Quasar variability at 850 microns

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ASIAA

Quasar submm emission

Probes regions of event-horizon scale, at least in nearby low-luminosity AGNs (Doeleman et al. 2008, 2012a,b)

Possible connection to NIR flares, with delay

- Possibly caused by adiabatically expanding plasma, producing NIR flare then submm emission at larger scale
- However, not always observed: maybe submm emission is a combination of outflowing and accreting gas

Data

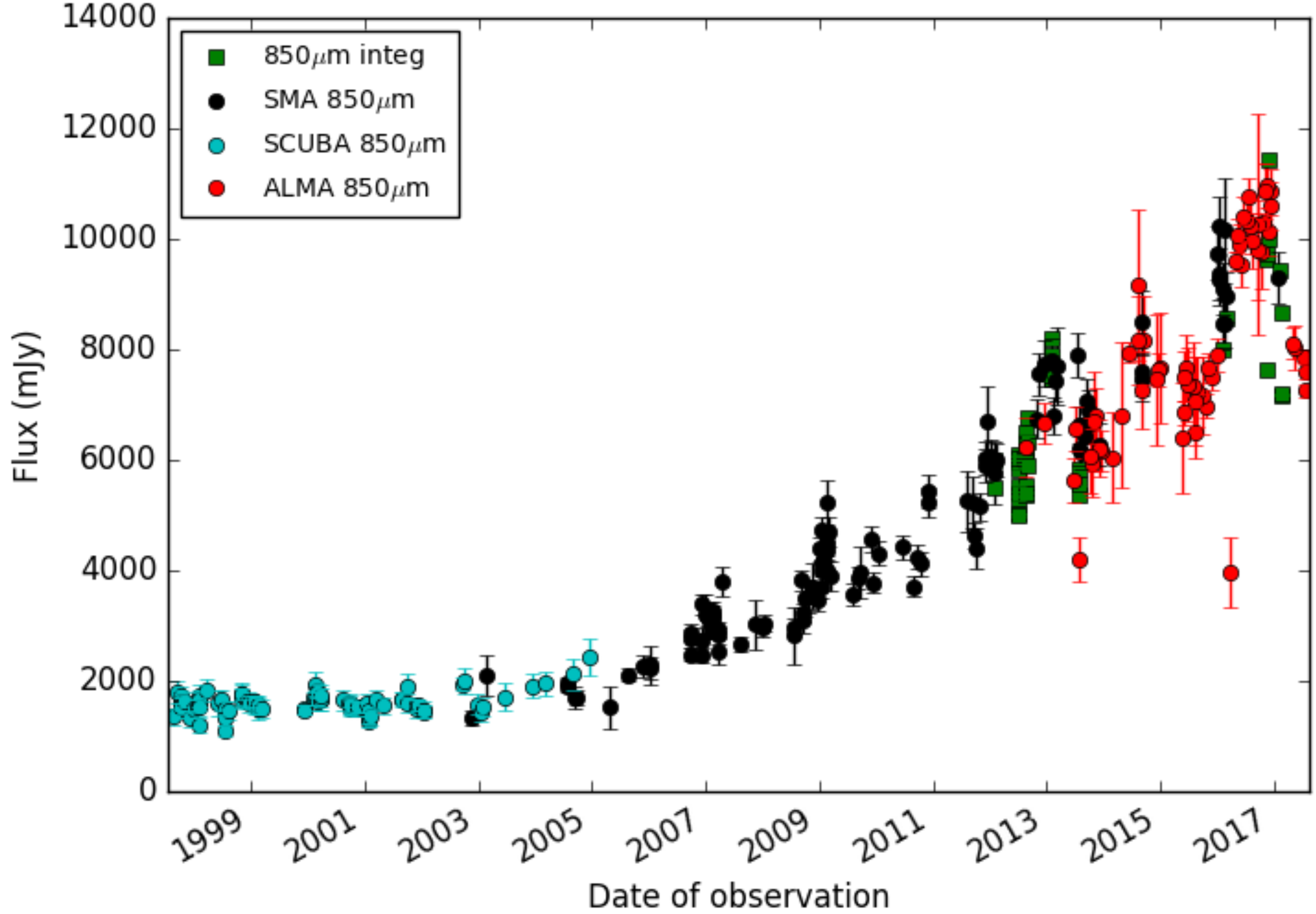
850um data from JCMT SCUBA2 continuum pointing sources − not previously been combined or published

Publically available SCUBA, SMA, ALMA data

Three often-observed sources: 3C273, 3C279, and 3C84

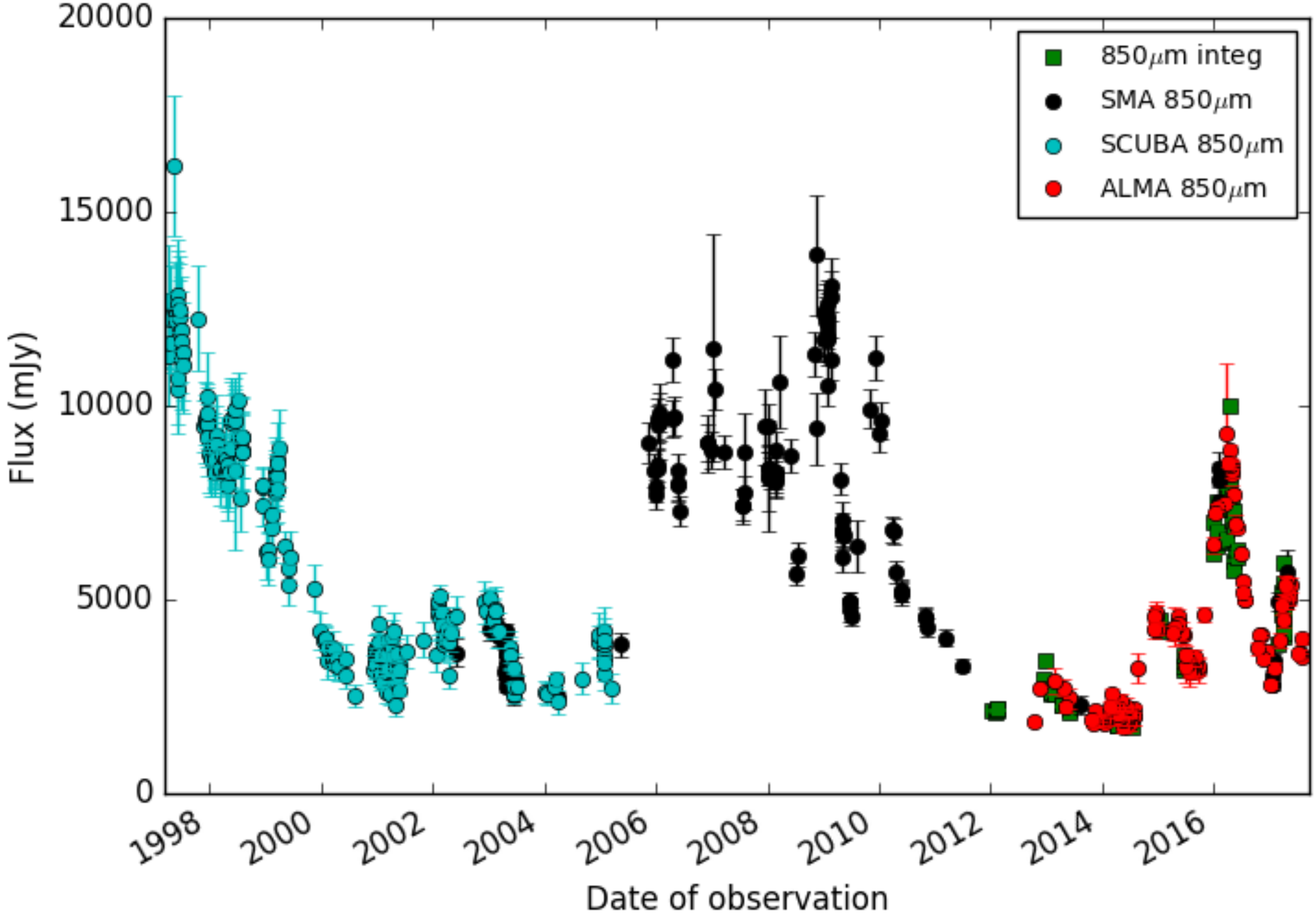
20-year time-series, around 300-600 data points per source

3C84



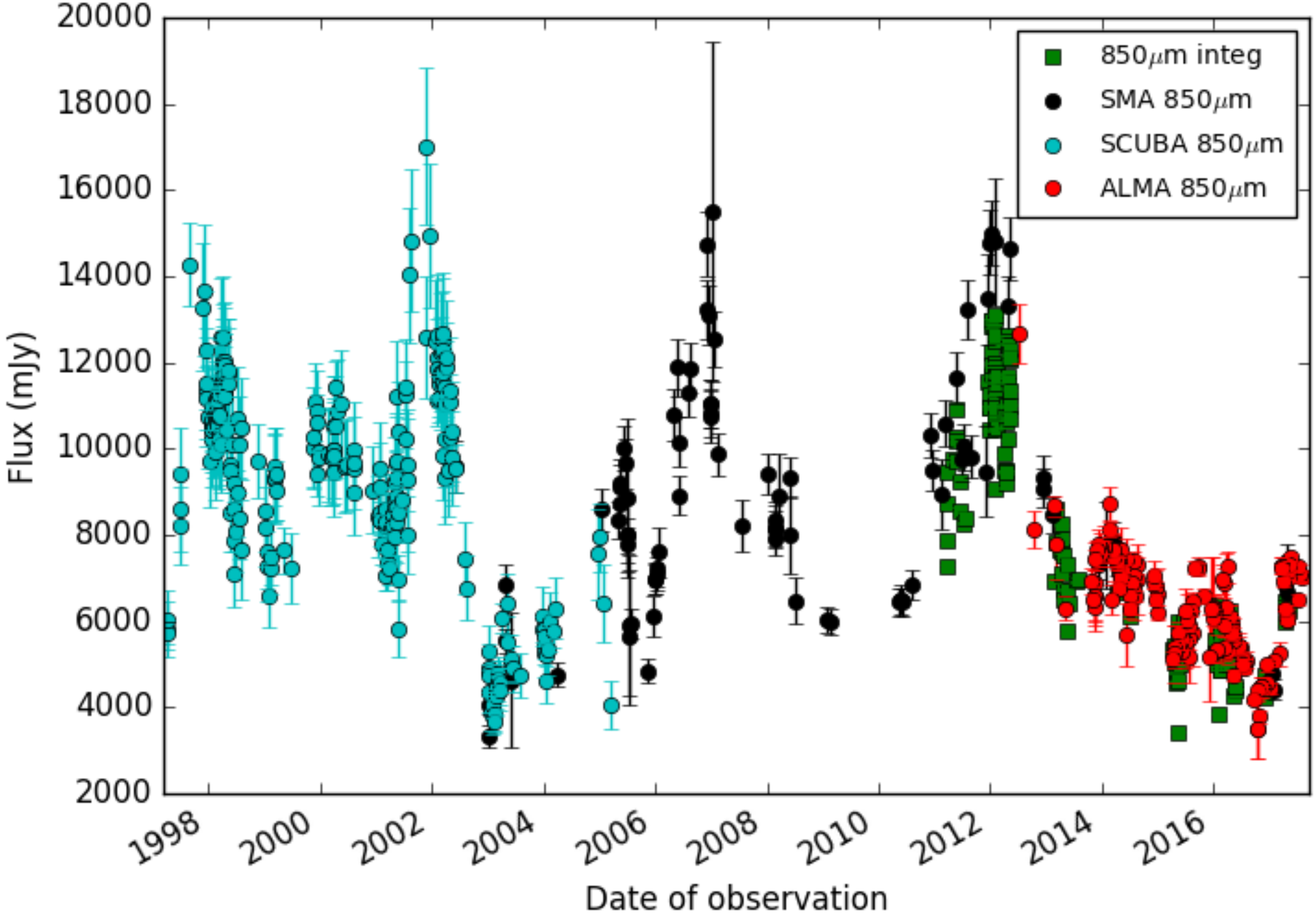
850μm integ
SMA 850μm
SCUBA 850μm
ALMA 850μm
Flux (mJy)
14000
12000
10000
8000
6000
4000
2000
0
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
Date of observation

3C273



Flux (mJy)
20000
15000
10000
5000
0
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date of observation
850μm integ
SMA 850μm
SCUBA 850μm
ALMA 850μm

3C279



850μm integ
SMA 850μm
SCUBA 850μm
ALMA 850μm
Flux (mJy)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Date of observation

Periodicity

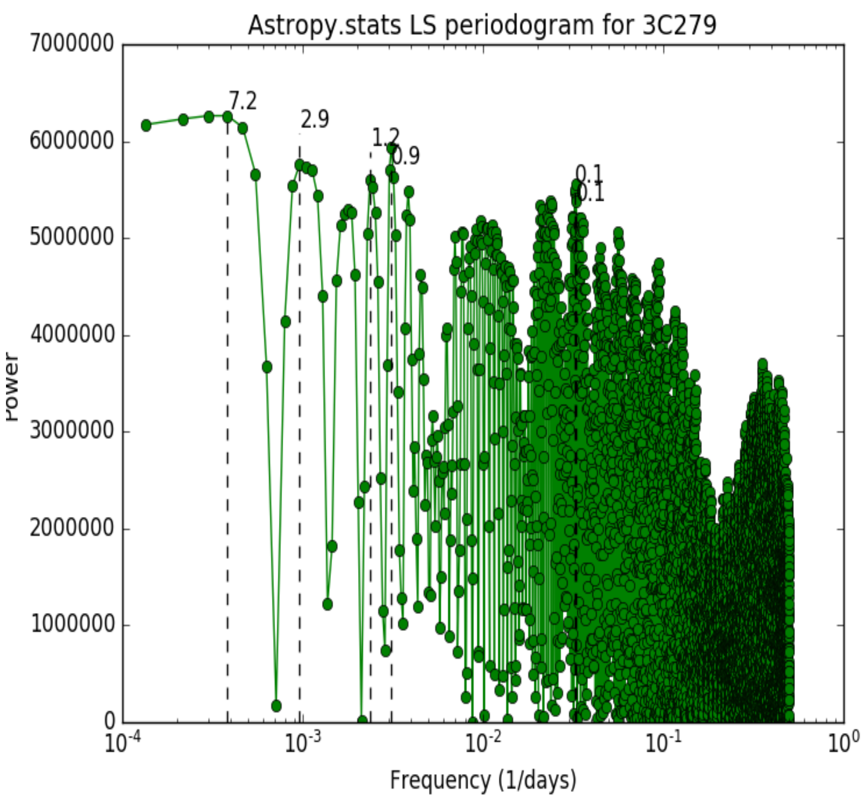
3C273 and 3C279 have apparent periodicity of around 11 and 5 years, respectively

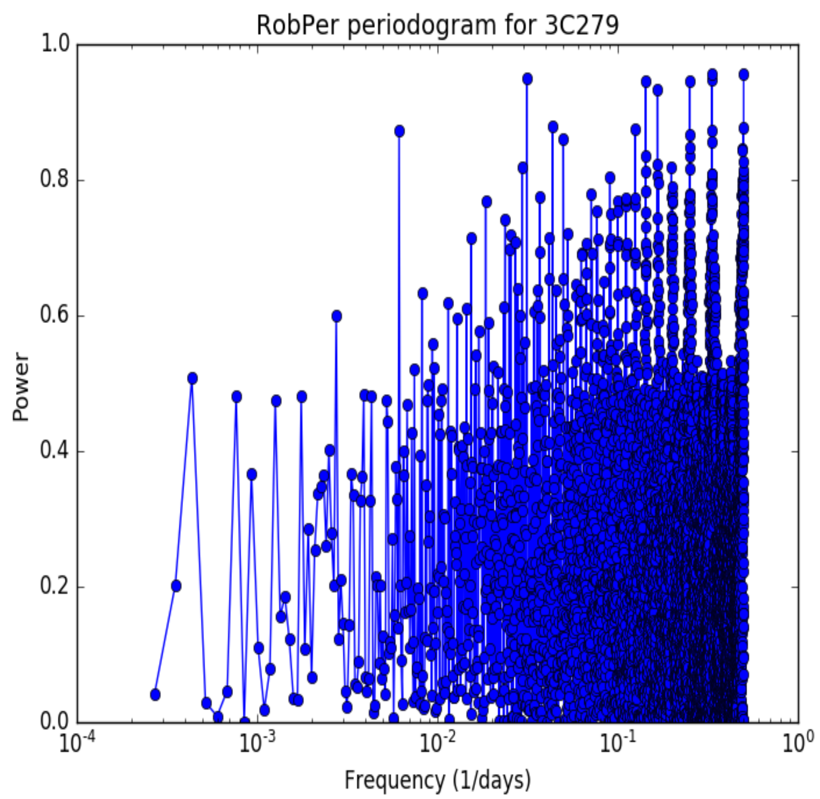
- Lomb-Scargle periodograms show no significant peaks, and vary significantly depending on implementation

Can also estimate period from period folding techniques, e.g. minimizing QMI (Quadratic Mutual Information)

- Find best-fit period to be ~10-12 years for both 3C279 and 3C273
- Uncertain, as length of time series is less than 2 periods

Lomb-Scargle periodograms for 3C279





Damped random walk model

Model quasar light curves as continuous time first-order autoregressive process (see Kelly et al. 2009; Dexter et al. 2014)

- E.g. power spectra are a first-order autoregressive process
- Continuous time: natural way to handle irregular sampling

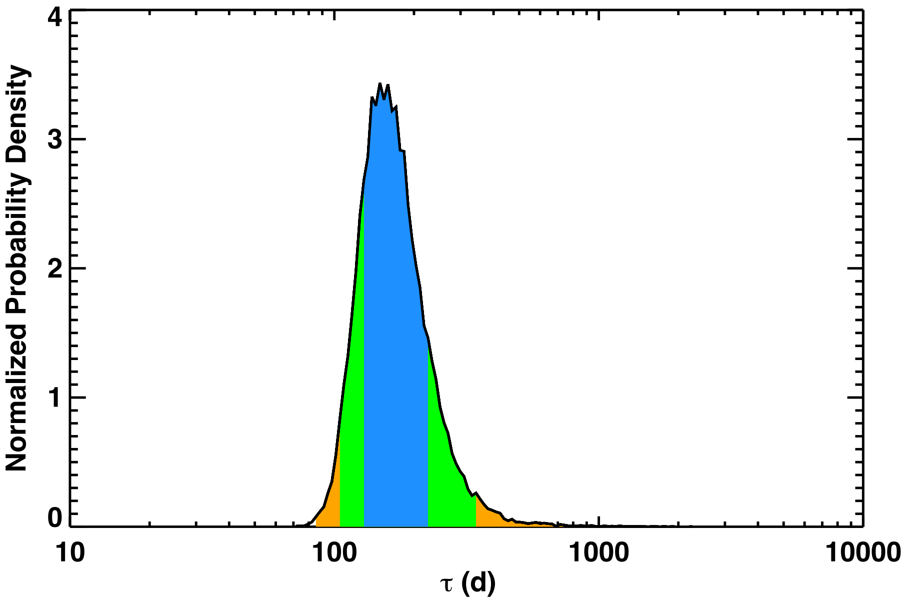
DRW described by a stochastic differential equation

$$dX(t) = \frac{1}{\tau} X(t)dt + \sigma\sqrt{dt}\,\varepsilon(t) + b\,dt$$

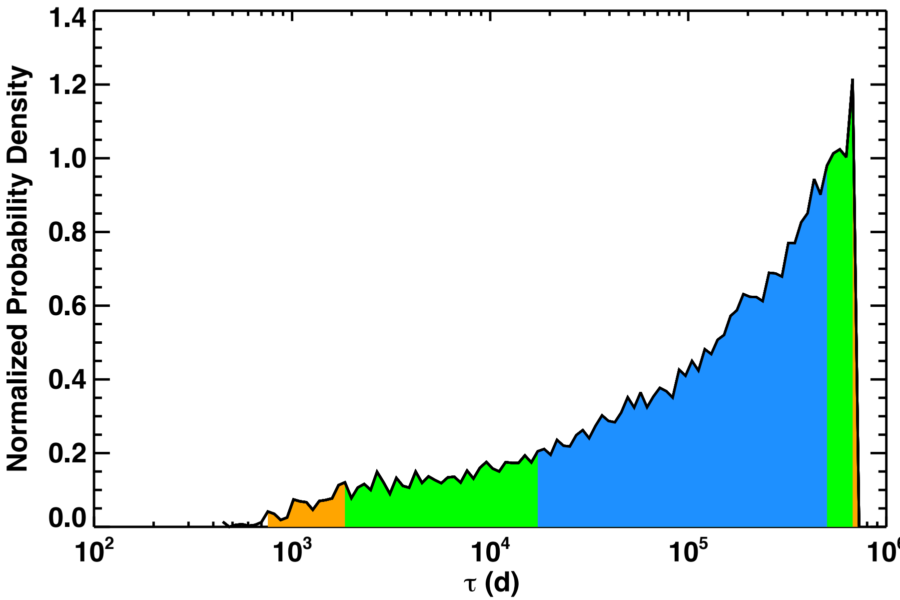
- X(t) = quasar flux, with mean $b\tau$ and variance $\tau\sigma^2/2$
- τ = characteristic timescale
- $\varepsilon(t)$ = a white noise process with zero mean and unit variance
- σ = variability on short timescales

DRW model results

3C279



3C84



DRW model results

Damped random walk characterised by short-term variability and long-term stability

- Red noise at short times and decorrelated white noise on long timescales
- Characteristic timescale τ where noise characteristics change
- Corresponds to a maximum fluctuation scale

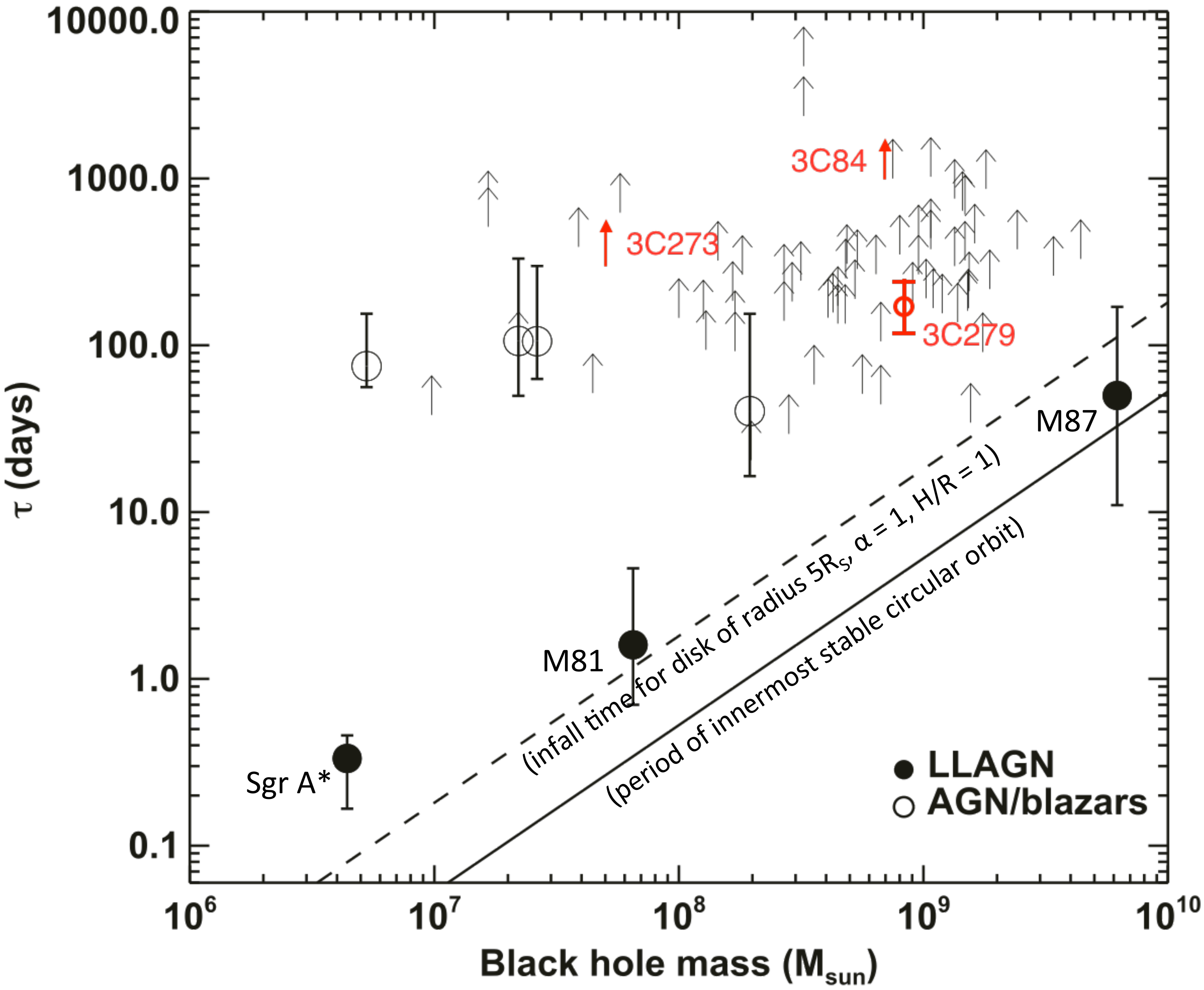
Constrain τ for 3C279 to be 160^{+60}_{-40} days (1σ errors)

- For the others find only lower limits: τ > 300 days and τ > 1000 days for 3C273 and 3C84, respectively

Characteristic timescales (1)

Bower et al. 2015 (see also Geoffrey Bower's talk) found a linear correlation between τ and black hole mass for three low-luminosity AGNs (Sgr A*, M81, M87)

- Surprising coherence between sources with vastly different scales, environments, and physical properties
- Time scale effectively tells you the radius at which the variability originates; close to the event horizon
- In Sgr A*, τ consistent with the viscous timescale (~10 orbital times)



Bower et al. 2015, Figure 4. SMA quasar data (1.3mm)

Characteristic timescales (2)

Higher-luminosity AGNs show larger τ (mainly lower limits) and no clear correlation with M_{BH}

- Emission originates further from the event horizon; may be due to optical depth or relativistic outflow in the jet
- Our data is consistent with Bower et al. 2015; with smaller errorbars

Plan to expand our work to all sources with sufficient data from SCUBA/SMA/ALMA/SCUBA2

- Measure many more τ with 2x longer time series
- Improved uncertainties will constrain potential correlation with M_{BH}

Summary

Wealth of submm calibration data to explore

Longer time series allow us to contrain more characteristic timescales, with better precision

More data to determine if characteristic timescales of AGN submm variability correlate with black hole mass