0.022	ESD			

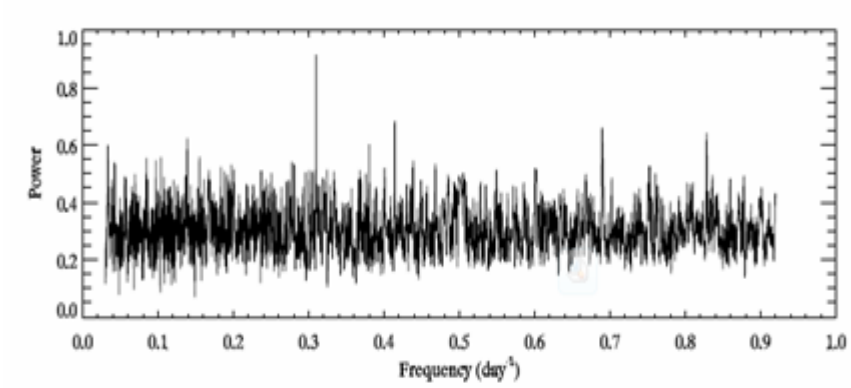
Transiting planets

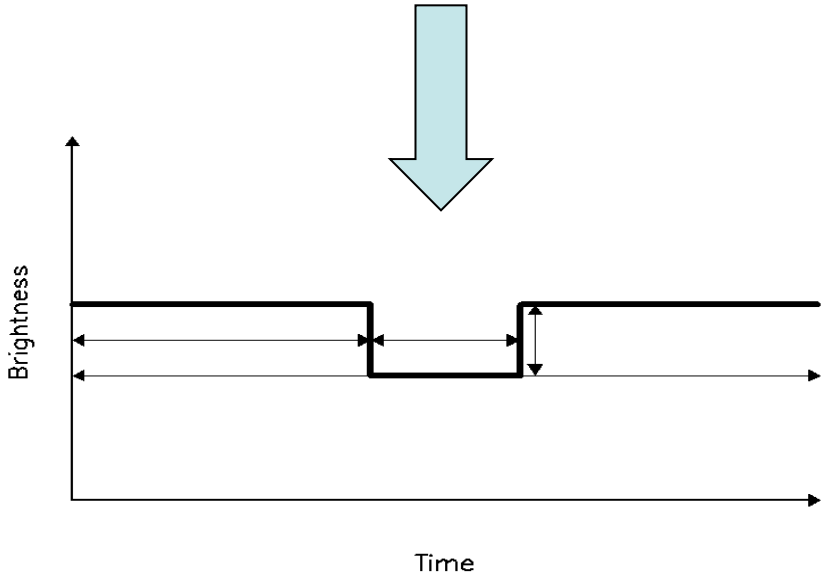




Photometry precision for different stars

Best case: RMS~0.004mag.





Box-Fitting Least Square Algorithm，searching transiting events

False Positive (FAP)

NANJING UNIVERSITY

Because of

1.Systematic error

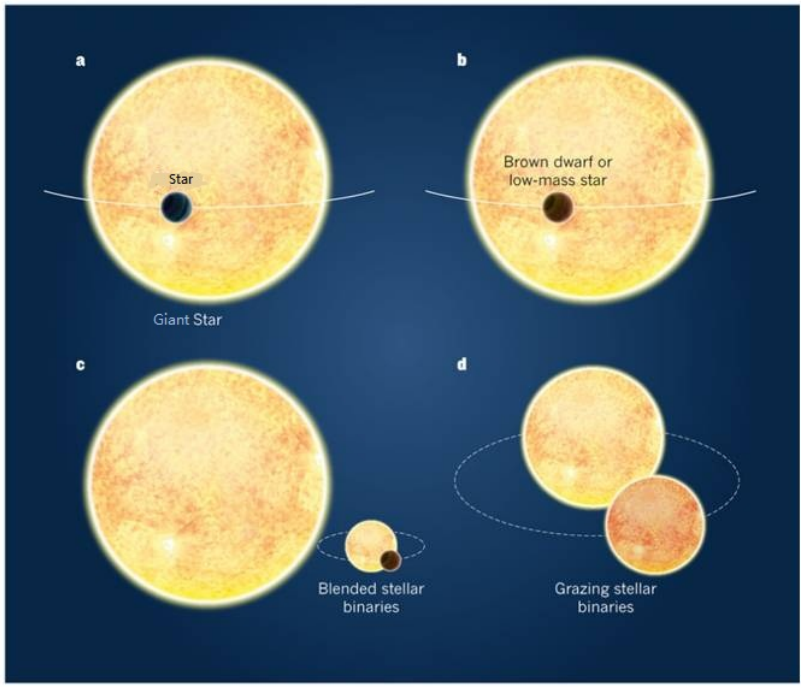
- low SNR
- fake period
- incomplete phase folded
- polluted from nearby variable stars

2.Physical events

(Binary eclipse in the background)

- ellipsoidal binary
- spectrum observation for giant star
- RV follow-up

…



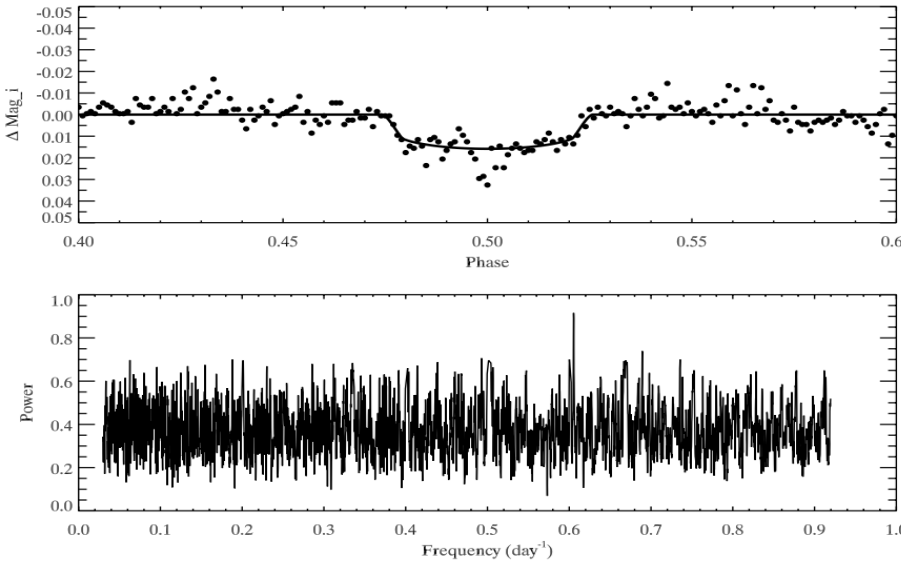
Most FAP detections are due to Binary Eclipse

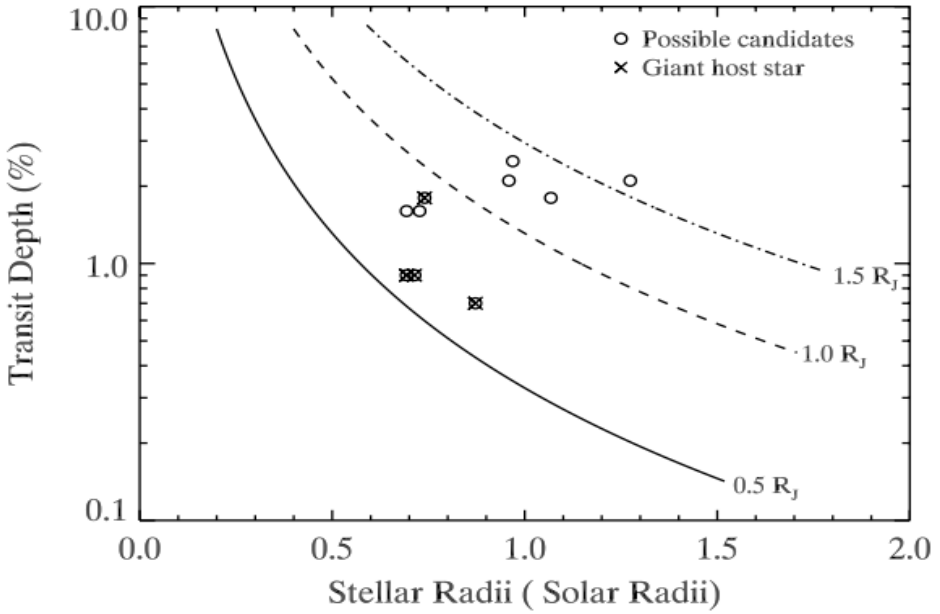
Table 1. Summary of CSTAR exoplanet transit candidates

CSTAR ID CSTAR J+	Epoch (2454500.0 +)	i (mag)	Period (d)	Duration (h)	Depth (mag)	R_* ($R_\odot$)	R_p (R_{Jup})	$B-V$ (mag)	$J-K$ (mag)	T_{eff} K	log(g)	S_p	$\Delta x^2/\Delta x^2_-$	S/N_{ellip}	S_r	η	P_δ | P_i
183056.78-884317.0	53.69665	9.84	9.924	10.004	0.021	1.214	1.531	0.48	0.31	—	—	F5	4.23	5.87	22.32	2.03	0.42 | 0.38
001238.65-871811.0	48.80221	10.59	5.371	2.269	0.021	0.959	1.356	0.69	0.43	5900	4.9	G5	3.53	0.28	8.78	0.65	0.66 | 0.74
014026.01-873057.1	46.69858	10.26	4.164	1.847	0.009	0.714	0.519	1.54	0.67	4800	0.6	Giant	1.48	0.26	10.37	0.71	0.15 | 0.44
021535.71-871122.5	46.50898	10.69	1.438	1.360	0.018	0.740	0.862	1.65	0.80	4600	3.3	Giant	2.69	0.45	12.10	0.71	0.48 | 0.23
022810.02-871521.3	50.90359	10.62	2.586	2.048	0.021	1.274	1.547	0.44	0.36	6100	3.5	F5	2.63	0.65	7.11	0.61	0.64 | 0.11
075108.62-871131.3	47.59870	10.41	2.630	2.298	0.016	0.693	0.742	1.24	0.95	4800	4.5	K7	1.52	0.75	8.60	1.02	0.17 | 0.42
110005.67-871200.4	47.11239	10.84	3.228	1.633	0.025	0.969	1.335	0.68	0.33	6300	3.9	G5	2.02	1.19	10.60	0.55	0.07 | 0.62
113310.22-865758.3	47.14206	9.97	1.652	2.045	0.016	0.727	0.794	1.06	0.60	4900	5.0	K4	1.63	1.72	6.96	1.03	0.45 | 0.40
132821.71-870903.3	46.53672	10.41	4.273	1.797	0.018	1.068	1.255	0.59	0.41	6000	4.5	G0	1.62	2.17	7.05	0.53	0.01 | 0.20
203905.43-872328.2	47.21003	10.35	2.216	2.691	0.007	0.872	0.636	0.79	0.68	4800	1.5	Giant	1.64	0.53	7.68	1.15	0.22 | 0.91
231620.78-871626.8	46.99121	10.76	1.408	1.676	0.009	0.693	0.569	1.39	0.81	4300	2.4	Giant	2.86	0.36	6.68	0.94	0.02 | 0.82

Giant Hosts

Six candidates around bright stars with *i_mag*=9.84-10.84 *(Wang et al. 2014 ApJS)*





Summary

1. Corrections of Systematic Errors
   - the inhomogeneous effect of cloud *(Wang Songhu et al)*
   - ghost image *(Meng Zeyang et al.)*
   - diurnal effects *(Wang, Meng et al.)*
2. Eclipsing Binaries (Yang Ming, Zhang Hui et al.)
   - Detached/ semi-detached/contact/ellipsoidal binaries
   - ETV
   - O'Connell effect
3. Transiting Planets *(Wang Songhu, Zhang Hui et al.)*
   - Checking the FAP
   - 6 Candidates