

# The Flaring UV Sky

B.Y. Welsh, J.M. Wheatley (University of California Berkeley), K. Heafield, M. Seibert (Caltech), S.E. Browne (University of California Berkeley) and the GALEX Science Team

## The GALEX Mission

GALEX is a NASA Small Explorer, launched in April 2003, and is currently surveying the sky at UV wavelengths from 1350-2800Å.

Several imaging surveys are currently underway:

- AIS: All Sky Survey, 40000 degrees<sup>2</sup> to AB=20.5 mag
- MIS: Medium Imaging Survey, 1,000 degrees<sup>2</sup> to AB=23 mag
- DIS: Deep Imaging Survey, 80 degrees<sup>2</sup> to AB=25 mag
- NGS: Nearby Galaxy Survey, 240 degrees<sup>2</sup> to AB=23 mag

Data is recorded as time-tagged photon events, enabling high time-resolution UV photometric observations.

Public releases of GALEX data are available at [galax.stsci.edu](http://galax.stsci.edu), at the Multi-Mission Archive at Space Telescope (MAST).

## UV Photometric Variability

GALEX has two photometric bands, NUV (1350-1750Å) and FUV (1750-2800Å), which operate simultaneously.

The GALEX Data Analysis Pipeline (Martin et al. 2005) uses Source Extractor software (Bertin and Arnouts 1996) to detect sources and compute aperture photometry on them, resulting in an AB magnitude (Oke 1974) in each photometric band.

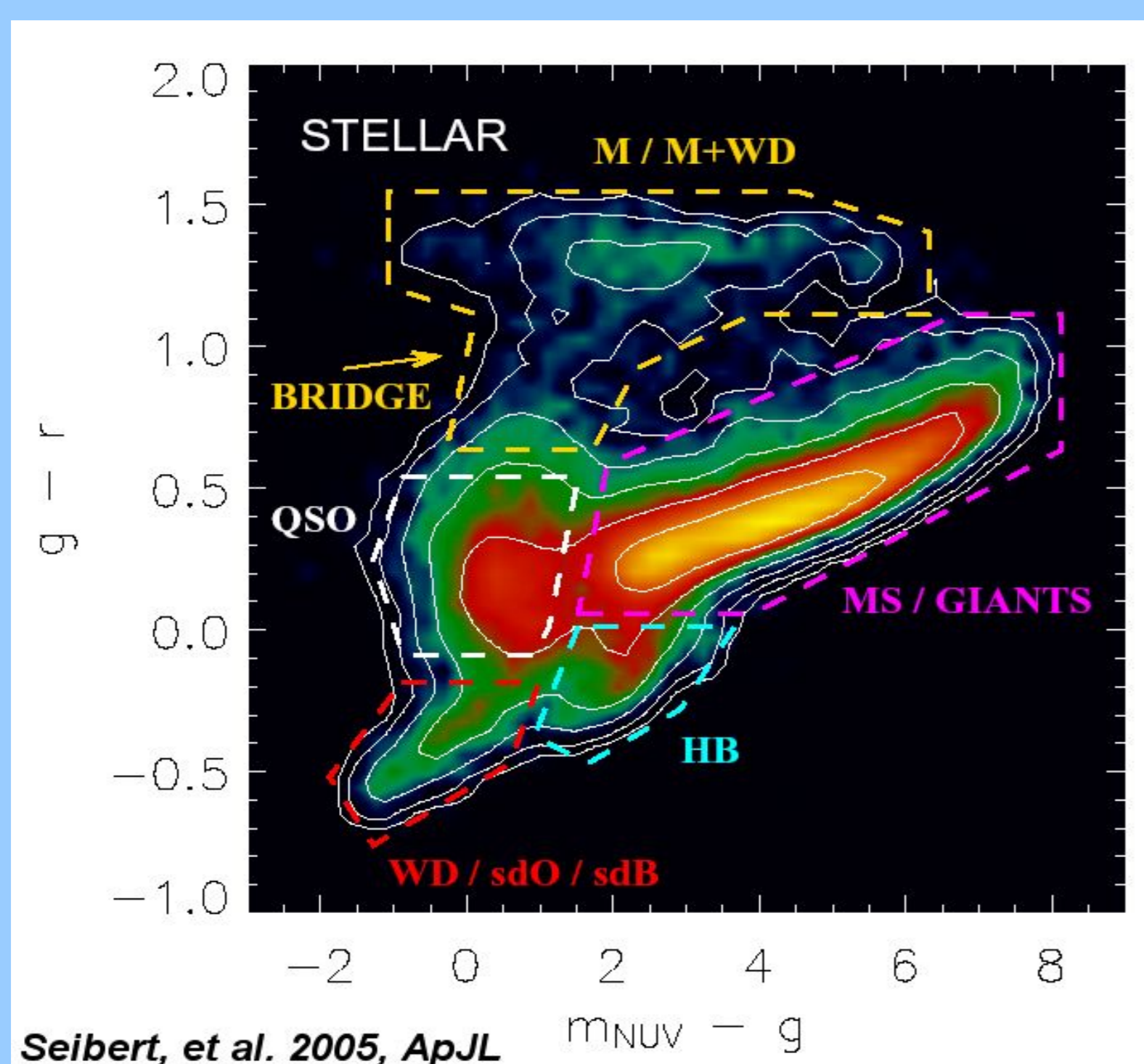
Variable sources are those that vary by more than the GALEX magnitude error in multiple observations, transients are sources that appear only once

GALEX has serendipitously obtained FUV and NUV light curves of numerous variable and transient astronomical objects in its first year of operations.

## The GALEX UV Variability (GUVV) Catalog

- The initial version of the catalog contains 91 variable and transient sources
- The GUVV ID contains the mean sexagesimal RA and Dec of the GALEX source
- GALEX data are summarized by the number of observations (Nobs), Number of detections (Ndet), Maximum brightness (Max, in AB mag), and brightness change ( $\Delta m$  in AB mag), for both NUV and FUV detectors.
- USNOB-1.0 catalog designations are included where available
- A portion of the GUVV catalog is shown below

GUVV ID	Discovery Survey	USNO-B1.0	ID	Type	Nobs	Ndet	NUV Max	m	Nobs	Ndet	FUV Max	m
J004347.9+421654.9	NGS	1322-0015866	CC And	Delta Sct	6	4	13.07	0.67	4	4	16.07	0.93
J004548.2+435509.1	DIS	0460-0006826			10	10	16.00	1.38	9	9	18.59	3.77
J010732.6+360956.5	NGS	1261-0017670	1RXS J010732.1+361001	X-ray source	2	2	20.01	0.60	2	2	21.47	0.55
J085218.1+311047.2	AIS	1211-0164505			3	3	15.00	0.33	3	3	18.77	0.37
J090054.7+303113.3	AIS		SDSS J090054.67+303113.3		2	1	19.69	-	2	1	20.92	-
J090808.2+004610.9	MIS				3	3	17.99	2.47	2	2	18.56	2.88
J090904.4+091714.4	AIS	0892-0180755	SDSS J090904.4+091713.1		3	1	17.96	-	1	1	18.11	-
J091324.0+091417.9	AIS	0992-0184047			3	1	19.93	-	1	1	20.15	-
J091557.2+094633.2	AIS	0997-0194437			3	3	18.89	0.10	0	0	-	-
J092458.8+021834.1	AIS	0923-0226013			2	1	19.31	-	0	0	-	-
J092551.9+015545.6	AIS	0919-0205611	HD 81463	A0 star	2	1	17.36	-	1	1	19.70	-
J092620.4+034541.8	AIS	0937-0186908			2	2	17.91	1.88	2	2	18.31	1.95
J092851.8+041630.0	AIS	0942-0172841	FIRST J092851.8+041630	Radio source	2	2	17.95	1.13	2	2	18.81	0.37
J093026.0+071221.6	AIS	0972-0216018	WW Leo	RR Lyrae-ab	2	2	15.83	0.97	1	1	19.51	-
J095801.1+021250.0	DIS	0922-0237968			93	2	19.68	3.42	1	1	20.67	-
J095816.1+014843.6	DIS	0918-0208424			47	1	20.04	-	1	1	21.33	-
J100133.3+014328.4	DIS	0917-0193609			96	82	17.21	2.00	26	26	19.01	4.85
J100141.5+020758.8	DIS	0921-0232170			140	97	20.82	2.22	10	10	21.89	1.80
J100152.1+021158.5	DIS	0921-0232199			93	89	18.80	3.10	70	70	20.62	2.58
J100209.5+020726.5	DIS	0921-0232253			93	2	19.58	2.38	2	2	19.73	2.65



Seibert, et al. 2005, ApJL

Figure 1. Color-color plot of GALEX sources using SDSS g-r color and GALEX NUV-g color.

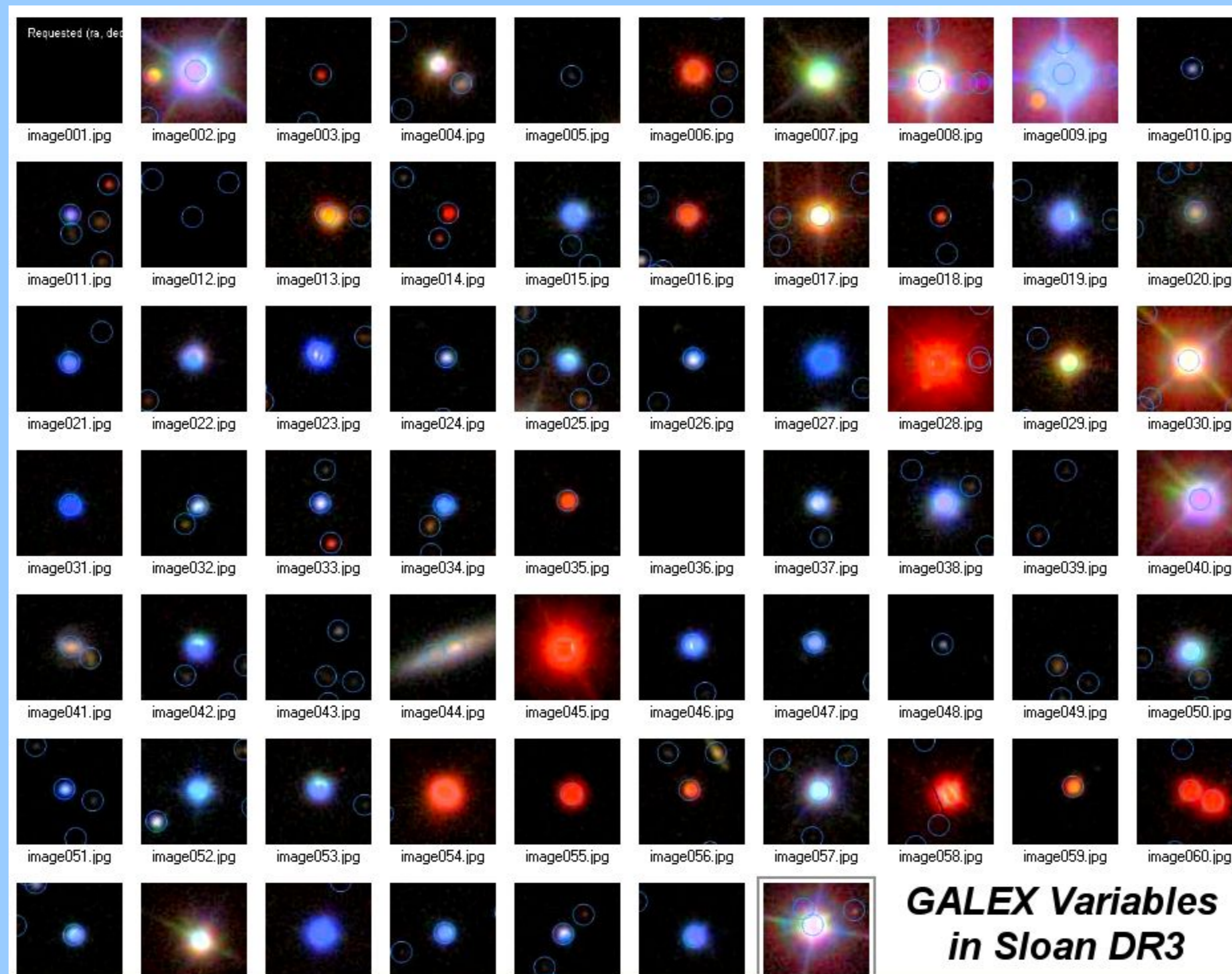


Figure 2. Sloan Digital Sky Survey (SDSS) images of GALEX variable objects from Data Release 3.

## How Many Variable Objects Will GALEX Detect?

- Based on the present rate of detection, GALEX should see 982 variable and transient sources during its mission lifetime

Survey Mode	Square degrees surveyed	Number of sources seen	Detections per square degree	Square degrees planned	Sources expected
AIS	2729	52	0.019	40,000	745
MIS	129	13	0.101	1,000	101
DIS	15	18	1.200	80	96
NGS	49	8	0.163	244	40
Total		91			982

## Examples of Source Variability

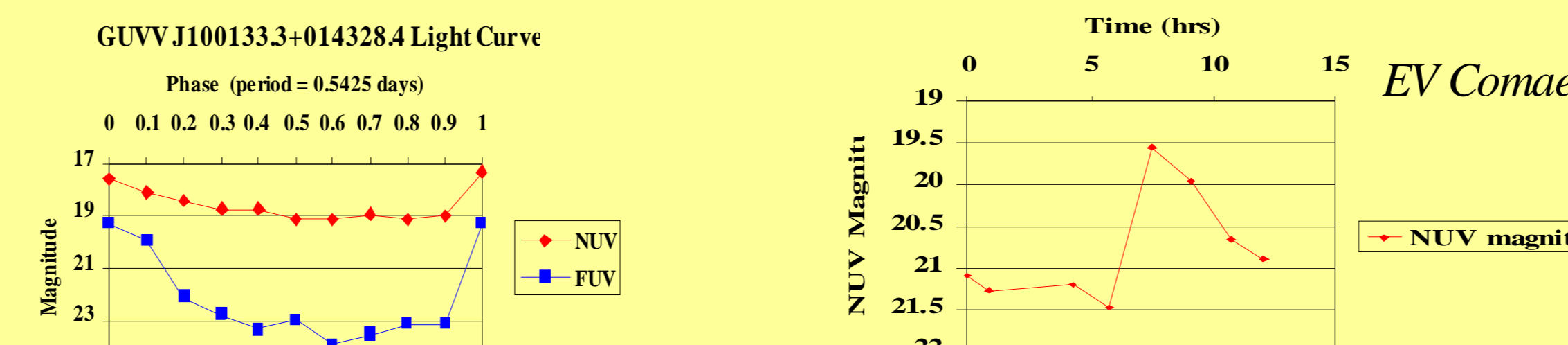
### RR Lyrae Stars

FUV brightness variation of 4-6 magnitudes is much larger than the ~1 mag variation observed in the visible

The FUV flux emitted by RR Lyrae stars varies greatly as the stellar temperature varies from 6000-8000K during radial oscillations

UV observations combined with visible light curves enable the determination of RR Lyrae metallicity

For a detailed discussion of the ultraviolet properties of RR Lyrae stars as seen by GALEX, see Wheatley, et al. 2005. (Available on Astro-ph)



## References

- Bertin, E. and Arnouts, S. 1996. SExtractor: Software for source extraction. A&A Supp. 117:393-404.
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- Oke, J.B. 1974. ApJ. Supp. 27:21.
- Robinson, et al. 2005. An Energetic Ultraviolet Flare on the dM4e Star GJ 3685A. In preparation.
- Seibert, et al. 2005. GALEX Observations of the Sloan Digital Sky Survey: A Comparison. ApJ Lett. accepted.
- Wheatley, J. et al. 2005. Large-Amplitude Ultraviolet Variations in the RR Lyrae Star ROTSE-J143753.84+34924.8. ApJ Lett. accepted.

## M-dwarf Ultraviolet Flares

GALEX has observed two massive flares on dMe-type dwarf stars at sub-second time resolution.

The April 2004 flare on the dM4e star GJ 3685A is illustrated below. This flare is 20 times more energetic than previously observed UV flares on M dwarfs. In addition to the two main peaks, numerous smaller microflares can be seen.

GALEX observed an increase of 6 magnitudes in 200s in both FUV and NUV

Four additional UV light curves of less intense M dwarf flares have also been obtained by GALEX

The brightest dM flares seen by GALEX have distances < 30pc

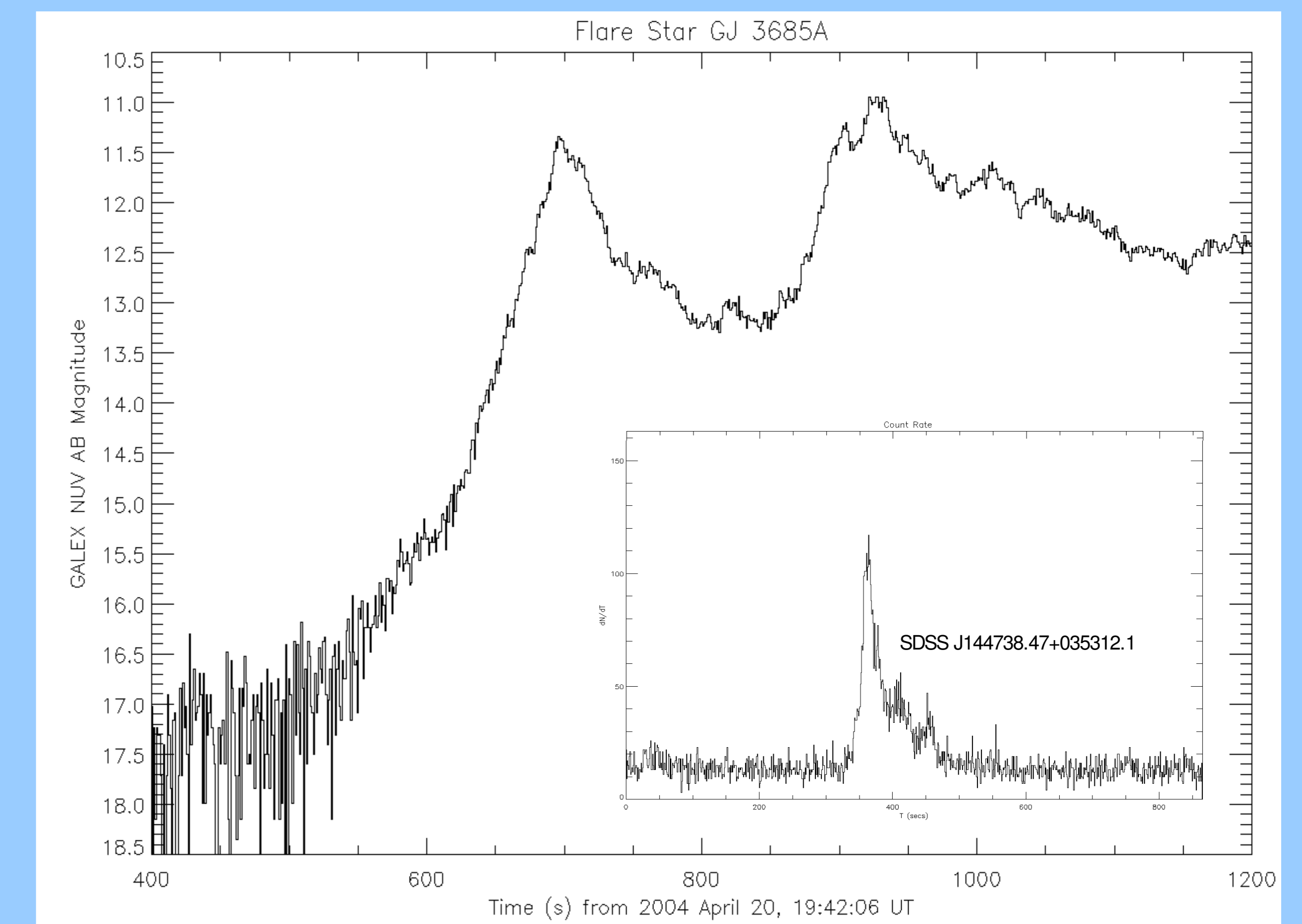


Figure 2. GALEX NUV (1750-2800Å) light curve of flare star GJ 3685A showing a six magnitude increase in 200s. Inset: A much smaller flare on the star SDSS J144738.47+035312.1.



Figure 3. GALEX images taken before (left) and during (right) the GJ 3685A flare.

## Implications

GALEX has repeated observations of 1.8% of the total area of the sky in 1.4 million seconds of integration time.

Based on the number of flares detected and the average energy per flare, we derive a total UV luminosity input (1350-2800Å) into the local ISM of  $3 \times 10^{28}$  ergs/s

-- This is equivalent to only  $10^{-5}$  of a B0 star luminosity

Based on energetics alone, although the majority of these flares are at distances of less than 30pc from the Sun, this total flux is insufficient to make a significant contribution to the ionization of the local interstellar medium.

Author contact: Barry Welsh, [bwelsh@ssl.berkeley.edu](mailto:bwelsh@ssl.berkeley.edu)