OB131394: The analysis of an ambiguous event

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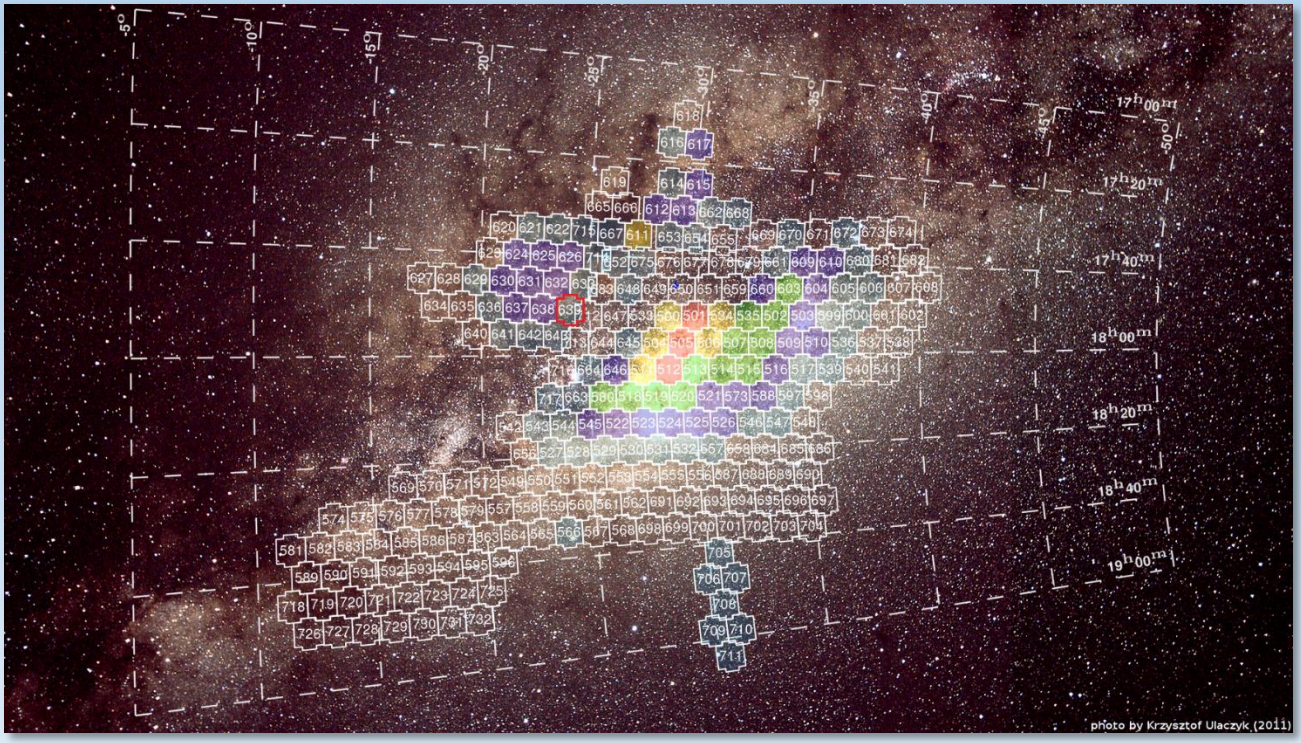
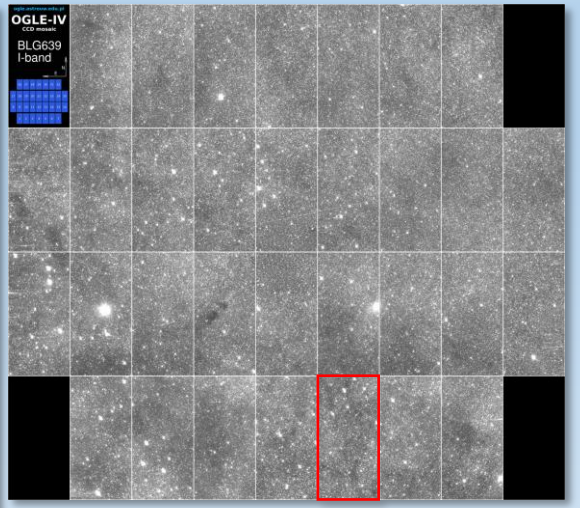
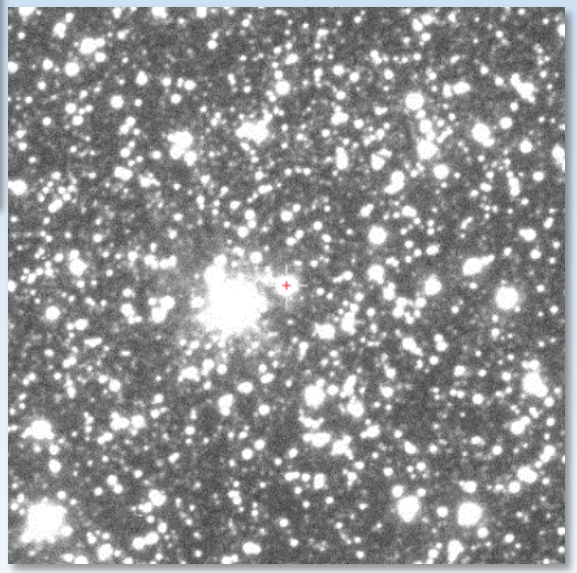
- Alerted on Friday July 26th 2013 by the OGLE Early Warning System

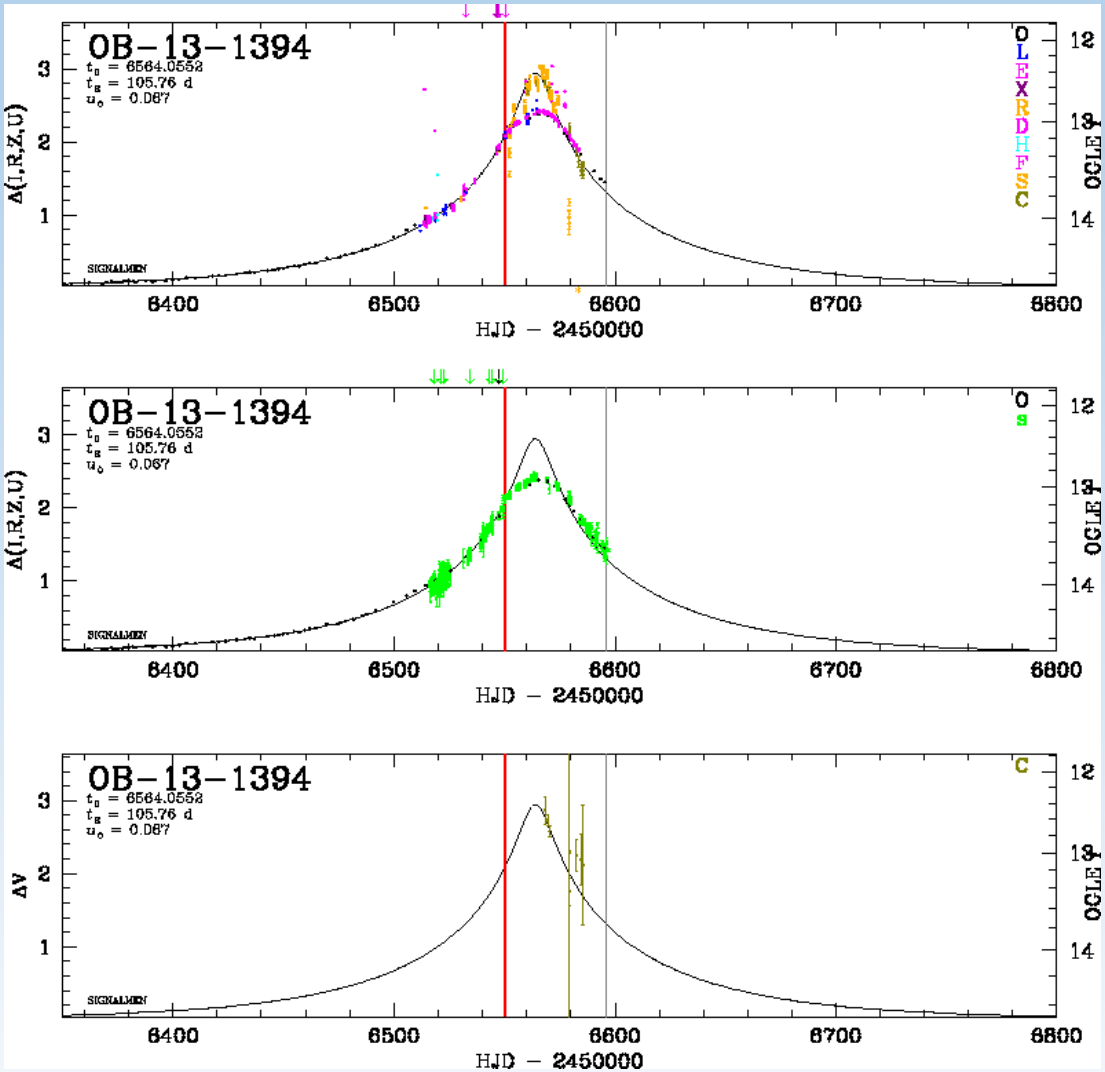






- Star #7273 in the OGLE-IV BLG**639.05** field
- RA(J2000.0): 17:50:25.86
  Dec(J2000.0): -24:34:57.3

- Slow evolution
- Anomaly detected on *Sun Sept 15th, 2013 at 00:33 UT* (2456350.5229 HJD)



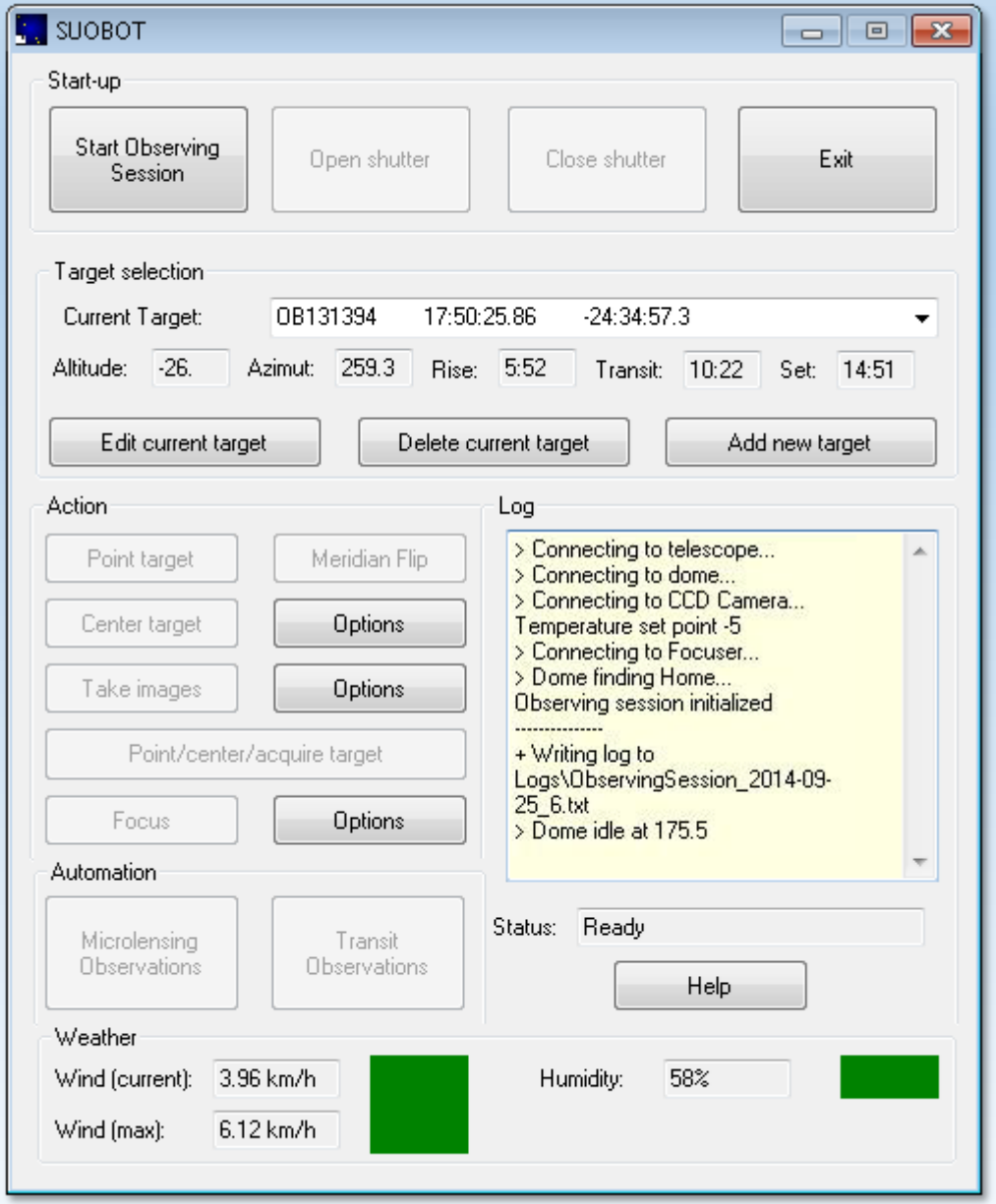
from ARTEMiS webpage

- **OGLE (2013/2014)**
- **μFUN:**
  - CTIO 1.3m (I, V)
- **RoboNet:**
  - LCOGT CTIO 1.0m A
  - LCOGT CTIO 1.0m B
  - LCOGT SAAO 1.0m A
  - FTS 2.0m
  - LCOGT SSO 1.0 A
  - LCOGT SSO 1.0 B

  Re-reduction of RoboNet data by Markus Hundertmark
- **MiNDSTEp:**
  - Danish 1.54m Lucky Cam
  - Salerno 0.35m

Followed by Salerno University Observatory (SUO):

- *Aug 11th - Oct 31st 2013*
- *53 nights*
- *883 frames*



Salerno University Observatory:

- 0.35m telescope
- SBIG ST-2000XM 1600x1200 0.54''/px
- Fully robotic telescope: SUObot
- Pipeline updates the light curve in real-time

2014 Microlensing campaign:

- 105 good nights since April to October
- 29 events followed

Real Time Modelling (RTModel by Valerio Bozza → Valerio's talk):

- Set of 236 initial conditions
- Downhill fitting with Levenberg-Marquardt algorithm
- The first model was published on the webpage
  http://www.fisica.unisa.it/GravitationAstrophysics/RTModel/2013/RTModel.htm
  on Sep. 15th 2013, at 1:45 UT

Offline:

- MCMC modelling has been conducted, with a more dense analysis starting from each model resulting from RTModel
- Contour integration code (by Valerio Bozza)
- No need to introduce limb-darkening since the observed lightcurve showed no clear evidence of a caustic crossing
- Long duration event: models taking into account for parallax and orbital motion better fit the data (asymmetric descent)
- Results show two models with the same χ^2 competing

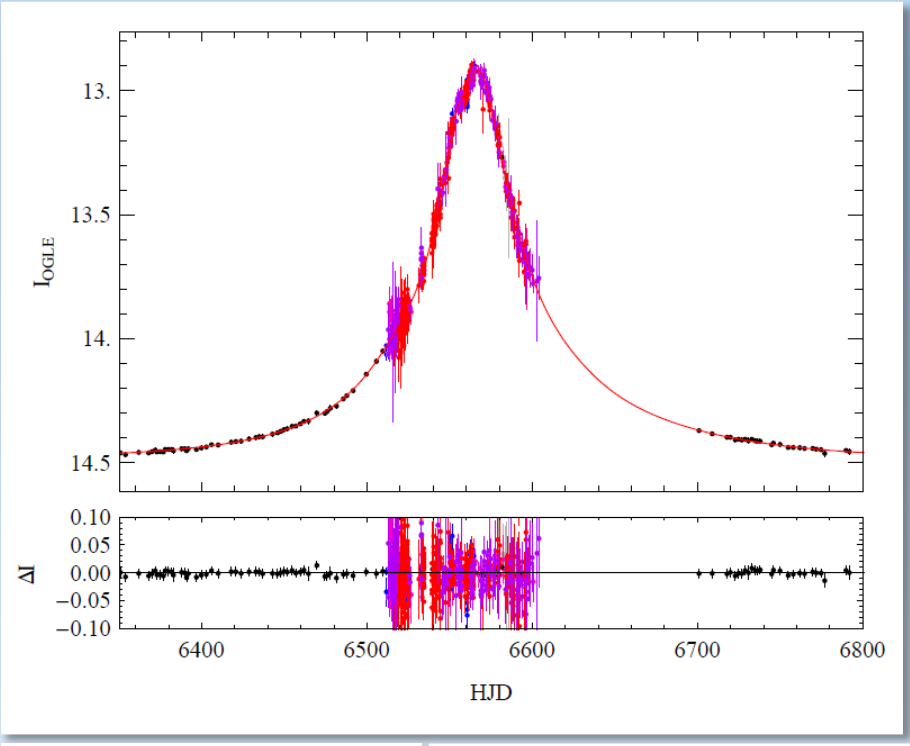
Binary Lens models for OB131394

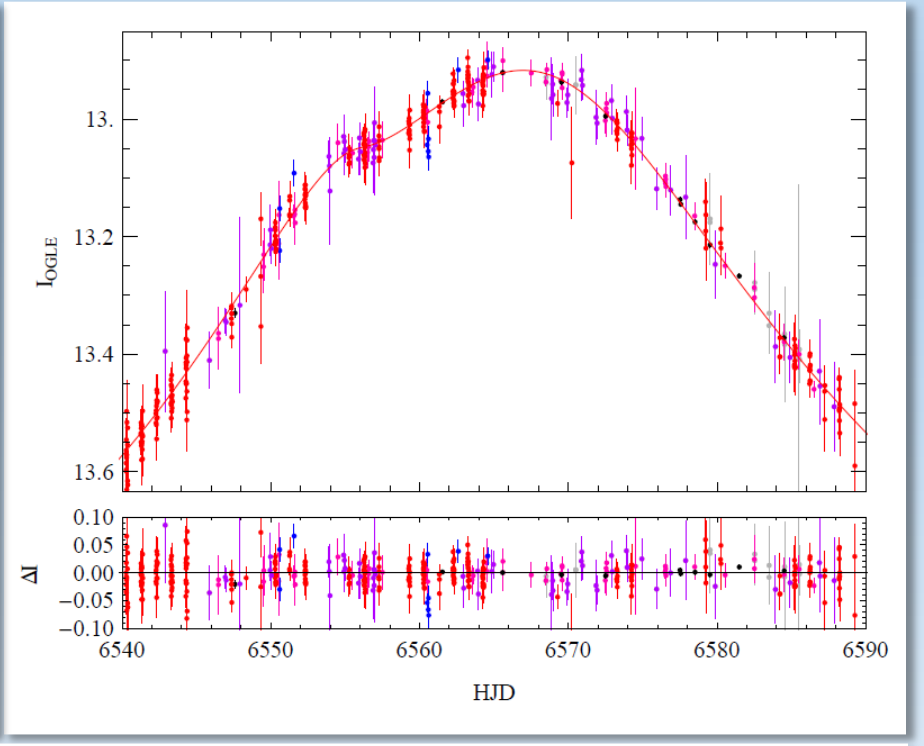
	Binary Lens	Parallax	Parallax+Orbital Motion
s	0.468056 ± 0.008593	0.943417 ± 0.002118	1.121460 ± 0.014828
q	0.049808 ± 0.003341	0.001241 ± 0.000095	0.014157 ± 0.001763
u_0	0.105349 ± 0.001915	-0.091602 ± 0.003110	-0.104099 ± 0.004272
θ (rad)	0.586225 ± 0.005269	2.62835 ± 0.01965	3.034440 ± 0.035729
ρ_*	0.000190 ± 0.002706	0.029510 ± 0.001893	0.023996 ± 0.002069
t_E (days)	109.096 ± 1.517	166.142 ± 5.380	124.149 ± 3.313
t_0 (HJD)	6565.24 ± 0.05	6567.00 ± 0.06	6570.10 ± 0.44
$\pi_\perp$	–	0.384678 ± 0.010245	-0.144687 ± 0.009152
$\pi_\parallel$	–	-0.039048 ± 0.005366	0.036266 ± 0.009152
ds/dt	–	–	0.002940 ± 0.000689
$d\theta/dt$	–	–	0.005805 ± 0.001382
ω_3	–	–	0.005705 ± 0.001632
f_b/f_s	2.02 ± 0.07	2.87 ± 0.13	2.50 ± 0.14
χ^2	1118.79 ± 3.18	1066.11 ± 3.84	1000.51 ± 4.48

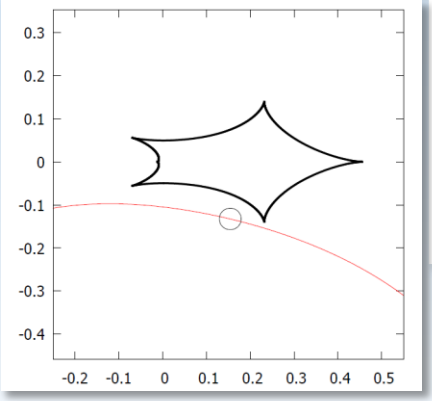
Binary Source models for OB131394

	Binary Source	Parallax	Parallax+Xallarap
t_E (days)	107.42 ± 1.50	168.70 ± 7.96	156.35 ± 10.95
FR	0.081197 ± 0.008873	0.100580 ± 0.011250	0.040583 ± 0.007214
u_1	0.120497 ± 0.002588	0.066675 ± 0.003850	0.133596 ± 0.010580
u_2	0.046823 ± 0.002786	-0.019599 ± 0.003206	0.064698 ± 0.004085
t_1 (HJD)	6567.60 ± 0.11	6567.65 ± 0.10	6564.36 ± 0.29
t_2 (HJD)	6553.15 ± 0.12	6552.12 ± 0.11	6561.65 ± 1.06
$\pi_\perp$	–	0.324195 ± 0.012366	0.349086 ± 0.018719
$\pi_\parallel$	–	-0.007330 ± 0.005988	0.009685 ± 0.018281
ds/dt	–	–	-0.140080 ± 0.016256
$d\theta/dt$	–	–	-0.130280 ± 0.018551
ω_3	–	–	0.003041 ± 0.000937
f_b/f_s	1.80 ± 0.07	4.23 ± 0.31	1.69 ± 0.27
χ^2	1181.30 ± 2.98	1046.32 ± 3.55	1001.90 ± 4.26

Binary lens: 0.06 $M_\odot$ host star + 0.9 M_J planet…







s=1.12146±0.014828 q=0.014157±0.00176267 u_0=−0.104099±0.00427225

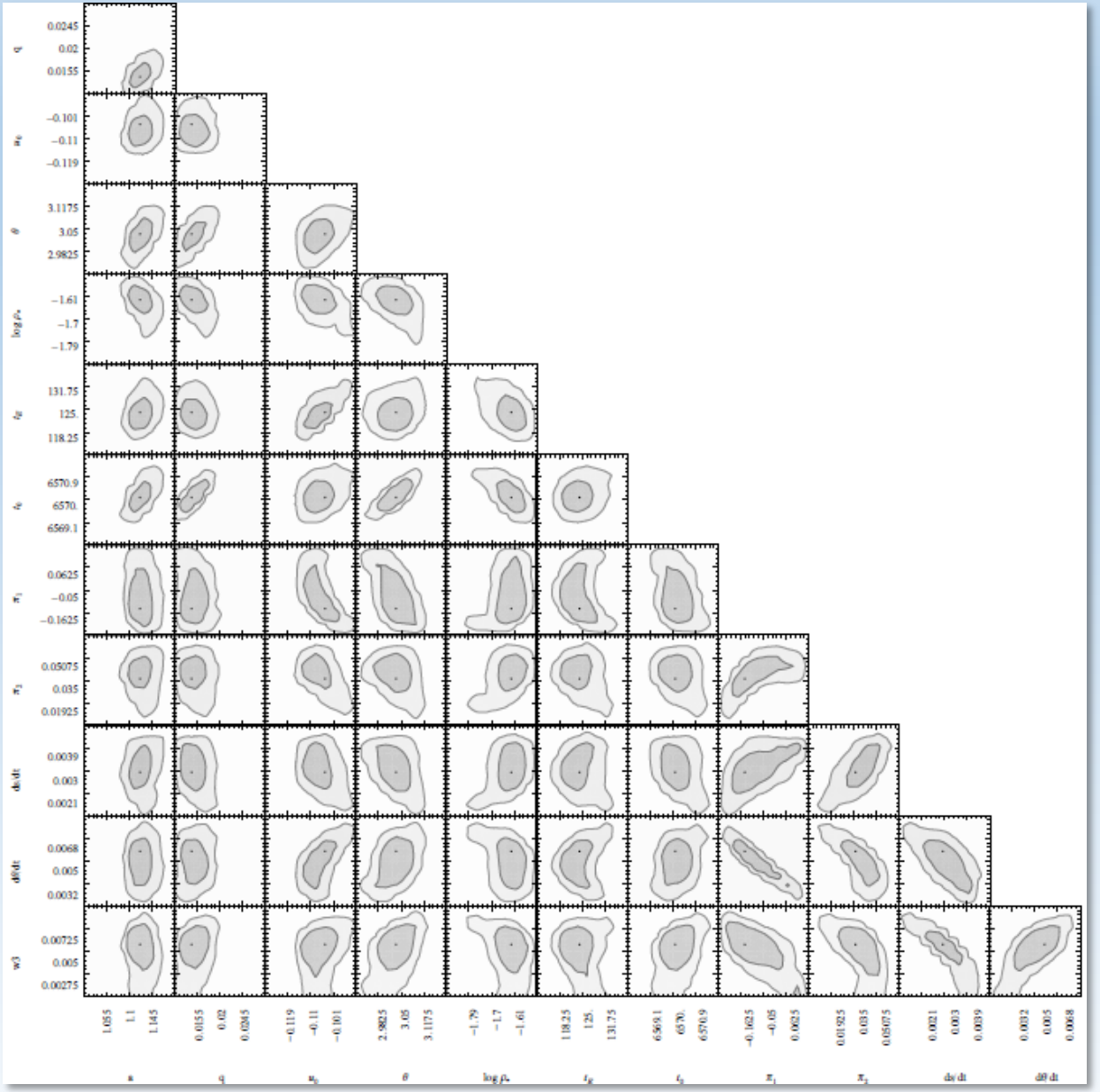
θ=3.03444±0.0357297 ρ_*=0.0239959±0.00216929 t_E=124.149±3.31323

t_0=6570.1±0.443648 π_1=−0.144687±0.0928676 π_2=0.0362659±0.00915171

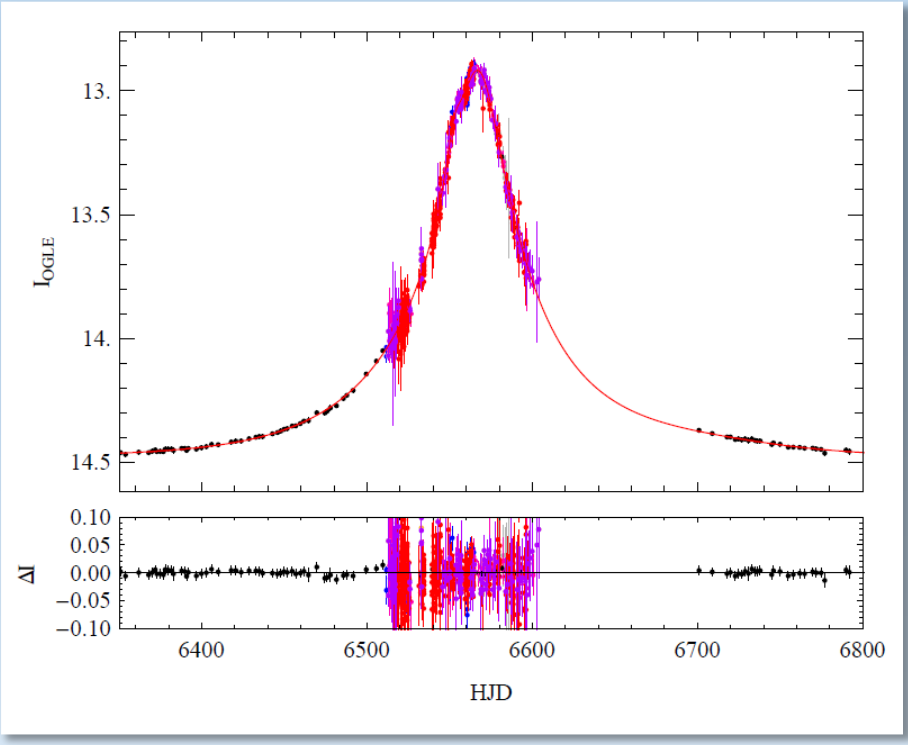
ds/dt=0.00293948±0.000688765 dθ/dt=0.00580541±0.00138198 ω_3=0.00570529±0.0016324

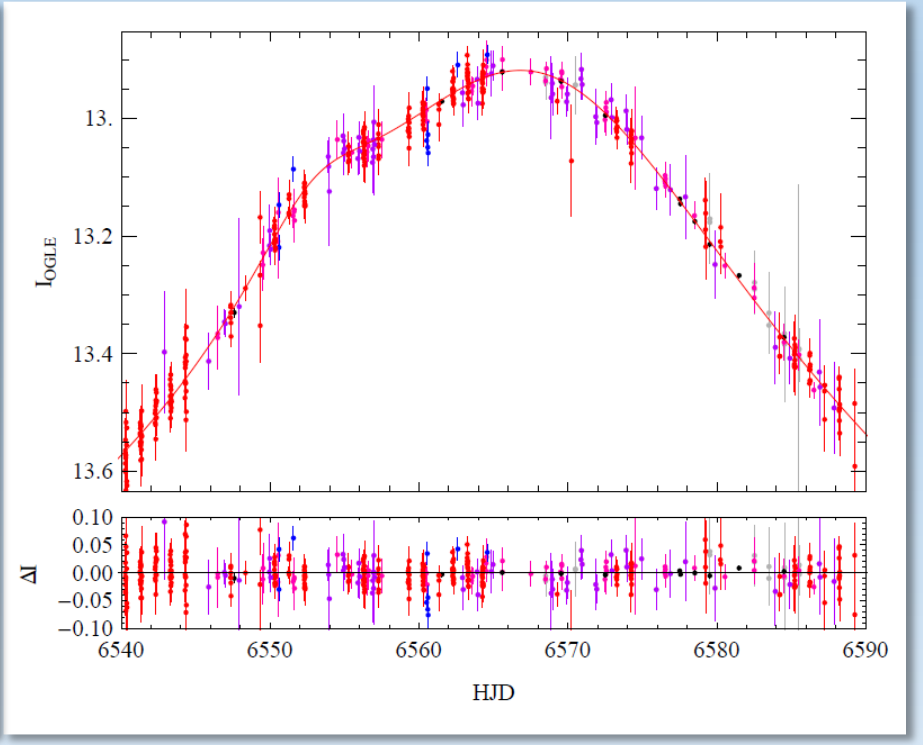
χ^2= 1000.51±4.65761 BF_o= 2.50468±0.141968

- *Two bumps due to the cusp grazings*


q
u0
θ
log ρ*
tE
t0
π1
π2
ds/dt
dθ/dt
w3
s
q
u0
θ
log ρ*
tE
t0
π1
π2
ds/dt
dθ/dt

…or a binary source?





t_E=156.35±10.9521 FR=0.0405834±0.0072141 u_1=0.133596±0.0105805

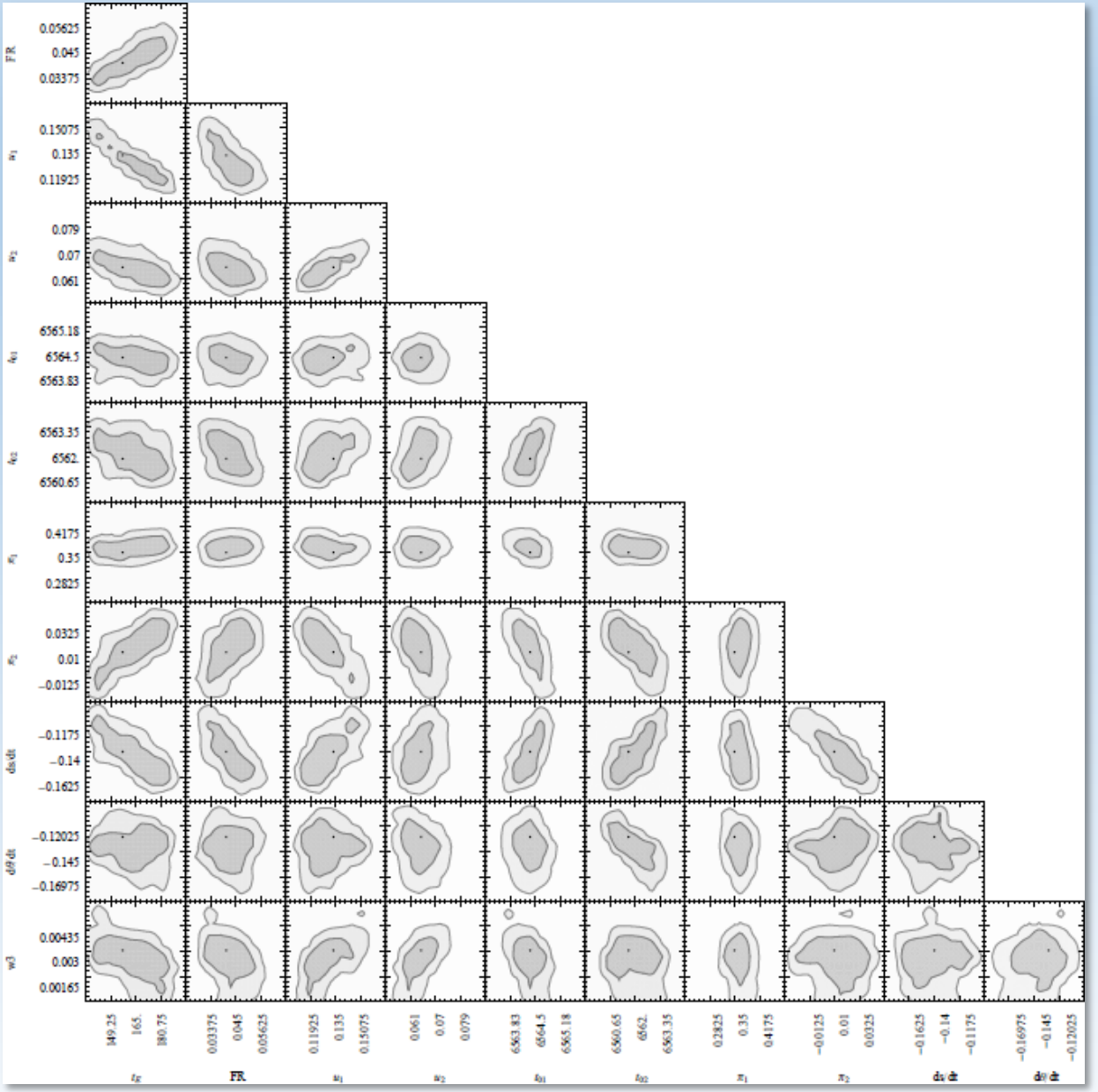
u_2=0.0646981±0.00408477 t_1=6564.36±0.289033 t_2=6561.65±1.05991

π_1=0.349086±0.0187186 π_2=0.00968502±0.0182811 ds/dt=−0.14008±0.0162558

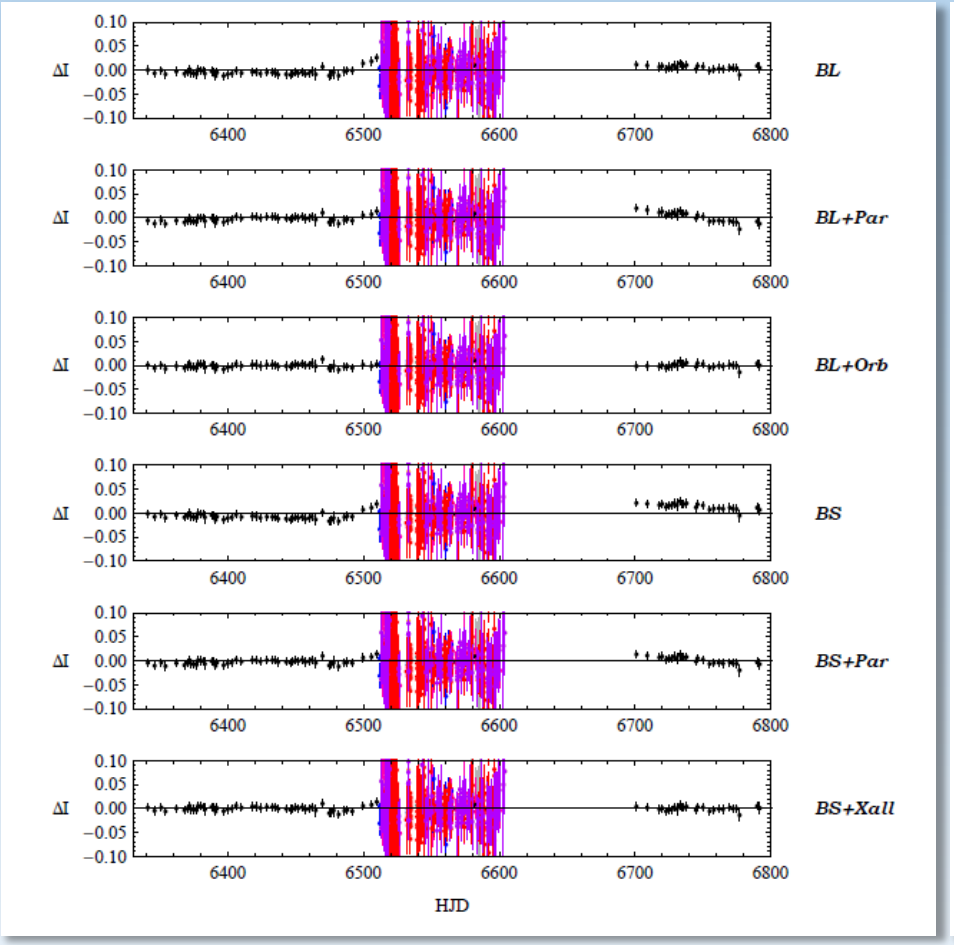
dθ/dt=−0.13028±0.0185514 ω_3=0.00304081±0.00093746

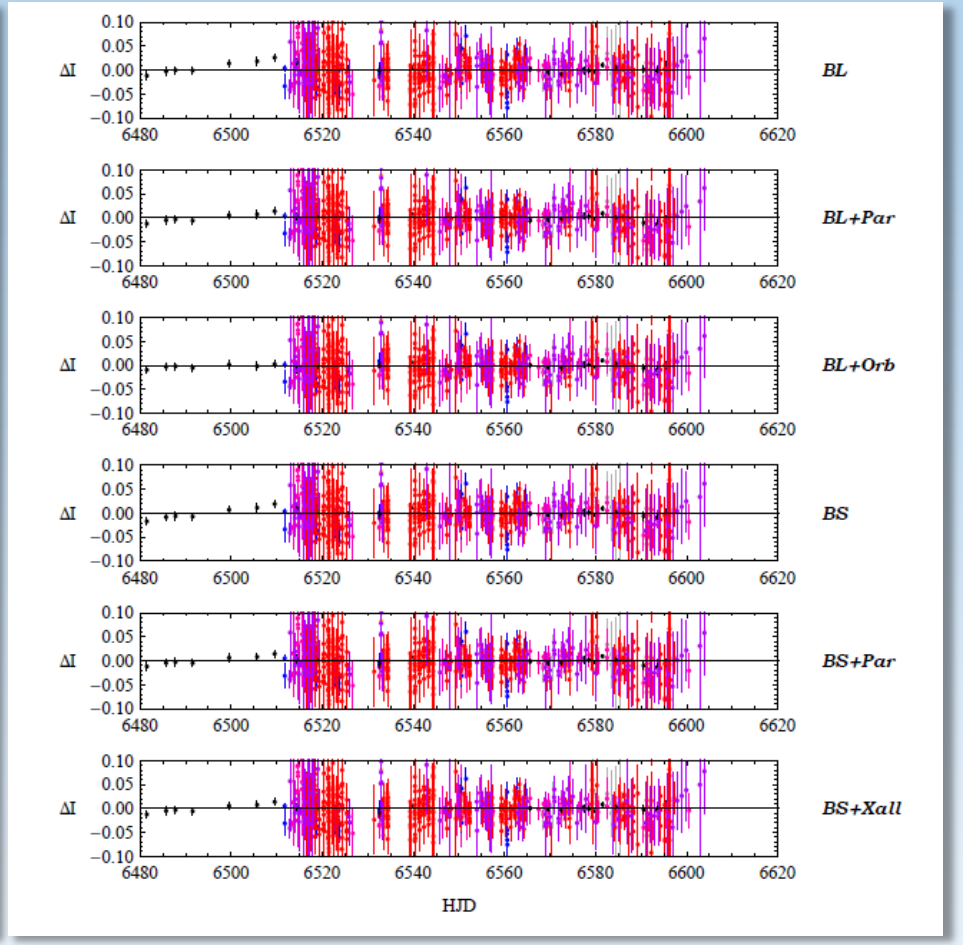
χ^2= 1001.9±4.25652 BF_o= 1.69085±0.269462

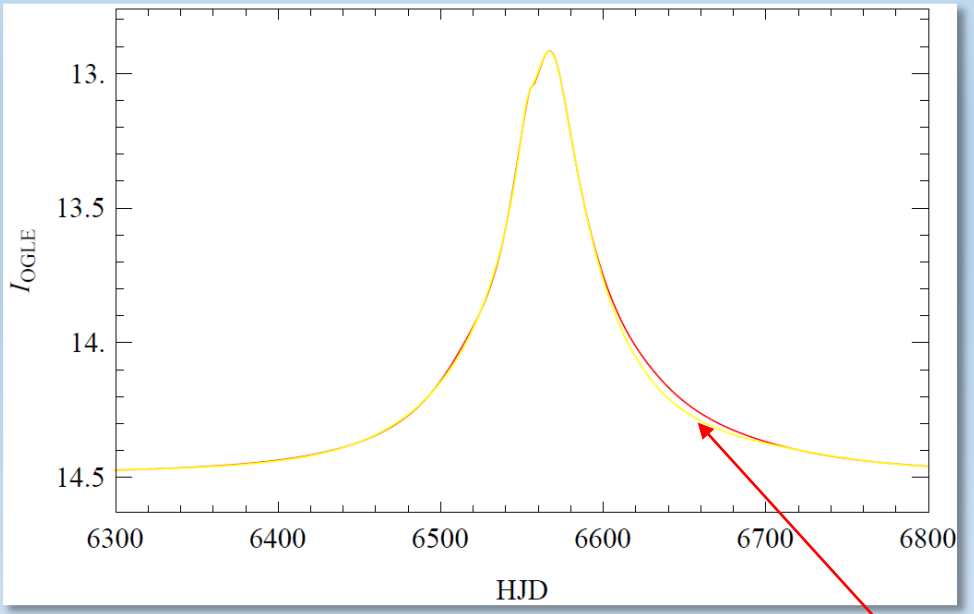
OB131394

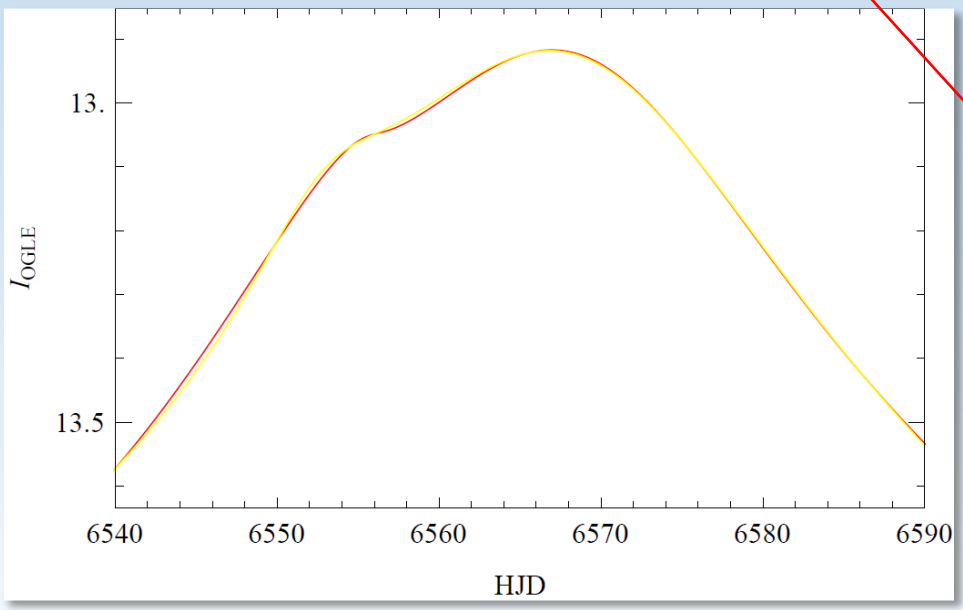

FR
π_1
π_2
x_{01}
x_{02}
π_1
π_2
ds/dt
dθ/dt
w3
0.05625
0.045
0.03375
0.15075
0.135
0.11925
0.079
0.07
0.061
6565.18
6564.5
6563.83
6563.35
6562.
6560.65
0.4175
0.35
0.2825
0.0325
0.01
−0.0125
−0.1175
−0.14
−0.1625
−0.12025
−0.145
−0.16975
0.00435
0.003
0.00165
149.25
165.
180.75
0.03375
0.045
0.05625
0.11925
0.135
0.15075
0.061
0.07
0.079
6563.83
6564.5
6565.18
6560.65
6562.
6563.35
0.2825
0.35
0.4175
−0.0125
0.01
0.0325
−0.1625
−0.14
−0.1175
−0.16975
−0.145
−0.12025
t_E
FR
x_{01}
x_{02}
π_1
π_2
ds/dt
dθ/dt

Residuals


ΔI
HJD
BL
BL+Par
BL+Orb
BS
BS+Par
BS+Xall

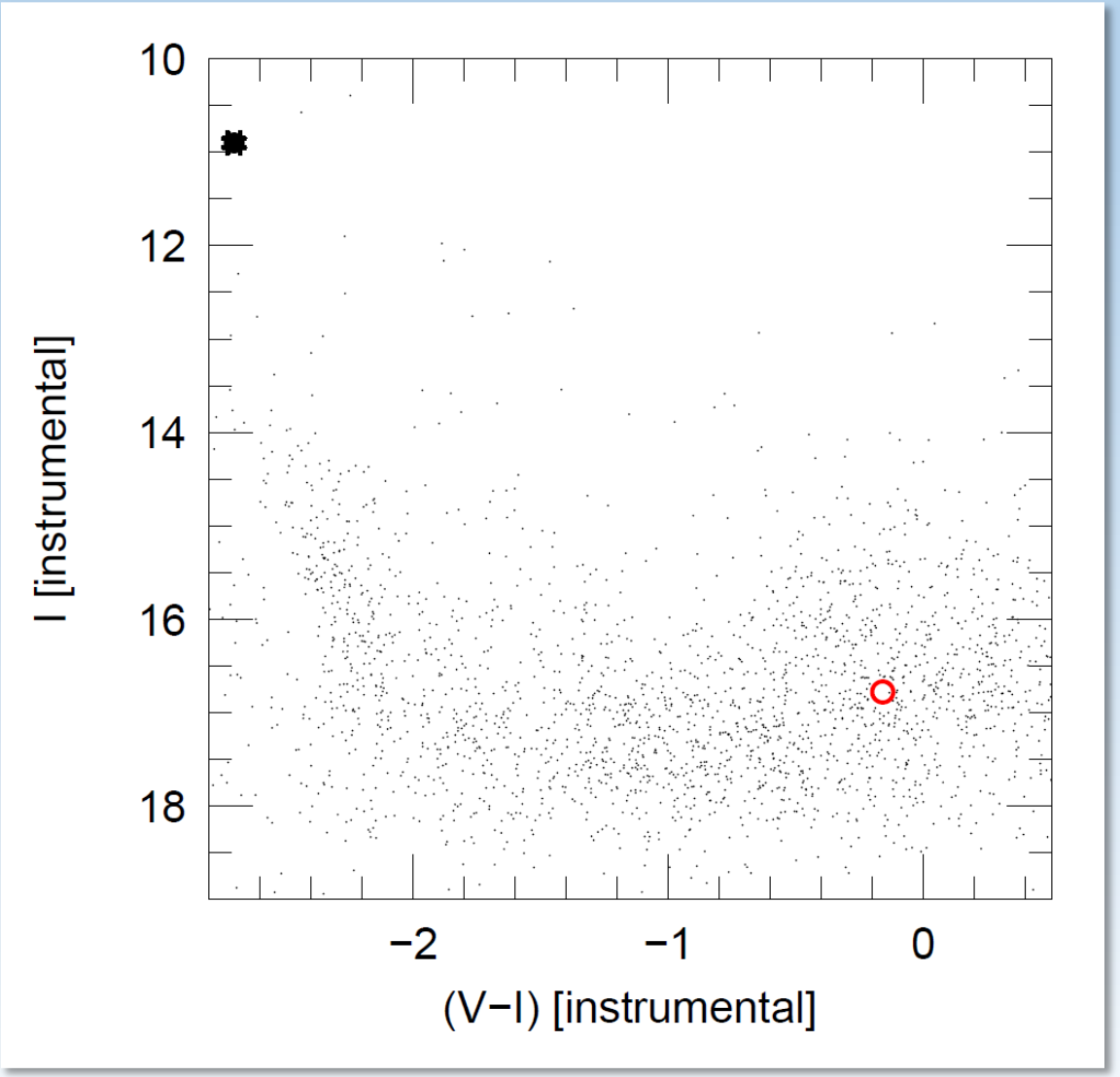

ΔI
HJD
BL
BL+Par
BL+Orb
BS
BS+Par
BS+Xall





- Fit comparison:
  - Binary Lens + Orbital Motion
  - Binary Source + Xallarap
- Biggest difference in the descent

- **Bright blue source in the foreground disk?**



CMD circulated by Andy Gould on Oct 8th, 2013

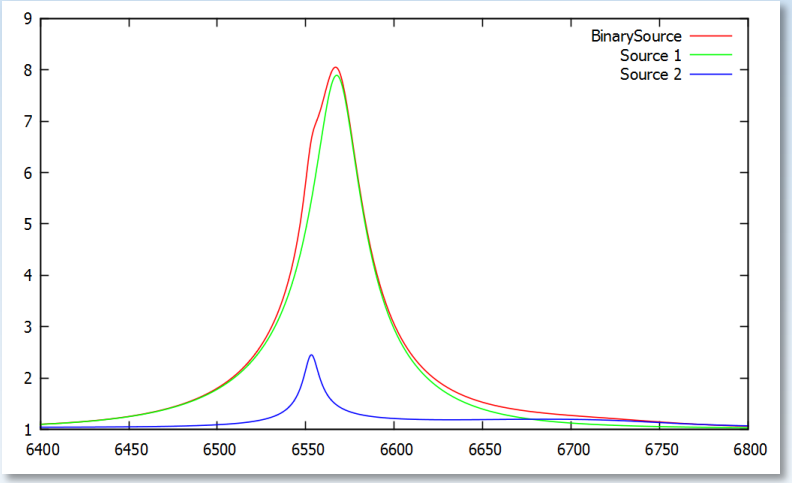
Spectral analysis (by Ian Thompson)

HJD	V1 (km/s)	V_2 (km/s)
6579.4925	4.56 ± 0.34	-25.87 ± 0.84
6931.4994	-24.51 ± 0.37	-11.00 ± 1.25

Communication received on Dec 13th, 2014

- Two spectra taken on Oct. 13th, 2013 and Sept. 30th, 2014 (Clay 6.5m Magellan Telescope at Las Campanas)
- Two different peaks in the CCF
- Similar peak strength ratio in the two years
- Probably this is a binary source!
- Another spectrum in June?

- It is possible to model the magnification of the single components of the binary system using the binary source solution with xallarap: the two bumps are caused by the two components



Conclusions

- Two models competing with the same χ^2:
  - Binary lens with planetary mass ratio
  - Binary source

- The long duration of the event made necessary to introduce non-static models:
  - Parallax
  - Orbital motion
  - Xallarap

- The weak but clear anomaly in the light curve can be due to a binary source as suggested by a subsequent spectral analysis

- The analysis conducted on this event draws our attention on the binary source/planetary lens degeneracy:
  - It may be useful to carry deeper analysis on events discarded due to weak anomalies: binary sources contaminate events with no evident caustic signature
  - Spectroscopic or multi-band measurements could reveal planetary lensing hidden behind an ambiguous anomaly
  - Statistical study on past microlensing events?