LNA LABORATÓRIO NACIONAL DE ASTROFÍSICA

FINK

Detection and characterization of exoplanets using Gravitational Microlensing:

OPD detections with a worldwide effort

Ted Leandro

lalmeida@lna.br

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÃO

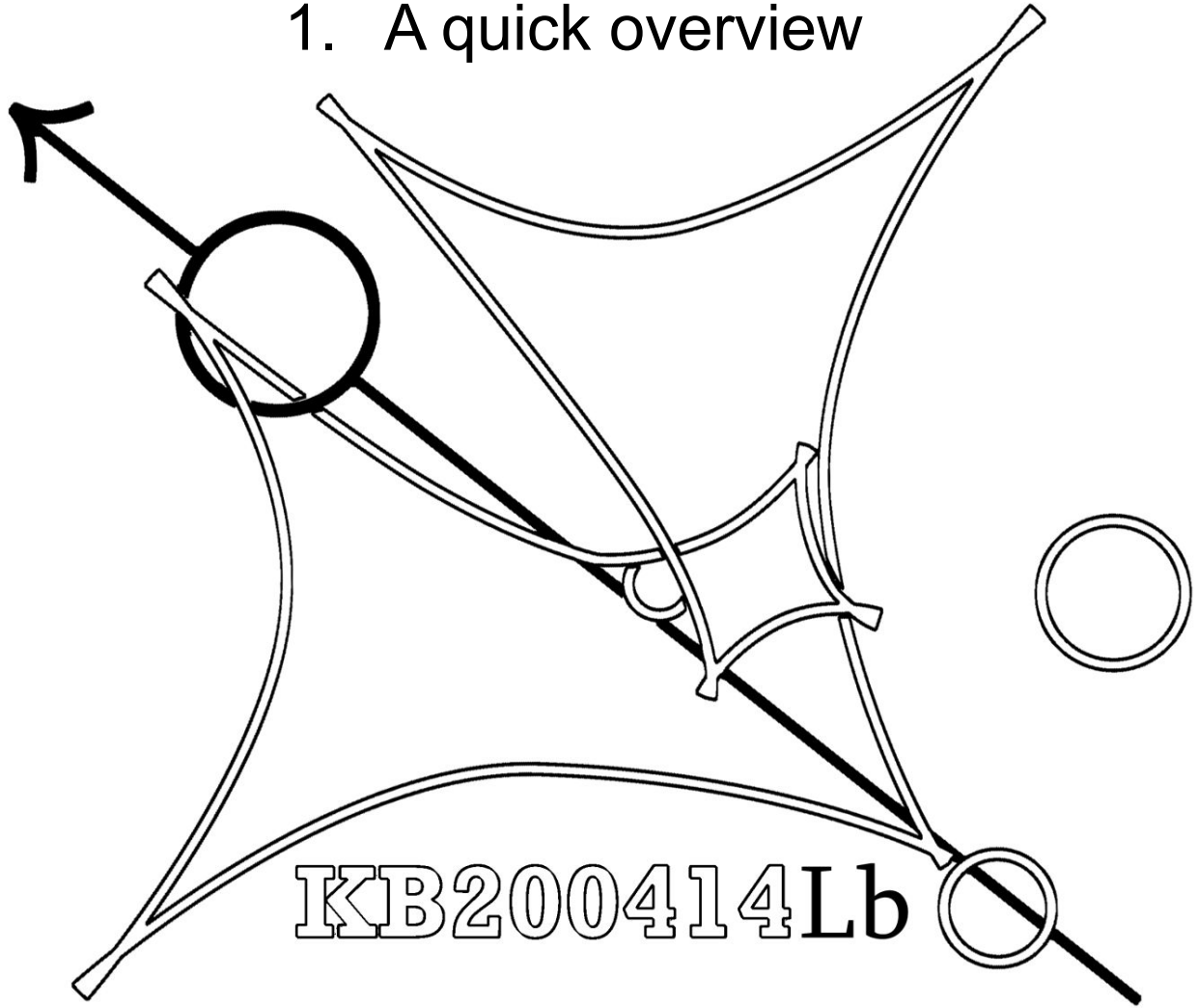
GOVERNO FEDERAL

BRASIL

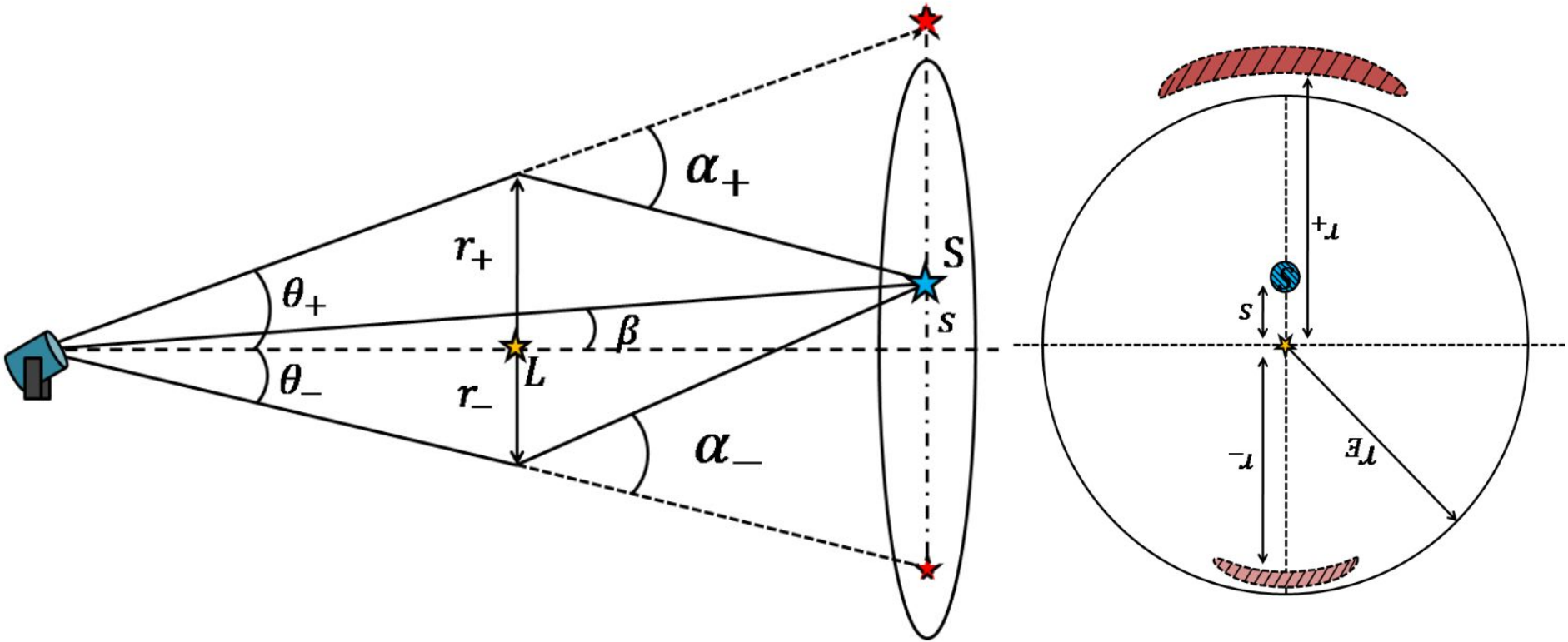
UNIÃO E RECONSTRUÇÃO

1. A quick overview
    a. GM in a nutshell
    b. Why?
2. The collaboration
    a. Before
    b. Now
3. How it is done
    a. The standard way
    b. The not so much standard way
    c. The premature way
4. What has been done
    a. OPD observations
    b. OPD detections
5. The future of GM for OPD
    a. Detections beyond the Galaxy

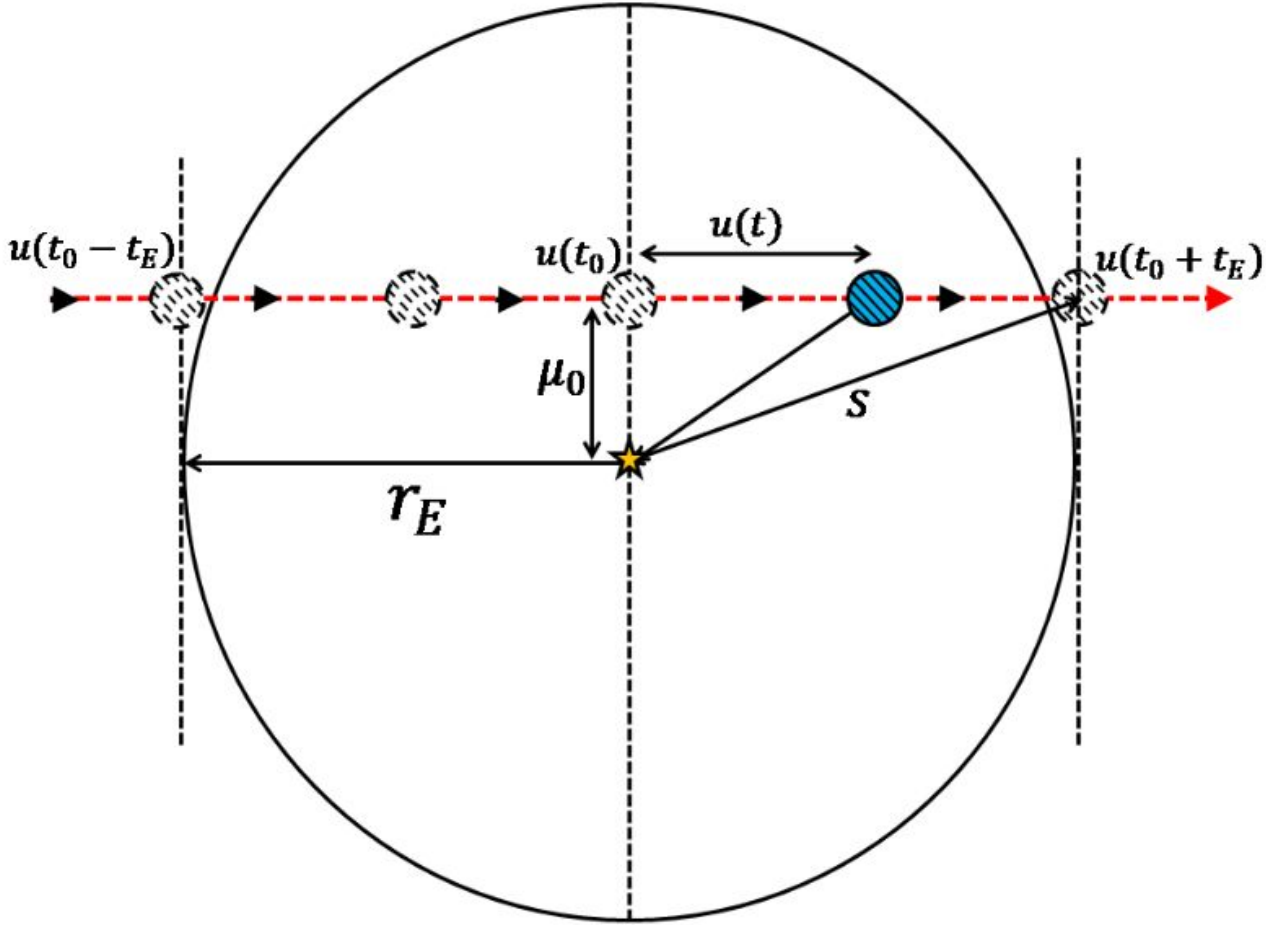
1. A quick overview



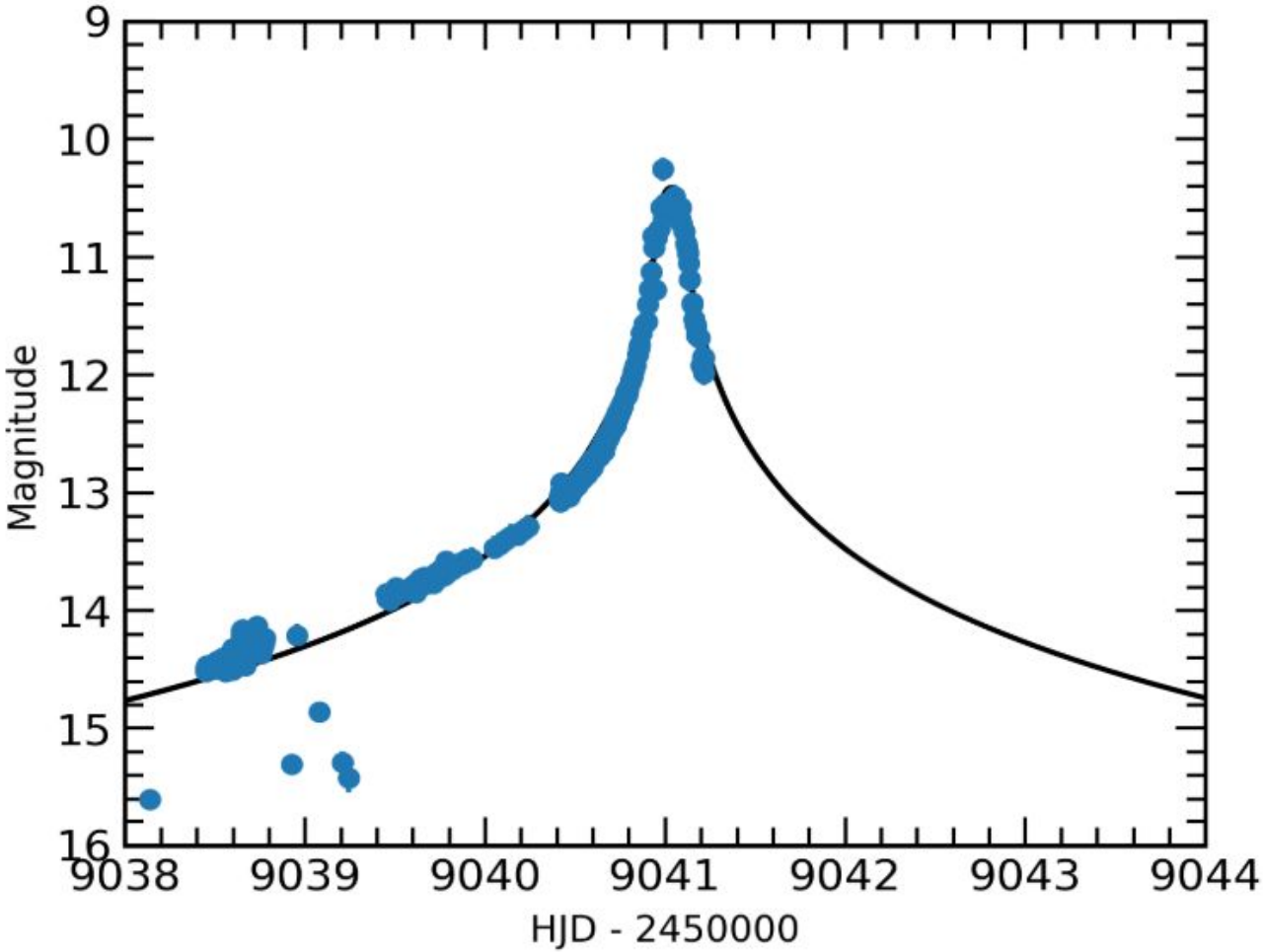
GM in a nutshell



GM in a nutshell

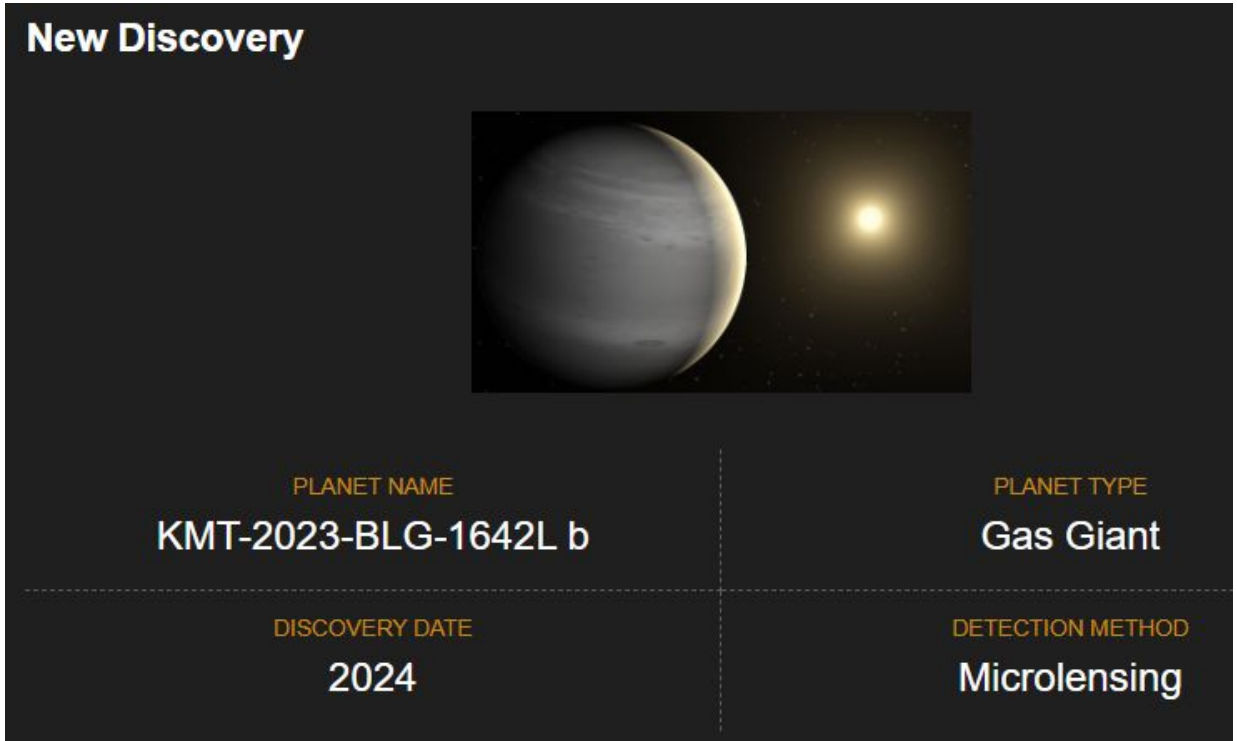


GM in a nutshell

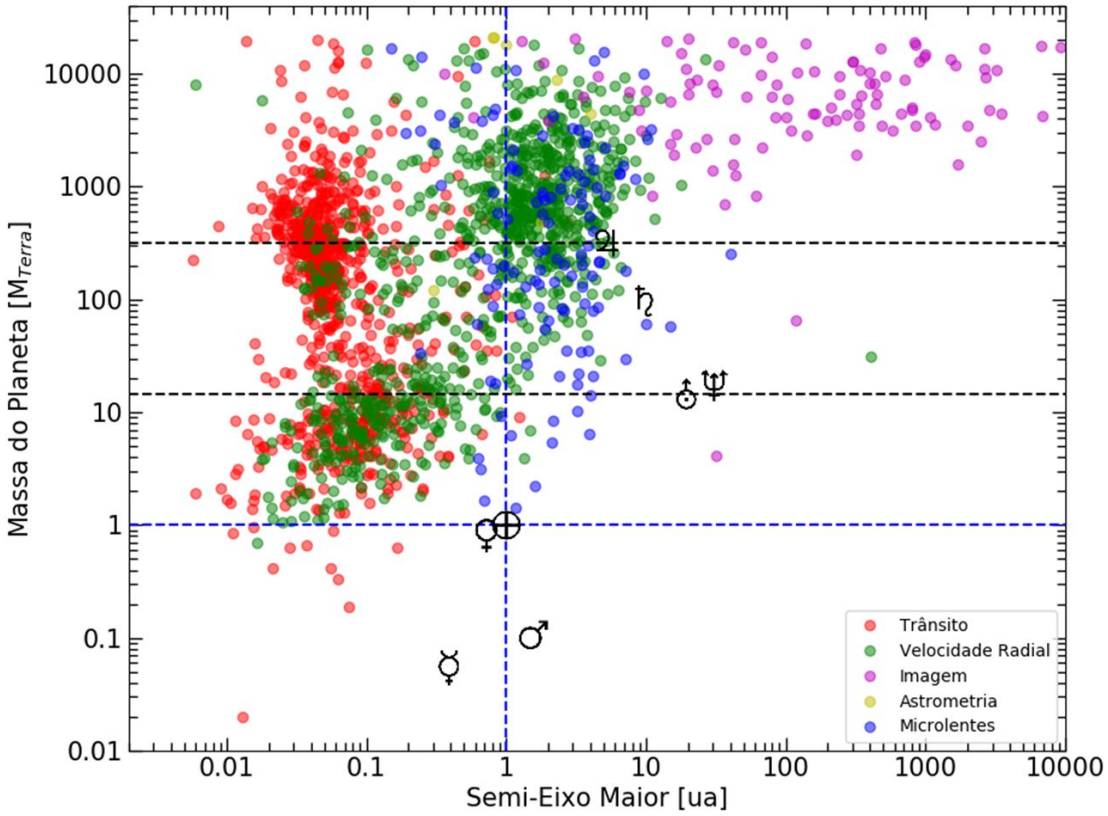


Until this morning:

263 planets
241 planetary systems
10 multiple planet systems

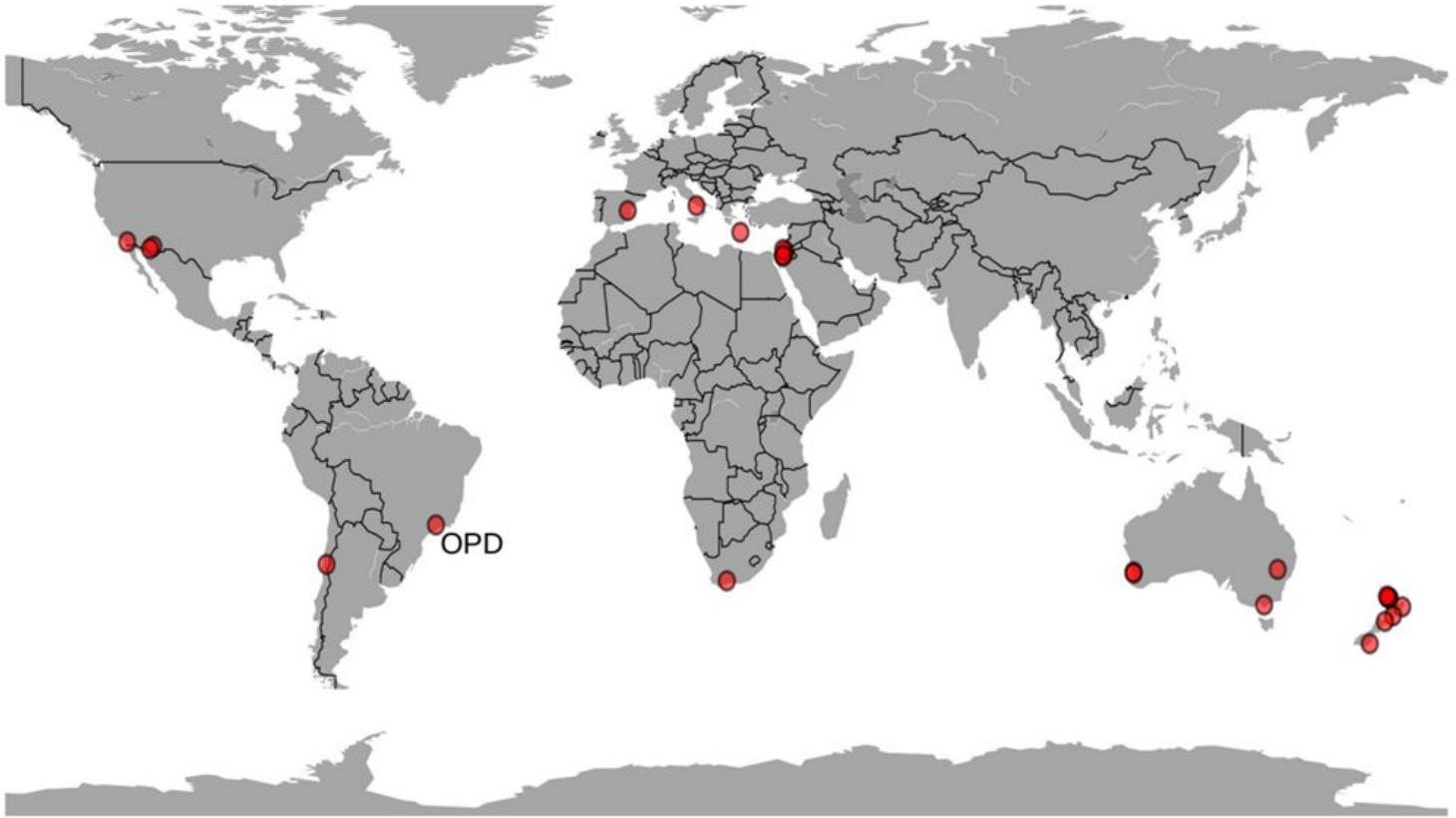


Why?


Massa do Planeta [M_{Terra}]
Semi-Eixo Maior [ua]
10000
1000
100
10
1
0.1
0.01
0.01
0.1
1
10
100
1000
10000
Trânsito
Velocidade Radial
Imagem
Astrometria
Microlentes

All at once

2. The collaboration



First Observations from OPD-Brazil

Planet Collaboration (2007-2011)
F. Jablonski and E. Martioli

Observations from OPD-Brazil

MicroFun Collaboration (2012-2017)
L. Andrade and F. Jablonski

Observations from OPD-Brazil

MicroFun Collaboration (2018-2020)
L. Andrade, L. Almeida, J. Nascimento

Observations from OPD-Brazil

MicroFun Collaboration (2021-2023)
L. Almeida

Observations from OPD-Brazil

MicroFun Collaboration (2021-2023)
L. Almeida

Observations from OPD-Brazil

MicroFun Collaboration (2024…)
L. Almeida and E. Martioli

Observations from OPD-Brazil Now

MicroFun Collaboration (2024…)
L. Almeida and E. Martioli
(Ted) (**Eder)**

Observations from OPD-Brazil
A Bunch of Interesting Stuff

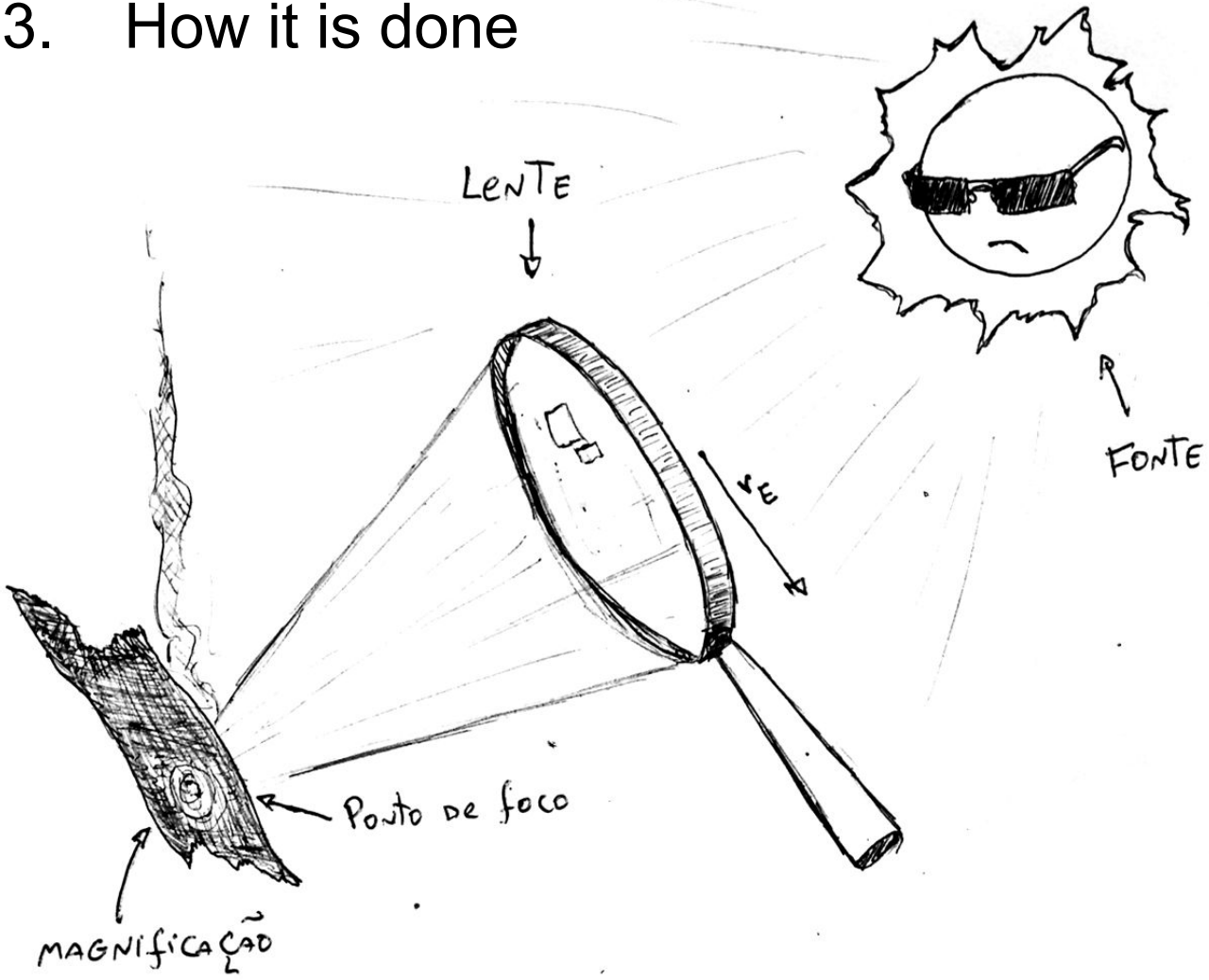
MicroFun Collaboration (2024…)
L. Almeida and E. Martioli
(Ted) (**Eder)**

Laerte

Diego

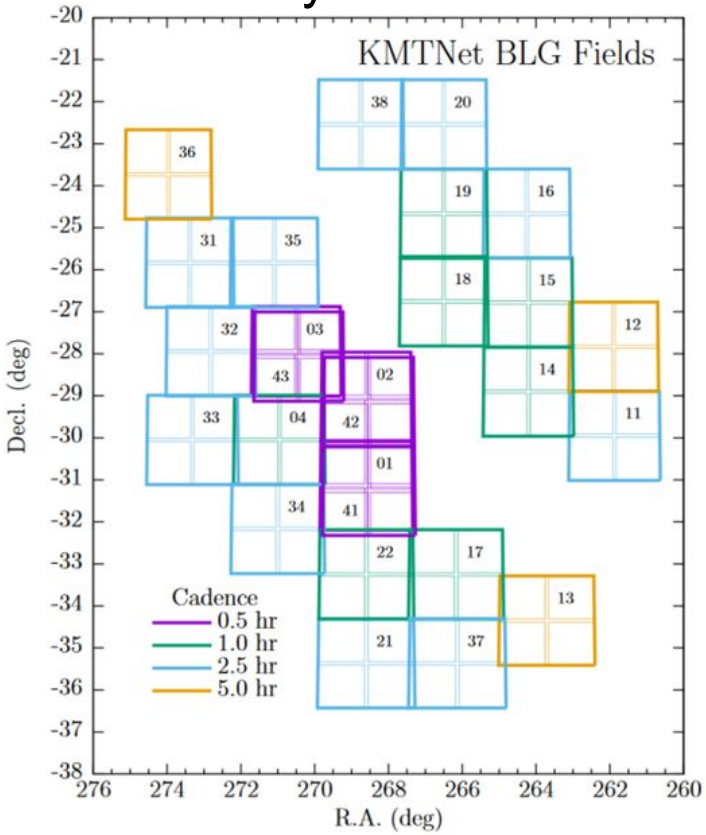
Hélio

3. How it is done

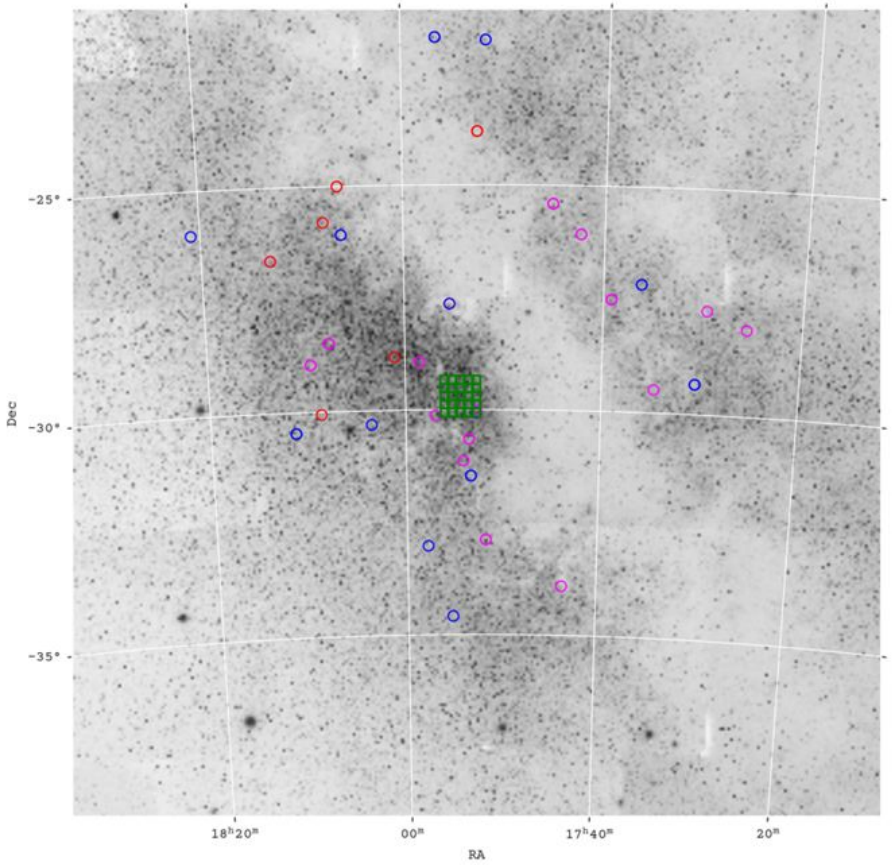


The observation

Survey contribution



Our own alerts



The standard procedure

[Astro-ufun-observer] Anomaly Alert: KB200414/MB20109

Inbox ×

MicroFUN Homebase via ASTRO-ufun-observer <a... Fri, Jul 10, 2020, 10:53 AM

to ufun-observer

Translate to Portuguese

Dear All,

KB200414/MB20109 is a high-magnification event that is currently undergoing an anomaly. The nature of the anomaly is currently unknown, but could be planetary. The event itself is very bright: Inow ~ 12.0, so easily accessible to small telescopes. observations are urgently needed.

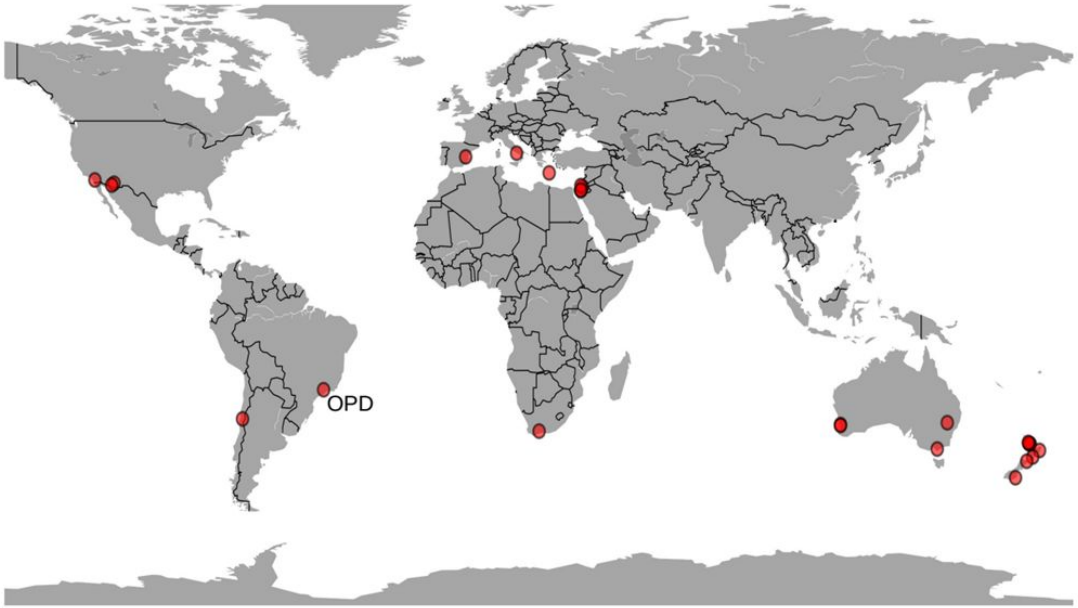
The attached figure from Weicheng Zang, who identified the anomaly, shows current data from MOA and LCO.

-- Jennifer

_____

ASTRO-ufun-observer mailing list
ASTRO-ufun-observer@lists.osu.edu
https://lists.osu.edu/mailman/listinfo/astro-ufun-observer

The standard procedure



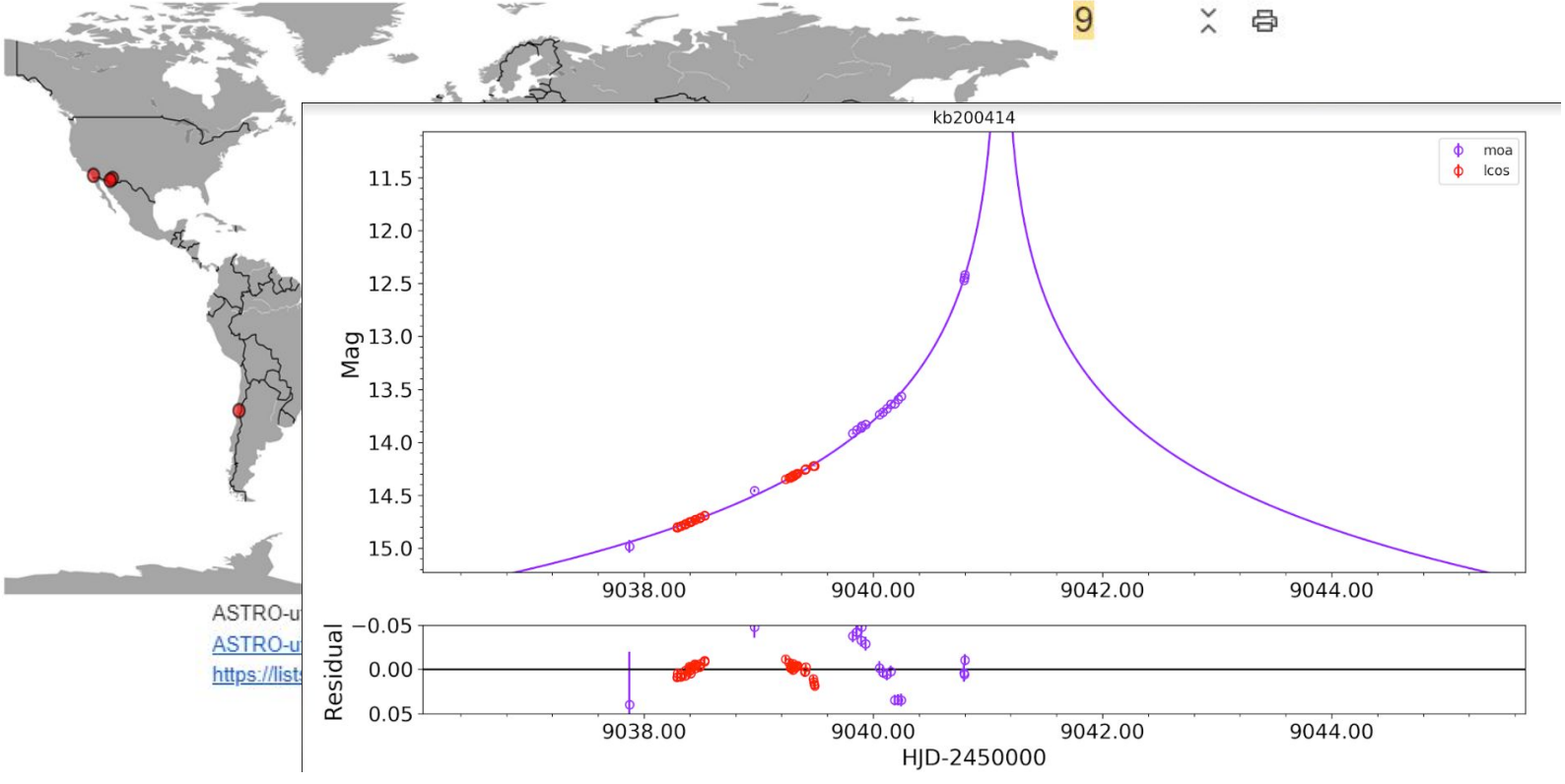
9

nature of the anomaly
ly accessible to small

MOA and LCO.

ASTRO-ufun-observer mailing list
ASTRO-ufun-observer@lists.osu.edu
https://lists.osu.edu/mailman/listinfo/astro-ufun-observer

The standard procedure



The standard procedure (Not so much)

Jennifer Yee <jyee.astro@gmail.com> Thu, Jul 9, 2020, 1:36 PM

to me, MicroFUN

Translate to Portuguese

Hi Ted,

KB200414/MB20109 is moderate to high magnification and may be undergoing an anomaly over the peak. Thus, this is the highest priority target for tonight and should be observed continuously from OPD, if possible.

attached light curve figure by Weicheng Zang.

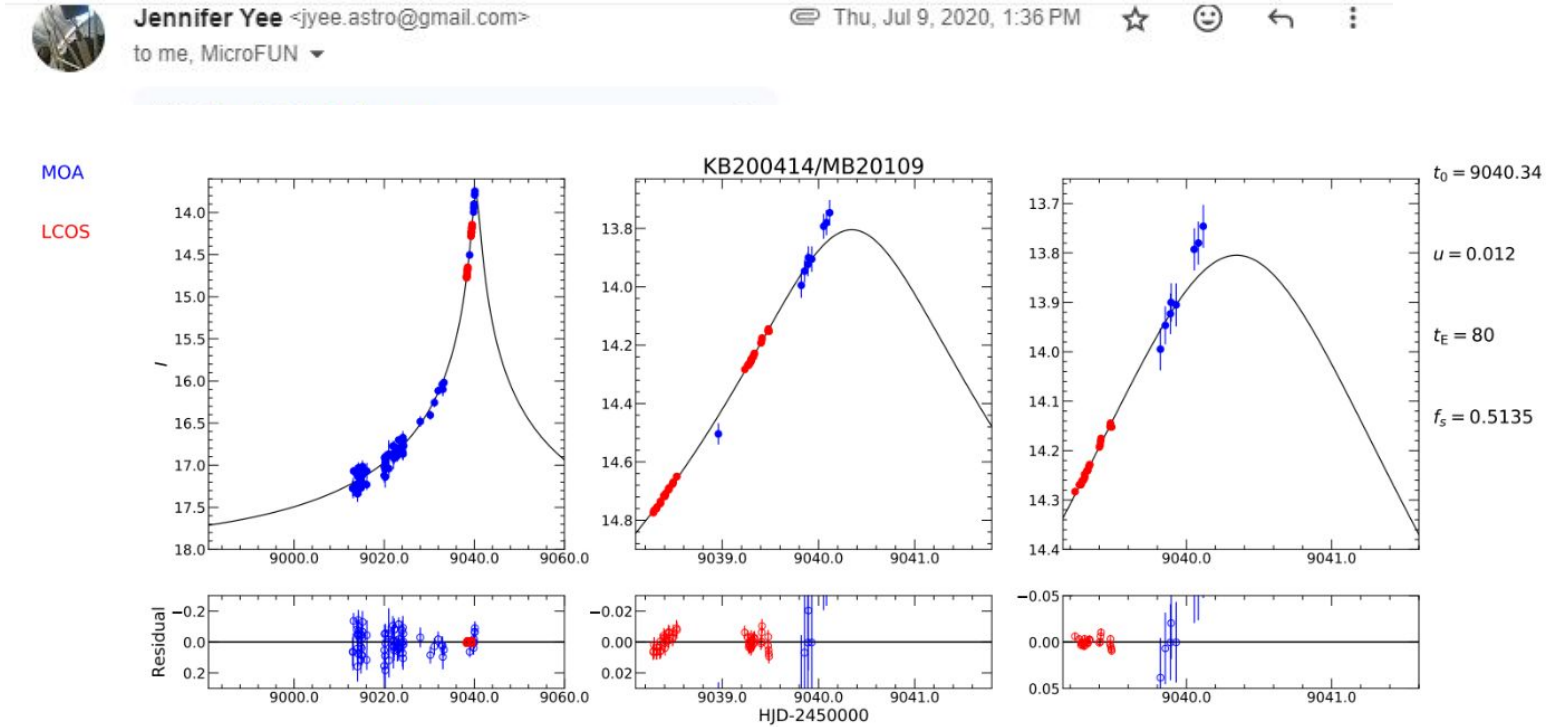
Thanks,

Jennifer

--

Dr. Jennifer Yee
jyee@cfa.harvard.edu

The standard procedure (Not so much)



The standard procedure (Not so much)

Ted <monolipo.physics@gmail.com> Jul 10, 2020, 9:33 AM

to Jennifer, MicroFUN

Hello Jennifer.
I was able to observe KB200414 all 3 nights. :D
The upload of those nights is being done now. I observe the first 2 nights with the 1.6m telescope and the last night with the 0.6m telescope.

From a preliminary analysis, it seems like the event is still rising and is gonna peak at really high magnification.
The observations will be at the MicroFun FTP server in just a bit (still uploading)

bests

Ted

•••

The premature procedure

(A)lert (G)enerator and (S)ingle Lens (F)itting for KMT

Gerar alertas pelo KMTnet e fitar 1 Lente com Mulens

Rotina criada para facilitar as noites de observacao de eventos de Microlentes Gravitacionais no OPD. Essa rotina precisa ser rodada em Python 3.x no Ubuntu, atraves do terminal do Linux no windows. Pois precisa dao MulensModel-master/source que nao funciona diretamente no Windows. O master do Mulens deve estar em algum lugar e ser chamado na primeira etapa do código.

A versão a ser utilizada do python DEVE ser anterior a 3.7. ou seja, a melhor é a 3.6.9. Para isso, primeiro verifique a sua versao atual do python

import sys print("Python version:", sys.version)

Se for da 3.7 para frente. Precisa instalar a anterior, ou ativar a anterior para usar com o jupyter-notebook. Para isso (ativar a versão anterior) basta sair de tudo e rodar do terminal bash:

pip3.6 install ipykernel python3.6 -m ipykernel install --user

E rodar o jupyter-notebook novamente e conferir se está na versão correta.

Informações básicas

Essa rotina utiliza a base publica da rede KMT

0 - Importar bibliotecas necessarias

The premature procedure

2 - Acesso a tabela da rede KMT no ano correto

In [4]:
```
ano = 2021

#-###############################################################################################
#-###############################################################################################
#-###############################################################################################
#-###############################################################################################
print("Acessando a tabela de alertas (pode demorar um pouquinho)...")
table_MN = pd.read_html('https://kmtnet.kasi.re.kr/~ulens/event/'+str(ano)+'/', match='Event')
print('Foi!')

#https://kmtnet.kasi.re.kr/~ulens/event/2023/
```

```
Acessando a tabela de alertas (pode demorar um pouquinho)...
Foi!
```

The premature procedure

2 - Acesso a tabela da rede KMT no ano correto

In [4]:
```
ano = 2021

#-#########################################################################################
#-#########################################################################################
#-#######
#-#######
print("Ac
table_MN
print('Fc
#https://
```

```
Acessandc
Foi!
```

3 - Definir epoca observacional e parametros de corte

In [8]:
```
jd = date_to_jd(2021,6,3) #Ano, mes e dia (data central das observacoes)
intervalo = 5  # quantos dias vai observar
u0 = 0.05   #buscara alertas com u0 menor do que esse valor

#-#########################################################################################
#-#########################################################################################
#-#########################################################################################
#-#########################################################################################
```

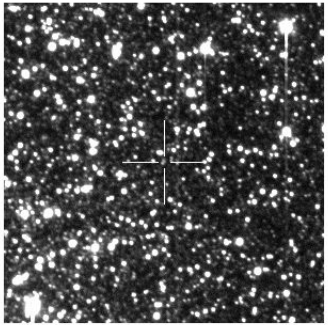
The premature procedure

```
JD =  2459368.5
Resumo dos alertas e links
u_0:  0.006 ,  3/6/2021 1:15 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-0247
u_0:  0.033 ,  4/6/2021 0:29 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-0678
u_0:  0.012 ,  31/5/2021 23:10 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-0967
u_0:  0.003 ,  5/6/2021 4:56 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1031
u_0:  0.032 ,  2/6/2021 15:0 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1057
u_0:  0.032 ,  5/6/2021 2:55 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1074
u_0:  0.009 ,  1/6/2021 3:3 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1080
u_0:  0.014 ,  31/5/2021 13:44 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1083
u_0:  0.008 ,  3/6/2021 20:54 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1084
u_0:  0.014 ,  1/6/2021 4:40 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1097
u_0:  0.02 ,  2/6/2021 13:20 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1115
u_0:  0.03 ,  3/6/2021 13:31 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1116
u_0:  0.014 ,  1/6/2021 13:54 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1120
u_0:  0.008 ,  4/6/2021 11:7 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1122
u_0:  0.01 ,  2/6/2021 10:33 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1125
u_0:  0.018 ,  4/6/2021 17:27 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1126
u_0:  0.011 ,  2/6/2021 17:4 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1128
u_0:  0.002 ,  3/6/2021 4:55 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1137
u_0:  0.002 ,  2/6/2021 18:31 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1141
u_0:  0.024 ,  4/6/2021 12:37 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1169
u_0:  0.022 ,  5/6/2021 6:29 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1181
u_0:  0.032 ,  31/5/2021 17:36 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1184
u_0:  0.015 ,  5/6/2021 3:16 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-1211
u_0:  0.023 ,  5/6/2021 1:20 https://kmtnet.kasi.re.kr/~ulens/event/2021/view.php?event=KMT-2021-BLG-3059

Tabela de informações
```

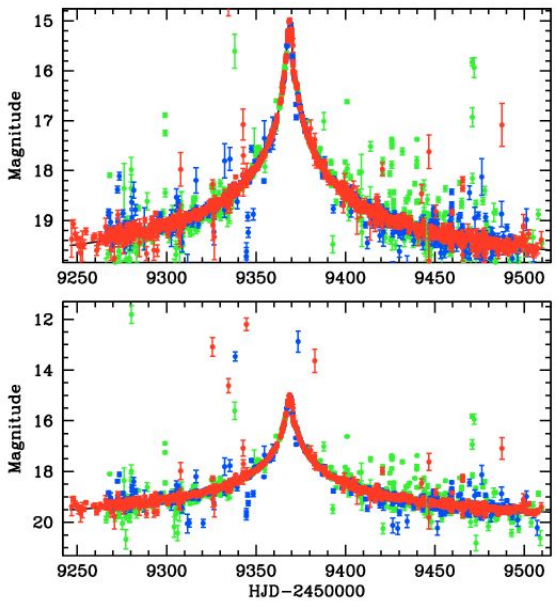
The premature procedure

Finding chart



Field	BLG15N0704
Star ID	015195
EFClassification	clear
ALClassification	clear
RA	17:37:55.89
Dec	-27:23:56.29
t_0	9368.67776
t_E	199.22
u_0	0.006
Isource	20.60
Ibase	20.00
Icat	20.14
Catalog type	DECam i
A_I	2.85
Related event	MB21127
Alert date	2021 Apr 05 04:02

pySIS light curve



KMTA15_I.pysis
KMTA15_V.pysis
KMTC15_I.pysis
KMTC15_V.pysis
KMTS15_I.pysis
KMTS15_V.pysis

gzipped tar file for all pySIS data

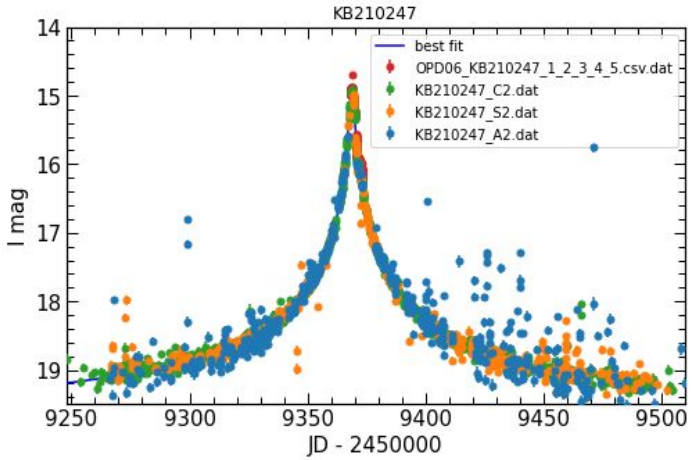
The premature procedure

```
Initial Trial
    t_0 (HJD)       u_0    t_E (d)
2459368.67776  0.006000   199.2200

Best Fit:
 t_0 = 2459368.73522, u_0 = 0.0014, t_E =  763.467
Chi2 =        17.63


Final parameters
    t_0 (HJD)       u_0    t_E (d)
2459368.73522  0.001448   763.4675

I_base =  20.0
I_now (last data avaliable) =  16.54  at JD = 9509.89382 (2021, 10, 22, 6, 27, '22/10/2021 6:27')
A_now =  24.14
A_max =  107.7  at JD = 9368.73022 (2021, 6, 3, 2, 31, '3/6/2021 2:31')
I_max =  14.92
```



The premature procedure

Possible high mag microlensing event KB221477

Ted <monolipo.physics@gmail.com> Tue, Aug 16, 2022, 4:31 AM

to astro-ufun-homebase

Hi, Andy and Jennifer.

I`ve been following the event KB221477 for 4 nights now. And it seems that it will reach A> 500 on the 17th. The last data from CTIO looks saturated on the KMT website, so the model presented there is not quite accurate.

After some basic photometry on the data I took here at OPD, the single lens model is presented below.

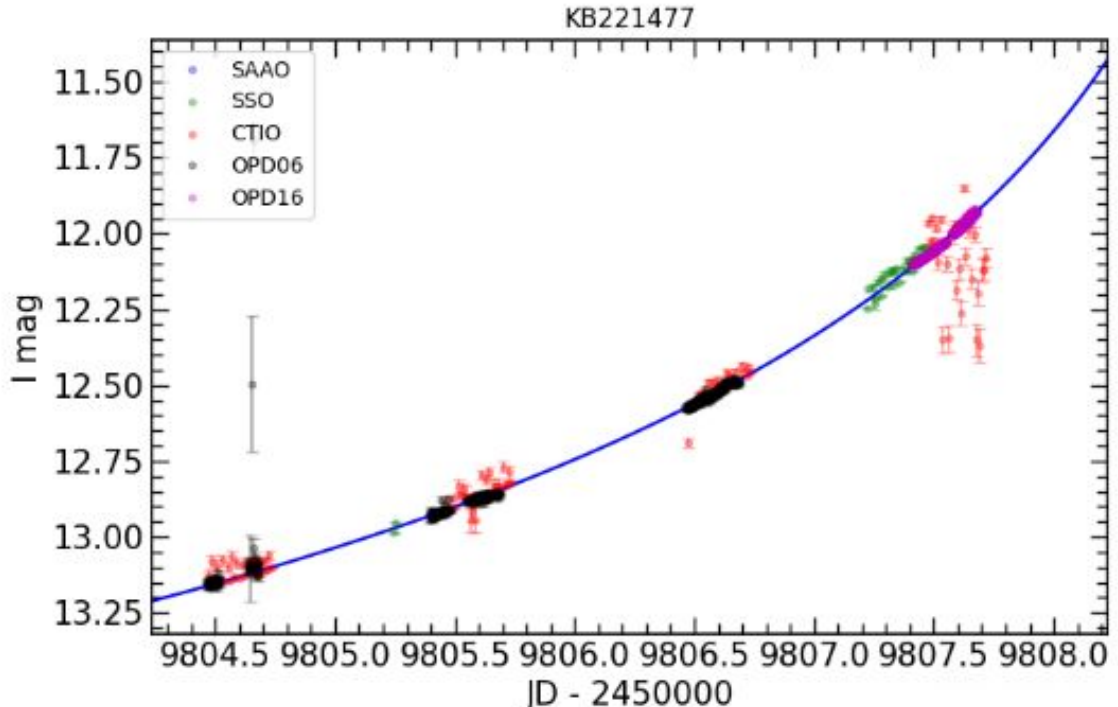
The premature procedure

Possible high mag microlensing event KB221477

Ted <monolipo.physics@gmail.com> Tue, Aug 16, 2022, 4:31 AM

to astro-ufun-homebase

Hi, Andy and Jennife
I've been following th
data from CTIO look
After some basic pho



The premature procedure ends up as the standard procedure

[Astro-ufun-observer] kb-22-1477: high-mag, extremely bright event peaking in about 24 hours Inbox ×

Gould, Andrew via ASTRO-ufun-observer <astro-ufun-... Tue, Aug 16, 2022, 10:51 AM

to ufun-observer@astronomy.ohio-state.edu

Translate to Portuguese ×

Hi uFUN,

kb-22-1477 will peak at very high or extreme magnification about 24 hours from now. As of now, it is about A=20, so already moderately sensitive to planets, but the magnification will increase rapidly

The baseline source is I_base=I4.75, so it could easily reach I=10 or brighter. So please be careful about saturation. (KMTC I-band is already saturated).

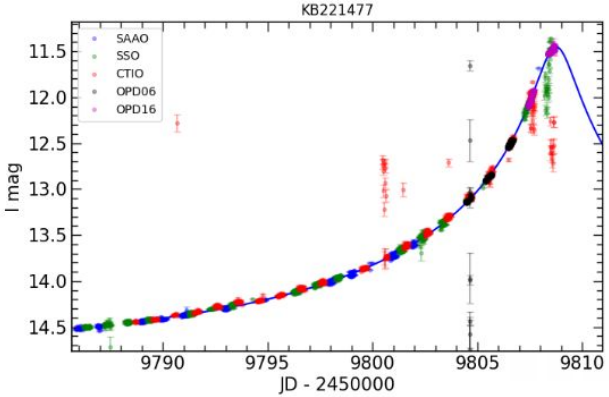
I will try to have updates. - andy

ASTRO-ufun-observer mailing list

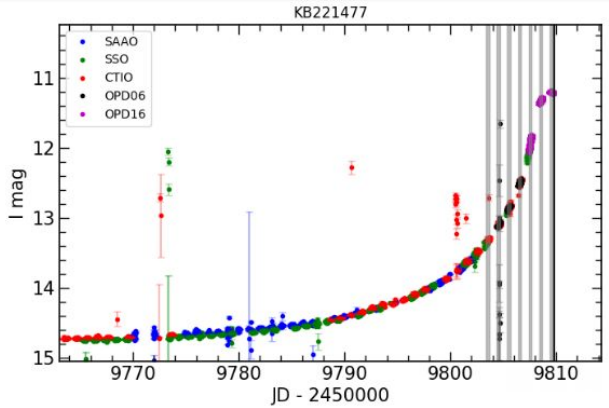
ASTRO-ufun-observer@lists.osu.edu

https://lists.osu.edu/mailman/listinfo/astro-ufun-observer

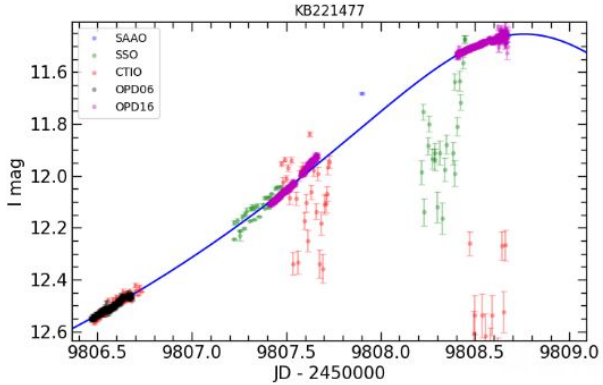
The premature procedure ends up as the standard procedure

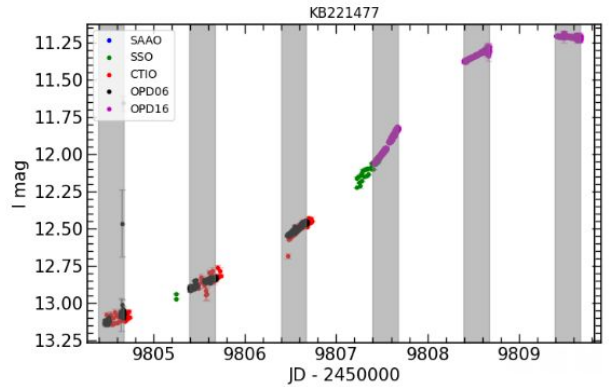


Below is a zoom near the peak



Below is a zoom near the peak





4. What has been done from OPD

- From 2018 to 2024 we have observed 100+ GM events
- From 2022 to 2024 alone it was 40+ MG events
- 16 were alerts by MicroFun
- The rest of the observations were our decision

DATA	TELESCOPIO	EVENTO	RA	DEC	T_0	t_E	u_0	T_{obs} (min)	FLAG
18mai22	OPD06	OB180798	17:56:57.11	-30:07:10.00	2458262.524	6.694	0.779	15	SL
18mai21	OPD06	OB180812	17:54:04.36	-31:08:08.10	2458275.657	14.729	1.07	232	SL
18mai22	OPD16	OB180797	17:34:39.17	-29:29:06.70	2458287.203	46.442	0.458	31	SL
18jun24	OPD06	OB180886	18:13:12.45	-26:36:59.30	2458293.83	53.61	0.012	70	SL
18jun23	OPD06	OB180886	18:13:12.45	-26:36:59.30	2458293.83	53.61	0.012	52	SL
18jun22	OPD06	OB180886	18:13:12.45	-26:36:59.30	2458293.83	53.61	0.012	20	SL
18jul10	OPD06	OB181074	17:52:39.91	-23:48:54.00	2458314.821	58.069	0.023	307	SL
18jul11	OPD06	OB181074	17:52:39.91	-23:48:54.00	2458314.821	58.069	0.023	307	SL
18jul12	OPD06	OB181074	17:52:39.91	-23:48:54.00	2458314.821	58.069	0.023	283	SL
18jul15	OPD16	OB181074	17:52:39.91	-23:48:54.00	2458314.821	58.069	0.023	226	SL
18jul13	OPD06	OB181074	17:52:39.91	-23:48:54.00	2458314.821	58.069	0.023	217	SL
18jul14	OPD16	OB181074	17:52:39.91	-23:48:54.00	2458314.821	58.069	0.023	47	SL
18mai22	OPD06	OB180771	18:06:25.05	-25:00:14.60	2458378.983	119.039	1.433	116	AN
18mai21	OPD06	OB180771	18:06:25.05	-25:00:14.60	2458378.983	119.039	1.433	48	AN
19jul27	OPD16	OB190033	18:08:38.26	-30:03:38.70	2458689.68	105.766	0.065	61	AN
19jul27	OPD16	OB191104	18:07:53.33	-25:47:47.20	2458692.558	12.112	0.591	25	SL
19jul27	OPD16	KB190960	18:01:04.04	-28:49:04.58	2458693.28081	63.67	0.014	70	AN
19jul31	OPD16	OB191181	17:55:26.83	-27:38:10.50	2458696.589	22.214	0.0001	443	HM
19jul29	OPD16	OB191181	17:55:26.83	-27:38:10.50	2458696.589	22.214	0.0001	250	HM

4. What has been done from OPD What do we need?

More meaningful alerts

Just a test

In [87]:
```
import requests
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import io

# Get latests 5 Early SN Ia candidates
r = requests.post(
  'https://fink-portal.org/api/v1/latests',
  json={
    'class': 'Microlensing candidate',
    'n': '50000'
  }
)

# Format output in a DataFrame
pdf = pd.read_json(io.BytesIO(r.content))
```

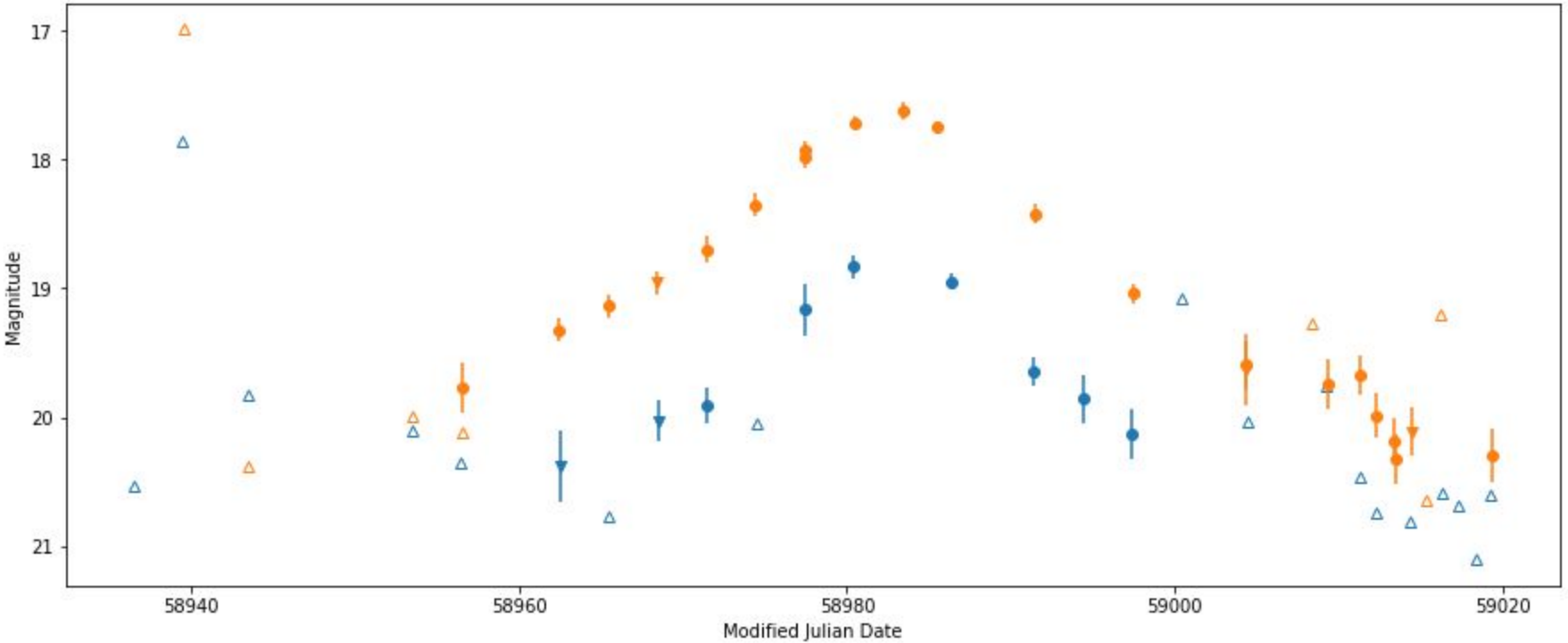
In [65]:
```
len(pdf)
```

Out[65]: 4937

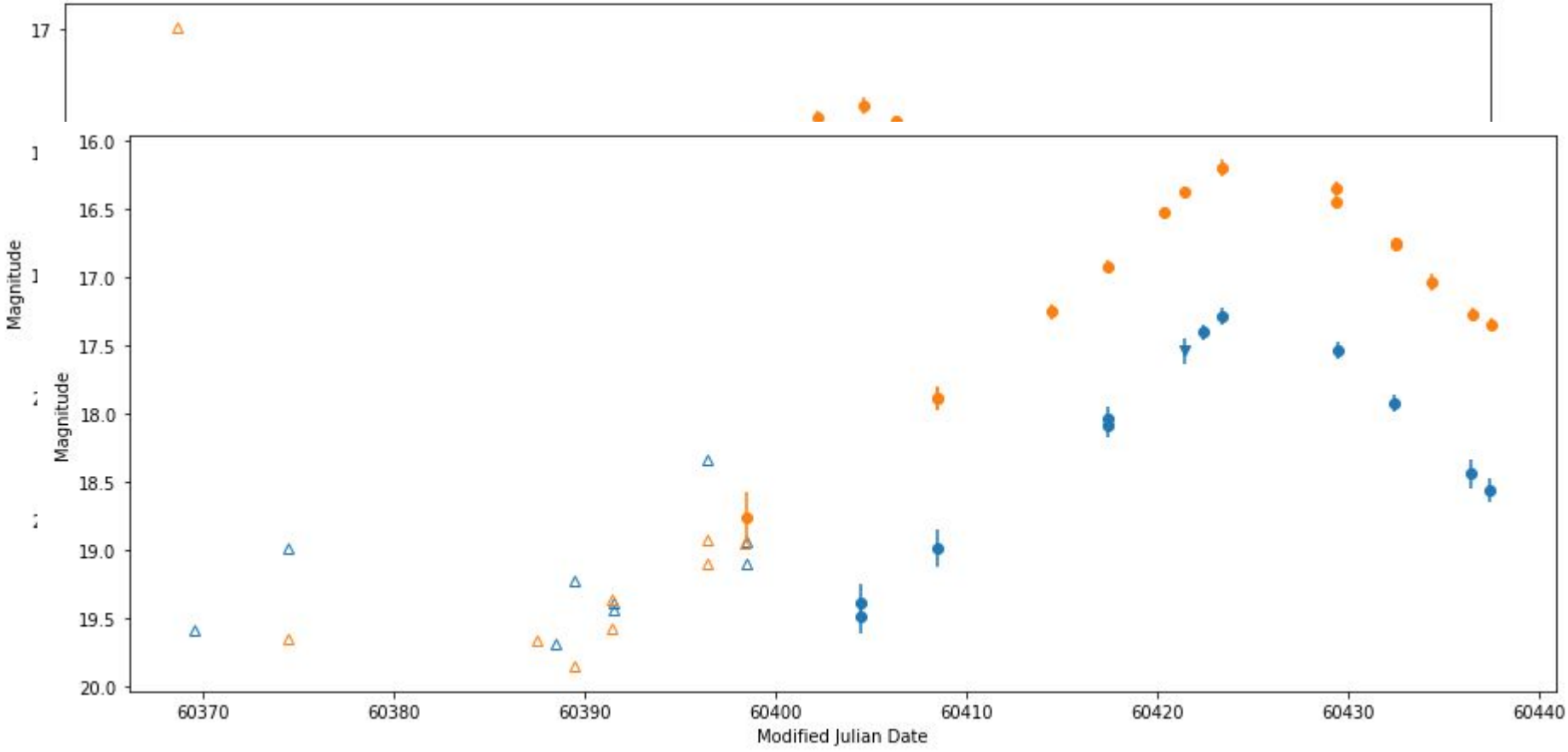
In [89]:
```
uniques = set(pdf['i:objectId'])
len(uniques)
```

Out[89]: 1611

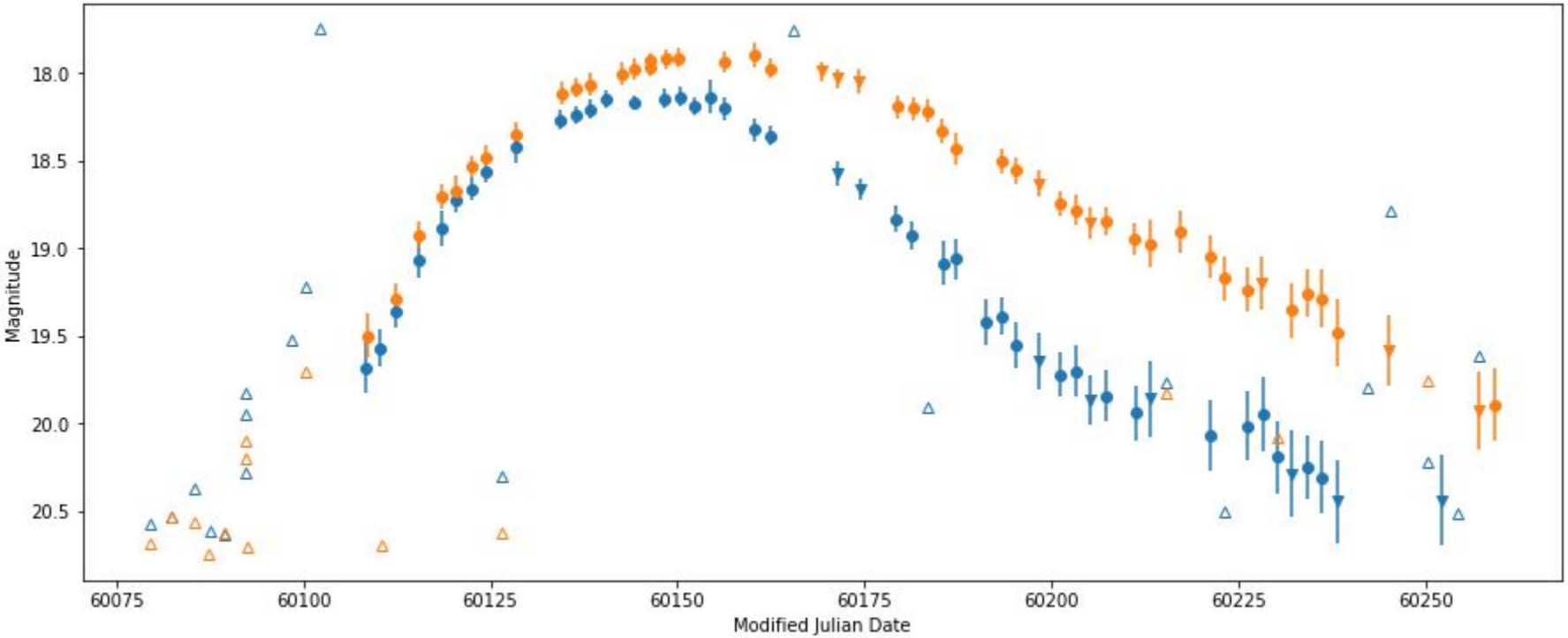
Some of them


17
18
19
20
21
Magnitude
58940
58960
58980
59000
59020
Modified Julian Date

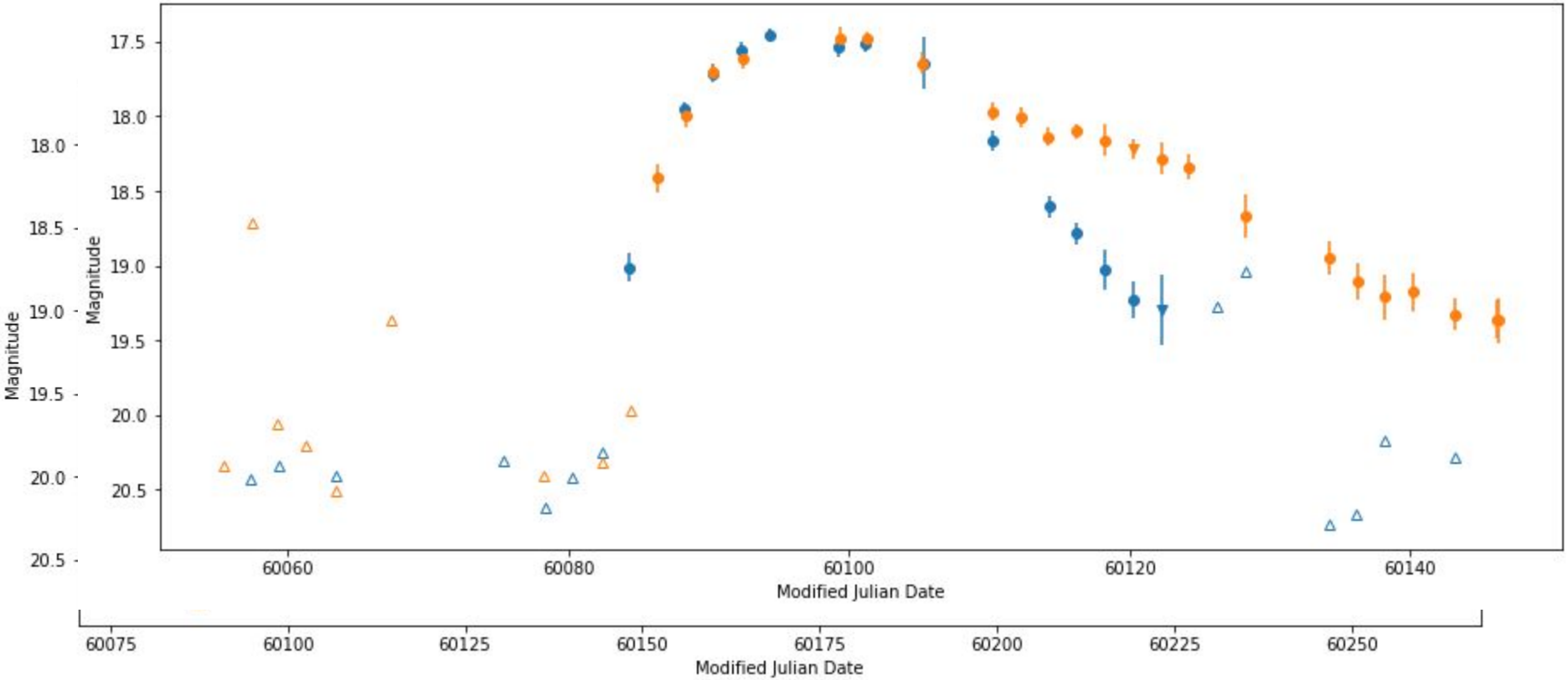
Some of them


Magnitude
16.0
16.5
17.0
17.5
18.0
18.5
19.0
19.5
20.0
60370
60380
60390
60400
60410
60420
60430
60440
Modified Julian Date

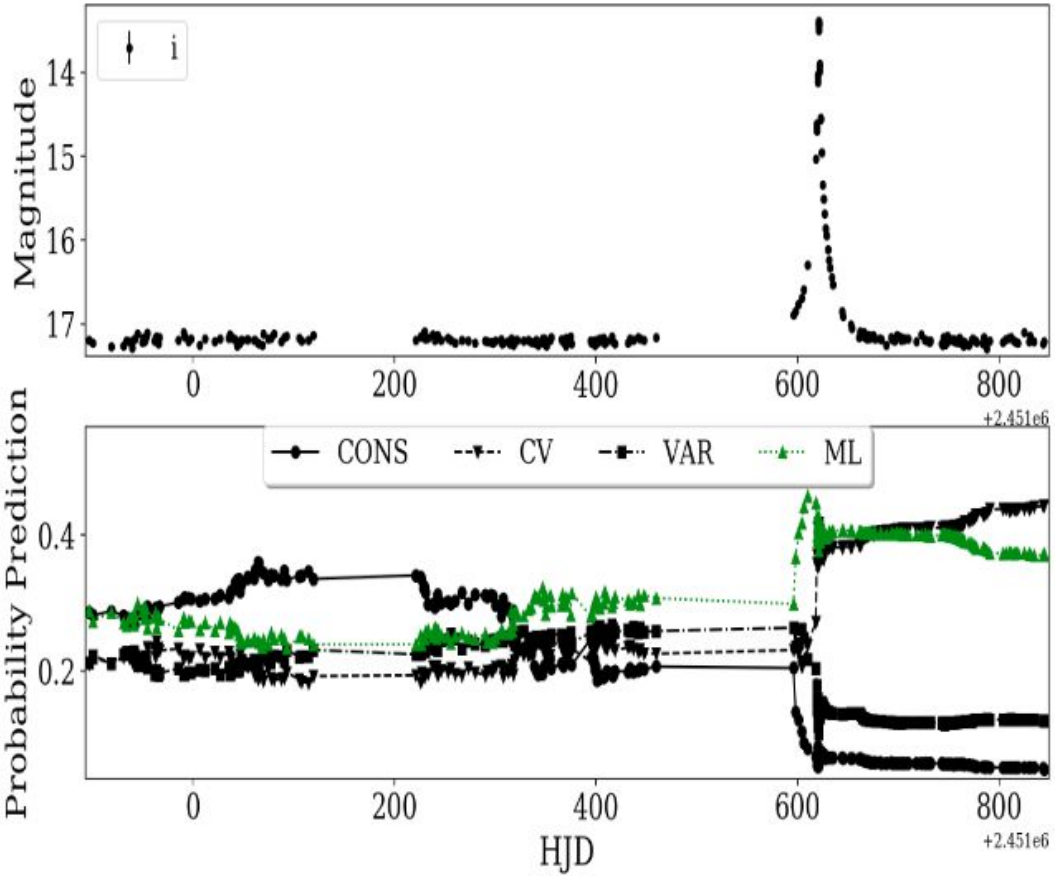
Most of them


Magnitude
18.0
18.5
19.0
19.5
20.0
20.5
60075
60100
60125
60150
60175
60200
60225
60250
Modified Julian Date

Most of them

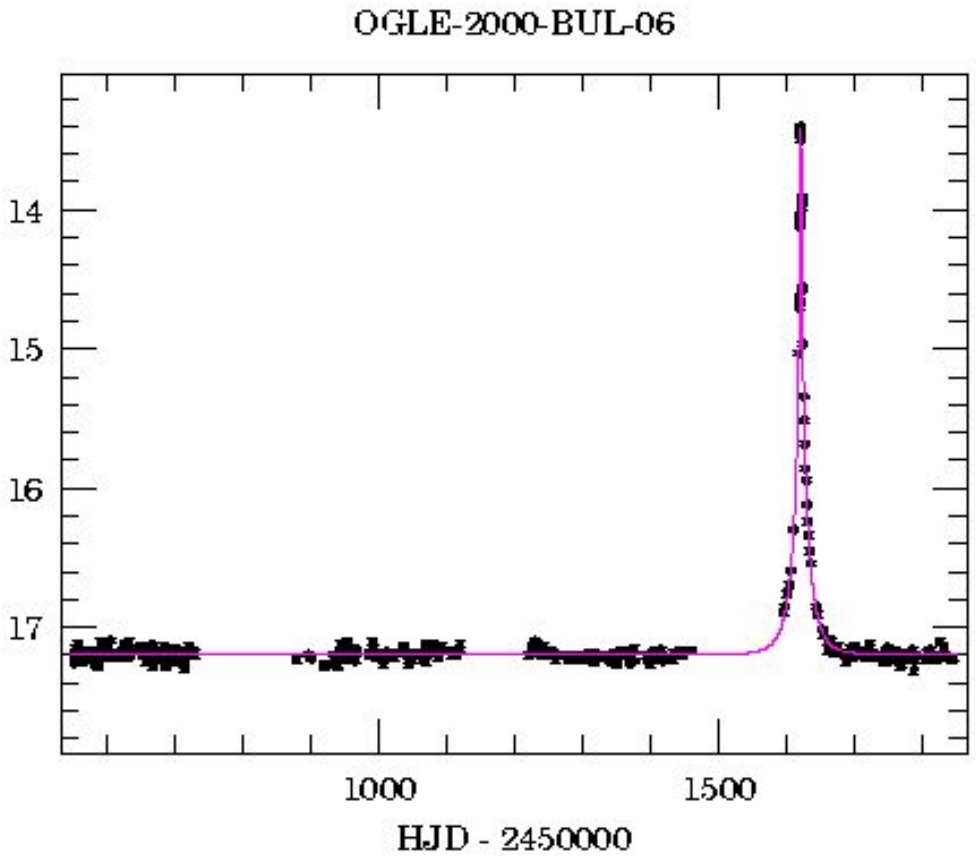

Magnitude
17.5
18.0
18.5
19.0
19.5
20.0
20.5
60060
60080
60100
60120
60140
Modified Julian Date
60075
60100
60125
60150
60175
60200
60225
60250
Modified Julian Date

The way they are classified (OGLE light curve)



D. Godines et al. 2020/ Lens Identification Algorithm

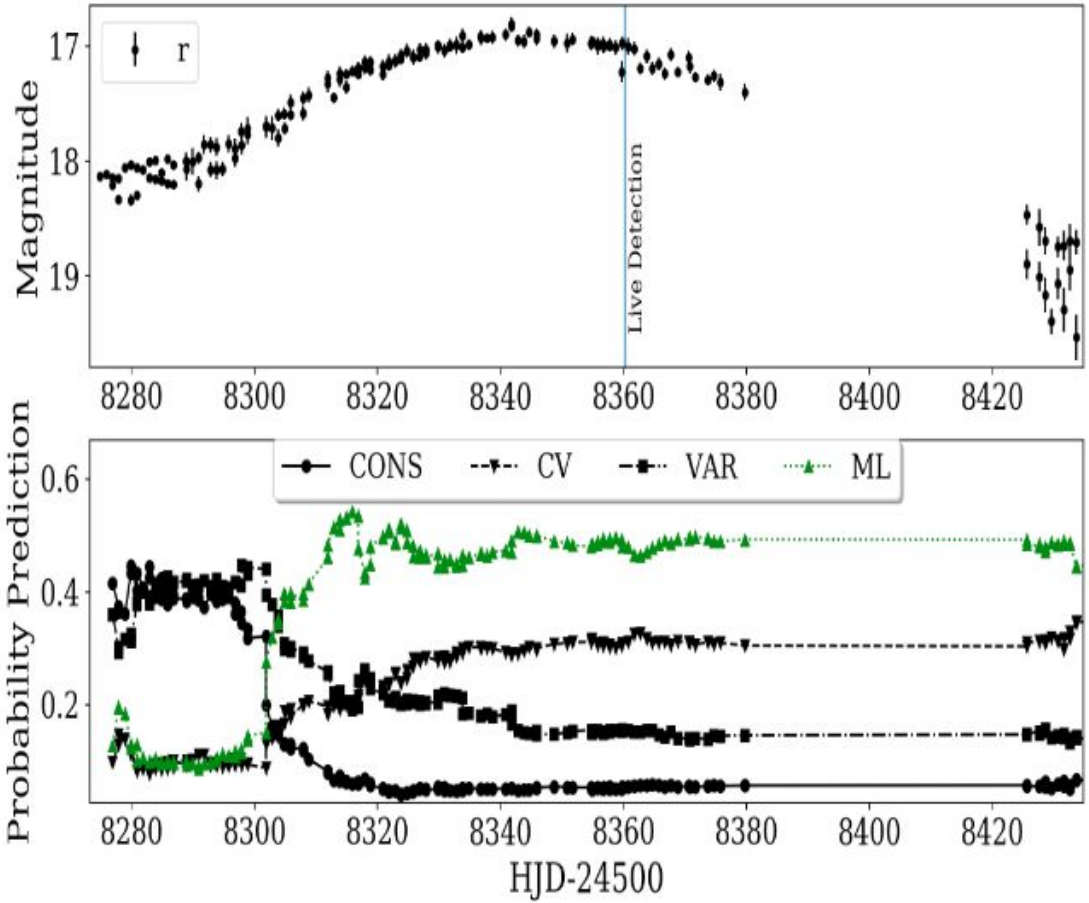
The way they are classified (OGLE light curve)



D. Godines et al. 2020/ Lens Identification Algorithm

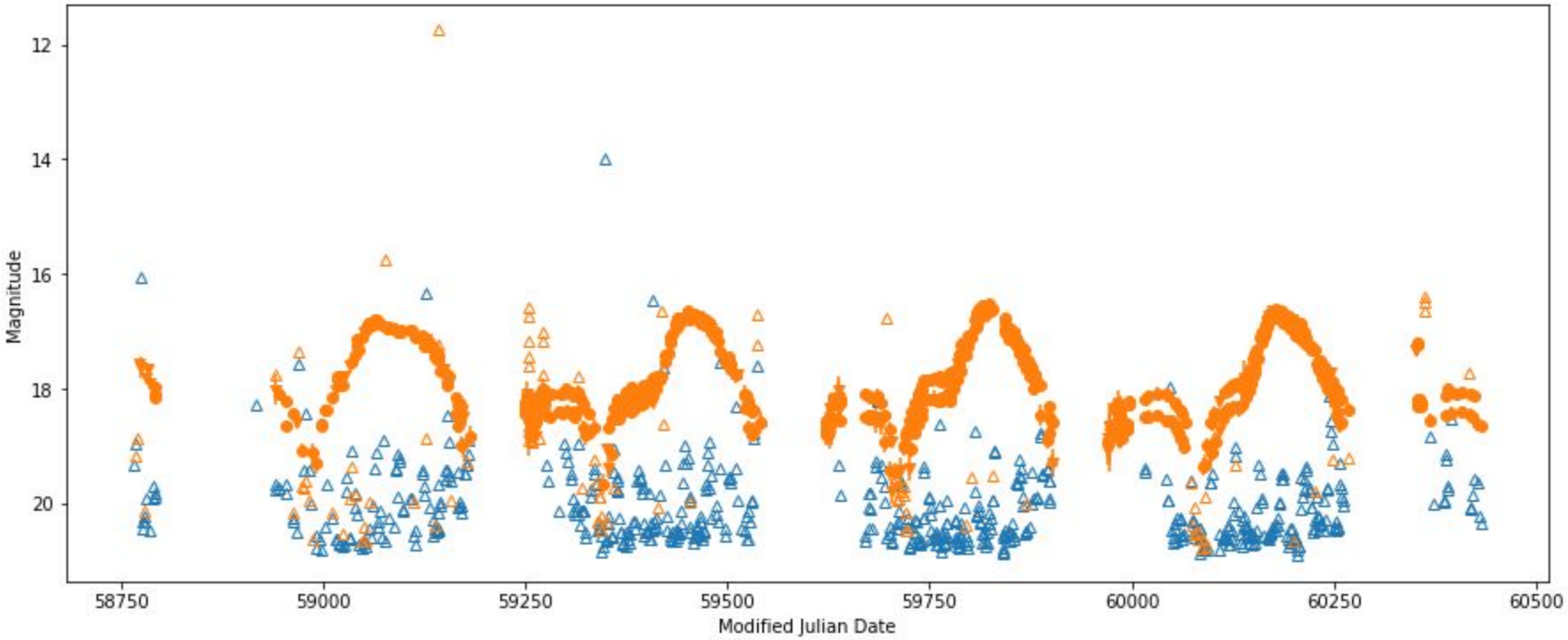
But

The way they are classified (ZTF18aayczxl)



D. Godines et al. 2020/ Lens Identification Algorithm

Turns out (ZTF18aayczxl)



Most of the probabilities are over 0.4

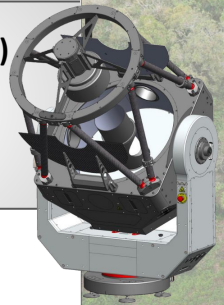
```
In [67]: for i in range(len(pdf)):
             #print(pdf['i:objectId'][i],pdf['i:ra'][i],pdf['i:dec'][i],
             print(pdf['i:objectId'][i],pdf['d:mulens'][i])
```

```
ZTF23abetwwi 0.3960469526
ZTF23abaxkwq 0.5046005829
ZTF23aanptpp 0.4024927729
ZTF23abcvams 0.5113978776
ZTF23aanptpp 0.37181742630000003
ZTF23abaxkwq 0.5066306027
ZTF23abaxlrz 0.4858832945
ZTF23abetwwi 0.40932020080000003
ZTF23abcvams 0.5397308937
ZTF23aanptpp 0.37929407130000004
ZTF23abcvams 0.48277555
ZTF23abaxkwq 0.48822251200000005
ZTF23abcvams 0.5446860206
ZTF23abcvams 0.5240359636
ZTF23abcvams 0.5156142244
ZTF23aanptpp 0.4044658727
ZTF23abbccir 0.3763966758
ZTF23abcvams 0.5333076871
ZTF23abcvams 0.5048829078
ZTF23aanptpp 0.3967146891
```

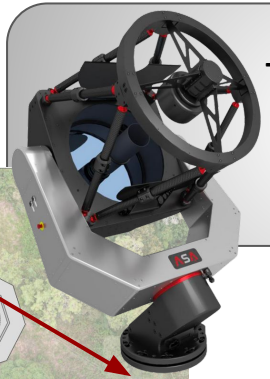
5. The future of GW for OPD

Telescope RC800 ASA (80cm)
Equatorial

Telescópio AZ800 ASA (80cm)
Alta-azimutal



Telescópio Solar INPE
RC500 ASA (50cm)

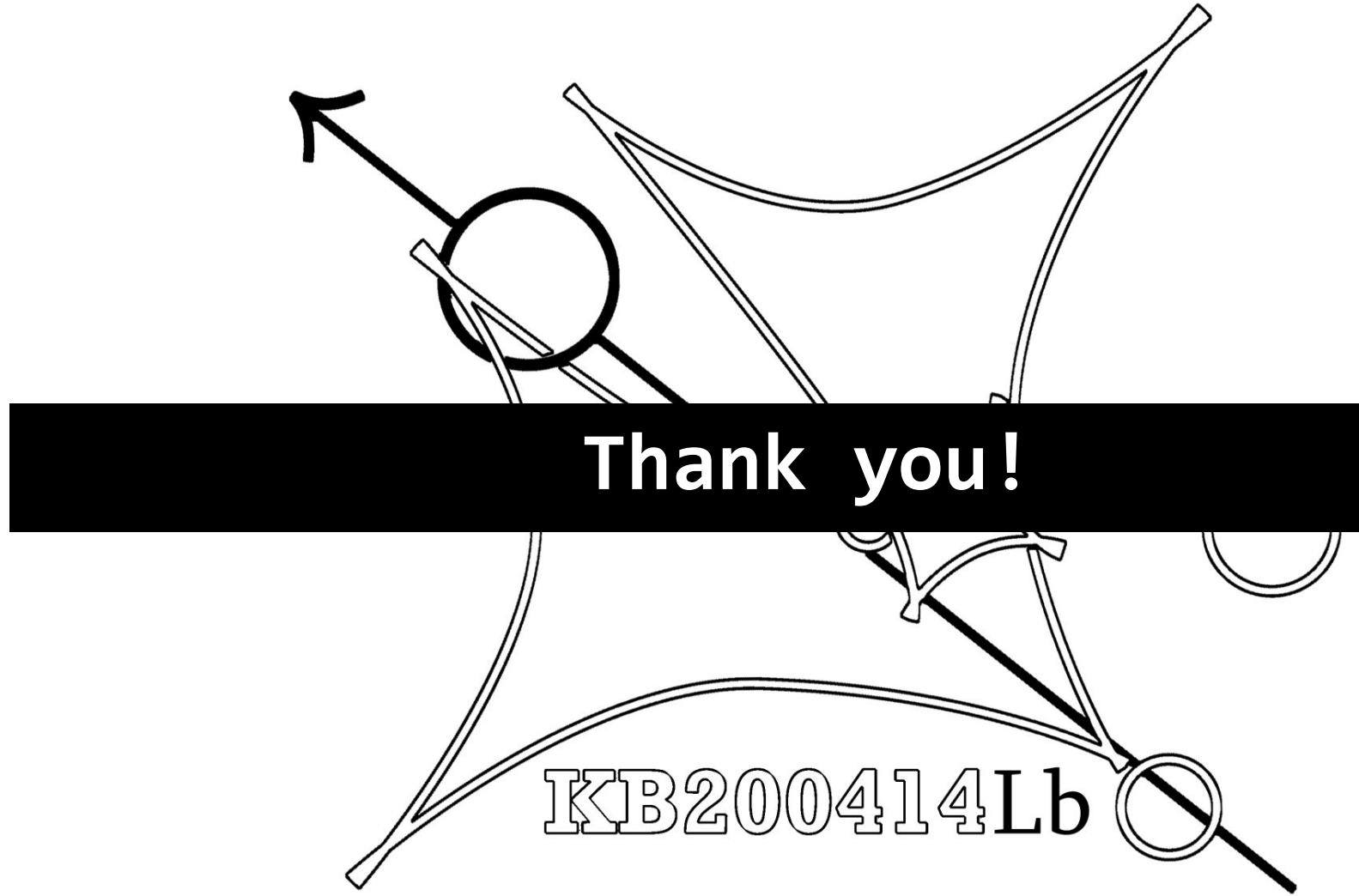


Telescópio EQ1000 ASA (1m)
Equatorial

Telescópio AZ1500 ASA (1.5m)
Alta-azimutal

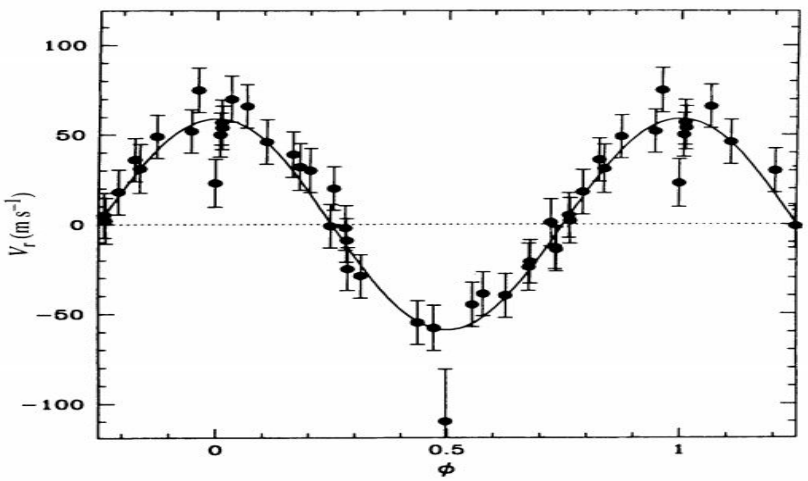
5. The future of GW for OPD

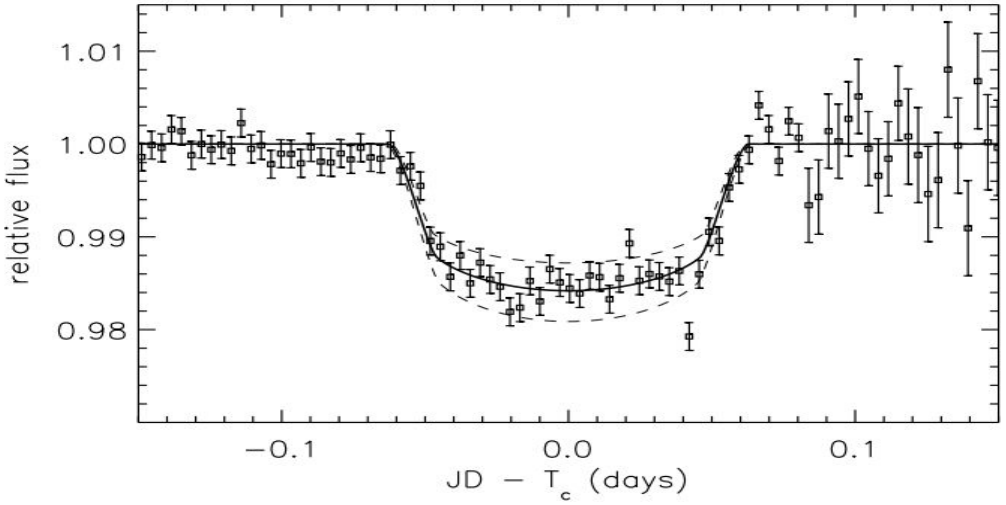
- More GM observations per year
- Online on-the-fly fitting interface
- Detections besides the center of our Galaxy (we have a few already)
- MORE observers (training the young)

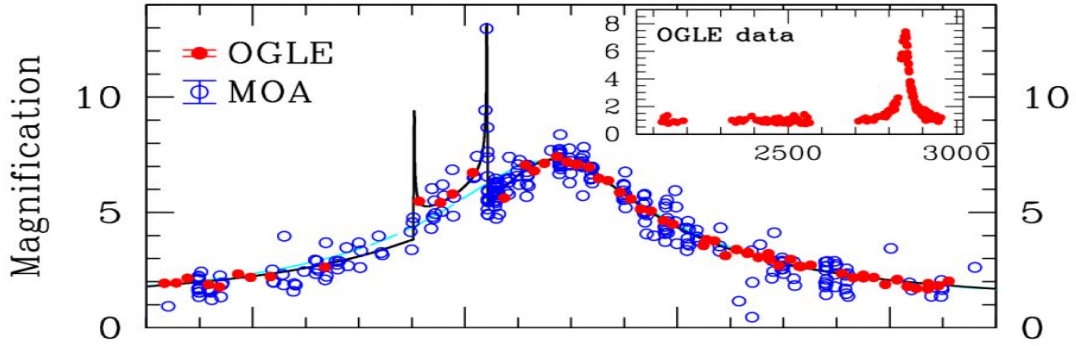


Thank you!

O QUE OS ASTRÔNOMOS ANALISAM:

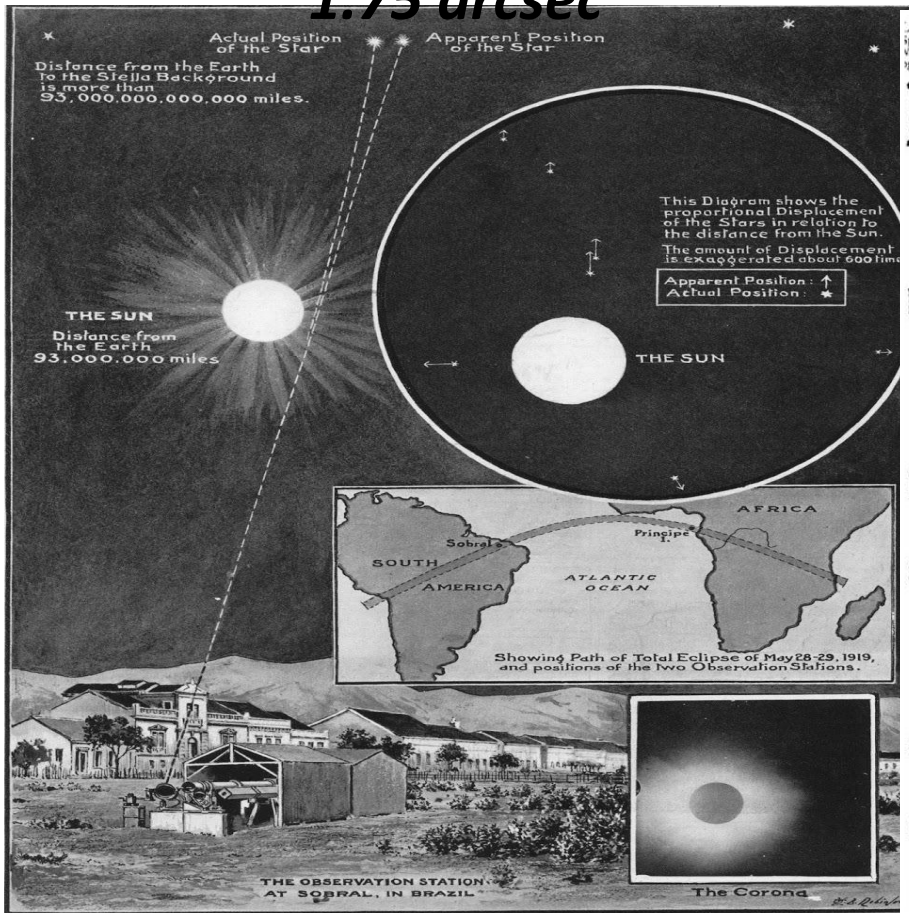






O princípio de Microlentes Gravitacionais

~ 1.75 arcsec



LIGHTS ALL ASKEW IN THE HEAVENS
Special Cable to THE NEW YORK TIMES.
New York Times (1857); Nov 10, 1919; ProQuest Historical Newspapers The New York Times (1851 - 2004)
pg. 17

LIGHTS ALL ASKEW IN THE HEAVENS

Men of Science More or Less Agog Over Results of Eclipse Observations.

EINSTEIN THEORY TRIUMPHS

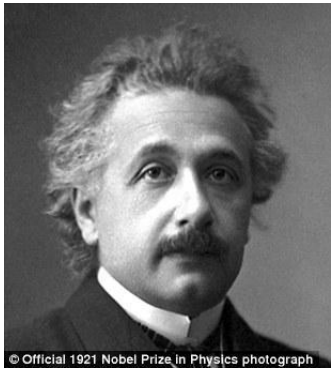
Stars Not Where They Seemed or Were Calculated to be, but Nobody Need Worry.

A BOOK FOR 12 WISE MEN

No More in All the World Could Comprehend It, Said Einstein When His Daring Publishers Accepted It.

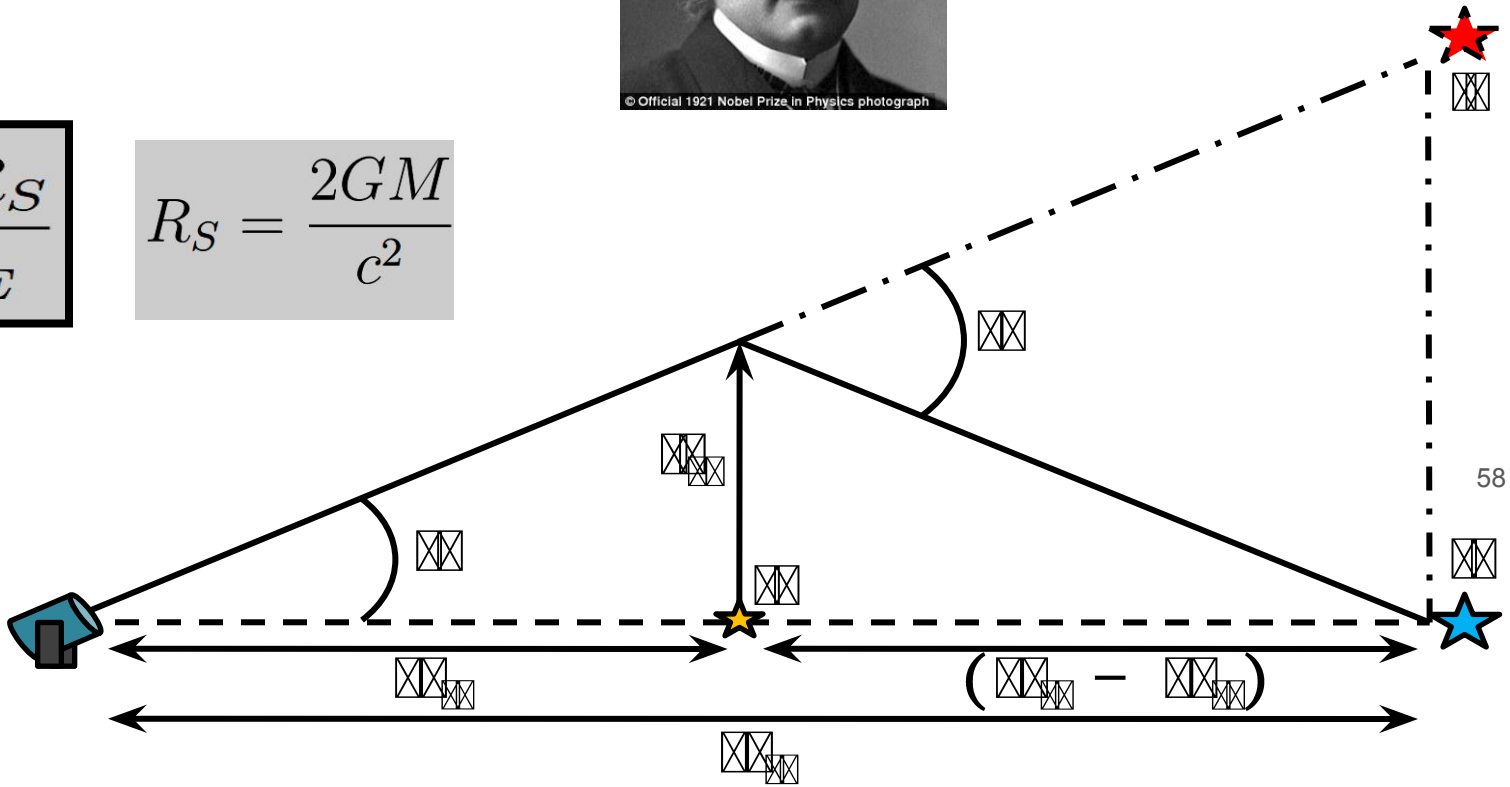
https://cosmictimes.gsfc.nasa.gov/teachers/downloads/posters/1919_poster.pdf

A Geometria de MLG
O Raio de Einstein



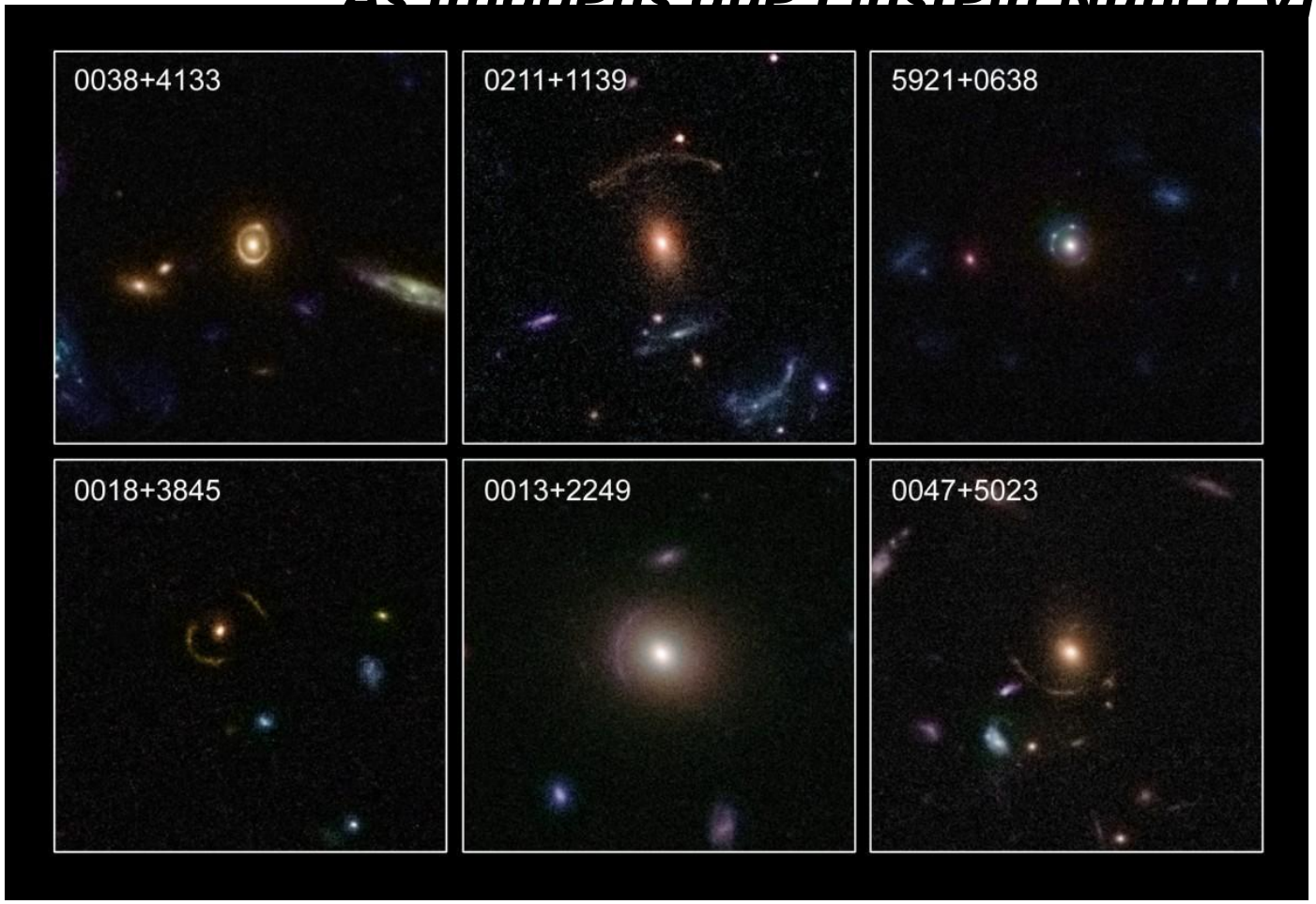
$$\alpha = \frac{2R_S}{r_E}$$

$$R_S = \frac{2GM}{c^2}$$



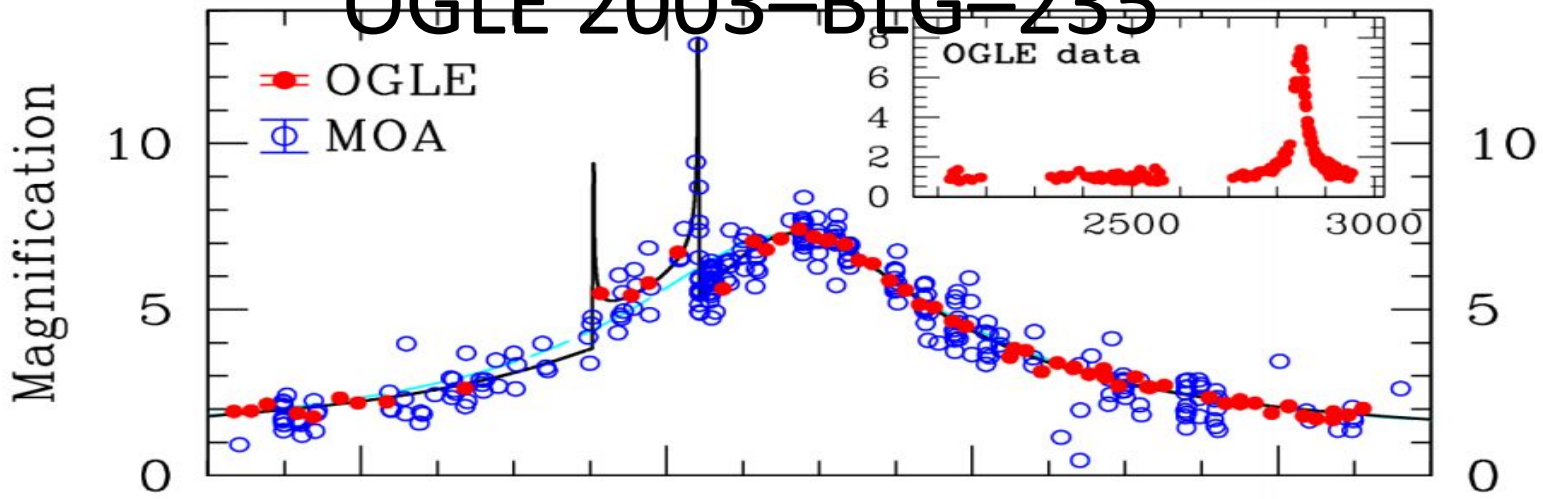
A Geometria de MLG

As Imagens que Einstein Nunca Viu



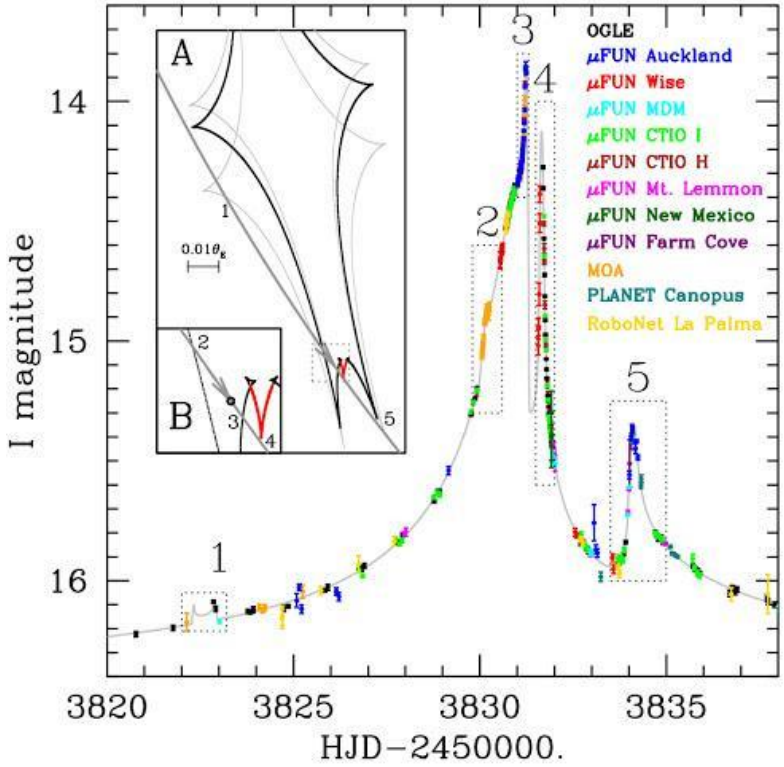
Primeiro Planeta Microlentes Gravitacionais:

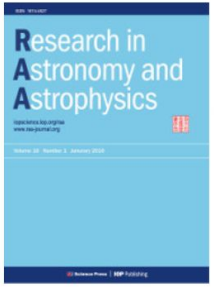
OGLE 2003-BLG-235

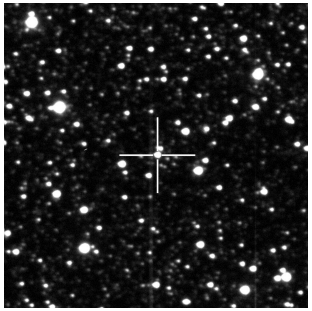


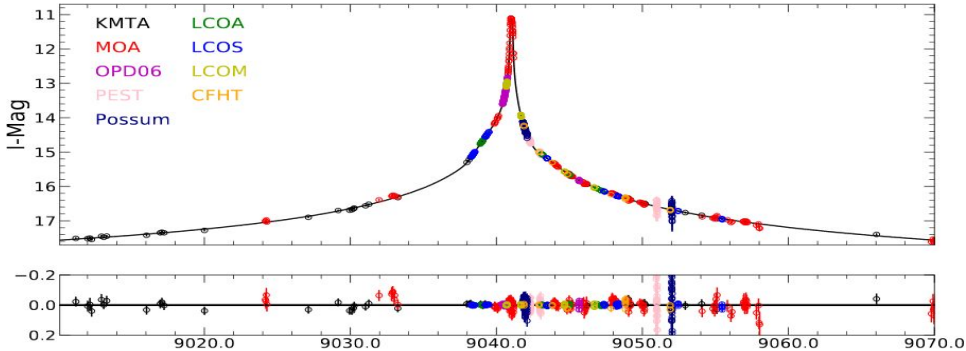
Menção Honrosa

OGLE-2006-BLG-109









$(M_1, M_2, M_3) \sim (0.3M_\odot, 1.0M_\oplus, 17M_J)$

An Earth-mass Planet in a Time of Covid-19: KMT-2020-BLG-0414Lb

Weicheng Zang,[1] Cheongho Han,[2] Iona Kondo,[3] Jennifer C. Yee,[4] Chung-Uk Lee,[5,6] Andrew Gould,[7,8] Shude Mao,[1,9] Leandro de Almeida,[10] Yossi Shvartzvald,[11] and Xiangyu Zhang[1]
(Leading Authors)

Michael D. Albrow,[12] Sun-Ju Chung,[5,6] Kyu-Ha Hwang,[5] Youn Kil Jung,[5] Yoon-Hyun Ryu,[5] In-Gu Shin,[5] Sang-Mok Cha,[5,13] Dong-Jin Kim,[5] Hyoun-Woo Kim,[5] Seung-Lee Kim,[5,6] Dong-Joo Lee,[5] Yongseok Lee,[5,13] Byeong-Gon Park,[5,6] and Richard W. Pogge[8]
(The KMTNet Collaboration)

John Drummond,[14] Thiam-Guan Tan,[15] José Dias do Nascimento Júnior,[10,4] Dan Maoz,[16] Matthew T. Penny,[17] and Wei Zhu[1,18]
(The LCO & μFUN Follow-up Teams)

Ian A. Bond,[19] Fumio Abe,[20] Richard Barry,[21] David P. Bennett,[21,22] Aparna Bhattacharya,[21,22] Martin Donachie,[23] Hirosane Fujii,[3] Akihiko Fukui,[24,25] Yuki Hirao,[3] Yoshitaka Itow,[20] Rintaro Kirikawa,[3] Naoki Koshimoto,[26,27] Man Cheung Alex Li,[23] Yutaka Matsubara,[20] Yasushi Muraki,[20] Shota Miyazaki,[3] Clément Ranc,[21] Nicholas J. Rattenbury,[23] Yuki Satoh,[3] Hikaru Shoji,[3] Takahiro Sumi,[3] Daisuke Suzuki,[28] Yuzuru Tanaka,[3] Paul J. Tristram,[29] Tsubasa Yamawaki,[3] and Atsunori Yonehara[30]
(The MOA Collaboration)

Andreea Petric,[31,32] Todd Burdullis,[31] and Pascal Fouqué[31,33]
(CFHT Microlensing Collaboration)

[1]*Department of Astronomy, Tsinghua University, Beijing 100084, China*
[2]*Department of Physics, Chungbuk National University, Cheongju 28644, Republic of Korea*
[3]*Department of Earth and Space Science, Graduate School of Science, Osaka University, Toyonaka, Osaka 560-0043, Japan*
[4]*Center for Astrophysics | Harvard & Smithsonian, 60 Garden St.,Cambridge, MA 02138, USA*
[5]*Korea Astronomy and Space Science Institute, Daejon 34055, Republic of Korea*
[6]*University of Science and Technology, Korea, (UST), 217 Gajeong-ro Yuseong-gu, Daejeon 34113, Republic of Korea*
[7]*Max-Planck-Institute for Astronomy, Königstuhl 17, 69117 Heidelberg, Germany*
[8]*Department of Astronomy, Ohio State University, 140 W. 18th Ave., Columbus, OH 43210, USA*
[9]*National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100101, China*
[10]*Universidade Federal do Rio Grande do Norte (UFRN), Departamento de Física, 59078-970, Natal, RN, Brazil*

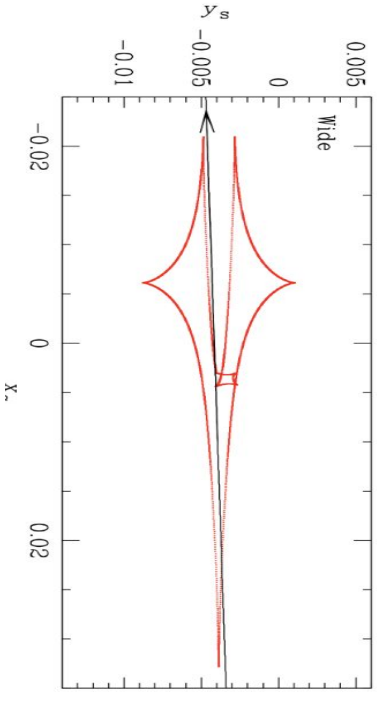


Diagrama Massa x Semi-Eixo Maior Atualizado