# ULXs long-term evolution: the key role of Swift/XRT

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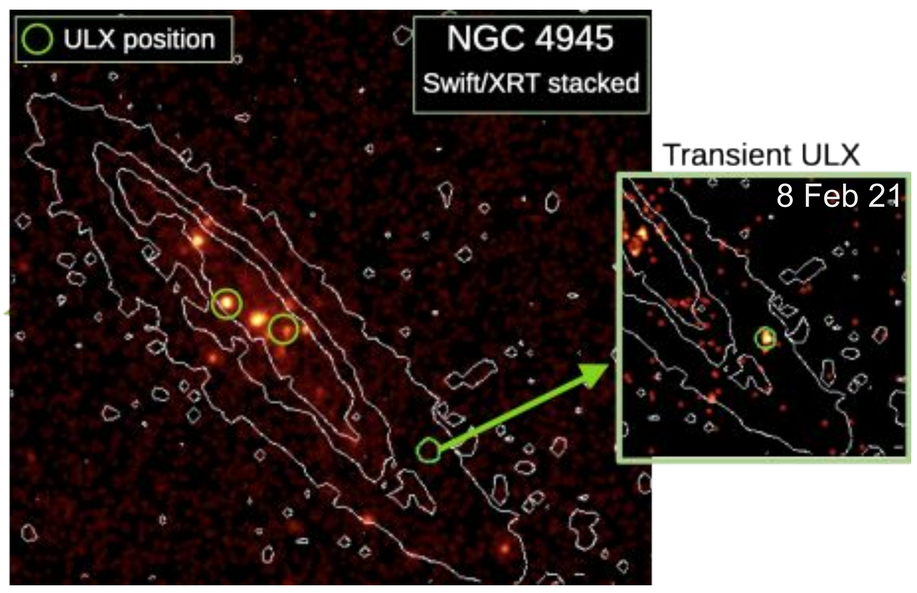
**Introduction**: Ultraluminous X-ray sources (ULXs): point-like, extragalactic X-ray sources, defined on a threshold luminosity of $10^{39}$ erg $s^{-1}$. Most of them are super-Eddington accreting X-ray binaries. ULXs are variable both on short and long timescales. To study the long-term evolution (days-months), we need monitorings. Swift/XRT is the only telescope which allows X-ray monitorings on such timescales, thanks to its flexibility and good sensitivity at soft X-rays.
In this poster, a few examples of variability patterns discovered thanks to Swift/XRT data are shown.

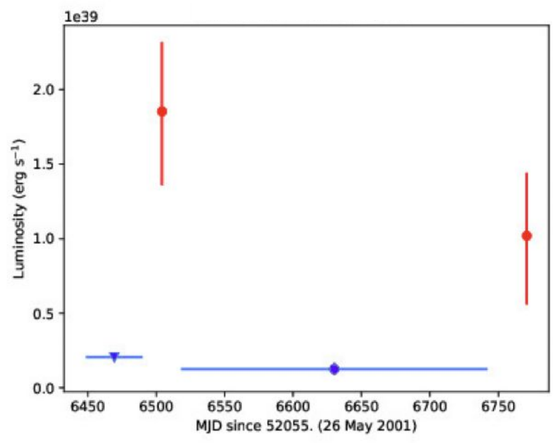
## TRANSIENT SOURCES




Some ULXs are not detected in all the observations or sometimes they are observed below the ULX luminosity threshold. These sources are characterized by flux variability of order of magnitudes.

In the figure: stacked X-ray image of NGC 4945 before February 8th, 2021, when a new transient ULX switched-on. In the inset, the transient ULX is clearly visible.

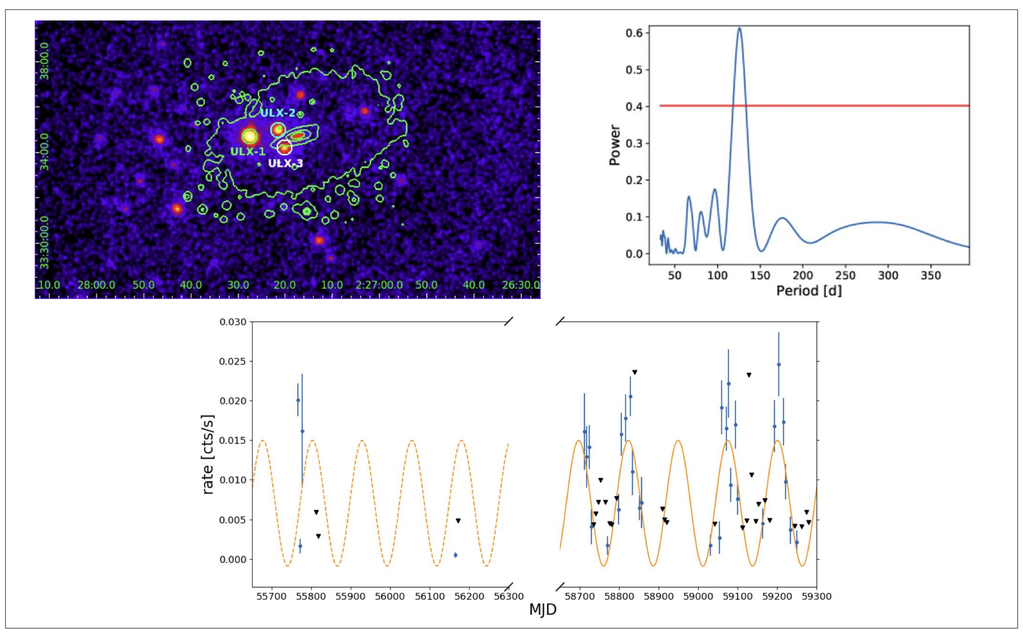
## FLUX BIMODALITY




In the figure: Swift/XRT light curve of a ULX in M101. Red points are detections; the blue triangle is an upper limit; the blue point is a stacking of observations, each of them resulted in an upper limit.

A bimodal flux distribution in the long-term light curve indicates two different flux states. A high flux state, with the ULX in super-Eddington accretion, and a low state, with a drastic reduction of the X-ray emission. A possible explanation for this flux distribution is a propeller effect: an inhibition of the accretion by a centrifugal barrier, produced by the magnetosphere of a highly magnetized neutron star.

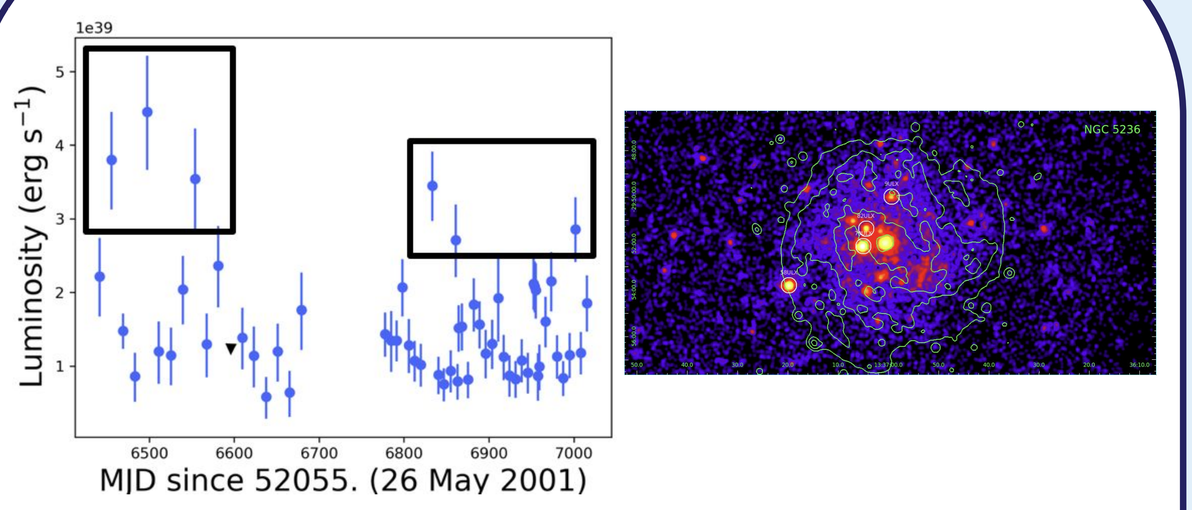
## LONG-TERM PERIODICITIES




NGC 925 ULX-3 is a transient ULX, with a long-term periodicity of ~ 126 d, probably caused by a super-orbital modulation. Even if different models have been proposed in the literature, it is still not clear which phenomenon causes such flux modulations. A possibility is a precession of the accretion flow.

In the images: Swift/XRT stacked image of NGC 925; Lomb-Scargle periodogram of ULX-3; long-term light curve of ULX-3, the periodicity is superimposed (from Salvaggio et al. 2022).

## FLARING ACTIVITY




A forest of narrow peaks is rarely observed in ULXs. In the few known examples, the flare duration has a timescale of hours. Thus this behaviour is usually observed in single deep exposures. But, in case of a longer flare duration, or of a large increase in flux, we may detect flaring activity in a long-term light curve.

In the figure: On the left, candidate flaring activity in the Swift-XRT light curve of a ULX in NGC 5236. On the right, Swift/XRT stacked image of NGC 5236.

**Conclusion**: It is still not clear how many black holes (BH) or neutron stars (NS) are contained in the ULX population. For less than 10 sources the NS nature has been confirmed, thanks to the detection of pulsations in the X-ray emission. The search for pulsations requires high quality data, available for a small fraction of ULXs. The pulsating-ULXs (PULXs) have common variability properties: transient behaviour, large variability factors, flux bimodality and super-orbital periodicities. These properties can be found through a long-term variability study. Swift/XRT is fundamental to search for these features, useful to select candidate PULXs even in the absence of pulsations. These studies are very important for the determination of ULX population demography.