

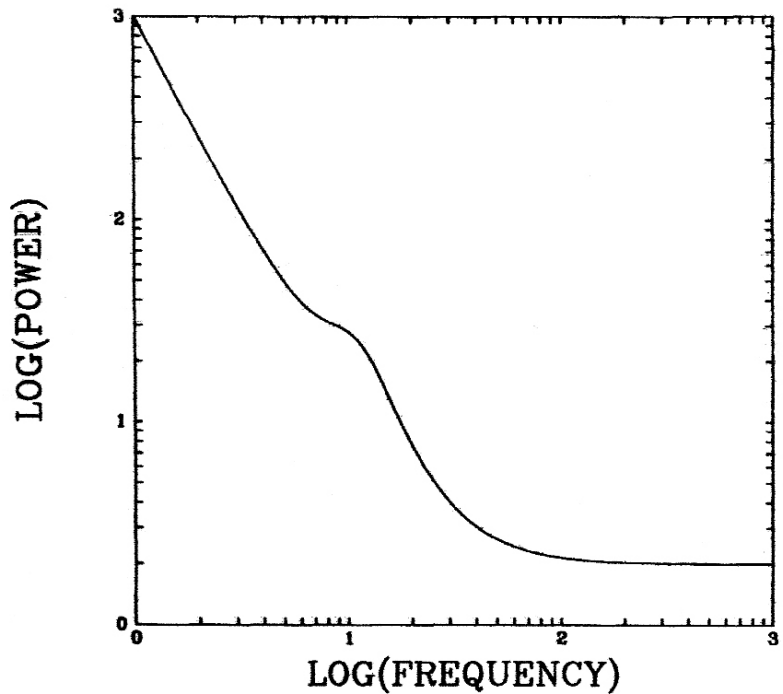
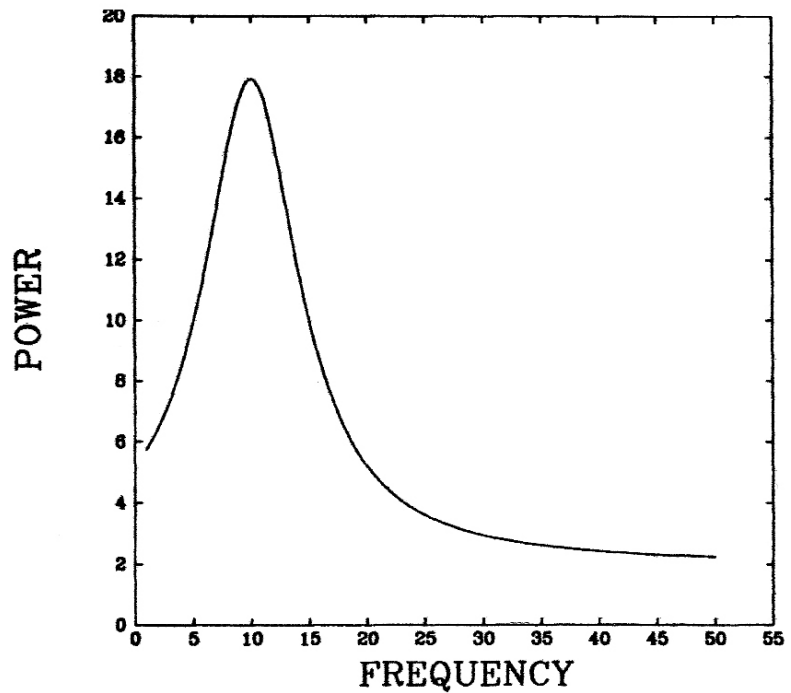
Quasi-Periodic Oscillations

Klaus Tichmann
3. December 2004

Topics

- Quasi-periodic Oscillations in general
 - What are QPOs?
 - Classification
 - Sources where QPOs were observed
- QPO Spectra
- Methods to detect QPOs
- Theoretical Models to explain QPOs

What are QPOs



Hasinger, van der Klis 89

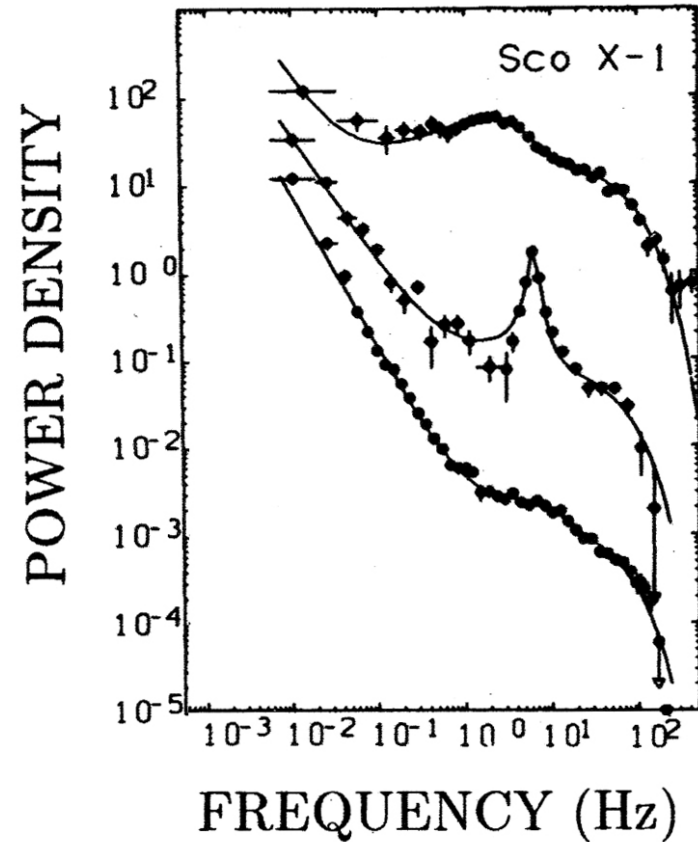
Classification

- "Normal" QPOs
- High Frequency QPOs
- Burst Oscillations

- Z-Shape Sources
- Atoll Shaped Sources
 - Banana Shaped Sources

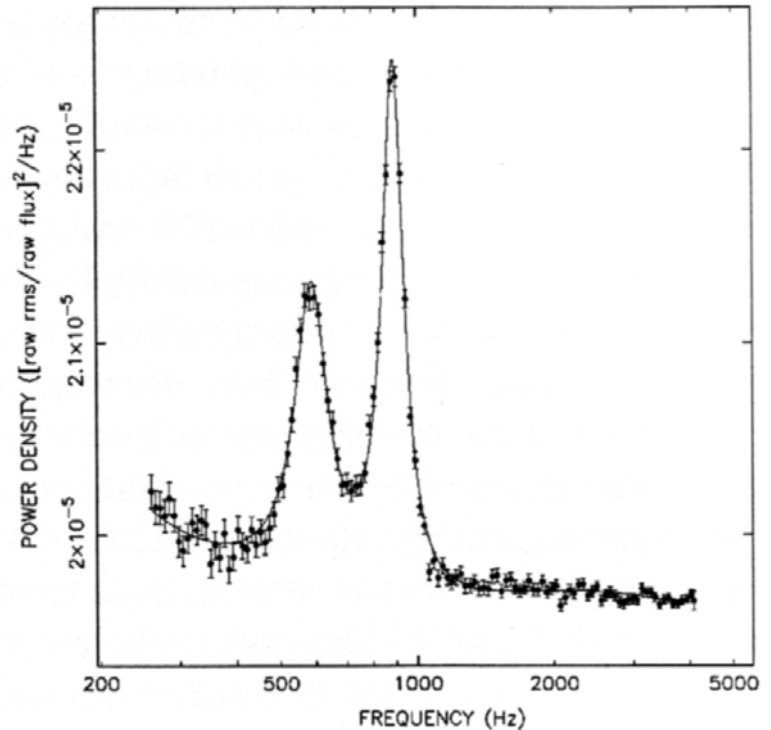
Normal (Low Frequency) QPOs

- Frequencies of up to 100Hz



High Frequency QPOs

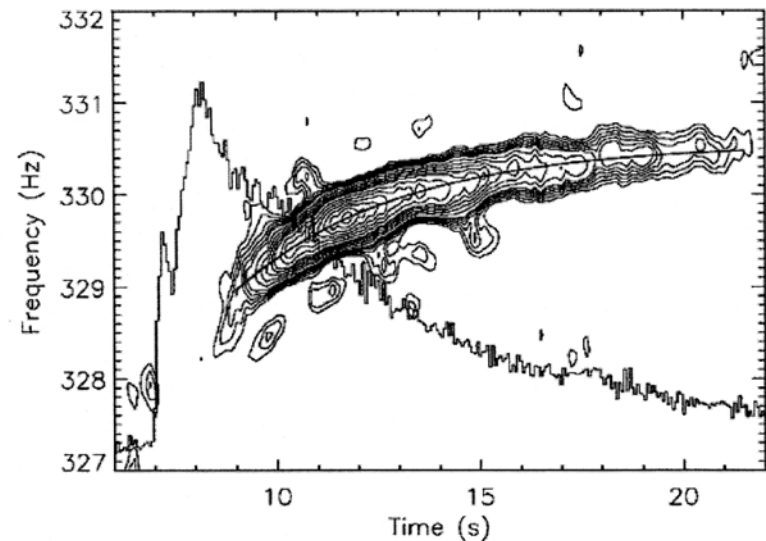
- Also known as kHz QPOs
- Often twin peaks



Van der Klis, 2000

Burst Oscillations

- Do not occur in every burst
- Result from anisotropic burning on the surface and rotation of neutron star
- Close to neutron star rotation frequency



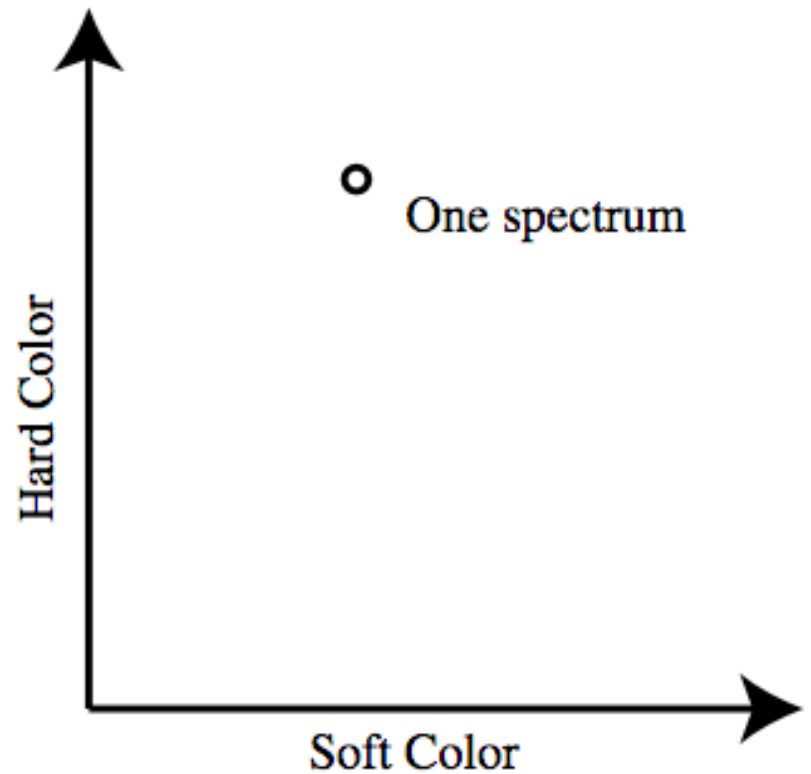
Van der Klis, 2000

Color Index

- Difference of magnitudes in two filters
- Magnitudes are a logarithmic scale!
- “Minimal Spectrum”

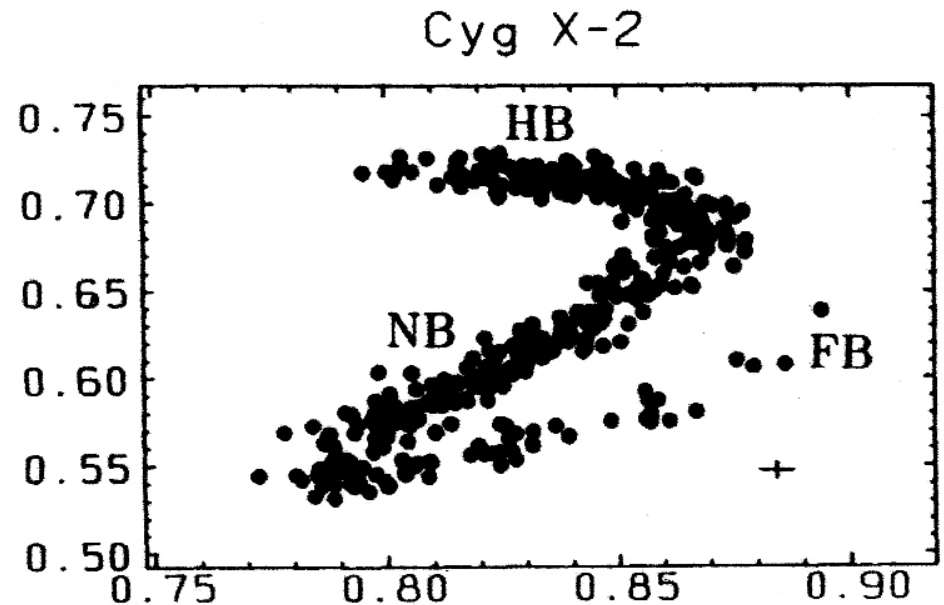
Color Color Diagrams

- Determine the hardness ratio (“color index”) in a hard and a soft X-Ray band
- Plot the hard versus the soft color
- Every X-Ray spectrum produces 1 point in the Color-Color Diagram



Shapes: Z-Shape

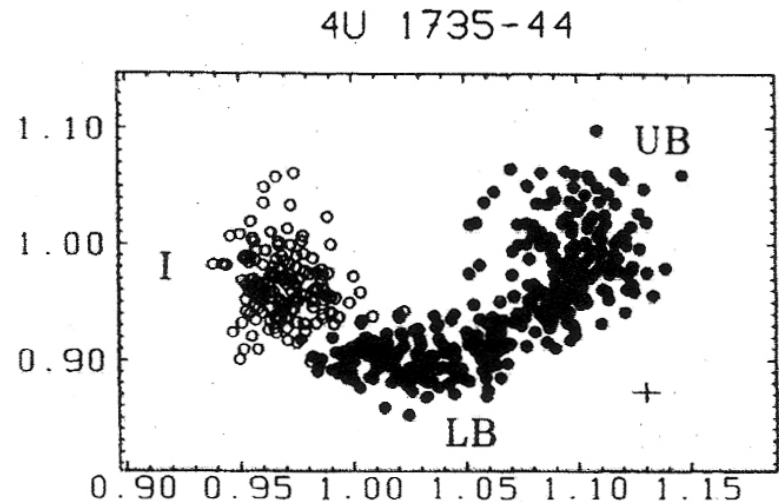
- Branches:
 - Horizontal Branch
 - Normal Branch
 - Flare Branch
- Very little scattering



Hasinger, van der Klis 89

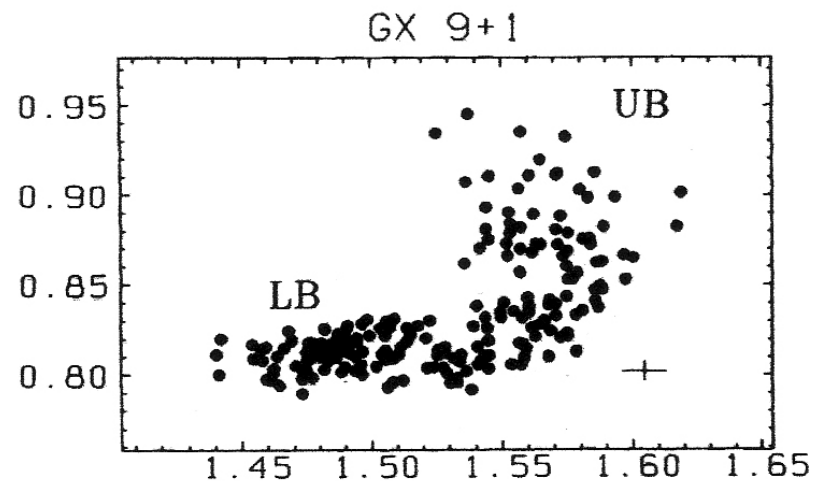
Shapes: Atoll Shapes

- No Z
- Two states:
 - Banana State
 - Island State
- Island Branch do not occur in fixed position



Shapes: Banana Shapes

- Larger scattering near top
- "Banana"-shaped branches
- Banana Branch
recurses in the same place

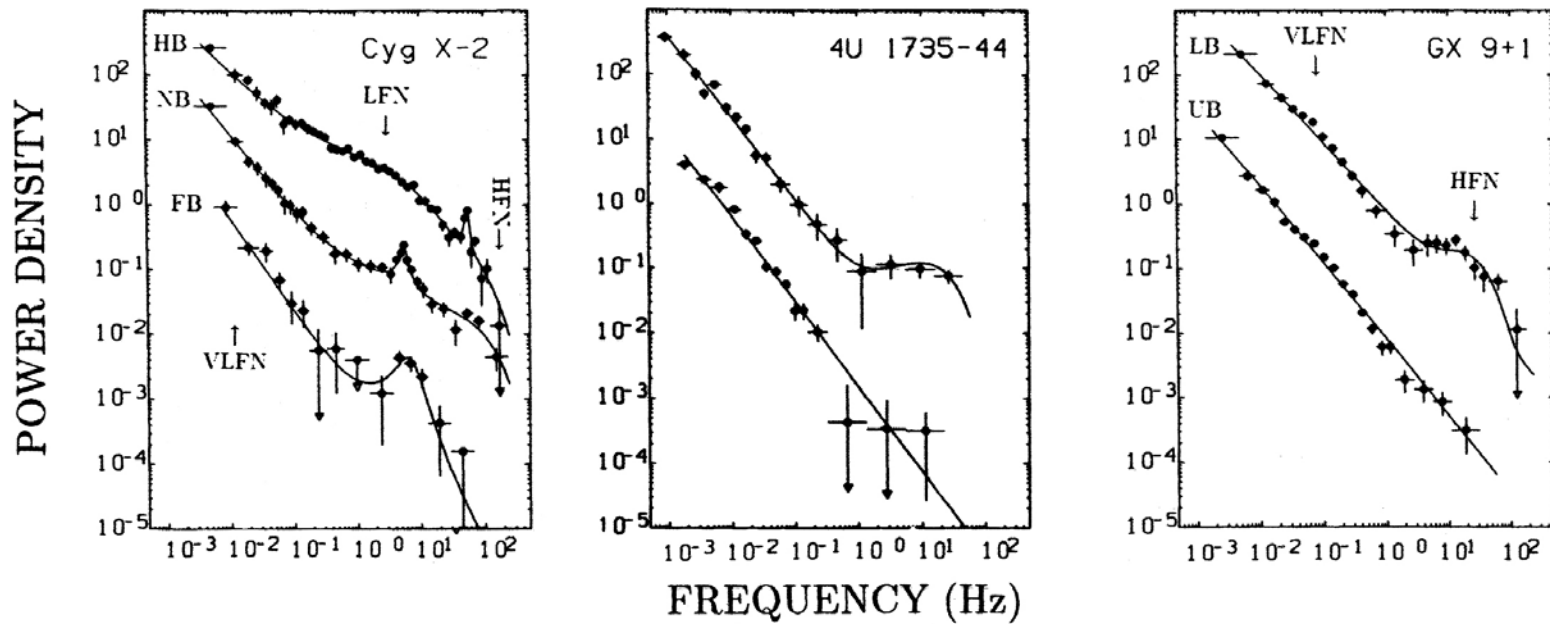


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Sources where QPOs were observed

- Low Mass X-Ray Binaries
 - Neutron Stars
 - X-Ray Bursters
 - Black Hole Candidates

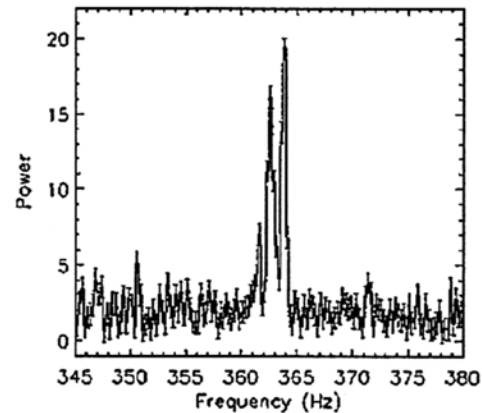
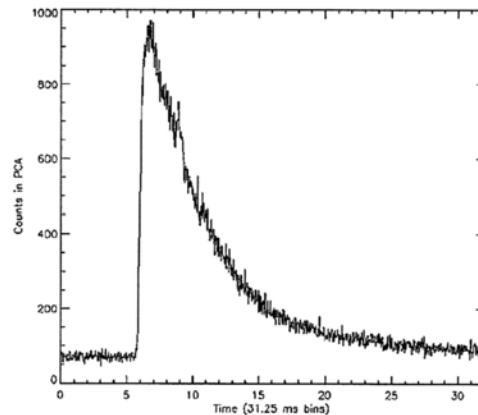
QPO Spectra



Hasinger, van der Klis 89

Detection of QPOs

- Data with high time resolution
- Discrete Fourier Transformation
- Subtract noise



Theoretical Explanations

- Beat-Frequency Model
- Relativistic Precession Model
- Photon Bubble Model
- Disk Mode Models

Beat-Frequency Model

- Accretion Disk and the Magnetosphere of the Compact Object rotate at different frequencies
- Inhomogeneities in the Accretion Disk interact with Anisotropies of the Magnetosphere
- A beat frequency occurs

Relativistic Precession Model

- Inclined eccentric orbits show
 - Nodal precession (wobble of the orbital plane)
 - Relativistic periastron precession
- Model identifies frequencies with orbit and precession frequencies

Photon Bubble Model

- Proposed to explain kHz QPOs in Sco-X1
- Photon bubbles form while the accretion takes place
- The bubbles rise up by buoyancy and burst on top in a quasi-periodic sequence
- The Model does not require rotation

Disk Mode Models

- The QPO frequency is interpreted as an oscillation mode of the accretion disk
- Some of the models can be interpreted as implementations of beat-frequency or precession models

Literature

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