Similar X-ray variabilities from the Sun and accretion disks

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Linear rms-flux relation of X-ray emission from accretion systems

- The root mean square variation of X-ray emission show a linear dependency to the contemporary average X-ray flux.
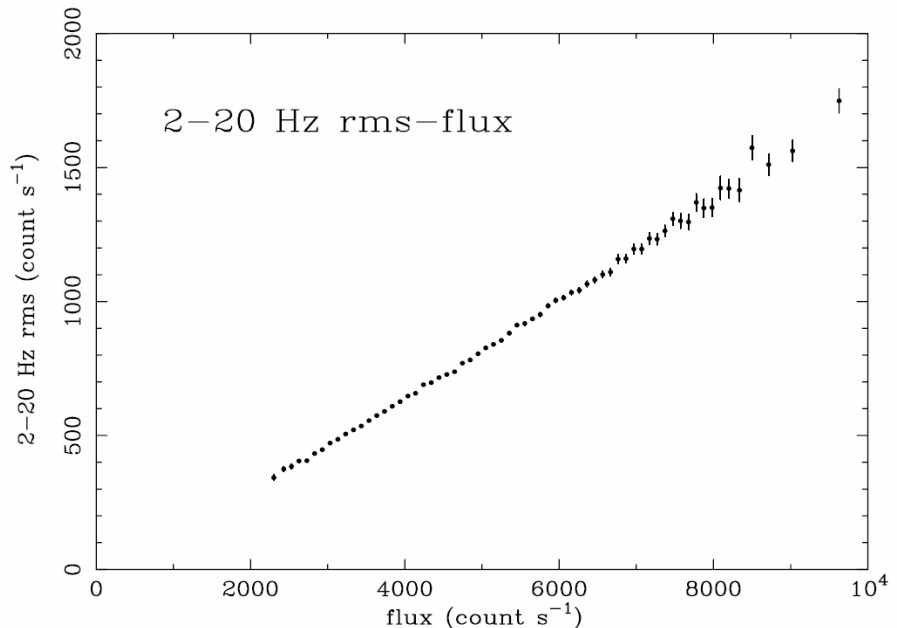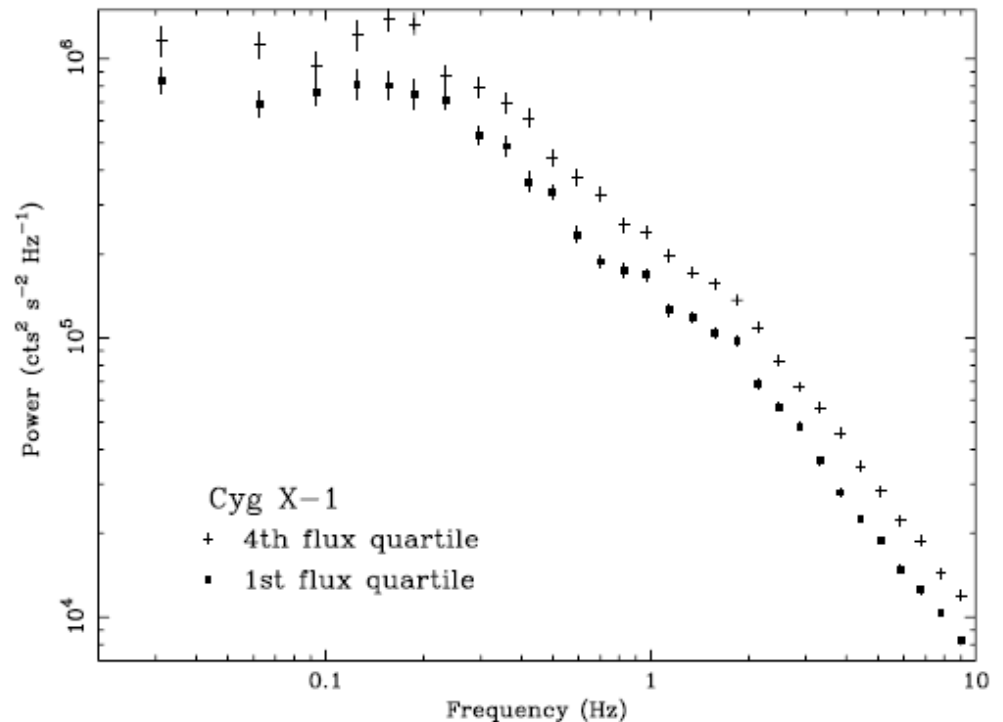

Uttley, et al. 2005

Phenomenon

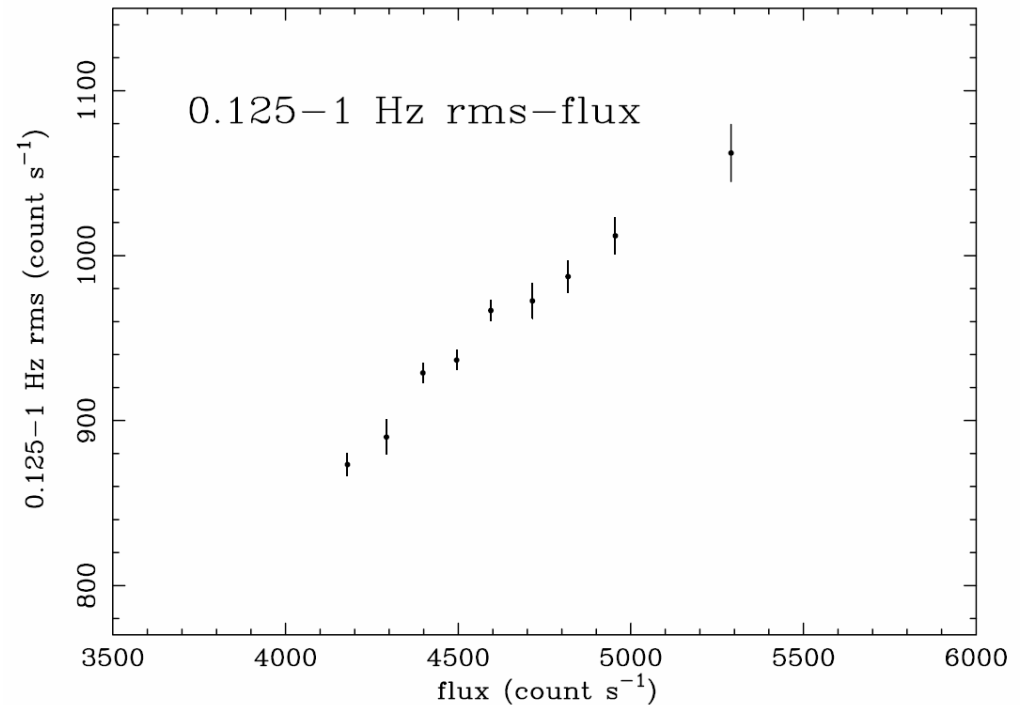- The shape of power spectrum keeps the same while the flux level changes.

Uttley & McHardy 2001

Phenomenon

- The linear relation is valid on any time scale time scale tested.

Uttley, et al. 2005

Model

- This relation is not consistent with the standard shot noise model, which is widely used for reproduce light curves with required power densities [Davies & Harte 1987].

- The linear relation requires some coupling among variablities.

Toy model

- A multiplicative process can give this linear relation.

$$x(t) = \prod_{i=1}^{\infty} \{1 + A_i \sin(2\pi v_i t + \phi_i)\}.$$

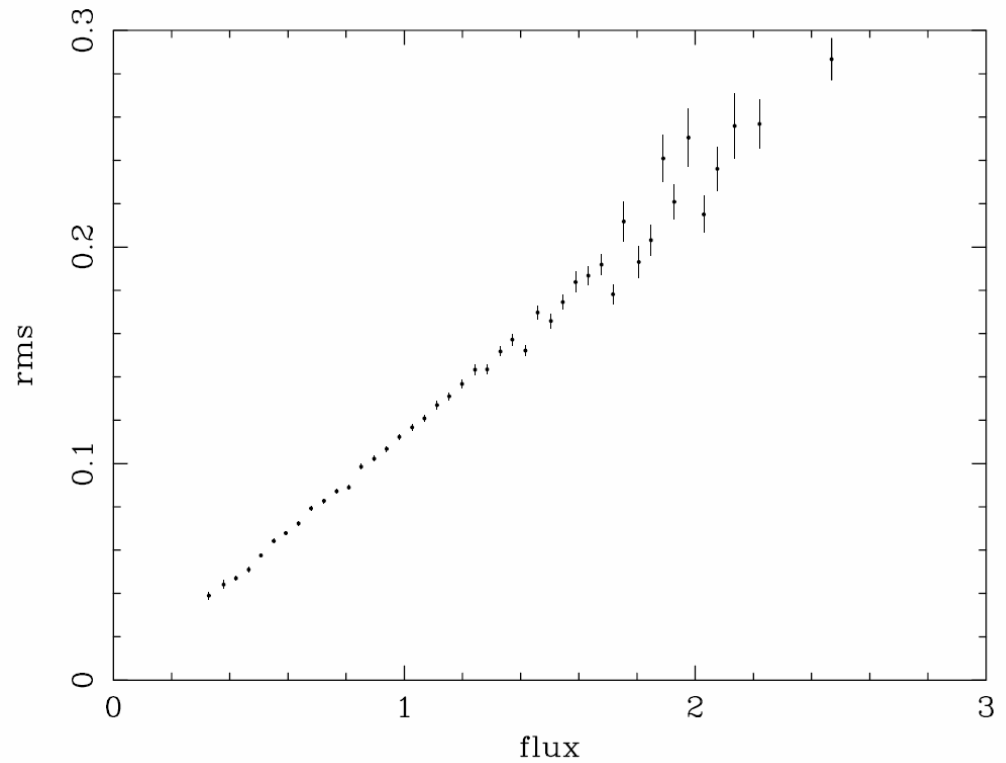- Also can be interpreted a exponential transform of a additive process.

$$\log[x_k] = \sum_{j=1}^{N/2} \log[1 + a_j(t_k)] \approx \sum_{i=1}^{N/2} a_j(t_k) = y_k$$

$$y_k = \sum_{j=1}^{N/2} A_j \sin(2\pi f_j t_k + \phi_j) = \sum_{j=1}^{N/2} a_j(t_k)$$

Vaughan & Uttley 2008

Toy model

- Simulated result

Uttley & McHardy 2001

Interpretation

- A model that has the require "coupling" of different time scales was discussed by Lyubarskii [Lyubarskii 1997]. In that model, the X-ray emission is produced only from the inner edge of the disc. Fluctuations at different radius have different time scales and they propagate inward to the inner edge and emits.

For the solar case?

- There is no accretion process in the Sun. Will its X-ray emission show same relation?

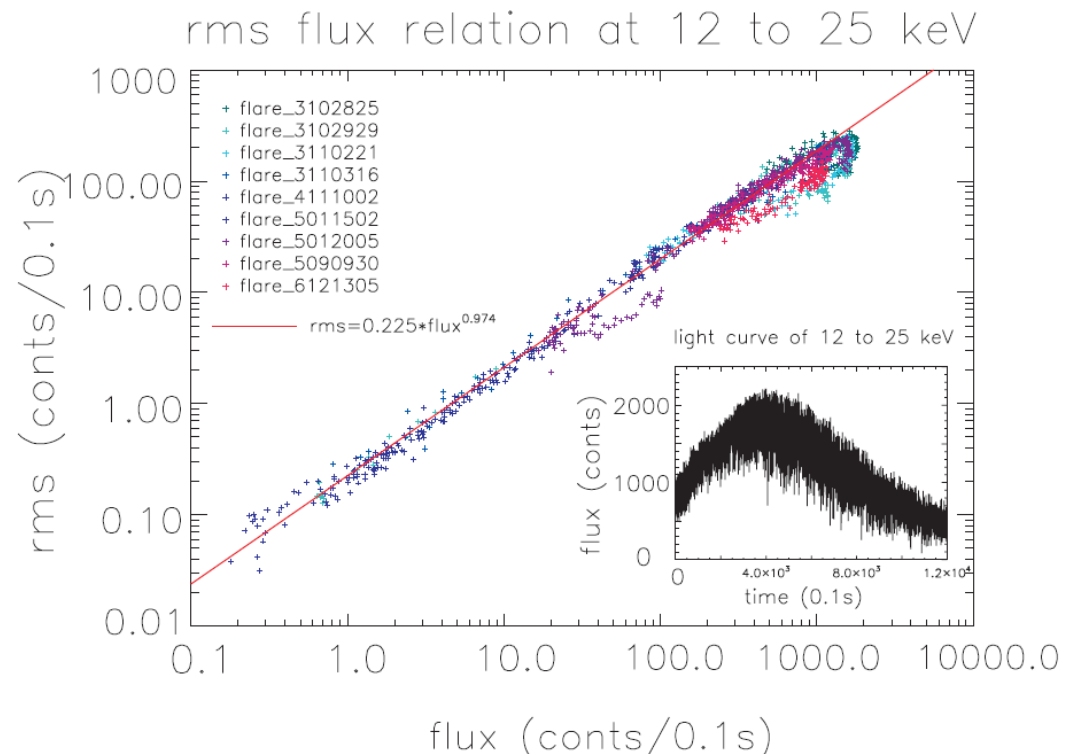- If so, the linear relation is not necessarily related to the dynamics of disk.

The data

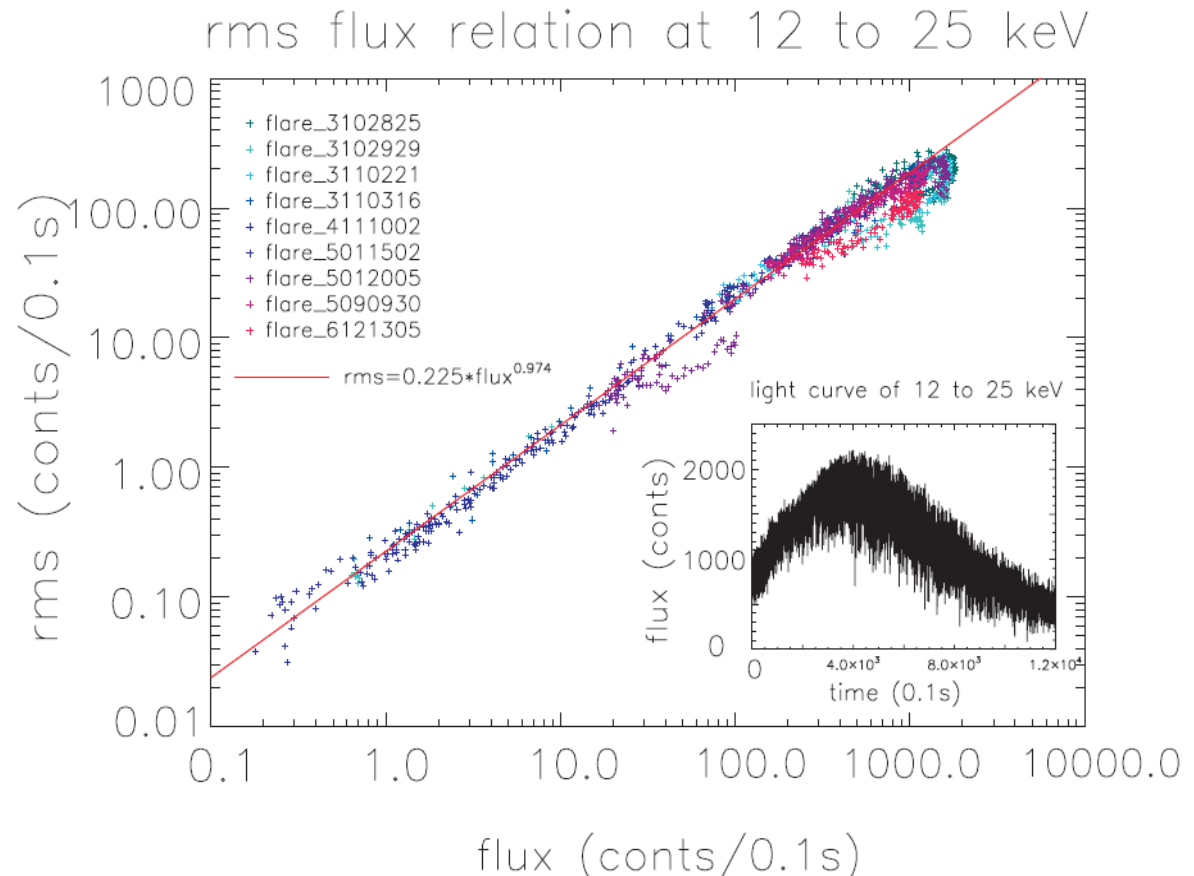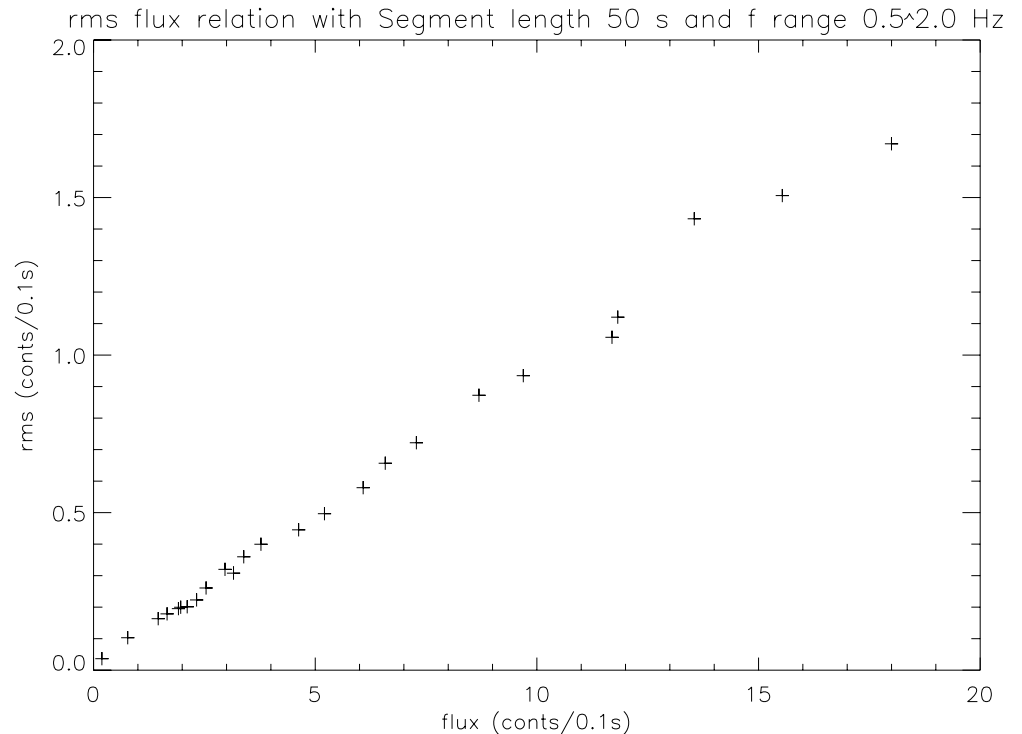- Our data are from the REUVEN RAMATY HIGH-ENERGY SOLAR SPECTROSCOPIC IMAGER (***RHESSI***)

The data

- As show in the figure, the rms variability and temporary flux show a linear relation over a dynamical range of 10^4 in energy band 3 to 25 kev

rms flux relation at 12 to 25 keV

The data

- As show in the figure, the rms variability and temporary flux show a linear relation over a dynamical range of 10^4 in energy band 3 to 25 kev.
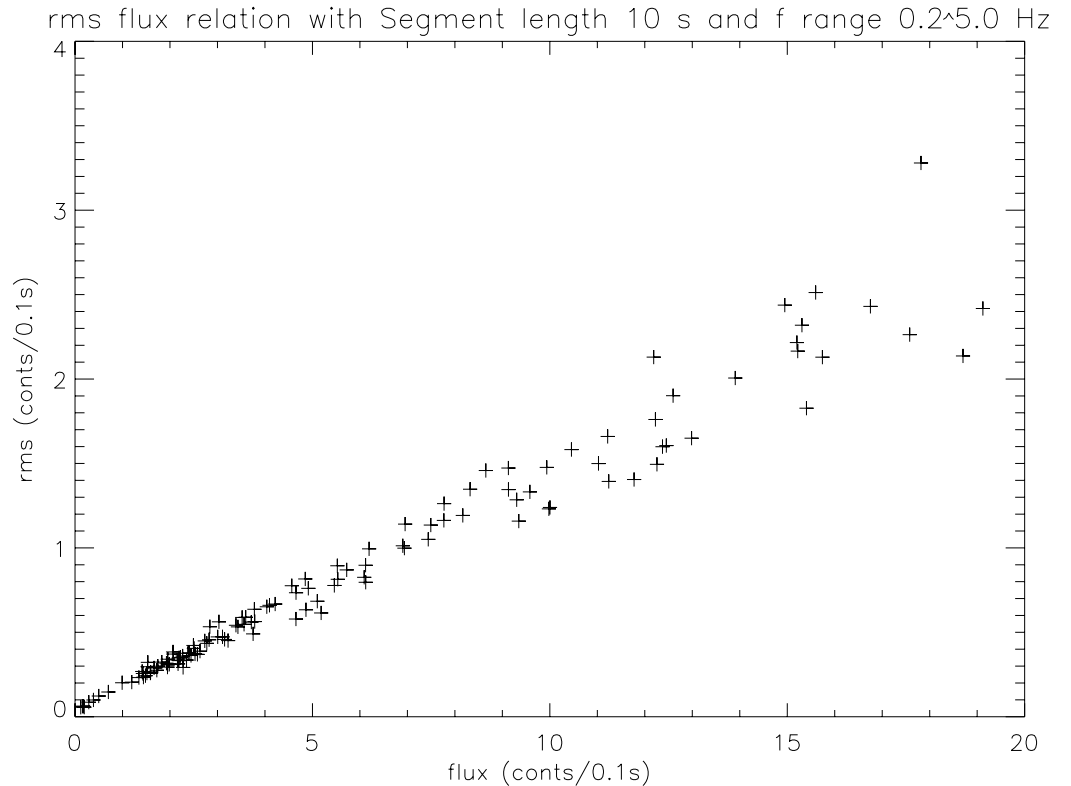

rms flux relation at 12 to 25 keV

flare_3102825
flare_3102929
flare_3110221
flare_3110316
flare_4111002
flare_5011502
flare_5012005
flare_5090930
flare_6121305

$rms = 0.225*flux^{0.974}$

light curve of 12 to 25 keV

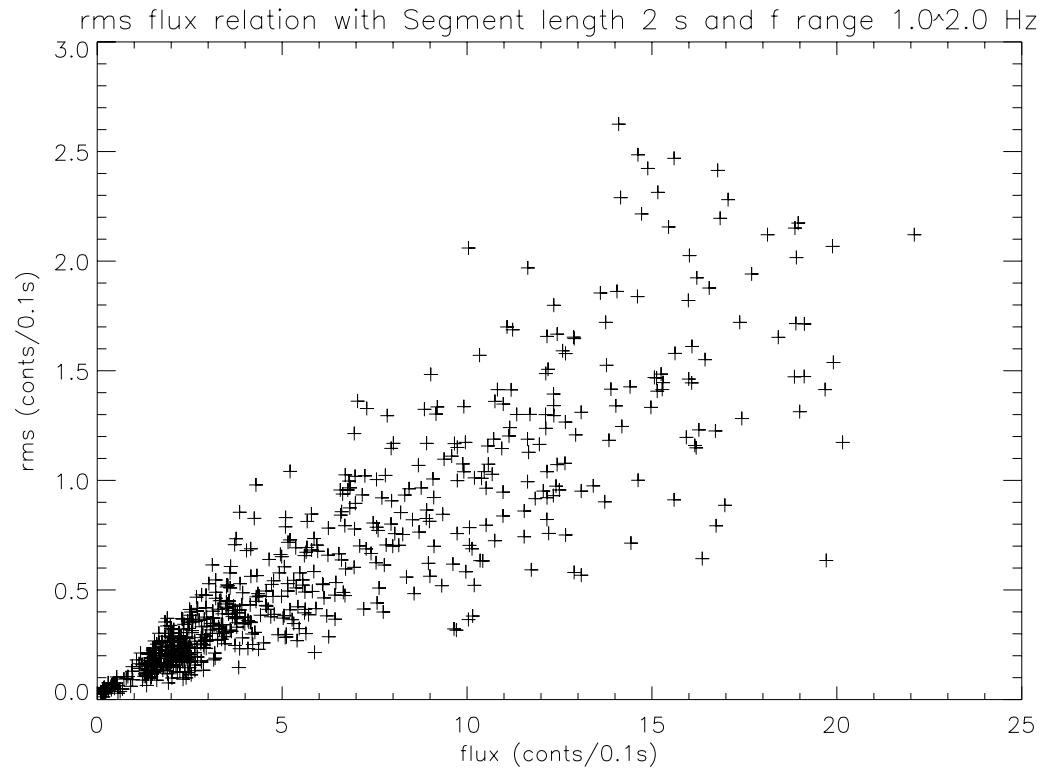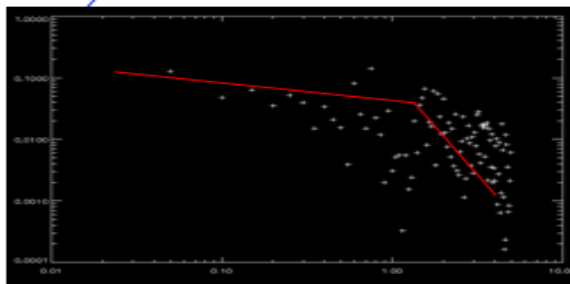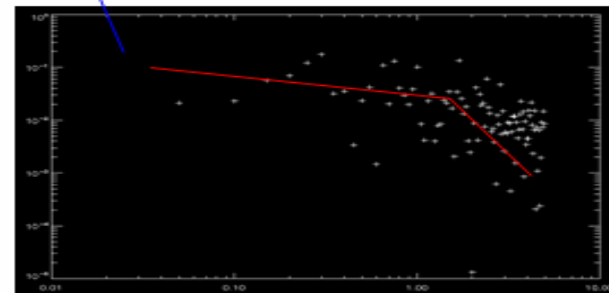# The data

- This relation is also valid for every time scale tested.

rms flux relation with Segment length 50 s and f range 0.5^2.0 Hz

The data

- This relation is also valid for every time scale tested.

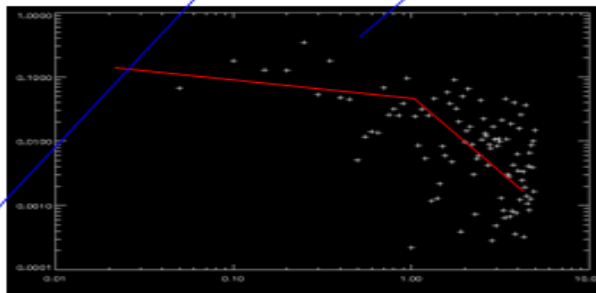rms flux relation with Segment length 10 s and f range 0.2^5.0 Hz

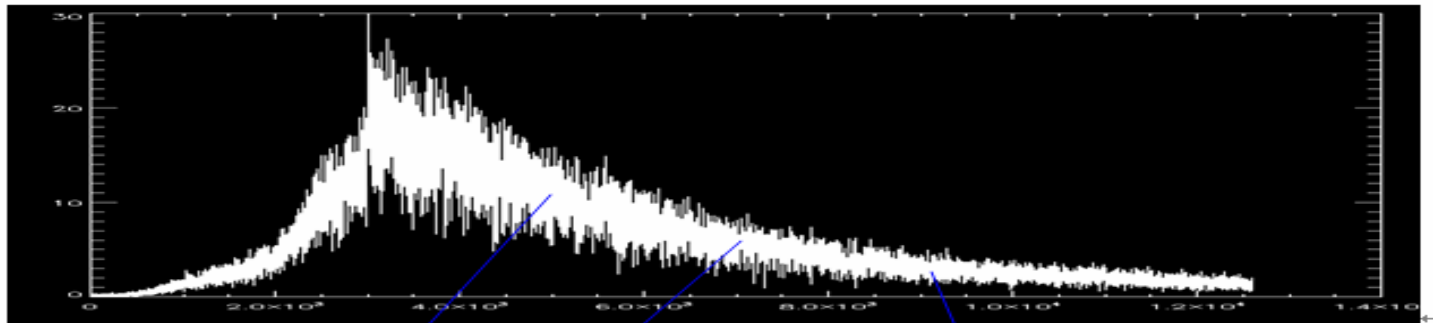# The data

- This relation is also valid for every time scale tested.

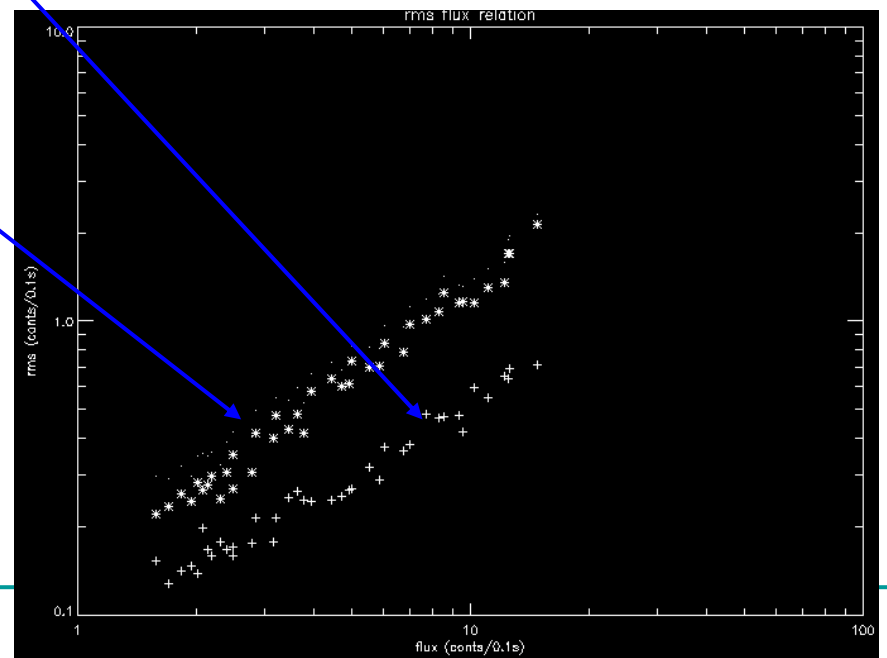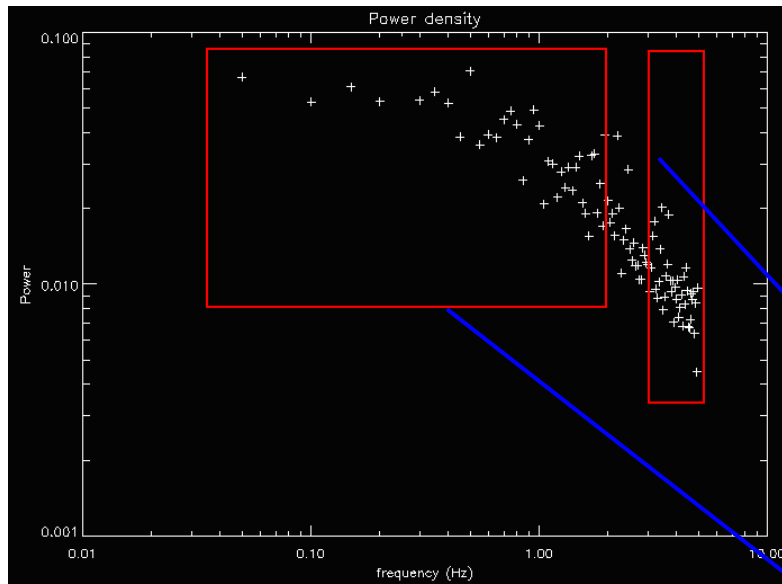rms flux relation with Segment length 2 s and f range 1.0^2.0 Hz

The data

- It can be seen that the power spectrum also keeps similar as the flux level varies.

The data

Constrain to models

- As we have found similar linear rms-flux relation in the Sun. It seems we don't need to introduce disk dynamics. This linear relation may comes from some common energy release process.

Constrain to models

- One problem of the toy model: It can not reproduce the power spectrum.
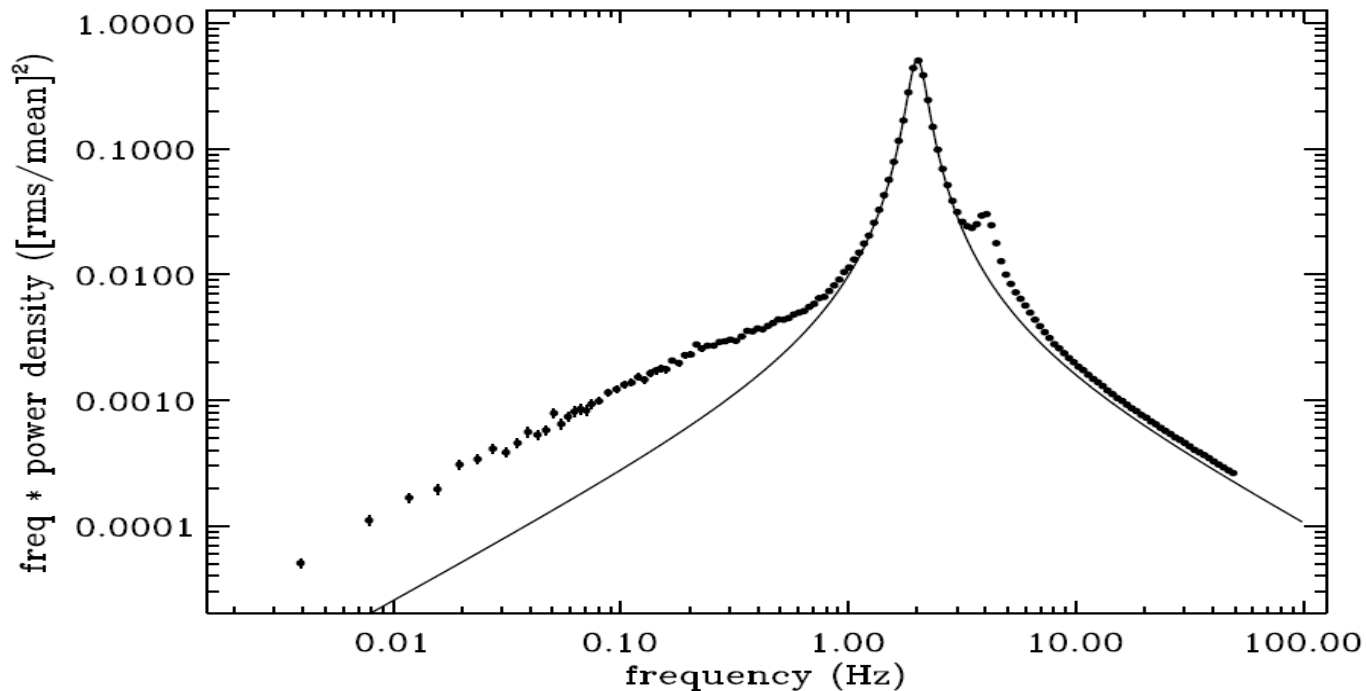
Constrain to models

- It is also difficult for a physics system to give a "exponential transform".

- If the energy release process is "clustered" and the flux level is mostly determined by the scale of the "cluster" while the related distribution of the cluster keeps the same.
  - If modulated by "large scale" magnetic field, self-organized criticality or the alternation between collisional and collisionless reconnection may produce this result.

Summary

- We find a similar linear rms-flux relation in the sun and X-ray binaries.

- The phenomenon can be interoperate as a energy release process which is "regulated" in a large (global?) scale.