Probing the micro-arcsecond structures of compact AGNs with interstellar scintillation

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ACADEMIA SINICA
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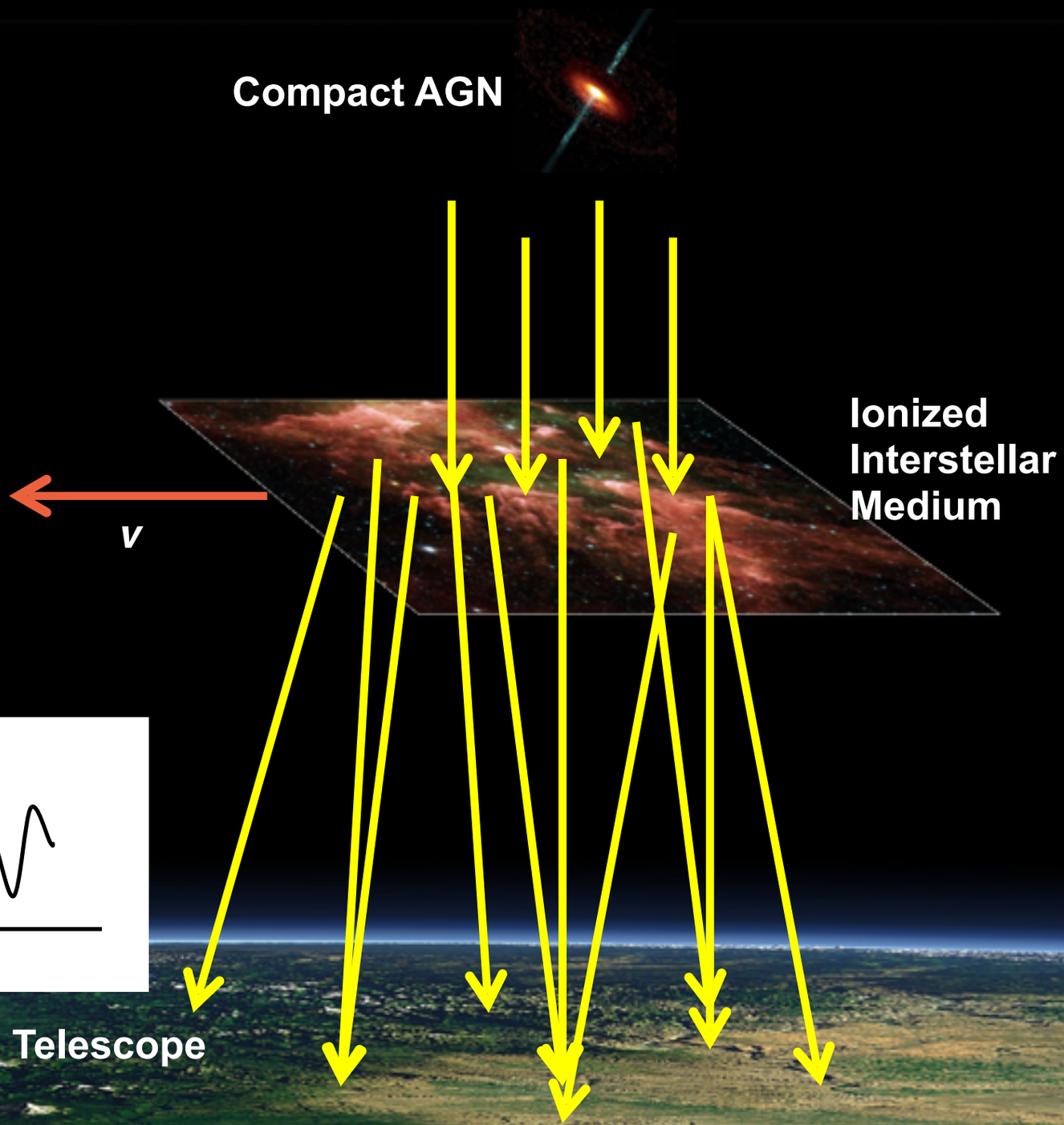
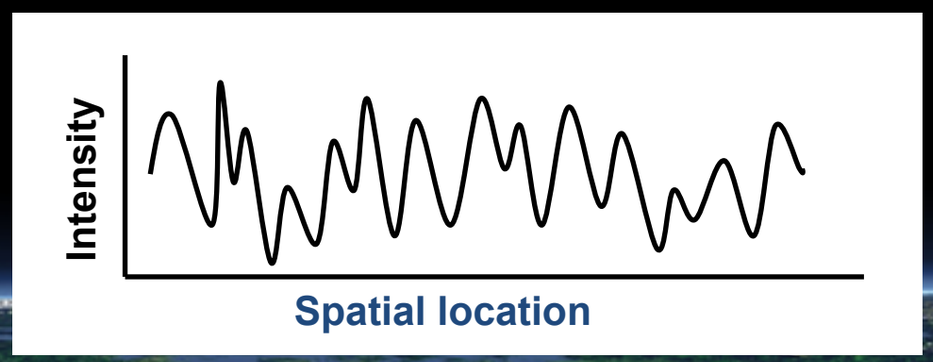
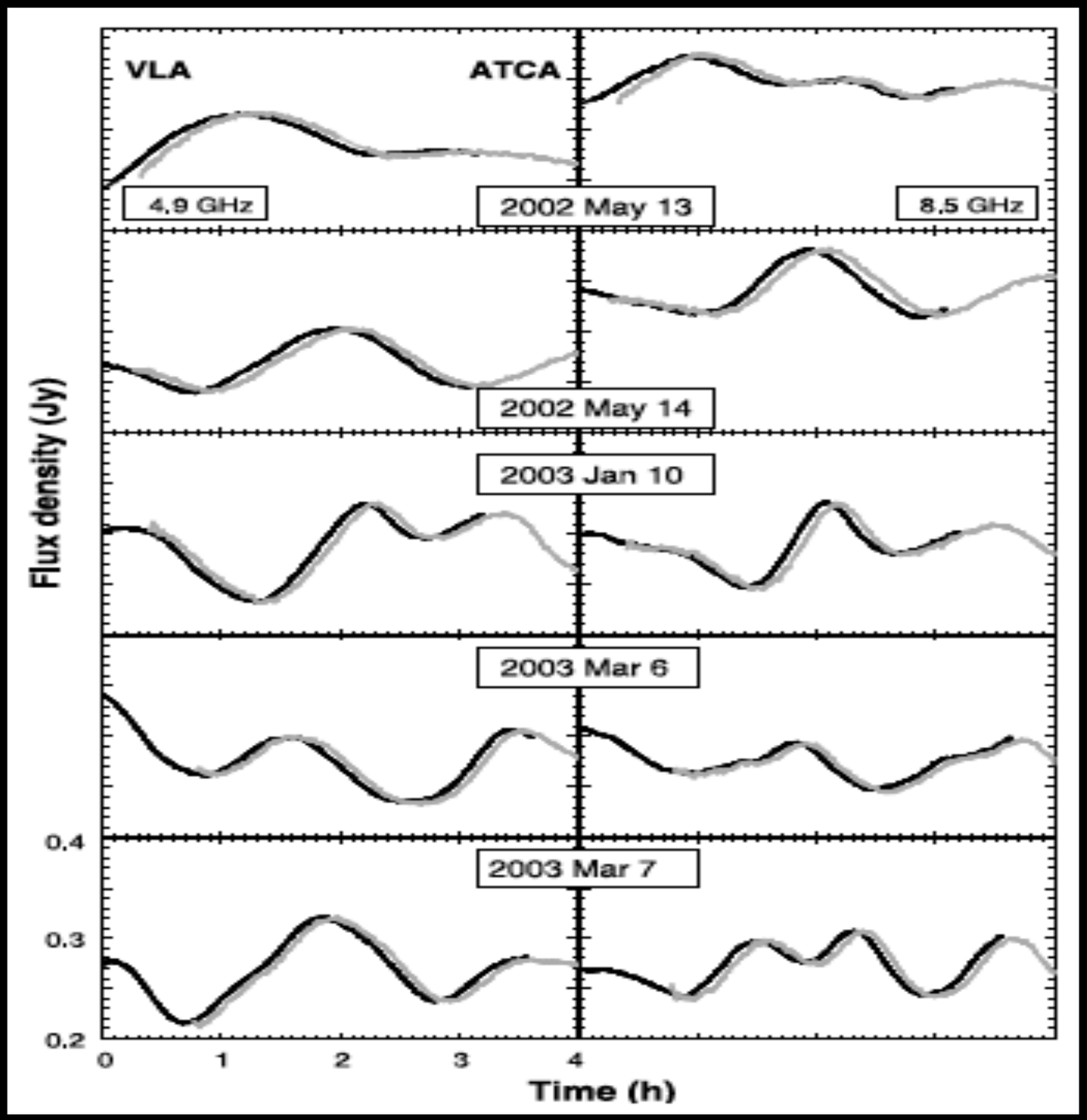
Interstellar scintillation (ISS) of compact AGNs





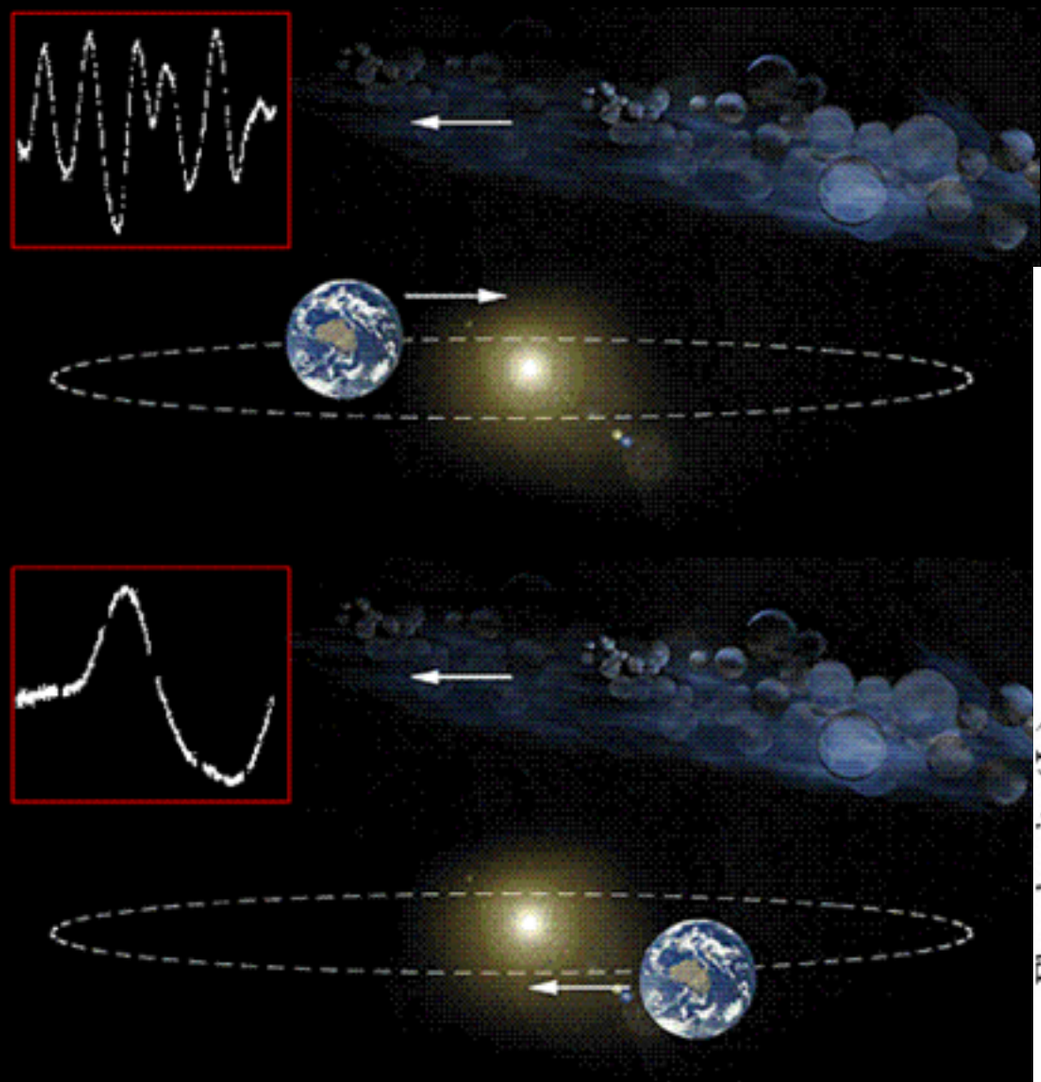
The case for interstellar scintillation (1): time delays between telescopes



PKS 1257- 326

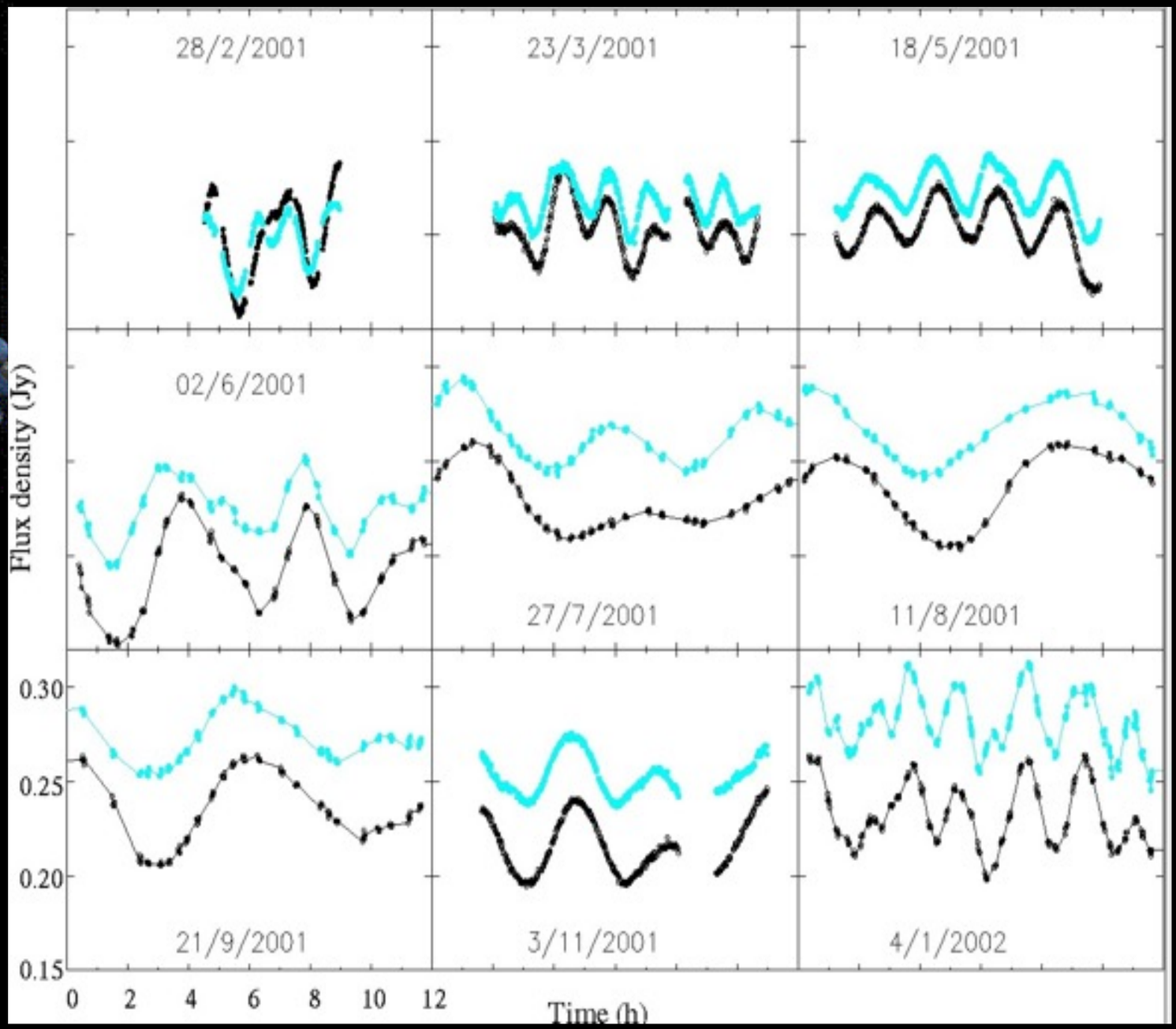
(Bignall et al., 2006)

The case for interstellar scintillation (2): annual cycles



(Bignall et al., 2003)

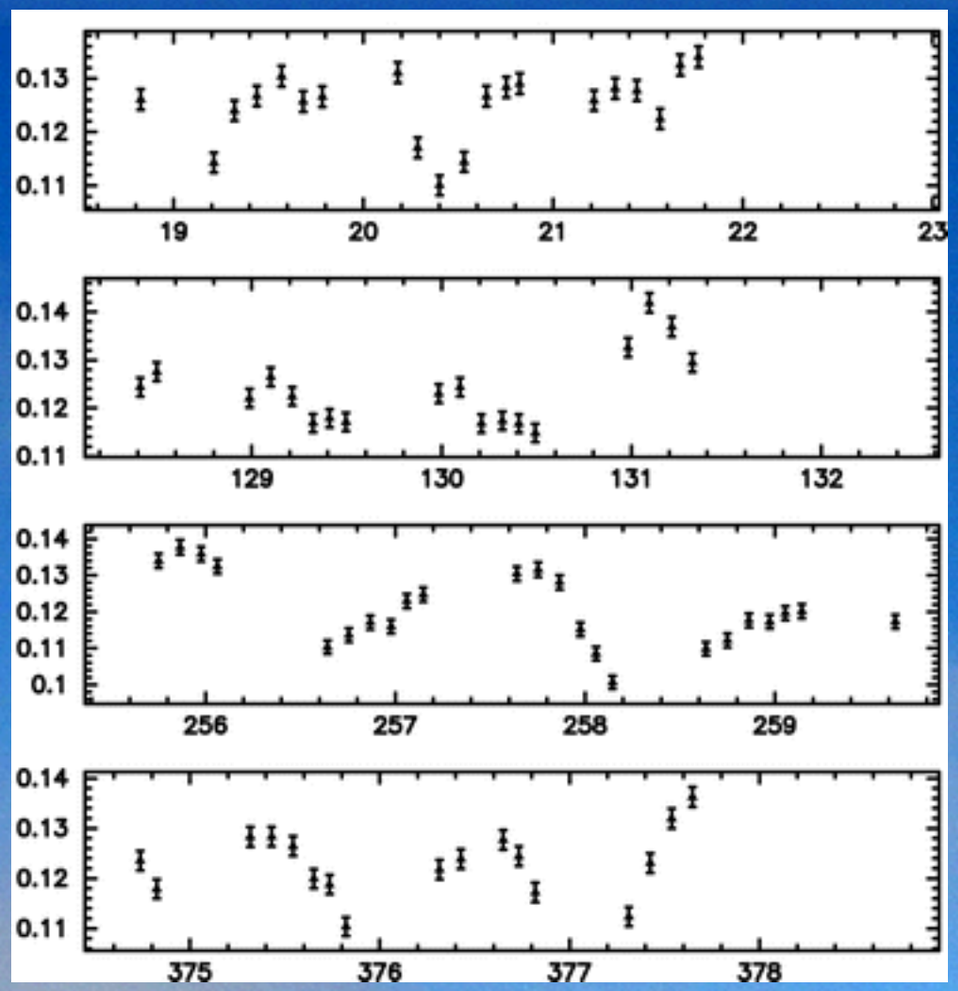
PKS 1257- 326



The Micro-Arcsecond Scintillation-Induced Variability (MASIV) Survey

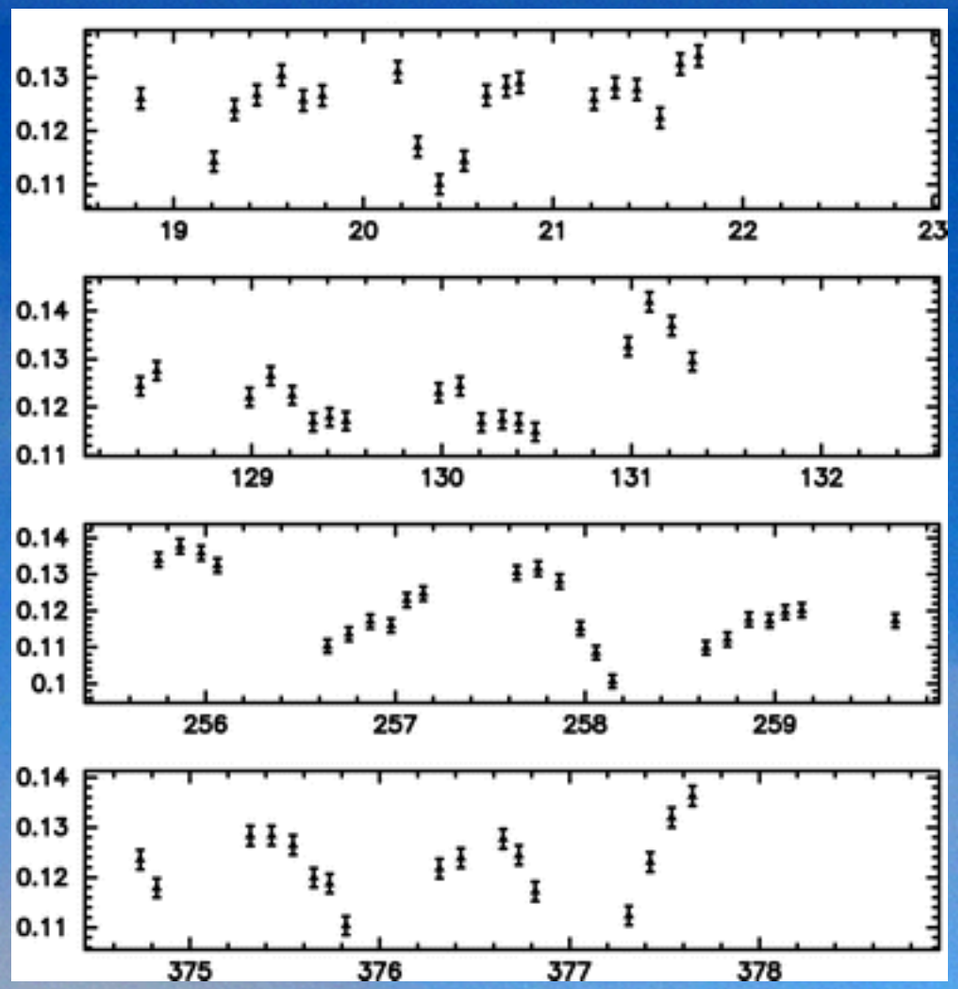
… and the Very Large Dis-Array

(Image Credits: Jim Lovell)



(Lovell et al. 2008)

The Micro-Arcsecond Scintillation-Induced Variability (MASIV) Survey



… and the Very Large Dis-Array

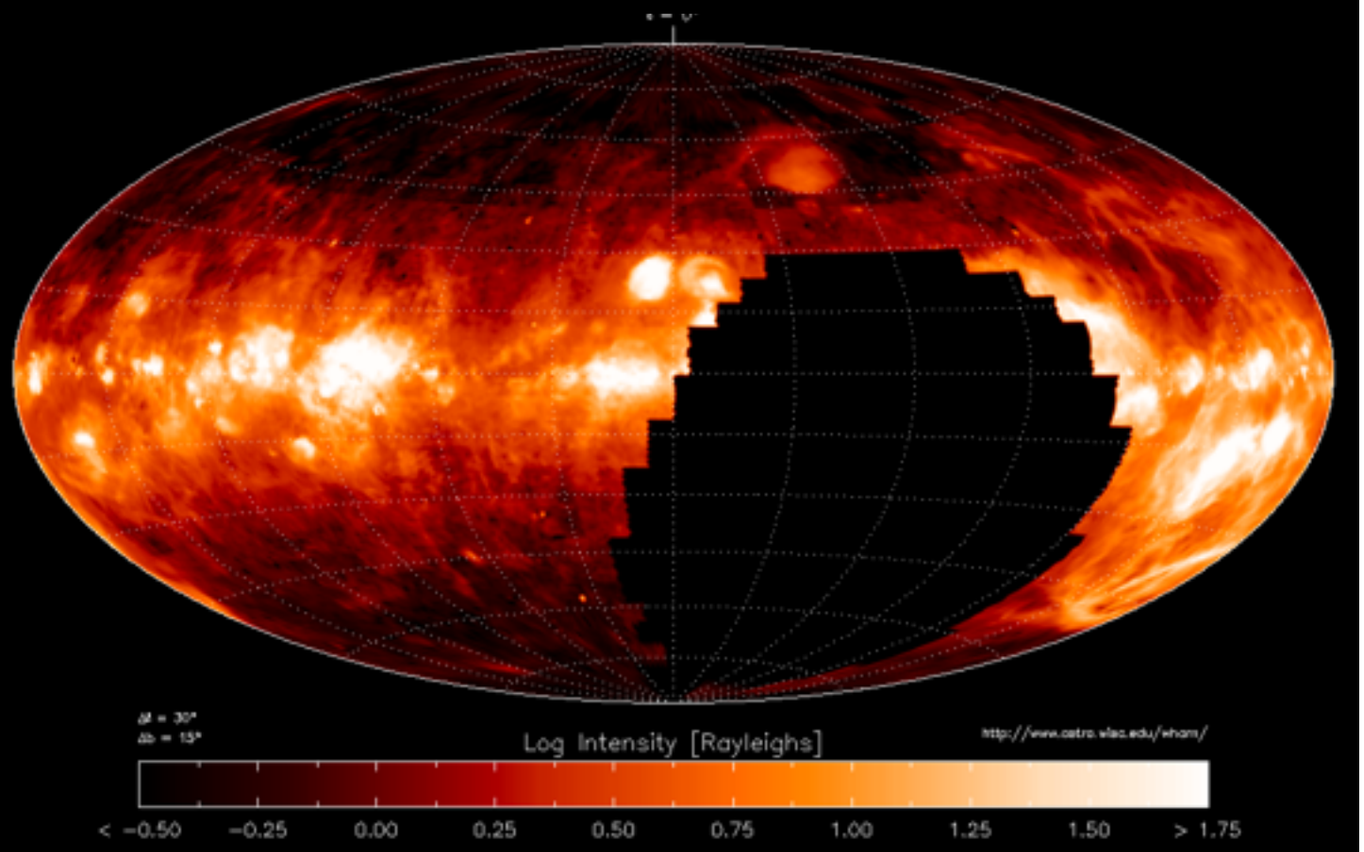
(Image Credits: Jim Lovell)

~ 58 % of compact radio AGNs exhibit 2% to 10% rms flux variations on intra/inter-day timescales

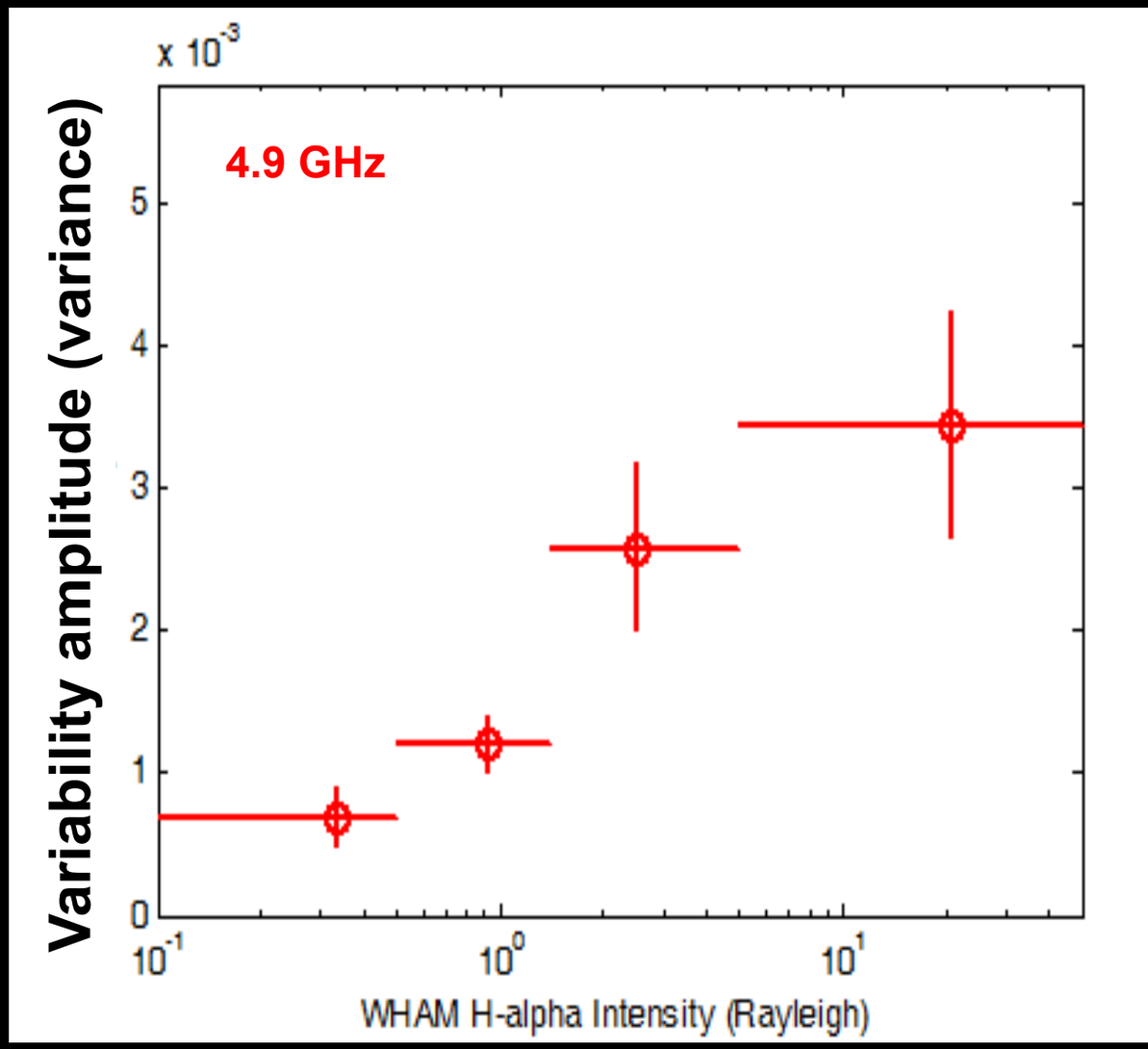
(Lovell et al. 2008)

The case for interstellar scintillation (3): galactic dependence

Wisconsin H-Alpha Mapper (WHAM) Survey

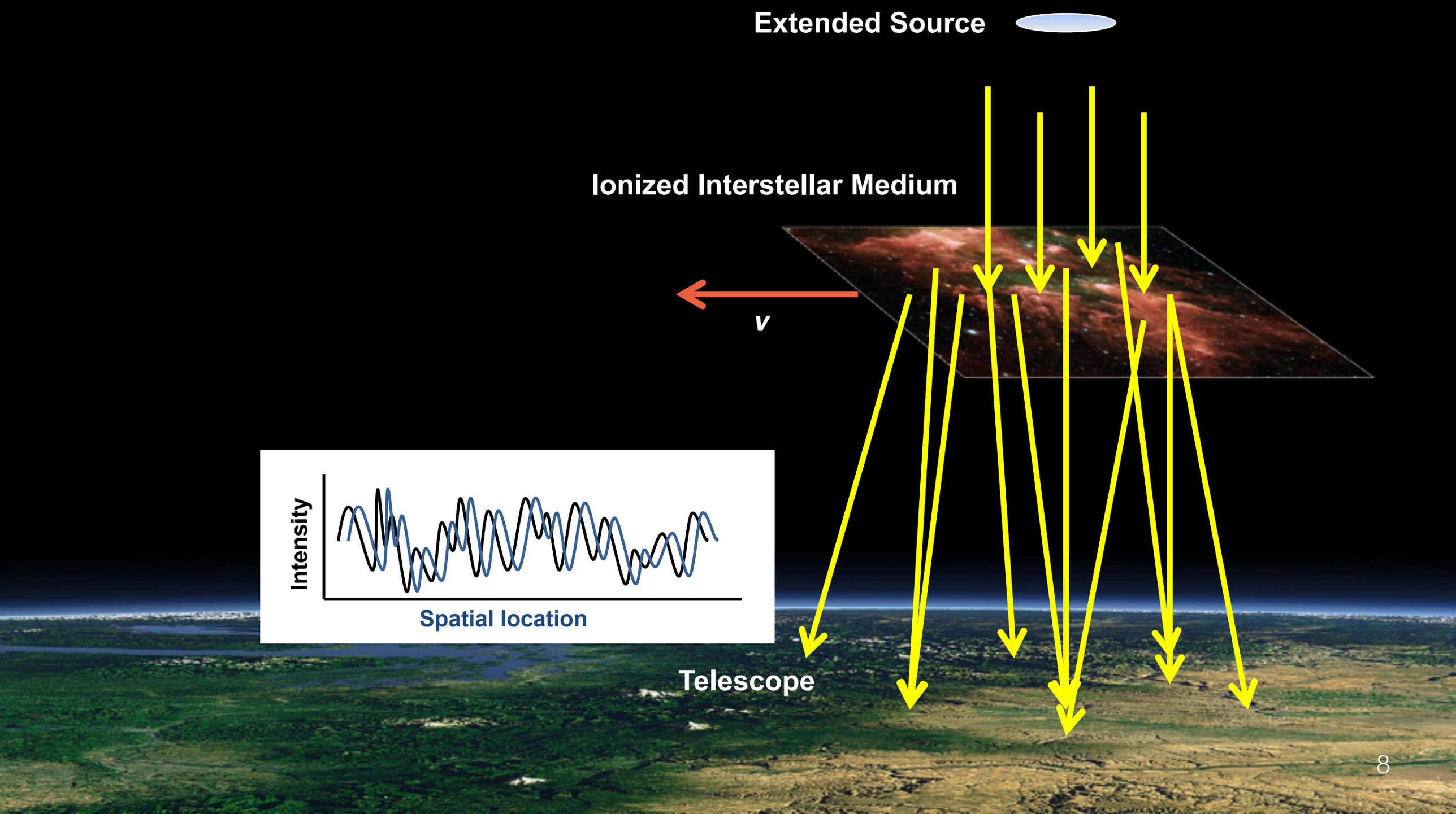


(Haffner et al, 2003)



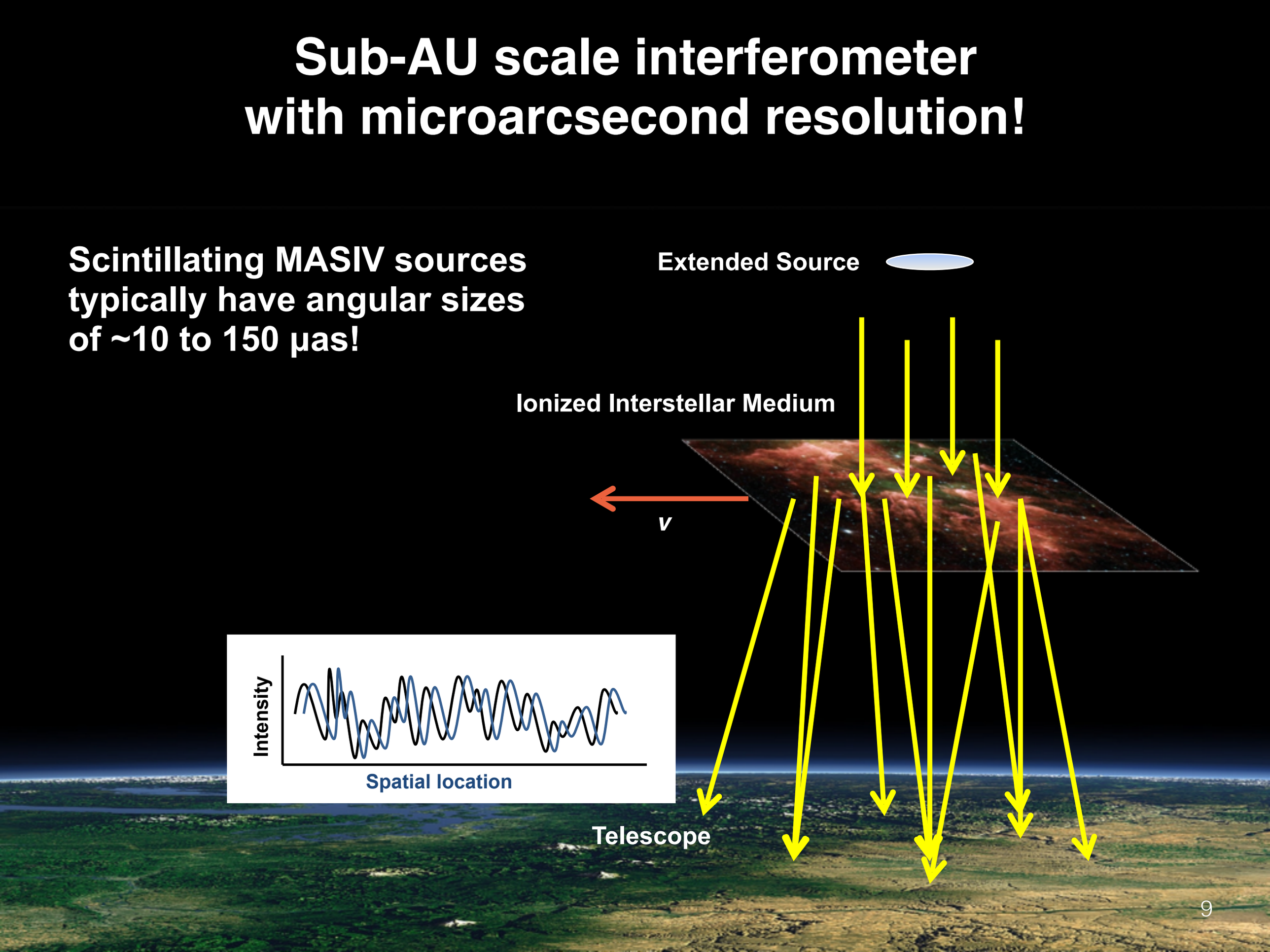
(Koay et al, AJ, 2011)

Sub-AU scale interferometer with microarcsecond resolution!



Sub-AU scale interferometer with microarcsecond resolution!

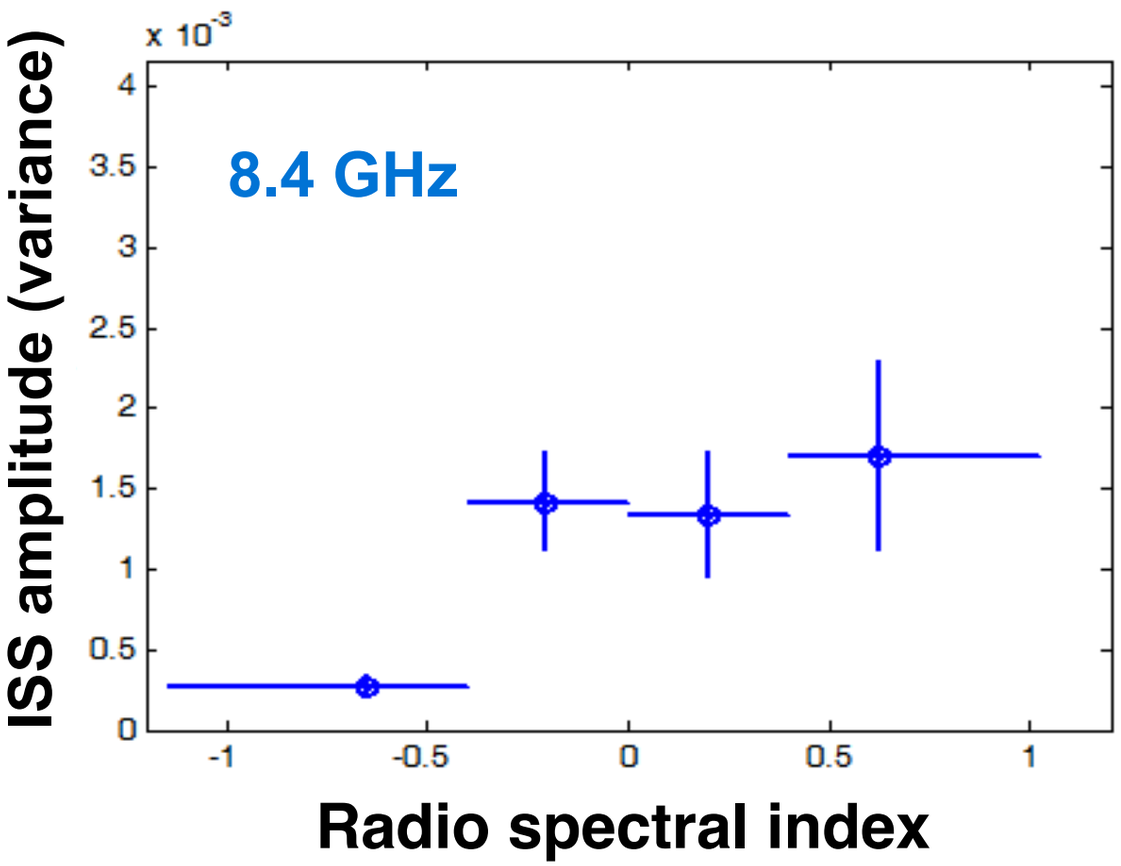
Scintillating MASIV sources typically have angular sizes of ~10 to 150 μas!

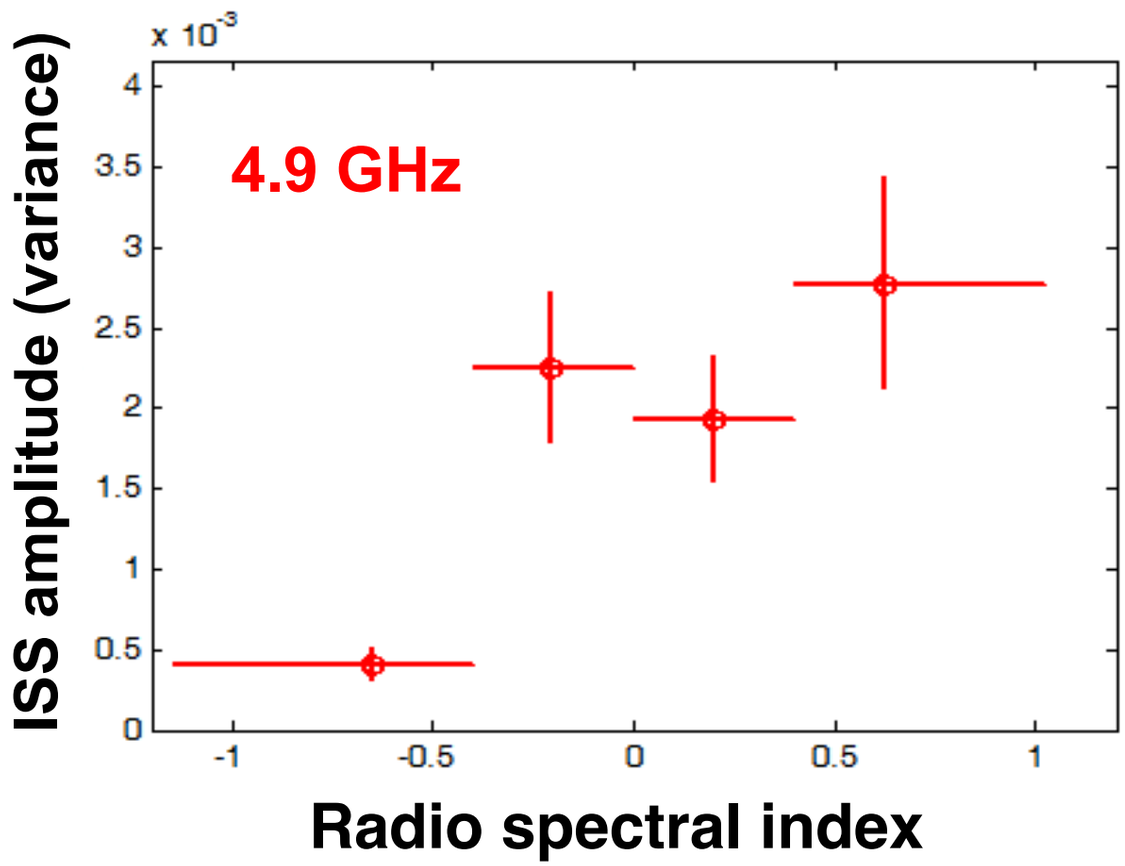


Dependence of ISS on radio core dominance

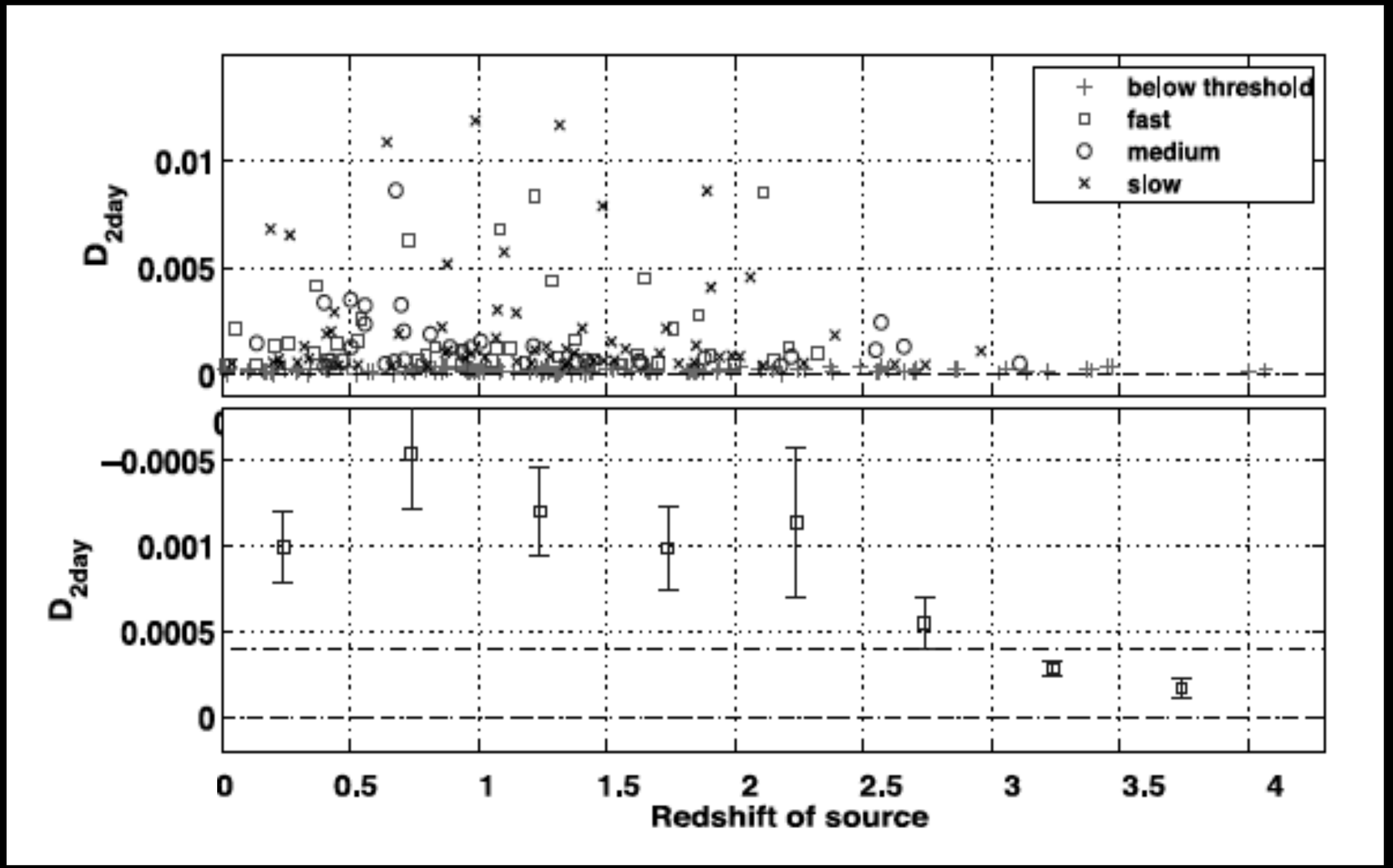
$$S \propto= \nu^{\alpha}$$

(Koay et al, AJ, 2011)





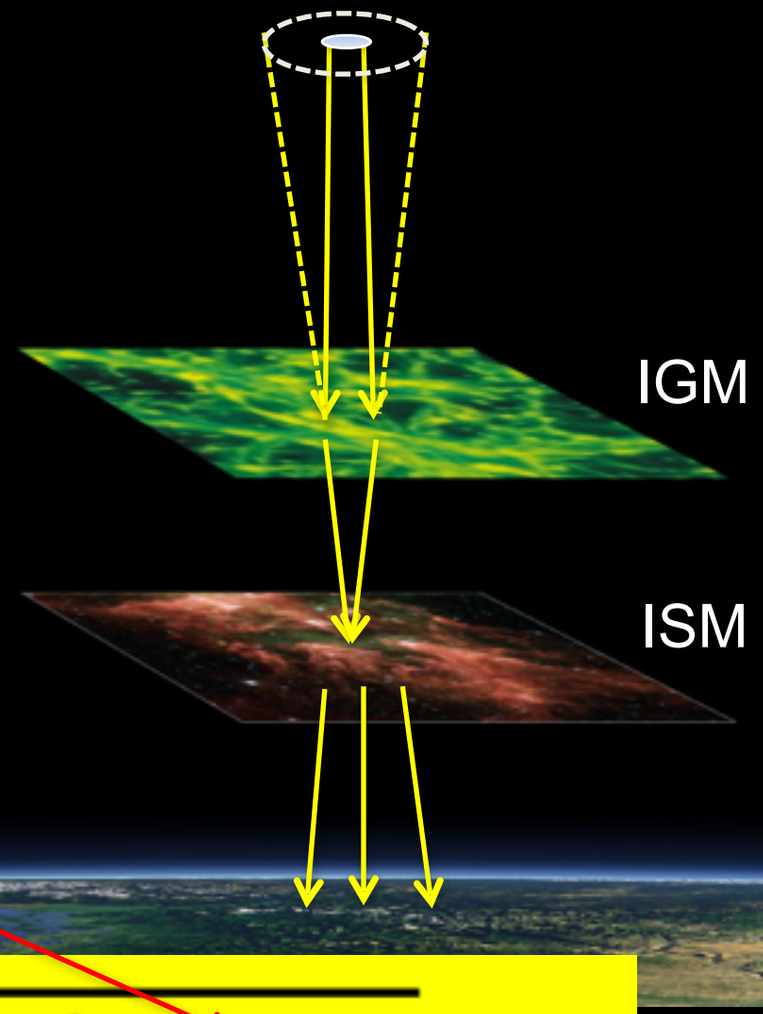
Most surprising result: Redshift dependence of ISS!



(Lovell et al., 2008)

What Causes This Redshift Dependence?

- Cosmological angular-size redshift relation?
- Source selection effects?
- Evolution of core/jet morphology?
- Scatter broadening in the ionized intergalactic medium?



wavelength

mean flux density

$$\theta = \sqrt{\frac{\lambda^2 S_\nu}{2\pi k T_{b,obs}}}$$

Boltzmann constant

brightness temperature in observer's frame

redshift

$$\theta = \sqrt{\frac{\lambda^2 (1+z) S_\nu}{2\pi k \delta T_{b,int}}}$$

Doppler boosting factor

intrinsic brightness temperature at source rest frame

Dual frequency follow-up observations: wavelength dependence of μas source sizes

$$\theta_{int} \propto \lambda$$

intrinsic source size

$$\theta_{scatt} \propto \lambda^2$$

angular broadening

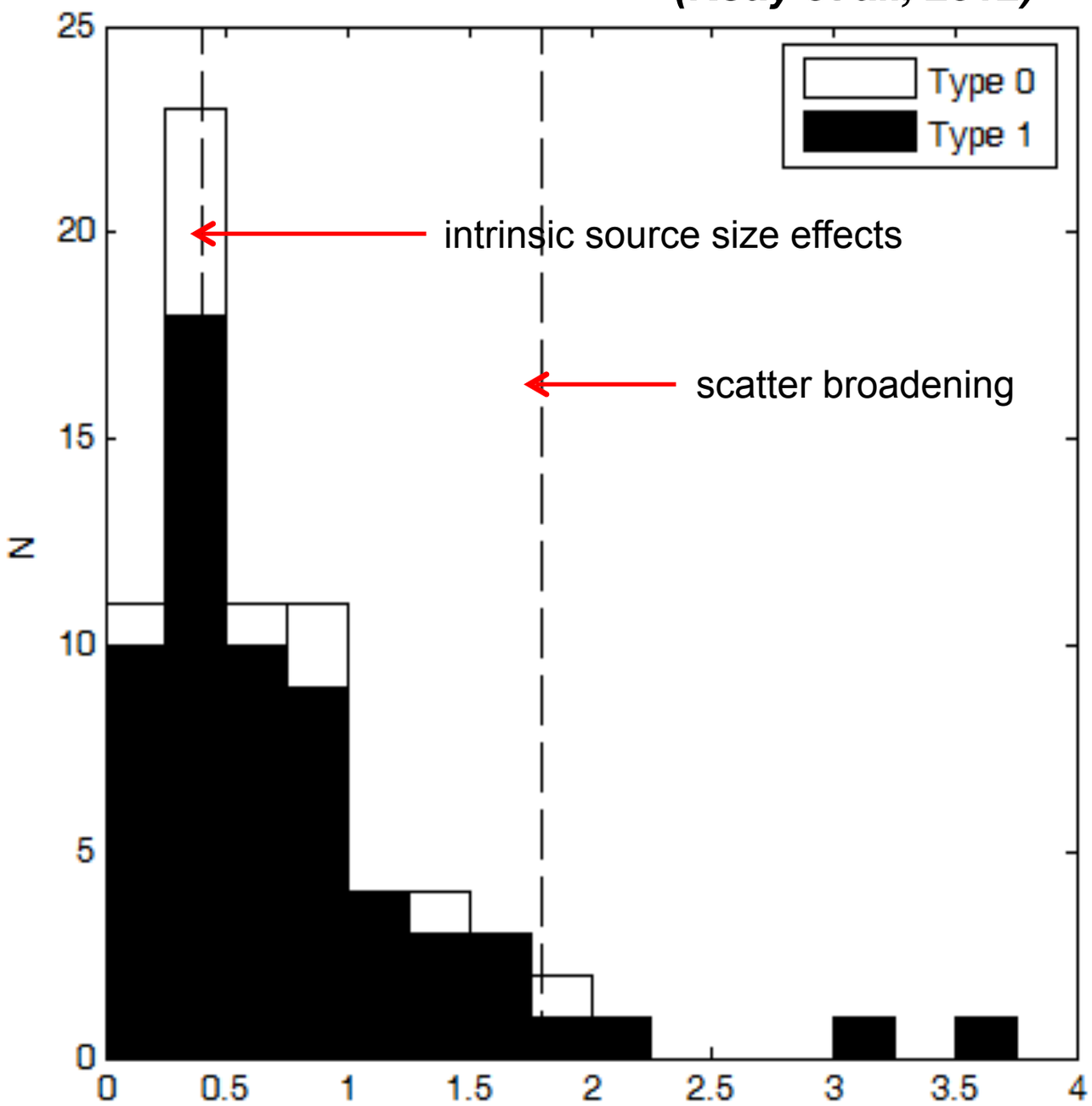
observed source size

$$\theta_{obs} = \sqrt{\theta_{int}^2 + \theta_{scatt}^2}$$

ratio of rms variability amplitudes, R_D

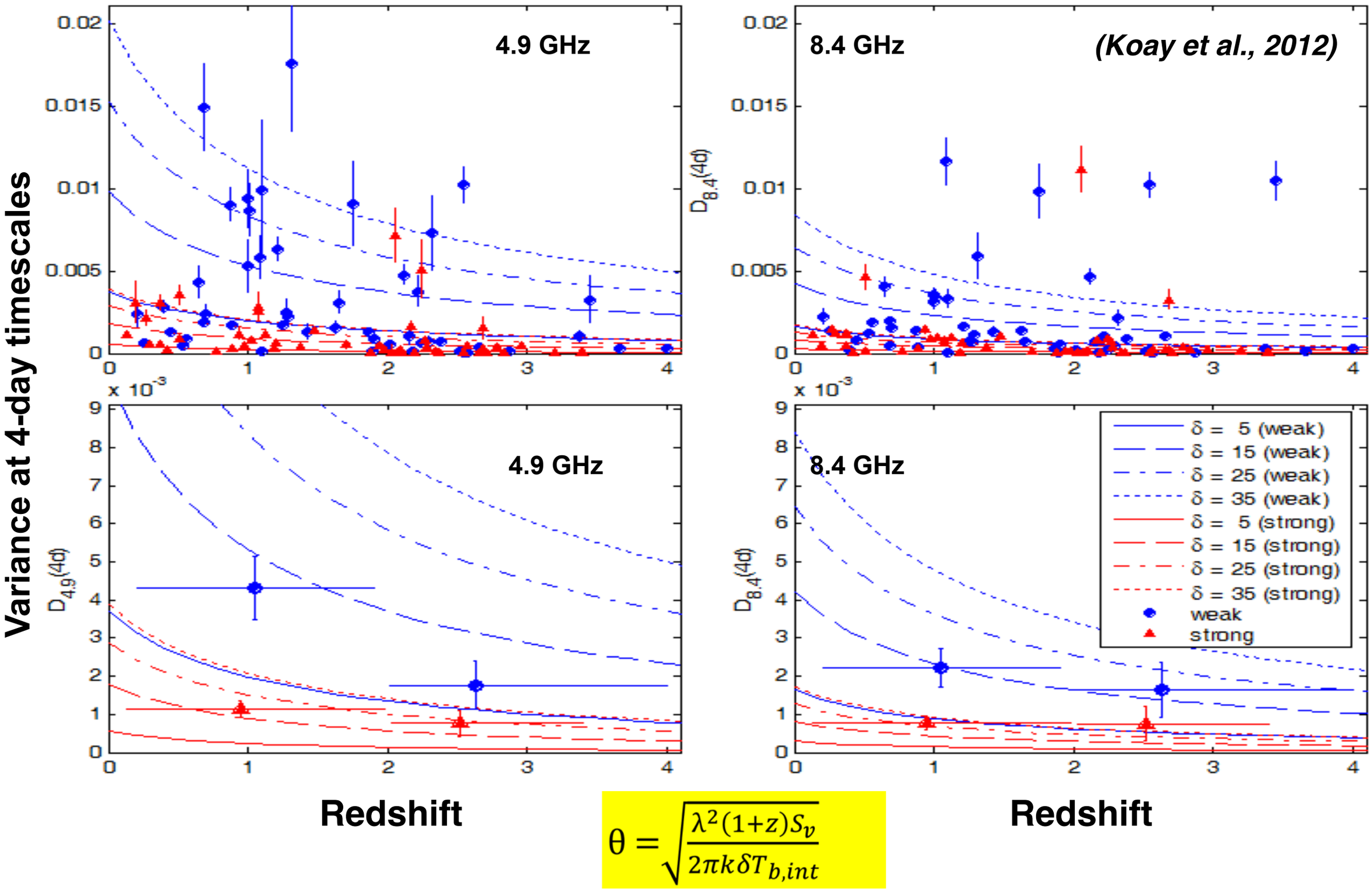
$$\frac{m_{8.4}}{m_{4.9}} \propto \left(\frac{\theta_{obs,4.9}}{\theta_{obs,8.4}}\right)^{\frac{7}{6}}$$

(Koay et al., 2012)



Ratio of 8 GHz to 5 GHz ISS amplitudes

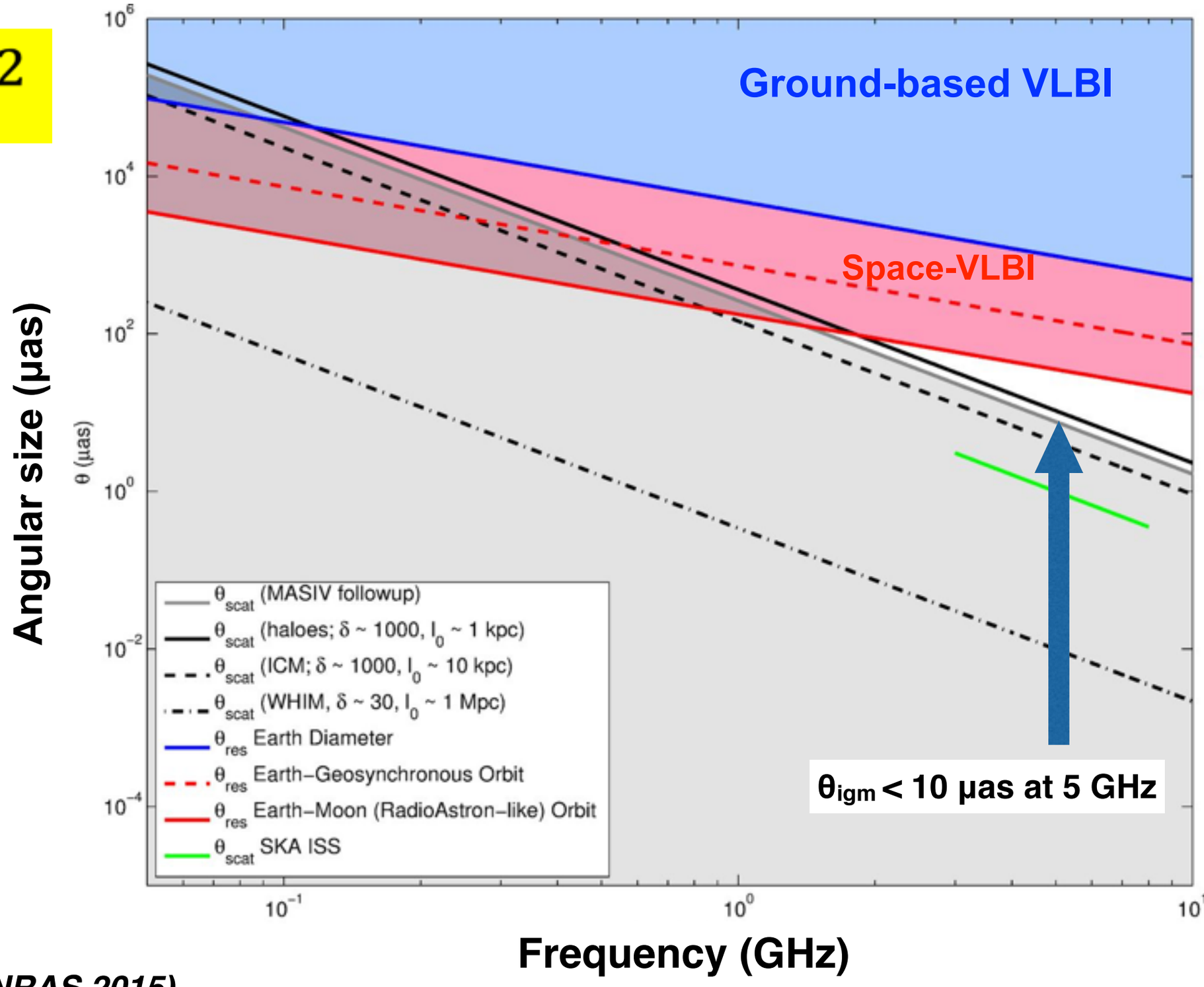
Origin of ISS Redshift Dependence



$$\theta = \sqrt{\frac{\lambda^2(1+z)S_v}{2\pi k \delta T_{b,int}}}$$

The strongest constraints on IGM scatter broadening

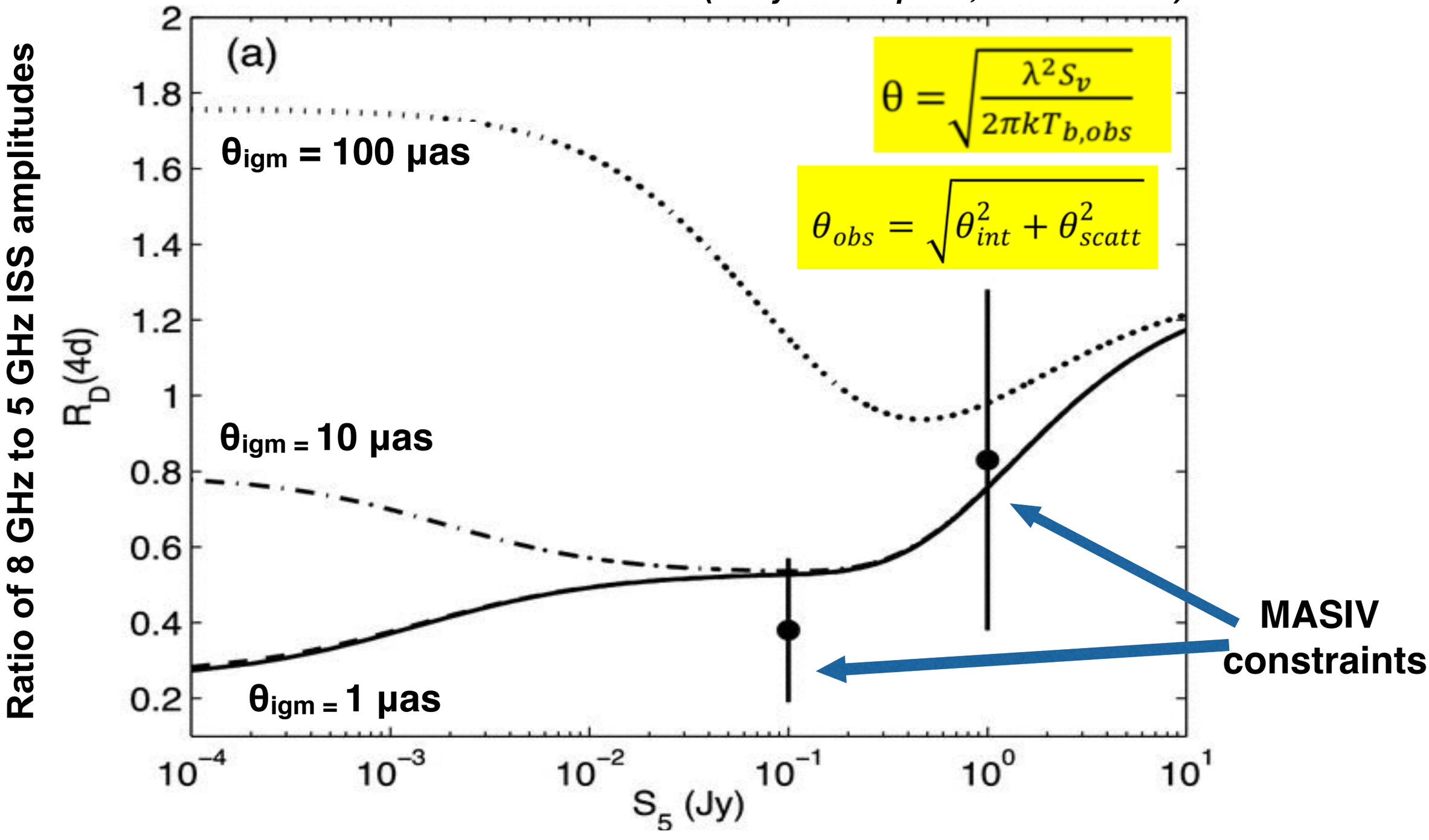
$$\theta_{scatt} \propto \lambda^2$$



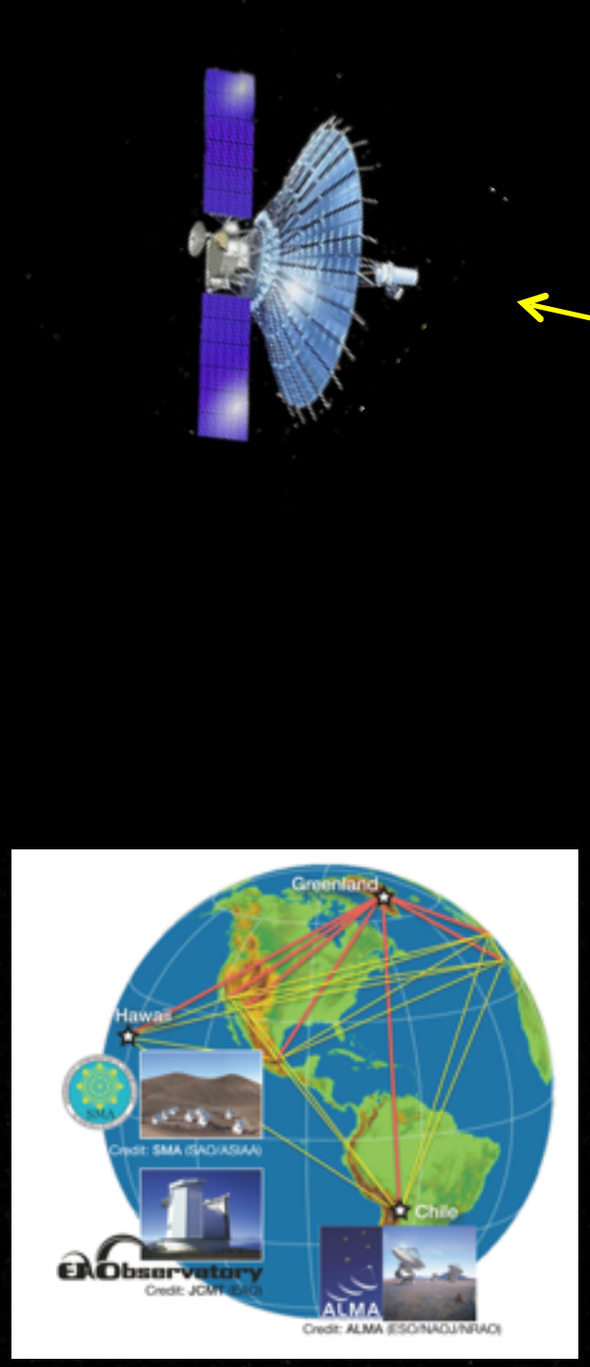
(Koay & Macquart., MNRAS 2015)

1 microarcsecond resolution with ISS and the SKA?

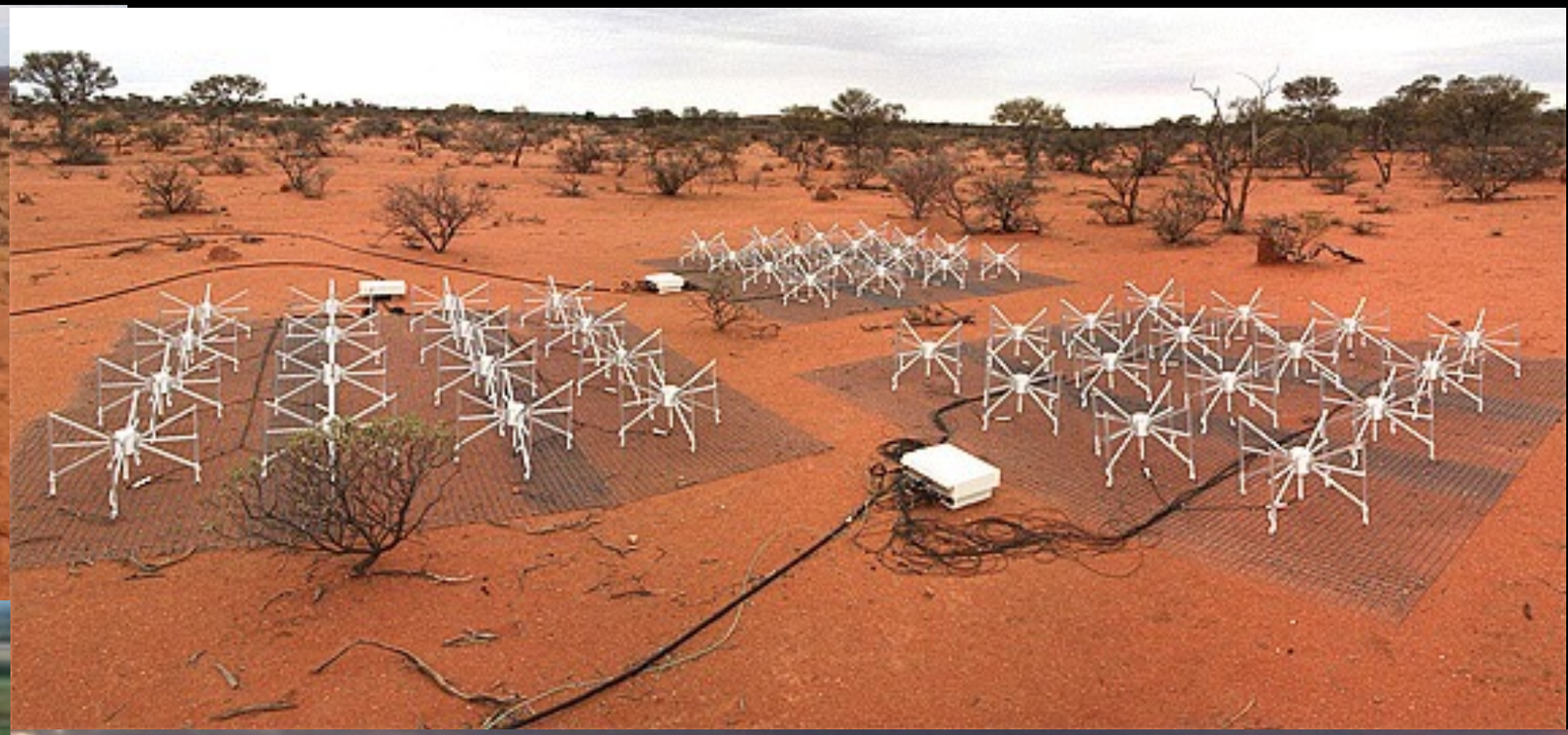
(Koay & Macquart., MNRAS 2015)



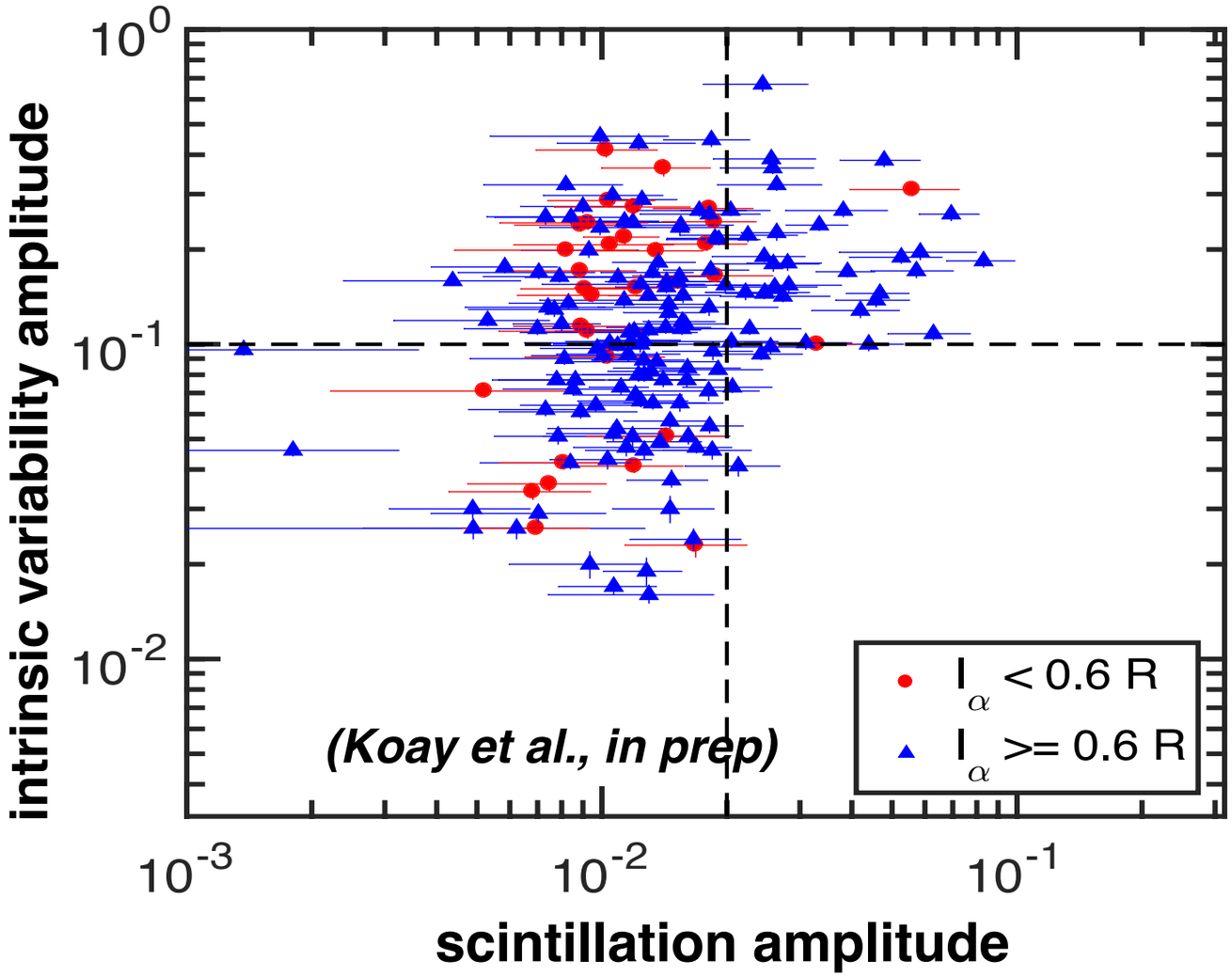
Space VLBI + mm-VLBI + ISS

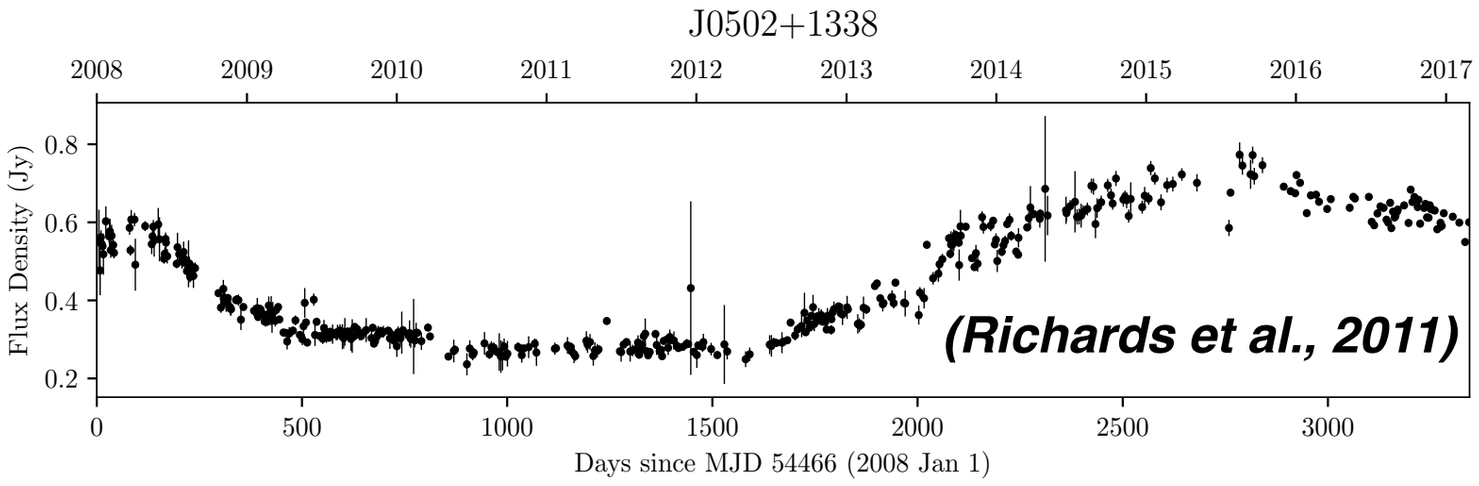


Variability studies on upcoming radio telescopes



ISS or intrinsic variability?





OVRO 40-m 15 GHz Blazar Variability Survey

(Richards et al., 2011)

Take home points

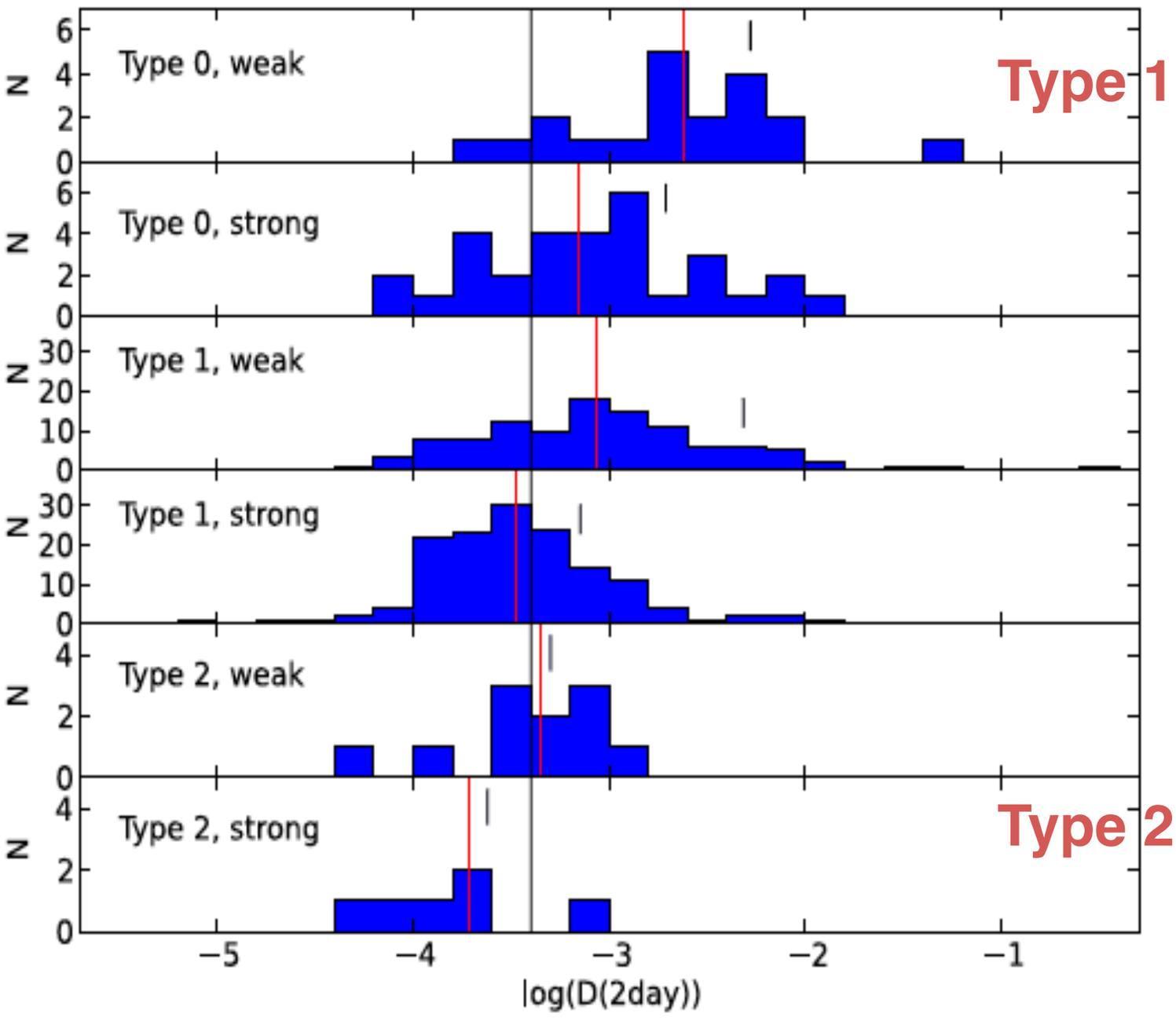
- ISS dominates cm-wavelength variability of compact AGNs on intra and interday timescales
- ISS is an excellent probe of microarcsecond structure of radio AGNs
- The sky coverage, observing frequency, cadence and timespan of future variability surveys will need to be selected carefully to enable these two effects to be distinguished

One astronomer's noise is another astronomer's data

~ Nicole Gugliucci

http://noisyastronomer.com/

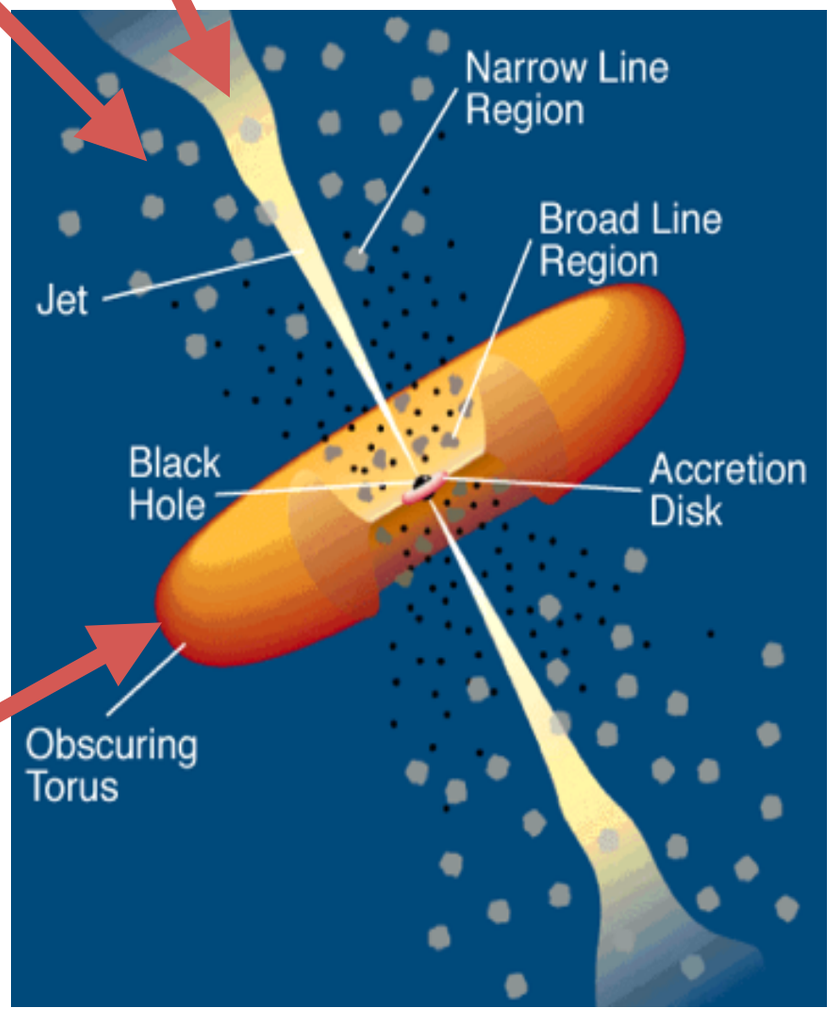
ISS and optical spectroscopic AGN classifications



Type 1

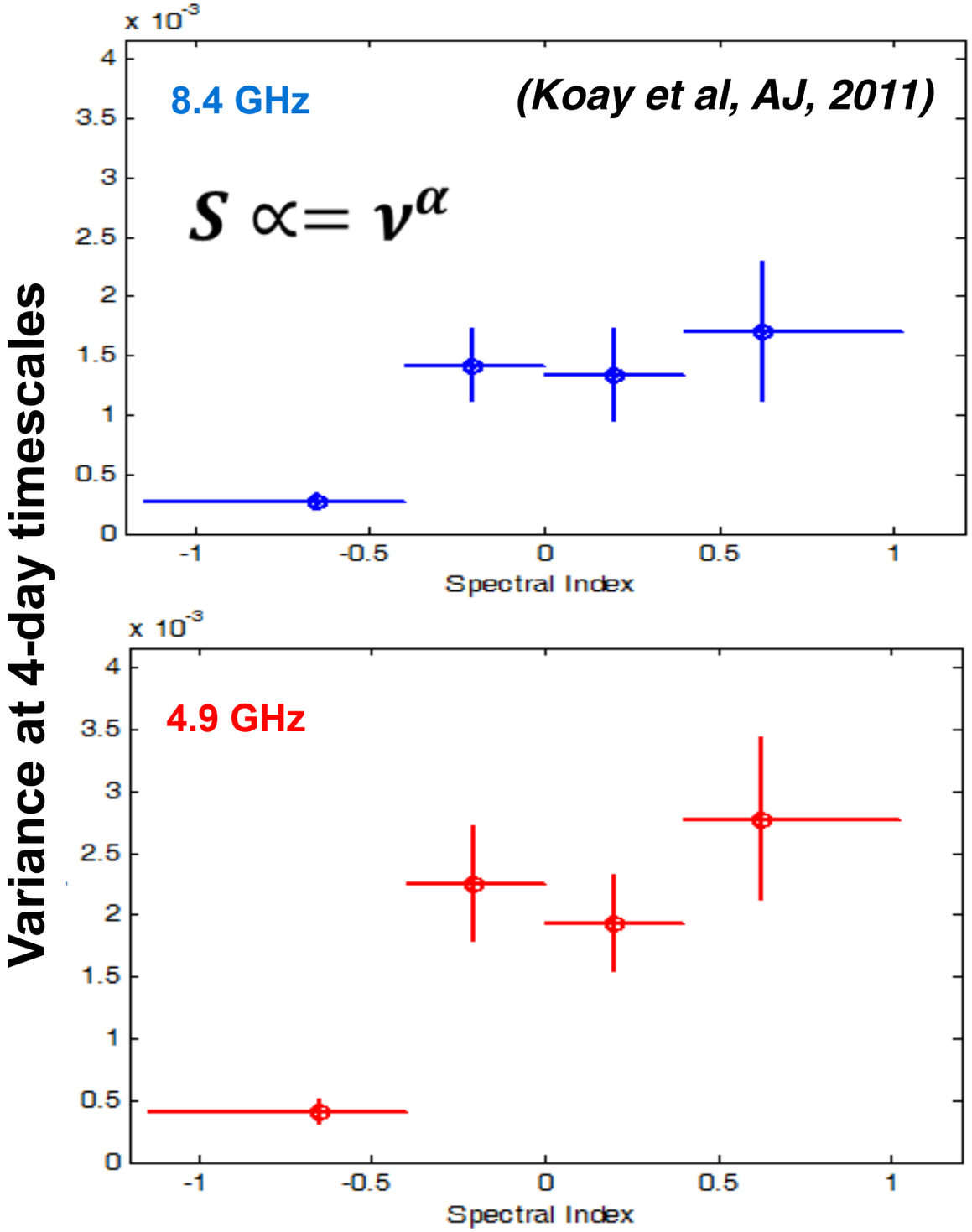
Type 0

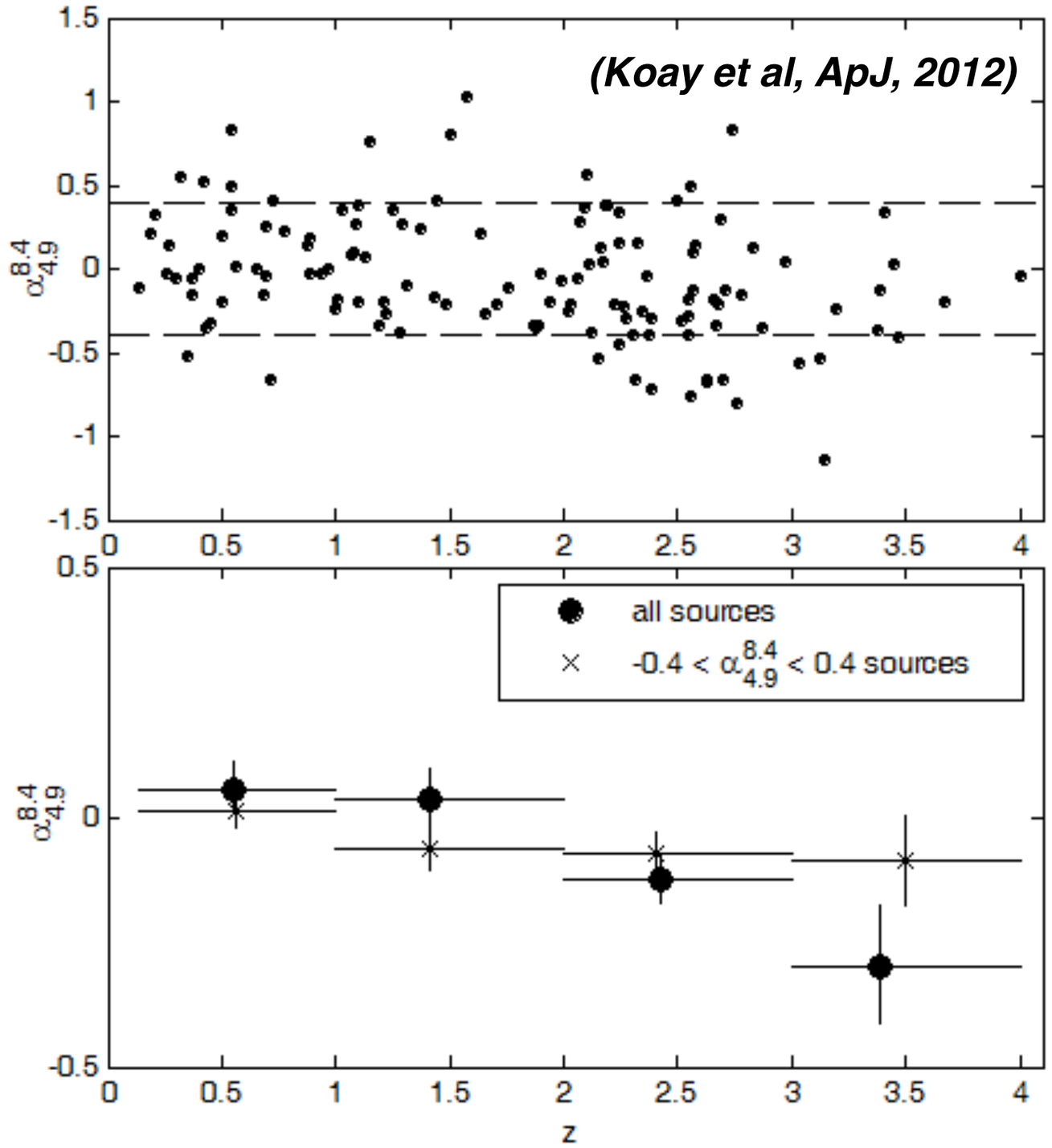
Type 2



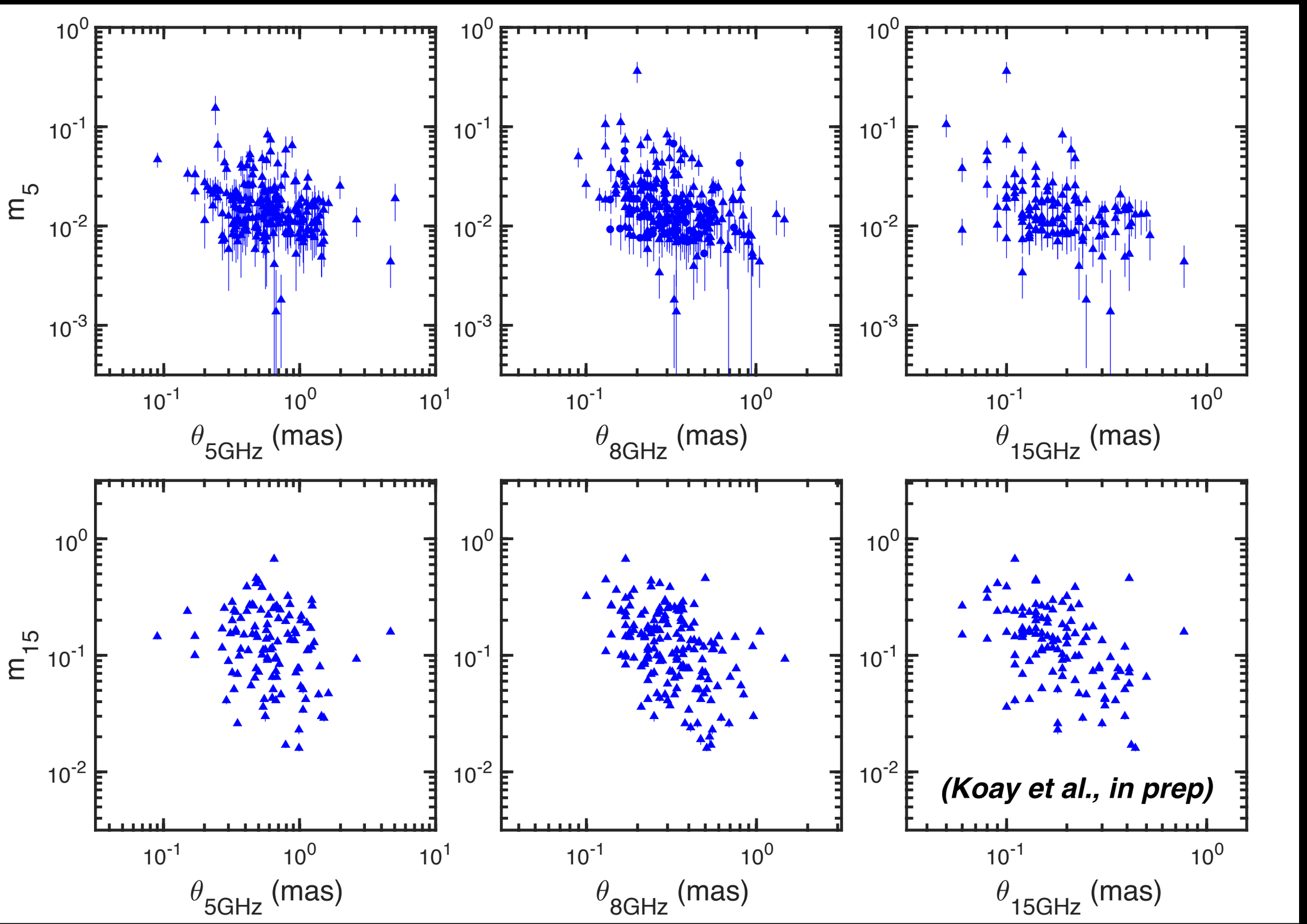
(Pursimo et al, ApJ, 2013)

Origin of ISS Redshift Dependence

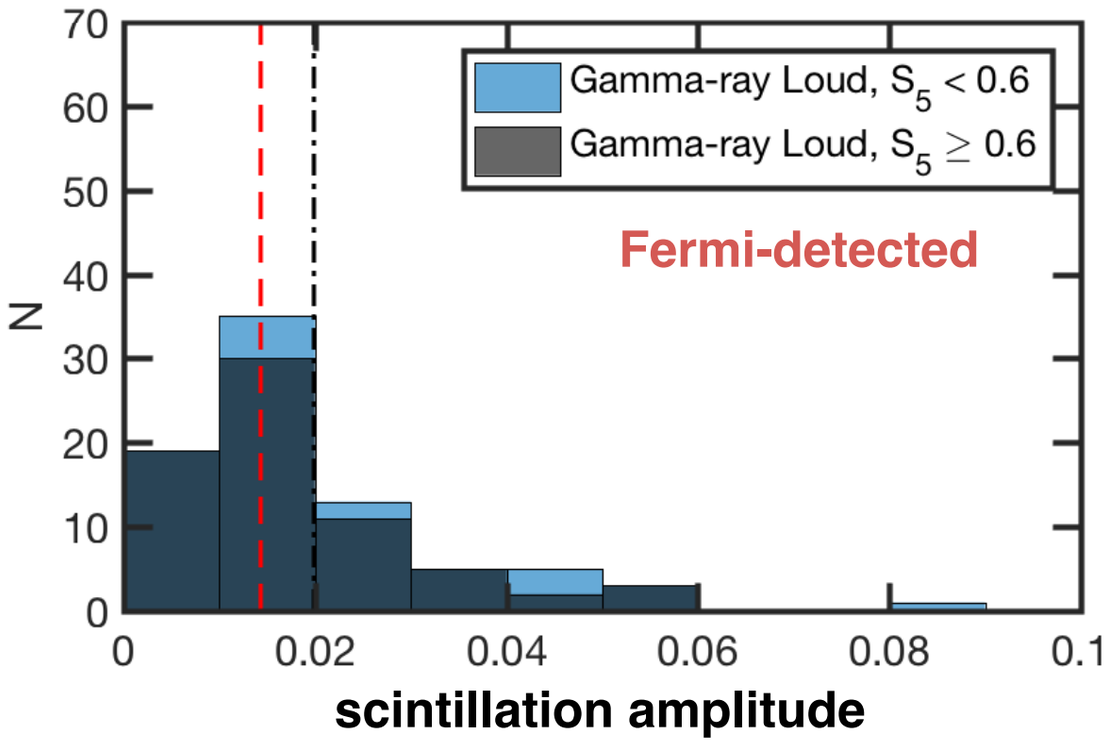


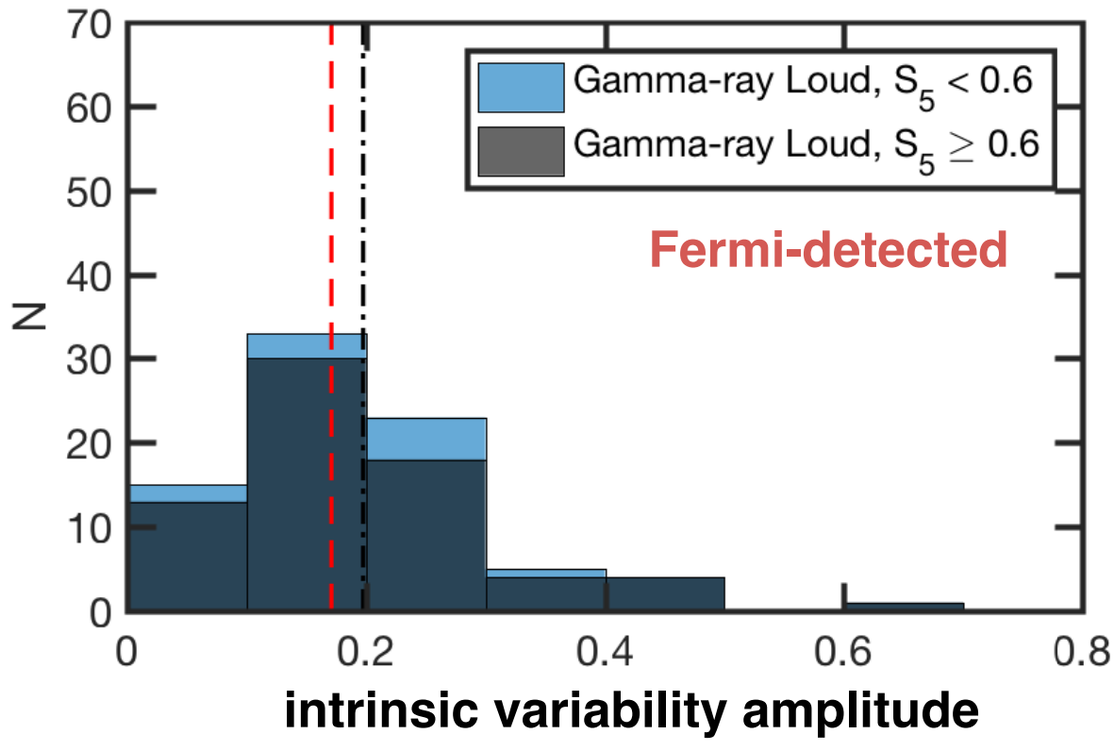


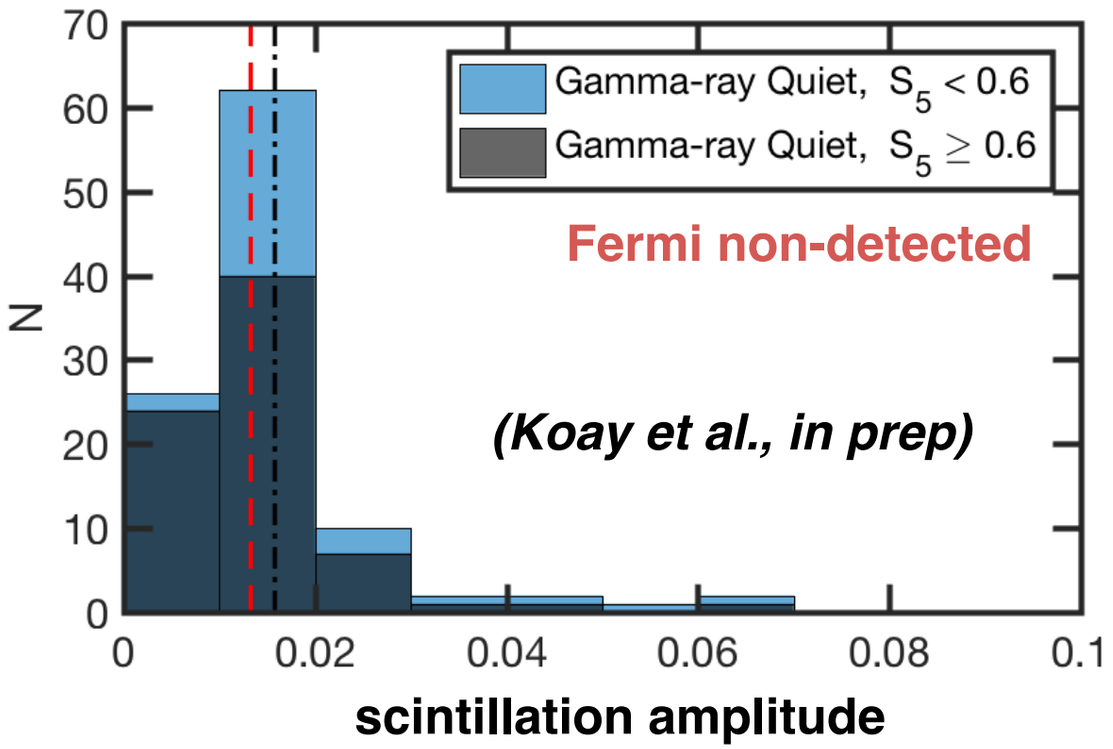
ISS, Intrinsic variability and VLBI radio core sizes

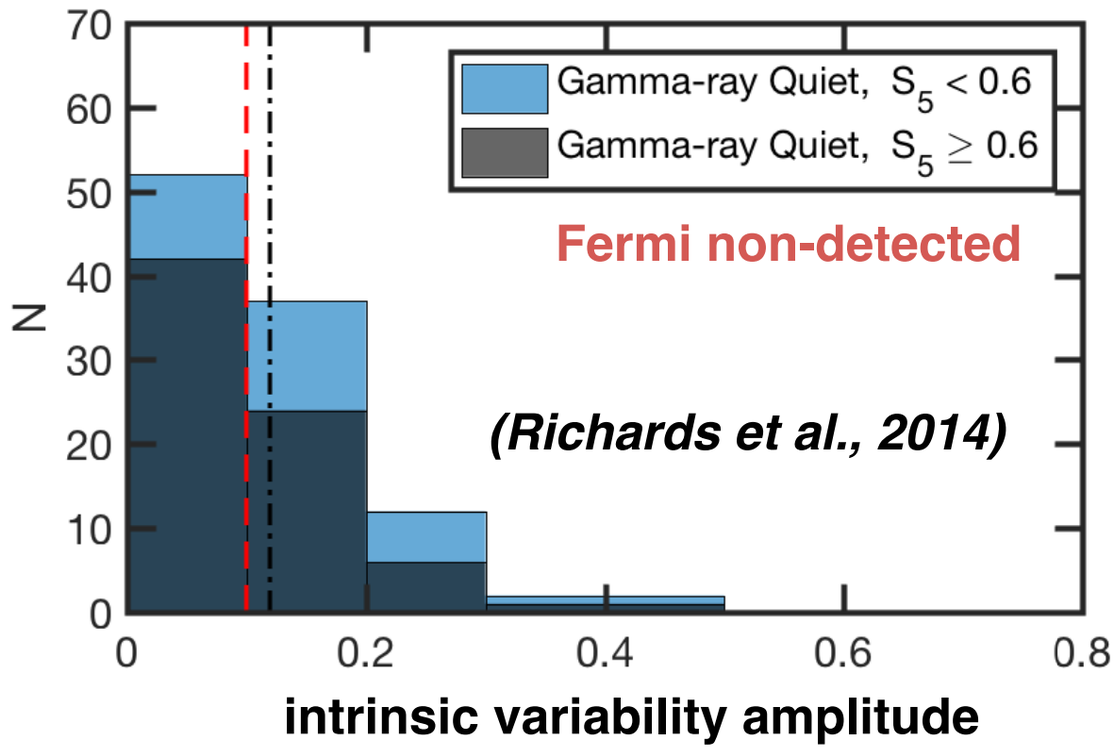


ISS and Gamma-ray loudness

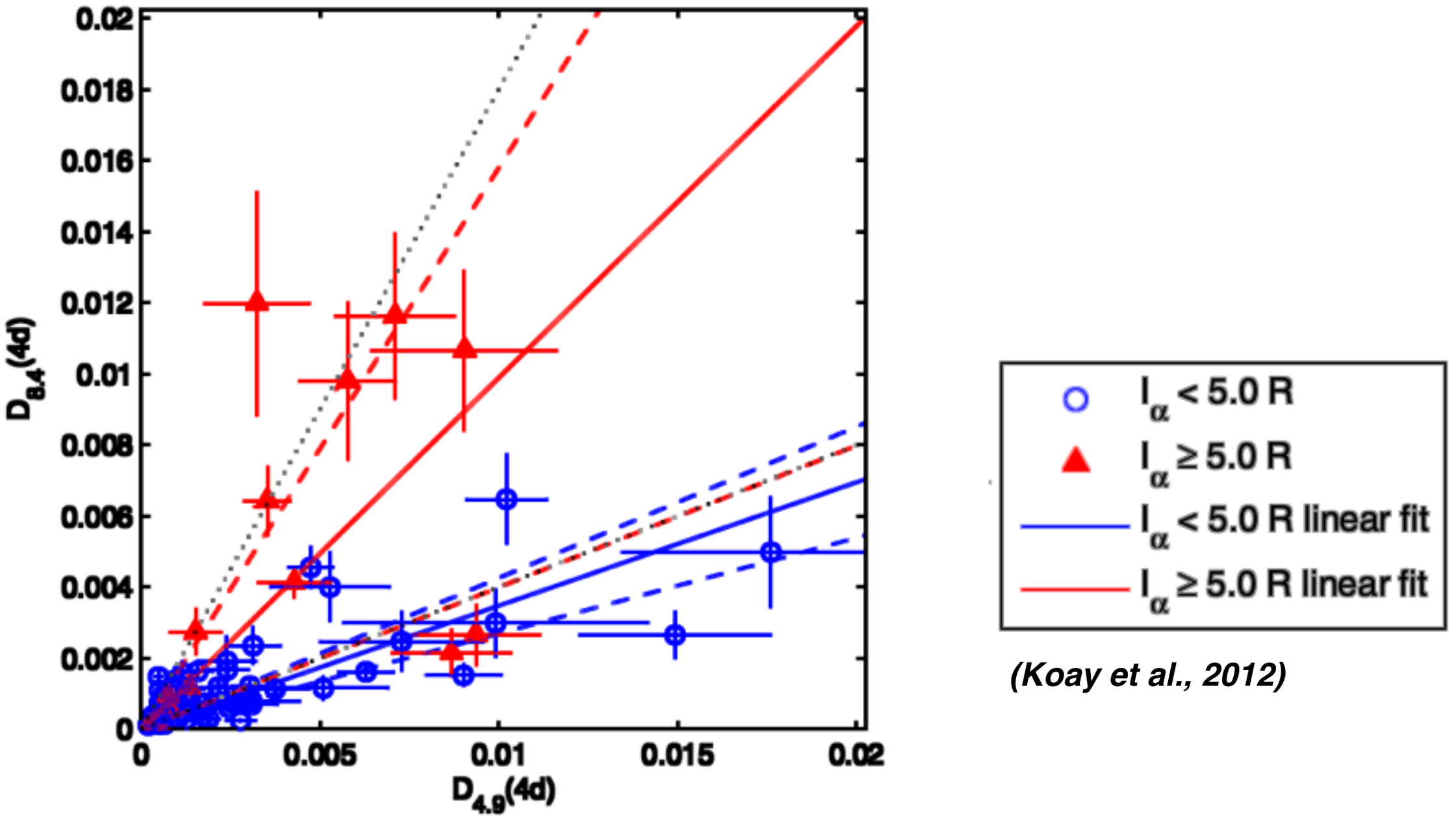








ISM or IGM scatter broadening?



(Koay et al., 2012)