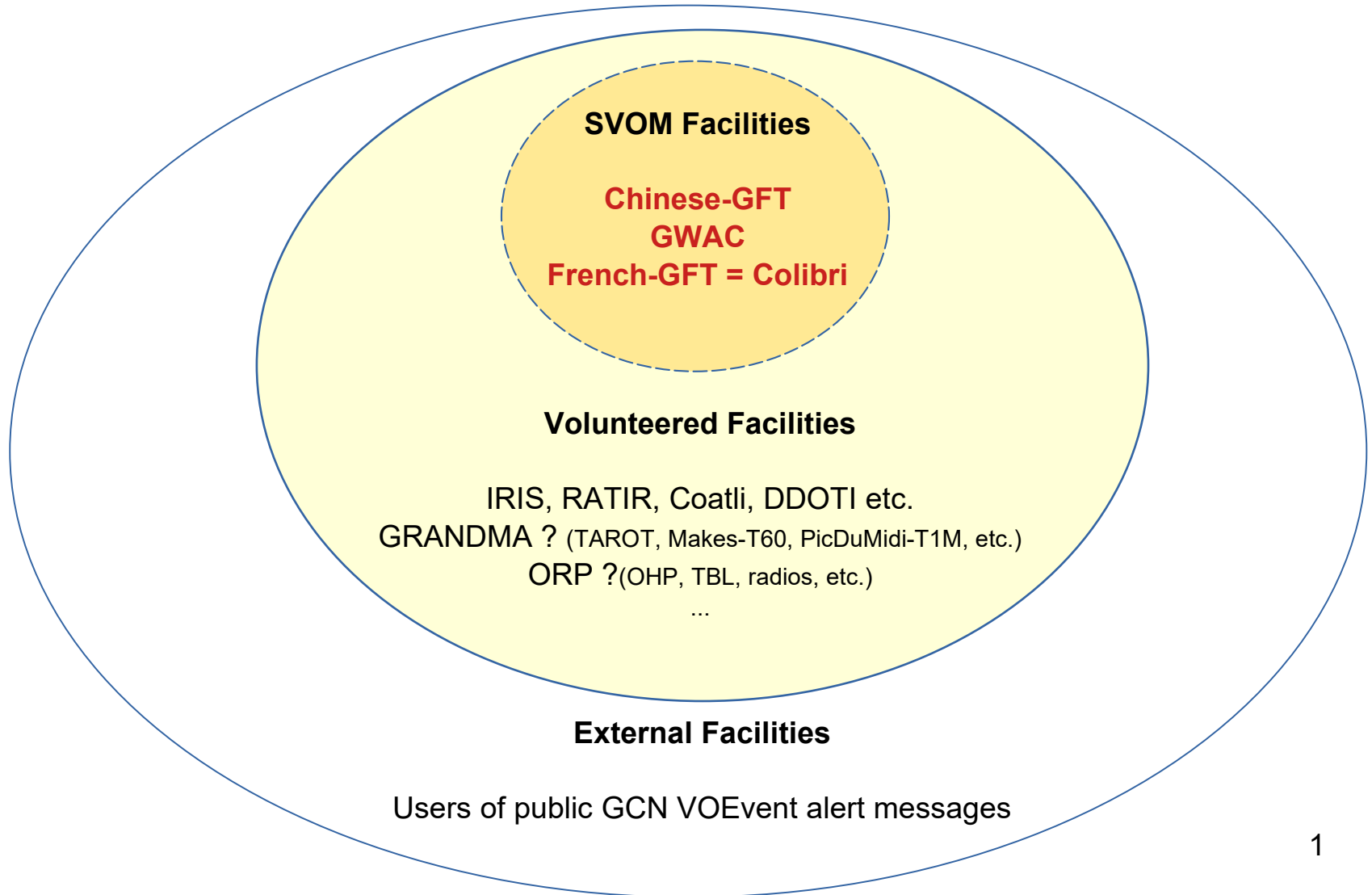


# Follow-up with robotic telescopes

Hands-on prepared by Nat Butler and Alain Klotz



## Some basics for optical photometry of optical counterparts

Optical wavelengths = Visible + Near Infrared

g ~ 500 nm blue/green

r ~ 600 nm orange/red

i ~ 750 nm

z ~ 850 nm

J ~ 1200 nm

H ~ 1600 nm

Color = differences between two bands

Optical color of the afterglow is due to:

- Spectral slope of the emission process
- Reddening by the cosmological redshift
- Reddening by the matter extinction of host / intergalactic / Milky Way

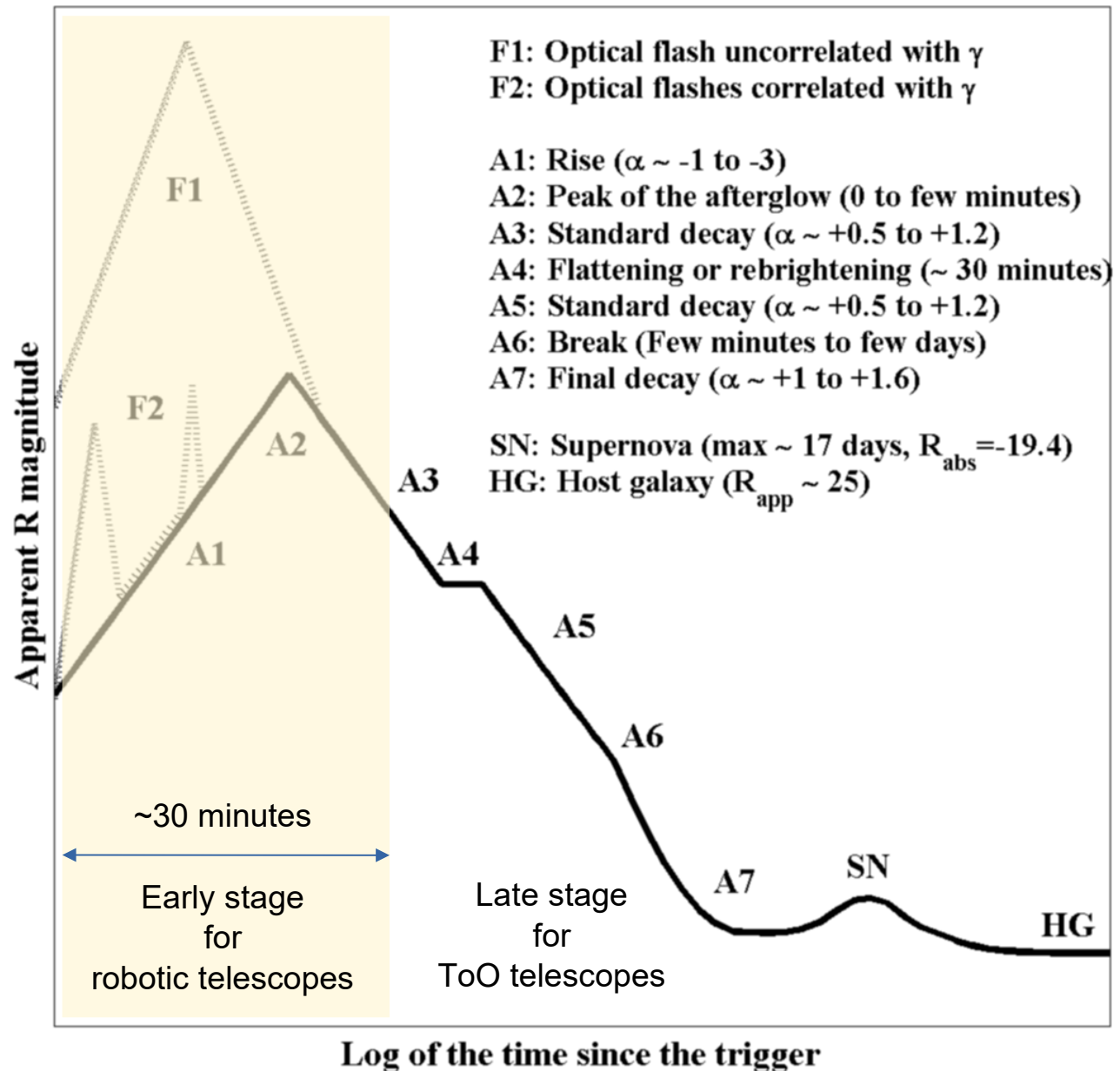
Usual color value (r-g) ~ 0.4 mag.

Generally the color does not evolve significantly (< 20%) during the first hours.

The interesting use of colors is to estimate the redshift before using spectrographs:

- Lyman Alpha break occurs at wavelength  $(1+z)*122$  nm
- E.g. Suppose the afterglow is not detected in (g,r,i) but detected in (z, J, H):  
 $z \sim 800/122 - 1 \sim 5.5$  (high redshift because  $> 5$ )
- Contact specialists of *photometric redshift* to valid and refine the photo-redshift value. 2

# Global scheme of optical light curves



Be careful

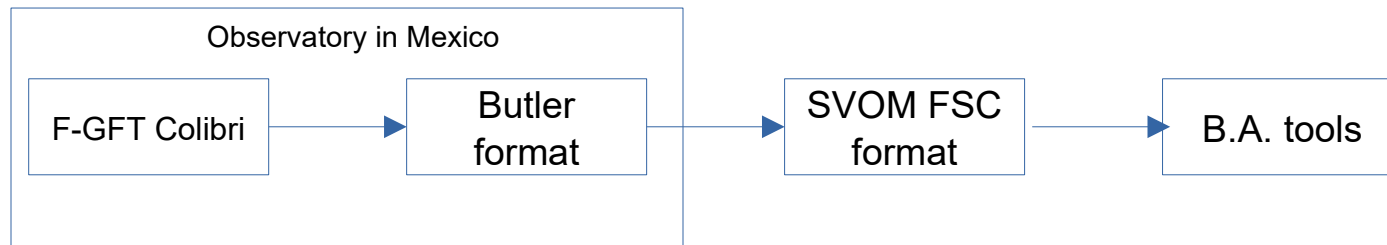
When brightness increases  
 = Flux density increases  
 = Magnitude decreases

## Which tools for the Burst Advocate ?

### SVOM B.A. tools for GFTs and GWAC are in development

Authors : Liping Xin, Damien Dornic, Nat Butler, etc.

Principle : Dynamic web pages generated by the on-line image analysis + database



### Current operational tools are existing for RATIR and Coatli telescopes

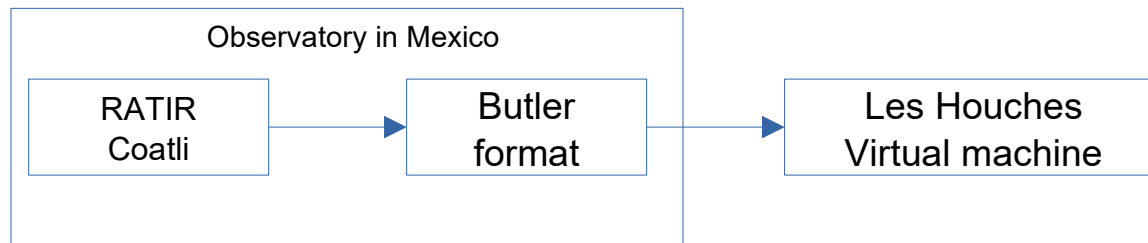
Authors : Nat Butler, A. Watson

Principle : Static web pages generated by the on-line image analysis.

This session shows how to interpret informations from real cases of RATIR and Coatli.

Home page of GRB **events to practice** is available in the virtual machine :

`/home/svomba/data/robotics/index.html`



## Comparison Colibri and RATIR, COATLI

	Response time	Field of view	Diameter	Filters	Channels
Colibri	< 1 min	26 x 26 arcmin	1.3 m	g, r, i, z, J, H	3
RATIR	~ 1 hour	1.3 x 1.3 arcmin	1.5 m	g, r, i, z, J, H, K	4
Coatli	< 1 min	8 x 12 arcmin	0.5 m	g, r, i	1



# Home page of GRB events to practice - GRB 191016A a nice light curve

## </home/svomba/data/robotics/index.html>

### Some RATIR and Coatli Observations from Fall 2019

---

#### RATIR

[GRB 191031D](#): short-duration burst. RATIR observed 4.65 to 5.49 hours after the BAT trigger ([public report](#)). Limits only.

[GRB 191016A](#): Detections obtained ([public report](#)).

[GRB 191011A](#): Optical detections and NIR limits obtained ([public report](#)).

[GRB 191001A](#): Fermi GRB detection, OT found by DDOTI! ([public report](#)). [DDOTI Observation](#)

#### Coatli

[GRB 191031D](#): short-duration burst. Coatli observed 5.4 to 7.4 hours after the trigger ([public report](#)). Limits only.

[GRB 191031A](#): limits only ([public report](#)).

[GRB 191016A](#): detections and nice variability ([public report](#)). [Full observation](#).

[GRB 191004B](#): weak detection ([public report](#)).

[ZTF19abvizsw](#): detection, possible untriggered GRB, ZTF source also detected by TESS ([public report](#)).

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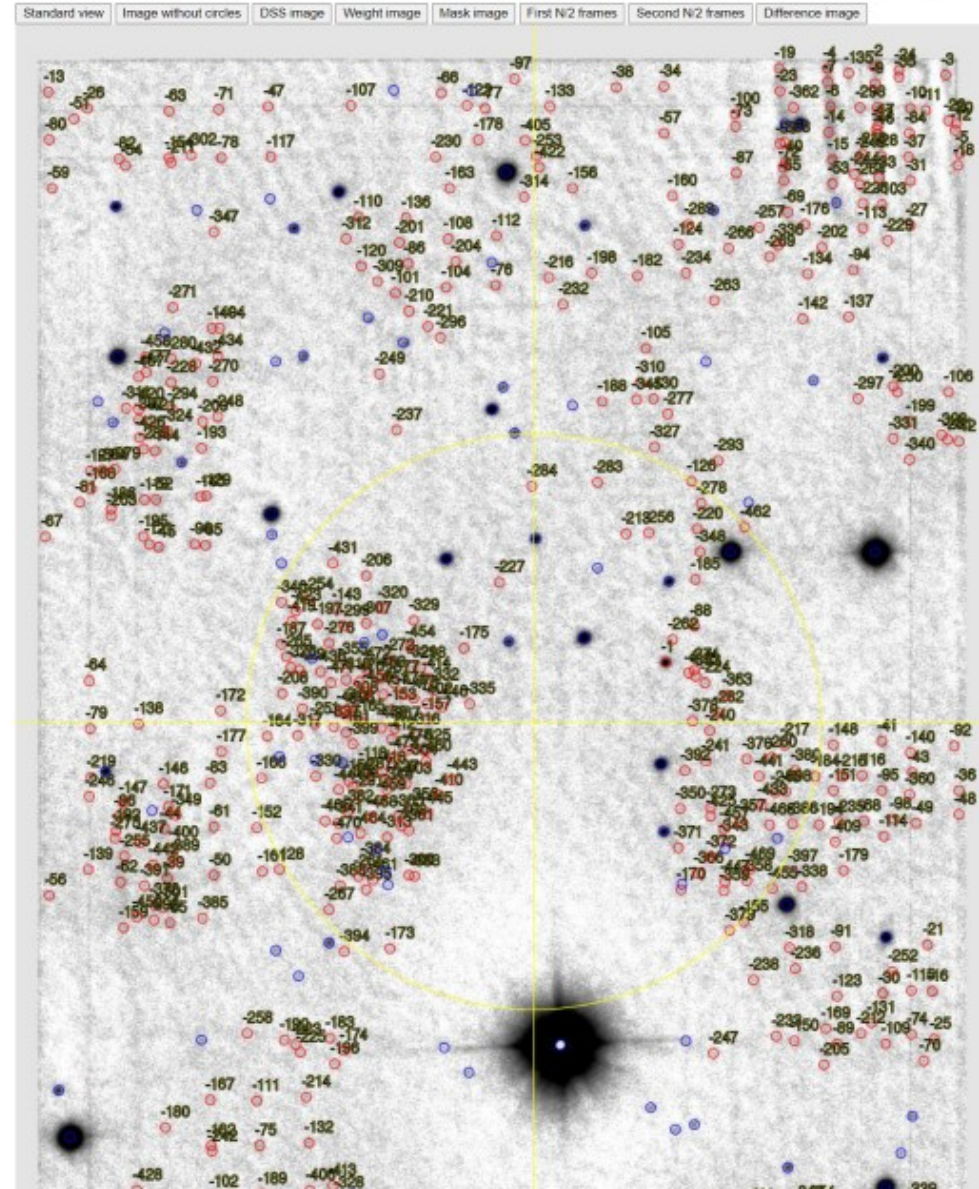
Last Updated: Fri 24 Jan 2020 07:02:39 PM UTC ([natbutler@asu.edu](mailto:natbutler@asu.edu))



## Case GRB 191016A - Coatli

### Step 1 - Check the sum of all images with / without marks

COATLI C0 w : RA 30.301591 , Dec 24.501627 [N=93 Frame(s), 20191016T041519 - 20191016T042944]  
Frame Size: 872 x 1242 Exposure Time: 465.0 seconds 10-sigma limiting mag: 18.48 Zero-Point: 23.08 FWHM: 6.94 pixels



Star ID > 0  
are matched  
in catalog

Stars with ID < 0  
are not matched  
in catalog

Go to the bottom  
list of stars



## Case GRB 191016A - Coatli

### Step 2 - Check the list of possible candidates (ID negative)

Sources within 180.0 arcsec from center: 30.295583 , 24.500889

#ID	RA	Dec	X	Y	mag	dmag	FWHM	Flags
<a href="#">-1</a>	30.269770	24.510229	582.422000	671.253000	15.803000	0.009692	5.78	91.0 arcsec from center
-88	30.263983	24.516312	608.074000	703.531000	18.345500	0.095650	8.38	117.5 arcsec from center
<a href="#">-118</a>	30.328597	24.494001	311.788000	576.716000	18.476500	0.107940	16.62	111.0 arcsec from center
<a href="#">-143</a>	30.332443	24.521770	287.964000	718.169000	18.562800	0.116876	15.14	142.2 arcsec from center
<a href="#">-153</a>	30.322641	24.504086	337.393000	629.509000	18.597800	0.120842	24.80	89.4 arcsec from center
<a href="#">-157</a>	30.315984	24.502156	368.823000	620.918000	18.602100	0.121139	15.08	67.0 arcsec from center
-158	30.331412	24.492022	299.092000	566.037000	18.605700	0.122993	15.02	121.6 arcsec from center
-164	30.346822	24.500410	225.503000	606.013000	18.619000	0.122969	4.98	167.9 arcsec from center
<a href="#">-165</a>	30.328807	24.502340	309.035000	619.378000	18.620500	0.123306	23.10	109.0 arcsec from center
-166	30.348161	24.493155	220.801000	568.604000	18.625200	0.123655	3.43	174.5 arcsec from center



Magnitudes of candidates are sorted by decreasing brightness (= increasing magnitudes)

There are lot of stars with mag > 18.3 (= confusion limit)

There is only one star at magnitude 15.8 => Good possible candidate

Click on the ID of the best candidates to display their light curves

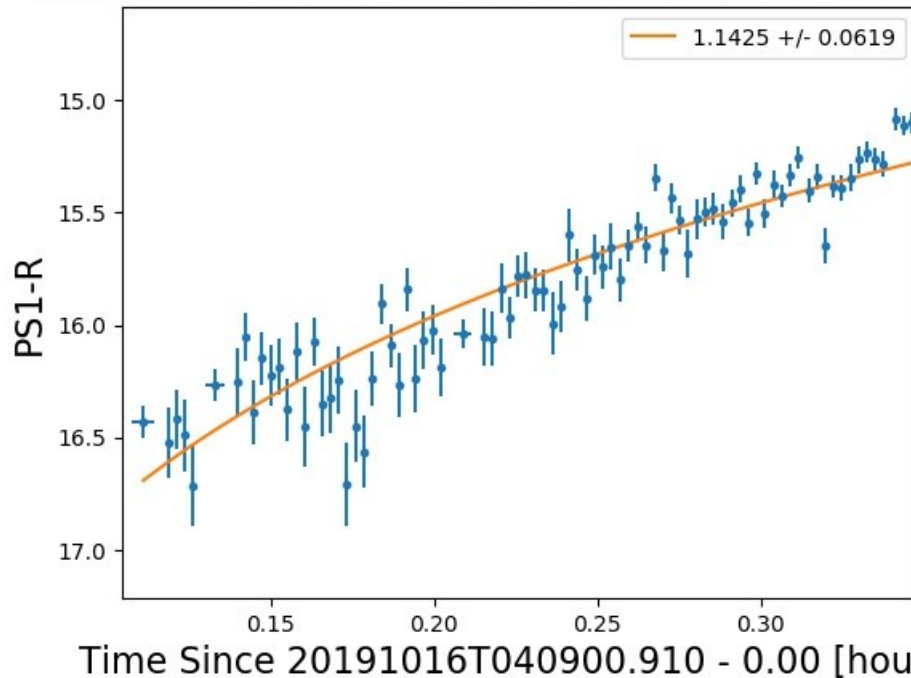
# Case GRB 191016A - Coatli

## Step 3 - Check the light curve of possible candidates

Sources within 180.0 arcsec from center: 30.295583 , 24.500889

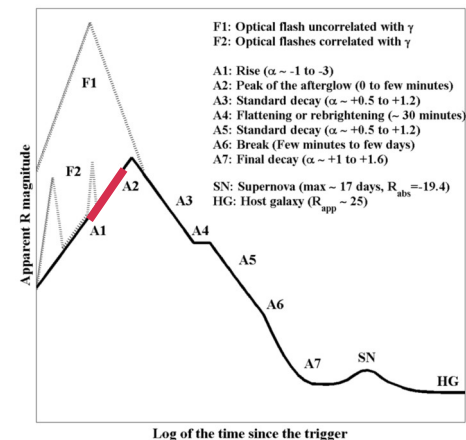
#ID	RA	Dec	X	Y	mag	dmag	FWHM	Flags
<u>-1</u>	30.269770	24.510229	582.422000	671.253000	15.803000	0.009692	5.78	91.0 arcsec from center
-88	30.263983	24.516312	608.074000	703.531000	18.345500	0.095650	8.38	117.5 arcsec from center
<u>-118</u>	30.328597	24.494001	311.788000	576.716000	18.476500	0.107940	16.62	111.0 arcsec from center
<u>-143</u>	30.332443	24.521770	287.964000	718.169000	18.562800	0.116876	15.14	142.2 arcsec from center
<u>-153</u>	30.322641	24.504086	337.393000	629.509000	18.597800	0.120842	24.80	89.4 arcsec from center
<u>-157</u>	30.315984	24.502156	368.823000	620.918000	18.602100	0.121139	15.08	67.0 arcsec from center
-158	30.331412	24.492022	299.092000	566.037000	18.605700	0.122993	15.02	121.6 arcsec from center
-164	30.346822	24.500410	225.503000	606.013000	18.619000	0.122969	4.98	167.9 arcsec from center
<u>-165</u>	30.328807	24.502340	309.035000	619.378000	18.620500	0.123306	23.10	109.0 arcsec from center
-166	30.348161	24.493155	220.801000	568.604000	18.625200	0.123655	3.43	174.5 arcsec from center

Light Curve for Source -1 (RA=30.269770, Dec=24.510229, Mag=15.8)



The flux increases until  
0.35 hour = 20 minutes

Optical peak is usually reached  
between 0 to 25 minutes



# Home page of GRB events to practice - GRB 191016A a nice light curve

## </home/svomba/data/robotics/index.html>

### Some RATIR and Coatli Observations from Fall 2019

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#### RATIR

[GRB 191031D](#): short-duration burst. RATIR observed 4.65 to 5.49 hours after the BAT trigger ([public report](#)). Limits only.

[GRB 191016A](#): Detections obtained ([public report](#)).

[GRB 191011A](#): Optical detections and NIR limits obtained ([public report](#)).

[GRB 191001A](#): Fermi GRB detection, OT found by DDOTI! ([public report](#)). [DDOTI Observation](#)

#### Coatli

[GRB 191031D](#): short-duration burst. Coatli observed 5.4 to 7.4 hours after the trigger ([public report](#)). Limits only.

[GRB 191031A](#): limits only ([public report](#)).

[GRB 191016A](#): detections and nice variability ([public report](#)). [Full observation](#).

[GRB 191004B](#): weak detection ([public report](#)).

[ZTF19abvizsw](#): detection, possible untriggered GRB, ZTF source also detected by TESS ([public report](#)).

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Last Updated: Fri 24 Jan 2020 07:02:39 PM UTC ([natbutler@asu.edu](mailto:natbutler@asu.edu))

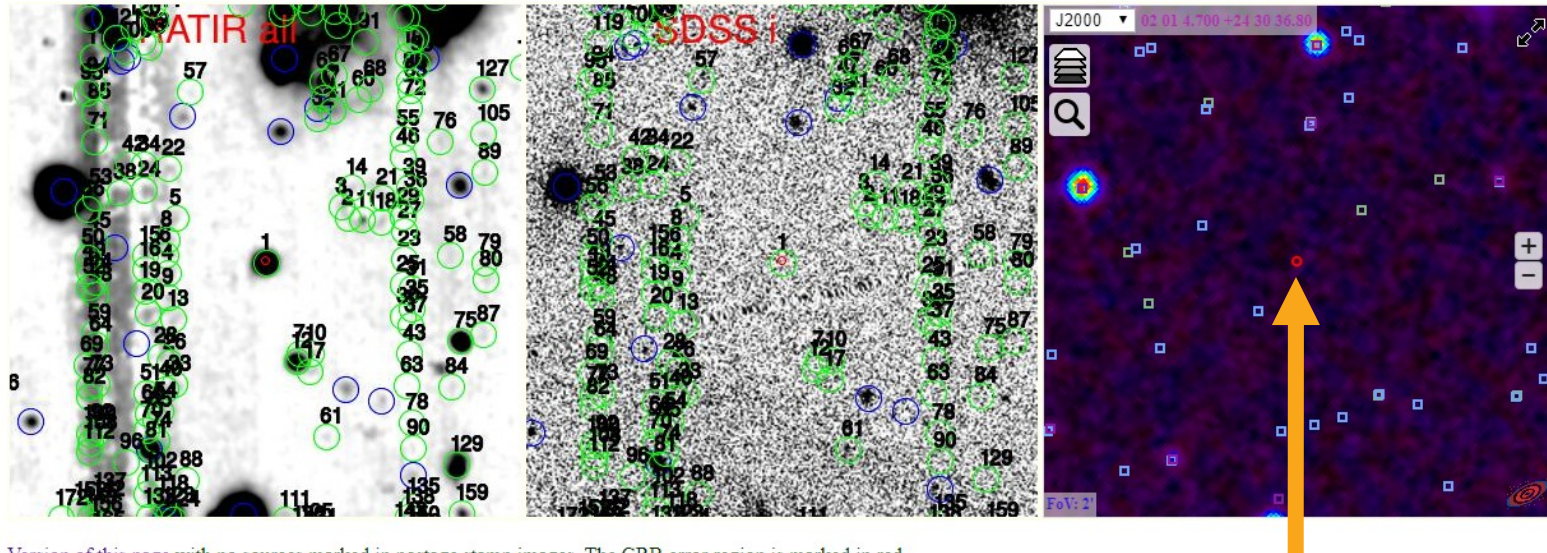


# Case GRB 191016A - RATIR

## Step 1 - Check the sum of all images with / without marks

RATIR Sources for GRB 191016A : 30.269745000000004 , 24.510225 [version8]

Star #1  
lies in the  
error region

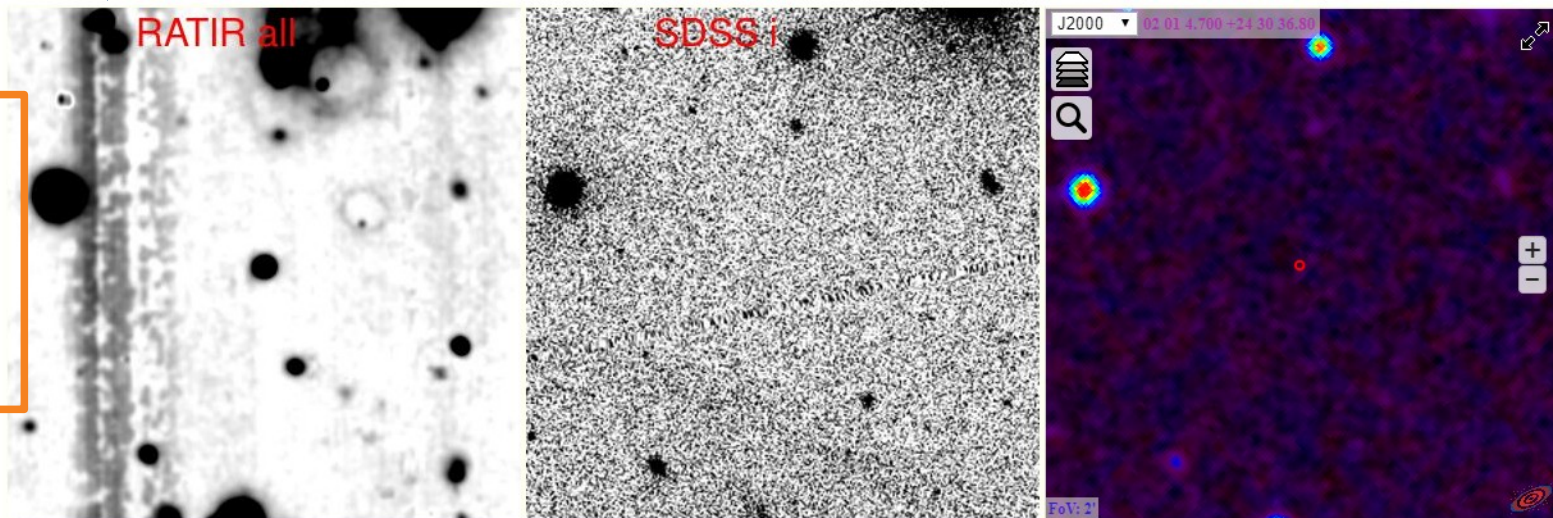


[Version of this page](#) with no sources marked in postage stamp images. The GRB error region is marked in red.

Link to toggle  
marks

Swift/UVOT small error region

Many stars  
are not  
detected  
in the  
SDSS images





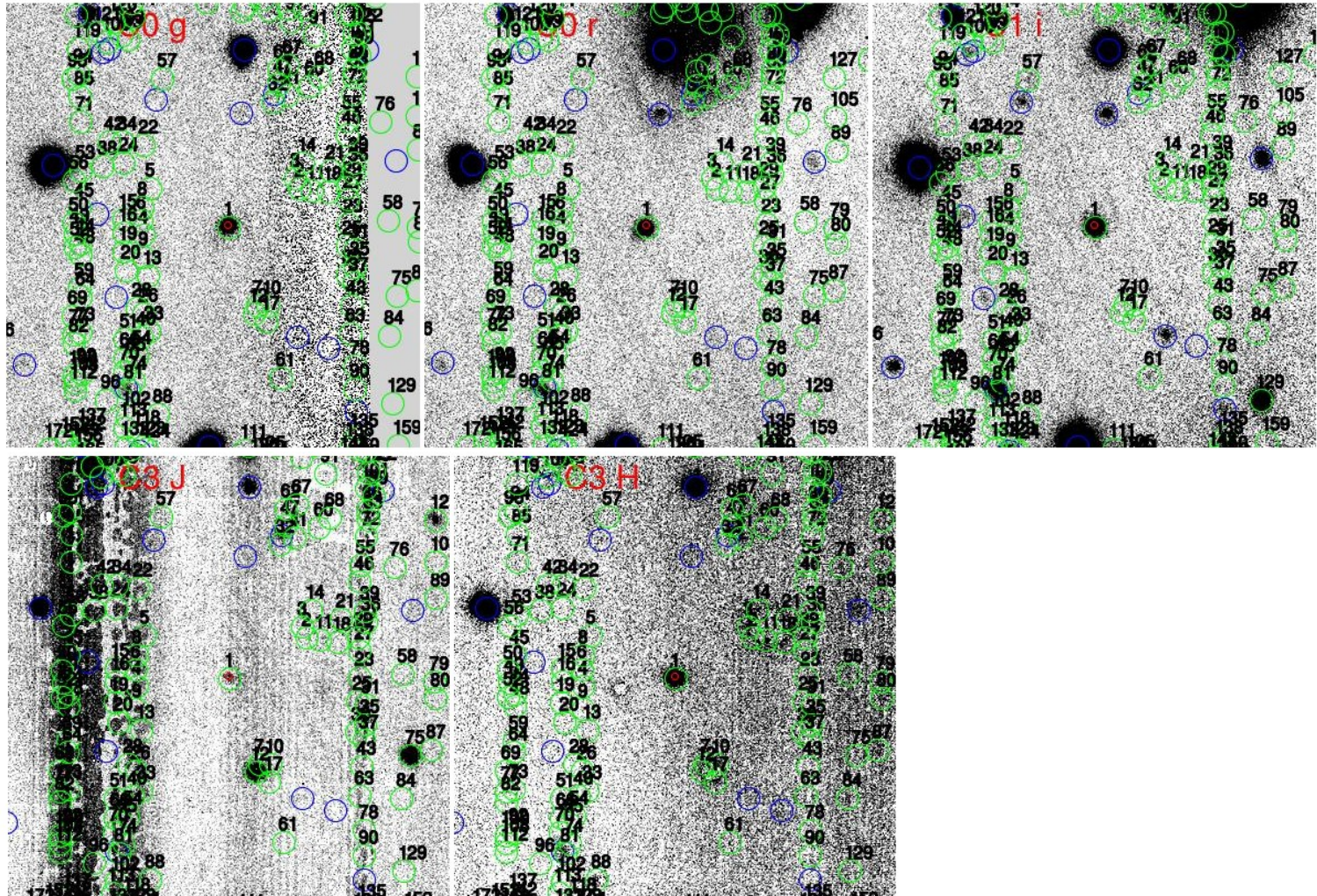
## Case GRB 191016A - RATIR

### Step 2 - Check the colors of the candidate(s)

Candidate #1  
is seen in all  
colors



Not a high  
redshift



## Case GRB 191016A - RATIR

### Step 3 - Check the photometry (candidate light curves, limits)

#### GRB Trigger Info:

Draft of GCN circular

#### AB System Photometry (sources within 1 arcmin):

R.A. Dec, Light curves of all sources

#### Source Statistics:

Temporal powerlaw, spectral powerlaw

#### Photometric Redshift Statistics (src=3600):

Photo-z

#### Photometric Calibration Info:

Zero points, magnitude limit for each color

#### Exposure Info:

Time, nb of exposures, field of view

#### Fits thumbnails:v

FITS (gzipped) images

#### Full-frame Images:

Jpeg images

Light curves  
of candidates

Limiting  
magnitude





# Case GRB 191016A - RATIR

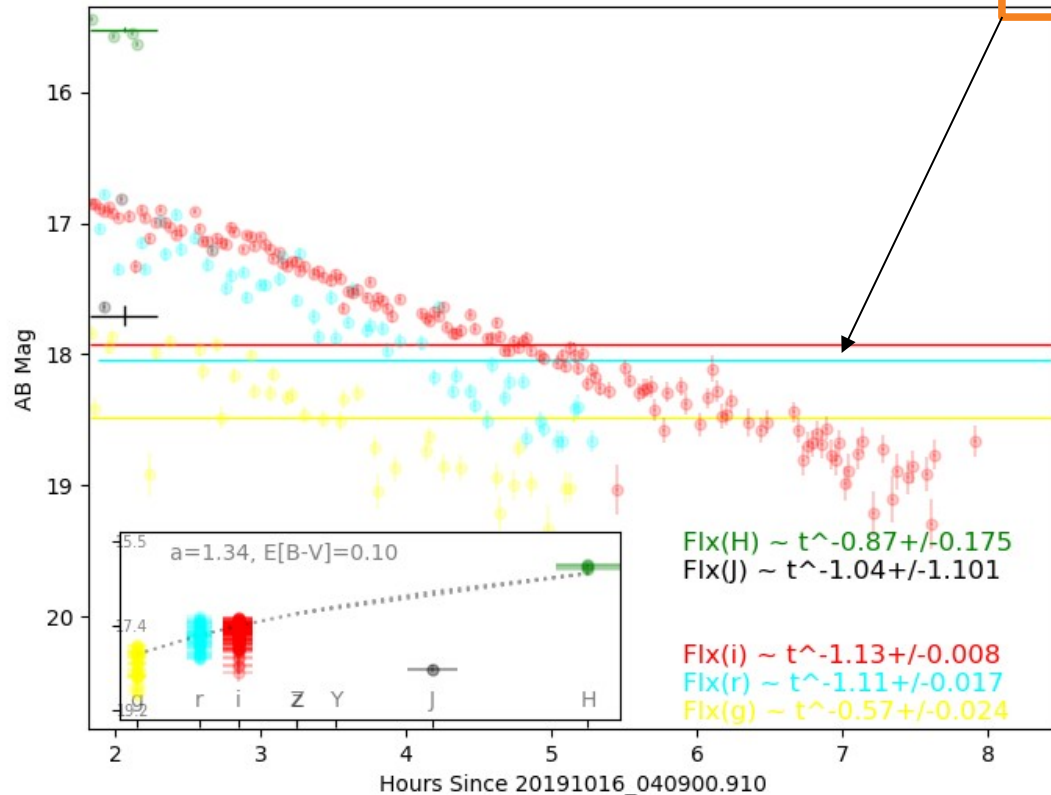
## Step 4 - Check the candidate light curve

### AB System Photometry (sources within 1 arcmin):

Notes: Non-zero magnitudes with uncertainty of zero are 3-sigma upper limits. Sources with magnitudes of 0.0000 are unobserved.

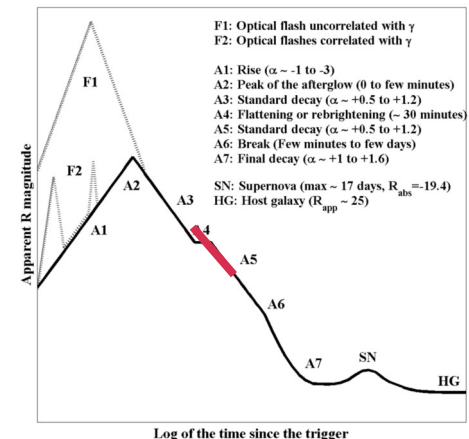
[Full sourcelist](#). [New sourcelist](#). [Calibration photometry](#).

#	idx	RA	DEC	g	dg	r	dr	i	di	Z	dZ	Y	dY	J	dJ	H	dH	z	dz	radius["]	catalogued?
#		3-sigma	limits:	21.6309		22.0207		22.8295		0.0000		0.0000		18.6061		18.2728		0.0000		(<120)	
#																					
1	3600	30.269676	24.510062	18.4890	0.0143	18.0455	0.0114	17.9179	0.0047	0.0000	0.0000	0.0000	0.0000	17.7061	0.0768	15.5224	0.0169	0.0000	0.0000	0.63	0

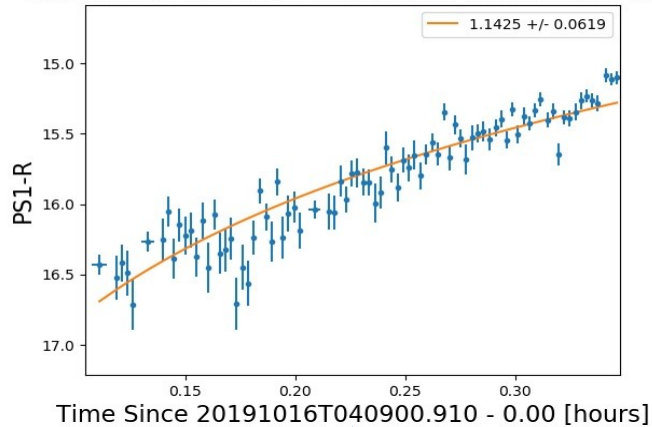


Limiting  
magnitudes ?

Check the decay  
Compare to -1



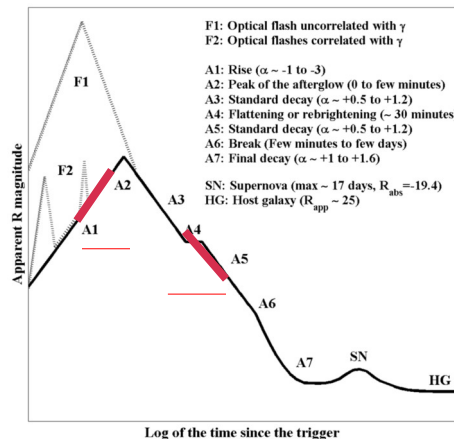
Light Curve for Source -1 (RA=30.269770, Dec=24.510229, Mag=15.8)



Coatli = Early light curve

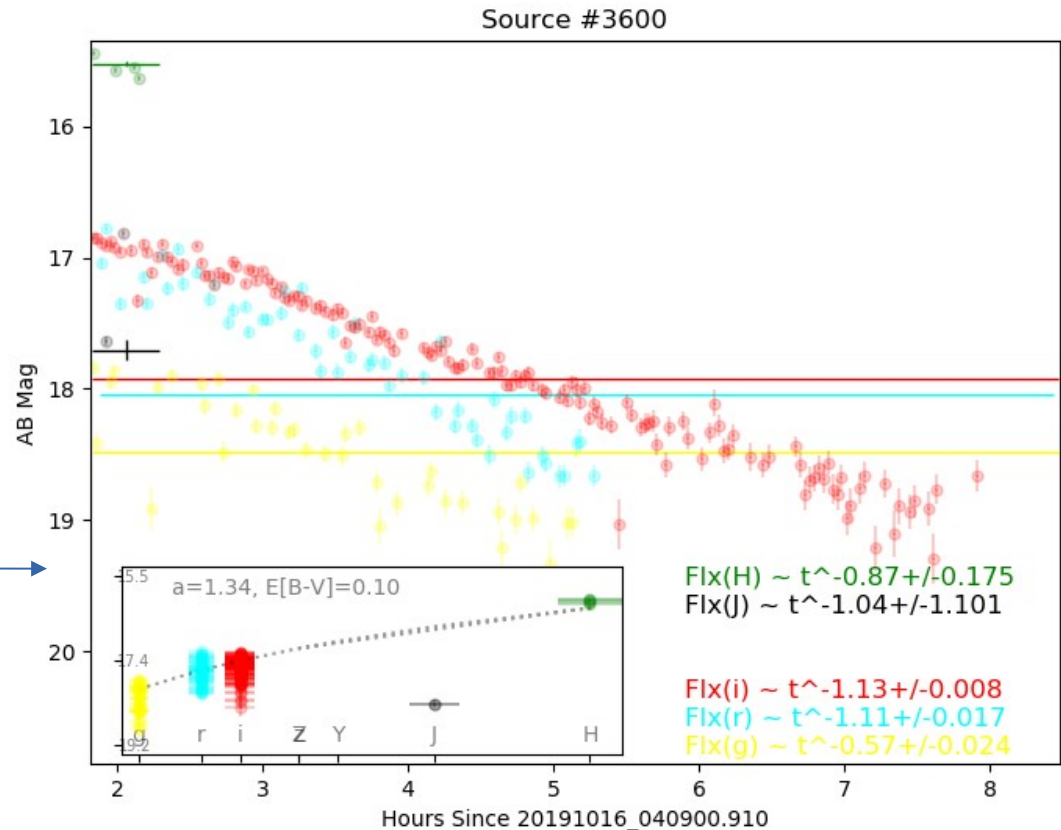
RATIR = Late light curve

GFT = Early + late light curves



## Case GRB 191016A - Coatli + RATIR

### Combining the candidate light curve



# Home page of GRB events to practice - GRB 191031D not detected

## </home/svomba/data/robotics/index.html>

### Some RATIR and Coatli Observations from Fall 2019

---

#### RATIR

[GRB 191031D](#): short-duration burst. RATIR observed 4.65 to 5.49 hours after the BAT trigger ([public report](#)). Limits only.

[GRB 191016A](#): Detections obtained ([public report](#)).

[GRB 191011A](#): Optical detections and NIR limits obtained ([public report](#)).

[GRB 191001A](#): Fermi GRB detection, OT found by DDOTI! ([public report](#)). [DDOTI Observation](#)

#### Coatli

[GRB 191031D](#): short-duration burst. Coatli observed 5.4 to 7.4 hours after the trigger ([public report](#)). Limits only.

[GRB 191031A](#): limits only ([public report](#)).

[GRB 191016A](#): detections and nice variability ([public report](#)). [Full observation](#).

[GRB 191004B](#): weak detection ([public report](#)).

[ZTF19abvizsw](#): detection, possible untriggered GRB, ZTF source also detected by TESS ([public report](#)).

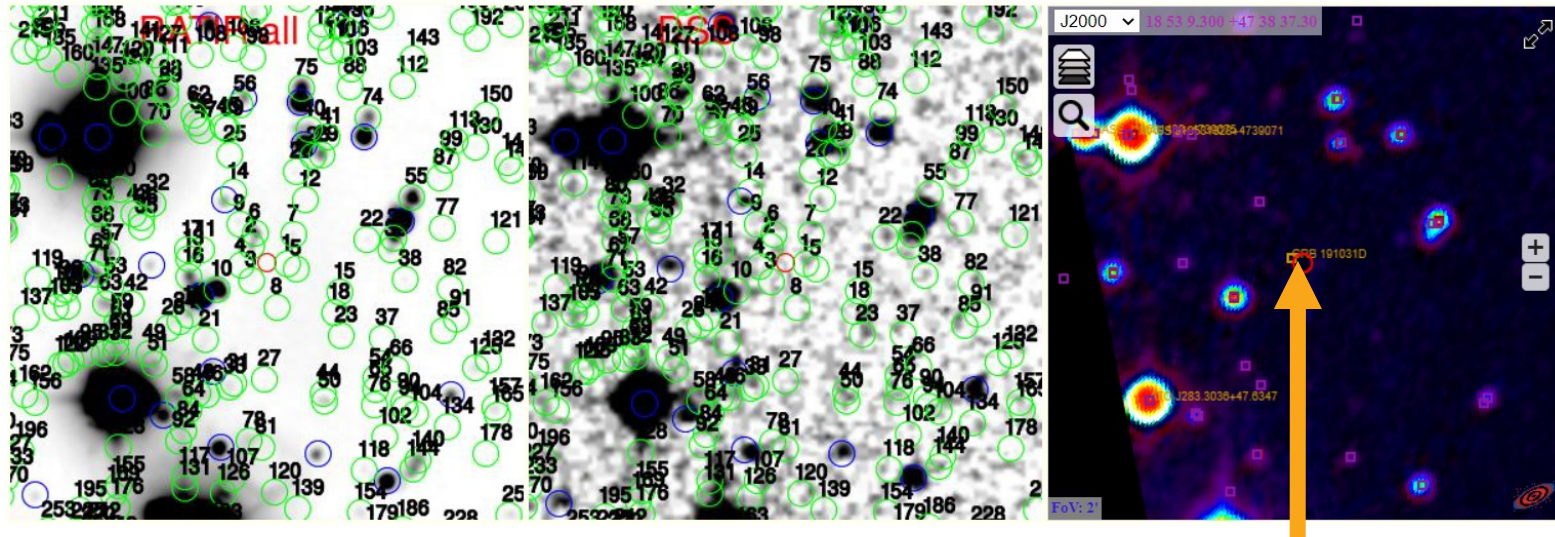
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Last Updated: Fri 24 Jan 2020 07:02:39 PM UTC ([natbutler@asu.edu](mailto:natbutler@asu.edu))

## Case GRB 191031D - RATIR

### Step 1 - Check the sum of all images with / without marks

RATIR Sources for GRB 191031A : 283.2889166666667 , 47.64369444444444 [version6]



No star is  
lying in the  
error region  
(red circle)

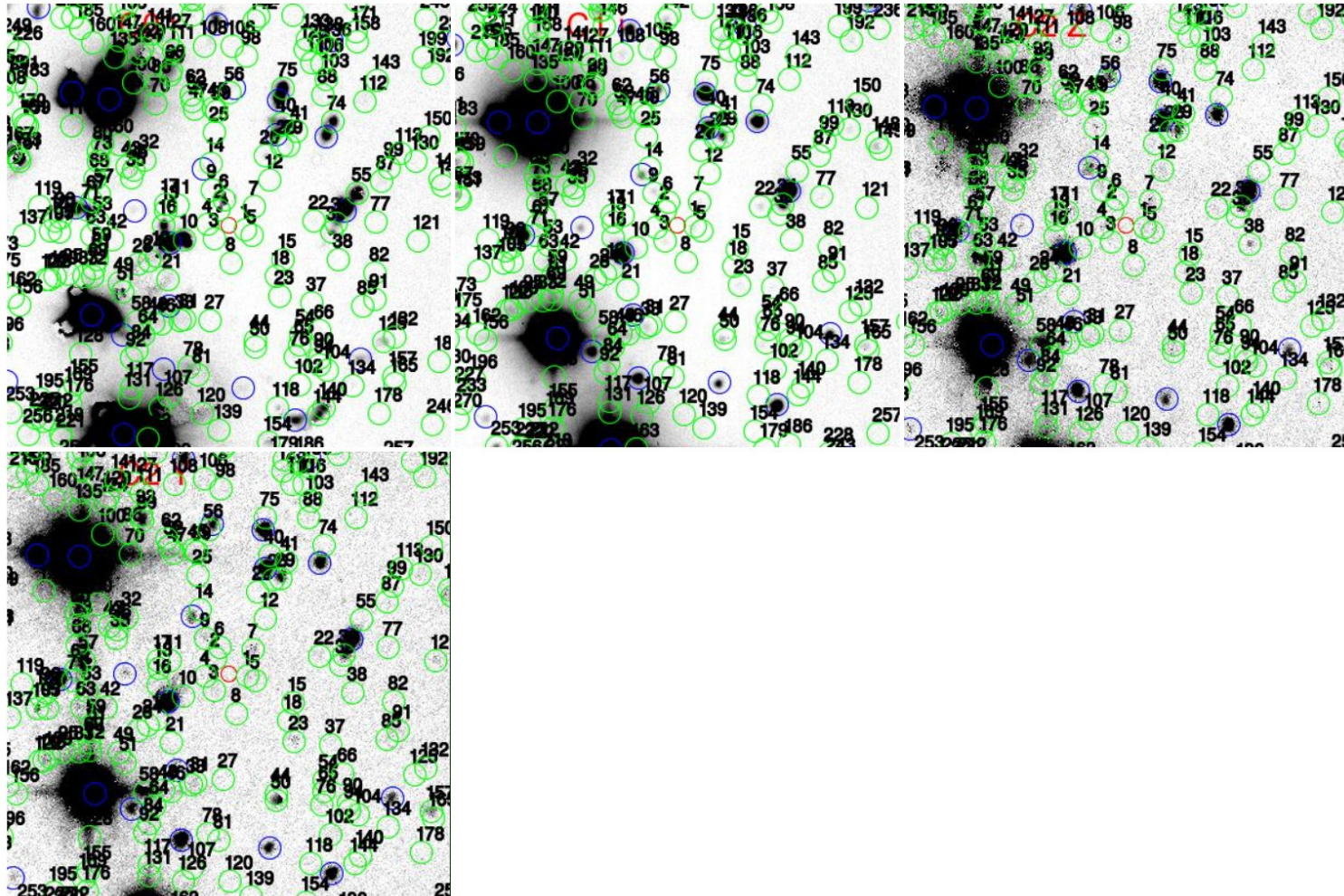
Swift/XRT small error region



## Case GRB 191031D - RATIR

### Step 2 - Check there is no candidate in infrared

No detection  
at any  
wavelength



## Case GRB 191031D - RATIR

### Step 3 - Check the draft of GCN for limiting magnitudes

Limiting  
magnitude



#### GRB Trigger Info:

Draft of GCN circular

#### AB System Photometry (sources within 1 arcmin):

R.A. Dec, Light curves of all sources

#### Source Statistics:

Temporal powerlaw, spectral powerlaw

#### Photometric Redshift Statistics (src=3600):

Photo-z

#### Photometric Calibration Info:

Zero points, magnitude limit for each color

#### Exposure Info:

Time, nb of exposures, field of view

#### Fits thumbnails:v

FITS (gzipped) images

#### Full-frame Images:

Jpeg images



# Case GRB 191031D - RATIR

## Step 3 - Check the draft of GCN for limiting magnitudes

### GRB Trigger Info:

GRB 191031A triggered at 20191031\_212331.029 UTC ( 1256592225.020000 )  
RA= 283.2889166666667  
DEC= 47.64369444444444  
ERROR= 2.2 [arcsec radius] Swift-XRT

Assuming 0.5 arcsec positional uncertainty in our images, there are 0 sources consistent with the 2.2 arcsec GRB 191031A Swift-XRT error circle.

### Draft GCN:

GRB 191031A: RATIR Optical and NIR Observations

Nat Butler (ASU), Alan M. Watson (UNAM), Alexander Kutyrev (GSFC), William H. Lee (UNAM), Michael G. Richer (UNAM), Ori Fox (STScI), J. Xavier Prochaska (UCSC), Josh Bloom (UCB), Antonino Cucchiara (UWI), Eleonora Troja (GSFC), Owen Littlejohns (ASU), Enrico Ramirez-Ruiz (UCSC), Jesús González (UNAM), Carlos Román-Zúñiga (UNAM), Harvey Moseley (GSFC), John Capone (UMD), V. Zach Golkhou (U. Wash.), and Vicki Toy (UMD) report:

We observed the field of GRB 191031A (XXX, et al., GCN XXX) with the Reionization and Transients Infrared Camera (RATIR; [www.ratir.org](http://www.ratir.org)) on the 1.5m Harold Johnson Telescope at the Observatorio Astronómico Nacional on Sierra San Pedro Mártir from 2019/11 1.09 to 2019/11 1.21 UTC (4.65 to 7.63 hours after the BAT trigger), obtaining a total of 1.78 hours exposure in the r and i bands and 0.74 hours exposure in the Z, Y, J, and H bands.

For a source within the Swift-XRT error circle, in comparison with the USNO-B1 and 2MASS catalogs, we obtain the following upper limits (3-sigma):

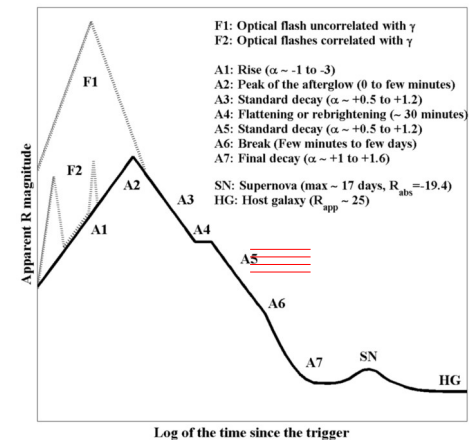
r > 22.44  
i > 23.69  
Z > 21.51  
Y > 21.40

These magnitudes are in the AB system and are not corrected for Galactic extinction in the direction of the GRB.

We thank the staff of the Observatorio Astronómico Nacional in San Pedro Mártir.

OPTIONAL BITS:

Further observations are planned.



Limiting  
magnitudes

# Home page of GRB events to practice - GRB 191011A Partially detected

## </home/svomba/data/robotics/index.html>

### Some RATIR and Coatli Observations from Fall 2019

---

#### RATIR

[GRB 191031D](#): short-duration burst. RATIR observed 4.65 to 5.49 hours after the BAT trigger ([public report](#)). Limits only.

[GRB 191016A](#): Detections obtained ([public report](#)).

[GRB 191011A](#): Optical detections and NIR limits obtained ([public report](#)).

[GRB 191001A](#): Fermi GRB detection, OT found by DDOTI! ([public report](#)). [DDOTI Observation](#)

#### Coatli

[GRB 191031D](#): short-duration burst. Coatli observed 5.4 to 7.4 hours after the trigger ([public report](#)). Limits only.

[GRB 191031A](#): limits only ([public report](#)).

[GRB 191016A](#): detections and nice variability ([public report](#)). [Full observation](#).

[GRB 191004B](#): weak detection ([public report](#)).

[ZTF19abvizsw](#): detection, possible untriggered GRB, ZTF source also detected by TESS ([public report](#)).

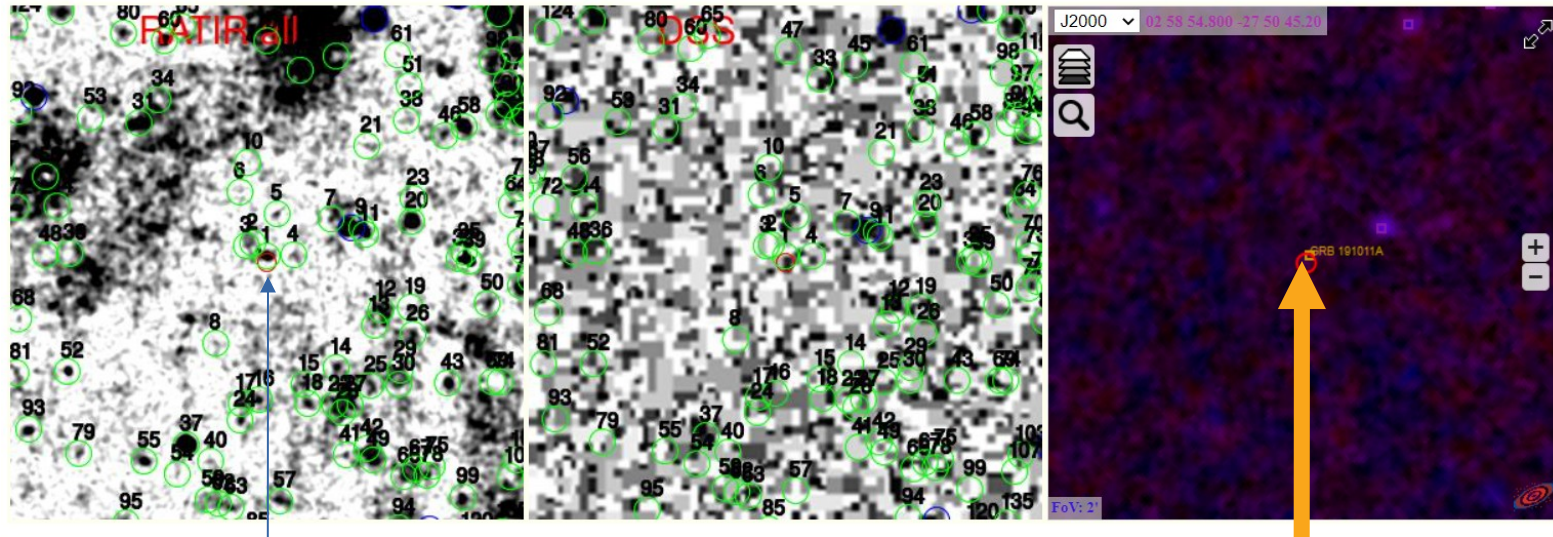
---

Last Updated: Fri 24 Jan 2020 07:02:39 PM UTC ([natbutler@asu.edu](mailto:natbutler@asu.edu))

## Case GRB 191011A - RATIR

### Step 1 - Check the sum of all images with / without marks

RATIR Sources for GRB 191011A : 44.72820833333335 , -27.84588888888889 [version6]



[Version of this page](#) with no sources marked in postage stamp images. The GRB error region is marked in red.

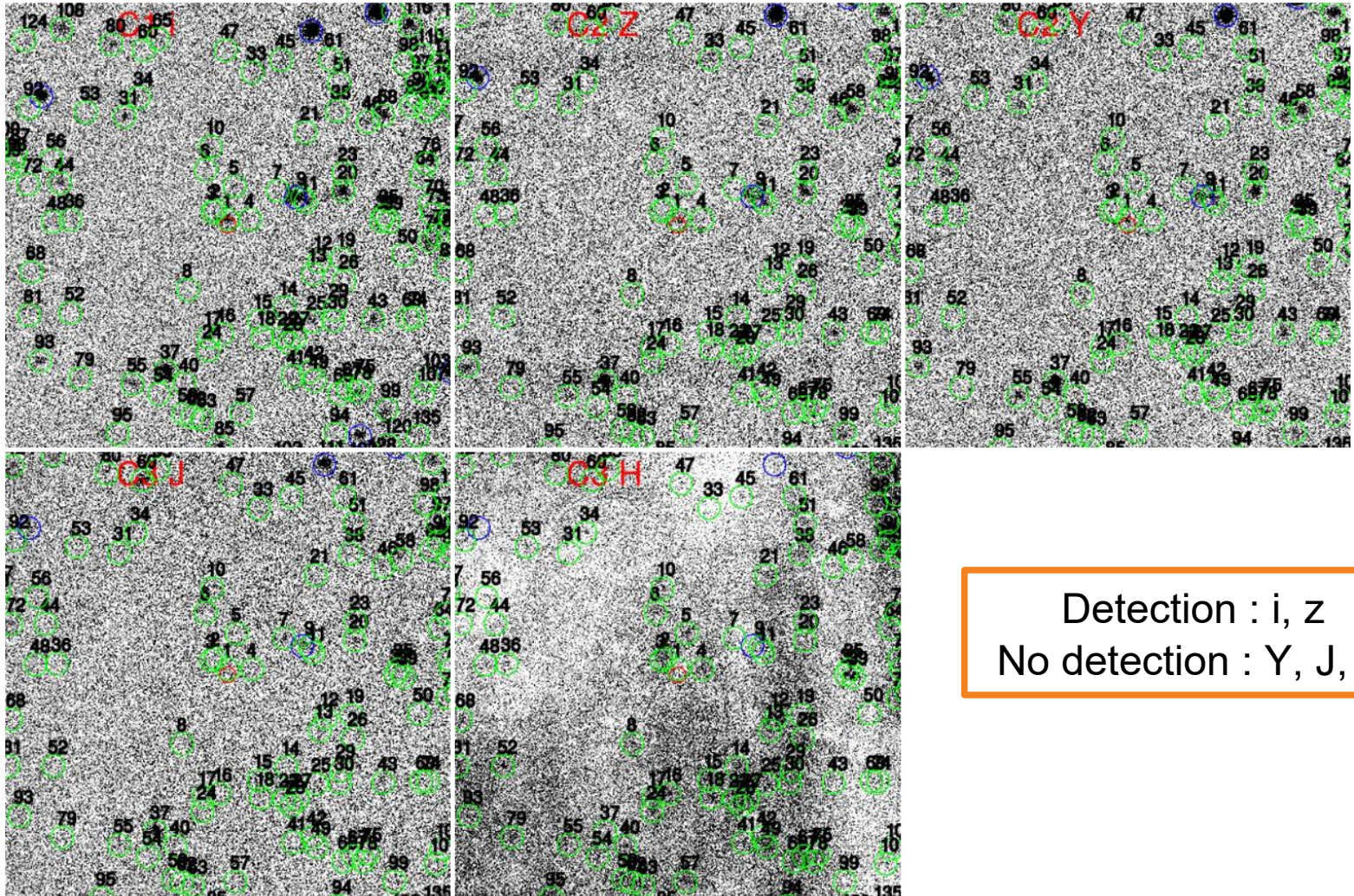
Swift/XRT small error region

A faint star is  
lying in the  
error region  
(red circle)



## Case GRB 191011A - RATIR

### Step 2 - Check filtered images where the candidate is detected



Detection : i, z  
No detection : Y, J, H

Not high redshift (seen in i implies redshift < 5)

Y, J, H not detected due to a lack of camera detectivity (instrumental bias)

## Case GRB 191011A - RATIR

### Step 3 - Check the photometry (candidate light curves, limits)

Magnitude of  
the candidate



GRB Trigger Info:  
Draft of GCN circular

Limiting  
magnitude

AB System Photometry (sources within 1 arcmin):  
R.A. Dec, Light curves of all sources

Source Statistics:  
Temporal powerlaw, spectral powerlaw

Photometric Redshift Statistics (src=3600):  
Photo-z

Photometric Calibration Info:  
Zero points, magnitude limit for each color

Exposure Info:  
Time, nb of exposures, field of view

Fits thumbnails:v  
FITS (gzipped) images

Full-frame Images:  
Jpeg images



# Case GRB 191011A - RATIR

## Step 3 - Check the draft of GCN for limiting magnitudes

### GRB Trigger Info:

GRB 191011A triggered at 20191011\_043556.430 UTC ( 1254803770.430000 )  
RA= 44.72820833333333  
DEC= -27.84588888888889  
ERROR= 2.2 [arcsec radius] Swift-XRT

Assuming 0.5 arcsec positional uncertainty in our images, there are 1 sources consistent with the 2.2 arcsec GRB 191011A Swift-XRT error circle.

### Draft GCN:

#### GRB 191011A: RATIR Optical and NIR Observations

Nat Butler (ASU), Alan M. Watson (UNAM), Alexander Kuttyrev (GSFC), William H. Lee (UNAM), Michael G. Richer (UNAM), Ori Fox (STScI), J. Xavier Prochaska (UCSC), Josh Bloom (UCB), Antonino Cucchiara (UWI), Eleonora Troja (GSFC), Owen Littlejohns (ASU), Enrico Ramirez-Ruiz (UCSC), Jesús González (UNAM), Carlos Román-Zúñiga (UNAM), Harvey Moseley (GSFC), John Capone (UMD), V. Zach Golkhou (U. Wash.), and Vicki Toy (UMD) report:

We observed the field of GRB 191011A (XXX, et al., GCN XXX) with the Reionization and Transients Infrared Camera (RATIR; [www.ratir.org](http://www.ratir.org)) on the 1.5m Harold Johnson Telescope at the Observatorio Astronómico Nacional on Sierra San Pedro Mártir from 2019/10 11.26 to 2019/10 11.48 UTC (1.60 to 6.94 hours after the BAT trigger), obtaining a total of 1.64 hours exposure in the r and i bands and 0.49 hours exposure in the Z, Y, J, and H bands.

For a source within the Swift-XRT error circle, in comparison with the USNO-B1 and 2MASS catalogs, we obtain the following detections and upper limits (3-sigma):

i = 21.59 +/- 0.13  
Z = 21.22 +/- 0.21  
Y > 21.76  
J > 19.81  
H > 20.54

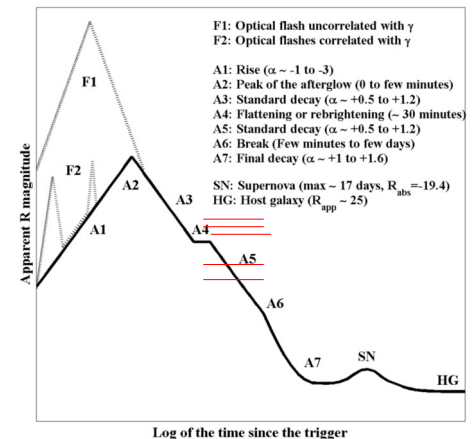
These magnitudes are in the AB system and are not corrected for Galactic extinction in the direction of the GRB.

We thank the staff of the Observatorio Astronómico Nacional in San Pedro Mártir.

#### OPTIONAL BITS:

Further observations are planned.

The source is located at RA, Dec = 2:58:54.78, -27:50:43.7 (J2000, +/-0.5").



Detections

Limiting  
magnitudes



# Home page of GRB events to practice - Analyze the other GRBs by yourself

## </home/svomba/data/robotics/index.html>

### Some RATIR and Coatli Observations from Fall 2019

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#### RATIR

[GRB 191031D](#): short-duration burst. RATIR observed 4.65 to 5.49 hours after the BAT trigger ([public report](#)). Limits only.

[GRB 191016A](#): Detections obtained ([public report](#)).

[GRB 191011A](#): Optical detections and NIR limits obtained ([public report](#)).

[GRB 191001A](#): Fermi GRB detection, OT found by DDOTI! ([public report](#)). [DDOTI Observation](#)

#### Coatli

[GRB 191031D](#): short-duration burst. Coatli observed 5.4 to 7.4 hours after the trigger ([public report](#)). Limits only.

[GRB 191031A](#): limits only ([public report](#)).

[GRB 191016A](#): detections and nice variability ([public report](#)). [Full observation](#).

[GRB 191004B](#): weak detection ([public report](#)).

[ZTF19abvizsw](#): detection, possible untriggered GRB, ZTF source also detected by TESS ([public report](#)).

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