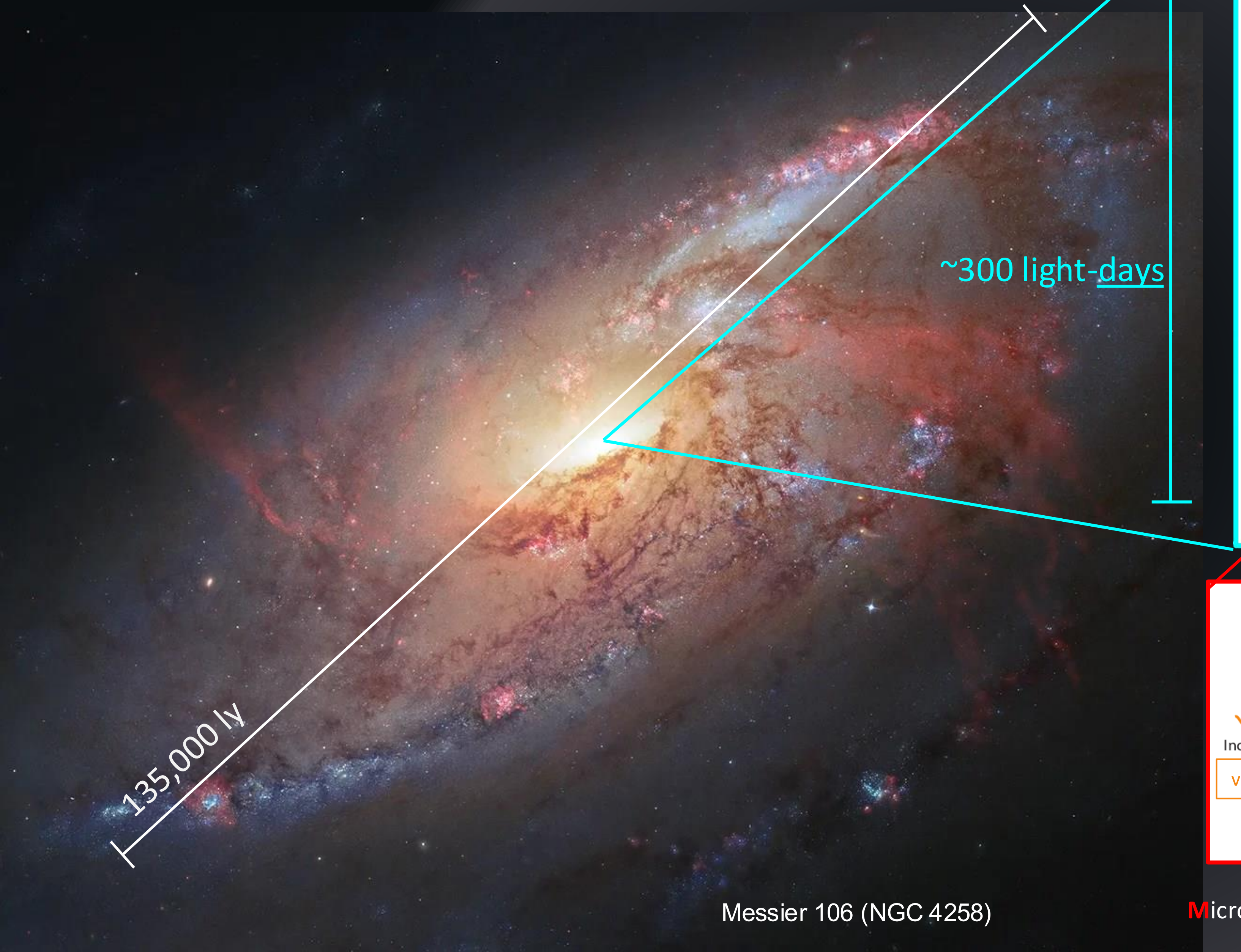
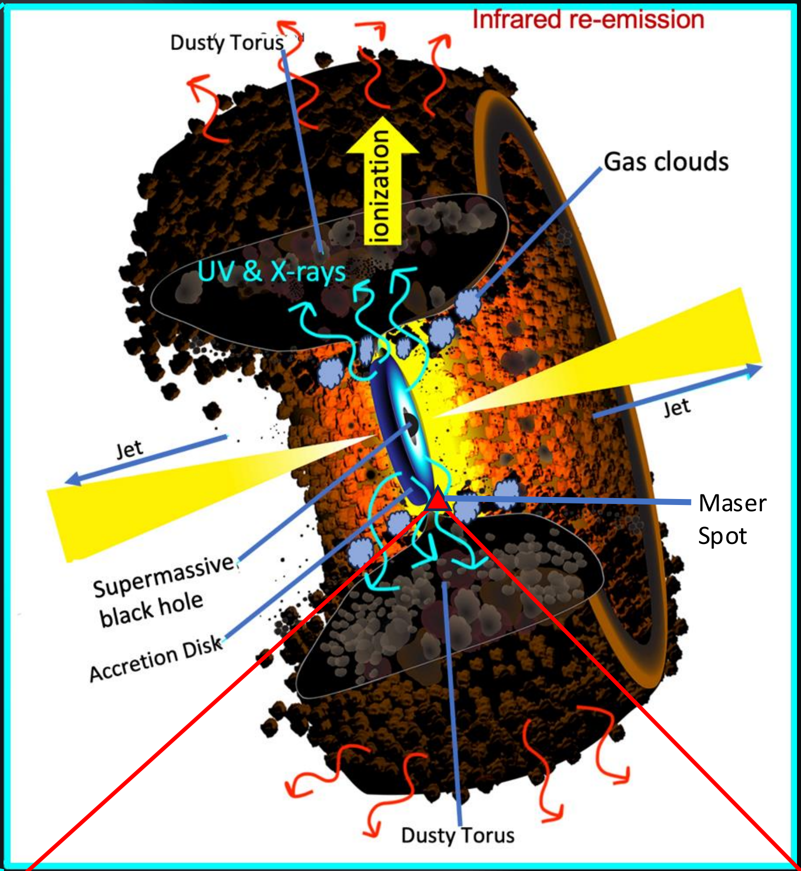
A WISE Look at Variability of Maser Galaxies

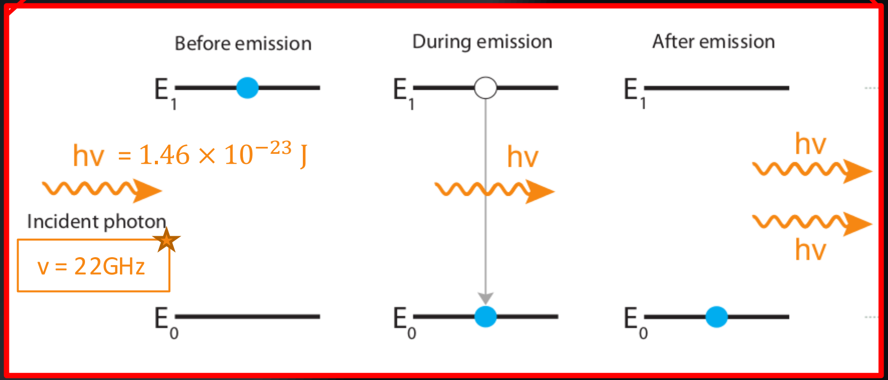
Erika Cherpes

Galactic Nuclear Emission -> Maser Activity



Credit: B. Saxton NRAO/AUI/NSF

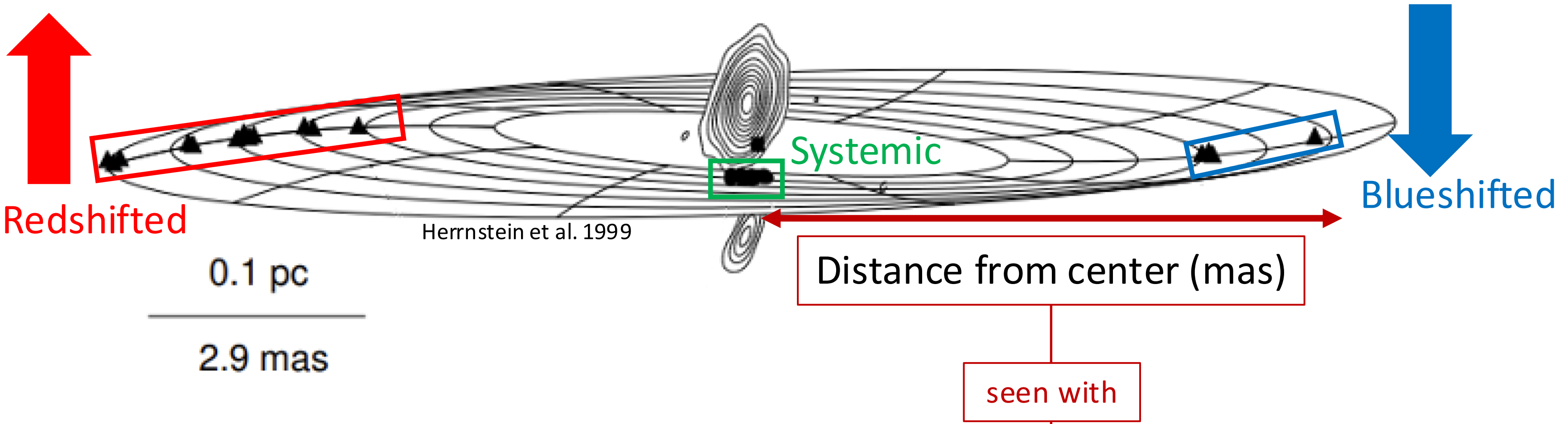


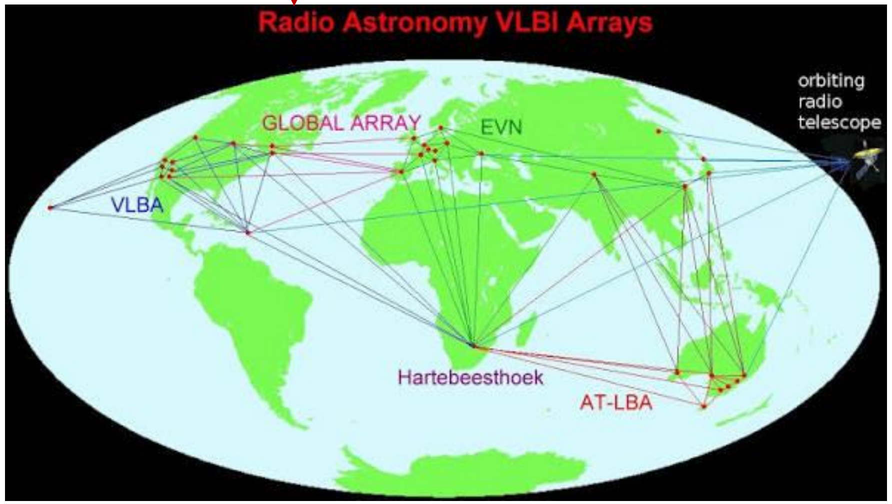


Credit: Scientific Volume Imaging

Microwave Amplification through Stimulated Emission of Radiation

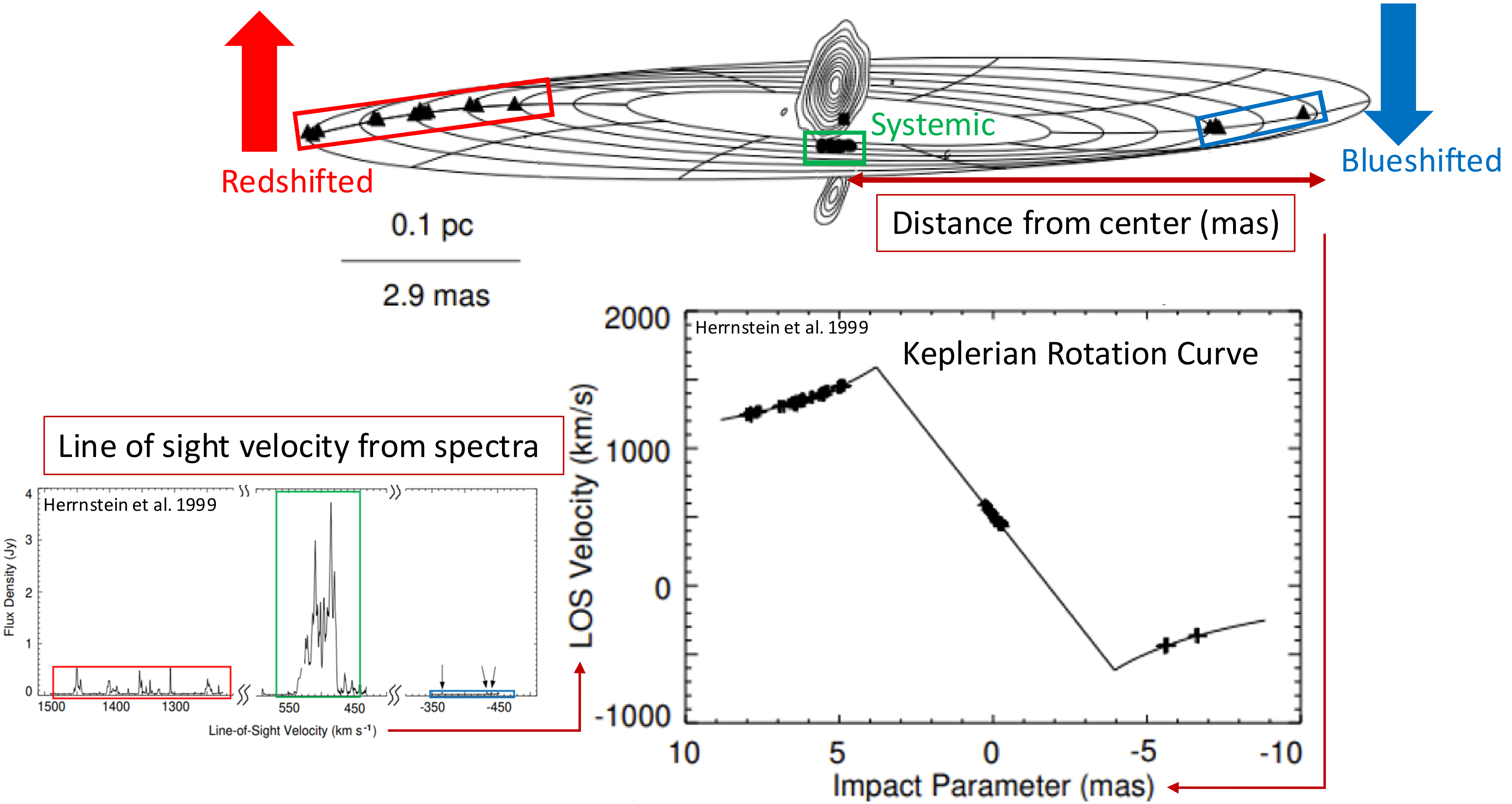
Megamaser Emission in a Disk-like Configuration



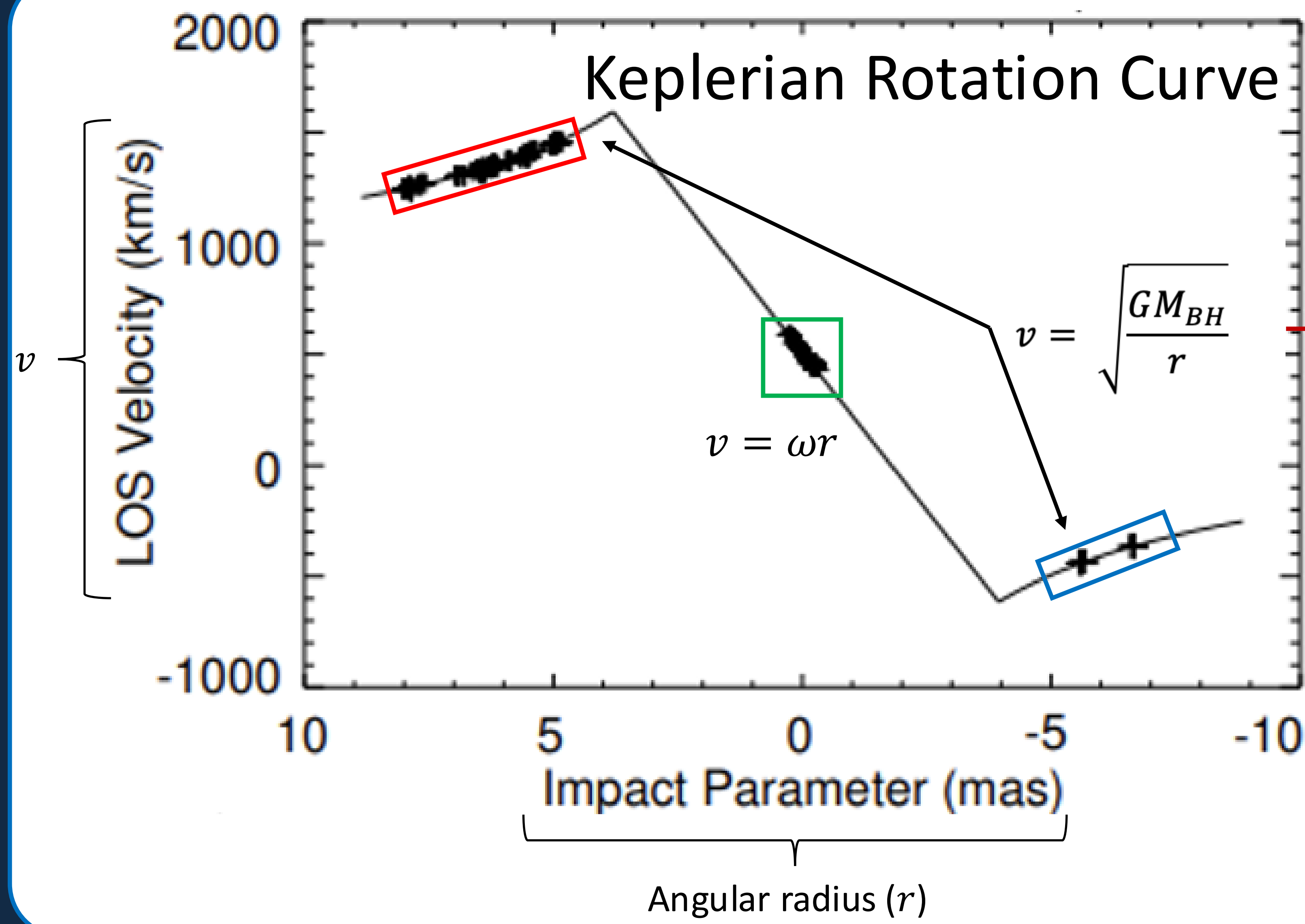


Credit: HartRAO/NRF

Megamaser Emission in a Disk-like Configuration



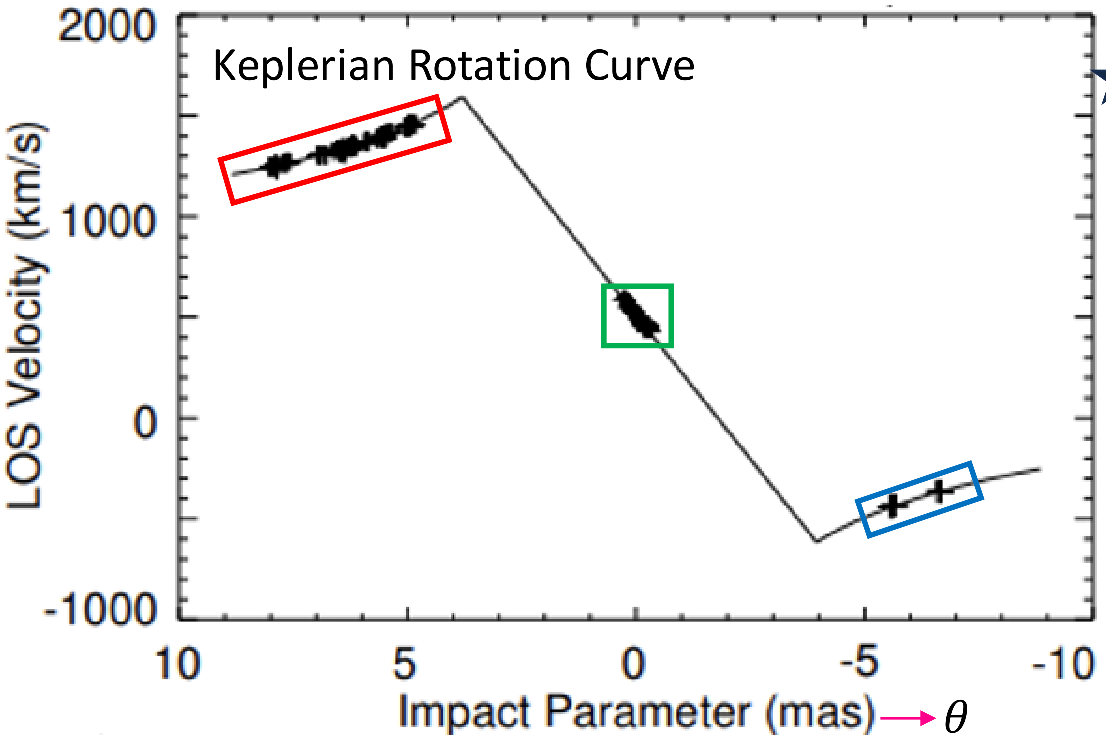
Maser Disk Constrains Black Hole Mass



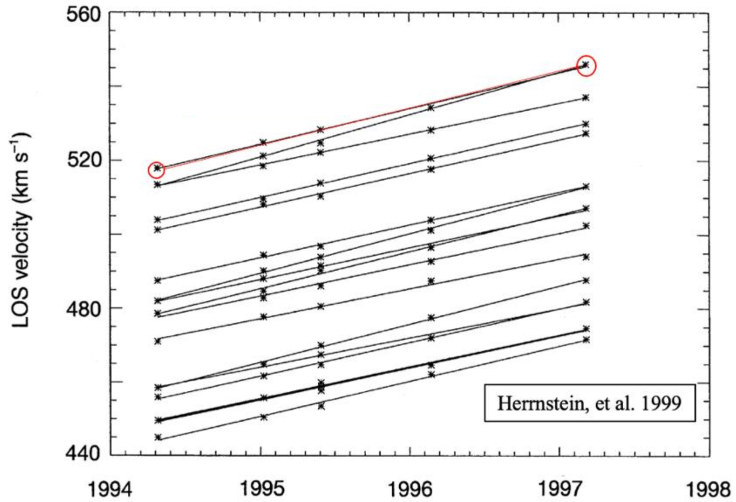
$$M_{BH} = \frac{v^2 r}{G}$$

Rotation curve gives us the most accurate way of calculating black hole mass

Calculating Distance Without Luminosity Ladders



$\rightarrow \theta$

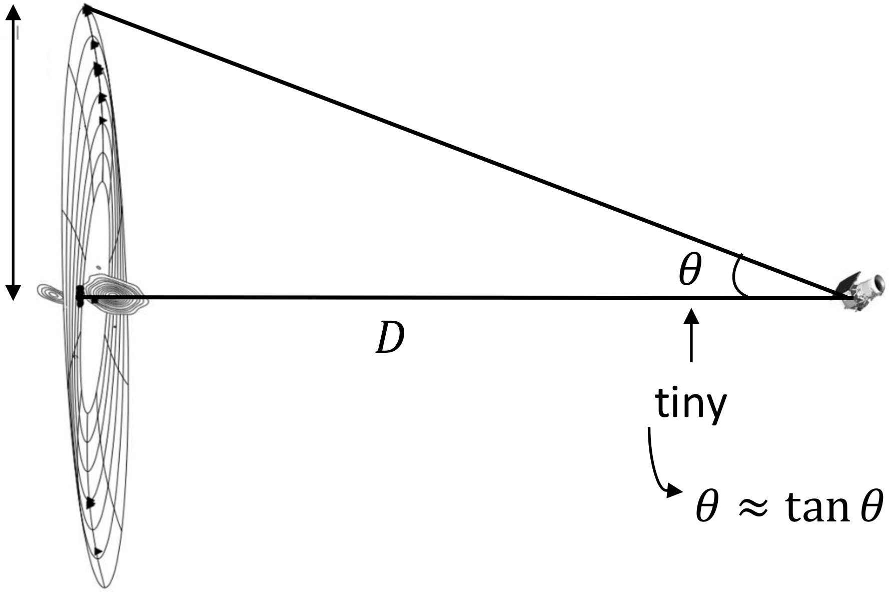


$$a_c = \frac{dv}{dt}$$

Centripetal acceleration from velocity over time

These calculations could help astronomers calculate the Hubble Constant, H_0, constraining the size and shape of our universe

$$\mathrm{r} = \frac{v^2}{a_c}$$



tiny

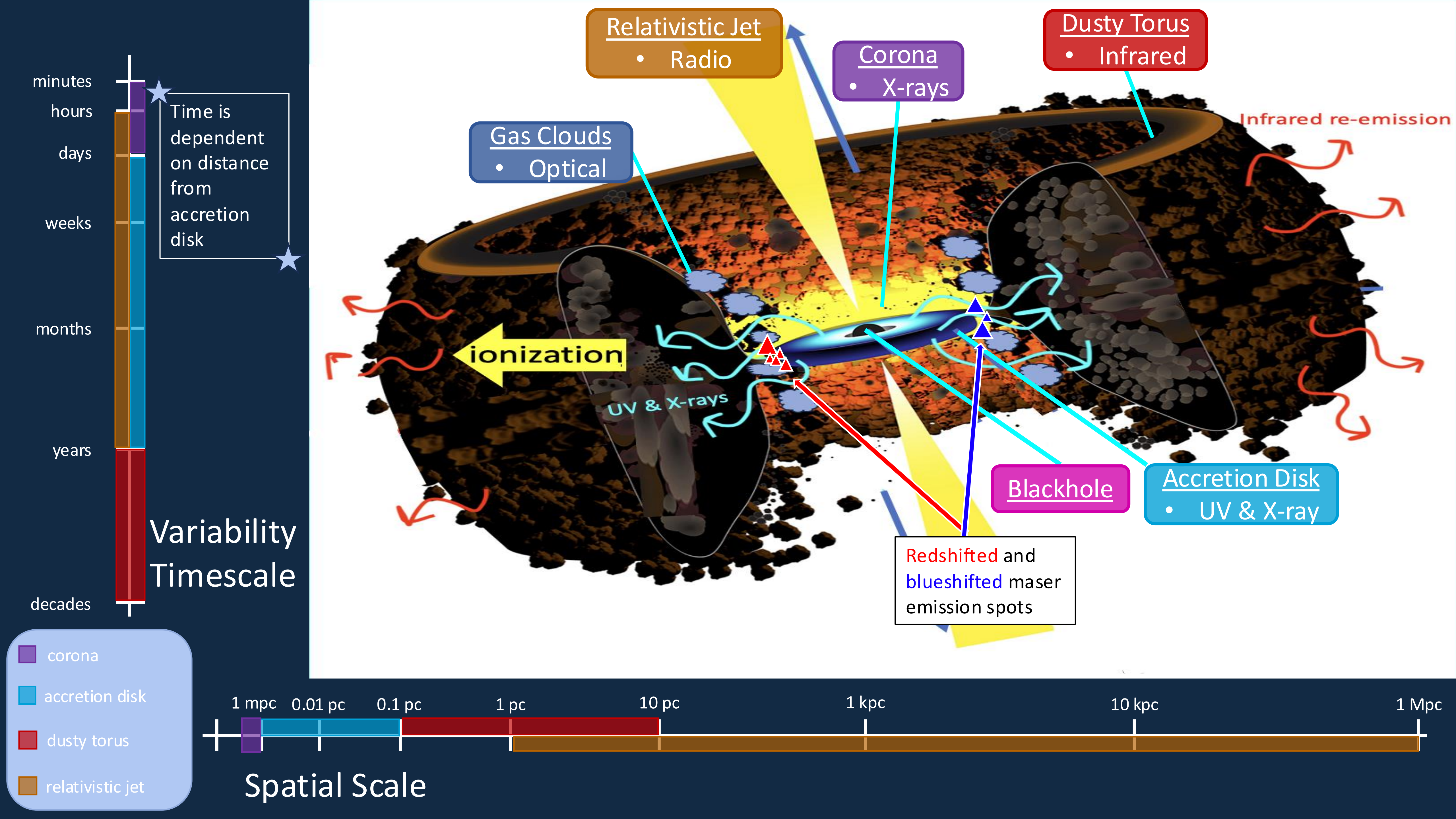
$$\theta \approx \tan\theta \approx \frac{r}{D}$$

$$\boxed{D = \frac{r}{\theta}}$$

Megamaser Disks = Holy Grail, but…

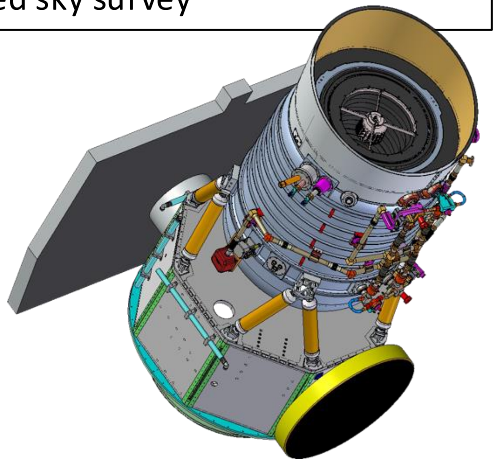
- Only 3% of all surveyed galaxies show maser emission
  - Of those, ~20% are the disk masers we need

- We need to determine where to actually look for these disk masers
  - What makes maser galaxies special?
  - Tentative relationship between masers and AGN
  - AGN activity exhibits variability
  - Multi-epoch data in mid IR available NOW!

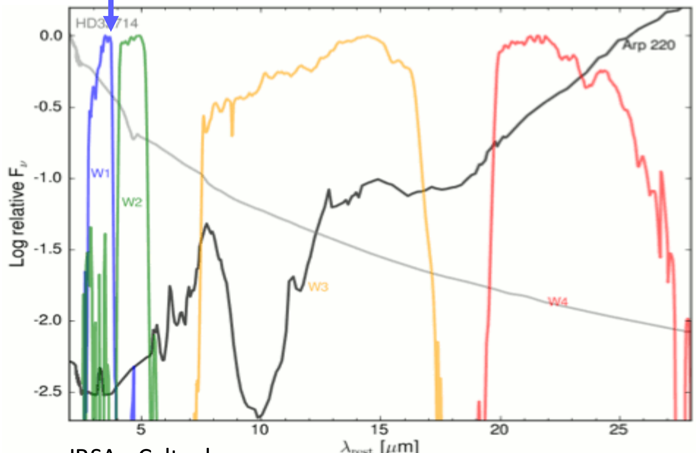

minutes
hours
days
weeks
months
years
decades
Time is dependent on distance from accretion disk
Variability Timescale
corona
accretion disk
dusty torus
relativistic jet
Relativistic Jet
• Radio
Corona
• X-rays
Dusty Torus
• Infrared
Infrared re-emission
Gas Clouds
• Optical
ionization
UV & X-rays
Blackhole
Accretion Disk
• UV & X-ray
Redshifted and blueshifted maser emission spots
1 mpc
0.01 pc
0.1 pc
1 pc
10 pc
1 kpc
10 kpc
1 Mpc
Spatial Scale

From Maser Catalog (~4000 galaxies) to Infrared Survey

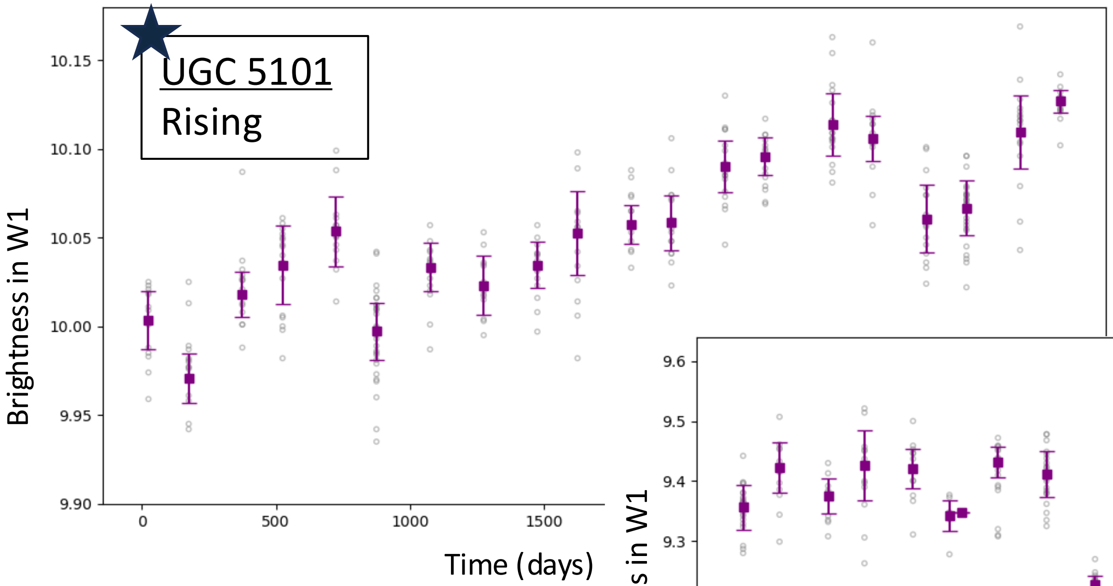
The Widefield Infrared Survey Explorer (WISE)
- Mid-infrared sky survey

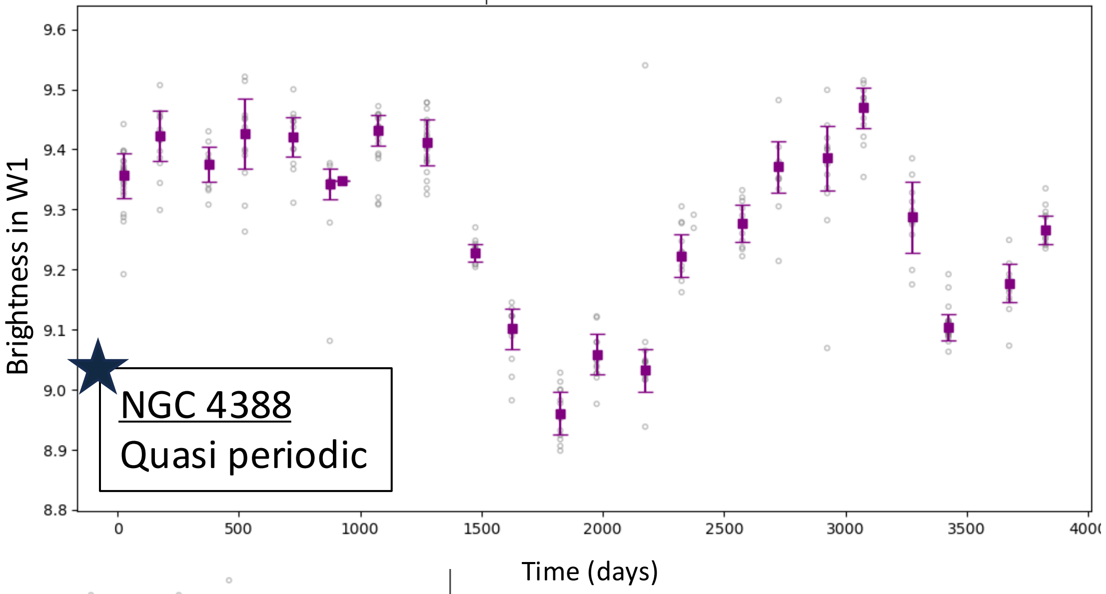


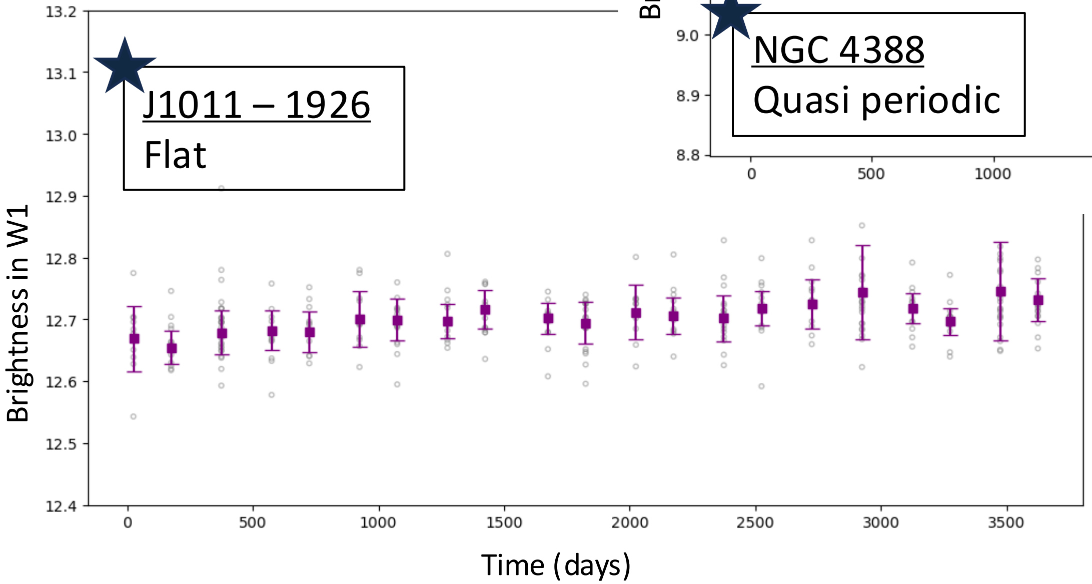
We use W1



IRSA - Caltech





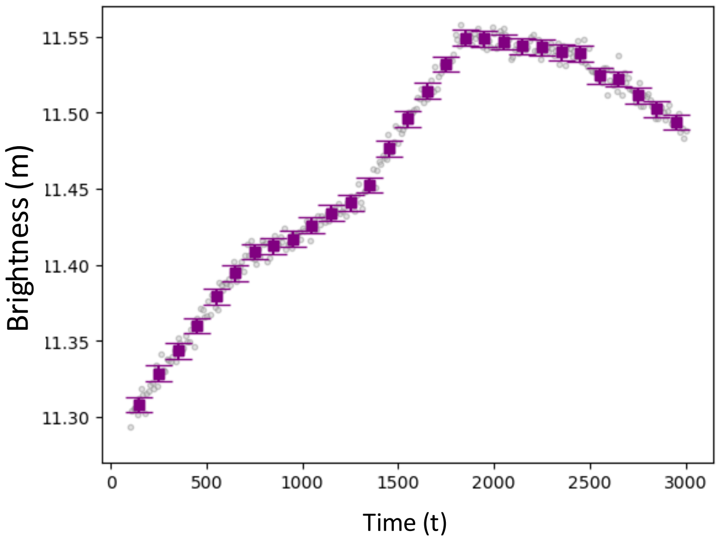


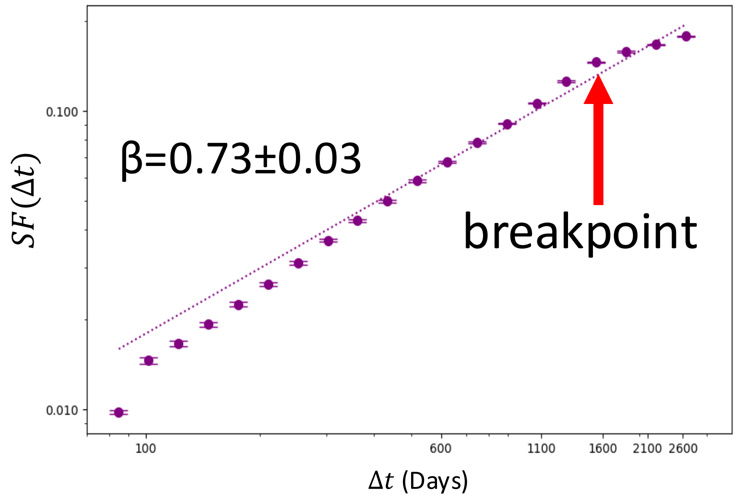
Structure Function and Simulated Data

- Structure Function (SF) reveals how brightness (m) changes as a function of time (t).

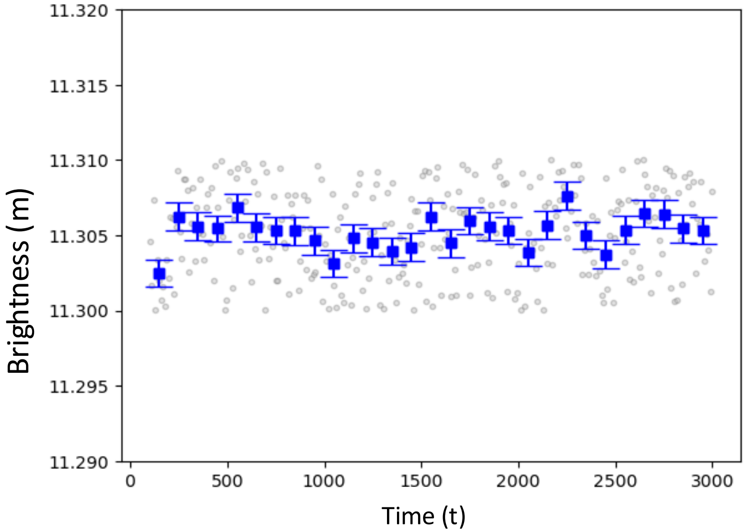
$$SF^2(\Delta t) = \frac{1}{N_{\Delta t,\mathrm{pair}}} \sum_{i=1}^{N_{\Delta t,\mathrm{pair}}} (m(t) - m(t+\Delta t))$$

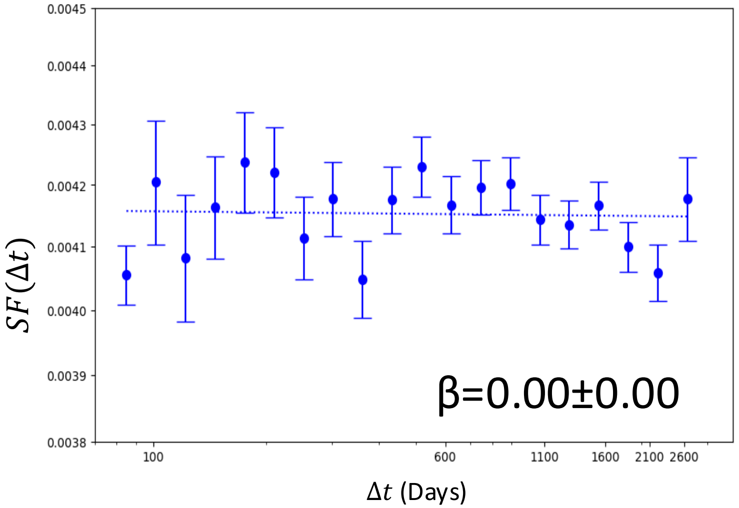
Son et al. 2023





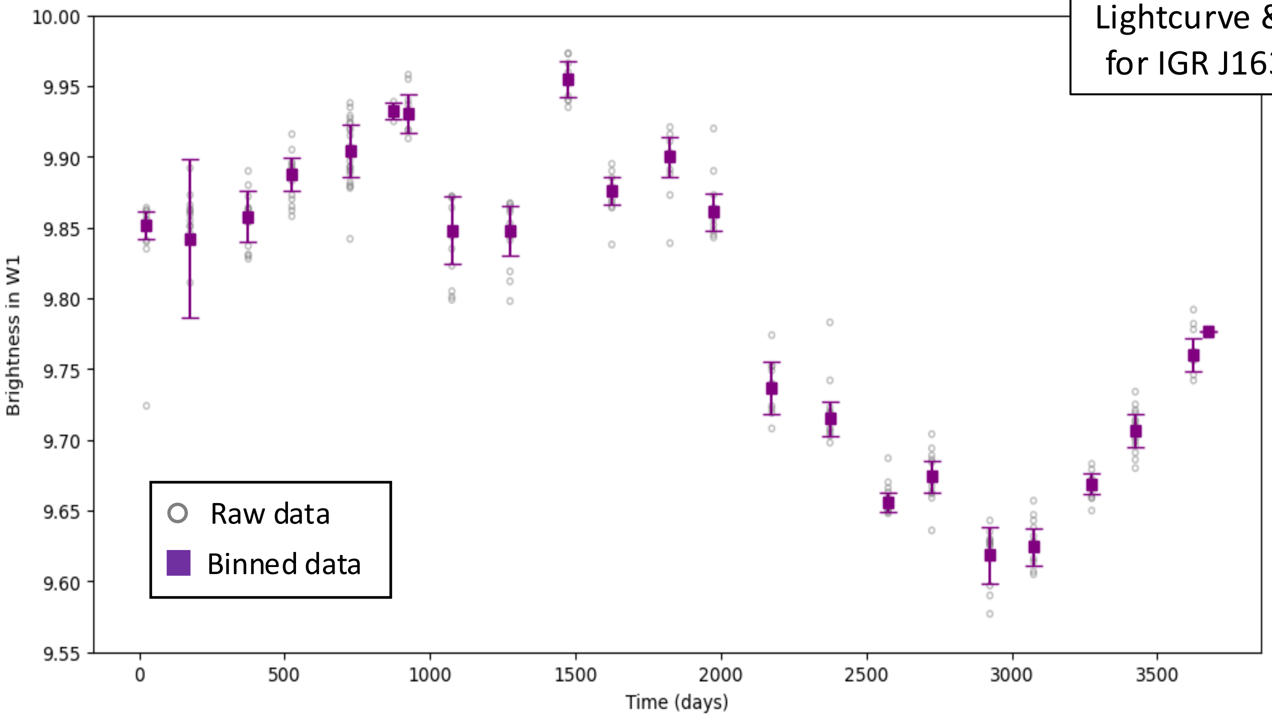
- Power-law fit ($SF(\Delta t) = \alpha \Delta t^{\beta}$) determines timescale of variability
  - Rising SF –> variability increases with Δt
  - Flattening SF at large Δt –> characteristic variability timescale
  - Flat SF –> Variability is white noise

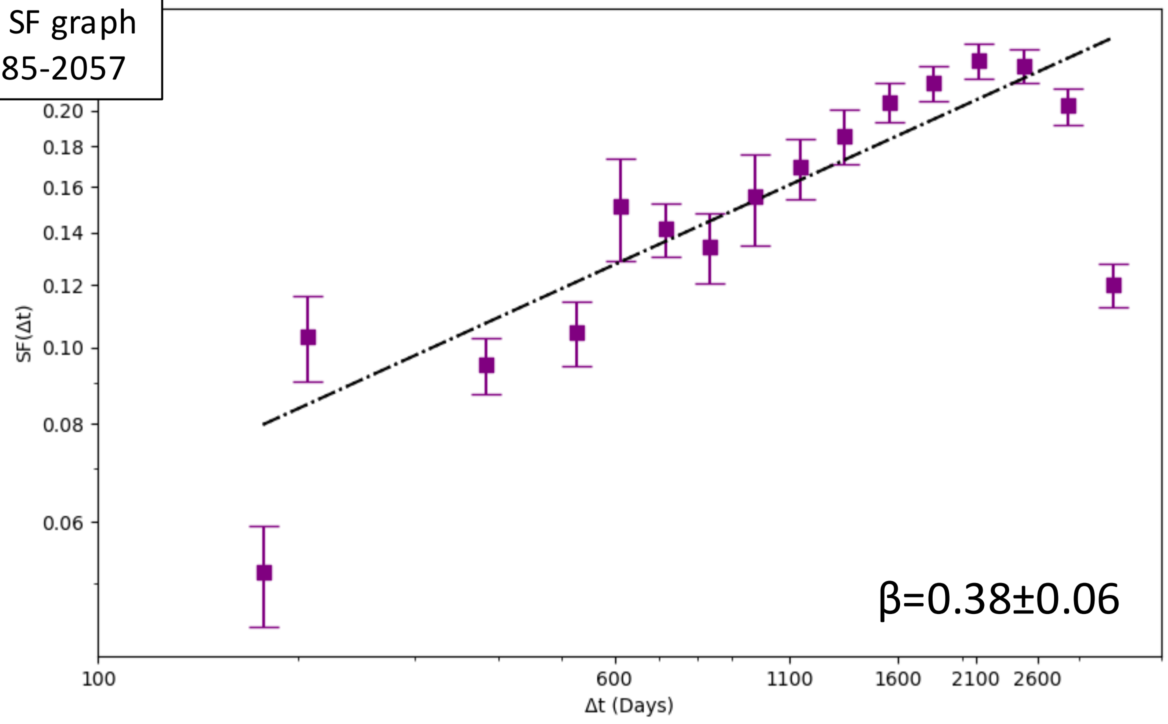




SF with Real Data: 2 Problems

Lightcurve & SF graph for IGR J16385-2057





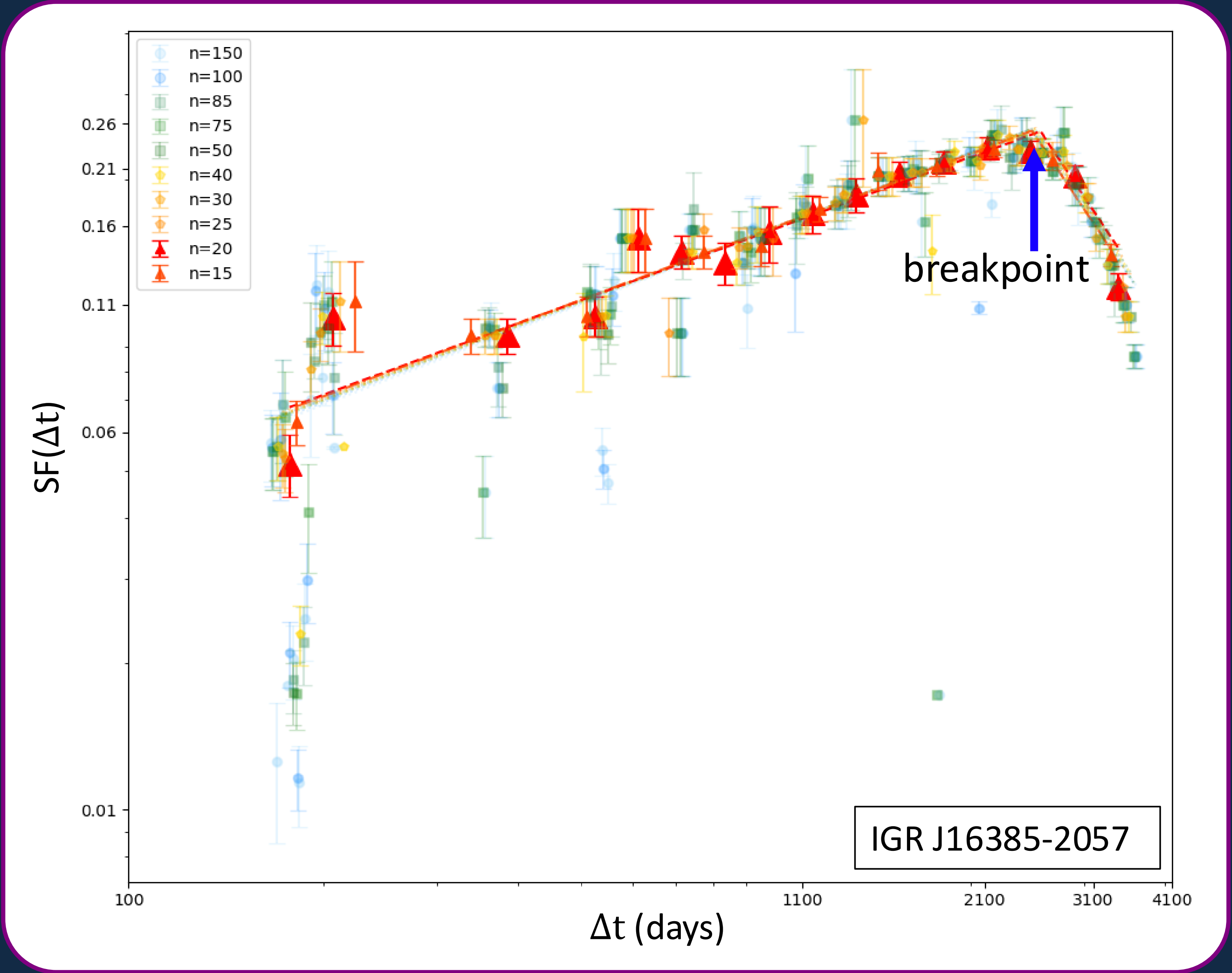
1. Real data is noisy

Binning puts our data into "boxes" and averages the values

2. Single power-law fit cannot properly describe SF shape

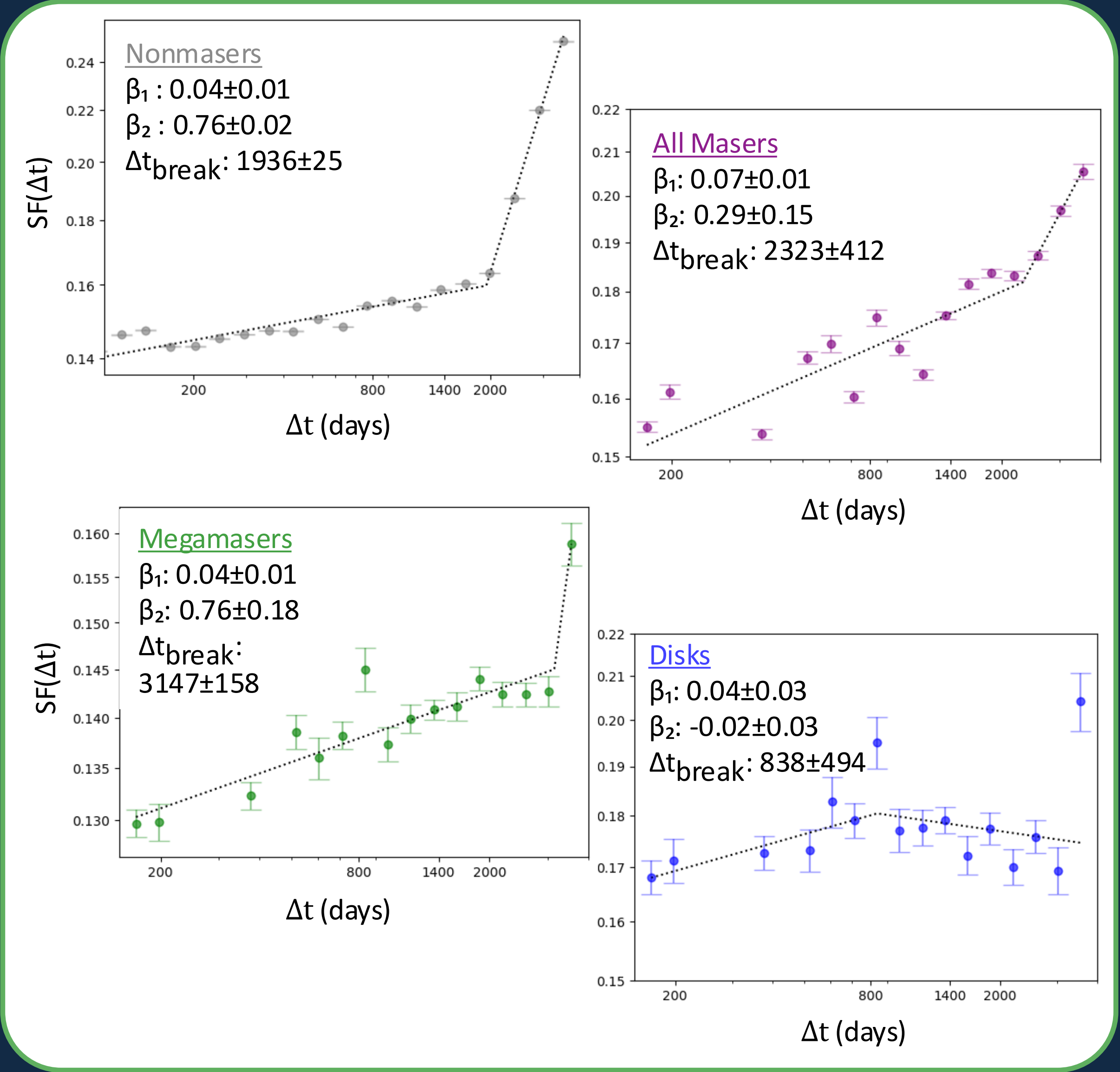
Broken power-law reveals variability characteristics

SF with Real Data: Optimal Bin Number & Broken power-law



- Agony: tested a wealth of bin numbers
- Smaller number of bins = better signal
- Bin number does not widely affect power-law fits
- Broken power-law fits real data best
- Breakpoint reveals characteristic timelag -> nature of variability

Results: Ensemble SF



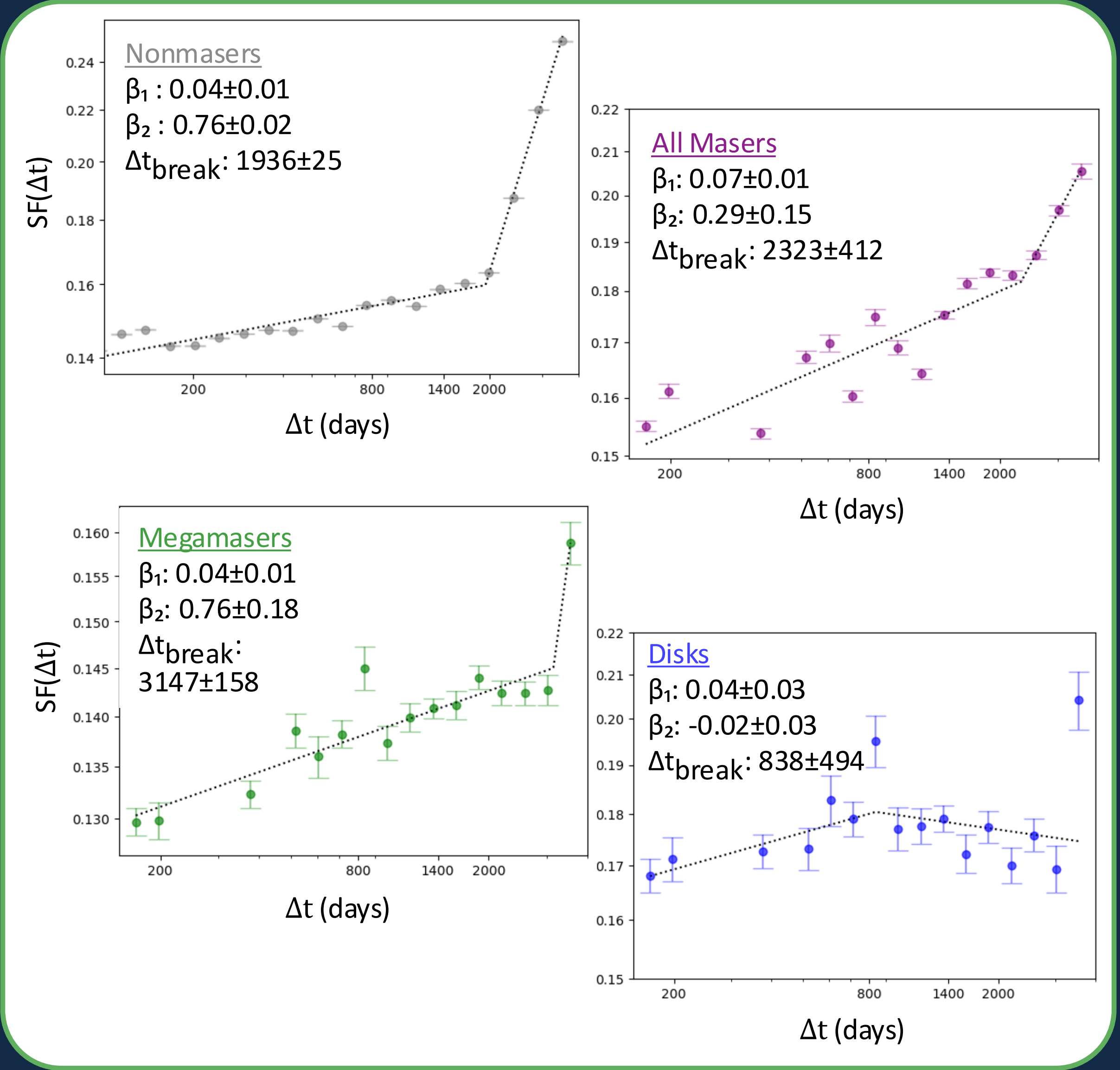
1. SF rise before breakpoint is stronger in the All Maser sample

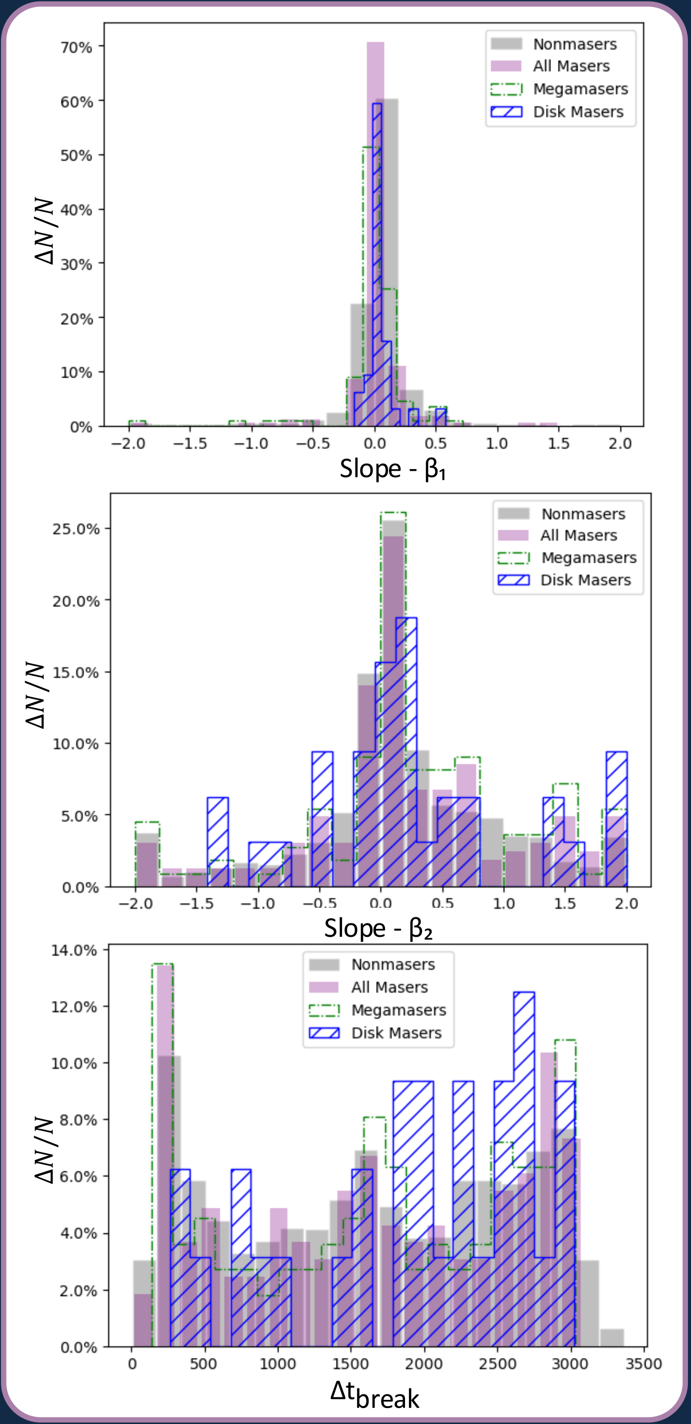
2. Flattening only happens for the Disks

3. at longer timescales all the other samples show increasingly stronger variability

4. Only Disks show characteristic timescale, all other just show a change in the variability strength
-> Supporting association with AGN

Results: Ensemble SF and Broken Power-law Distributions





- No statistically significant difference in variability between nonmaser and maser galaxies
- Further parameterization of the Structure Function is needed
  - -> calculate SF for W2 and W1-W2 color
  - -> More robust handling of photometric noise and uncertainty