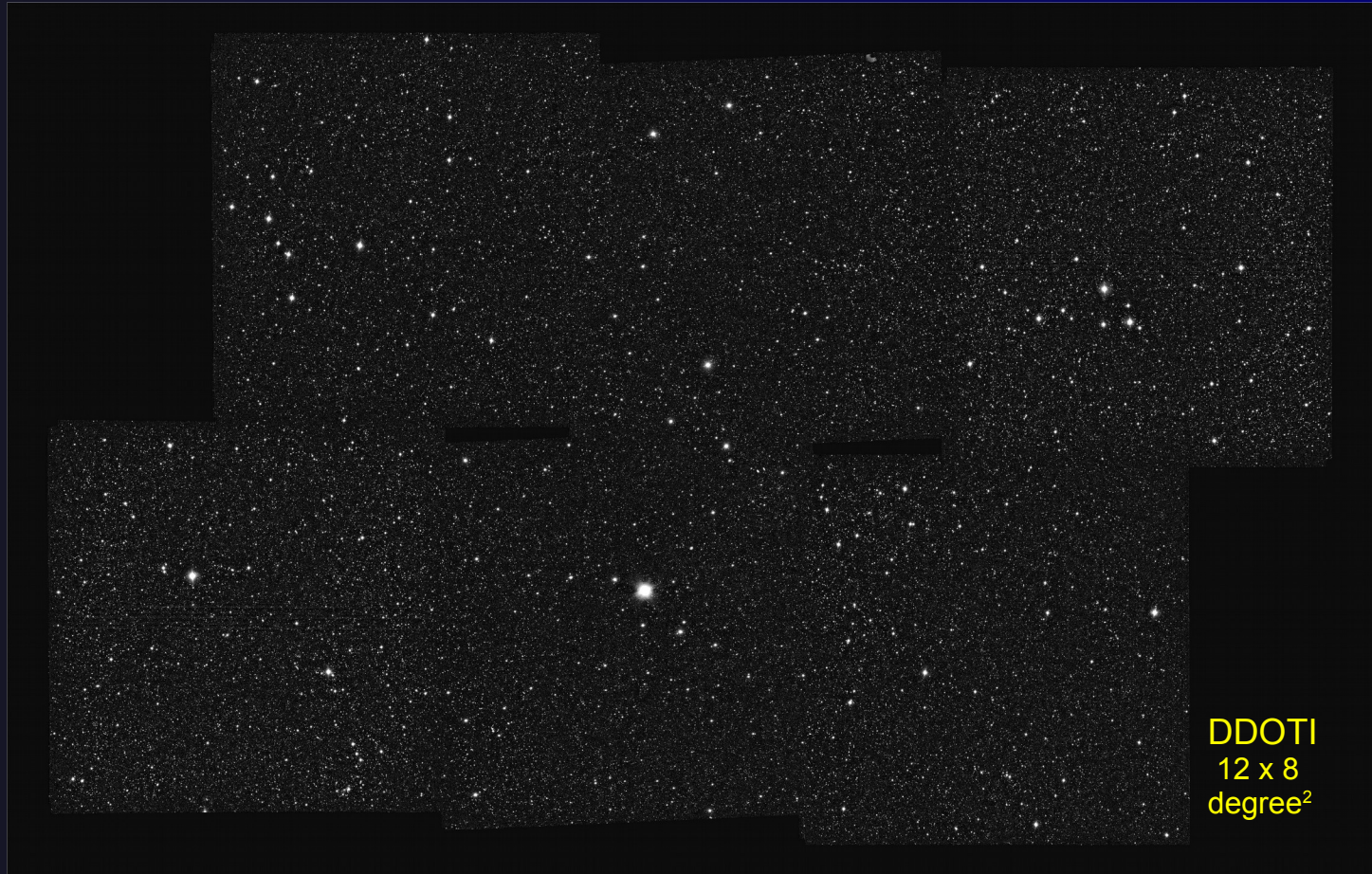


# Colibri Reduction Pipeline



Nat Butler  
(ASU Cosmology Initiative)

# Summary

- \* RATIR pipeline as basis for Colibri

  - active since 2012, unchanged for years now

- \* Active Development on Coatli/DDOTI

  - (same underlying tools, but)

    - more interactive (Coatli)

    - faster (DDOTI)

# Optical/NIR Pipeline Approach

All open source software, running in linux.

Cronjobs and shell scripts: embarrassingly parallel execution.

Core tasks/scripts:

Image reduction (bias-subtraction, flat-fielding, etc.) in cfitsio

Distortion/linearity corrections using custom python scripts

Images aligned with custom python scripts and astrometry.net

Image stacking using swarp

Photometry (aperture or PSF) using a combination of sExtractor and custom python scripts.

# Optical/NIR Pipeline Approach

Higher Level summary:

Images are mapped to a common pixel grid (swarp) → accurate lightcurves AND colors.

Catalog comparison allows for photometric calibration and new source identification.

Webpage to Summarize Results:

Plot lightcurves and SEDs. Determine photometric redshifts. Etc.

# Example: The RATIR 6 channel Camera

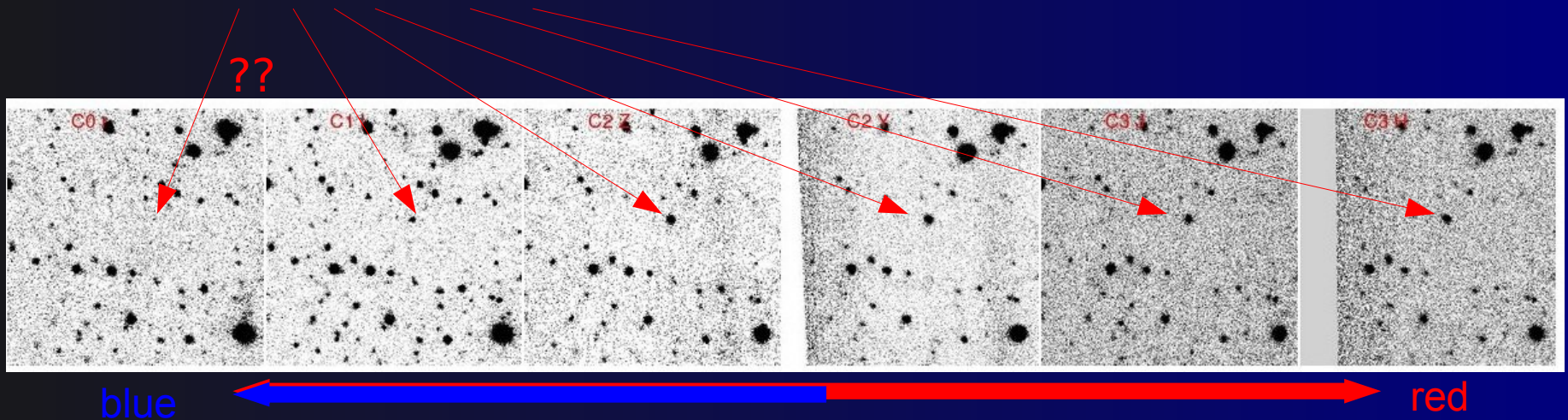
“Reionization And Transients InfraRed camera”

US/Mexican Collaboration.

Online Since Fall 2012.

Simultaneous images in 6 “colors.”

First  $z \sim 6$  GRB detected in June 2013.



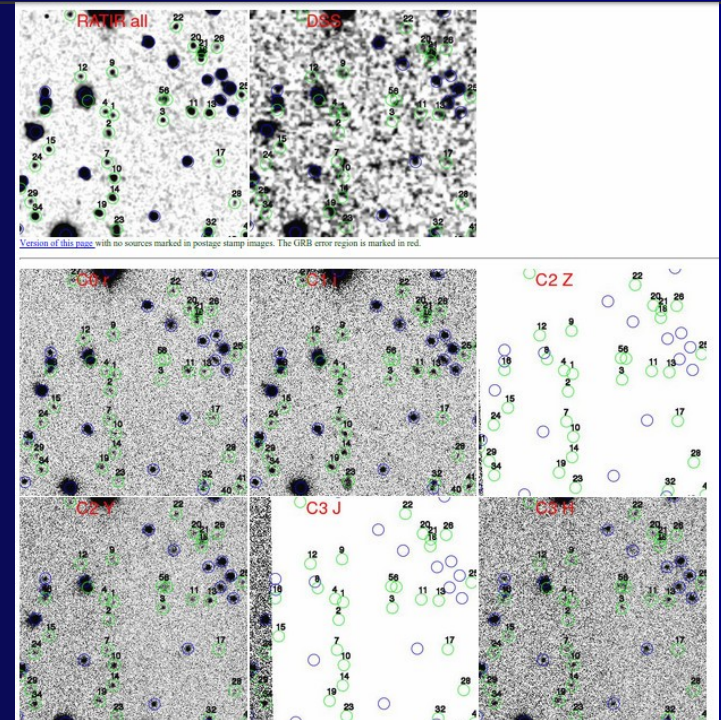
# Fully Automated in Software

Telescope responds within minutes,  
thanks to Alan Watson (and others).

(interrupts, schedules, and slews)

Images (6 channels):  
reduced,  
sources identified,  
compared to existing catalogs.

New sources publicized automatically!



Version of this page, with the sources marked in postage stamp images. The GRB error region is marked in red.

**GRB Trigger Info:**

GRB 130606B triggered at 20130606\_115533.000 UTC ( 1094554947.000000 )  
RA= 218.574  
DEC= 22.111  
ERRDM= 368.0 [arcsec radius] gcn-14795

Assuming 0.5 arcsec positional uncertainty in our images, there are 896 sources consistent with the 360.0 arcsec GRB 130606B gcn-14795 error circle.

Draft GCN:

GRB 130606B: RATIR Optical and NIR Observations

Nat Butler (ASU), Alan M. Watson (UNM), Alexander Kutryev (GSFC), William H. Lee (UNM), Michael G. Richer (UNM), Chris Klein (UCB), Ori Fox (UCB), J. Xavier Prochaska (UCSC), Josh Bloom (UCB), Antonio Cucchara (IRAU/GSFC), Eleonora Troja (GSFC), Sam Laitinen (ASU), Enrique Ramirez-Ruiz (UCSC), Jose A. de Diego (UNM), Leonid Georgiev (UNM), Jesús González (UNM), Carlos Rosan-Zúñiga (UNM), Neil Gehrels (GSFC), and Harvey Moseley (GSFC) report:

We observed the field of GRB 130606B (XXX, et al., GCN XXX) with the Rezonization and Transients Infrared Camera (RATIR; www.ratir.org) on the 1.2m Harold Johnson Telescope at the Observatorio Astronómico Nacional on Sierra San Pedro Mártir from 2013/06 7.16 to 2013/06 7.25 UTC (15.97 to 18.10 hours after the BAT trigger), obtaining a total of 0.36 hours exposure in the r and i bands and 0.36 hours exposure in the Z, Y, J, and H bands.

For a source within the gcn-14795 error circle, in comparison with 2MASS, we obtain the following detections and upper limits (3-sigma):

r	> 22.50 +/- 0.20
i	> 22.17 +/- 0.19
Z	> 22.42
Y	> 21.58 +/- 0.34
J	> 21.18
H	> 21.06

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

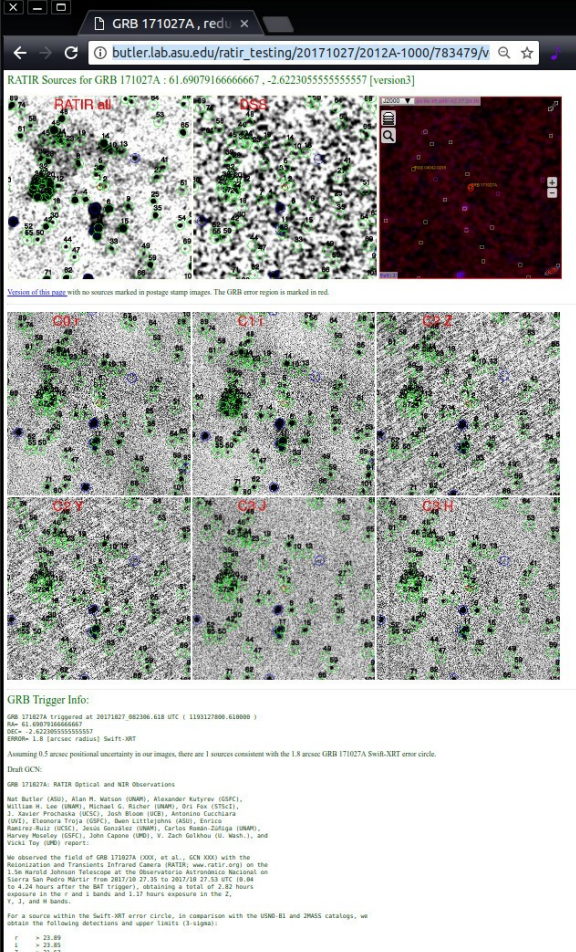
We thank the staff of the Observatorio Astronómico Nacional in San Pedro Mártir.

# An Example RATIR Page

This is an auto-generated webpage  
For a RATIR event in October 2017.

The webpage shows our 6 images, with  
DSS stars and the Swift  
XRT error circle.

The new source is  
identified and a GCN circular is drafted.



RATIR Sources for GRB 171027A : 61.69079166666667, -2.6223055555555557 [version3]

GRB Trigger Info:

GRB 171027A triggered at 20171027\_082306.618 UTC ( 1191217800.618000 )  
RA: 61.69079166666667  
DEC: -2.6223055555555557  
EWOV= 1.8 [arcsec radius] Swift-XRT  
Assuming 0.5 arcsec positional uncertainty in our images, there are 1 sources consistent with the 1.8 arcsec GRB 171027A Swift-XRT error circle.

Draft GCN:

GRB 171027A: RATIR Optical and XRT Observations

Nat Butler (ASU), Alan W. Nelson (UMN), Alexander Kutyrev (OSFC),  
William M. Lee (UMN), Michael S. Richter (UMN), Ori Fox (STScI),  
T. Saverio Peruchina (OSFC), Zach Kruse (UCR), Antonino Galante  
(OSU), Elisavira Treja (OSFC), Dani Littlejohn (ASU), Eric  
Rastner-Russ (OSFC), Jesse Gruber (UMN), Carles Simón-Delgado (UMN),  
Harvey Mestley (OSFC), John Capone (UPM), v. Zach Galikou (U. Wash.), and  
Vladislav (UPM) report:

We observed the field of GRB 171027A (XXX, at zL = GCN XXX) with the  
Redstart and Transient Bifurcated Camera (RATIR, www.ratir.org) on the  
1.5m Nordic Johnson Telescope at the Observatorio Astronómico Nacional on  
Torre San Pedro Norte from 2017-10-27 20:35 to 2017-10-27 23:59 UT (0.84  
to 4.24 hours after the BAT trigger), obtaining a total of 2.82 hours  
exposure in the r and i bands and 1.13 hours exposure in the z,  
y, j, and w bands.

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

r	> 23.89
i	> 23.81
z	> 23.81
y	> 23.81
j	> 23.81
w	> 23.81

# An Example RATIR Page

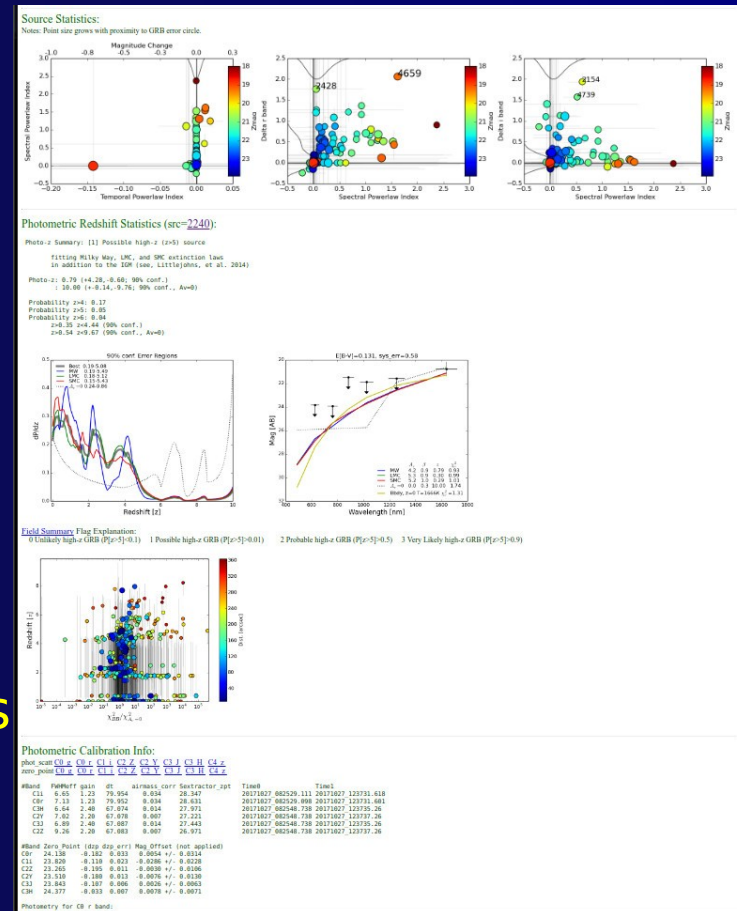
Now look further down the page:

This event is detected in H, and possibly in J, but not bluer.

Color and time histories are used to help identify interesting sources.

Photo-z are calculated (quickly) for all sources in the field.

The new source photo-z and models are plotted along with statements about the photo-z included in GCN.





# Example: The DDOTI



6 telescopes: 70 deg<sup>2</sup> field

# The DDOTI

Also, fully automated in software.

This single image contains 40,000 stars and galaxies.

Find the needle in the haystack!

(All sources shown are catalogued.)

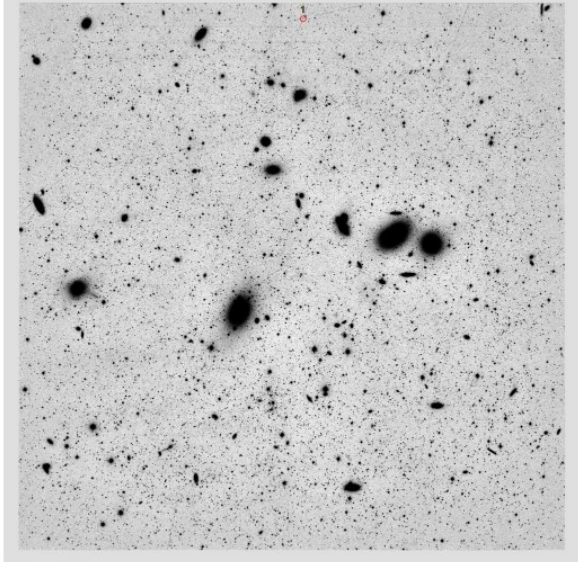
Chromium Web Browser

20170622T044310 17 CO\_W redux - Chromium

file:///home/nrbutler/flat\_test/CO/stack\_20170622T044310\_CO\_W\_17.html

Apps Getting Started free movies invert lightness Plex/Web

DDOTI CO Sources for: RA 187.33078938, Dec 12.57046889 [17 Frame, 20170622T044310 - 20170622T051654]



[Image without circles](#)

USNO-B1 R Band Photometry (Uncatalogued Sources, SNR>10, Nmax=50):

#	id	RA	DEC	mag	mag	mag	tw	shape	shape	ch12	n_detect
1	187.22819280	14.51642800	17.0789	0.0592	6.8000						

[Calibration Source Photometry](#)

Substacks made for this field:

#	file	X-range	Y-range	RA1	RA2	DEC1	DEC2	EXPOSURE	FWHM	Mag.10s	ZeroPoint
f00	stack_CO.fits	1-1887	1-1882	188.386984	189.341666	18.644625	11.594645	1820.0	5.8	18.23	21.44
f01	stack_CO.fits	1888-3774	1-1882	187.311320	188.382462	18.649858	11.596635	1820.0	5.5	17.94	21.36
f02	stack_CO.fits	3775-5661	1-1882	185.275715	187.310749	18.650905	11.594649	1820.0	5.9	17.81	21.37
f03	stack_CO.fits	5662-7549	1-1882	185.275715	186.239649	18.647069	11.589519	1820.0	6.9	17.82	21.40
f10	stack_CO.fits	1-1887	1883-3764	188.701414	189.346317	11.590073	12.645555	1820.0	2.1	19.11	21.31
f11	stack_CO.fits	1888-3774	1883-3764	187.311322	188.386416	11.595205	12.647733	1820.0	1.9	19.31	21.32
f12	stack_CO.fits	3775-5661	1883-3764	186.232259	187.310749	11.597103	12.645560	1820.0	1.9	19.49	21.48
f13	stack_CO.fits	5662-7549	1883-3764	185.269099	186.235883	11.595205	12.639962	1820.0	3.8	18.87	21.51
f20	stack_CO.fits	1-1887	3765-5646	188.395881	189.352976	12.648516	13.696466	1820.0	2.8	19.28	21.31
f21	stack_CO.fits	1888-3774	3765-5646	187.311324	188.396844	12.646116	13.698830	1820.0	2.3	19.13	21.31
f22	stack_CO.fits	3775-5661	3765-5646	186.226767	187.310749	12.648201	13.696471	1820.0	2.8	19.42	21.47
f23	stack_CO.fits	5662-7549	3765-5646	185.262388	186.239655	12.646116	13.694966	1820.0	2.3	19.17	21.49
f30	stack_CO.fits	1-1887	5647-7528	188.399966	189.361986	13.690941	14.649622	1820.0	2.3	18.84	21.33
f31	stack_CO.fits	1888-3774	5647-7528	187.311316	188.393368	13.697627	14.648869	1820.0	2.1	18.84	21.28
f32	stack_CO.fits	3775-5661	5647-7528	186.222783	187.310749	13.699389	14.645723	1820.0	2.2	19.29	21.45
f33	stack_CO.fits	5662-7549	5647-7528	185.252517	186.226190	13.697627	14.642003	1820.0	2.5	18.51	21.50

[Distortion Correction](#)

Total Execution Time for All Tasks: 4.68 minutes [\[logfile\]](#)  
2017-02-14 14:43, 8 users, load average: 4.96, 3.16, 2.22  
Last Updated: Thu Apr 12 03:47:02 UTC 2018 (nrbutler@uwm.edu)

# The DDOTI

For DDOTI, I try to avoid operations directly on the large (6k x 6k) images.

Image operations (e.g. flat fielding) row-wise with cfitsio.

SExtractor/swarp to apply common apertures across frames for photometry.

The rest of the work is in catalog space.

Pipeline runs for 6 cameras on a single 4-core machine!

Chromium Web Browser

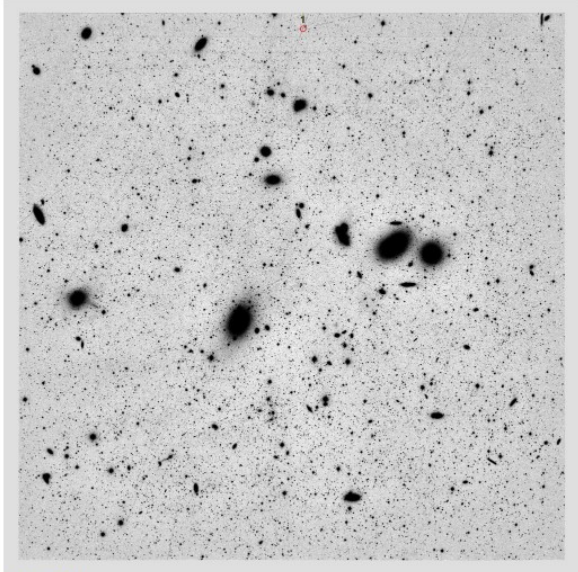
20170622T044310 17 CO\_W redux - Chromium

20170622T044310 x

file:///home/nrbutler/flat\_test/CO/stack\_20170622T044310\_CO\_W\_17.html

Apps Getting Started free movies invert lightness Plex/Web

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[Image without circles](#)

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Substacks made for this field:

#	file	Xrange	Yrange	RA1	RA2	DEC1	DEC2	EXPOSURE	FWHM	Mag:10i	ZeroPoint
f00	stack_CO.fits	1-1887	1-1882	188.386984	189.341666	10.644625	11.594645	1020.0	5.8	18.23	21.44
f01	stack_CO.fits	1888-3774	1-1882	187.313220	188.382462	10.649858	11.596635	1020.0	5.5	17.94	21.36
f02	stack_CO.fits	3775-5661	1-1882	186.235615	187.310749	10.650905	11.594649	1020.0	5.9	17.81	21.37
f03	stack_CO.fits	5662-7549	1-1882	185.275715	186.239649	10.647069	11.589519	1020.0	6.9	17.82	21.40
f10	stack_CO.fits	1-1887	1883-3764	188.301414	189.346317	11.590073	12.645569	1020.0	2.1	19.11	21.31
f11	stack_CO.fits	1888-3774	1883-3764	187.313222	188.386416	11.592205	12.647733	1020.0	1.9	19.31	21.32
f12	stack_CO.fits	3775-5661	1883-3764	186.232259	187.310749	11.597103	12.645569	1020.0	1.9	19.49	21.48
f13	stack_CO.fits	5662-7549	1883-3764	185.269099	186.235883	11.592205	12.639962	1020.0	3.8	18.87	21.51
f20	stack_CO.fits	1-1887	3765-5646	188.395881	189.352976	12.640516	13.696466	1020.0	2.8	19.28	21.31
f21	stack_CO.fits	1888-3774	3765-5646	187.313224	188.396844	12.646116	13.698038	1020.0	2.3	19.13	21.31
f22	stack_CO.fits	3775-5661	3765-5646	186.226767	187.310749	12.648291	13.696471	1020.0	2.8	19.42	21.47
f23	stack_CO.fits	5662-7549	3765-5646	185.262388	186.239655	12.646116	13.694966	1020.0	2.3	19.17	21.49
f30	stack_CO.fits	1-1887	5647-7528	188.399966	189.361986	13.690941	14.649622	1020.0	2.3	18.84	21.33
f31	stack_CO.fits	1888-3774	5647-7528	187.312126	188.392368	13.697627	14.648069	1020.0	2.1	18.84	21.28
f32	stack_CO.fits	3775-5661	5647-7528	186.222783	187.310749	13.699389	14.645723	1020.0	2.2	19.29	21.45
f33	stack_CO.fits	5662-7549	5647-7528	185.252517	186.226190	13.697627	14.642003	1020.0	2.5	18.51	21.50

[Distortion Correction](#)

Total Execution Time for All Tasks: 4.68 minutes [\[log\]](#)  
2017-02-10 14:43, 8 users, load average: 4.96, 3.16, 2.22  
Last Updated: Thu Apr 12 01:47:02 UTC 2018 (nrbutler@amu.edu)

# DDOTI → Colibri

DDOTI utility for Colibri:

Reductions elements have been greatly sped-up versus RATIR.

Can now:

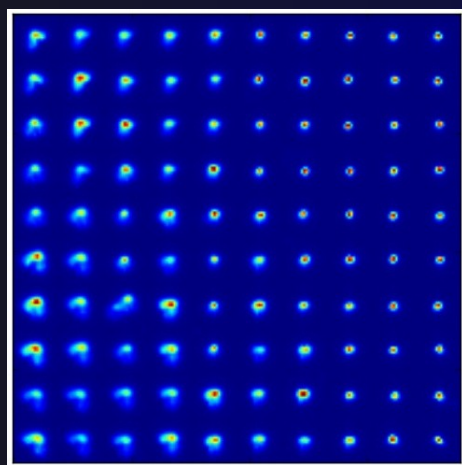
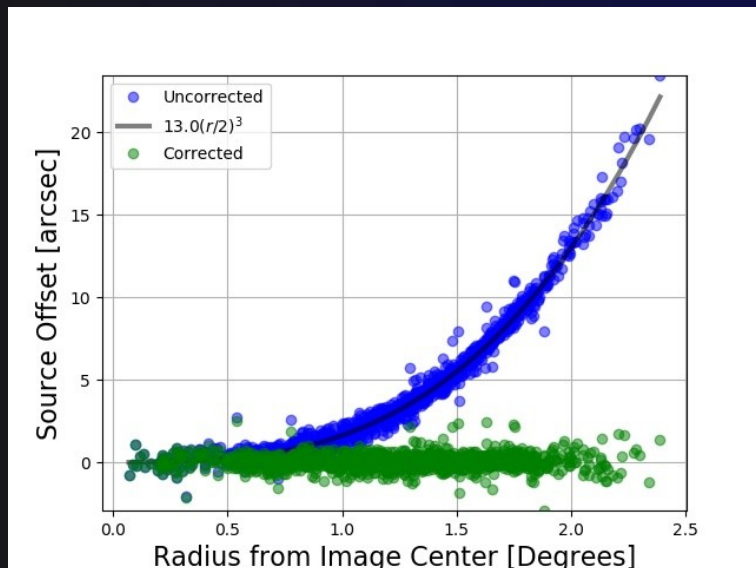
Be faster:

- Handle all files and catalogs in fits binary
- Avoid most python scripts in favor of c

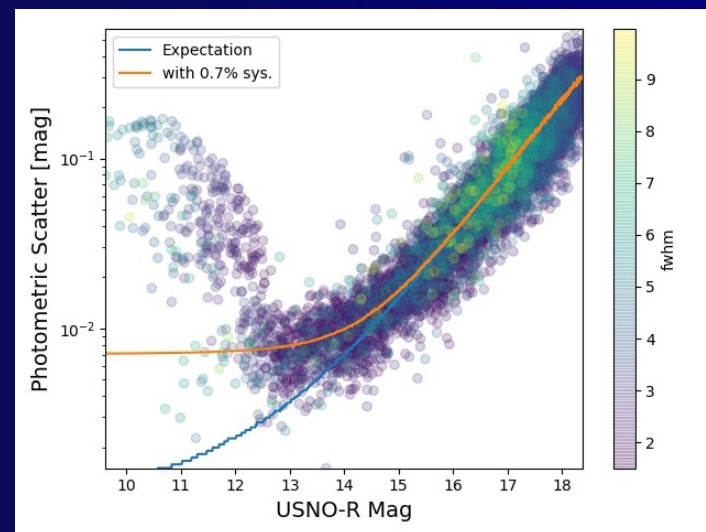
Do more:

- Correct for Distortions and PSF variations
- Remove satellite trails
- Apply sextractor apertures in custom c code
- Utilize local (USNO/APASS) catalogs

# DDOTI → Colibri



+

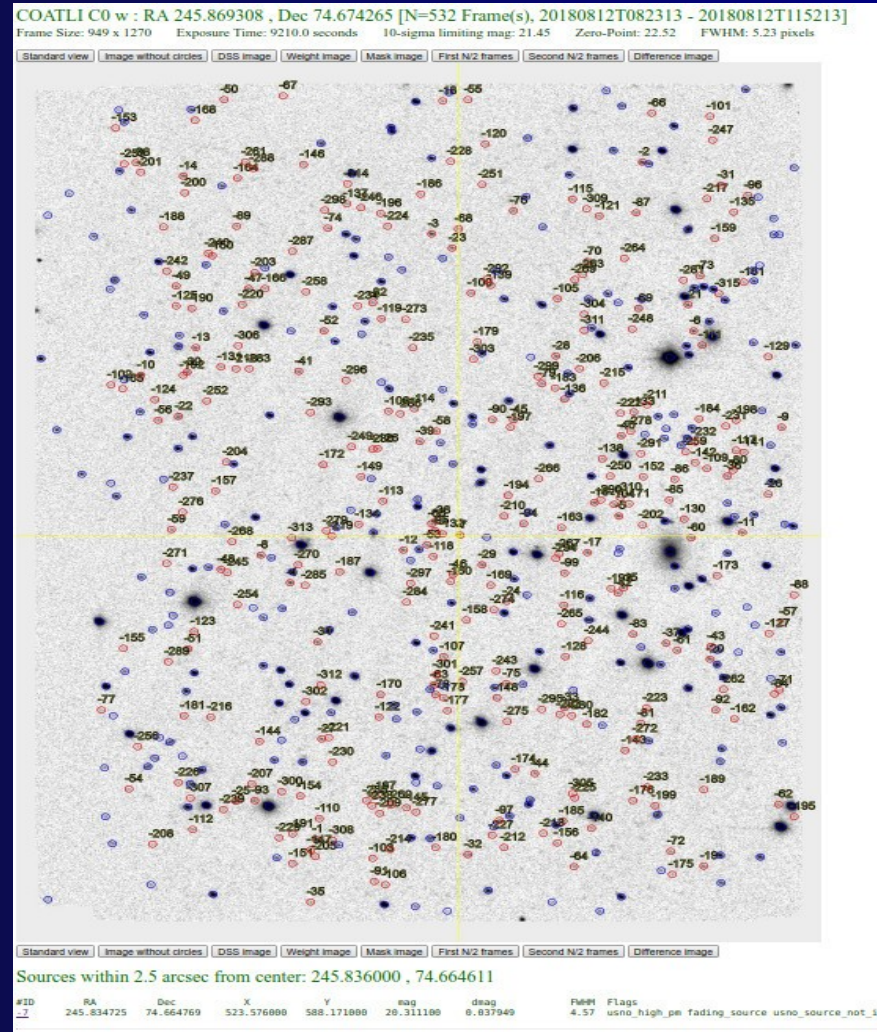


# Final Example: Coatli

Another telescope / pipeline running on San Pedro.

Field of view more like Colibri.

Good example of other visuals and tools that could be provided to an SVOM duty operator.



# Conclusions

I have been working with Damien to understand the Colibri/SVOM requirements.

I have the working RATIR pipeline, very close to what we need.

Rolling out the final Colibri pipeline will depend on seeing data (distortions, noise characteristics, etc.).

Will benefit from development on DDOTI and Coatli.