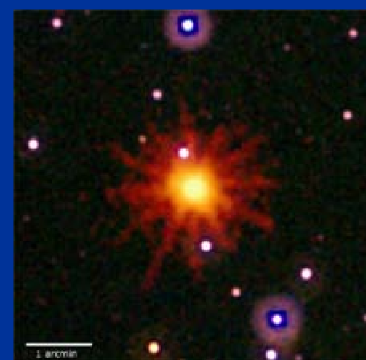
The first 2 years in the lifetime of the newly born jet associated to SWIFT J1644+57



Alberto J. Castro-Tirado

(IAA-CSIC Granada)

Relativistic Jets Meeting

Granada, 10 Jun 2013

Outline

I. Introduction

II. SWIFT J1644+57: a unique transient

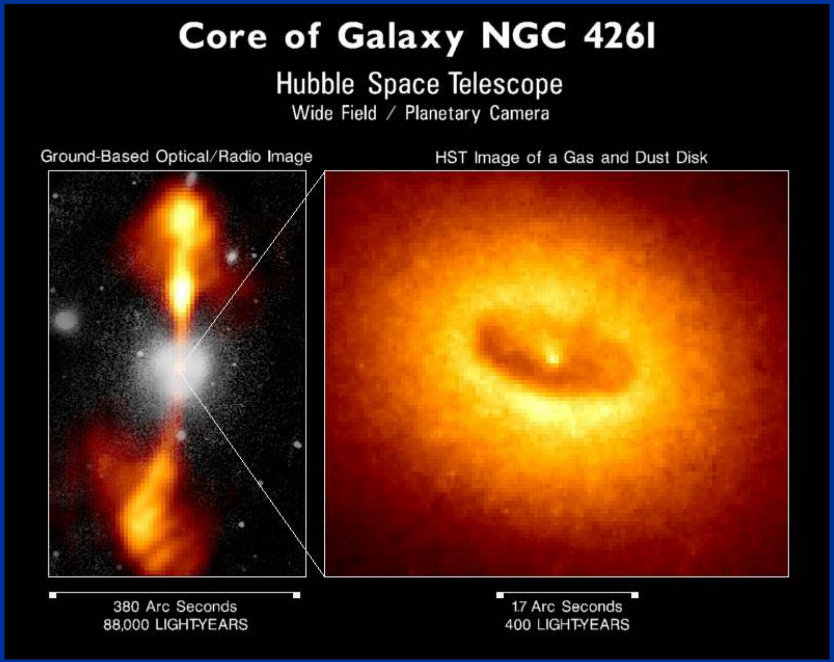
III. A jet in real time

Conclusions

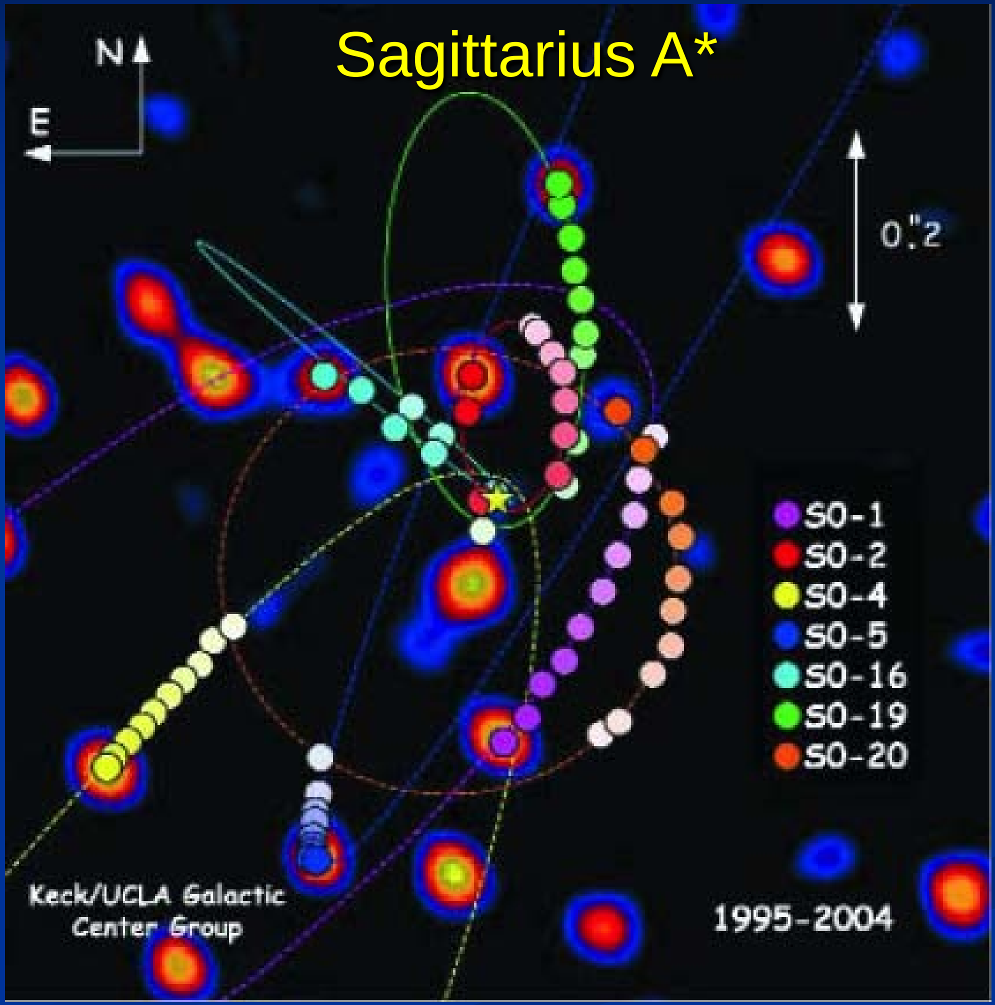
I. Introduction

Massive black holes
(M > 10^6 M_S) in:

Active galactic nuclei



Quiescent galactic nuclei



$2,7 \times 10^6$ M_S < M < $3,5 \times 10^6$ M_S)

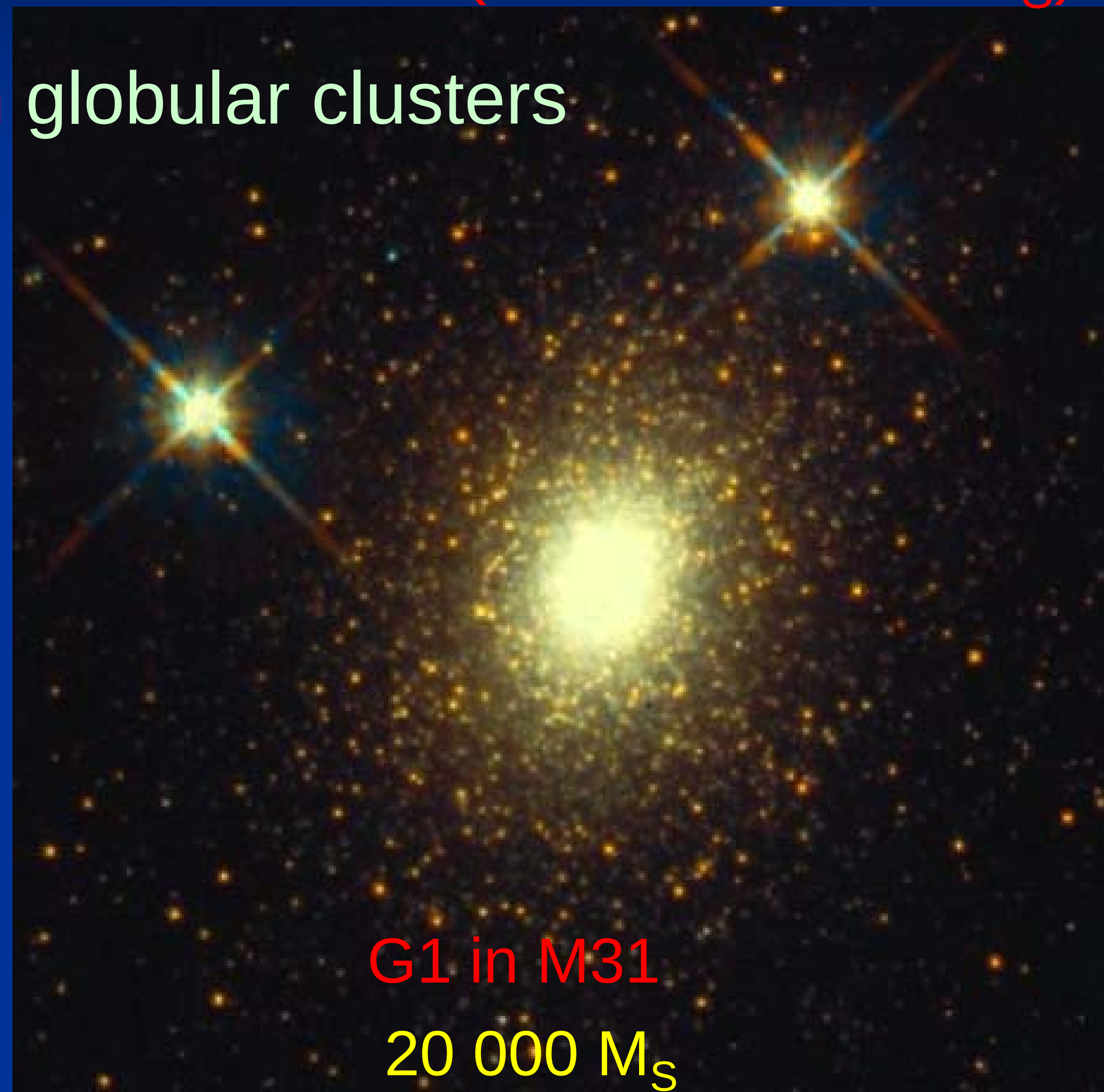
I. Introduction (2)

Intermediate mass black holes ($10^3 < M < 10^6$ M_S)

in globular clusters

M15 in the MW

4000 M_S



G1 in M31

20 000 M_S

I. Introduction (3)

Low mass black holes (3.2 < M < 18 M_S)
in our Galaxy

15 Aug 1992

Castro-Tirado et al. (1992)

GRS 1915+105

The brightest source in the hard X-ray sky at that time!

A microquasar (Mirabel et al. 1994)

14 +/- 4 M_S

Greiner et al. (2001)

I. Introduction (4)

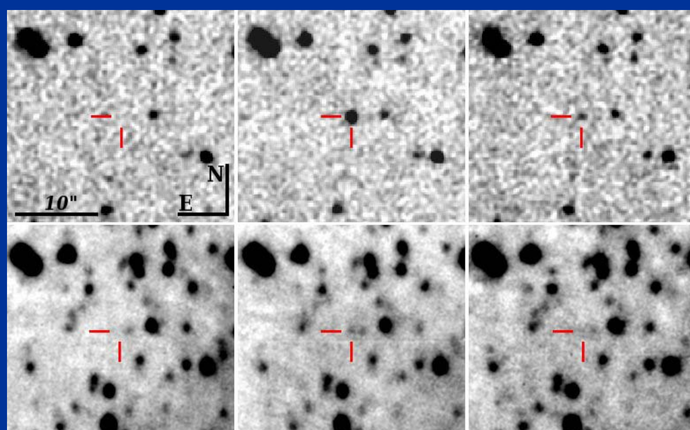
In GRS 1915+105, ~10 kpc from the Sun in our own Galaxy, it seems that we have seen the onset of a new *persistent* source, still brightening 21 yr after its discovery.

Have we ever seen the onset of an AGN ?

High energy transients in the *Swift* era

Since 2004 (the *Swift* launch year), three *BIZARRE* objects detected by *Swift* have joined the high-energy transients zoo:

1. SWIFT J1955+26, resembling a classical 8-s long GRB (only one seen in 7 yr)



Evolved magnetar? (C-T et al. 2008, Nat 455, 506) altough it has been proposed to be just an optical bursting XRB (Rea et al. 2011, ApJ 729, L21) in OUR galaxy

2. SWIFT J1644+57, resembling a 1-hr extremely long duration GRB (Bloom et al. 2011, Levan et al. 2011, Burrows et al. 2011, Zauderer et al. 2011, …) interpreted as a TDE

3. SWIFT J2058+0516, also interpreted as a TDE (Cenko et al. 2011, …)

II. SWIFT J1644+57

Collaborators

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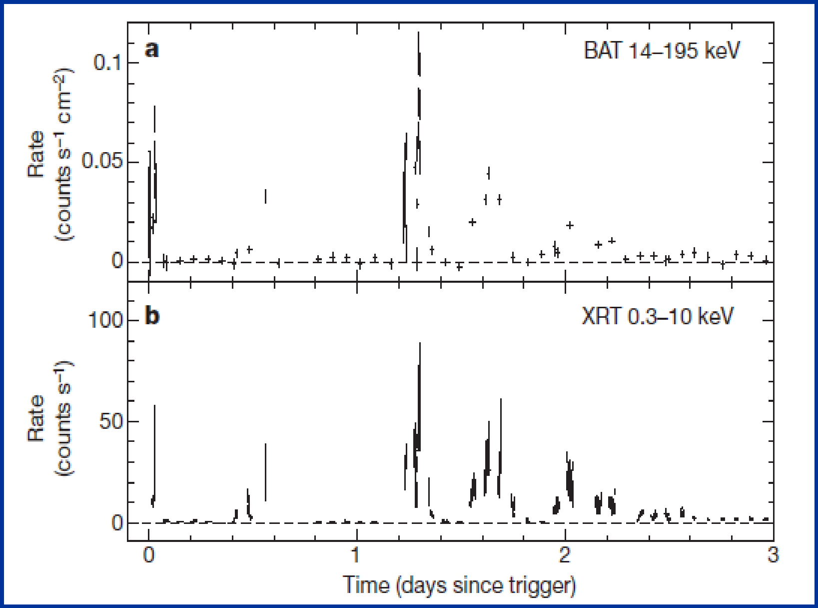
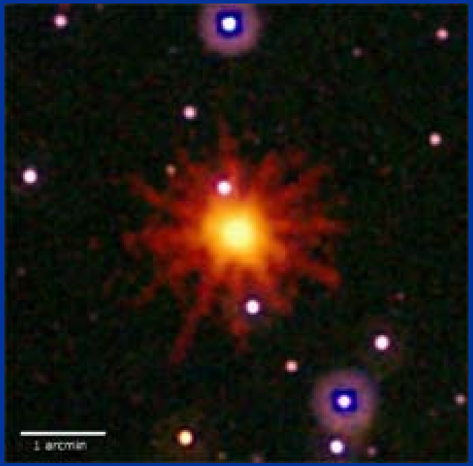
II. SWIFT J1644+57 (2)

Detected by *Swift* on 28 March 2011 (initially dubbed GRB 110328)

Astronomers immediately realized that this source was very peculiar, being very bright with a strong HE flaring activity lasting much longer than in all other GRBs.



Burrows et al. (2011)



NASA/*Swift*/S. Imler

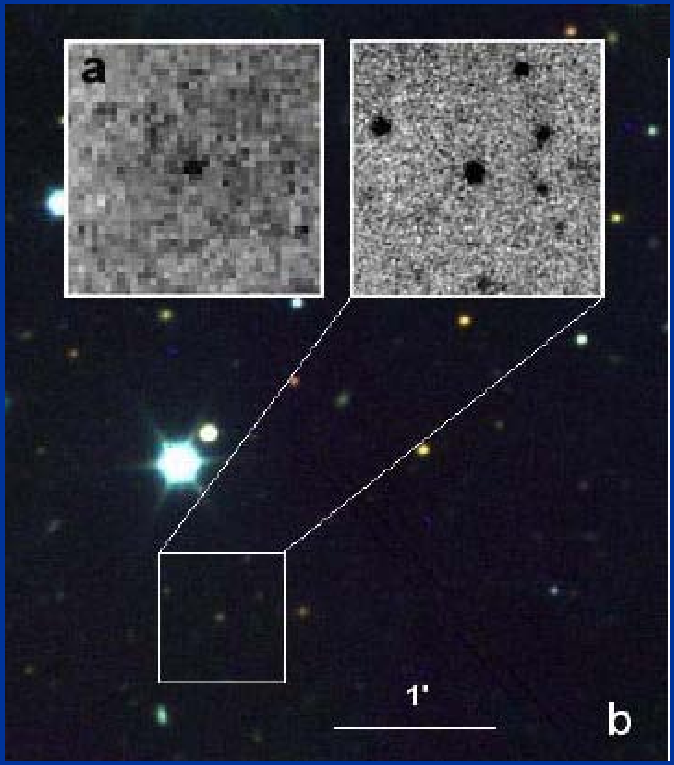
III. Swift J1644+57 (3)

Early time optical imaging

Early time photometric observations carried out within minutes by the 1.5 m telescope at Solar Sayan Observatory in Mondy (Siberia). Optical transient emission (R = 19.7) detected !

R-band

X-rays

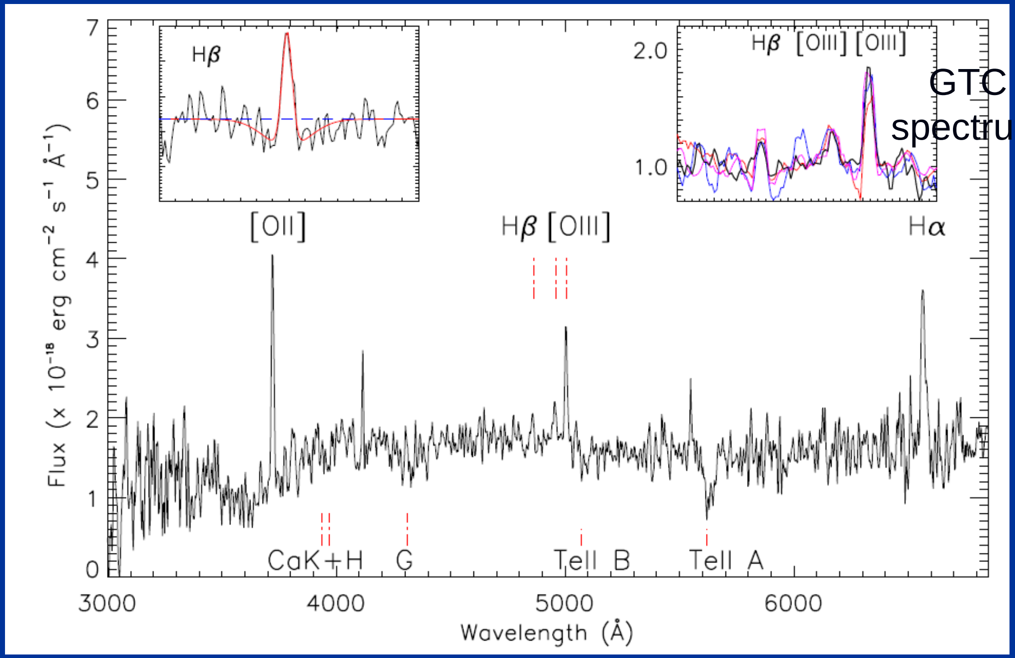


C-T et al. (2013)

III. Swift J1644+57 (4)

Early time optical spectroscopy

Early time spectroscopic observations carried out by both the GTC (15.7 hr after the onset of the event) and by the 6.5 m Gemini telescope, proved that the new transient, dubbed Swift J164449.3+573451 (hereafter Sw J1644+57), happened within a galaxy 920 Mpc away (z = 0.354) *but* the *transient* optical emission was already gone at that time...

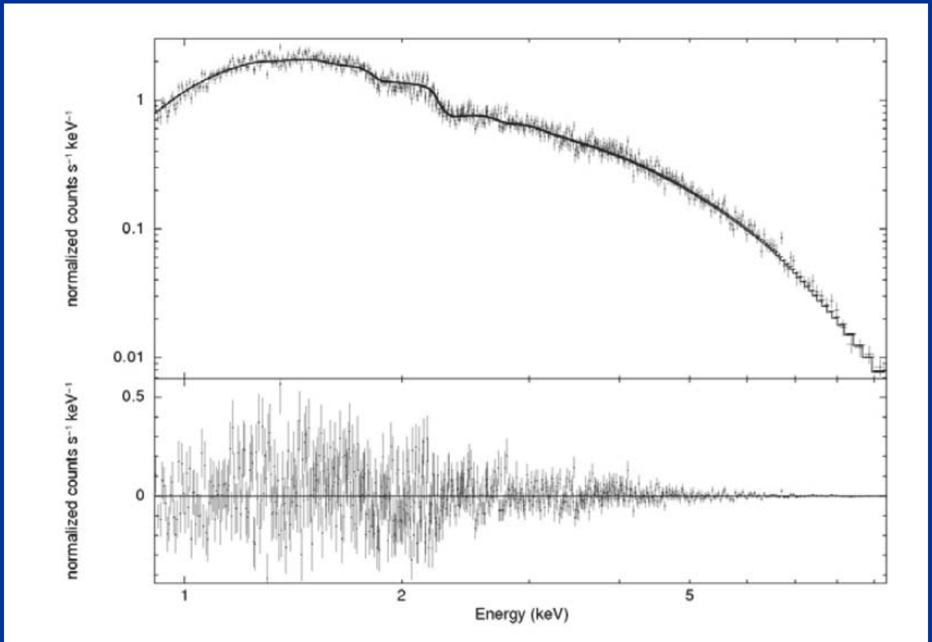


Levan et al. 2011, Science 333, 199

III. Swift J1644+57 (5)

Early time multiwavelength observations

An *XMM-Newton* observation was performed by our team, 3 days after the onset of the event.

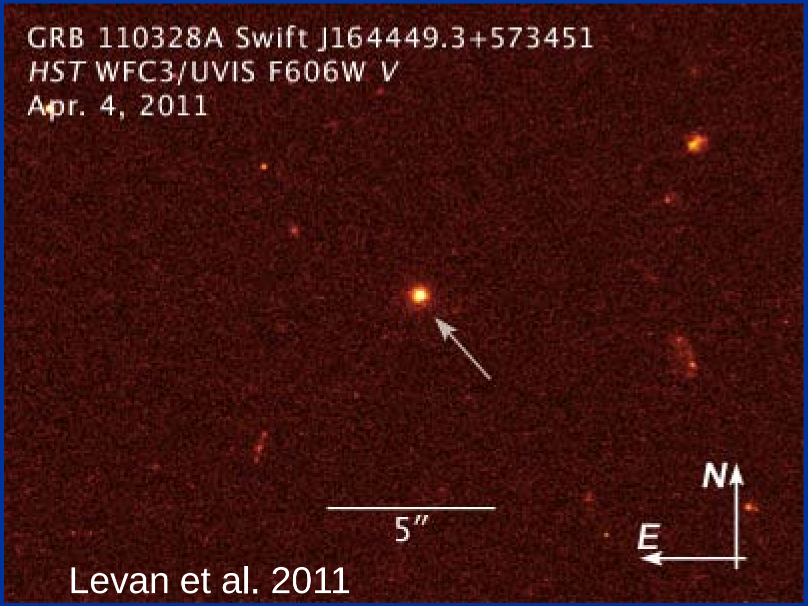


No thermal component in the X-ray spectrum, fitted by a variable, hard X-ray component. No emission lines detected.

III. Swift J1644+57 (6)

Early time multiwavelength observations

Subsequent radio observations at centimetre (Zauderer et al. 2011, Pooley et al. 2011) and millimetre (Zauderer et al. 2011, C-T et al. 2012, 2013) wavelengths confirmed the existence of a radio source, **coincident with the optical position associated with the nucleus of the host galaxy** (also imaged by *HST*), with flux densities at cm and mm wavelengths of ~5 and ~20 mJy respectively, with indication of a rising state at that time.

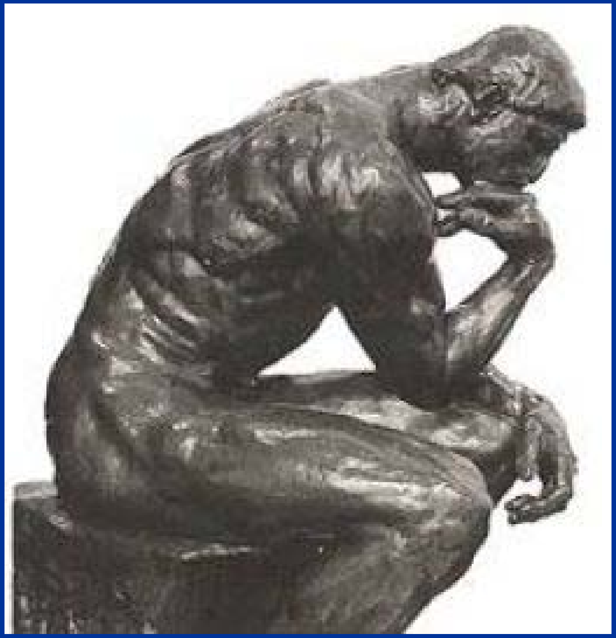


Levan et al. 2011

All this observational evidence pointed to a bizarre high-energy event, with a behaviour unlike anything seen since *Swift* was launched in 2004.

III. Swift J1644+57 (7)

What is its nature???



III. Swift J1644+57 (8)

Observational facts

A positional coincidence (within 0.2 kpc) with the host galaxy nucleus.

Rapid time variability in X- and gamma-rays ($\leq 10^2$ s) which implies a compact source of ≤ 0.15 AU, i.e. a few times the Schwarzschild radius of a ~10^6 M_s BH.

High X- and gamma-ray luminosity of ~10^{47} erg/s, i.e. exceeding the Eddington luminosity of a 10^6 M_s BH by 2-3 orders of magnitude.

Lack of previous radio to gamma-ray activity to a much deeper limits, pointing to a rapid onset.

Long-term X-ray luminosity evolution exceeding $L_x \propto t^{-5/3}$ as expected from the fall-back of tidally disrupted material.

IV. A jet in real time

A relativistic TDF

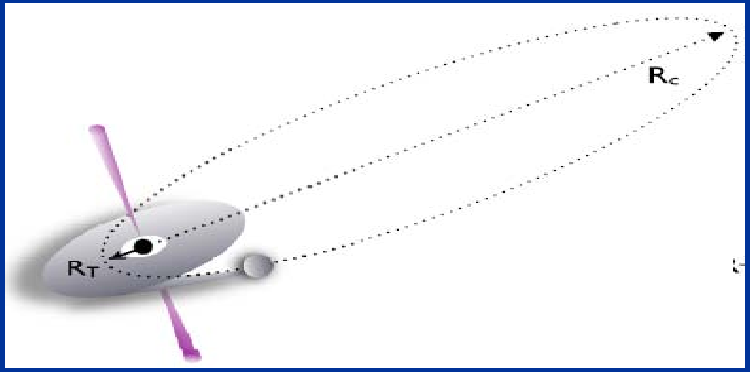
The widely accepted interpretation is a **relativistic tidal disruption flare (TDF)** of a star, which was torn apart by the gravitational forces, when passing too near to a dormant at the nucleus of the observed host galaxy, leading to the formation of a "mini-blazar" with the jet seen face-on.

Basic ingredients:

-a main-sequence star and a $\sim 10^6\ M_s$ BH (Bloom et al. 2011, Barres de Almeida and De Angelis 2011)

-a white dwarf and a $\sim 10^4\ M_s$ BH (Krolik and Piran 2011)

U. Of Warwijk / Mark A. Garlick

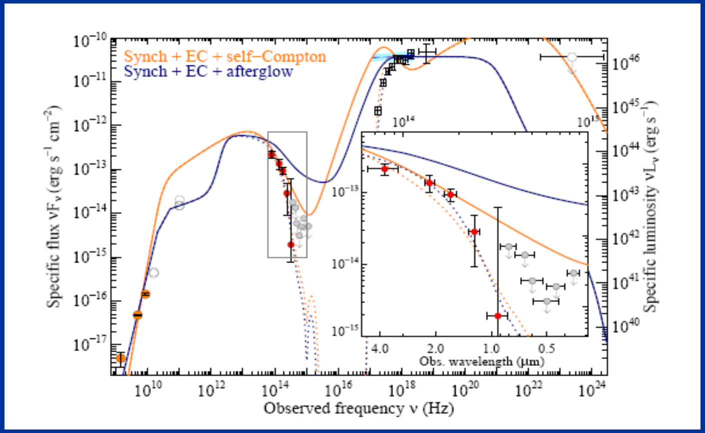


Krolik and Piran (2011)

IV. A jet in real time (2)

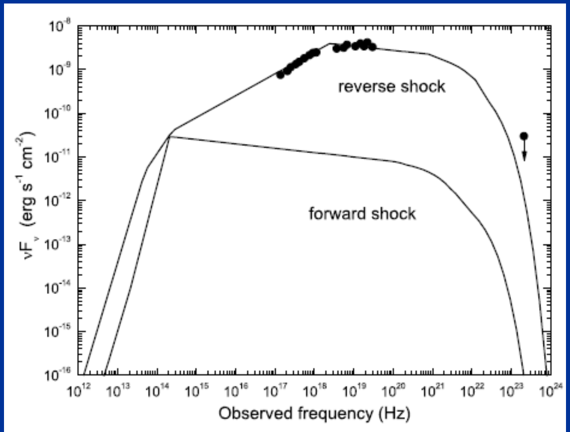
A relativistic TDF

This is also supported by energetic ($E_K = 3 \times 10^{50}$ erg 22 d post burst) and variability arguments, which suggest that the jet is at least mildly relativistic, exhibits high collimation, and its spectrum is dominated by synchrotron and inverse Compton emission (Burrows et al. 2011; Zauderer et al. 2011). An internal shock model has been also proposed (Wang and Cheng 2012) with a relativistic reverse shock and a Newtonian forward shock.



$T_0 + 2.9$ d

Bloom et al. (2011)



$T_0 + 1.35$ d

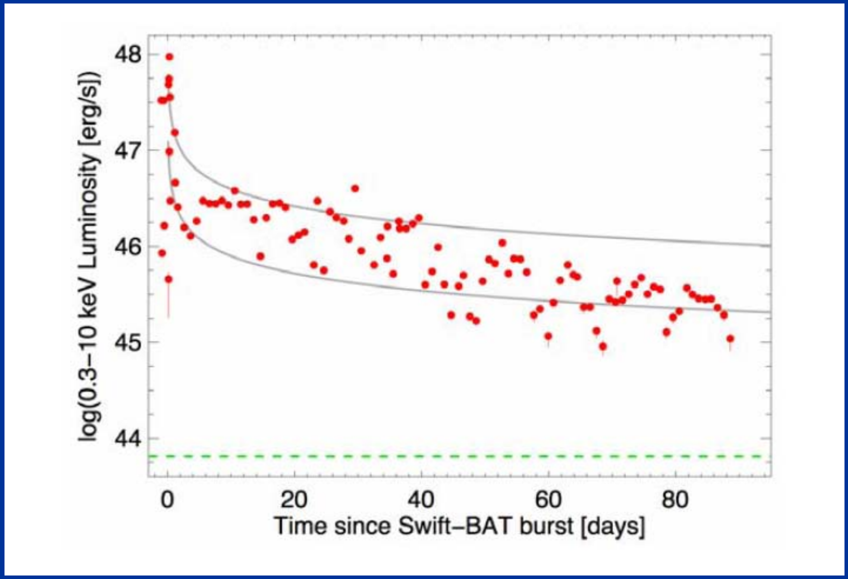
Wang and Cheng (2012)

IV. A jet in real time (3)

A relativistic TDF

The super-Eddington luminosity and the early X-ray peak lasting 10^5 s can be explained by the debris fallback time for a TDF (Zauderer et al. 2011).

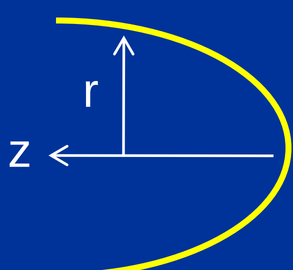
Follow-up observations by *Swift* revealed that the X-ray emission initially stayed in a plateau with a 0.3-10 keV flux of ~1-3 x 10^{-11} erg/s/cm^2, and then decayed down to ~3 x 10^{-12} erg/s/cm^2, *approx.* following the expected decay in the case of a single event associated with a tidal disruption flare (TDF), i.e. $t^{-5/3}$.



IV. A jet in real time (4)

400 days of mm observations at PdBI

Plateau du Bure Interferometer (PdBI) mm obs starting 3.5 d post-burst and still going on. Additional cm obs at Effelsberg and EVN. (C-T et al. 2013).



The only consistent model we get is the simplest one with a jet faced-on, Γ and s constant, $\gamma = 2.3$ and $r \propto z^{1/5}$, (i.e. a mini-blazar).

IV. A jet in real time (5)

Major Issues

The formation of a relativistic jet was not predicted in standard tidal disruption models (Ress 1988, Strubbe and Quataert 2009).

The Sw J1644+57 jet is highly “particle starved” (Burrows et al. 2011), favouring a magnetically launched jet (Lei and Zhang 2011).

A very marginal detection of NIR polarization (P = 7.4 +/- 3.5%, 2.1σ) 17 days post-burst also support the jet origin of the nIR emission (Wiersema et al. 2012).

How much is the integrated energy release in the relativistic outflow? E_j (beaming corrected) ~ 10^{52} erg (Berger et al. 2012), comparable to the overall E (Bloom et al. 2011)

Both cm and mm observations are also most essential in order to map the density profile around a previously dormant AGN (Berger et al. 2012).

IV. A jet in real time (6)

How relativistic jets are generated from the accretion of matter onto compact objects?

A plausible mechanism to launch a jet is to tap spin energy from of the BH through a magnetic field , which connects the BH event horizon and a magnetic load (Blanford and Znajek 1977) with the jet being Poynting flux dominated (Burrows et al. 2011, Gao 2012, Tchekhovskoy et al. 2012) and a moderated to high spin rate ($a_{\bullet}$ = 0.63-0.90) in the case of Sw J1644+57 (Lei and Zhang 2011)

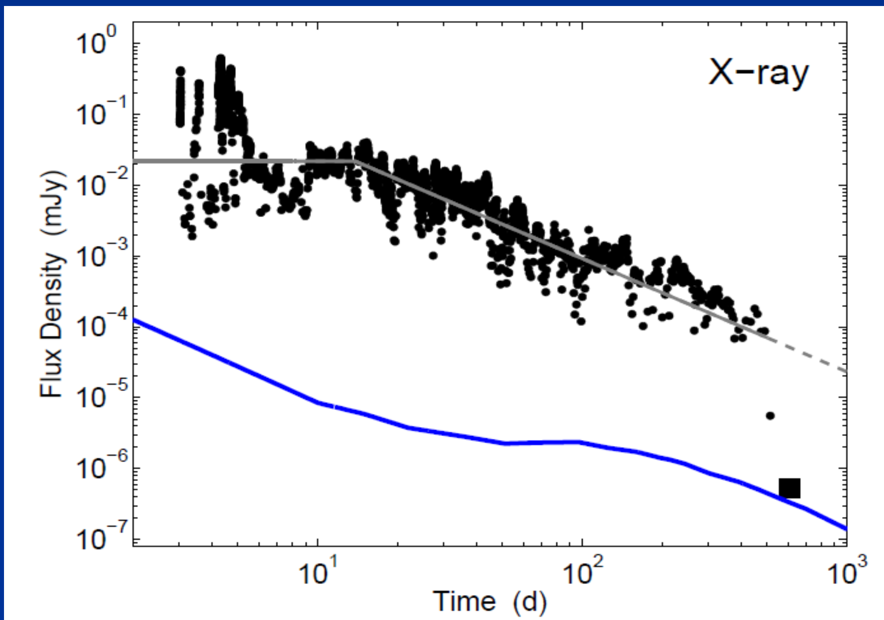
A conical jet could have led to a cilindrical one at late times (Di Cao and Wang 2012) with initial Lorentz factor $\Gamma_j \sim$ 10-20 and $\Theta j \sim$ 0.01-0.1 for the jet opening angle (Metzger, Giannios and Mimica 2012).

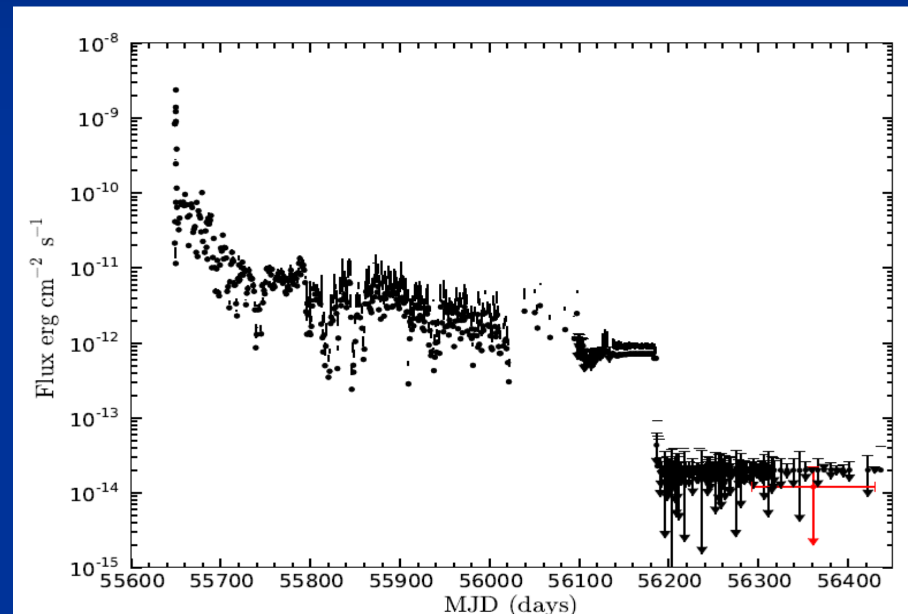
The relativistiic jet could have been launched with a wide range of Lorentz factors, obeying $E (> \Gamma_j) \propto \Gamma_j^{-2.5}$ (Berger et al. 2012).

A two component model (inner relatvistic jet (with $\Gamma_j \sim 15$) and the outer trans-relativistic jet (with $\Gamma_j \leq 1.2$) has been also proposed (Liu, Pe’er and Loeb 2012).

IV. A jet in real time (7)

The evolution after two years





Zauderer et al. (2012)   X-ray data from *Swift*/XRT   C-T et al. (2013)

At *t* = 500 d, the rapid decline points to internal dissipation of the inner jet, rather to a forward shock emission, with the relativistic jet turning off when the mass accretion rate droped below M_{Edd} indicating a peak accretion rate of ~ 330 M_{Edd} and an accreted mass of ~0.15 M_s and E_j ~ 10^{52} erg (Zauderer et al. 2012).

IV. A jet in real time (8)

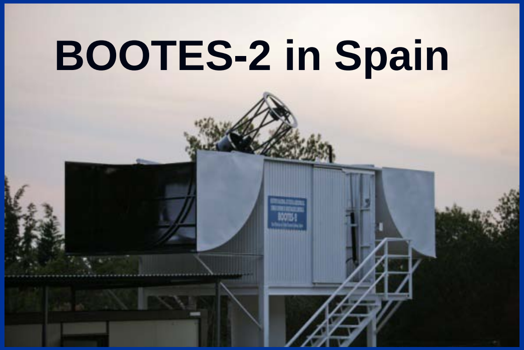
Another interpretation on the basis of continuing activity?

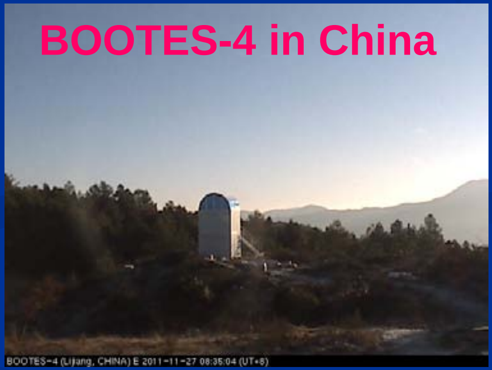
Are we seeing the onset of a dormant AGN, a larger scale version of the GRS 1915+105 superluminal source, whose onset was discovered in 1992 (C-T et al. 1992, Mirabel et al. 1994) and still is brightening in the X-ray sky?

Long-term monitoring (X-ray, nIR, mm) and future high-resolution eENV, EVLA and VLBI radio observations can shed light onto its nature. A detailed study of future activity periods of Sw 1644+57, including simultaneous X-ray/optical/nIR/mm monitoring will contribute to discern whether the source is a newly awaken AGN.

Ongoing developments

BOOTES (Burst **O**bserver and **O**ptical **T**ransient **E**xploring **S**ystem**)**, is becoming a worlwide network (3 so far) of 0.6m Ø identical robotic telescopes, EMCCD cameras and filters (R and g’r’i’ZY) should help rapidly pointing to these events as soon as they go off. Synergy with GTC !.





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Conclusions

On 28 Mar 2011, the *Swift* satellite detected an unusual source, and new observational facts presented here suggest that Sw 1644+57 may not only represent a short-lived flaring episode due to accretion process (TDF or non-TDF) by the central massive BH in a z = 0.354 galaxy, **which allowed us to see the formation of a jet in real time.** The case of Sw 1644+57 -and similar events- provides an unique opportunity to observe in "real-time" the progressive formation of a relativistic jet. .

Some numbers: The SN rate per 16 arcmin squared per year is about 20, and this corresponds to an all-sky SN rate of 6 SN/sec (~500.000/day)

The universal GRB rate is 3/day, or x300 correcting by beaming, i.e. 0.02 GRB/sec (~1700/day)

How many TDFs or AGN “waking-up episodes” are out there? 0.0001/sec (~9/day)

Multiwavelength observations (photometry, spectroscopy, polarimetry) should be a must in order to be ready for the next one !

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