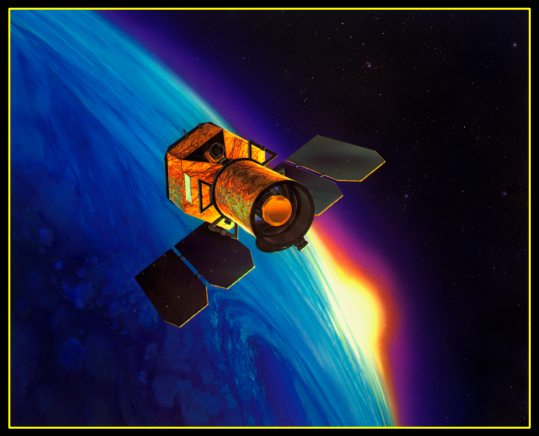
gPhoton: A MAST Archive of Every GALEX UV Photon Event and Software for Lightcurve and Image Creation



Chase Million (Million Concepts)

Bernie Shiao (STScI)

Scott Fleming (CSRA / STScI)

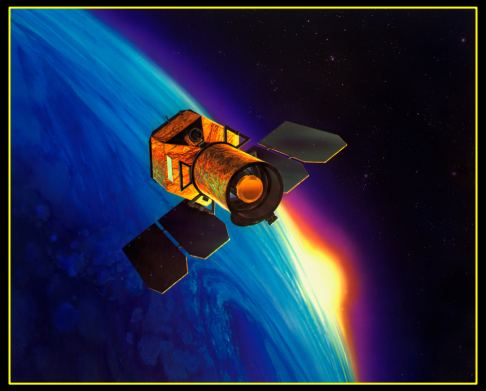
Michael Tucker (STScI summer intern)

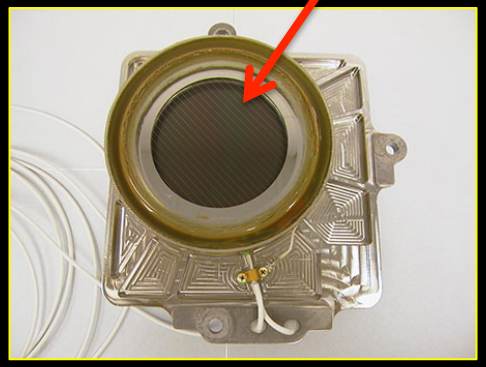
Myron Smith (STScI, retired)

+several early beta testers

The GALEX Mission At A Glance

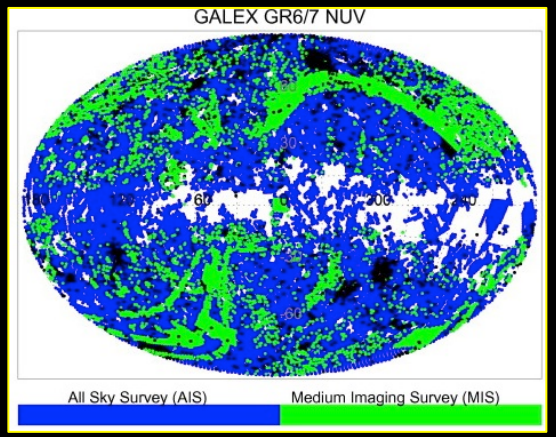
0.005 sec.





- Launched 28 April 2003 — Retired 28 June 2013
- 1.2 deg. diameter FoV — FUV + NUV (simultaneously)
- FUV = 1350-1750 Å — NUV = 1750-2750 Å
- Phot. (5-6" resolution) — Spec. (R ~ 100-250)
- Microchannel Plate Detector — Records photon events (x,y,t)

- Nearly all-sky survey (77% of sky), primary goal was to study star formation history of galaxies. Observed while in Earth's shadow (30 min. max.), could repeat a given field as desired.
- Mission split into several different sub-surveys:
  - AIS = Broad + shallow, *m* ~ 20.5, 100-200 s
  - MIS = Medium, *m* ~ 23, 1,500 s
  - DIS = Deep, *m* ~ 25, 30,000 s
  - NGS, Nearby Galaxies, *S* ~ 27.5, 200+ galaxies
  - GII program for guest observations, CAI for calibrations



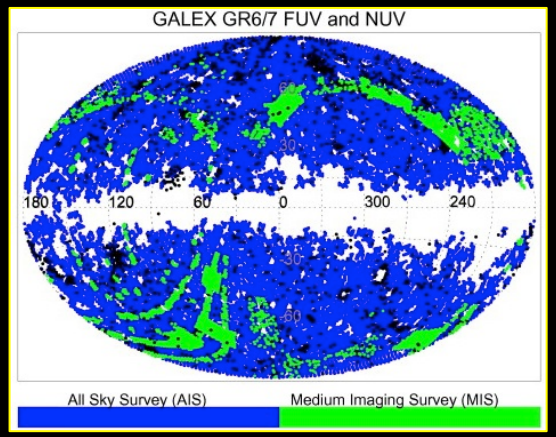
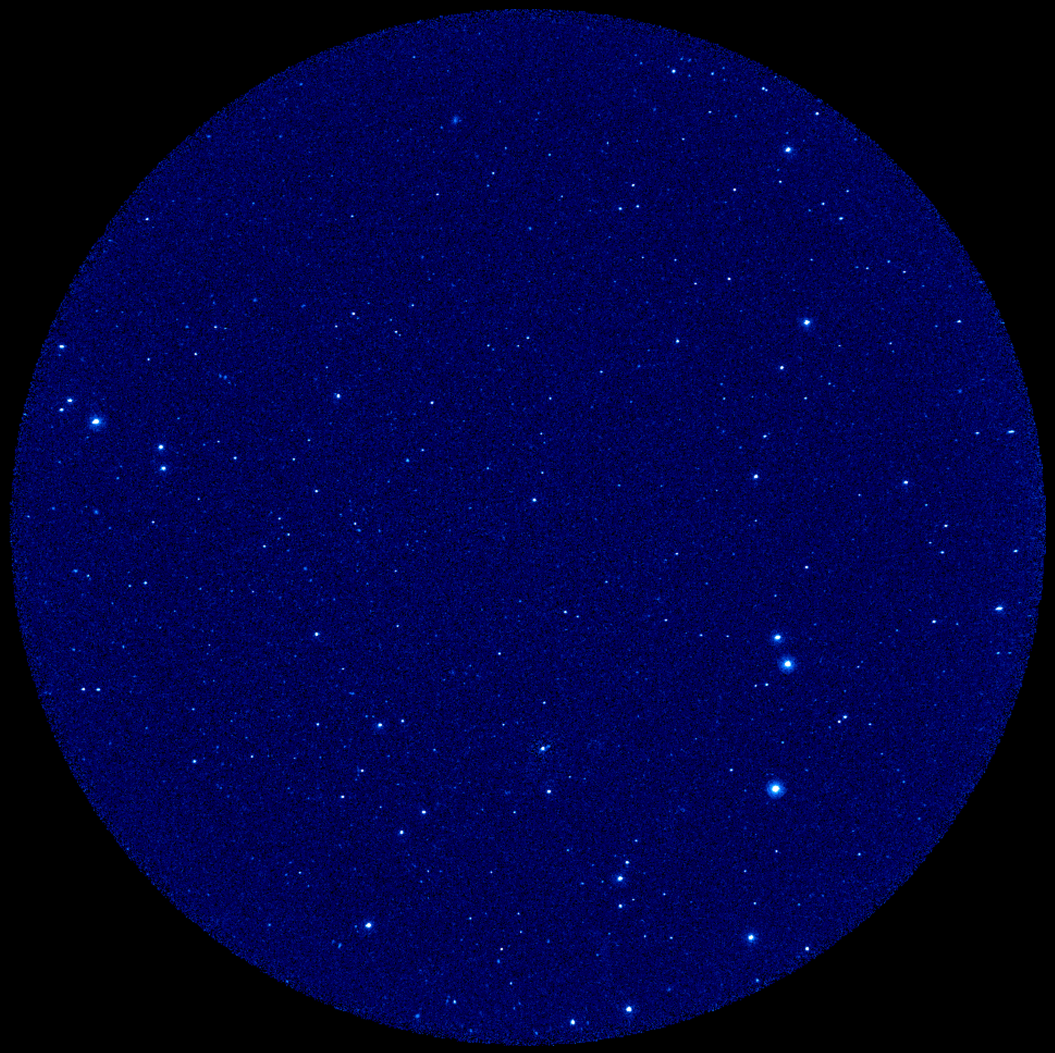


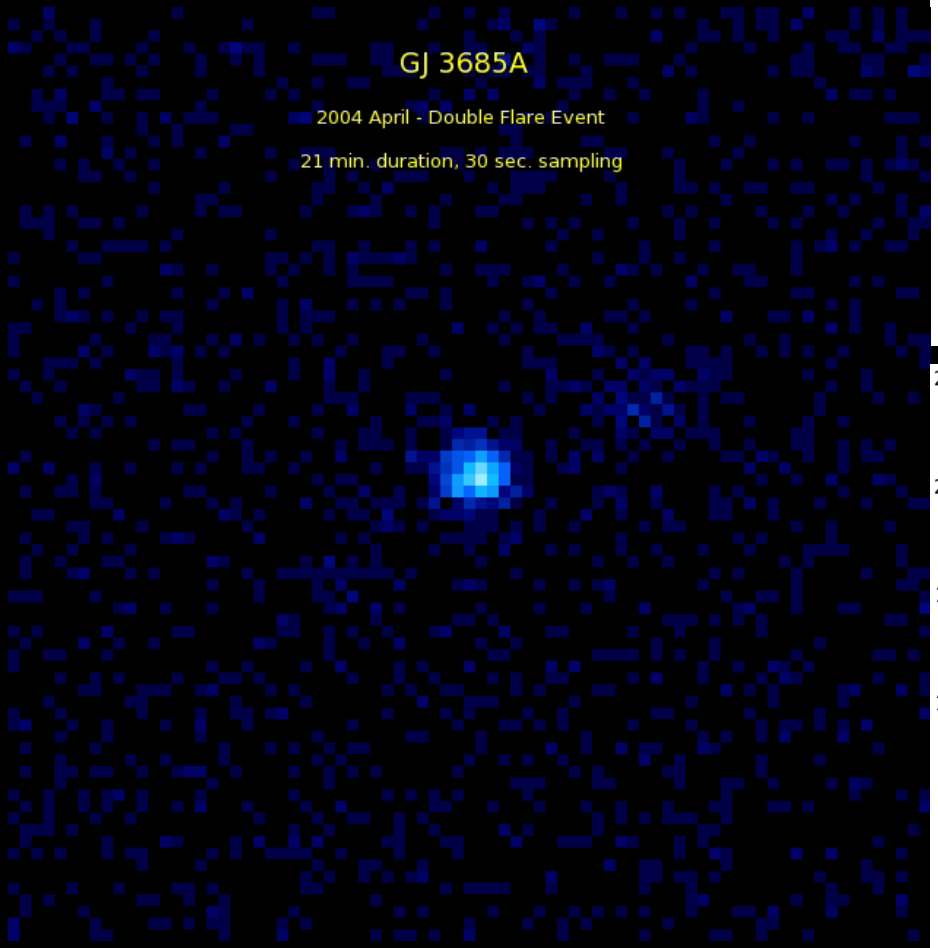
Image credits (right): *Taken from Bianchi, Conti & Shiao 2014, J. Advances in Space Research, 53, 900*

Available GALEX Products – Example Visit Image (20.7 minutes)



GJ 3685A Flare

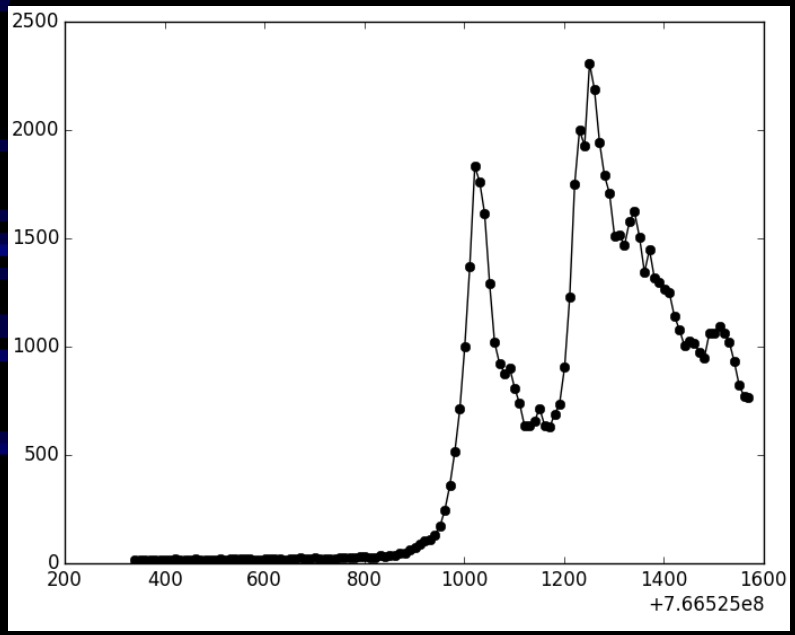
Use gMap and gAperture to study the double-peaked 2004 flare of GJ 3685A.




```
from gPhoton.gMap import gMap

def main():
    gMap(band='NUV', skypos=[176.91975,
0.25561], stepsz=30., skyrange=[0.0333, 0.
0333], cntfile='gj_3685a_count_movie.fits',
trange=[766525335.,766526573.])

if __name__ == '__main__':
    main()
```



gPhoton – How To Install, Available Commands

Software is open-source, written in python.

https://github.com/cmillion/gPhoton

MAST page: https://archive.stsci.edu/prepds/gphoton/

- 1.1 trillion rows, distributed across 10 databases and 999 partitions (130 TB on disk).
- Larger than PanSTARRS 3π catalog (but not as many columns).
- No SQL required – (coordinates, time bins, apertures) all in python wrapper.
- Enables creation of images and light curves at user-defined spatial and temporal scales.

Three primary commands:

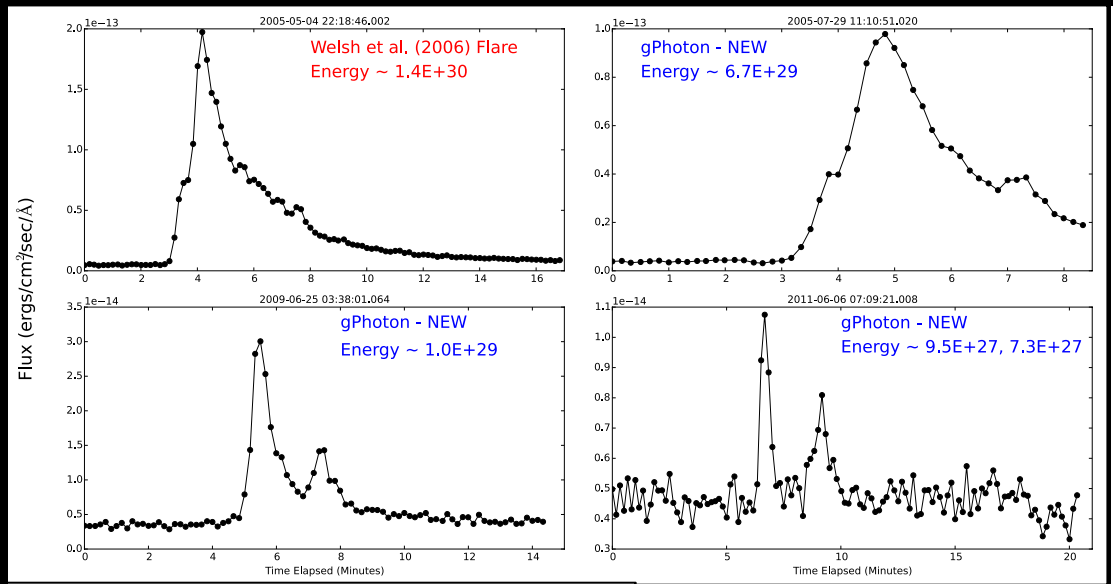
1. gFind – Given a coordinate and area, report available data as observing time ranges.
2. gMap – Given a coordinate, area, and optional step size, create count and/or calibrated images and data cubes (movies).
3. gAperture – Given a coordinate, step size, and optional apertures, create time series lightcurves that include counts and background-subtracted fluxes per time bin.

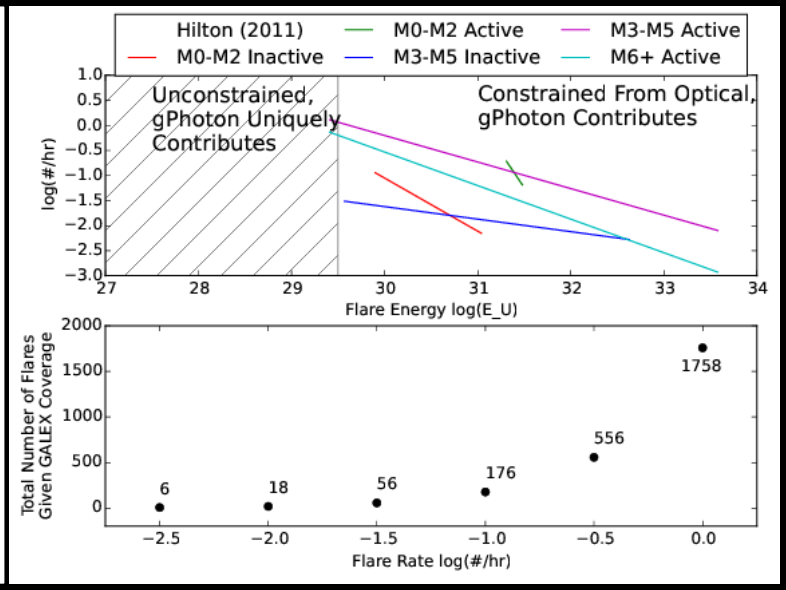
CR Dra Flares

```
from gPhoton.gAperture import gAperture

def main():
    gAperture(band='NUV', skypos=[244.27246917, 55.26919386], stepsz=10., csvfile='cr_dra_lc.csv', radius=0.006, annulus=[0.007,0.009])

if __name__ == '__main__':
    main()
```





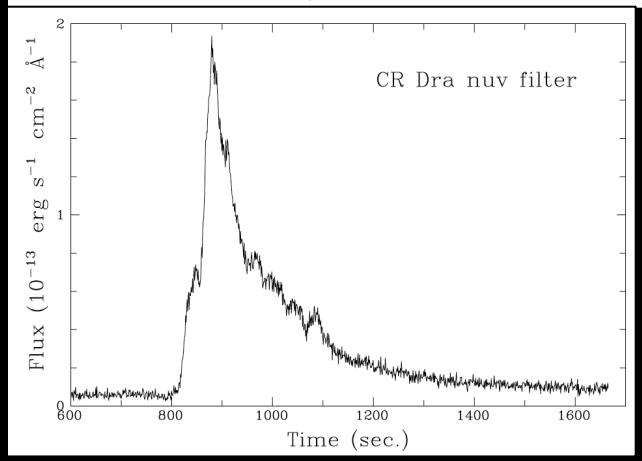
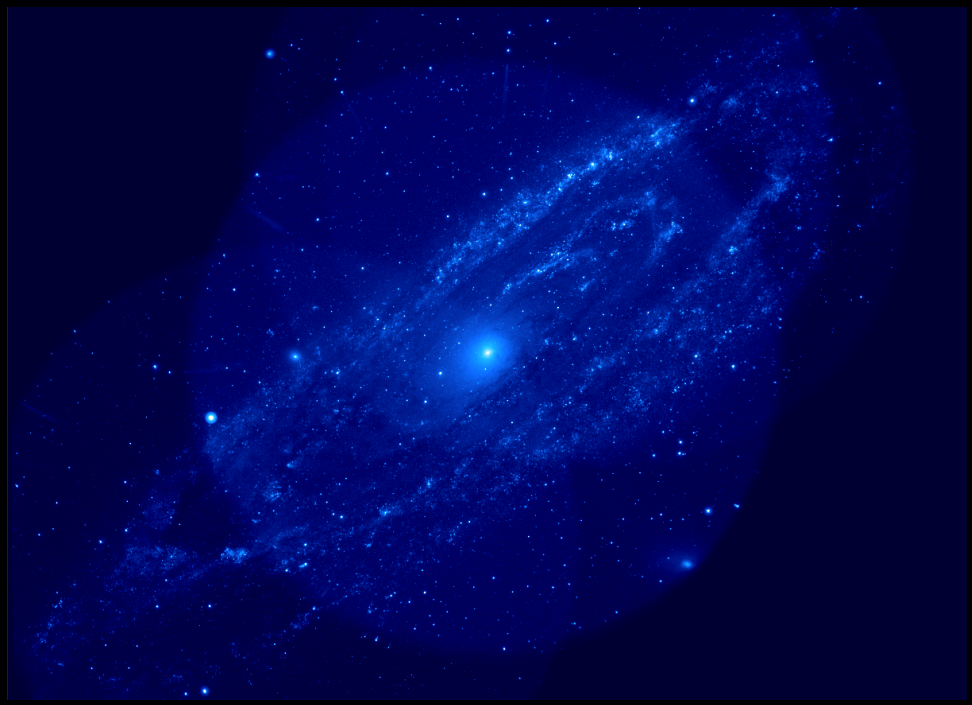


Fig. 1 in Welsh et al. (2006), *A&A*, 458, 921.

M31 Wide-Field Image

Astronomy Picture of the Day, 24 July 2015

gPhoton (NUV)

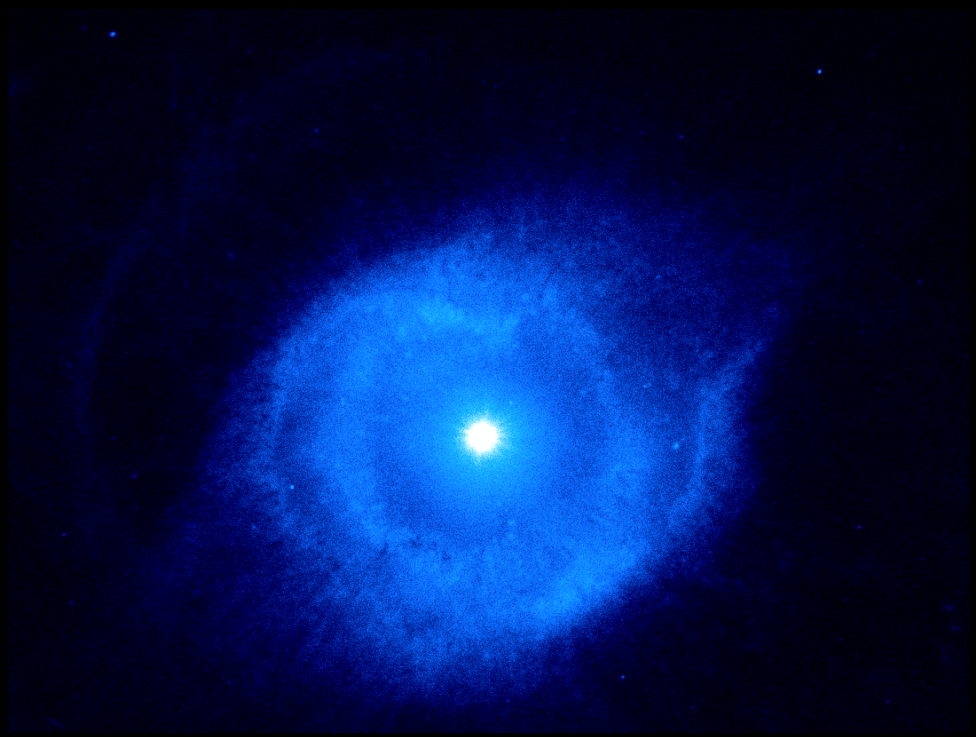


```
[me@mymachine]$ gMap -b 'NUV' --skypos [10.6833,41.2692] --skyrange [3,1] --count
'm31_nuv.fits’ --coadd --memlight 10
```

Some Other Examples

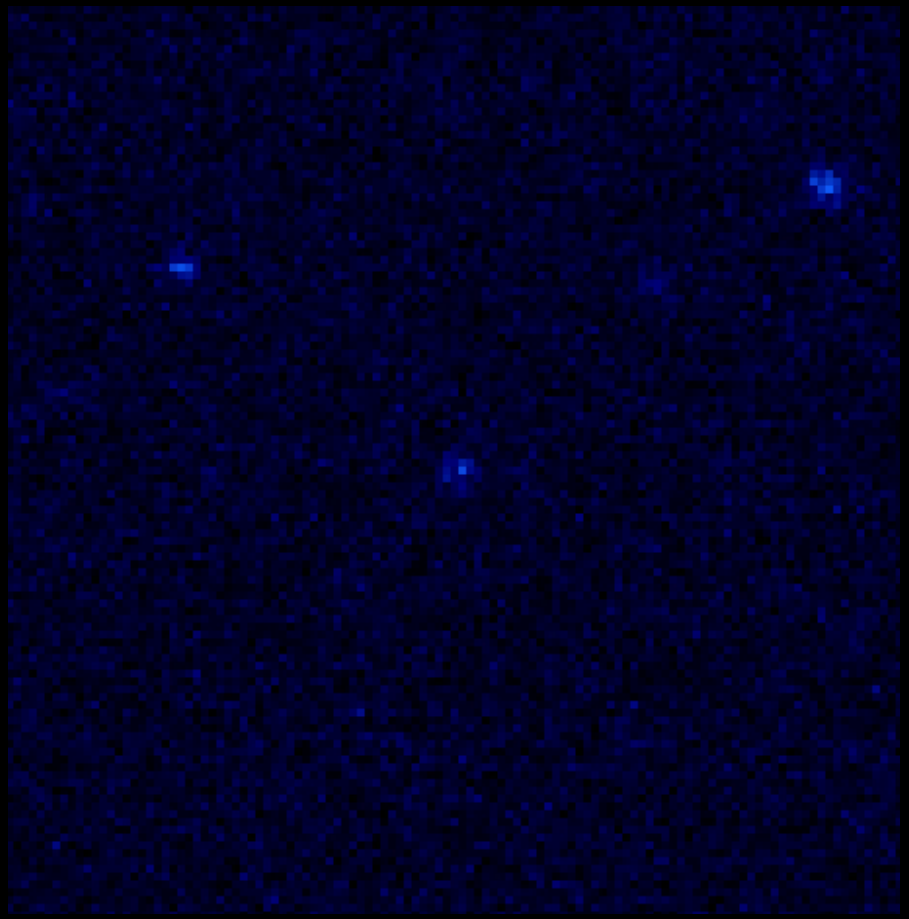
M83 NUV

NGC 7293 (Helix Nebula) FUV

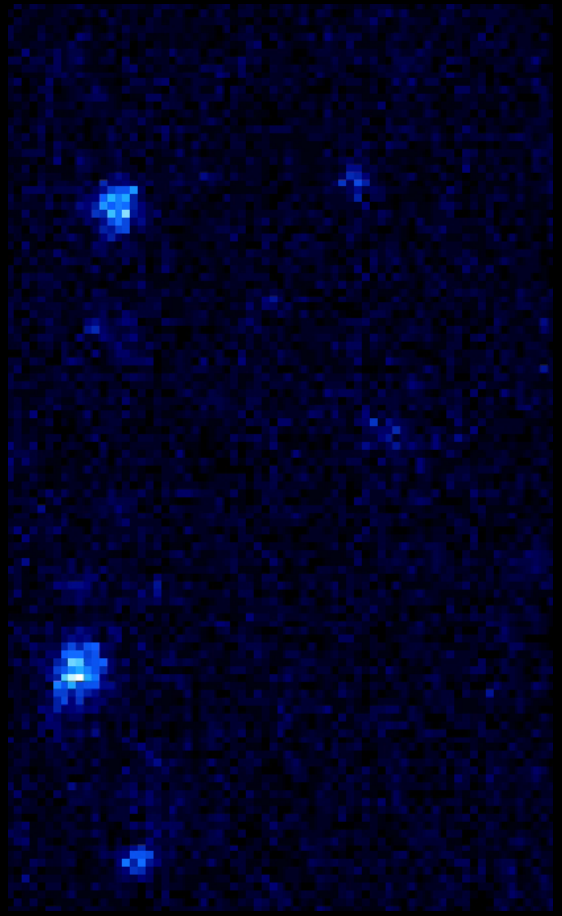


Some Other Examples

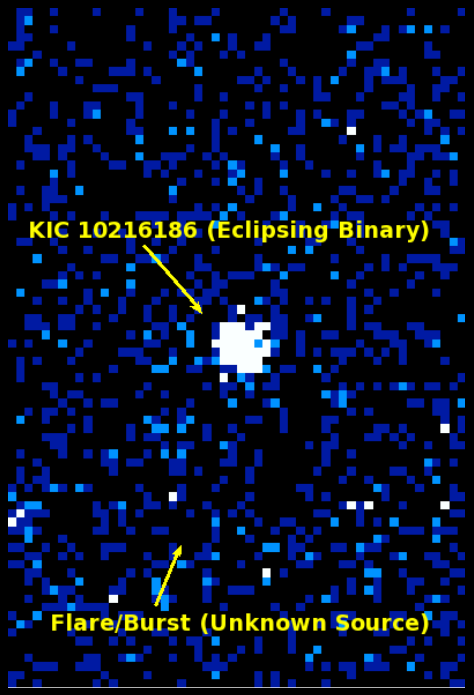
Possible Cataclysmic Variable

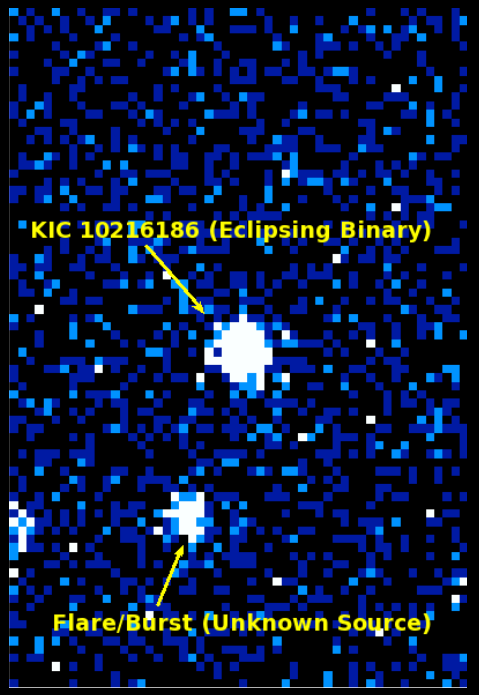


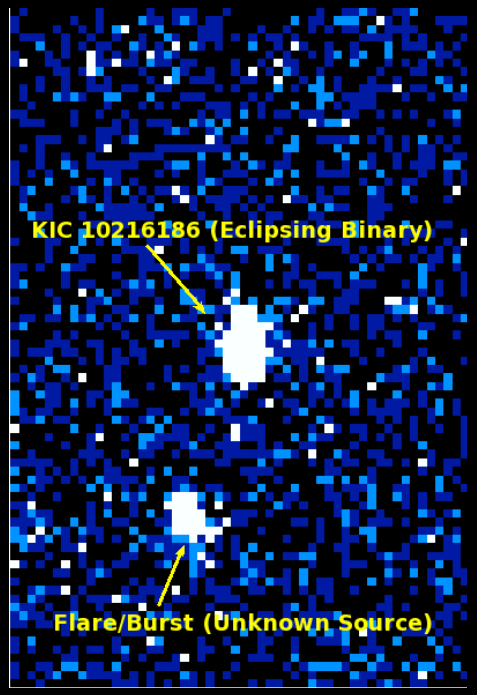
Possible Galactic Outburst

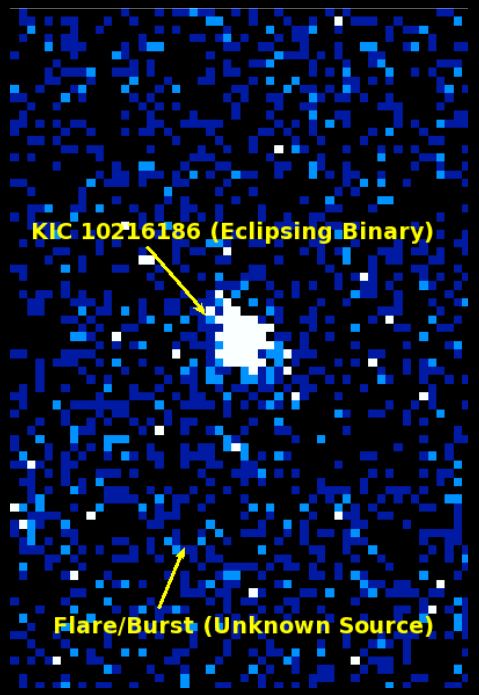


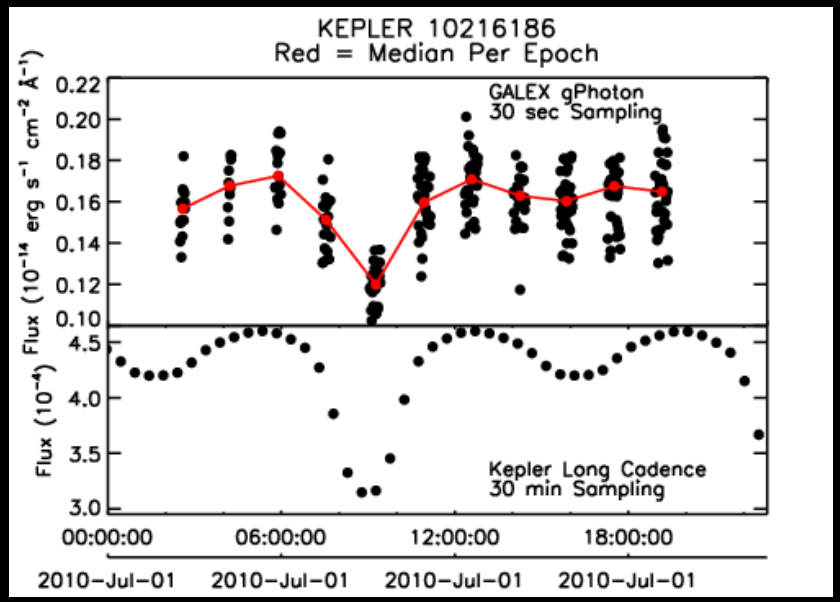
Some Other Examples – Kepler Field







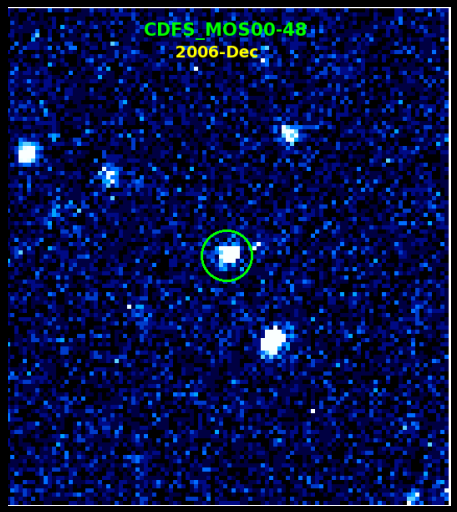




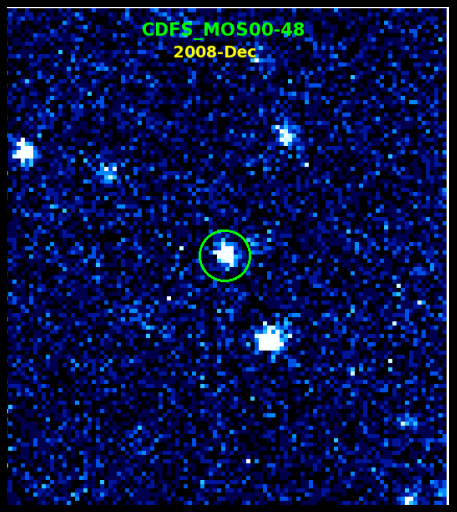
AGN Album Images For Long-Term Variability

This AGN (CDFS MOS00-48, Gezari et al. (2013), *ApJ*, 766, 60) decreases in flux after 7 years. With gPhoton it's easy to create such albums of image frames to look for transients.

2003 Nov.



2006 Dec.



2008 Dec.

2010 Dec.

```
from gPhoton.gFind import gFind
from gPhoton.gMap import gMap

def main():
   # Get sets of observations (min. of 1000 second durations).
   exp_times = gFind(band="nuv", skypos=[53.5173, -27.9419], quiet=True, minexp=1000.)

   # How many of these sets are there?
   n_sets = len(exp_times["NUV"]["t0"])

   # Loop over each obs. set and create a count image.
   for i, t_start, t_end in zip(xrange(n_sets), exp_times["NUV"]["t0"], exp_times["NUV"]["t1"]):
      gMap(band="NUV", skypos=[53.5173, -27.9419], skyrange=[0.06666,0.06666], cntcoaddfile="coadd_ep"+'{0:03d}'.format(i+1)+".fits", trange=[[t_start, t_end]],
overwrite=True)

if __name__ == "__main__":
   main()
```

gPhoton Status

- Public as of Aug. 2015. v1.27.0 = latest branch, calibration improvements, flagging.
- Intro. paper to be submitted (likely to ApJ) in a few weeks (v1.27.0 tied to paper).
- Roadmap for future development includes: GUI, support for spectra, support for other time-tagged missions, simulator / source injector, job management.
- MAST-led science: Project Blacklight = catalog of all GALEX sources that undergo variation at < 1 hour time scales (S. Fleming).
- White dwarf pulsators, eclipsing objects, stellar flares, SNe shock breakouts, sdB stars, Be stars, CVs, XRBs, other transients(?).
- Great synergy with PanSTARRS (deep, high spatial resolution images and optical colors for classification).
- Lessons learned (large, on-demand database of atomic-level data, server configuration, package development) applicable to TESS FFIs.
- *TESS light curves on demand, without ever having to download a FITS file.*