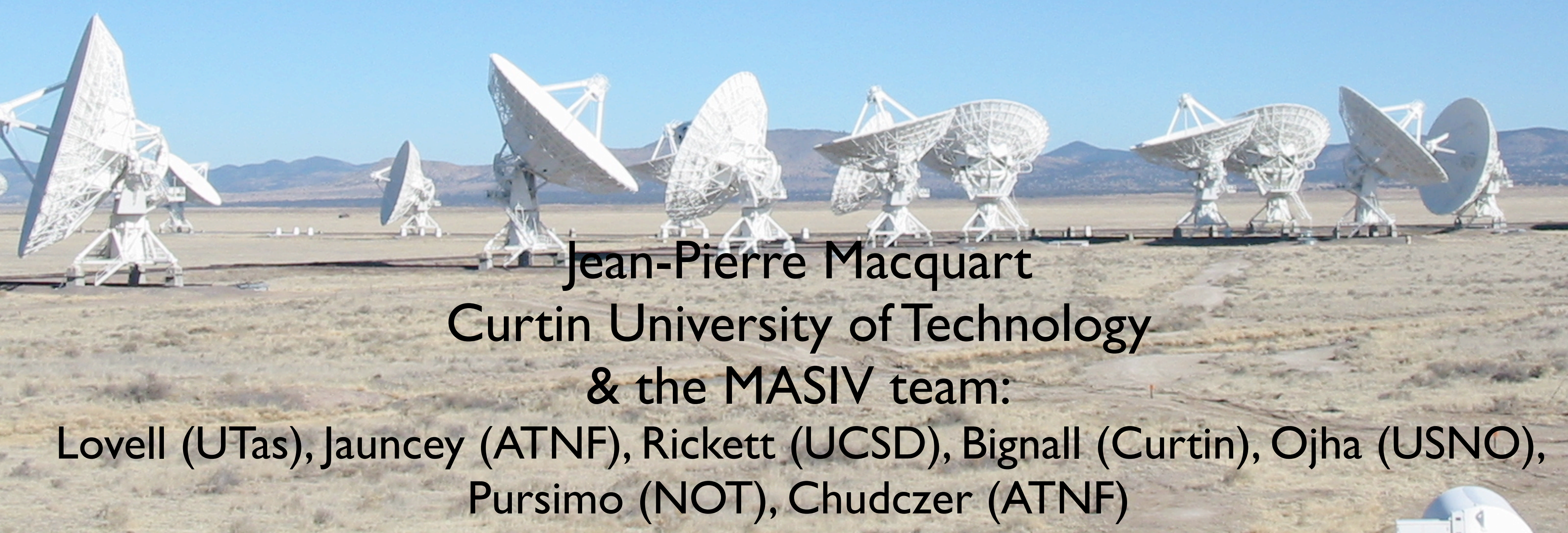
Redshift-dependent Intra-Day Variability in Quasars

Micro-arcsec AGN jet evolution or angular broadening by IGM baryons?



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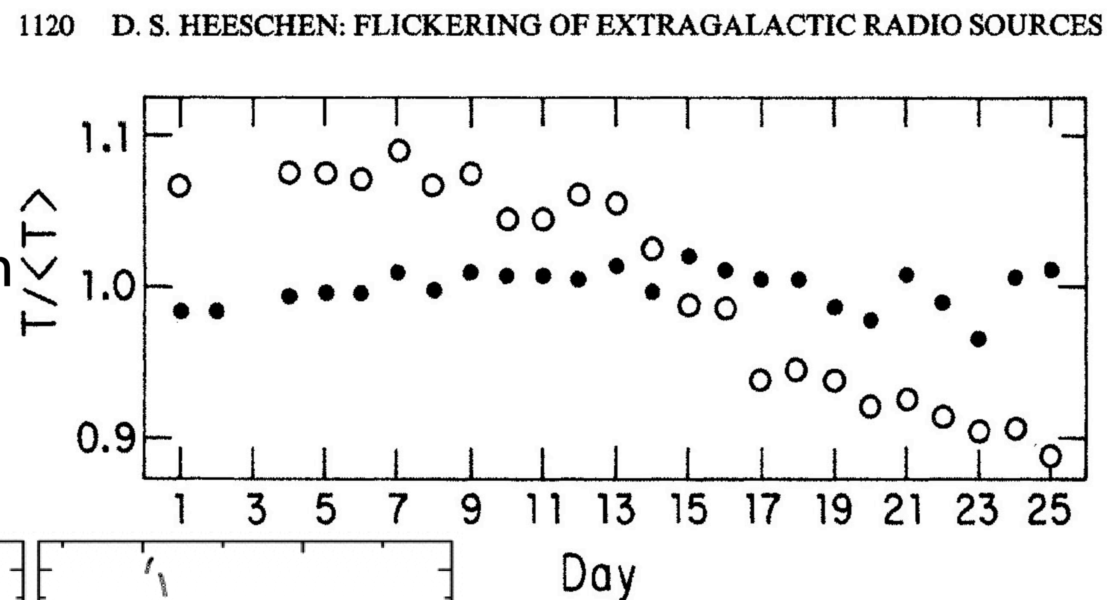
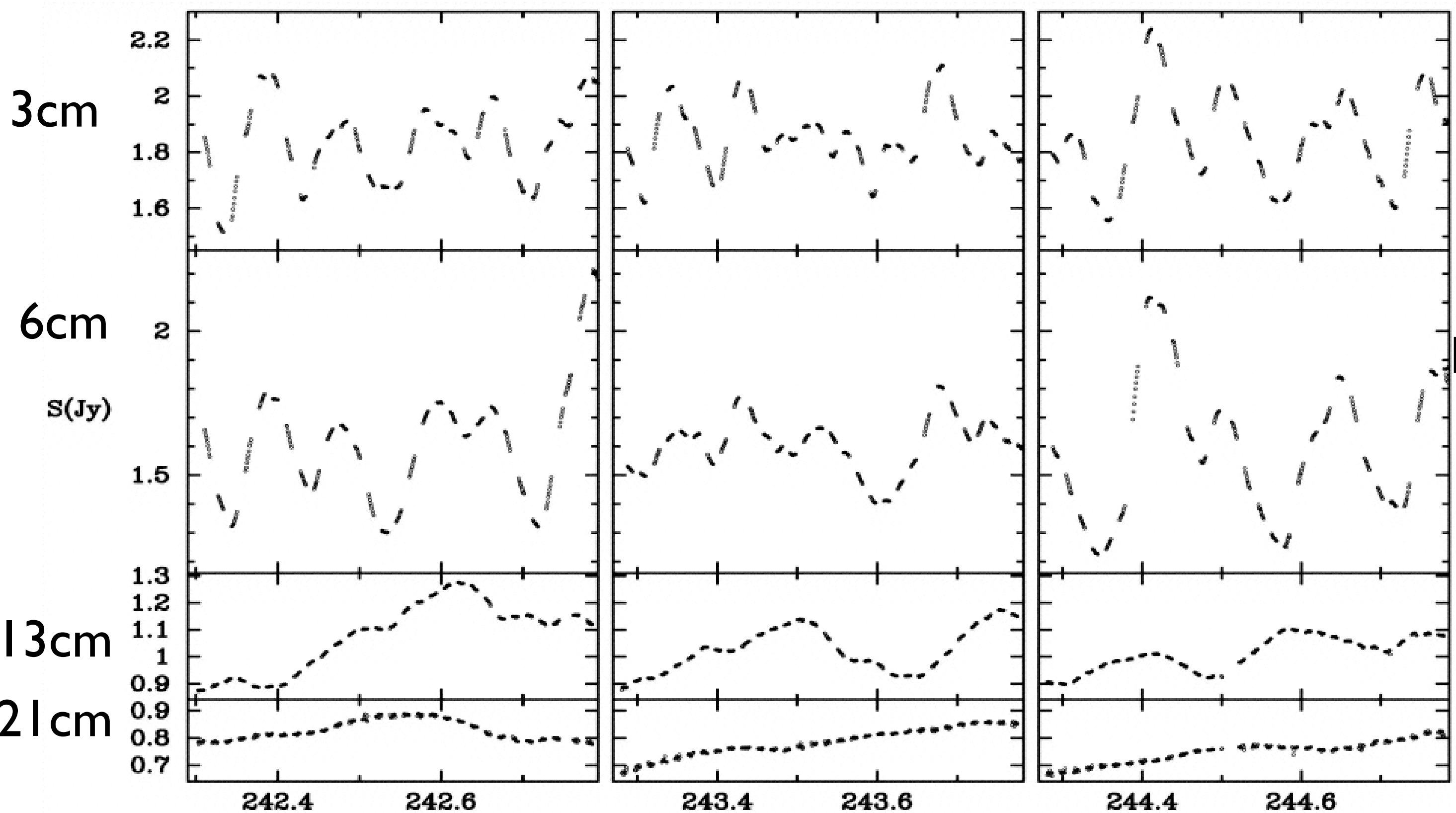
Radio Intra-Day Variability

Discovery

2-20 day flickering reported by Heeschen (1984) and followed up with Effelsberg (Heeschen, Krichbaum et al. 1987)





1hr variations in PKS 0405-385
Kedziora-Chudczer et al. 1997

What's in it for me?

- The intra-day variability of compact quasars exhibits a redshift dependence
- This is either due to
  - an intrinsic change in AGN compactness or
  - angular broadening due to turbulence in the IGM
- We have a test to distinguish the two effects

Micro**A**rcsecond **S**cintillation-**I**nduced **V**ariability survey

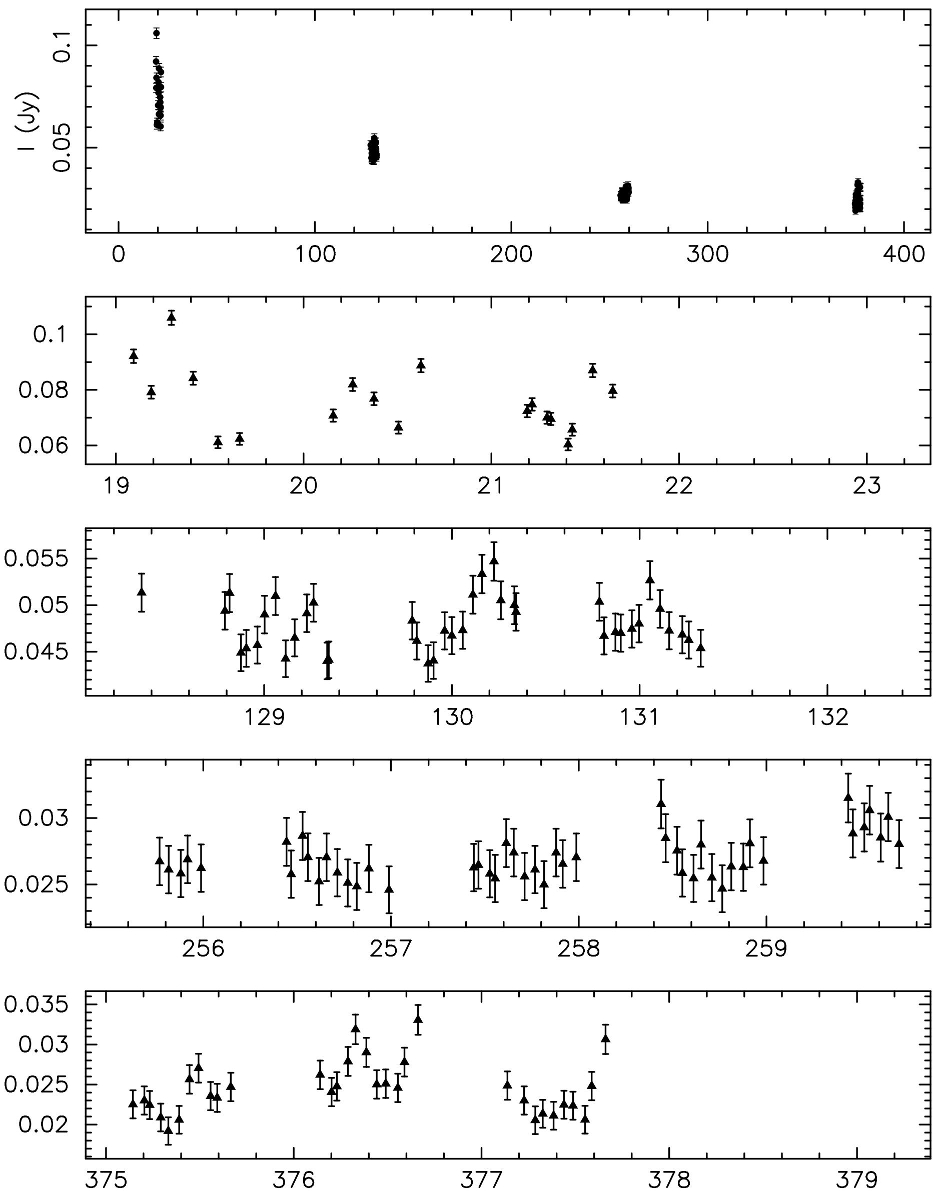
4-epoch survey for intra-day variability (IDV) of 700 compact flat/inverted 0<z<4+ sources in Jan (72h), May (72h), Sept (96h) 2002, Jan (72h) 2003
(& 72h in Jan 2006)

Survey sources contained weak (105<S<130mJy), intermediate (130<S<600mJy) and strong (S>600 mJy) groups

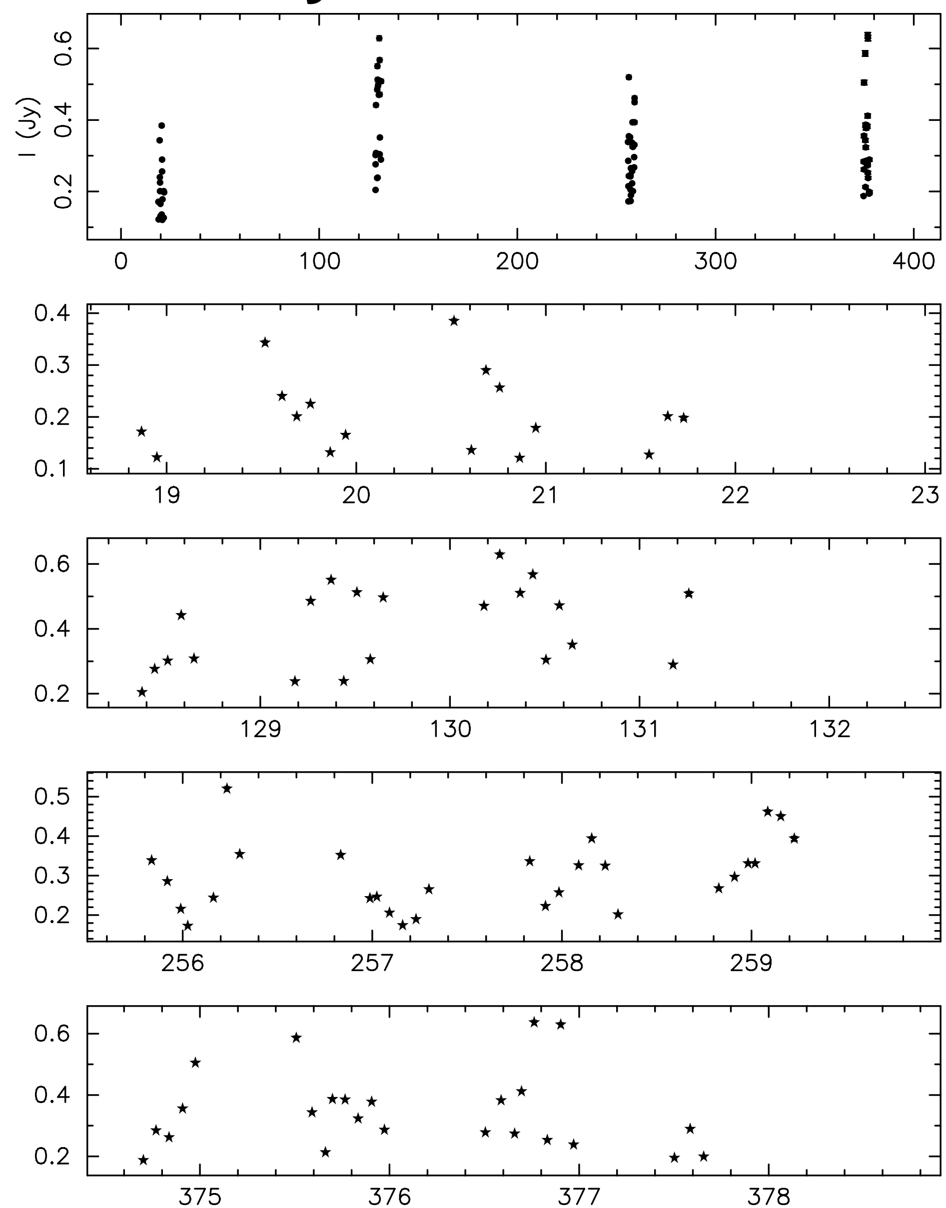
>56% showed IDV (Lovell et al. 2008)

Examples of MASIV variability

J0949+5819



J1819+3845

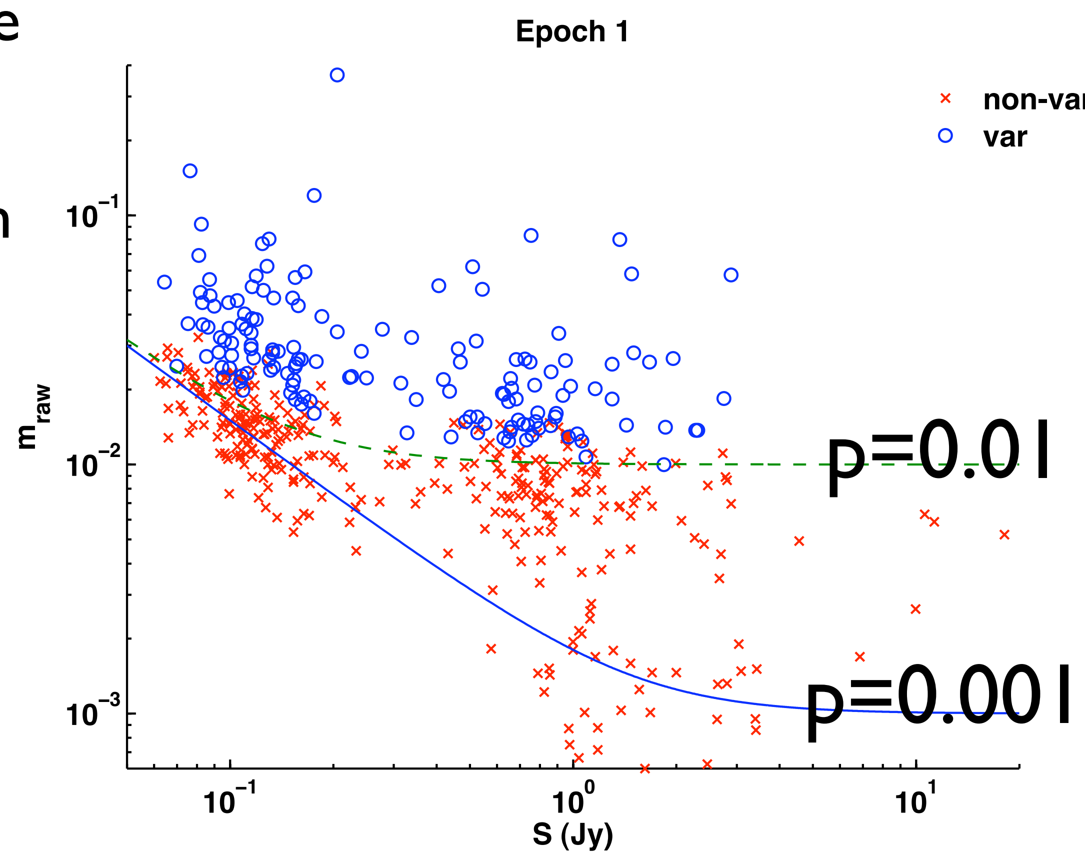


Variability Classification

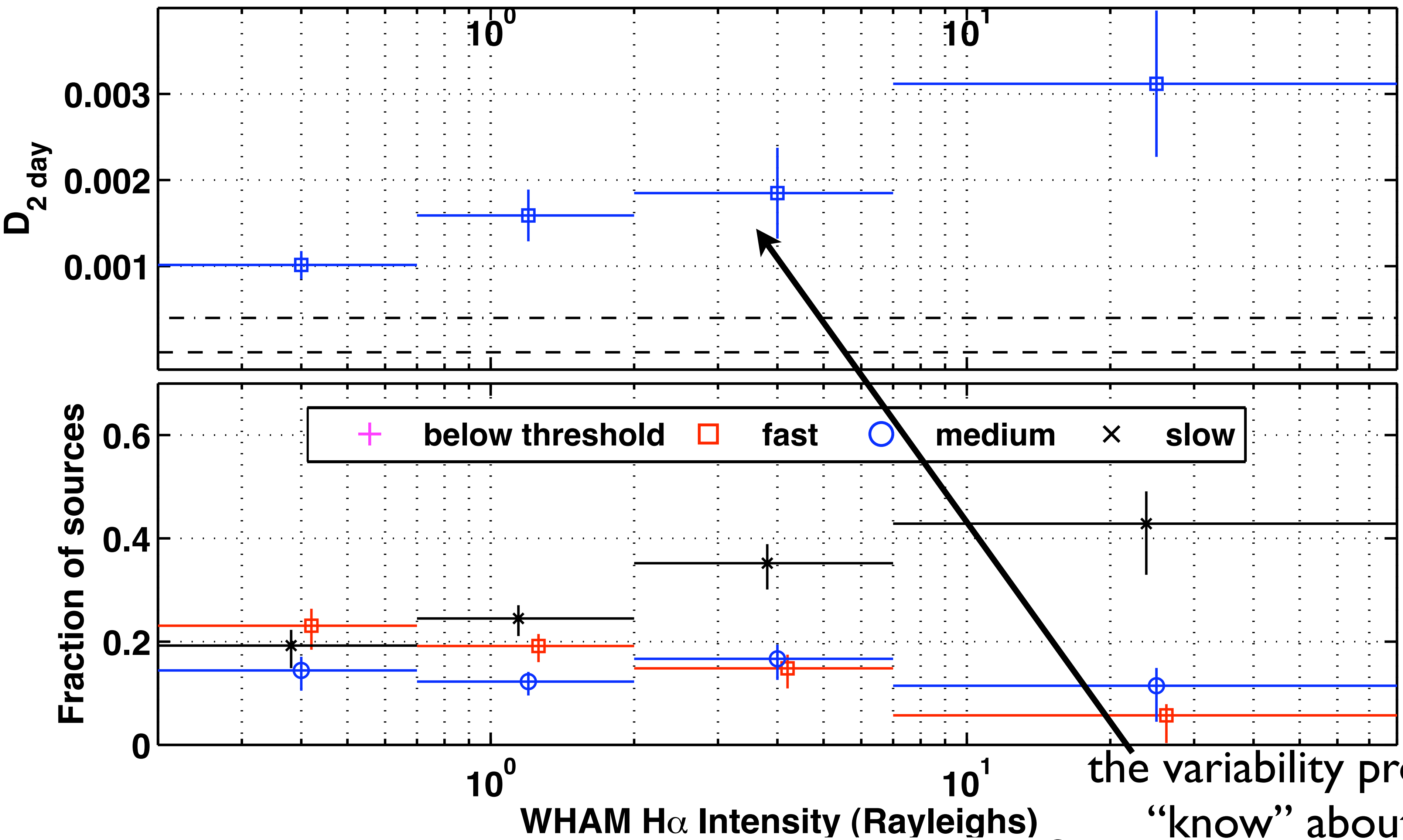
$$\sigma_{\rm err} = \sqrt{(s/\bar{S})^2 + p^2}\,.$$

thermal noise — systematic (e.g. antenna mispointing)

- RMS > $2\sigma_{err}$ with p=0.01, S=1.5mJy -- effectively computing χ^2 and selecting sources with 95% chance of being IDVs
- Supplemented by visual inspection to detect slow variables (justification: χ^2 not an ordered statistic)



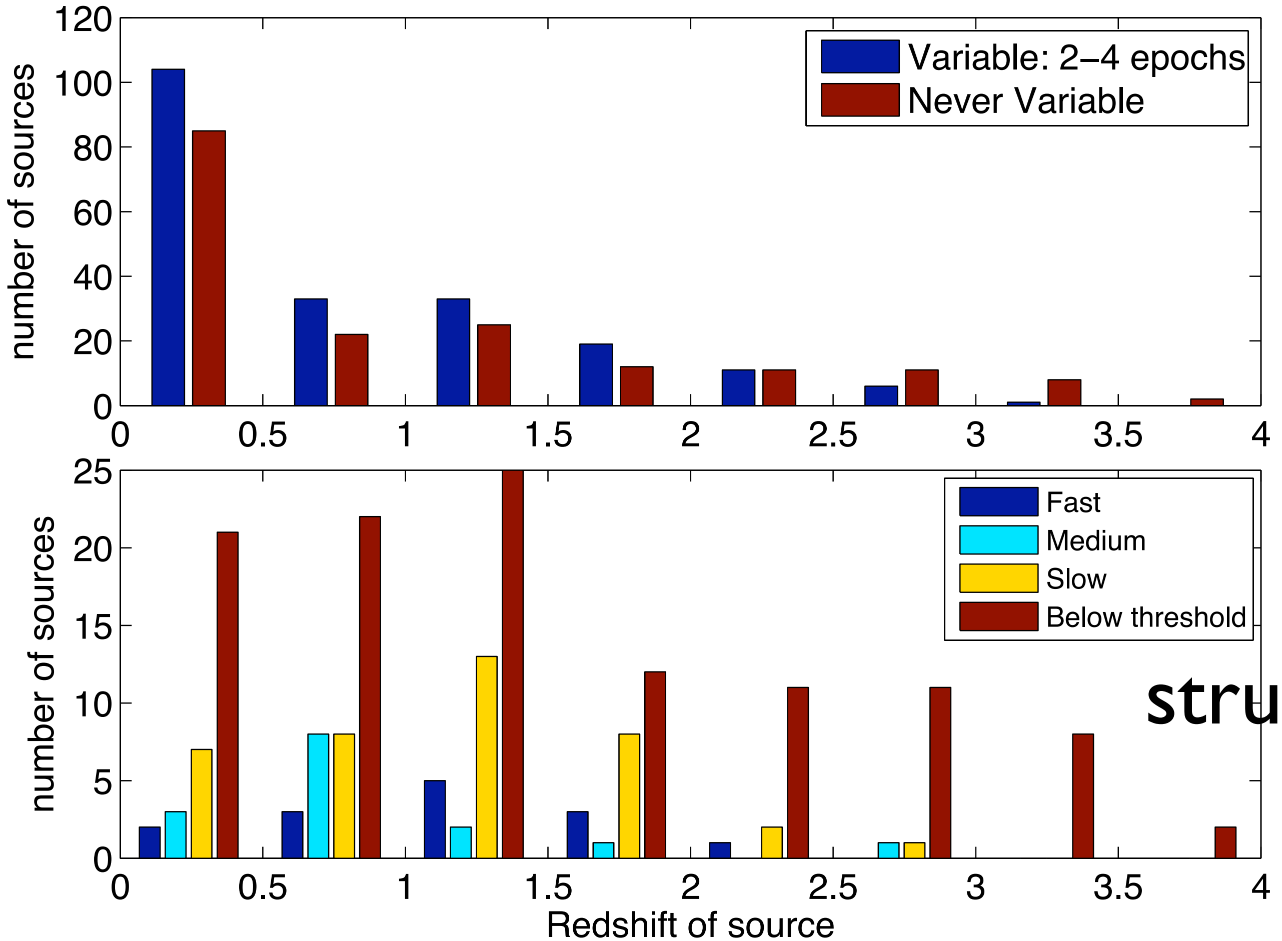
The variations are dominated by interstellar scintillation



$$\mathrm{H}\alpha\ (\mathrm{i.e.\ EM}) \propto N_e^2, \quad \mathrm{SM} \propto \Delta N_e{}^2$$

the variability properties "know" about our Galaxy's interstellar medium

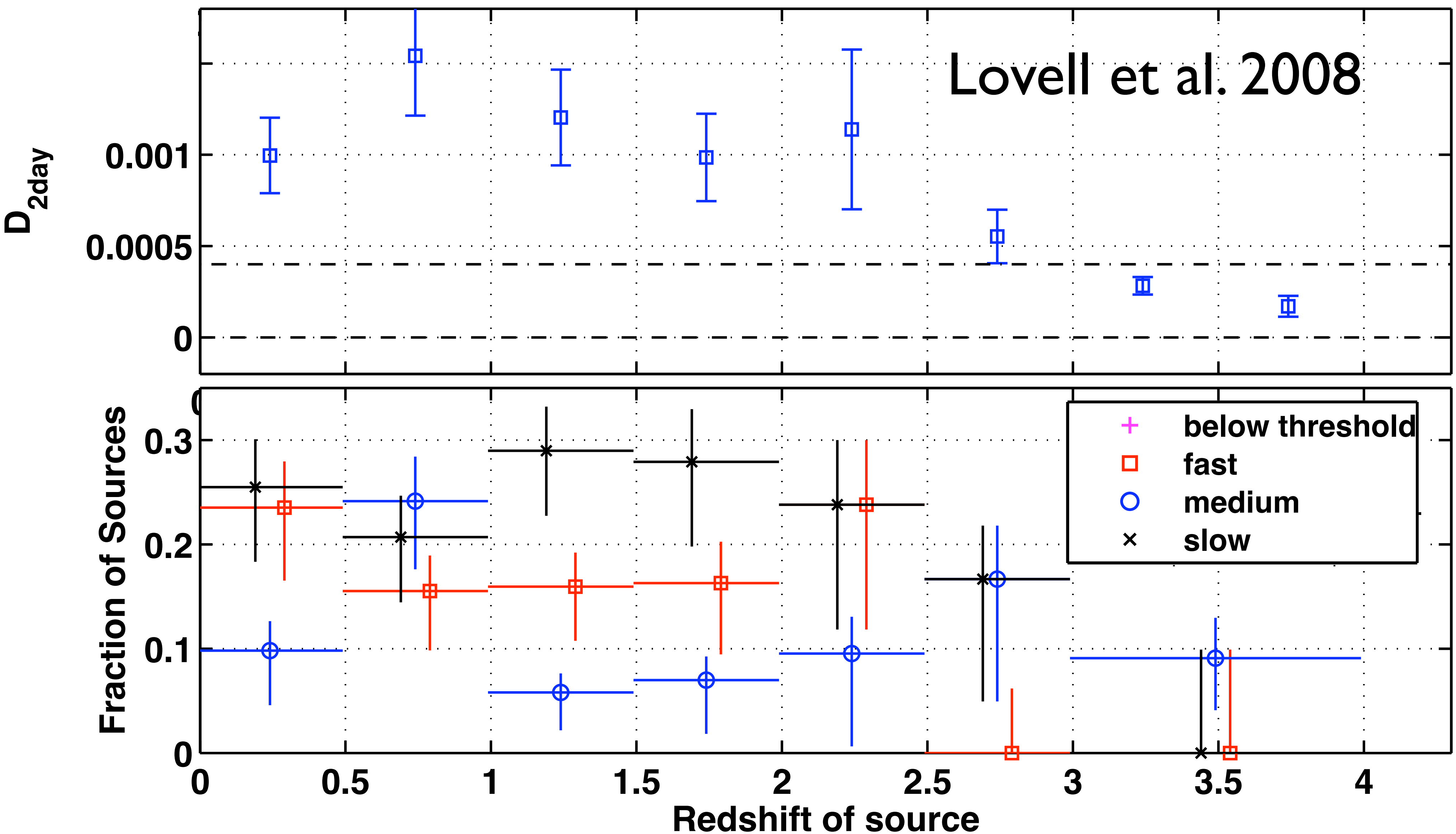
IDV redshift distribution



RMS+by-eye method

structure function method

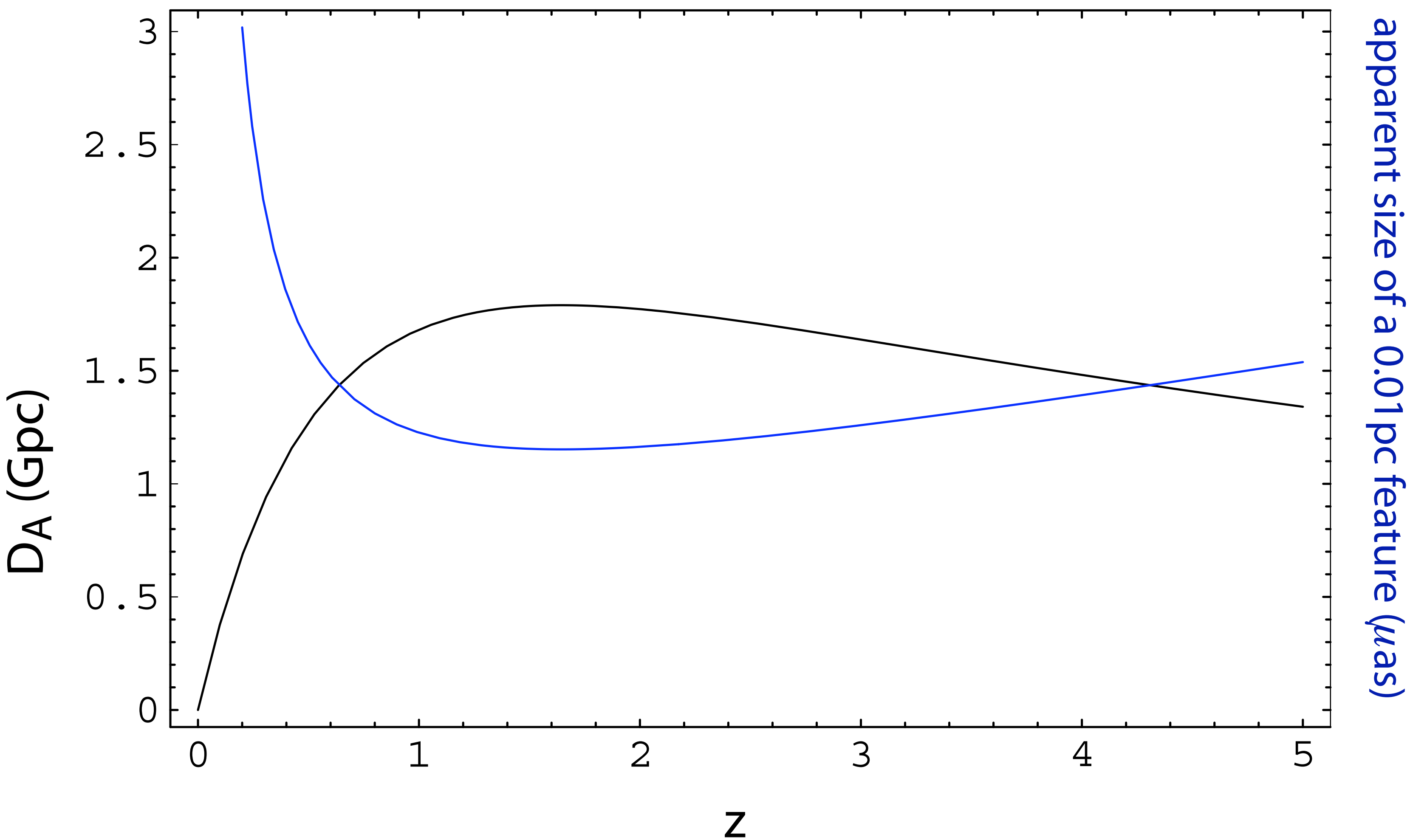
IDV timescale is also z-dependent



A decrease in scintillation implies an increase in (micro-as) source sizes.

Possible causes of a redshift dependence

Variation of angular diameter distance for a source of fixed proper length

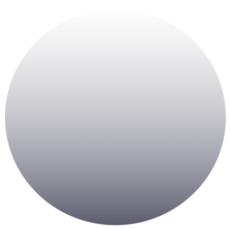


Understanding source size evolution in terms of brightness temperatures

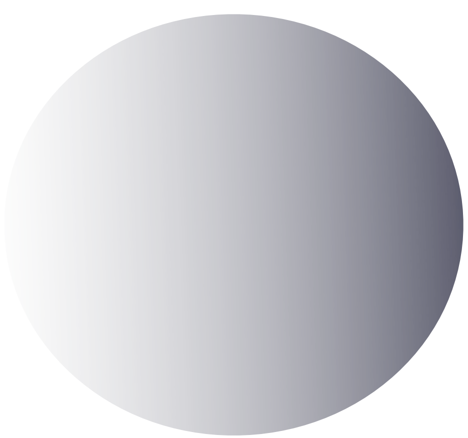
$$\theta_{\rm obs} \propto \left[K \frac{S_{\nu,\rm obs}(1+z)}{\mathcal{D}} \right]^{1/2}, \qquad K = \frac{c^2}{2\pi\nu^2\, k T_B}$$

T_B limit argument applies as long as power input high enough that source is dominated by IC radiation losses

10^{12} K IC limit?

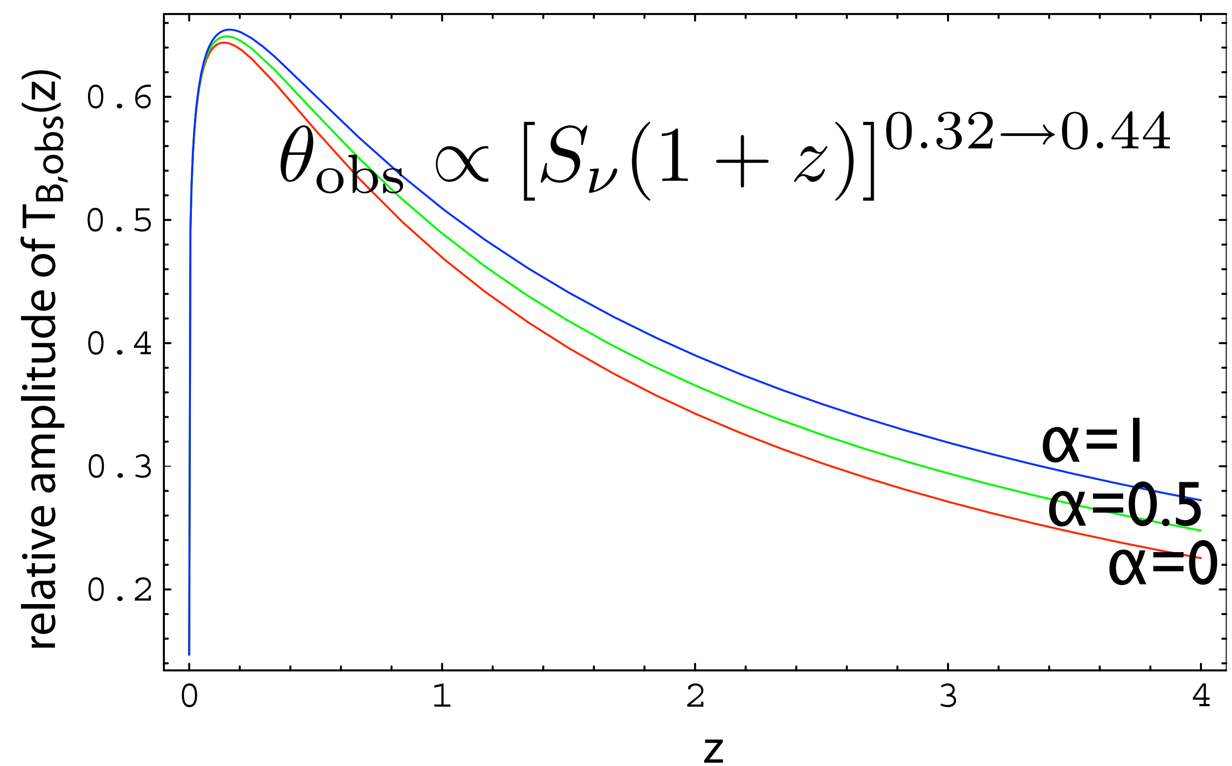


Low S_ν, but compact

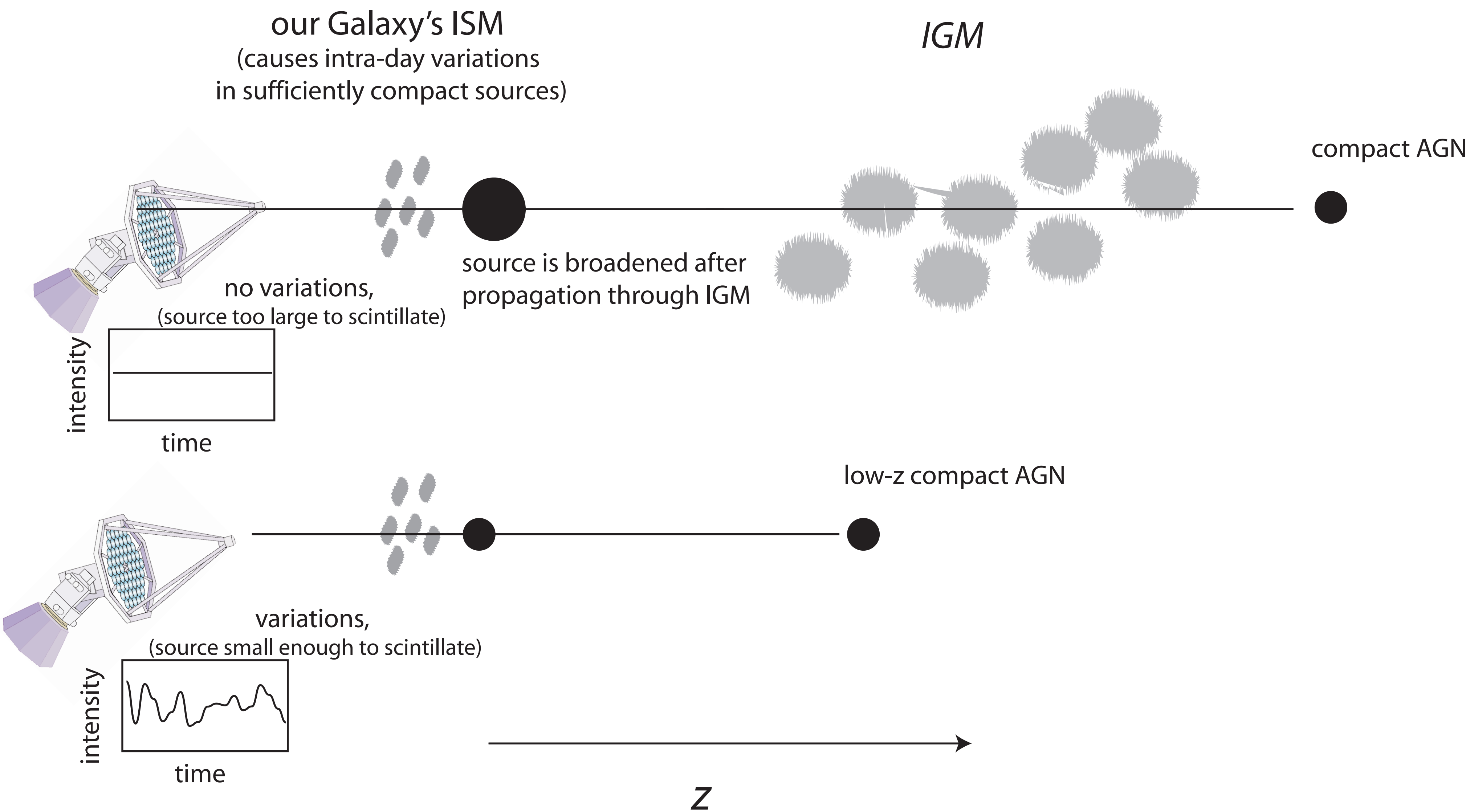


High S_ν, but diffuse

If source radiates at the *equilibrium brightness temperature* (Readhead 1994):



Explanation I: IGM scattering



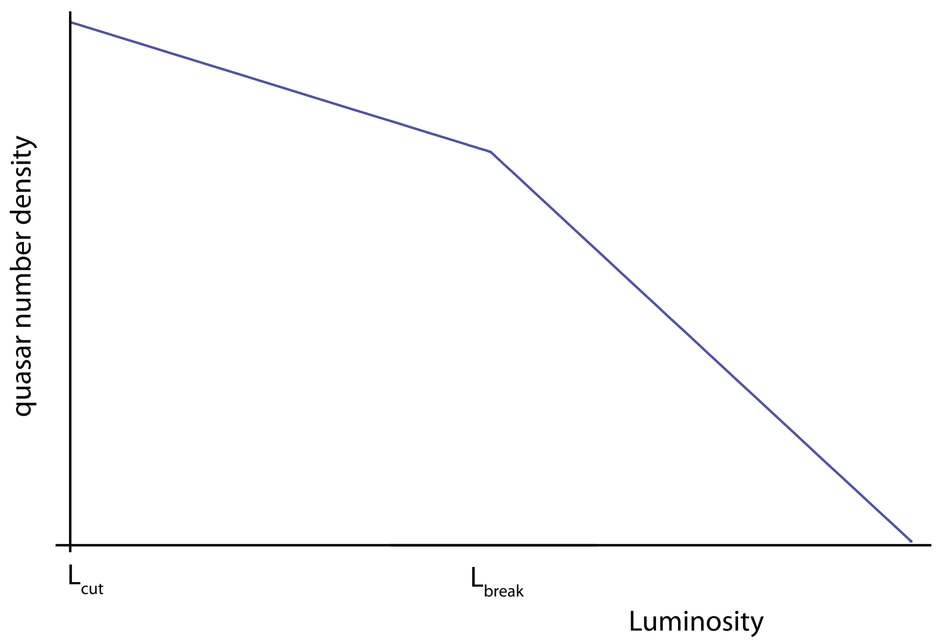
Explanation II: intrinsic AGN evolution

- Model source population in terms of

  i. a luminosity distribution combined with

  ii. a Doppler beaming distribution

- For (i) we use a power law radio luminosity function with lower cutoff L_{cut} that steepens at L_{break} (after Peacock 1987, Willott et al. 1998)



- For (ii) we assume a power law distribution in Lorentz factor to derive $p(\mathcal{D})$.

Evolution in intrinsic AGN properties

- To make things simple we can initially assume
  - all our AGN are radiating near a common temperature (e.g. the 10^{12}K Inverse Compton limit)
  - the ISM responsible for the IDV is located at similar distances (D_{ISS}) for all sources and has a comparable scattering strength (λ_t) in all directions
- The mean-square modulation index (i.e. intensity variance) for a group of sources at redshift z is

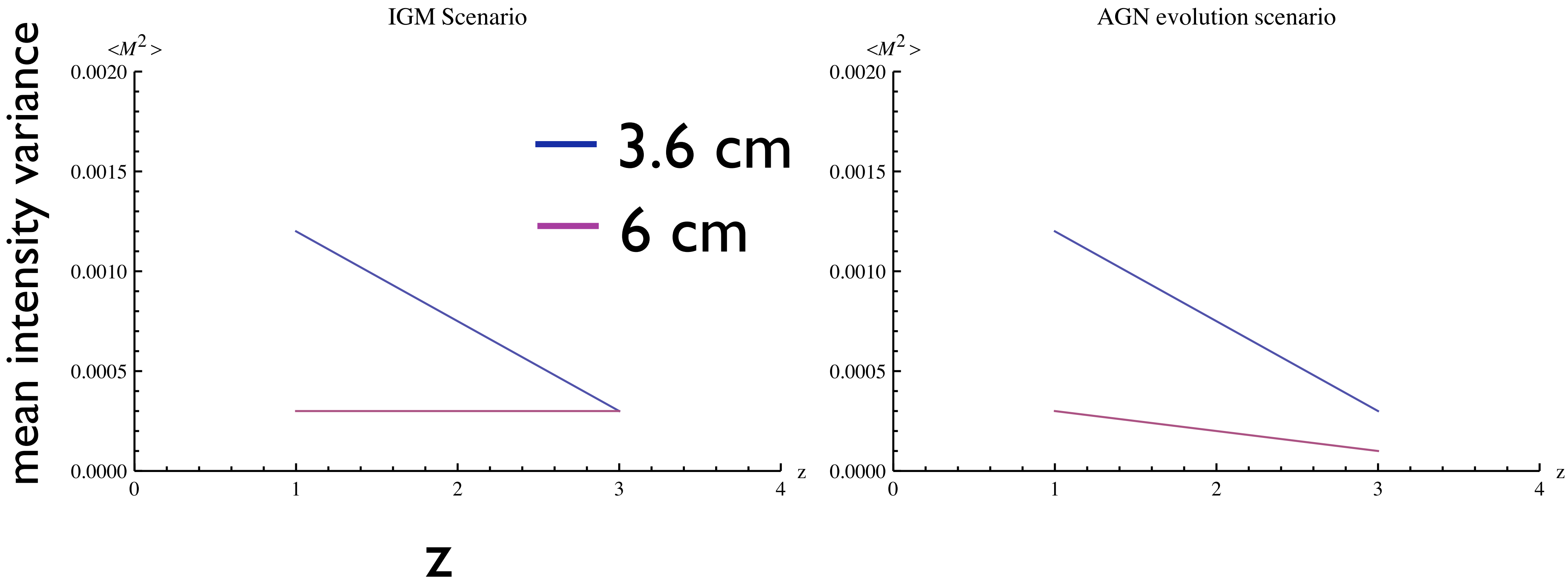
$$\langle M^2 \rangle = 0.0018\, f_c\, (1+z)^{-1} \left(\frac{S_{\rm cut}}{1\,{\rm Jy}}\right)^{-1} \left(\frac{\lambda_t}{6\,{\rm cm}}\right)^{-2.8} \left(\frac{\lambda}{6\,{\rm cm}}\right)^{1.8} \left(\frac{T_B}{10^{12}\,{\rm K}}\right) \left(\frac{D_{\rm ISS}}{500\,{\rm pc}}\right)^{-1}.$$

- where f_c is the fraction of the entire source flux density that resides in the compact component of the AGN. The choice f_c=0.1 reproduces the survey statistics!

- To see a strong evolution in $\langle M^2 \rangle$ we must therefore have
  - strong evolution in S_{cut} (but existing RLFs suggests this is unlikely)
  - a strong evolution in $f_{c.}$ A test with a 219 source VSOP AGN sample (Dodson et al. 2008) shows that there *may* be evolution in f_c, but a lack of z>2 sources makes the result ambiguous.

VLA/EVLA test

- The IDV amplitude ν-dependence differs between the two interpretations



- Test: observe a large sample of z>2 AGN at both 4.8 and 8.6 GHz and measure the IDV frequency dependence (with z<2 control sample)

- **EVLA's** large instantaneous frequency coverage is an enormous advantage in charting IDV frequency dependence between C and X bands (or higher). **Faster** EVLA can do more than 5 subarrays, thus more sources simultaneously!

- For IDVs in general: capable of monitoring extremely fast sources, pol'n.

Concluding remarks

- MASIV has uncovered a redshift dependence in IDV properties. Is it
  - angular broadening due to turbulence in the IGM or
  - intrinsic evolution in micro-arcsec AGN properties
  - or both?
- There is a simple test to distinguish between the two mechanisms

ASKAP as a transients detector

for various modes of operation

ASKAP ideal as a survey instrument
EVLA ideal for followup