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A New X-ray Probe for Supermassive Black Holes in Nearby (Inactive) Galaxies

S. KOMOSSA
Max-Planck-Institut für extraterrestrische Physik, Postfach 1312, 85741 Garching

Abstract

In the last few years, giant-amplitude, non-recurrent X-ray flares have been observed from several galaxies. Ground-based optical spectra of these galaxies do not show any signs of AGN activity. The extreme X-ray properties in outburst – quasar-like X-ray luminosities and giant amplitudes of variability – nearly inevitably call for the presence of supermassive black holes at the centers of the flaring galaxies. The observations were interpreted in terms of the long-predicted tidal disruption flares of stars captured by supermassive black holes. We provide a short review of the original observations and recent results.

1.1 Introduction

It has long been suggested that supermassive black holes in non-active galaxies might be tracked down by occasional tidal disruptions and subsequent accretion of stars. A tidal disruption event would reveal itself by a luminous flare of electromagnetic radiation (e.g., Lidskii & Ozernoi 1979, Rees 1988, 1990). A star on a radial 'loss-cone' orbit gets tidally disrupted after passing the tidal radius. About 75%–90% of the gaseous debris becomes unbound and is lost from the system. The rest will eventually be accreted by the black hole.

1.2 X-ray Flares, Interpreted as Stellar Tidal Disruption Events

With the X-ray satellite *ROSAT*, some rather unusual observations have been made in the last few years: the detections of giant-amplitude, non-recurrent X-ray outbursts from a handful of galaxies which lack AGN-indications in optical spectra. Based on the huge observed outburst luminosity, and other properties, the observations were interpreted in terms of tidal disruption events (e.g., Komossa & Bade 1999, Li et al. 2002). Four X-ray flaring galaxies – NGC 5905 (Fig. 1.1 and 1.2), RXJ1242–1119, RXJ1624+7554, RXJ1420+5335 – were identified and there is a possible fifth candidate (Tab. 1), all of which show similar properties (see Komossa 2002 for a review):

- huge X-ray peak luminosity (up to $\sim 10^{44}$ erg/s),
- giant amplitude of variability (up to a factor ~ 200),
- ultra-soft X-ray spectrum ($kT_{\rm bb} \simeq 0.04$-0.1 keV),
- absence of optical signs of Seyfert activity in ground-based spectra (and in HST spectra when available, with one exception: an HST spectrum of NGC 5905 reveals weak high-excitation emission lines, further discussed below).

These observations nearly inevitably call for the presence of supermassive black holes as ultimate energy reservoirs to power the flares (see the extended discussion by Komossa & Bade 1999, and Komossa 2002). The events are therefore of the general kind suggested by Lidskii & Ozernoi (1979) and Rees (1988) to be used as tracers of SMBHs in otherwise non-active galaxies (i.e., galaxies which appear non-active to the observer, as judged from typical, ground-based observations).

NGC 5905 was recently observed using the Hubble Space Telescope in an ongoing effort to put ever better constraints on the presence of extremely weak AGN activity in this galaxy. These observations led to the detection of weak high-excitation emission lines in the very nucleus of NGC 5905 (Gezari et al. 2003, these proceedings), indicating the presence of a low-luminosity Seyfert 2 nucleus.

Table 1.1. *Summary of the X-ray properties of the flaring galaxies during outburst (NGC 5905: Bade et al. 1996, Komossa & Bade 1999, RXJ1242–1119: Komossa & Greiner 1999, RXJ1624+7554: Grupe et al. 1999, RXJ1420+5334: Greiner et al. 2000; for first results on another candidate see Reiprich & Greiner 2001. Based on the position they report, we refer to this source as RXJ1331–3243).* $T_{\rm bb}$ *denotes the black body temperature derived from a black body fit to the data (cold absorption was fixed to the Galactic value in the direction of the individual galaxies).* $L_{\rm x,bb}$ *gives the intrinsic luminosity in the (0.1–2.4) keV band, based on a black body fit. We note that this is a lower limit to the actual peak luminosity, since we most likely have not caught the sources exactly at maximum light, since the spectrum may extend into the EUV, and since we have conservatively assumed no X-ray absorption intrinsic to the galaxies.*

galaxy name	redshift z	$kT_{\rm bb}$ [keV]	$L_{\rm x,bb}$ [erg/s]	factor of variability
NGC 5905	0.011	0.06	$3\ 10^{42*}$	170
RXJ1242–1119	0.050	0.06	$9\ 10^{43}$	> 20
RXJ1624+7554	0.064	0.097	$\sim 10^{44}$	200
RXJ1420+5334	0.147	0.04	$8\ 10^{43}$	150
RXJ1331–3243	0.051			

*Mean luminosity during the outburst; since the flux varied by a factor $\sim$3 during the observation, the peak luminosity is higher.

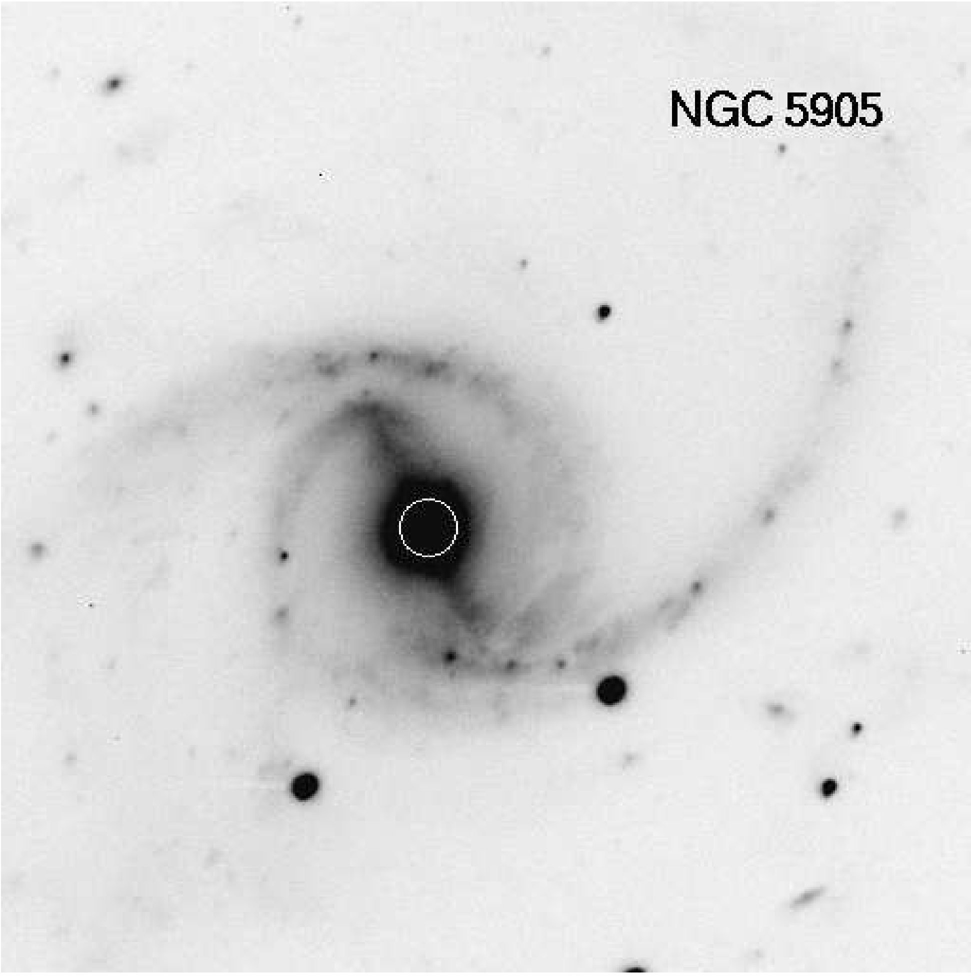

Fig. 1.1. Optical image of the galaxy NGC 5905 (Hubble-type SBb). The circle marks the positional uncertainty of the X-ray emission.

1.3 The Search for New X-ray Flares

Future X-ray observations of the flare events are expected to open up a new window to detect and investigate SMBHs and their immediate environment in galaxies. Both, high-quality X-ray spectra, and rapid multi-wavelength follow-up observations will be of great importance. The following aspects are of particular interest:

- The flare will illuminate the material surrounding the nucleus. Reprocessing of the radiation into emission-lines and their temporal variability will provide valuable diagnostics of the physical conditions in the circum-nuclear matter.
- X-ray observations with high spectral and temporal resolution might open up a chance to probe the realm of strong gravity, since the temporal evolution of the stellar debris will depend on relativistic precession effects around the Kerr metric.

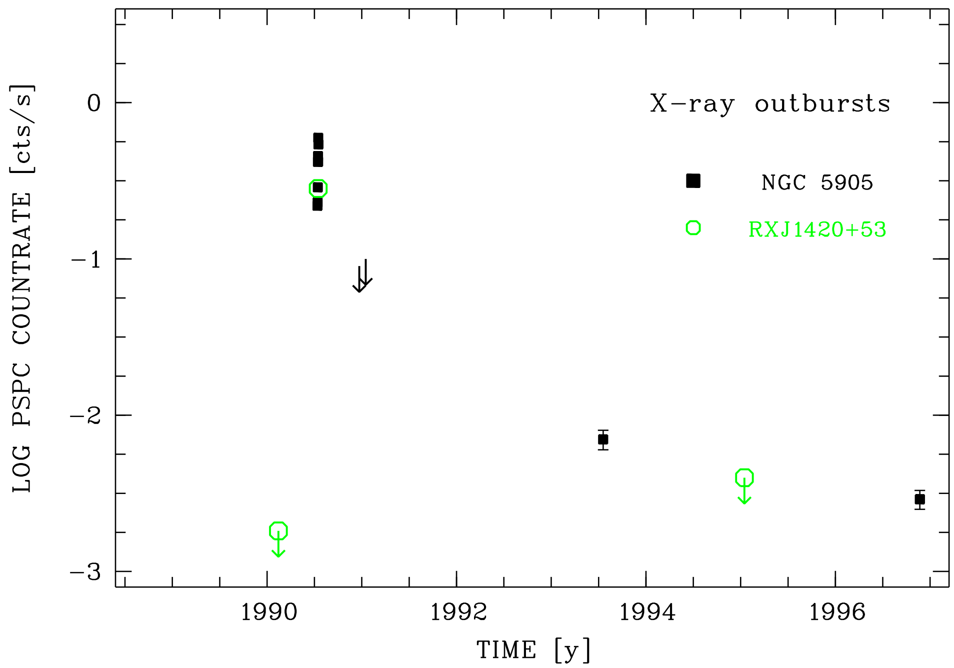

Fig. 1.2. X-ray lightcurve of NGC 5905 (black squares), and RXJ1420+53 (open circles; shifted in time to match the outburst date of NGC 5905). Arrows denote upper limits. A preliminary analysis of an archival *ASCA* observation of NGC 5905 carried out in 1999 shows that the source flux did not drop further compared to the last *ROSAT* observations.

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