QUasi-periodic Eruption Survey for galaxy Transients (QUEST)

A Citizen Science Program to Search for the Heartbeats from Black Holes

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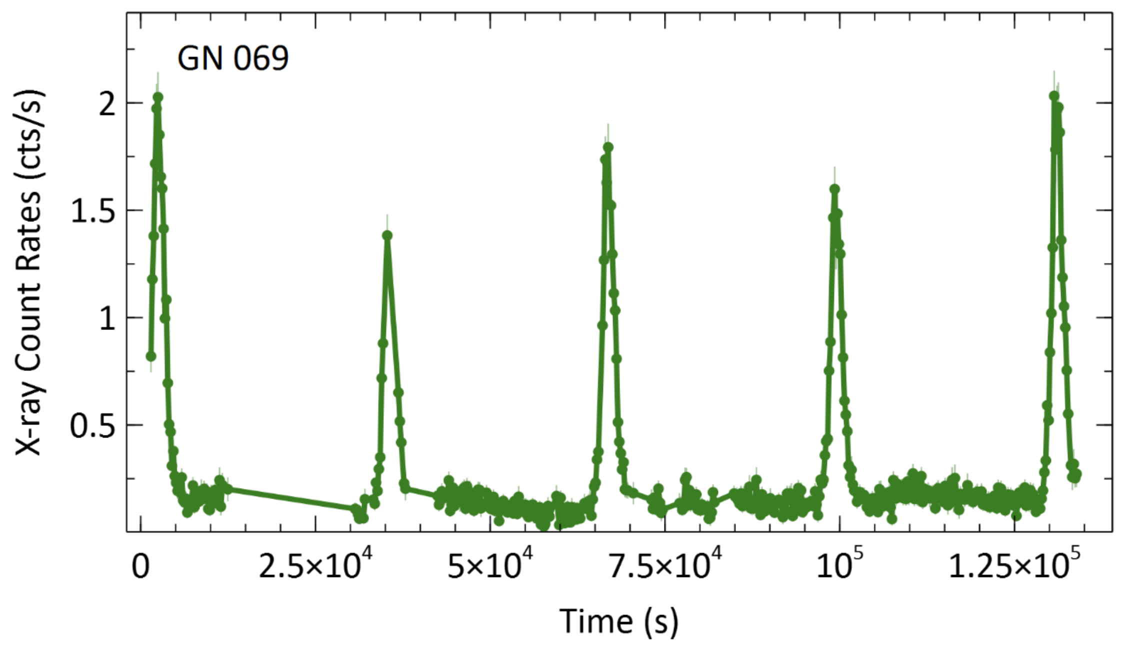
What are Quasi-Periodic Oscillations?

Only very recently, in 2019, astronomers have uncovered a rather rare phenomenon, quasi-periodic eruptions (QPEs), from supermassive black holes nestled within galaxies using X-ray telescopes. Imagine the scene: a sudden surge in X-ray luminosity by a factor of 100, only to retreat to its quiescent state within a mere hour. But here's the kicker – this X-ray flare repeats itself with near-clockwork precision, like the pulsating rhythm of heartbeats from black holes. What's more, these bursts of X-ray photons exhibit a symphony of symmetry, with their rise and decay mirroring each other. See the image below for an example of QPEs in GN 069.



Why do we need more samples of QPEs?

QPEs are exceptionally rare phenomena. Currently, astronomers have identified only six galaxies exhibiting QPEs. These events are closely linked to the growth processes of black holes, which can occur through various mechanisms such as accreting mass (ref 4), merging with other supermassive black holes (ref 6), or interacting with nearby stars (ref 5).

To gain deeper insights into QPEs and their origins, astronomers require a substantial sample size of similar galaxies. This broader dataset is essential for drawing conclusive evidence about the nature of these events, the dynamics surrounding supermassive black holes, and understanding their frequency in the universe. Such discoveries contribute significantly to our comprehension of black hole evolution.

Why do we need your help?

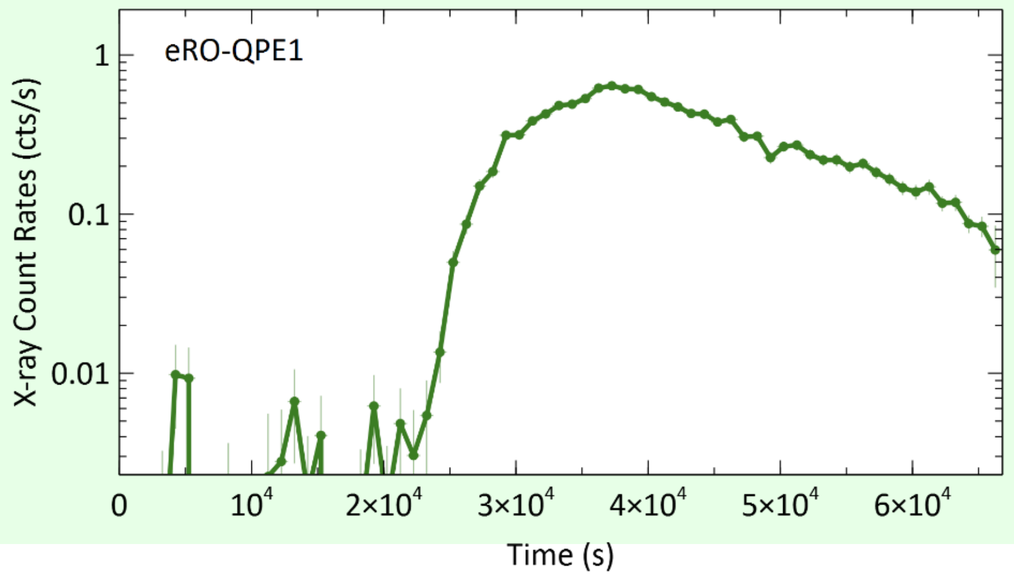
Together, we can embark on an exciting mission – to amass a sample of galaxies with QPEs, joined with the power of artificial intelligence our team has been relying on. In this adventure with us, you will explore data collected by missions from the famous XMM-Newton telescope, the flagship of European X-ray astronomy launched in 1999, to the latest extended Roentgen Survey by the joint German–Russian Spectrum-Roentgen-Gamma mission, launched in July 2019.

To start QUEST with, we have 34,000 sets of data from the archive of XMM-Newton. It is impossible for individual astronomers to investigate each of them.

Why not machine learning?

While machine learning techniques, including neural network algorithms, have been applied to our datasets (ref 3), their effectiveness is contingent upon the quality and completeness of training data. Astronomical observations frequently encounter challenges such as missing time intervals due to various factors like background noise. Our current Neural Network needs to work on observations with limited exposure time or very gappy data. Following is an example of an early archival observation of a QPE our Neural Network had trouble classifying, because the observation was not long enough to cover one full flare period. The flare is rather 'broad' compared to the full length of the observation. Its QPE signal was later confirmed by longer observations. We are updating our Neural Network approach to better meet these needs. So stay tuned for our results.

In contrast, human observation remains invaluable for identifying patterns, such as flares in data with missing time intervals or rather short exposure, which may elude automated algorithms.



Fun facts of QPEs

Known five QPEs are all found in low-mass galaxies hosting a relatively smaller supermassive black holes of mass between

$10^{5\text{-}7}$

solar masses.

Only X-ray telescopes

can find QPEs because they only exit in the X-ray wavelength.

The periods of QPEs are between

2-20 hours.

The peak bolometric luminosity of QPEs can reach $10^{42\text{-}44}$ erg/s, which is

10-100 *more*

luminous than their quiescent luminosities.

The energy given out in the form of QPE radiation in one year is approximately the equivalent of

2 Earth masses *(ref 1)*

in, for example, GN 069, the first galaxy with detections of QPEs.

So far, we have detected only

6

galaxies with QPEs (ref2).

How can I help QUEST?

As a ***school teacher***, you can seamlessly integrate QUEST into your curriculum, enhancing your students' understanding of astrophysics while aligning with high school physics concepts. For instance, the periodicity of regular flares in QPEs directly correlates with Keplerian orbital periods near black holes, offering a rich opportunity to bridge classroom learning with real-world scientific exploration. Feel free to incorporate our program materials into your teaching resources, and for further assistance or information, don't hesitate to reach out to Jiachen, the program leader.

We're also enthusiastic about facilitating hands-on workshops at your school, where we can engage directly with your students and guide them through participating in QUEST.

If you're a ***professional astronomer or physicist*** eager to contribute to our project, we welcome your involvement as a valued collaborator. We're actively seeking professionals to join our team, assist with testing, and enrich our Discussion board with your insights. Please don't hesitate to contact Jiachen via email to express your interest and explore collaboration opportunities.

Scan this QR code to access the preview of our program on Zooniverse. Our website is still under internal tests and will be fully online soon.

Scan this QR code to email our program leader Jiachen Jiang at jcjiang12@outlook.com.

Other scientific potential of QUEST

The primary goal of this program isn't solely centred on QPE identification. By engaging with QUEST, you're not only assisting in uncovering QPEs but also contributing to the discovery of highly variable galaxies, AGNs, quasars, or generally X-ray point sources with diverse characteristics unrelated to QPEs. These galaxies present intriguing opportunities for exploring various aspects of astrophysics beyond QPE phenomena.

References

1 Miniutti et al. 2019 Nature, 573, 381. This calculation assumes the peak luminosity of the QPE remains consistent for one year. The total radiation energy is 10^{43}ergs/s x 365 days x 24 hrs x 3600 secs x 6% x 0.5 = 9.5×10^{48}ergs. This value is approximately $2xM_{Earth}c^2 \approx 10^{49}$ergs.

2 Arcodia et al. 2024 A&A, 684, A64

3 Webbe R. et al. 2023, RAS T.&I., 2, 238

4 Raj, A. & Nixon, C. J. 2021, ApJ, 909, 82

5 King, A. 2020, MNRAS, 493, L120

6 Ingram, A., et al. 2021, MNRAS 504, 5512