“Spoon-feeding” an AGN

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Introduction

- IC 3599 (weakly active galaxy, Coma Cluster, 92 Mpc, \( z = 0.021 \))

- Soft X-ray discovery: RASS detection (December 1990)


- Putative tidal disruption event (TDE) by the central massive black hole
  \( (M_{\text{BH}}^{\text{IC3599}} \sim 3 \times 10^5 M_\odot) \), even if

  IC 3599 is an active galaxy

  (Grupe et al. (1995), Brandt et al. (1995), Komossa & Bade (1999), Vaughan et al. (2004))

X-ray flux decrease (~100)
Total and partial TDEs

PARABOLIC ORBITS

\[ R_{\text{pericenter}} \lesssim R_{\text{tidal}} \sim R_\ast \left( \frac{M_{\text{BH}}}{M_\ast} \right)^{\frac{1}{3}} (\beta = \frac{R_{\text{tidal}}}{R_{\text{pericenter}}} \gtrsim 1) \]

Total disruption of the star

Bound debris → accretion → bright flare

\[ L_{\text{bolometric}} \sim (t - t_0)^{-\frac{5}{3}} \]
Total and **partial** TDEs

**PARABOLIC ORBITS**

\[ R_{\text{pericenter}} \gtrsim R_{\text{ tidal}} \sim R_*(\frac{M_{\text{BH}}}{M_*})^{\frac{1}{3}} \quad (\beta = \frac{R_{\text{tidal}}}{R_{\text{pericenter}}} \lesssim 1) \]

Partial disruption of the star

Bound debris → accretion → less bright flare

\[ L_{\text{bolometric}} \sim (t - t_0)^{-\frac{5}{3}} \]
Total and partial TDEs

ECCENTRIC BOUND ORBITS

Transfer of a fraction of the mass of the involved star for each orbital period

A flare for each orbital period + “spoon-feeding” (MacLeod et al. 2013, only theorized) of a weakly active galaxy over several orbital periods

“Spoon-feeding” more frequent but less energetic than “classical” TDEs
IC 3599: our work with Swift

ROSAT and Chandra (1990-2002)
IC 3599: our work with Swift

Where does this emission come from?
AGN's variability

1) Power spectral density (PSD) of a typical AGN of $3 \times 10^5 \text{M}_\odot$

- $\sim \nu^{-1}$
- $\sim \nu^{-2}$

PHYTON light curve simulations with an unrealistic 100% rms variability

Maximum variability of a factor of about 6-7, too low compared to IC 3599 variability

McHardy et al. (2004)

2) Selection of the most variable (>20 variability factor) AGNs already sampled in the literature

From each light curve, random extraction (100000 times for each object) of 7 points (the number of points comprising the first TDE of IC 3599); fit with $(t - t_0)^{(-5/3)} + \text{cost}$; evaluation of the probability to have the best obtained $\chi^2$ (over 100000 trials)

$P(\chi^2_{\text{best}}) = P(\text{TDE}) = 4.66 \sigma, 4.53 \sigma$

Grupe et al. (2001)
Grupe et al. (2014)
IC 3599: our work with Swift

\[(t - t_0)^{(-5/3)}\] power laws

\[\chi^2_{\text{red}} \sim 0.83 \text{ (d.o.f. = 11)}\]

\[P_{\text{orb}} \sim 9.5 \text{ yr}\]

\[
\begin{align*}
\alpha &= 1.55 \div 4.05 \\
(90\% \text{ confidence level})
\end{align*}
\]

First peak exponential decay:
\[t_{\text{decay}} \sim 107 \pm 8 \text{ d}\]
(90% confidence level)

Third peak exponential decay:
\[t_{\text{decay}} \sim 101 \pm 26 \text{ d}\]
(90% confidence level)

related events
IC 3599: our work with Swift

Disk temperature folding: $(t - t_0)^{-5/12}$ power law \((-\frac{5}{12} = (\frac{1}{4})(-\frac{5}{3})\))

- First passage
- Second passage
- Third passage

$X^2_{\text{red}} \sim 0.6 \text{ (d.o.f. = 6)}$

$X^2_{\text{red without costant}} \sim 32 \text{ (d.o.f. = 6)}$

$X^2_{\text{red with costant}} \sim 6.6 \text{ (d.o.f. = 5)}$
IC 3599: the nature of the involved star

\[ \dot{M}_{\text{peak}} = \frac{L_{\text{peak}}}{\eta c^2} \sim 0.01 M_\odot \text{yr}^{-1} \ (\eta \sim 0.1) \]
\[ \Delta M \sim \frac{E_{\text{outburst}}}{\eta c^2} \sim 2.5 \times 10^{-3} M_\odot \] (accreted mass per episode)

Guillochon & Ramirez-Ruiz (2013): fitting formulae from hydrodynamical simulations on TDEs (stars approximated as polytropes, no imposed star's mass-radius relation)

SSE (Hurley et al. (2000)) software to trace the evolution of stars with different initial masses

\( \gamma = 4/3 \): massive stars on main sequence or Hertzsprung gap
\( \gamma = 5/3 \): no massive stars on main sequence or giant stars

MS or HG star, \( \beta < 1.85 \) partial disruption
MS star, \( \beta < 0.9 \) partial disruption

- main sequence
- Hertzsprung gap
- red giant branch
- core-helium burning
- asymptotic giant branch
**IC 3599:** the nature of the involved star

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- MS or HG star
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- MS star
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\( e \sim 0.995 \)
Conclusions

- IC 3599 observed emission already classified in the literature as coming from the tidal disruption of a star orbiting around the central massive black hole

- From new *Swift*/XRT observations (2010-2014) new X-ray luminosity increase and decrease very similar to the already analysed event

- The first ever observed periodic partial tidal disruption event with “spoon-feed” of the AGN

- Involved star: probably a (massive) star that is coming out the main sequence
  
  - Star totally consumed in ~ 10000 years; next peak in 2019
Thanks everybody for your attention