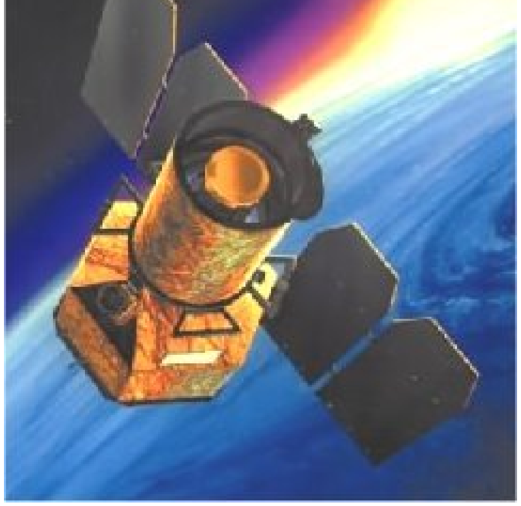
Searches for Flares and Flashes with GALEX



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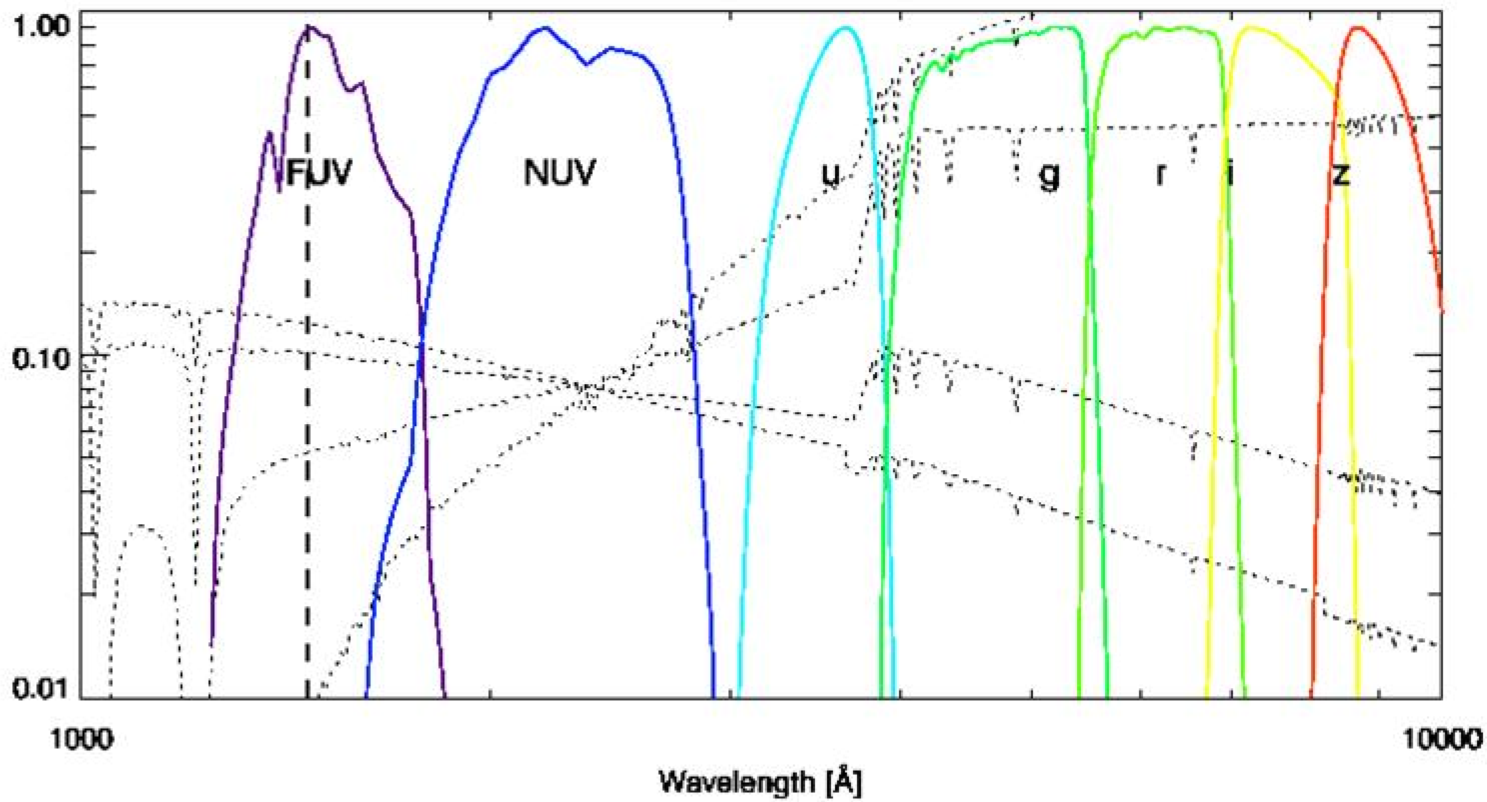
Transient Universe -- March 13, 2006

Outline

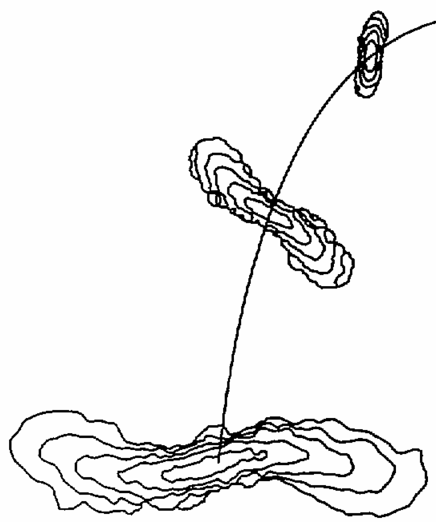
i. Capability of GALEX to Study Variability
ii. Tidal Disruption Flares: Theory and Observations
iii. Search for Flares with GALEX
iv. Search for Flashes with GALEX
v. Future Dedicated Time Domain Survey

Capabilities of GALEX

- Time-tagged photon data (time resolution of 5 msec)
- Deep Imaging Survey Fields (>30 ksec accumulated over 3 years)
- Large field of view (1.2 sq. deg.) and a large survey volume
- Low sky background (source detection with 10 photons)
- Simultaneous NUV (1750 - 2750 Å) and FUV (1350 - 1750 Å) imaging
- Simultaneous R=100/200 NUV/FUV spectroscopic grism data



Tidal Disruption Events



A star will be disrupted when:

$R_p < R_T \approx R_\star (M_{BH}/M_\star)^{1/3}$

Evans & Kochanek (1989)

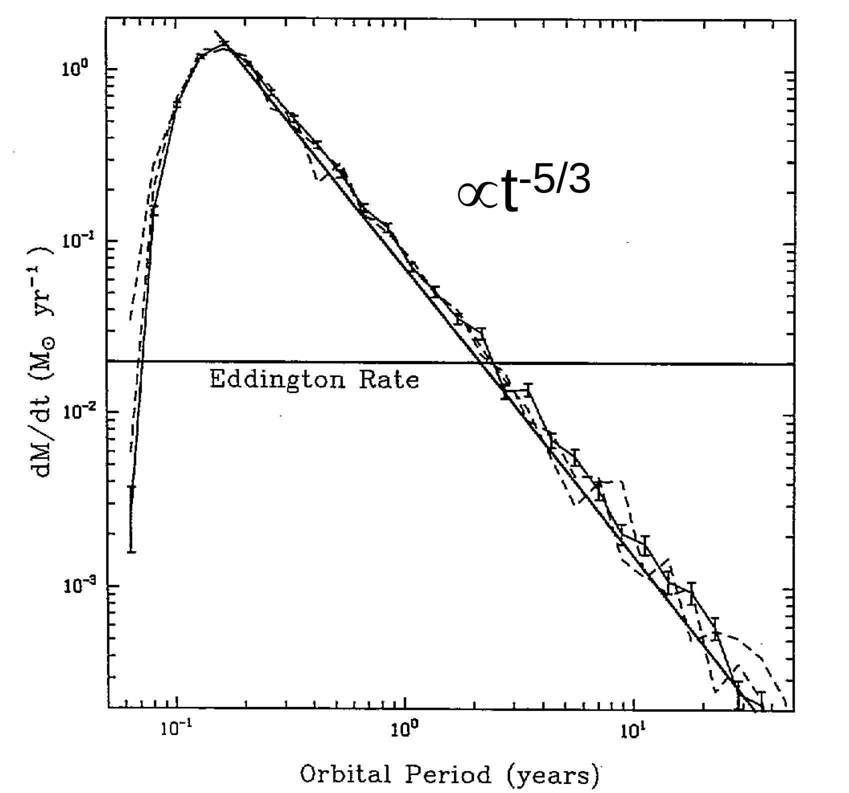
The bound fraction of the stellar debris falls back onto the black hole, resulting in a luminous accretion flare.

Properties of a Tidal Disruption Flare

- For 10^6-5×10^7 $M_\odot$ black holes, the stellar debris accretes in a thick disk (Ulmer 1999)

- $L_{flare} \approx L_{Edd} = 1.3\times10^{45}\ M_7$ erg s^{-1}
- $T_{eff} \approx (L_{Edd}/4\pi R_T^2\sigma)^{1/4} = 3\times10^5\ M_7^{1/12}$ K
- $L(t) = \varepsilon(dM/dt)c^2 \propto t^{-5/3}$
- $dN/dt \propto \sigma^{7/2} M_{BH}^{-1} \propto M_{BH}^{-1/4} \approx 10^{-4}$ yr^{-1} (Wang & Merritt 2004)

Tidal disruption theory predicts rare but luminous flares that peak in the UV/X-ray domain, with decay timescales ~ months.



Evans & Kochanek (1989)

Why Search For Tidal Disruption Events?

- They are an unambiguous probe for supermassive black holes lurking in the nuclei of normal galaxies.

- They may contribute to black hole growth over cosmic times, and the faint end of the AGN luminosity function.

- The luminosity, temperature, and decay of the flare is dependent on the mass and spin of the black hole.

- Tidal disruption rates are sensitive to the structure and dynamics of the stellar nucleus.

Flares Detected by ROSAT

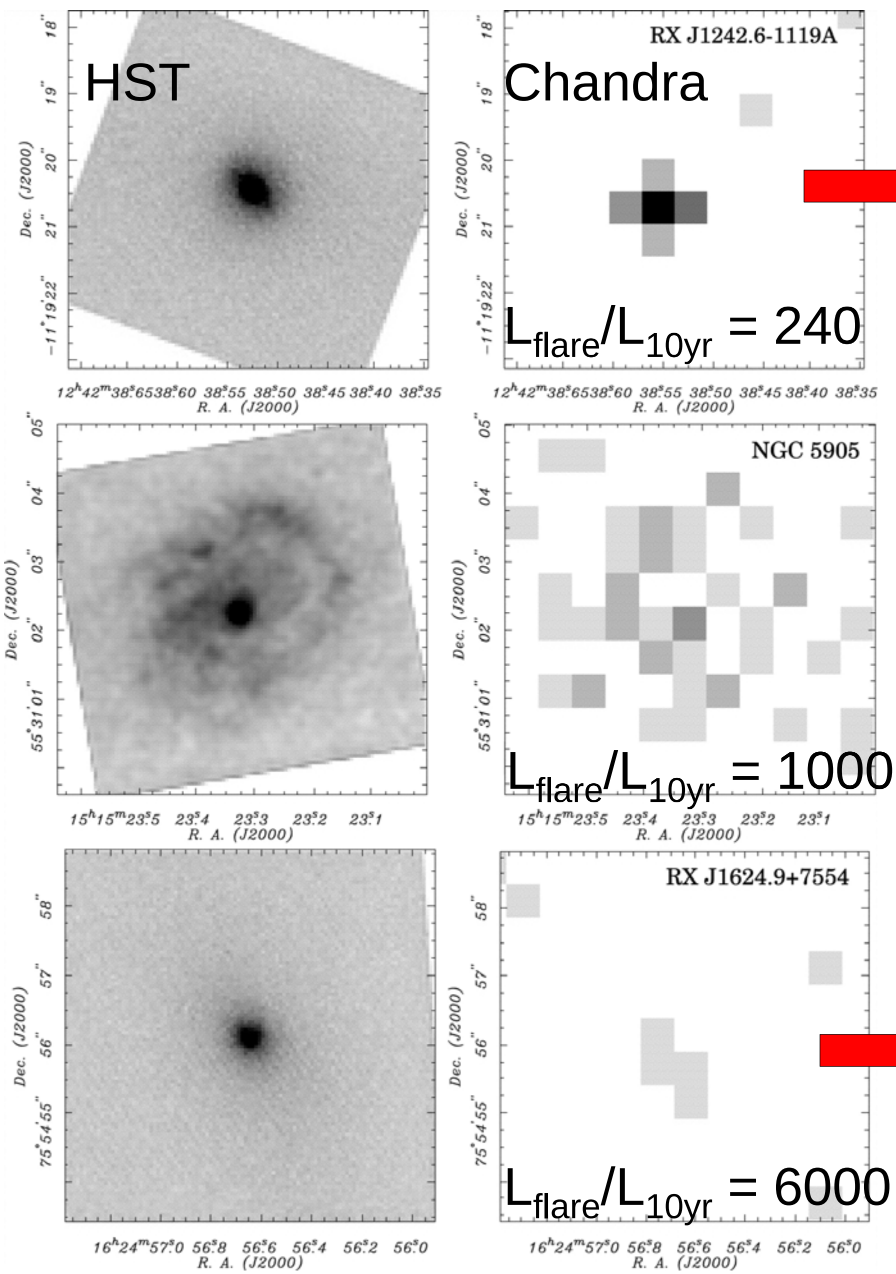
The ROSAT All-Sky Survey (RASS) conducted in 1990-1991 was an excellent experiment to detect TDEs since it sampled 3×10^5 galaxies in the soft X-ray band (0.1 - 2.4 keV).

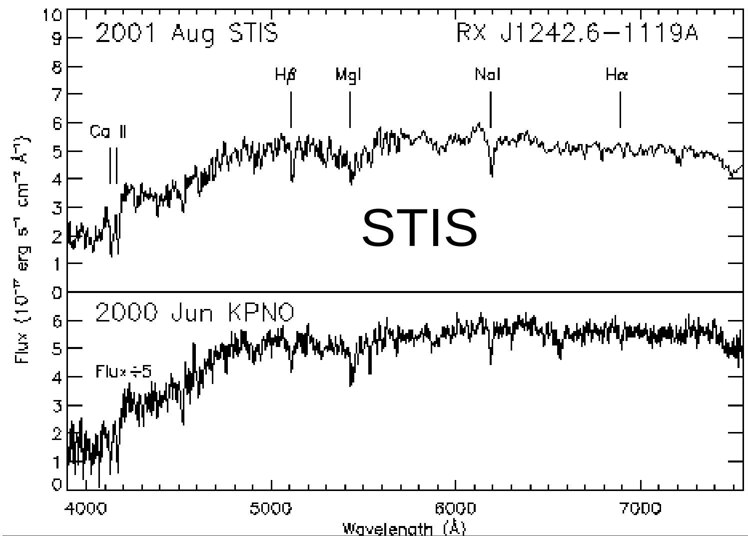
	Name	α (J2000.0)	δ (J2000.0)	N_H[a]	z	Amp_{var}[b]	Phase	Date
NLSy1	WPVS 007..................	00 39 15.8	−51 17 03	2.6	0.0288	392	RASS	1990 Nov 10–12
		...	...	...	...	...	Pointed	1993 Nov 11–13
Sy1.9	IC 3599	12 37 41.2	+26 42 27	1.3	0.0215	225	RASS	1990 Dec 10–11
		...	...	...	...	...	Pointed	1993 Jun 17
non-active	RX J1420.4+5334.......	14 20 24.4	+53 34 12	1.2	0.147	>21	RASS	1990 Dec 5–8
		...	...	...	...	...	Pointed	1990 Jul 19–23
non-active	NGC 5905..................	15 15 23.2	+55 31 05	1.4	0.0126	45	RASS	1990 Jul 11–16
		...	...	...	...	...	Pointed	1993 Jul 18
non-active	RX J1624.9+7554.......	16 24 56.5	+75 54 56	3.8	0.0636	>42	RASS	1990 Oct 7–15
		...	...	...	...	...	Pointed	1992 Jan 13

- $T_{bb} = 6 - 12 \times 10^5$ K
- $L_x = 10^{42} - 10^{44}$ ergs s^{-1}
- t_{flare} ~ months
- Event rate ≈ 1×10^{-5} yr^{-1} (Donley et al. 2002)

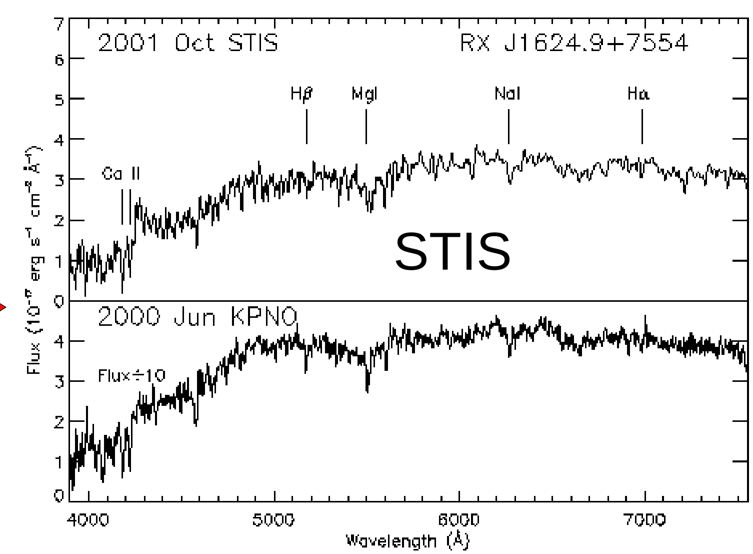
Properties of a tidal disruption event!

Halpern, Gezari, & Komossa (2004)

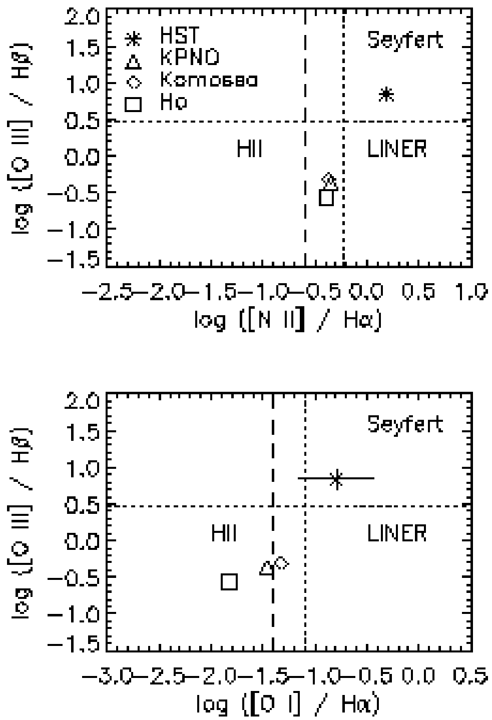


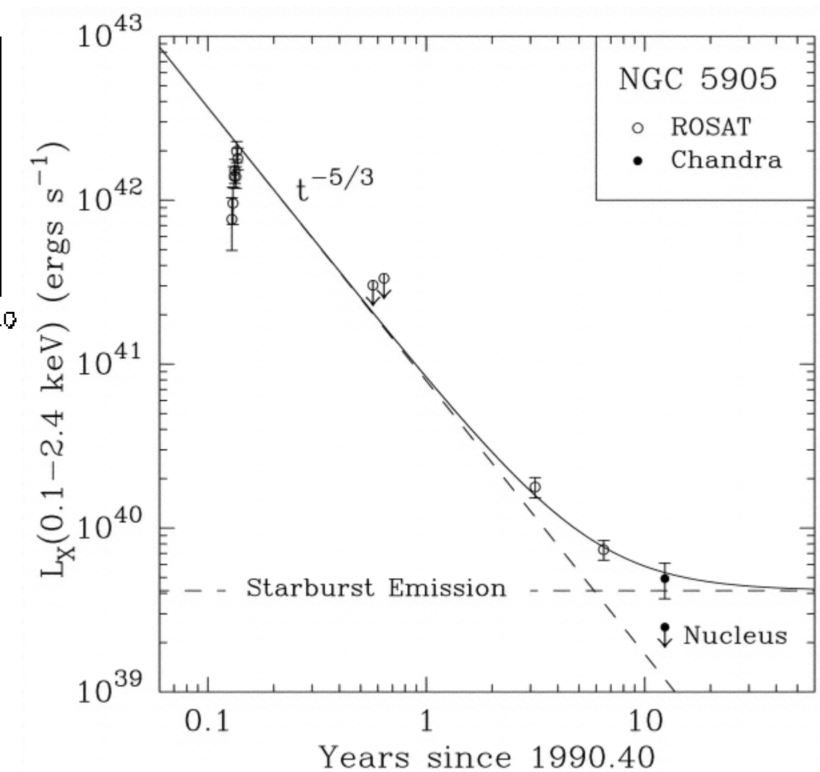


Follow-up narrow-slit HST/STIS spectra confirmed the galaxies as non-active (Gezari et al. 2003).



NGC 5905





Halpern, Gezari, & Komossa (2004)

- Narrow-line emission requires excitation by a persistent Seyfert nucleus (Gezari et al. 2003).

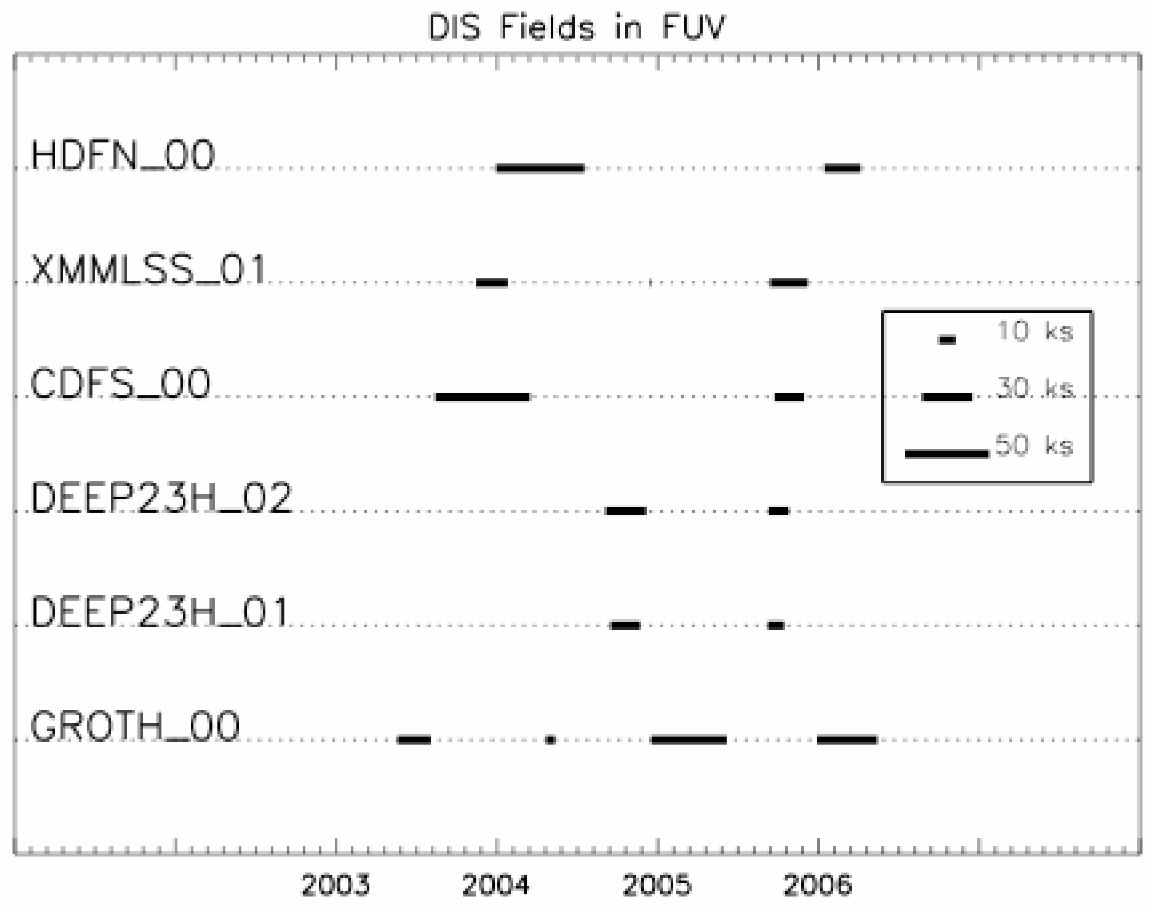
- Seyfert nucleus in it inner 0.”1 was previously masked by H II regions in ground-based spectra

- The Chandra upper-limit on the nuclear X-ray luminosity is consistent with the predicted L_x from L(Hα) for LLAGNs, of ~ 9 x 10^{38} ergs s^{-1}.

Li et al. (2002) modeled the event as the partial stripping of a low-mass star, or the disruption of a brown dwarf or giant planet.

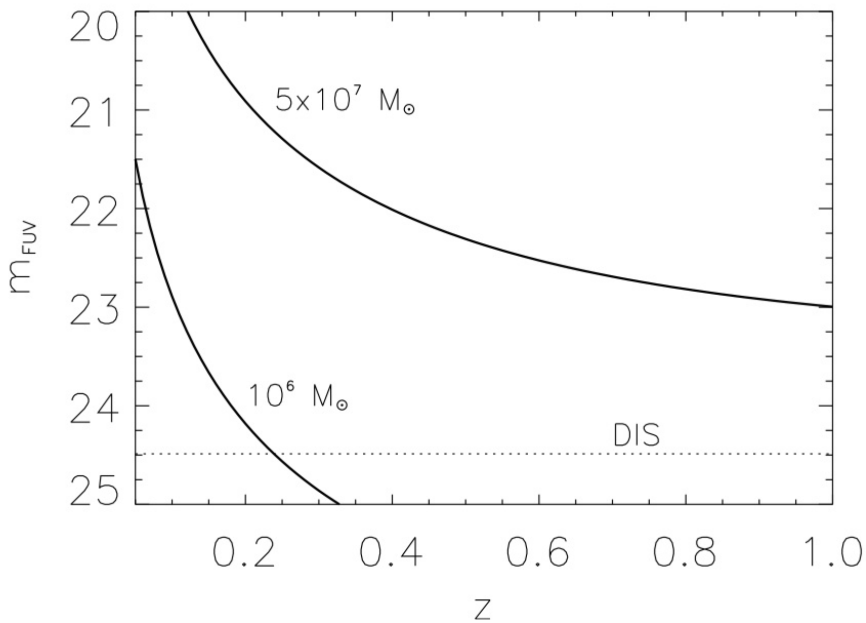
Why Search for TDEs with GALEX?

• GALEX FUV band is sensitive to Rayleigh Jean's tail of the soft X-ray blackbody emission.
• Better contrast in the FUV than in the optical, due to two effects: host bulge luminosity fainter by 2 mag, and flare luminosity brighter by 2 mag.



TOO observations with Chandra and Keck will probe the early-phase of decay of TDEs for the first time!

Detection Rate with GALEX



A large K correction makes *unextincted* flare flux detectable by DIS out to high z.

$$R = \int_{10^6 M_\odot}^{5\times 10^7 M_\odot} \dot{N}(M_{\rm BH}) N(M_{\rm BH}) V(M_{\rm BH})\, dM_{\rm BH}\ {\rm yr}^{-1}.$$

$6.5\times10^{-4}\ \mathrm{yr}^{-1}\ (M_{BH}/10^6\ M_\odot)^{-.25}$ (WM 2004)

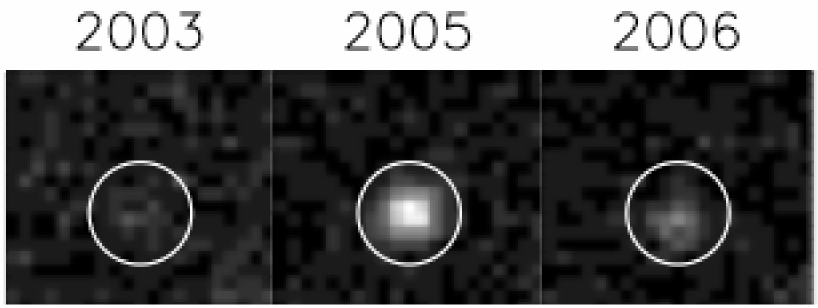
E+S0 luminosity function
$M_{BH} = 8.1\times10^{-5}\ (L_{bulge}/L_\odot)^{0.18}$
(FS 1991, MT 1991, MF 2001)

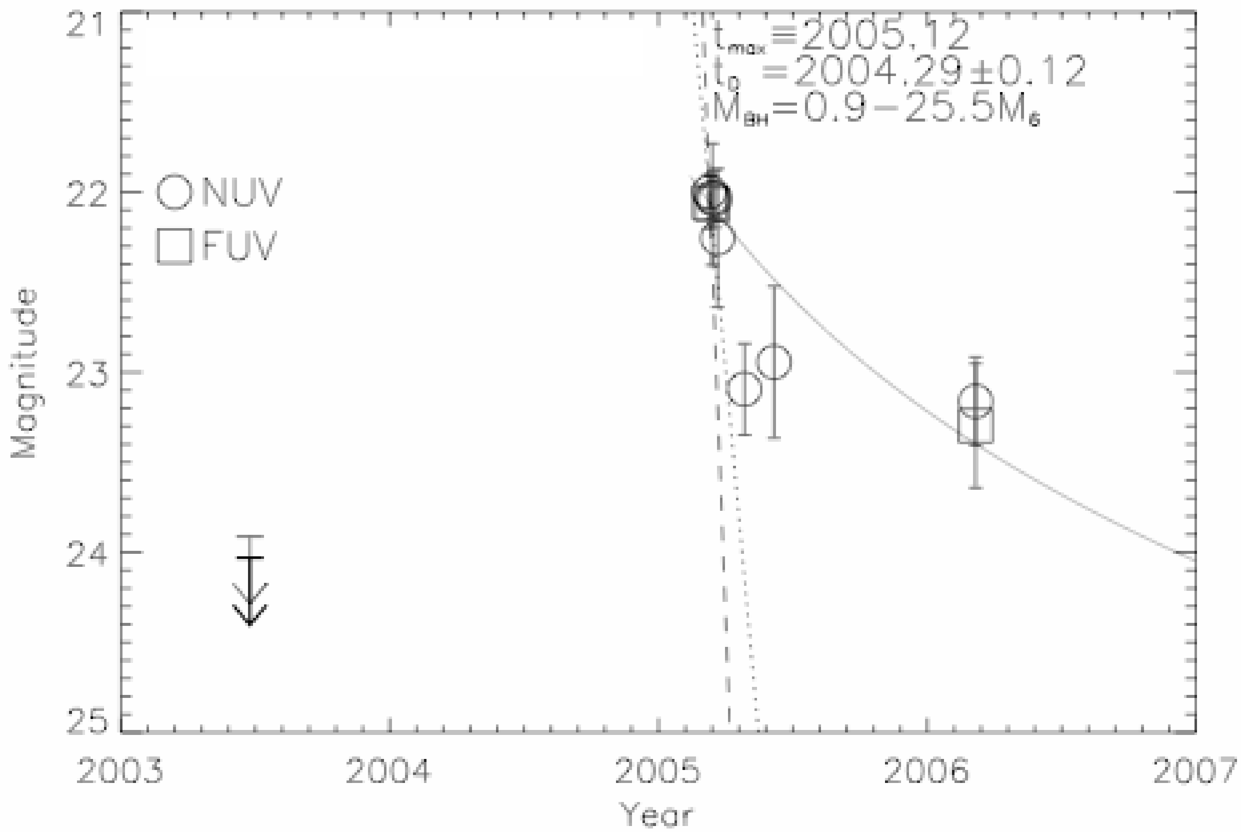
Volume to which flares can be detected in a 10 ks DIS exposure

Yields 5 events yr^{-1} $\mathrm{sq.deg}^{-1}$ ($z \leq 1$)

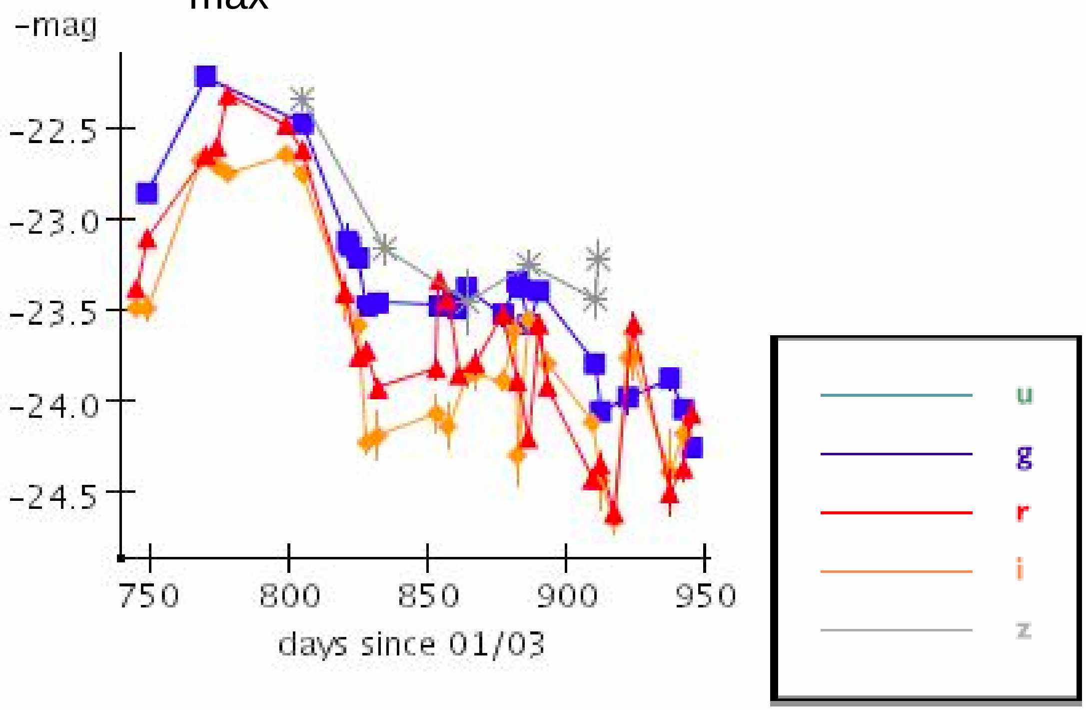
Flare Candidates So Far…

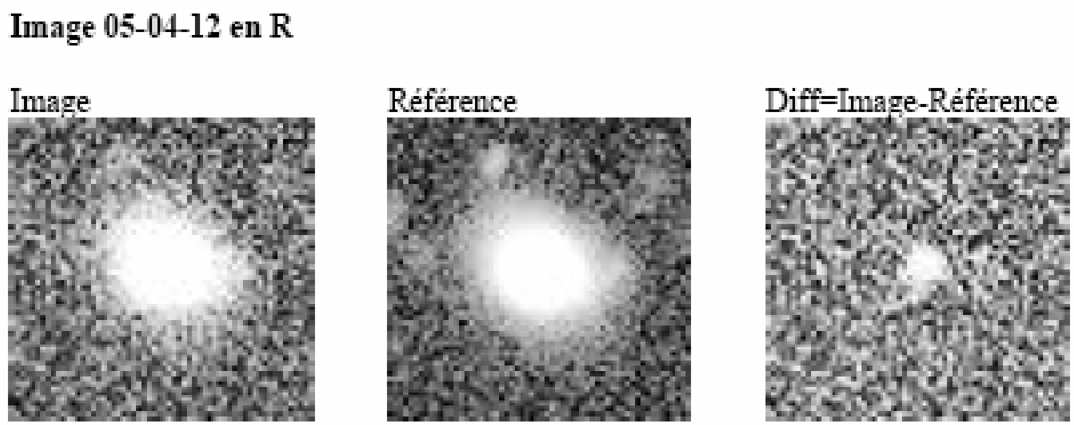
Candidate in GROTH





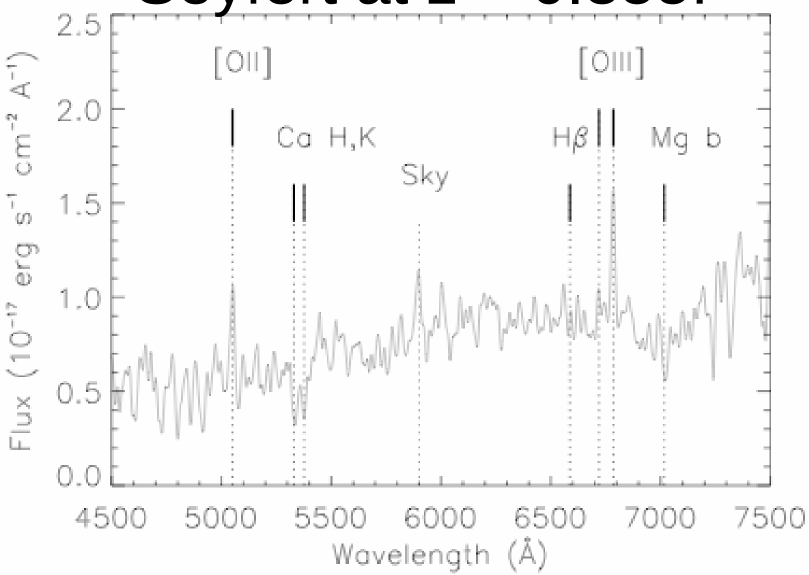
$t_{max} \approx 2005.12$





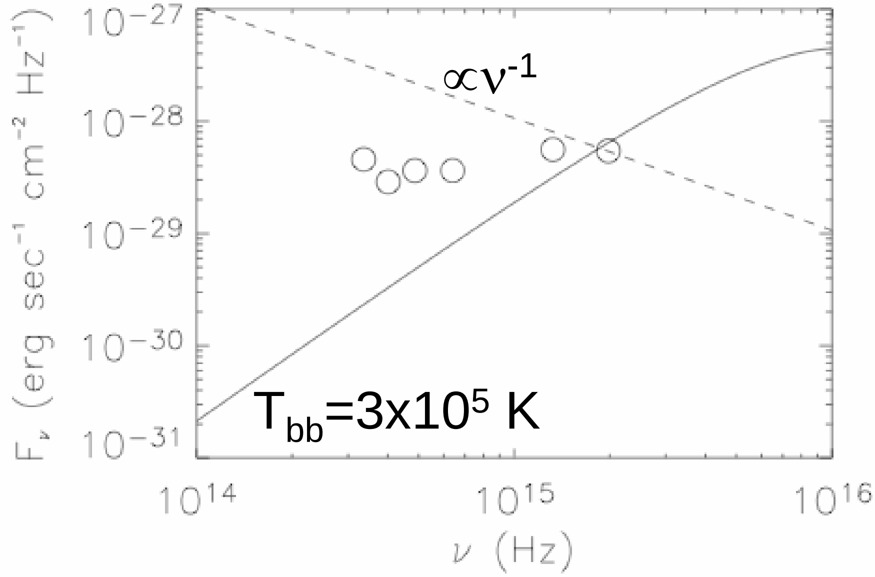
Optically resolved galaxy!

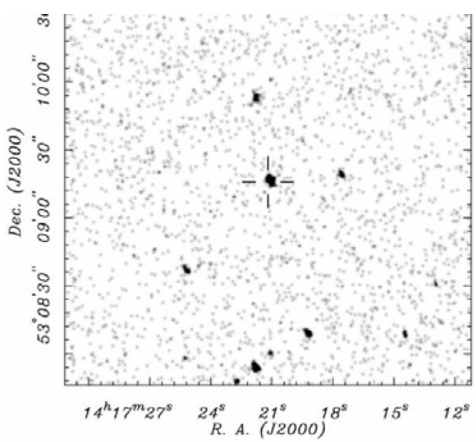
Seyfert at z = 0.355!



Jan 2006 MDM 2.4m optical spectrum

Flare SED



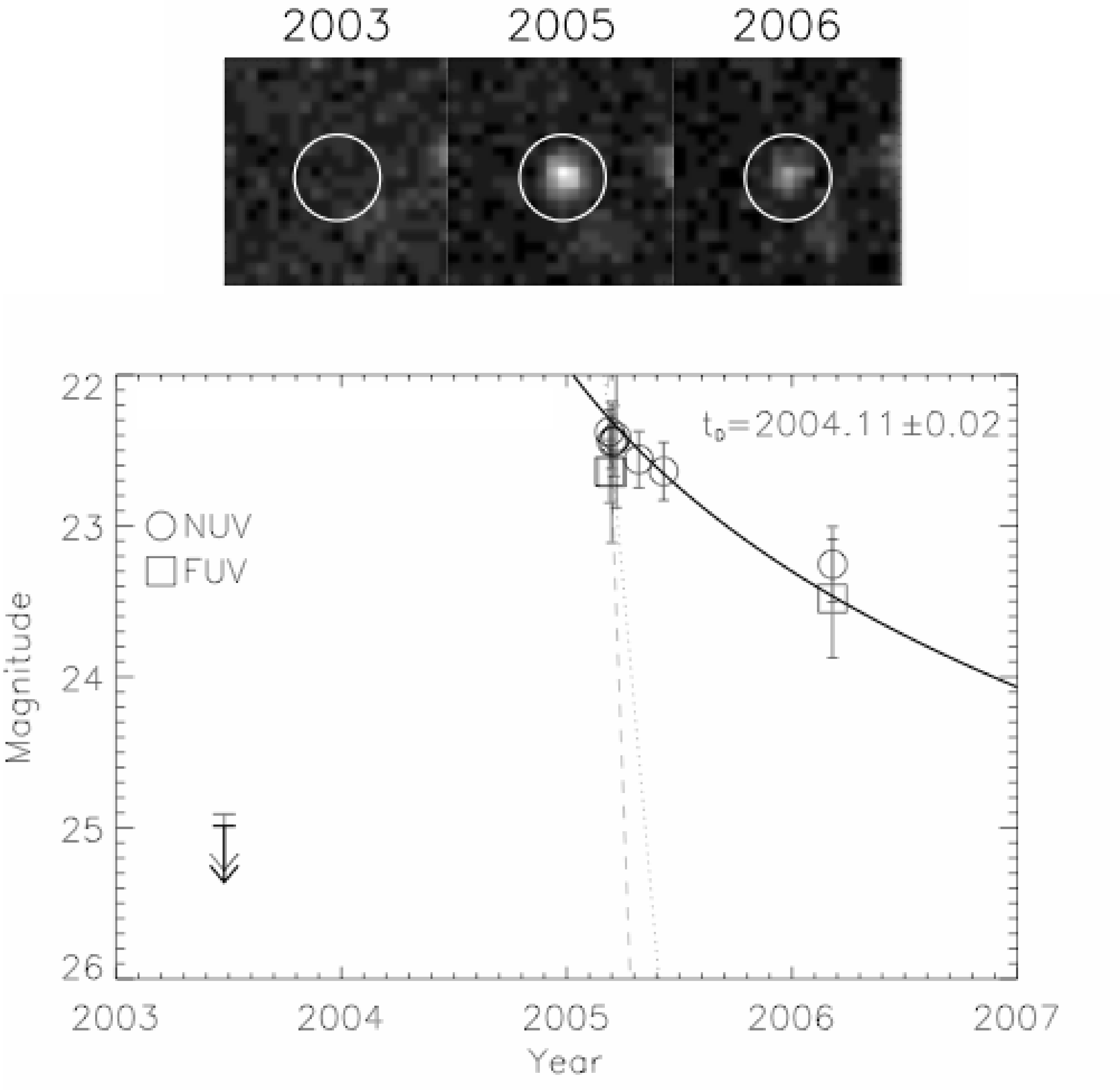


Archival Chandra ACIS detection in April 2002 with $L_x \approx 9.3x10^{42}$ ergs s^{-1}

- Does not look like a soft blackbody, or a typical Seyfert power-law.

- Presence of persistent Seyfert activity makes the tidal disruption scenario difficult to prove.

Candidate in GROTH



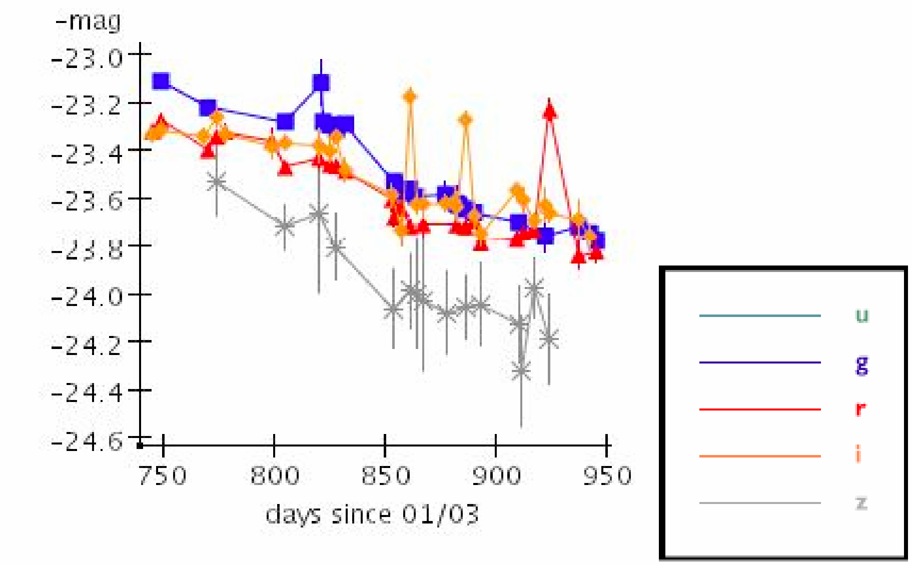
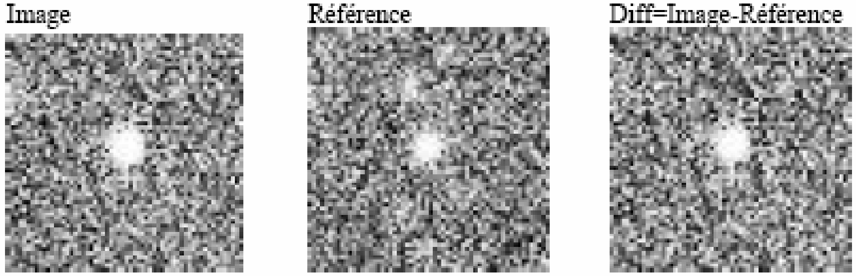


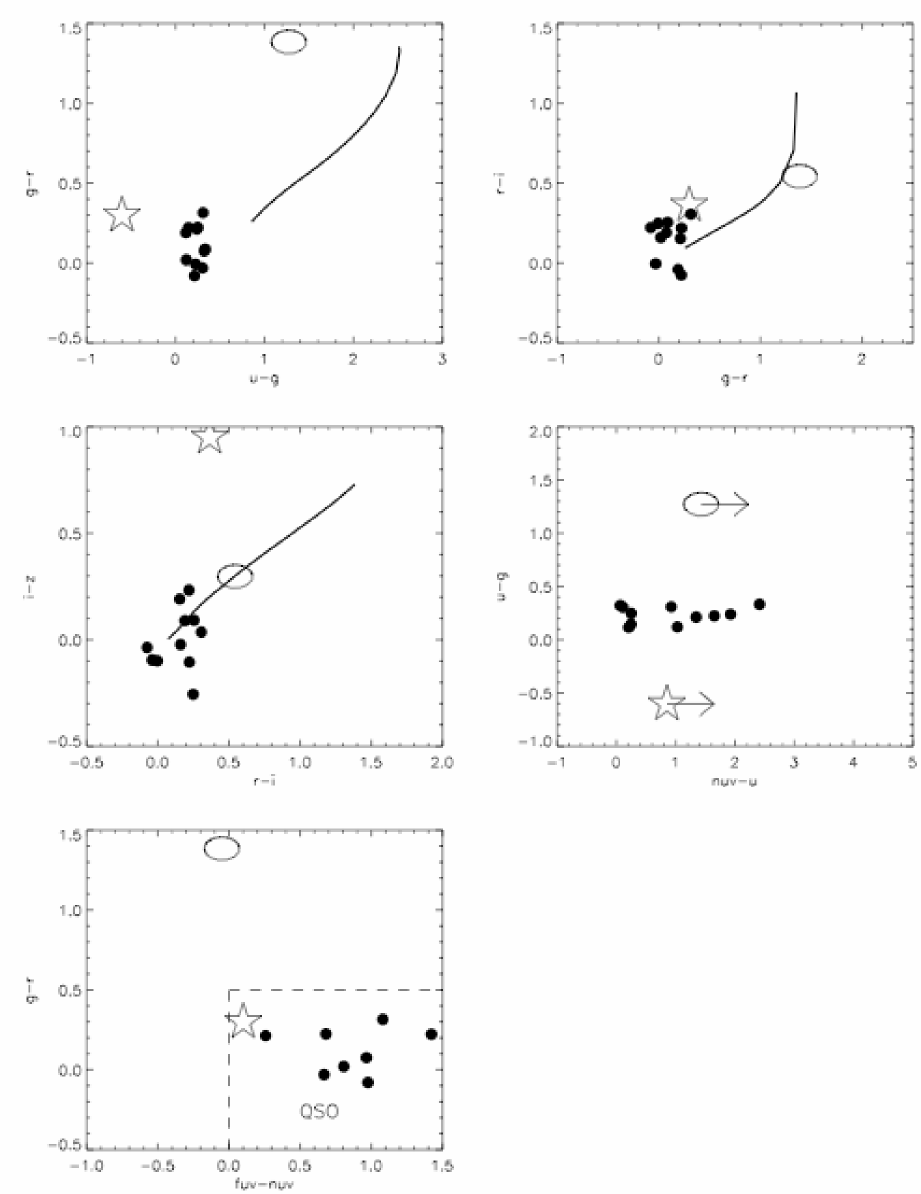
Image 05-04-12 en R

Image | Référence | Diff=Image-Référence



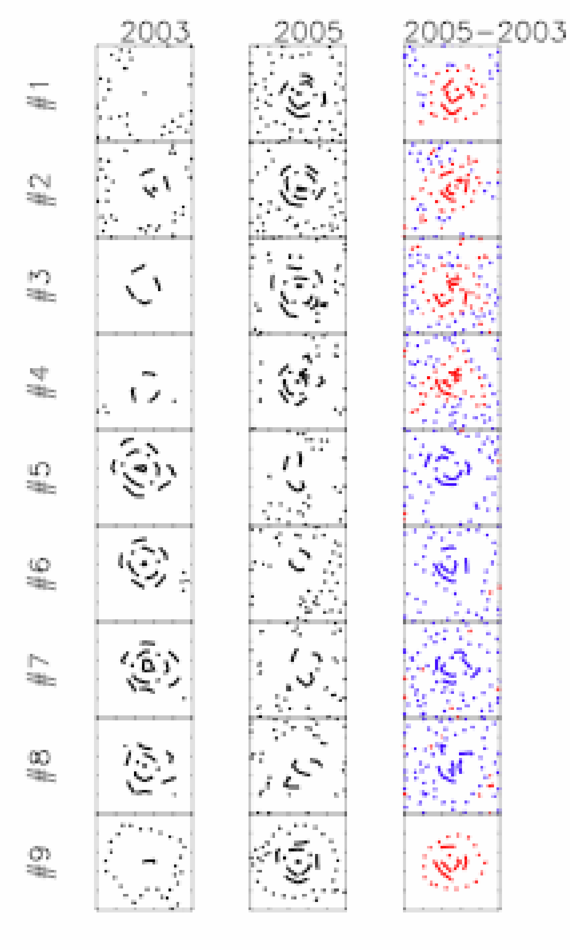
Optically unresolved quasar!

Colors

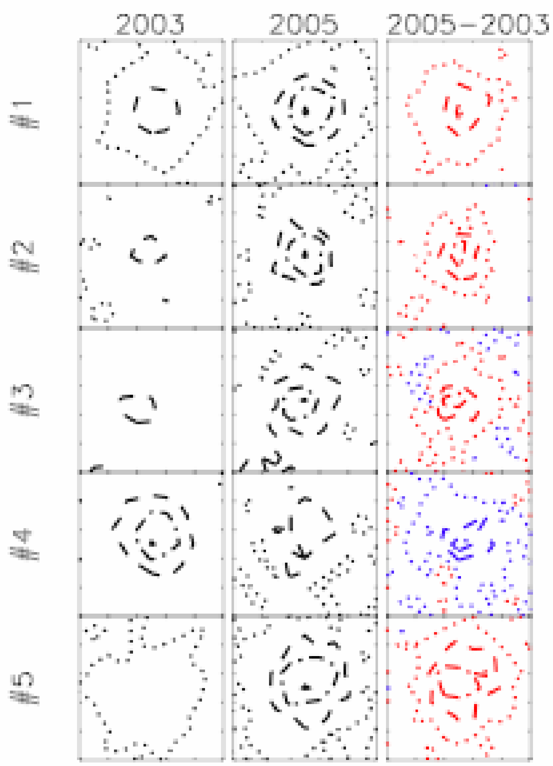


Many more candidates to investigate…

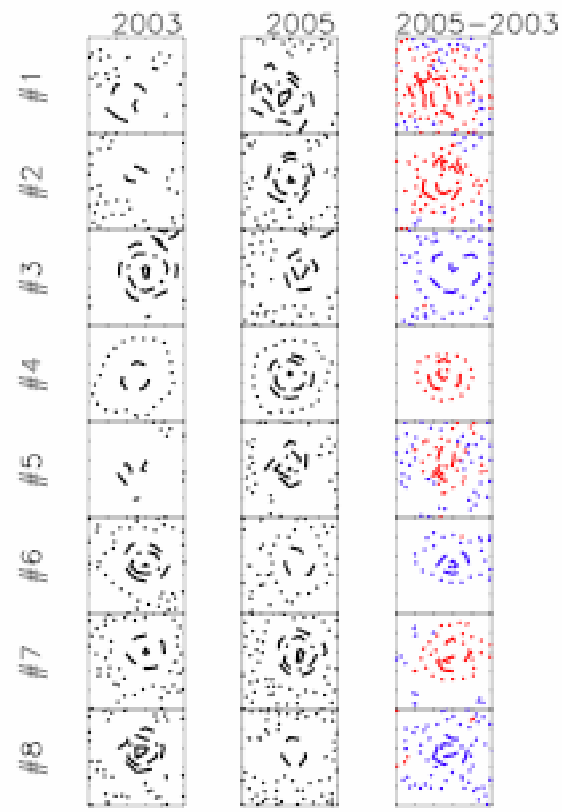
XMMLSS



CDFS

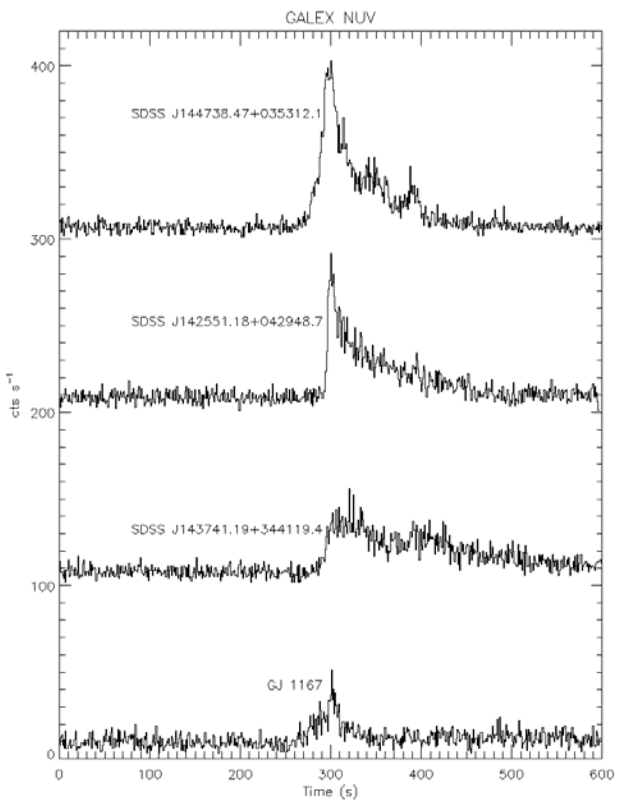


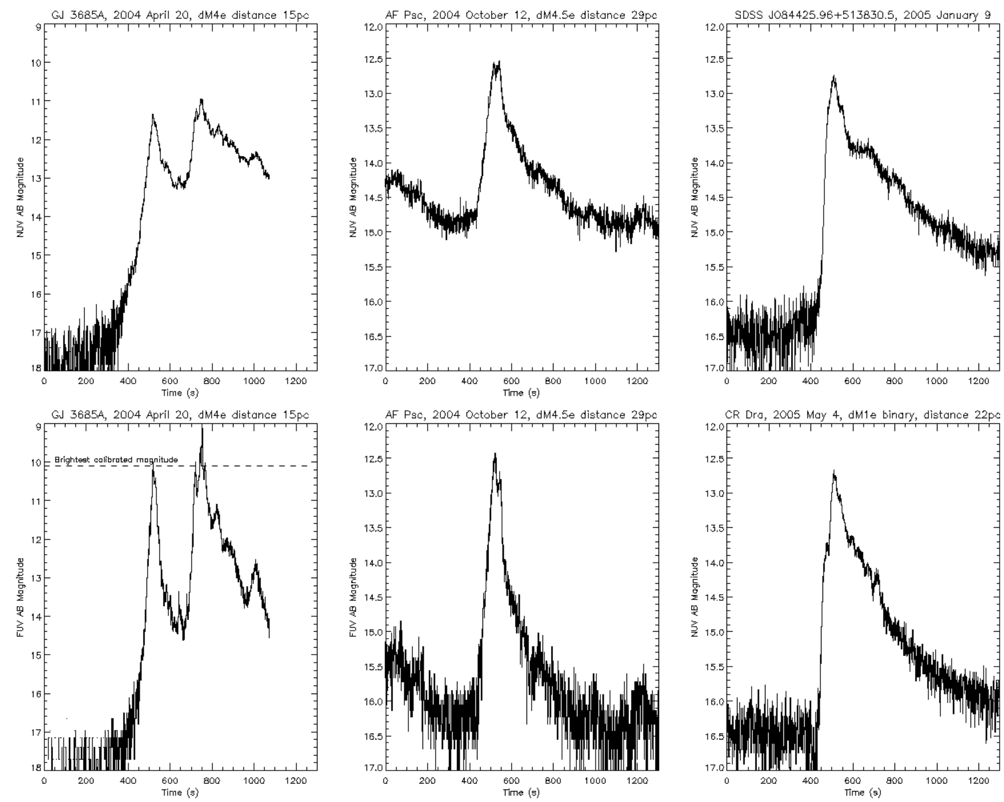
HDFN



Flashes Discovered by GALEX

- 84 variable sources detected (RR Lyraes and dMe flare stars)
- Lightcurves of M-dwarf flare stars with msec resolution recovered by photon-tagged data
- GJ 3685A is 20 times more energetic than previously observed UV flares, with an increase in brightness by 20,000 in less than 200 sec!





Wheatley et al. (2005)

Dedicated Time Domain Survey

- First time domain survey in UV
- Designed to complement future ground-based TDS (PanStarrs, LSST)
- All time-domain products, notably variable object alerts, will be immediately made public for community follow-up
- Produce automated pipeline triggers to generate IAU and/or GCN circulars
- Prevalence of UV-bright early evolution of flaring objects
- The TDS may detect: supernovae, gamma-ray faint bursts, novae, macronovae, magnetic degenerate binaries, low mass x-ray binaries, chromospherically active stars, QSOs and AGNs, pulsating degenerates, luminous blue variables

Table 2 – Time Domain Survey

	Wide	Medium	VIRGO	Deep
Ω[deg^2]	1000	100	16	7
Cadence	1/day	1/week	1/day	1/month
Visits	10/yr	10/yr	30/yr	3/yr
Depth/Visit	AIS	MIS	MIS	DIS
M_{NUV}	15		-8	-16
MW yrs			~10	
Orbits	0 [2000]	0 [2000]	500	1500