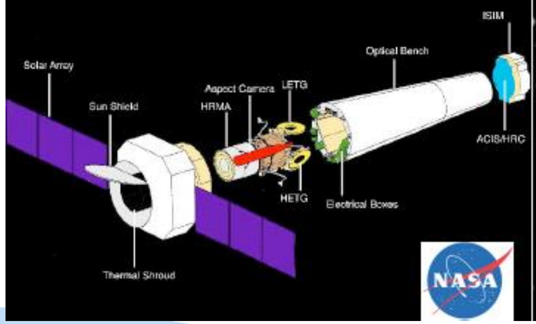



# Einstein Probe's perspective: AGN and ULX

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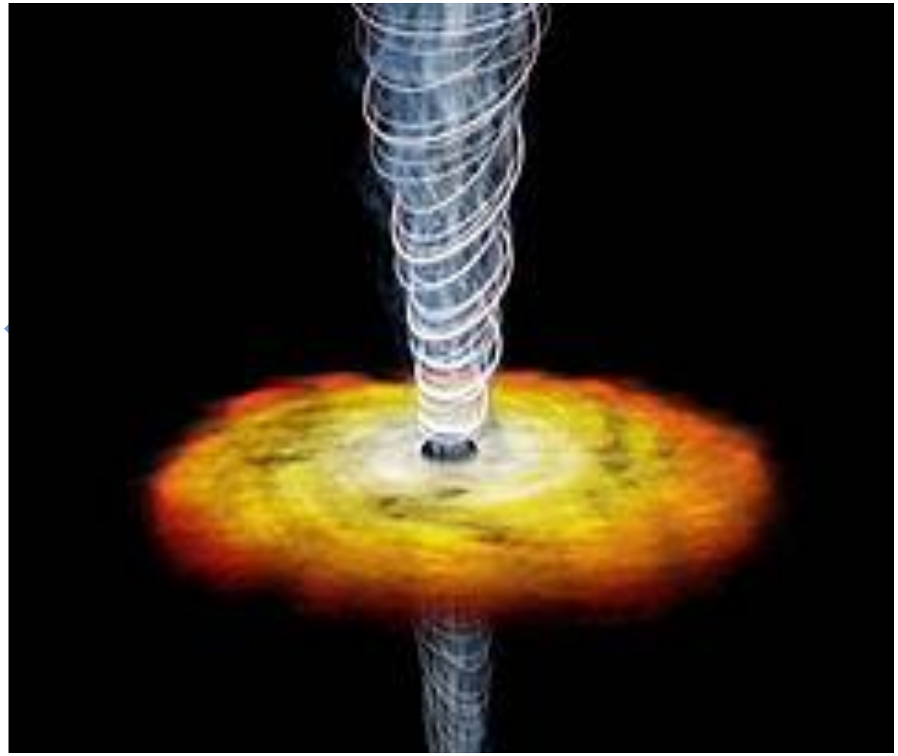
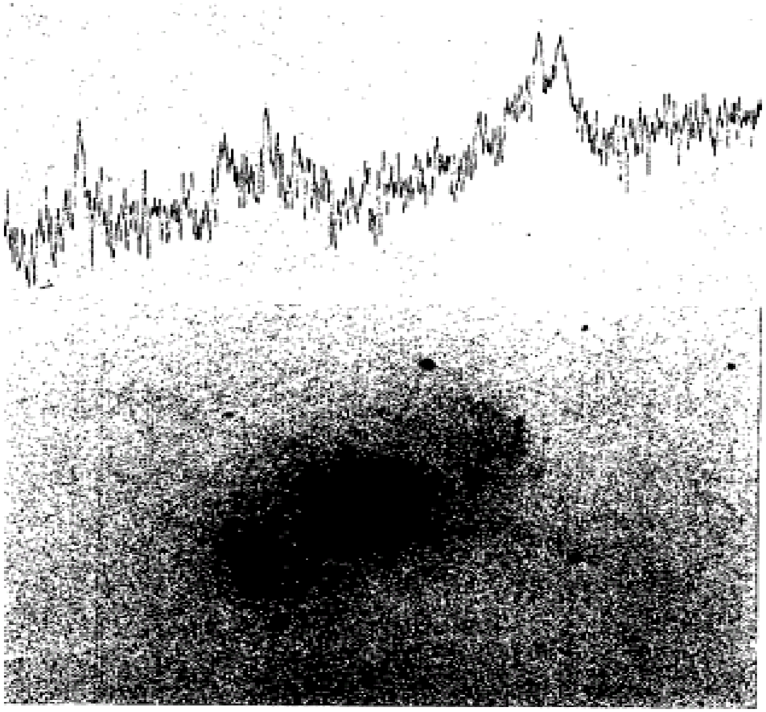
# Outline

- Active galactic nuclei: X-ray timing properties
- Observations by Einstein Probe
- Nature of ultraluminous X-ray sources: Stellar mass BH, IMBH or Massive BH ?
- Observations by Einstein Probe

# AGN: variable X-ray sources

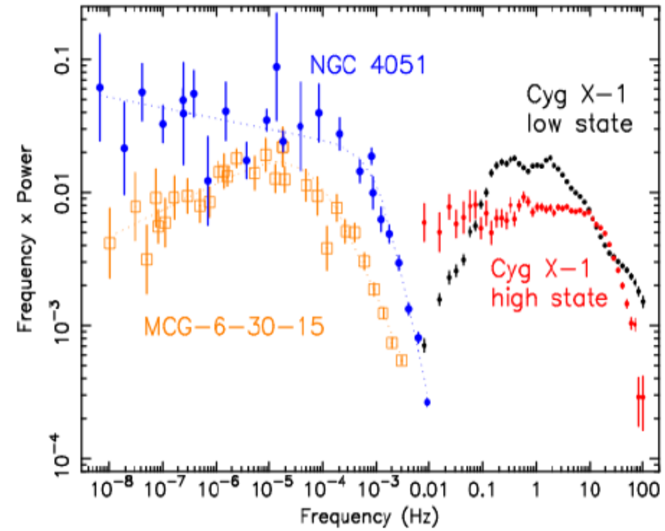
- AGN是吸积的超大质量黑洞，有强的X射线辐射
- X射线辐射区致密，是高度变化的X射线源

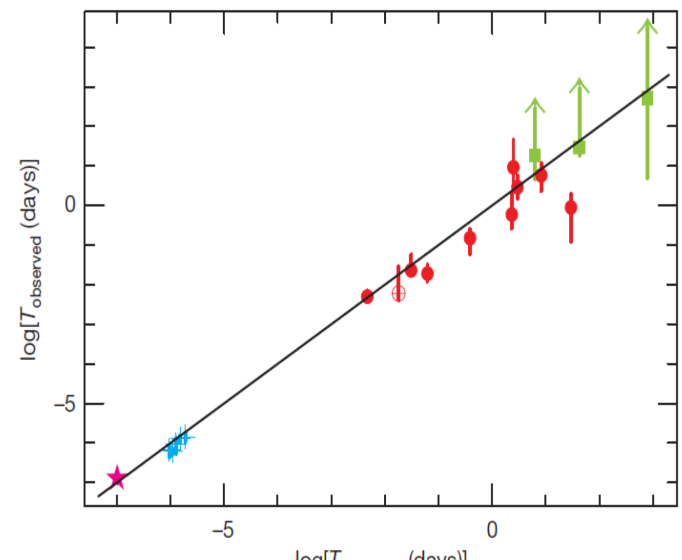




# 功率谱密度（PSD）

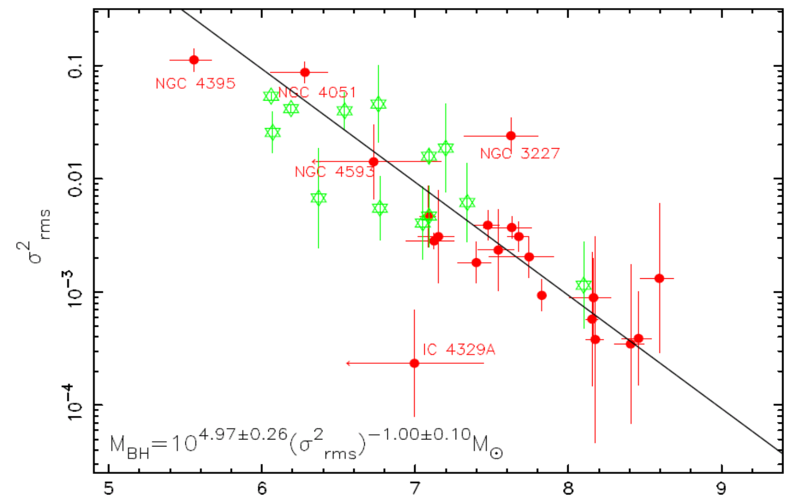
- 功率谱密度（PSD）可能具有一个普遍的形式：一个截断密率谱
- AGN是尺度放大的X射线双星 (McHardy et al. 2006)
- 特征时标由PSD的截断频率决定，对于AGN，一般几小时到几月，需要非常长的观测时间
- EP能够长时间的监测一大批AGN，决定它们的功率谱密度并测出它们的特征时标

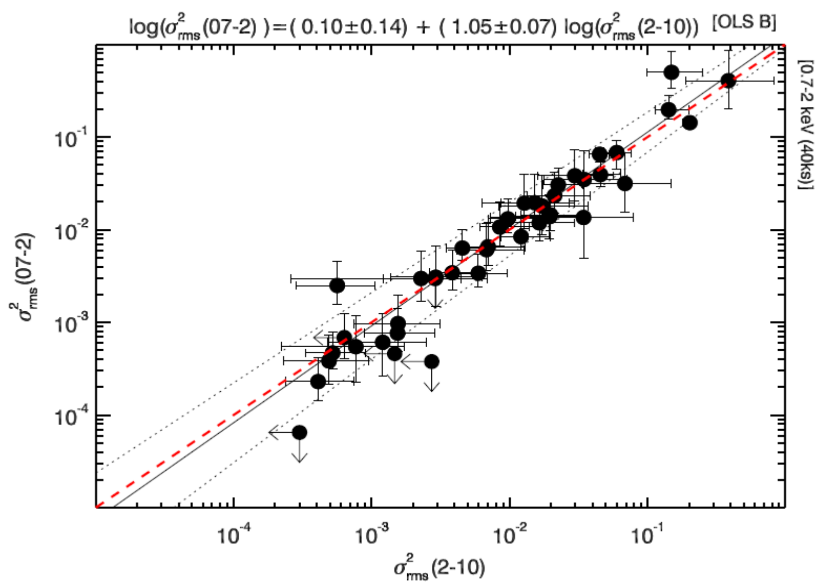


# X-ray variability amplitude

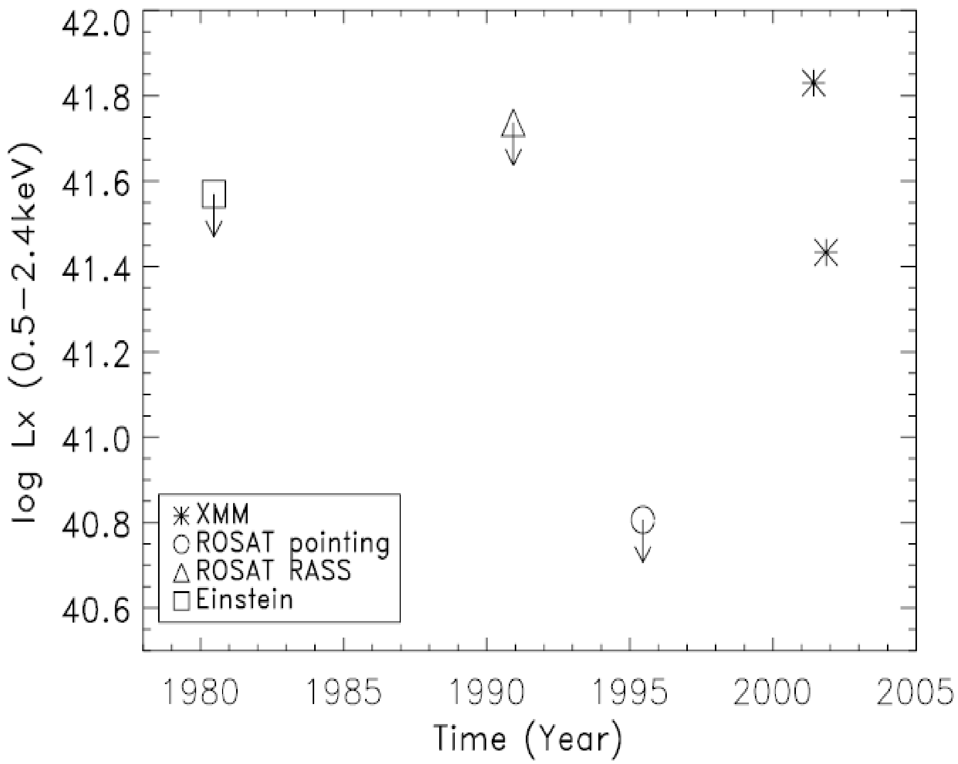
- Correlation bewteen XVA and BH mass show small intrinsic dispersion(Zhou et al. 2010; Ponti et al. 2012)
- EP能够长时间的监测上千AGN，计算它们的XVA，估计黑洞质量
- 实际上通过X射线光变监测也可能发现新的AGN，获得更完备的AGN样本



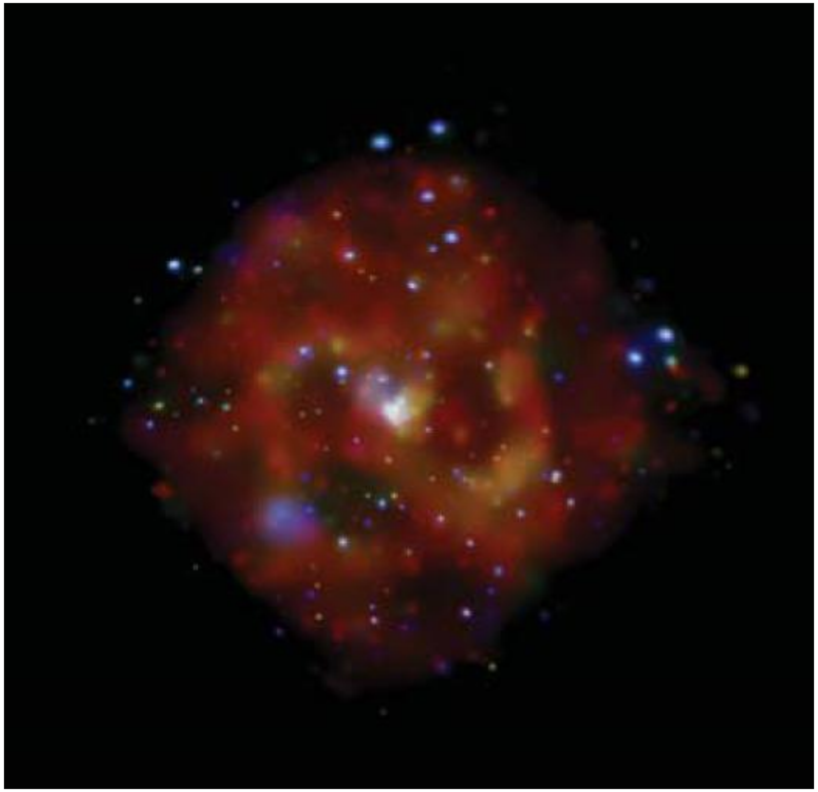
# AGN谱态变化

- X射线双星常有能谱态变化
- AGN是尺度放大的X射线双星，也可能有能谱态变化，但是很难观测到
- NGC 7589(Yuan et al. 2004）
- EP能够以前所未有的时间跨度长时间的监测一大批AGN，捕捉AGN剧烈的光变和耀发，有可能发现一批AGN能谱态演化的事例



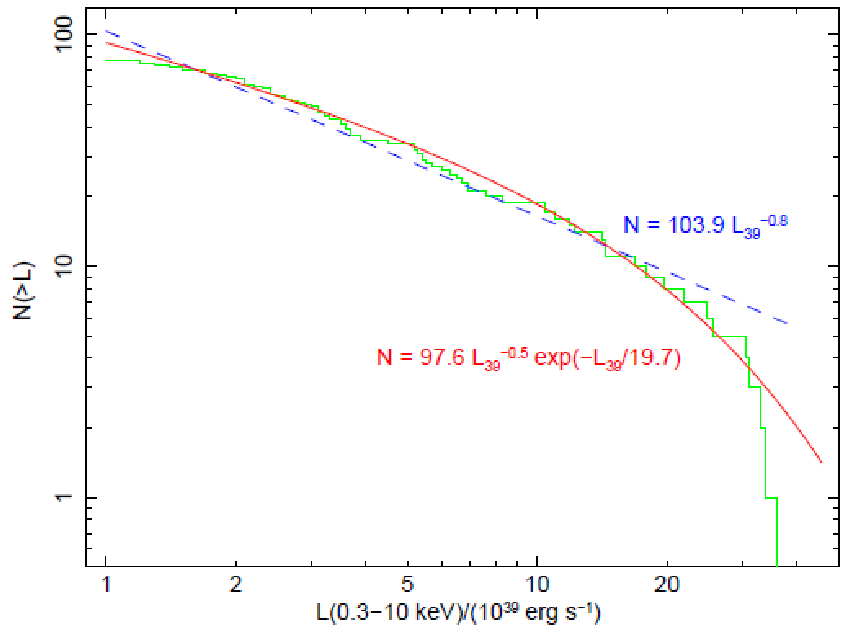
# Nature of ultraluminous X-ray sources

- Off-nuclear X-ray sources with $L_x > 10^{39}$ erg/s
- Stellar mass BH ?
- IMBH ?
- or Massive BH ?
- Different population(Feng & Soria 2011) ?



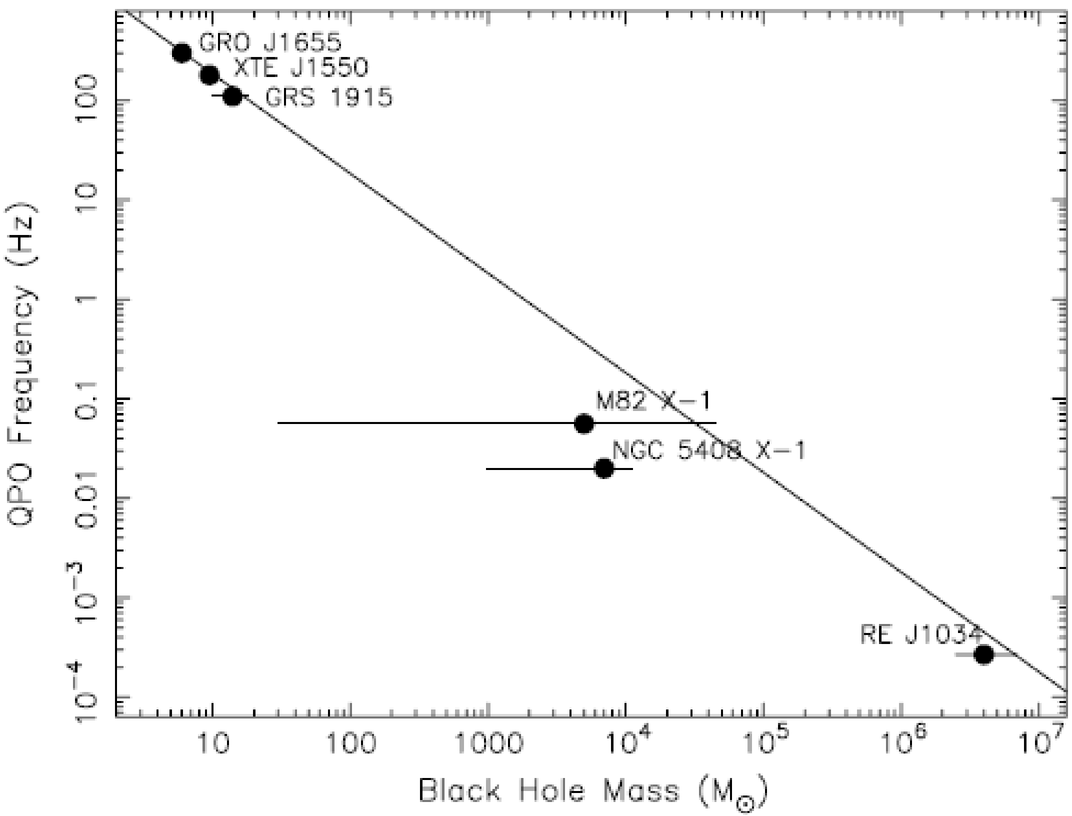
# Evidence for stellar-mass BH

- Radio and X-ray emission of a transit source in M31(Middleton et al. 2013 Nature)
- ULX LF matches the slope and normalization of  HMXB distribution (Swartz et al. 2011)



# Evidence for IMBH

- QPO detected in a few ULXs



# BH mass from XVA for some ULXs

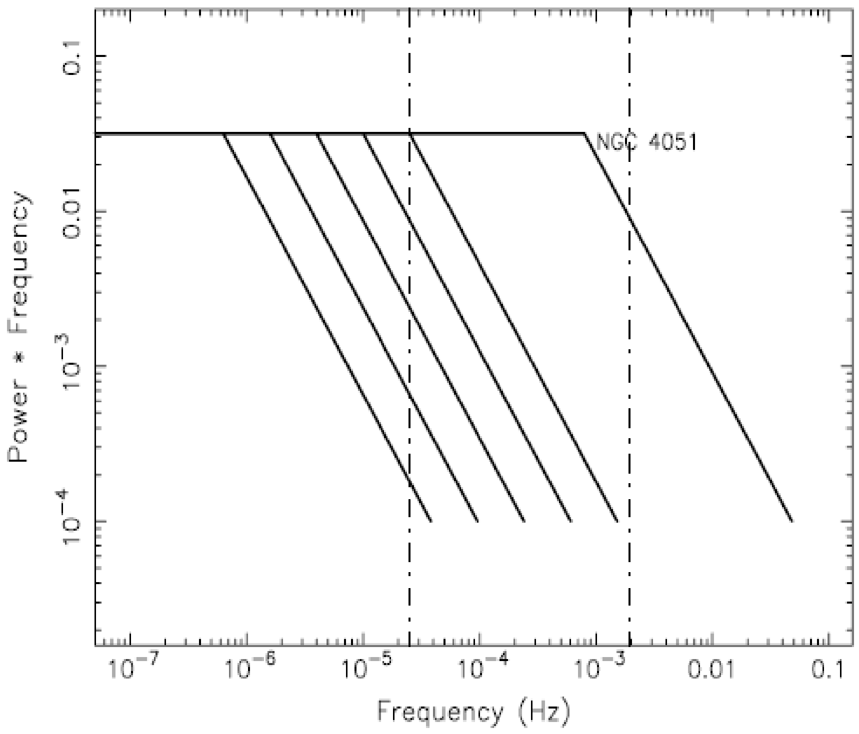
TABLE 2. GONZÁLEZ-MARTÍN ET AL. (2011)'S ULX SAMPLE WITH BEST-QUALITY DATA

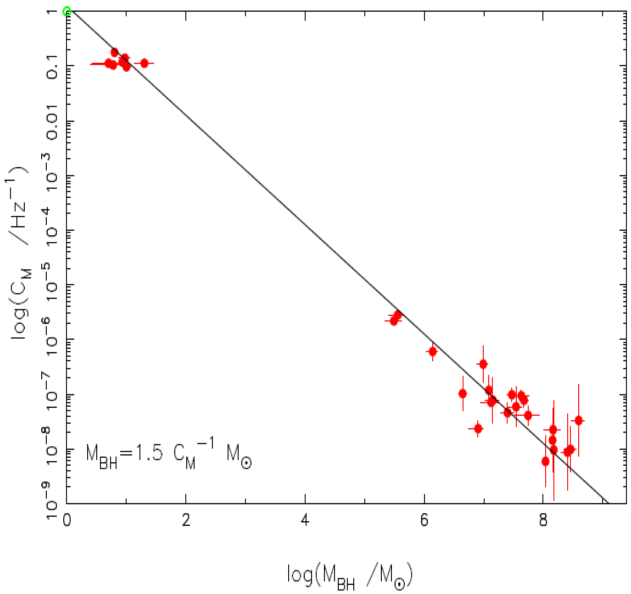
| Souce Name | $\sigma^2_{\rm rms}$ ($\times 10^{-3}$) | Data Segment | $\log(L_{2-10\rm keV})$ | $\log M_{\rm BH}$ |
|---|---|---|---|---|
| NGC55ULX | $147 \pm 2.1$ | 1 | 38.7 | $5.80 \pm 0.15$ |
| NGC253PSX-2 | $6.5 \pm 1.3$ | 4 | 39.4 | $7.15 \pm 1.12$ |
| NGC1313X-1 | $2.0 \pm 0.9$ | 4 | 39.6 | $7.66 \pm 2.8$ |
| NGC1313X-2 | $16.2 \pm 0.9$ | 4 | 39.5 | $6.76 \pm 0.35$ |
| NGC2403X-1 | $< 8.3$ | 3 | 39.2 | ... |
| HoIIX-1 | $1.3 \pm 1.0$ | 1 | 39.6 | $7.85 \pm 5.0$ |
| M81X-6 | $4.9 \pm 1.5$ | 3 | 39.5 | $7.27 \pm 2.6$ |
| M82X-1 | $0.9 \pm 0.2$ | 3 | 40.4 | $8.02 \pm 2.0$ |
| HoIXX-1 | $0.6 \pm 0.4$ | 3 | 39.8 | $8.19 \pm 5.6$ |
| NGC3628X-1 | $0.6 \pm 6.2$ | 1 | 40.0 | $< 8.8$ |
| NGC4559X-1 | $13.0 \pm 6.6$ | 1 | 39.6 | $6.86 \pm 4.6$ |
| NGC4945X-2 | $< 27.0$ | 1 | 39.0 | ... |
| NGC5204X-1 | $1.6 \pm 2.5$ | 1 | 39.6 | $< 7.97$ |
| NGC5408X-1 | $10.2 \pm 3.0$ | 4 | 39.4 | $6.96 \pm 2.2$ |
| POX52 | $93 \pm 11$ | 3 | 40.7 | $6.00 \pm 1.1$ |

Notes: Assuming a universal broken power-law shape of PSD, $M_{\rm BH}$ is estimated from $\sigma^2_{\rm rms}$ based on the correlation derived from radio-quiet reverberation mapping AGN (Zhou et al. 2010). It is nearly the same as AGN. Assuming a double broken power-law shape of PSD, $M_{\rm BH}$ of these objects were found to be $2.5-30\times10^3$ $M_\odot$ (González-Martín et al. 2011).

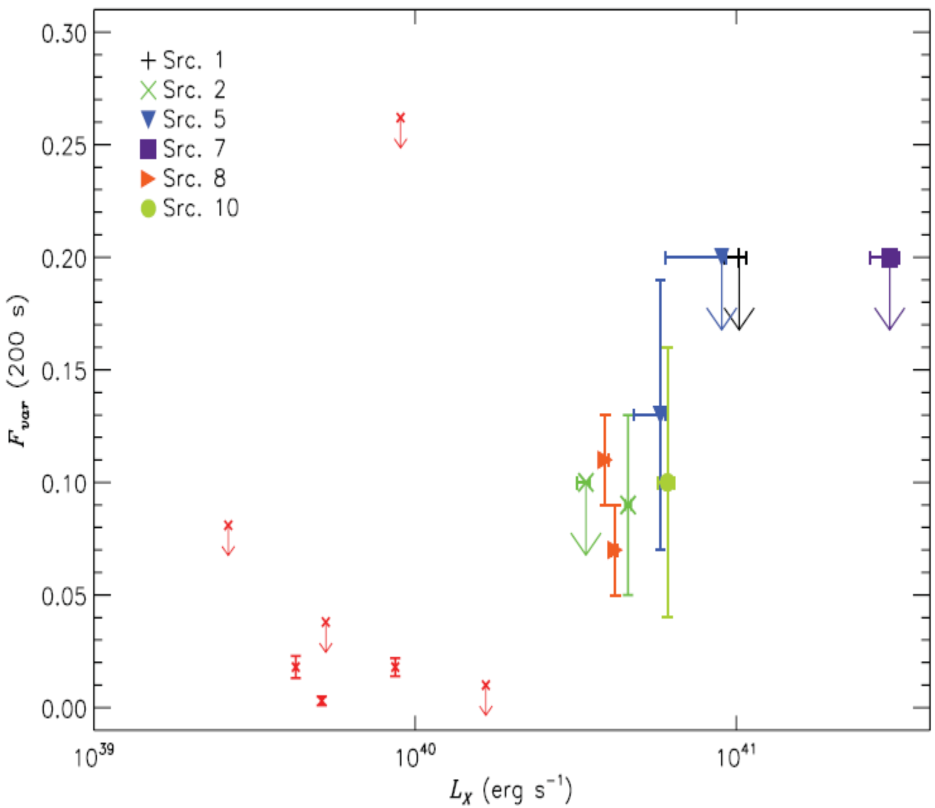
# A Smoking gun for ULX nature: PSD shape

- Assumed universal power-law shape of the PSDs at high frequency(e.g., Zhou et al. 2010)
- It seems that it is not bad from Galactic X-ray binaries to active galactic nuclei (Gierlinski et al. 2008; Zhou et al. 2010; Papadakis 2013)



# X-ray variability for ULXs




- X-ray variability for high-luminosity ULXs is larger (Sutton et al. 2012)
- Does low-luminosity ULXs have larger masses than high-luminosity ULXs, or there are different populations among ULXs (and thus different PSD shape )? This is an open question since the high-quality PSDs still lack (Heil et al. 2009)

# Einstein Probe（1）

- EP有2角分的空间分辨率，全天扫描1800s曝光的一次观测，在0.1-4 keV上的流量灵敏度达到$3*10^{-12}$ erg $s^{-1}cm^{-2}$，而一天曝光达到的灵敏度是$5*10^{-13}$ erg $s^{-1}cm^{-2}$。足够观测到临近星系的已知的一些ULX，比如M33 X-8 （0.1-4keV流量 $1.7*10^{-11}$ erg $s^{-1}cm^{-2}$），Ho II X-1（$6*10^{-12}$ erg $s^{-1}cm^{-2}$）等，并且可以对它们进行连续数年的监测，研究它们的流量和能谱态变化，在从未研究过的跨度为四个数量级的时间尺度上来揭示它们的光变特性，限制它们PSD的形状，以及黑洞质量

- 一天之内，EP将可以探测到6Mpc内所有ULX。根据Chandra观测的统计研究，对于10Mpc以内的418个亮星系中的102个星系的统计，共有10/31个ULX达到爱因斯坦探针的每个轨道/每天曝光的灵敏度（Liu 2011）。因此，预计全天有40/120个ULX能够被爱因斯坦探针每个轨道/每天曝光在连续数年的时间内监测。由于ULX一般都具有几倍甚至几十倍的光变，爆发持续数天乃至数月，因此EP将可能探测到30Mpc以外的ULX

# Einstein Probe（2）

- 存在一种暂现的ULX，处在显著的爆发态。它们被认为是银河系内大质量黑洞X射线双星的河外对应体。最近Nature杂志上发表了发现了M31星系中的一个此类天体的文章（Middleton et al. 2013），根据文章中给出的结果，对M31星系10年监测发现的此类天体的数目只有1-2个。通过监测10Mpc以内所有的邻近星系，我们预计EP将可能每年探测到40-80个爆发态的ULX。我们期待EP能够发现较多的此类暂现天体，并重新估计此类天体的探测概率

- 相对于现在的高灵敏度小视场望远镜，EP视场非常大，能够覆盖全天，我们期待发现新的ULX，进一步推进ULX的分布与统计研究。EP对邻近星系中的ULX的观测将有助于研究黑洞的形态统计学，中等质量黑洞在宇宙中的数量到底有多少等基本问题

# Thank You !

# Physical models for X-ray variability

- Shots model (Terrell 1972; Poutanen & Fabian 1999):

  there is a distribution of shot time scale, with the value of $f_b$ being inversely proportional to the duration of the longest shots. The variance of the counting rate fluctuations is inversely proportional to the mean rate of the occurrence of flares. One can then assume that all time-scales and the luminosity of the individual shots is proportional to the BH mass
- Propagation perturbation model (Lyubarskii 1997; Uttley 2004) : slower variations in the accretion rates occur at larger radii and propagate inwards, coupling together with the faster variations produced at smaller radii. The modulations in the accretion rate propagate to the X-ray emission region and produce variations in the X-ray flux. $f_b$ is expected to be inversely proportional to the size of the X-ray emission region

# Thank You !