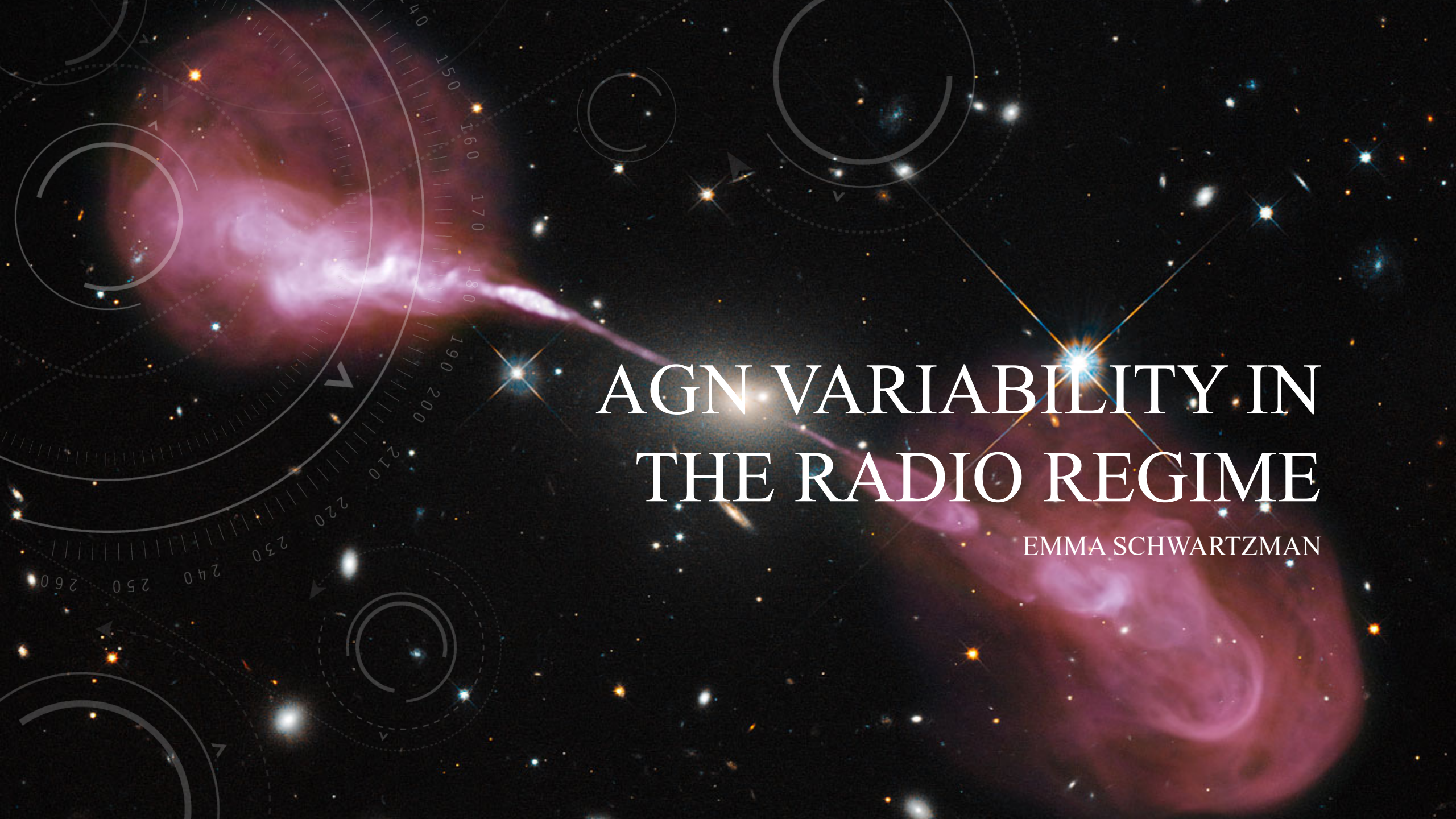


AGN VARIABILITY IN THE RADIO REGIME

EMMA SCHWARTZMAN

Radio Sky:

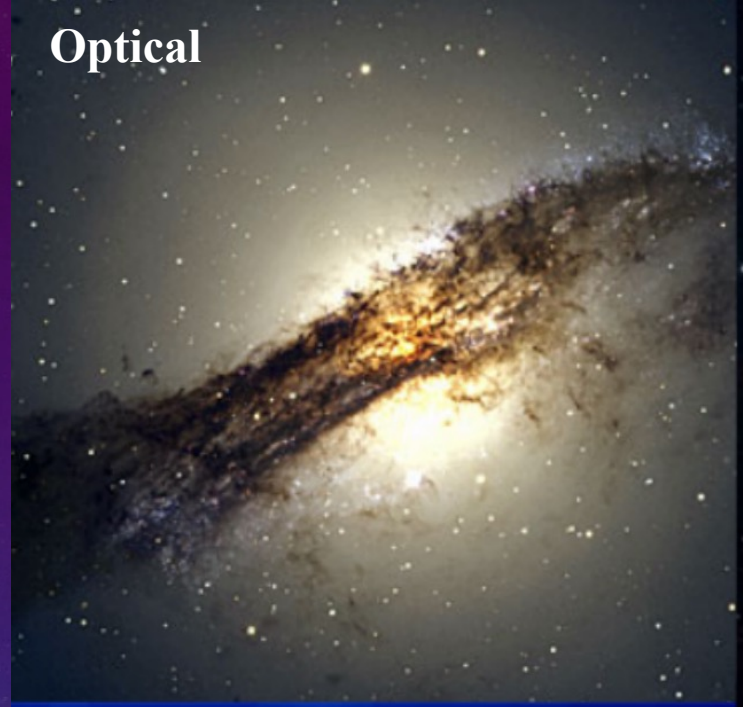
Bright Radio Sky
- Radio galaxies
- Quasars

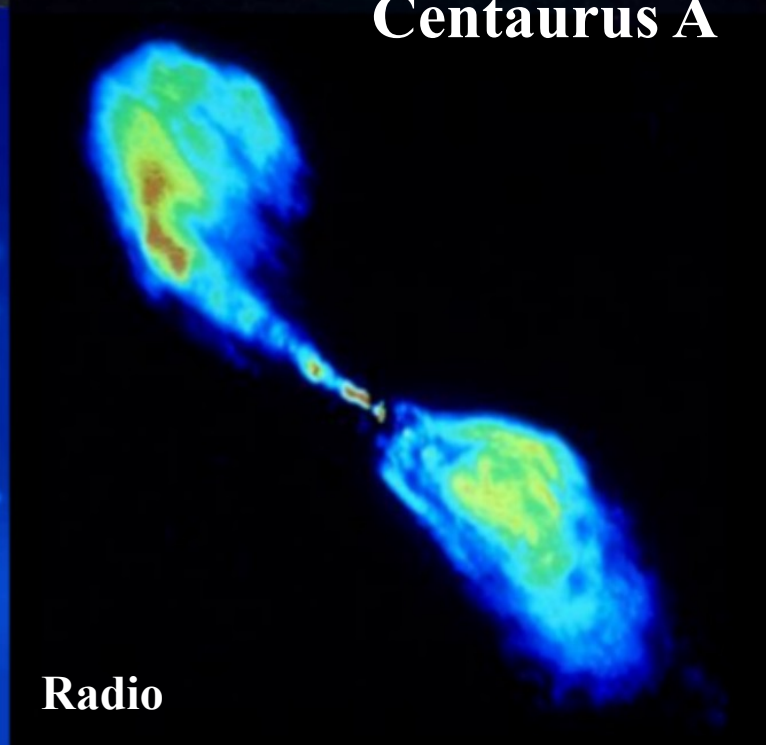
Faint Radio Sky
- Star forming galaxies
- Non-jetted AGN

Intrinsic Events:

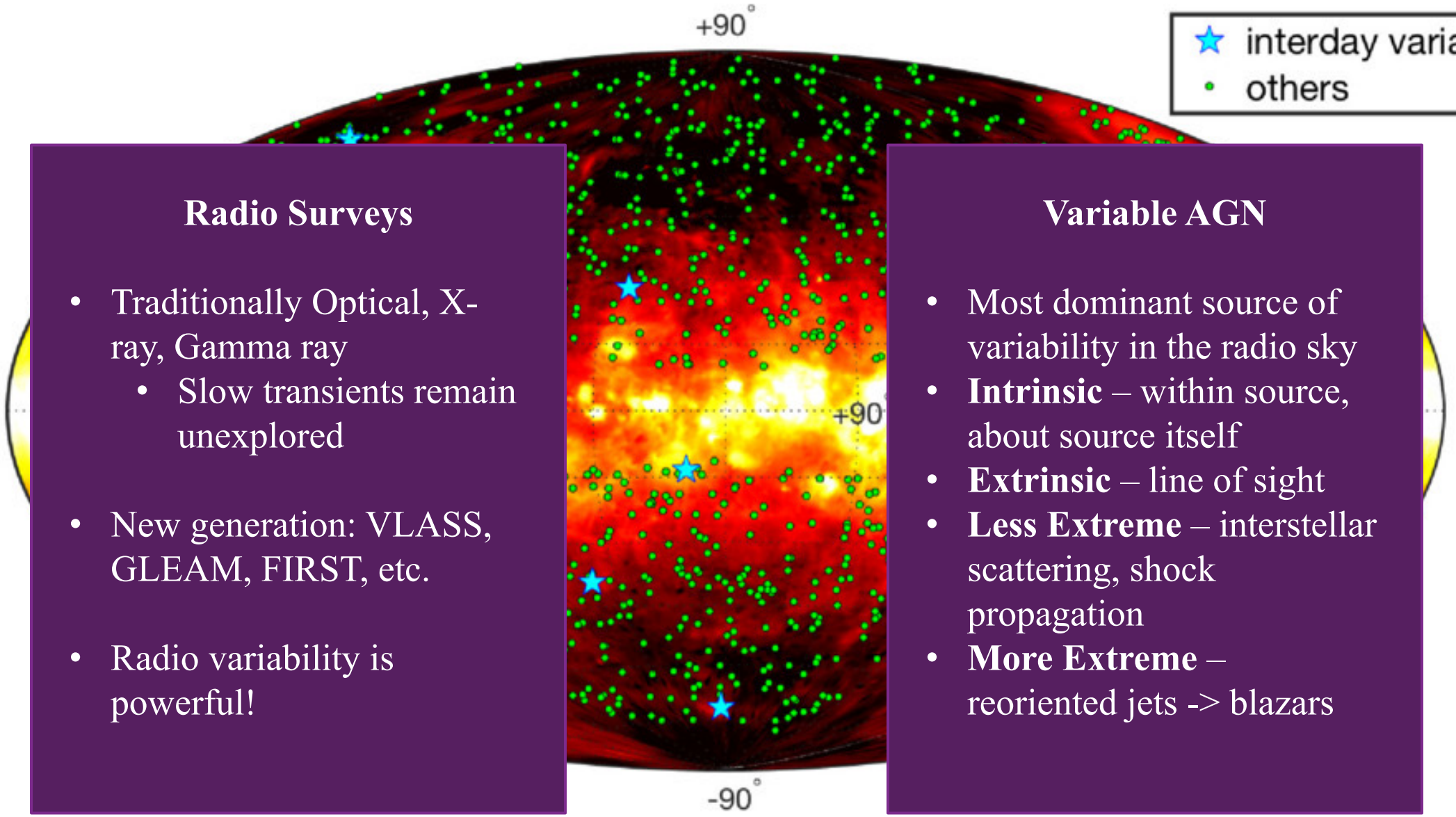
Jetted AGN
- Non-thermal
- Relativistic jets

Non-Jetted AGN
- Thermal emission
- Accretion disk





Centaurus A



Radio Surveys

- Traditionally Optical, X-ray, Gamma ray
  - Slow transients remain unexplored
- New generation: VLASS, GLEAM, FIRST, etc.
- Radio variability is powerful!

Variable AGN

- Most dominant source of variability in the radio sky
- **Intrinsic** – within source, about source itself
- **Extrinsic** – line of sight
- **Less Extreme** – interstellar scattering, shock propagation
- **More Extreme** – reoriented jets -> blazars

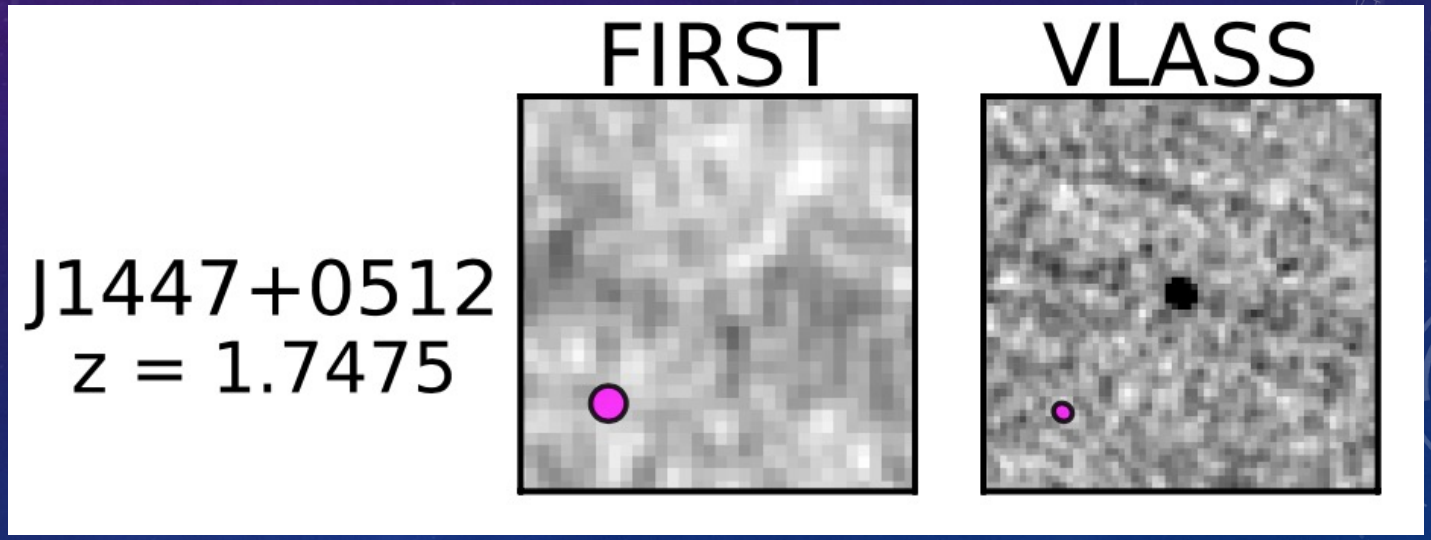
Quasars That Have Transitioned from Radio-quiet to Radio-loud on Decadal Timescales Revealed by VLASS and FIRST

KRISTINA NYLAND,[1] DILLON Z. DONG,[2] PALLAVI PATIL,[3,4] MARK LACY,[3] SJOERT VAN VELZEN,[5,6] AMY E. KIMBALL,[7] SUMIT K. SARBADHICARY,[8] GREGG HALLINAN,[2] VIVIENNE BALDASSARE,[9,*] TRACY E. CLARKE,[10] ANDY D. GOULDING,[11] JENNY GREENE,[11] ANDREW HUGHES,[12] NAMIR KASSIM,[10] MAGDALENA KUNERT-BAJRASZEWSKA,[13] THOMAS J. MACCARONE,[14] KUNAL MOOLEY,[15] DIPANJAN MUKHERJEE,[16] WENDY PETERS,[10] LEONID PETROV,[17] EMIL POLISENSKY,[10] WIPHU RUJOPAKARN,[18,19] MARK WHITTLE,[4] AND MATTIA VACCARI[20,21]

FIRST

VLA

VLASS

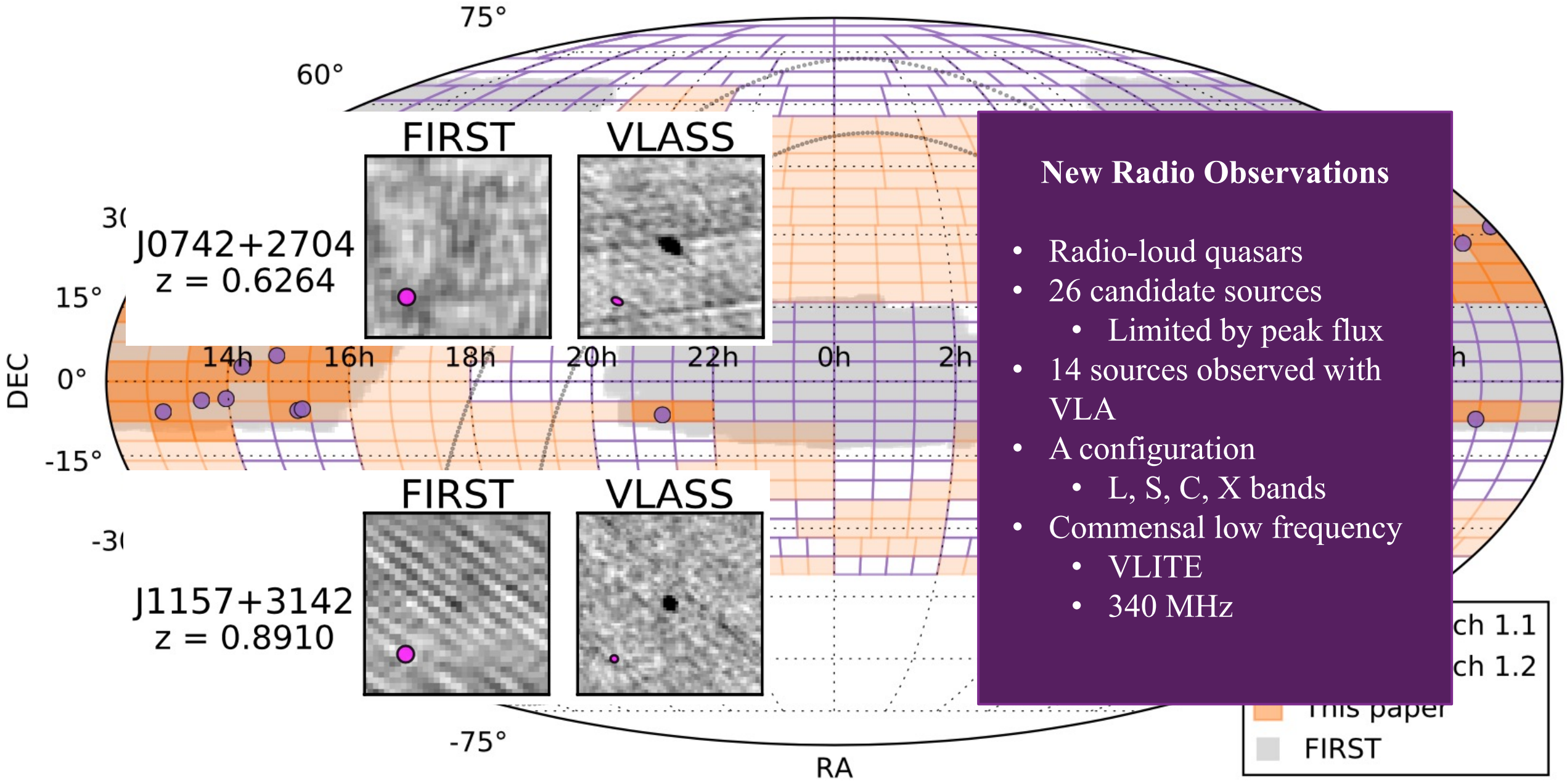


FIRST – 20cm, pre-upgraded VLA

VLASS – 2-4 GHz, high resolution

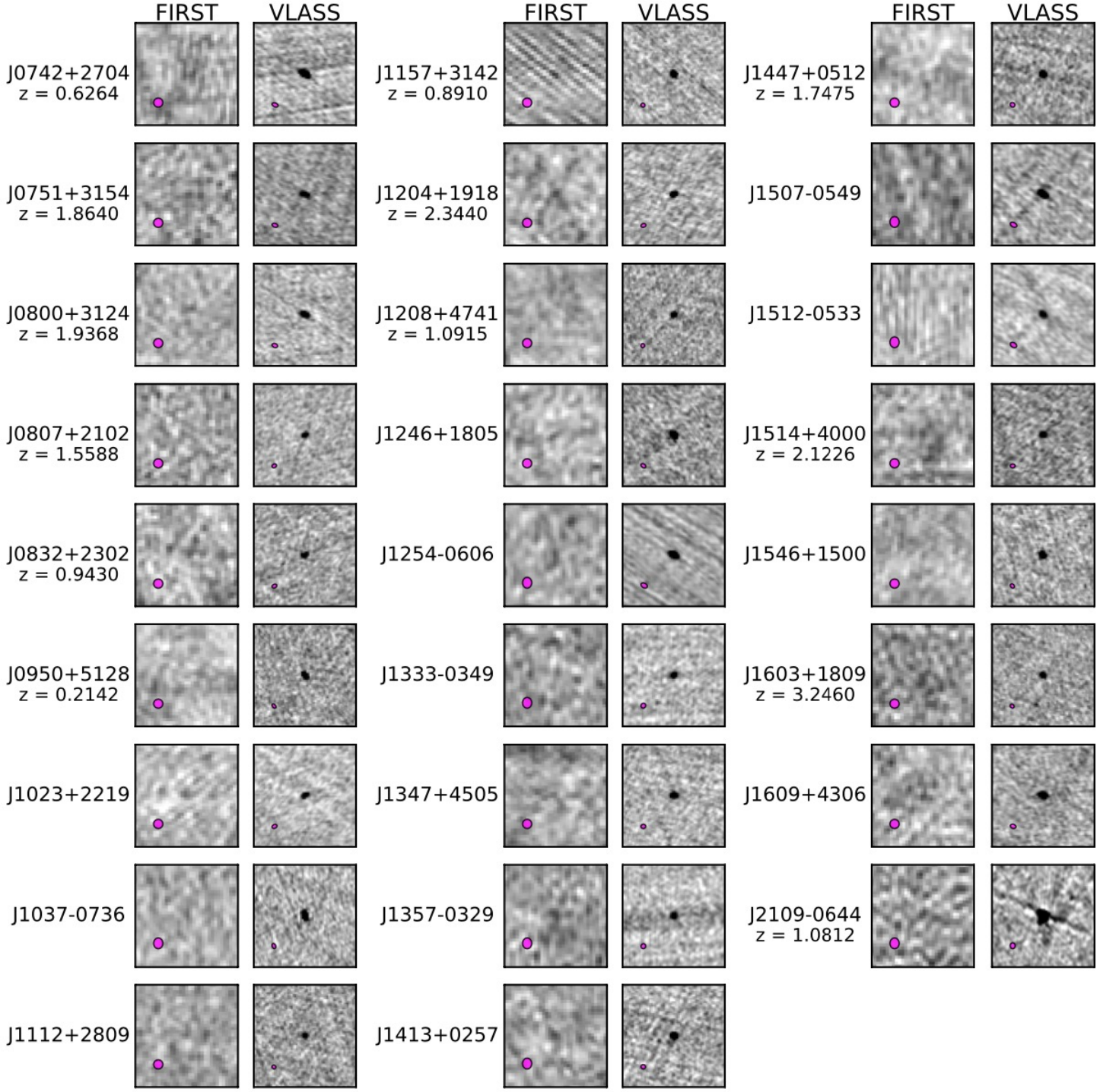
Optical and Infrared AGN selection techniques
obscured and unobscured populations
Minimum peak flux density limit
sample of radio-variable AGN

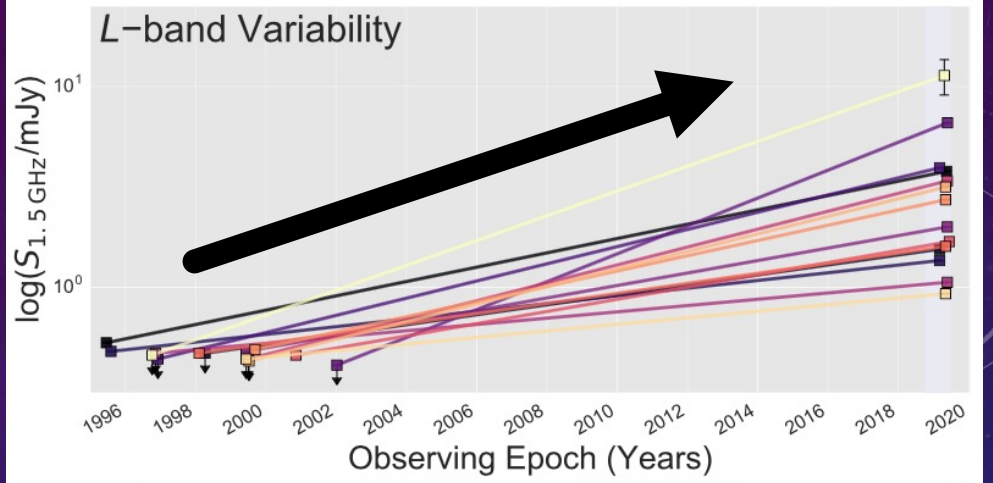
VLA

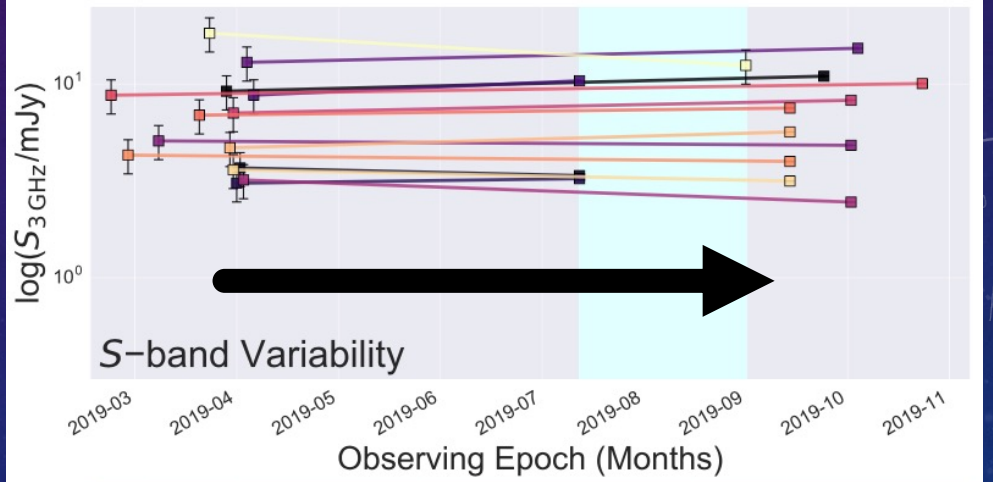


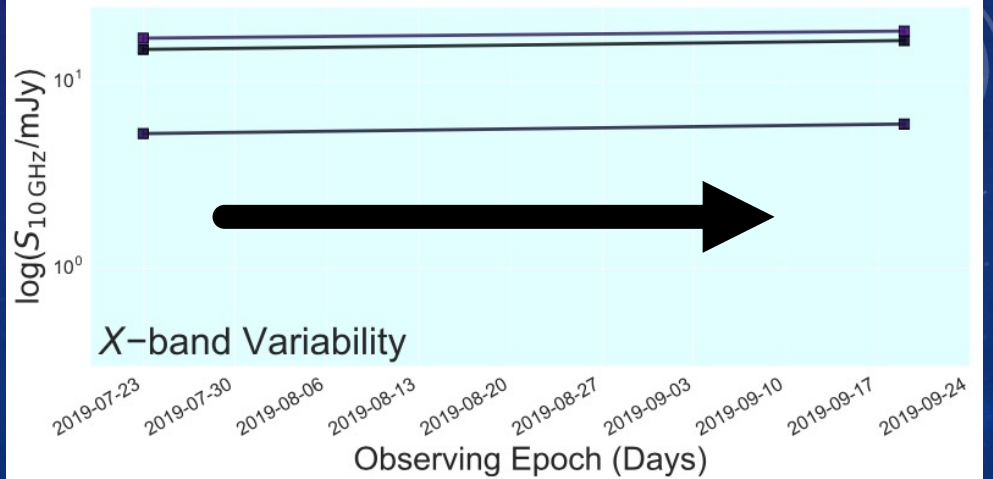
New Radio Observations

- Radio-loud quasars
- 26 candidate sources
  - Limited by peak flux
- 14 sources observed with VLA
- A configuration
  - L, S, C, X bands
- Commensal low frequency
  - VLITE
  - 340 MHz


FIRST
VLASS
J0742+2704
z = 0.6264
J0751+3154
z = 1.8640
J0800+3124
z = 1.9368
J0807+2102
z = 1.5588
J0832+2302
z = 0.9430
J0950+5128
z = 0.2142
J1023+2219
J1037-0736
J1112+2809
J1157+3142
z = 0.8910
J1204+1918
z = 2.3440
J1208+4741
z = 1.0915
J1246+1805
J1254-0606
J1333-0349
J1347+4505
J1357-0329
J1413+0257
J1447+0512
z = 1.7475
J1507-0549
J1512-0533
J1514+4000
z = 2.1226
J1546+1500
J1603+1809
z = 3.2460
J1609+4306
J2109-0644
z = 1.0812


L−band Variability
log(S1.5 GHz/mJy)
Observing Epoch (Years)


S−band Variability
log(S3 GHz/mJy)
Observing Epoch (Months)

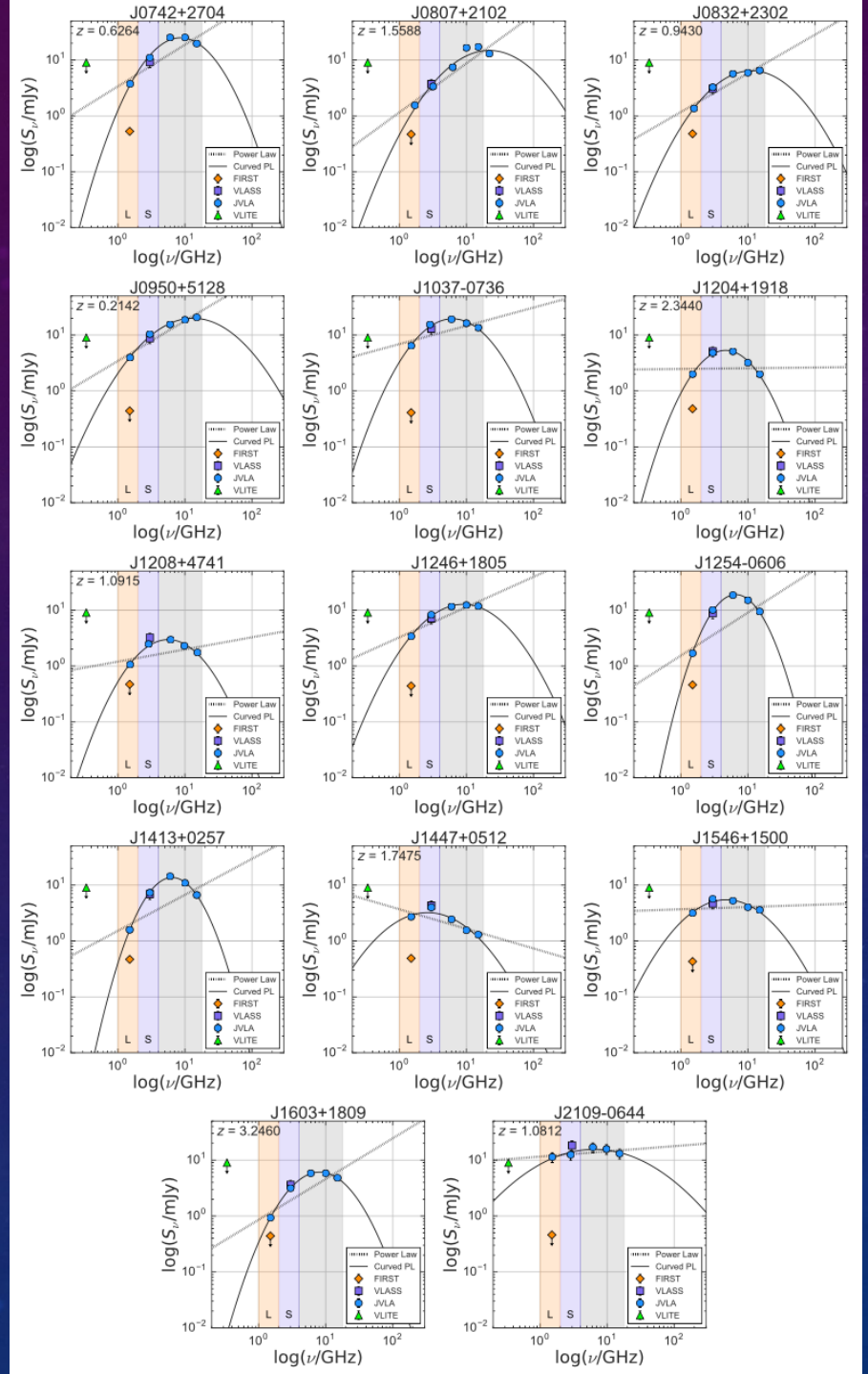

X−band Variability
log(S10 GHz/mJy)
Observing Epoch (Days)

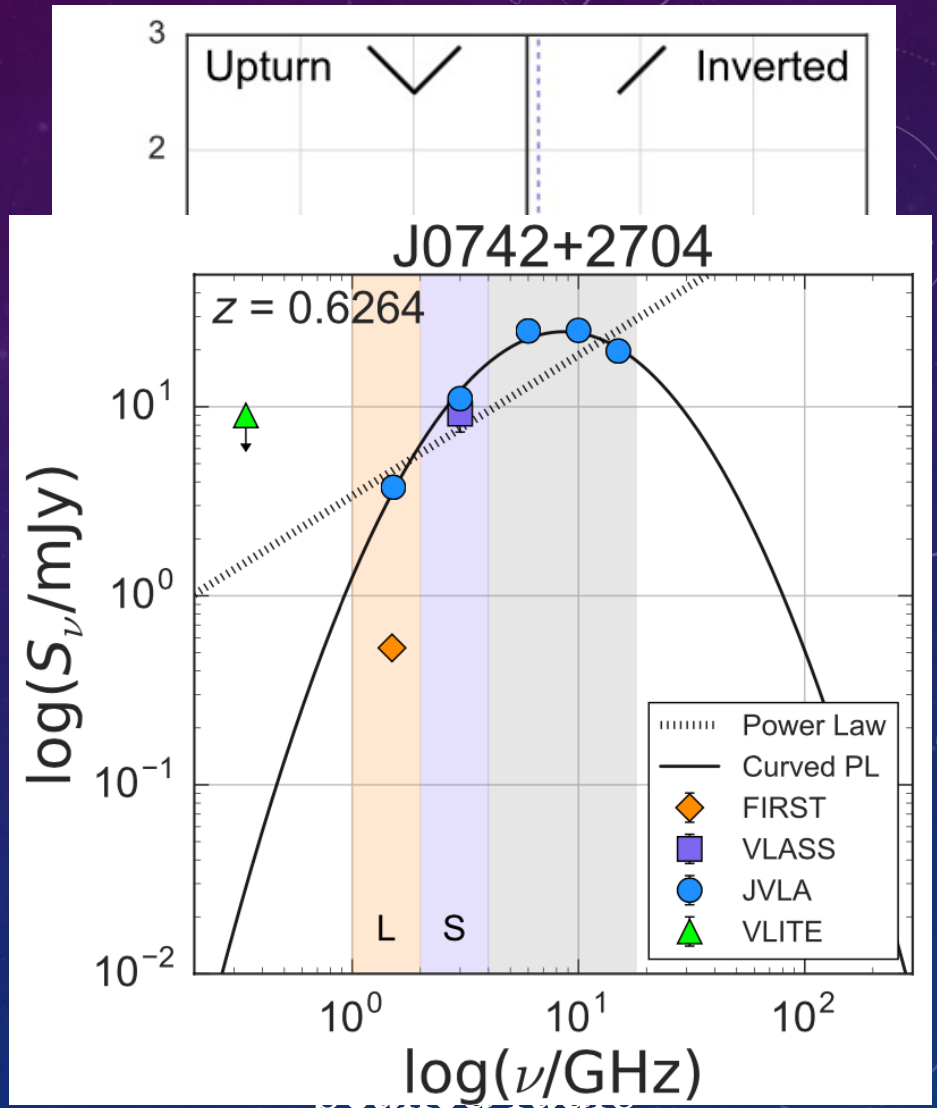
Broadband radio SEDs :

- Multiband JVLA imaging
- VLASS detections
- FIRST 3σ
- VLITE upper limit

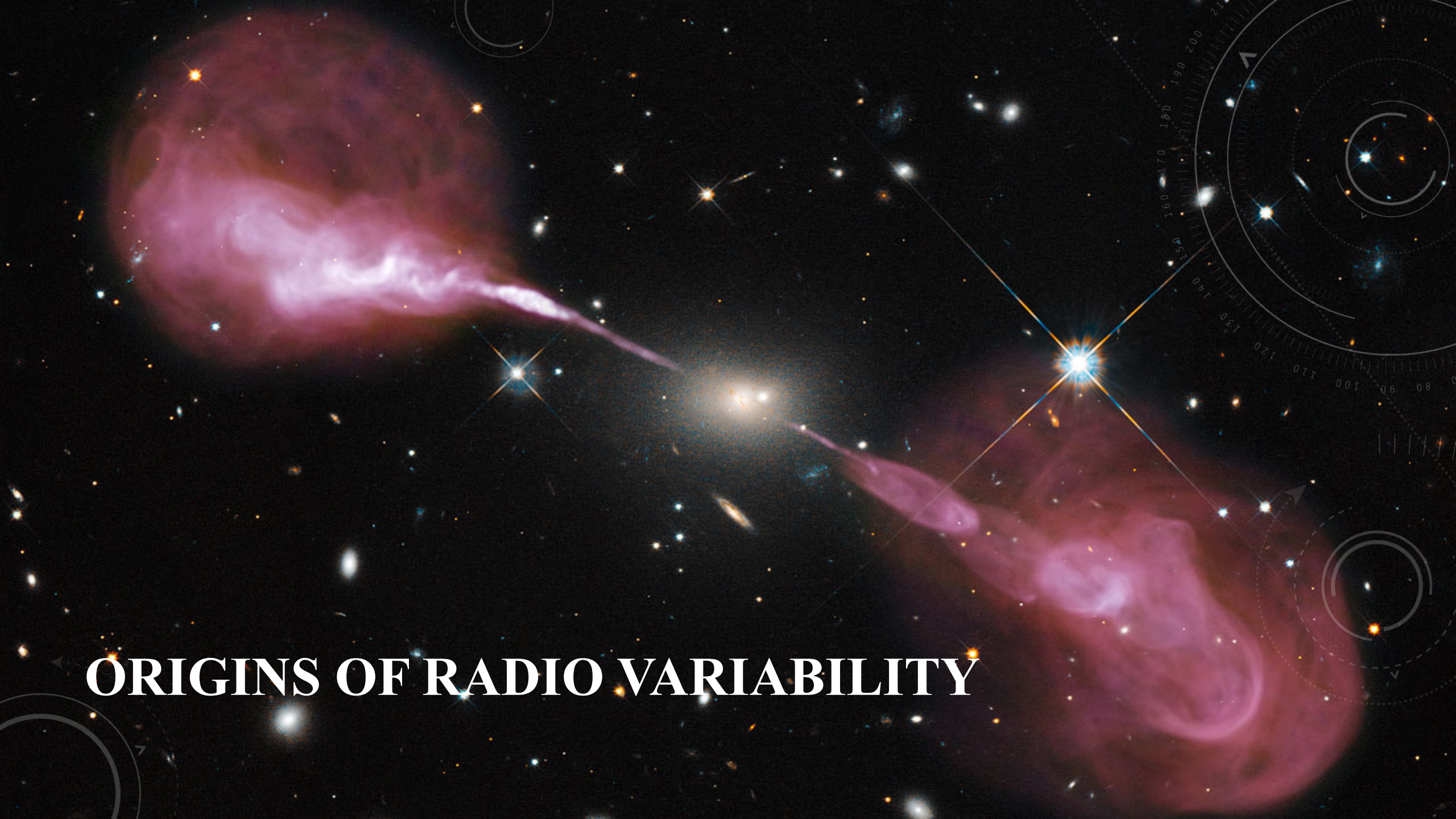
Mapped with:

- Standard non-thermal power-law model
- Curved power-law model





spectral shapes

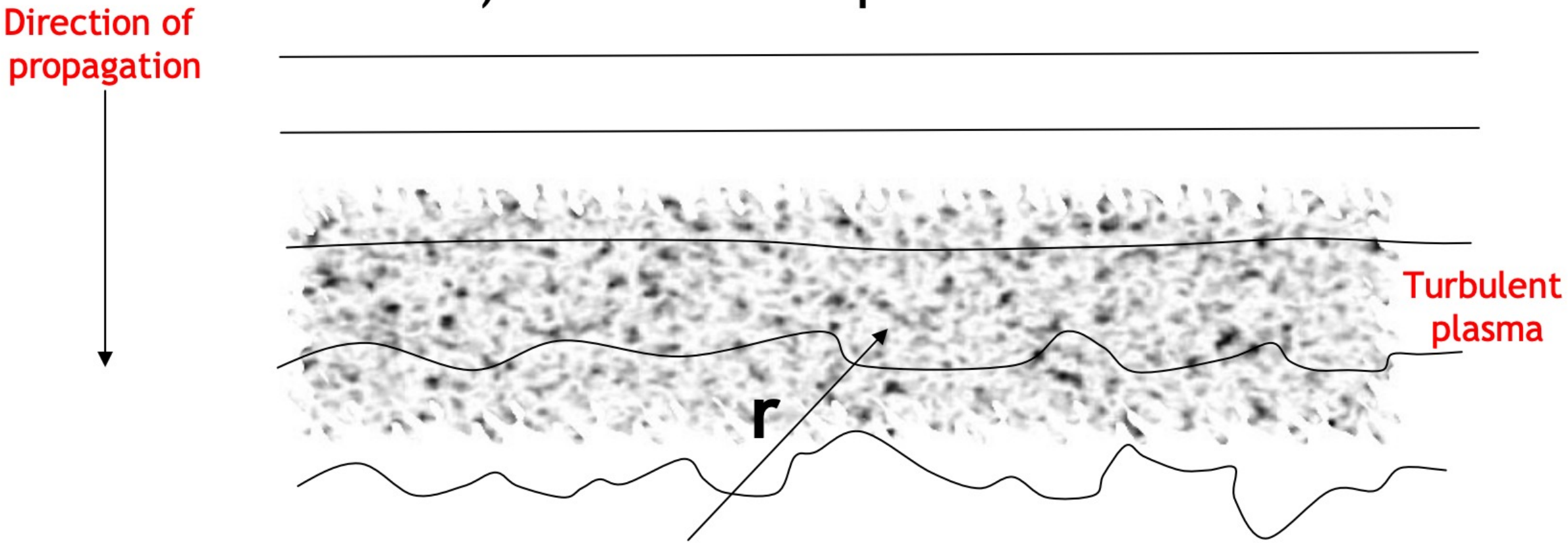


ORIGINS OF RADIO VARIABILITY

Plasma Propagation Effects:

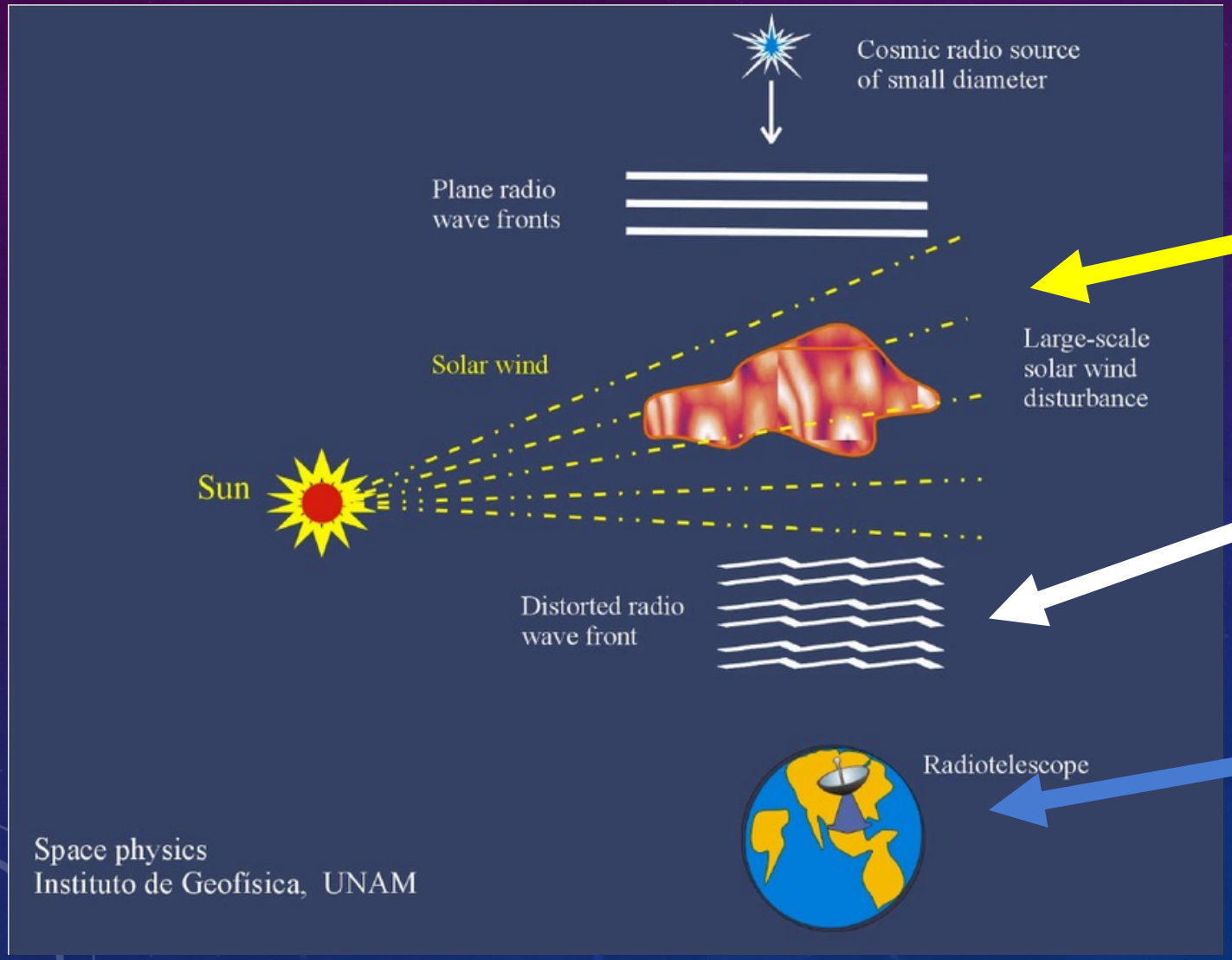
Interplanetary Scintillation
Interstellar Scintillation
Extreme Scattering Events

- A plasma with refractive index variations (typically 0.1% in the ISM) will distort a plane wavefront



Plasma Propagation Effects:

Interplanetary Scintillation
Interstellar Scintillation
Extreme Scattering Events



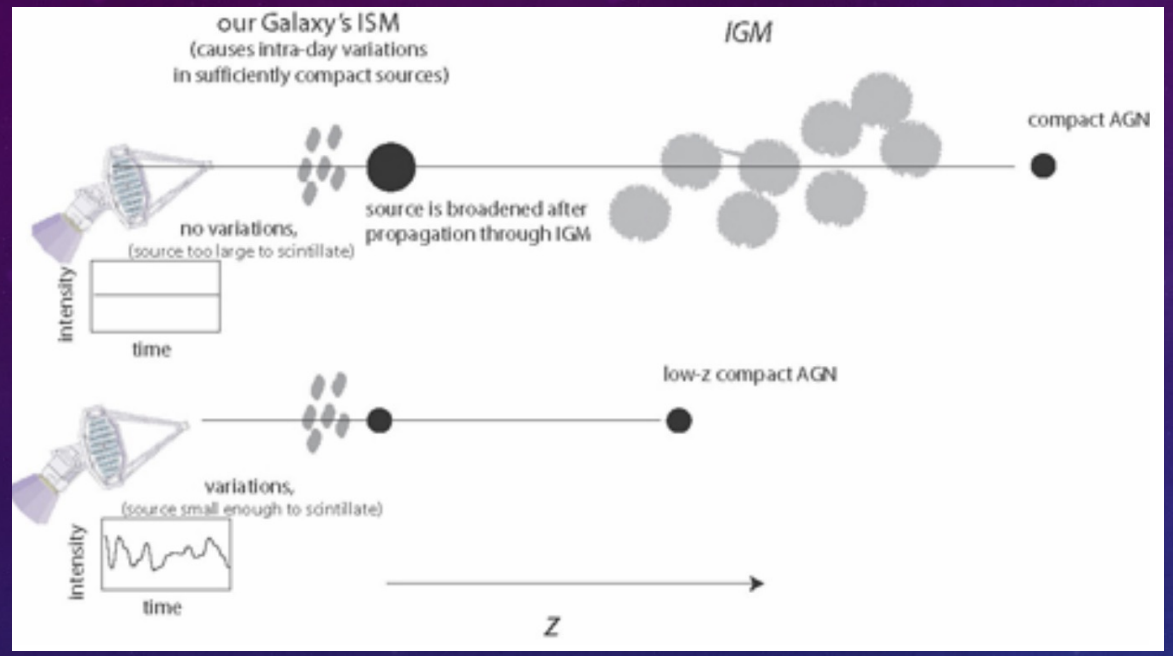
Turbulence from solar wind plasma

Rapid flux variability on **seconds** timescales

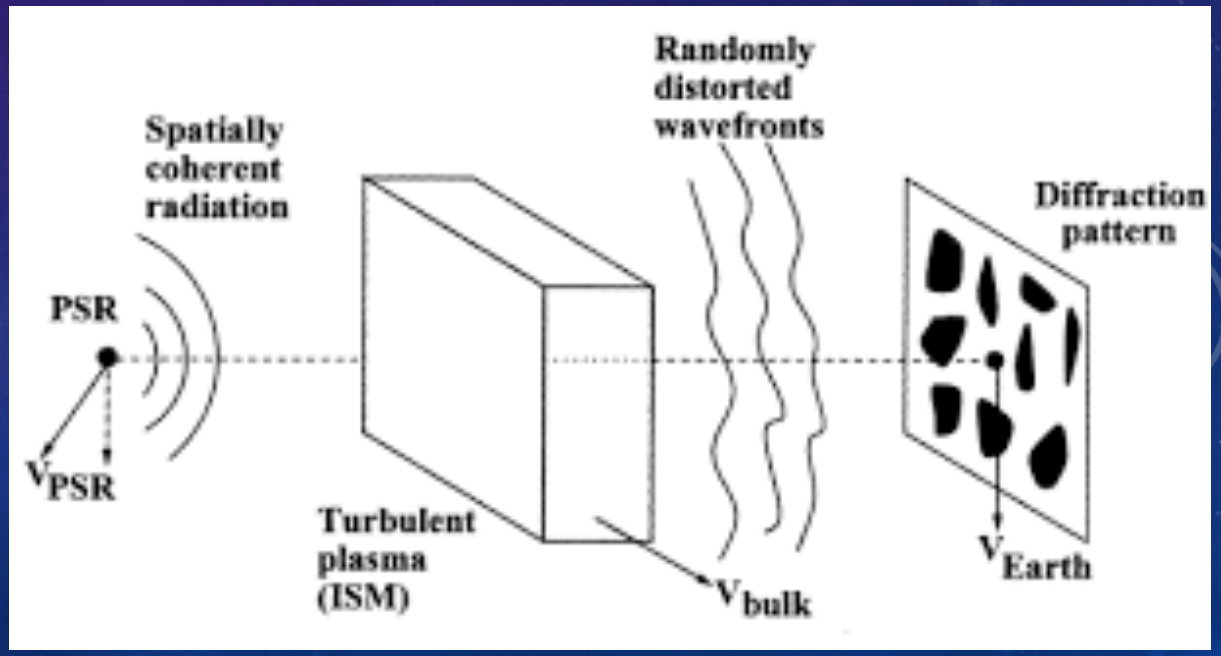
Compact radio AGN

Plasma Propagation Effects:

Interplanetary Scintillation
Interstellar Scintillation
Extreme Scattering Events



Refraction/Diffraction of radio waves by fluctuations in plasma or B fields
- Refractive variability on hours/days

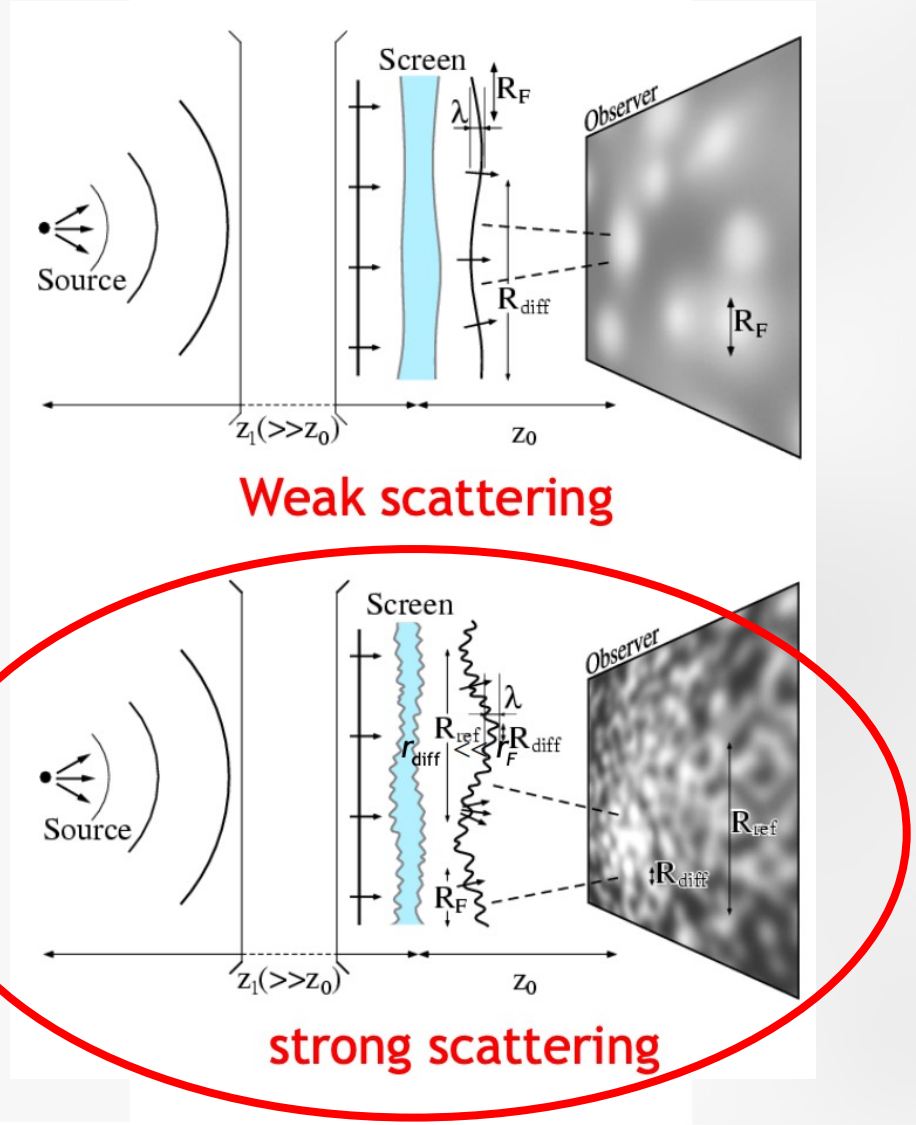


Diffractive ISS variability associated with interference
- Even shorter timescales

Plasma Propagation Effects:

Interplanetary Scintillation
Interstellar Scintillation
Extreme Scattering Events

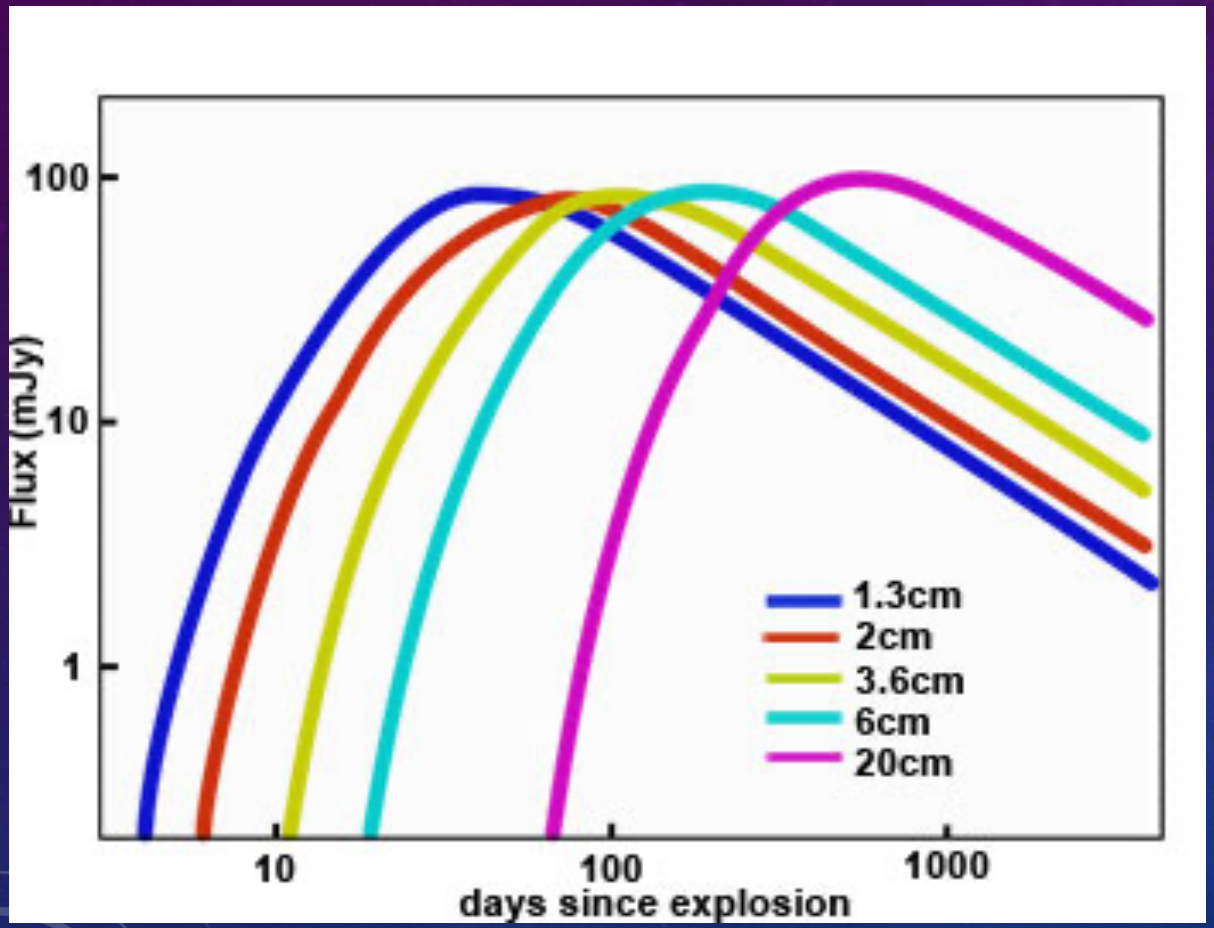
Caused by refractive defocusing – caused by high-density plasma lens passing in front of compact radio source

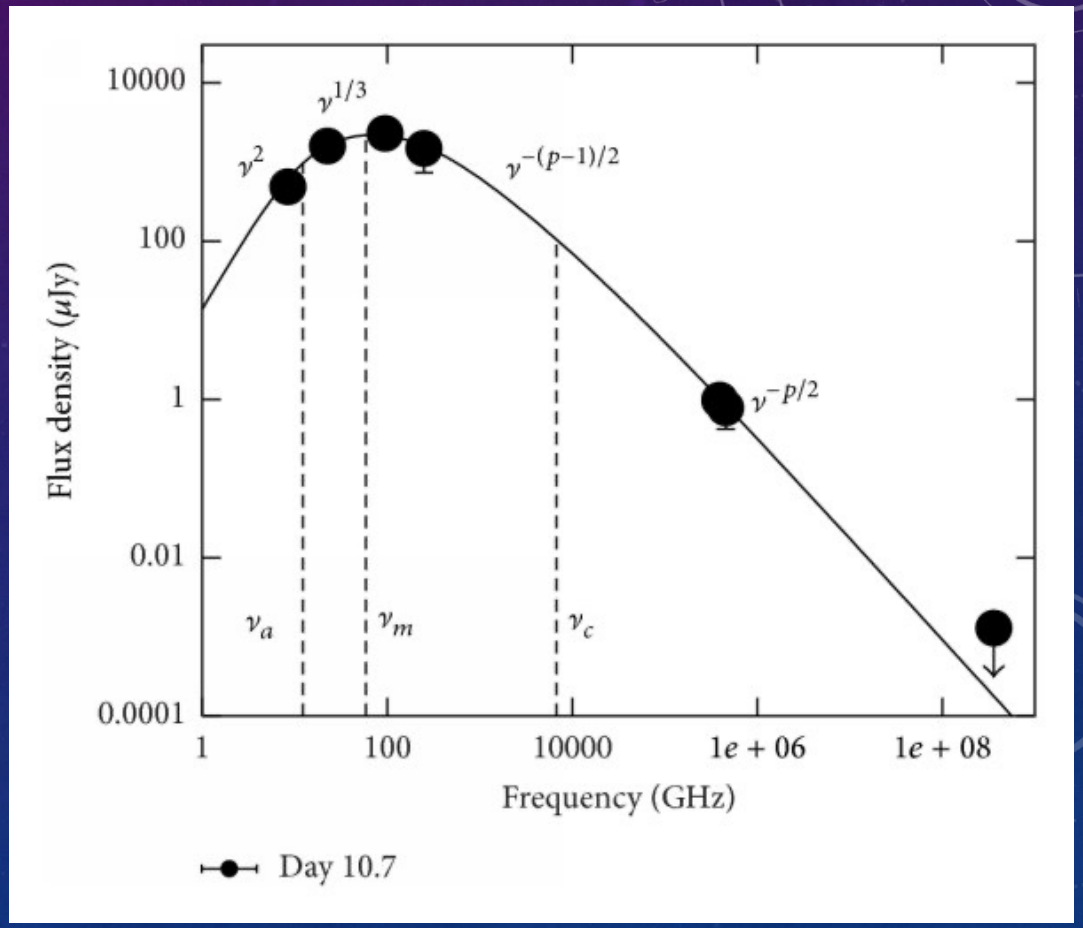


Creates characteristic U-shaped light curve – similar to exoplanets

Variability timescales generally weeks to months

Supernovae and GRBs:





Intrinsic AGN Variability:

Intrinsic Events:

- Blazars
- Young jets
- FR I/II cores
- Low luminosity AGNs
- Jet reorientation

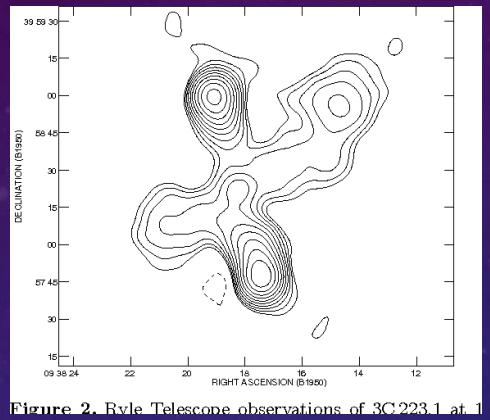
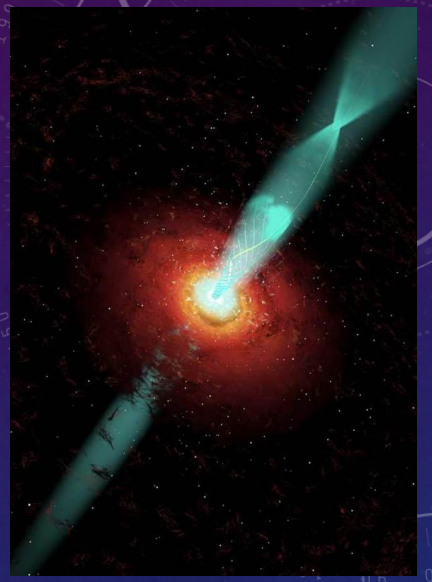
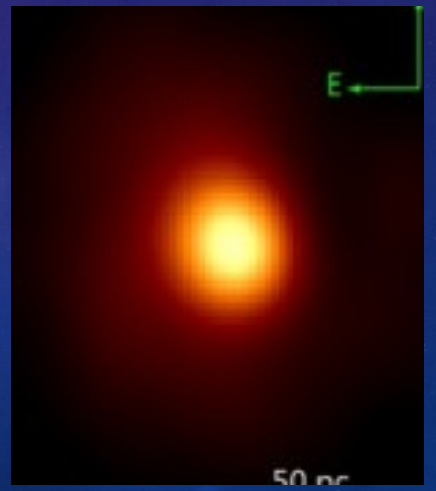
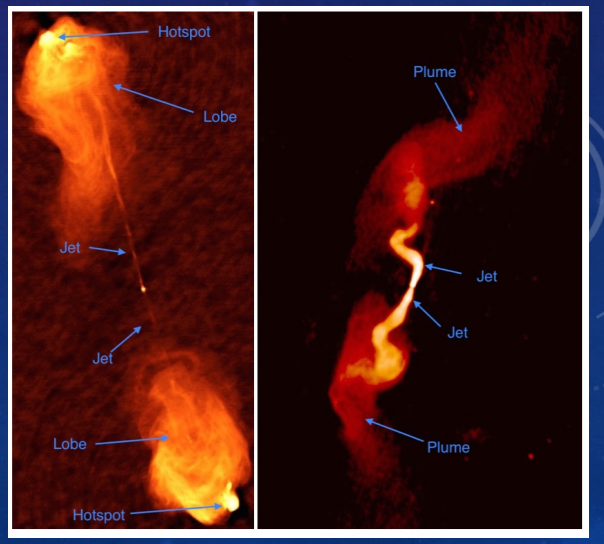


Figure 2. Ryle Telescope observations of 3C 223.1 at 1



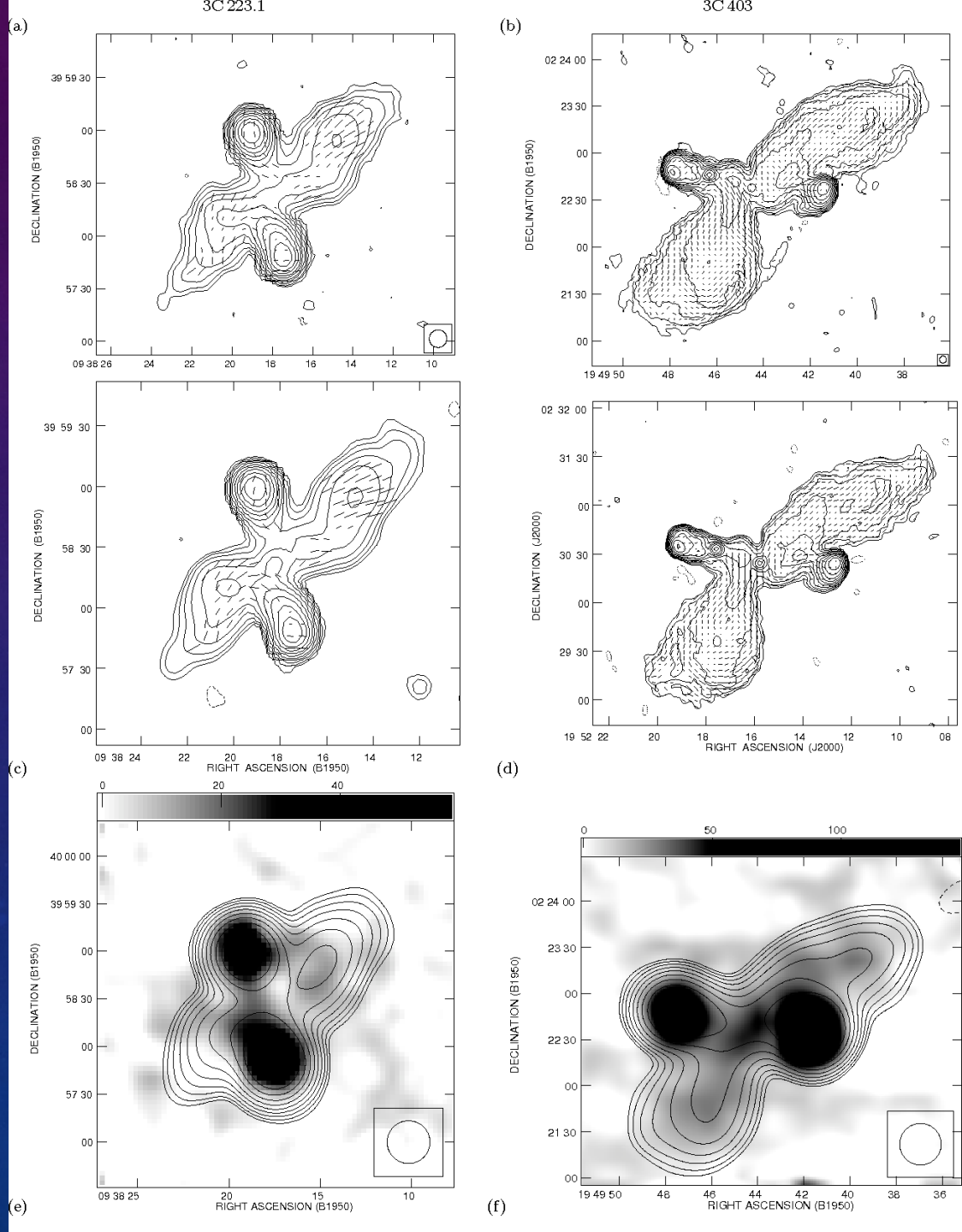




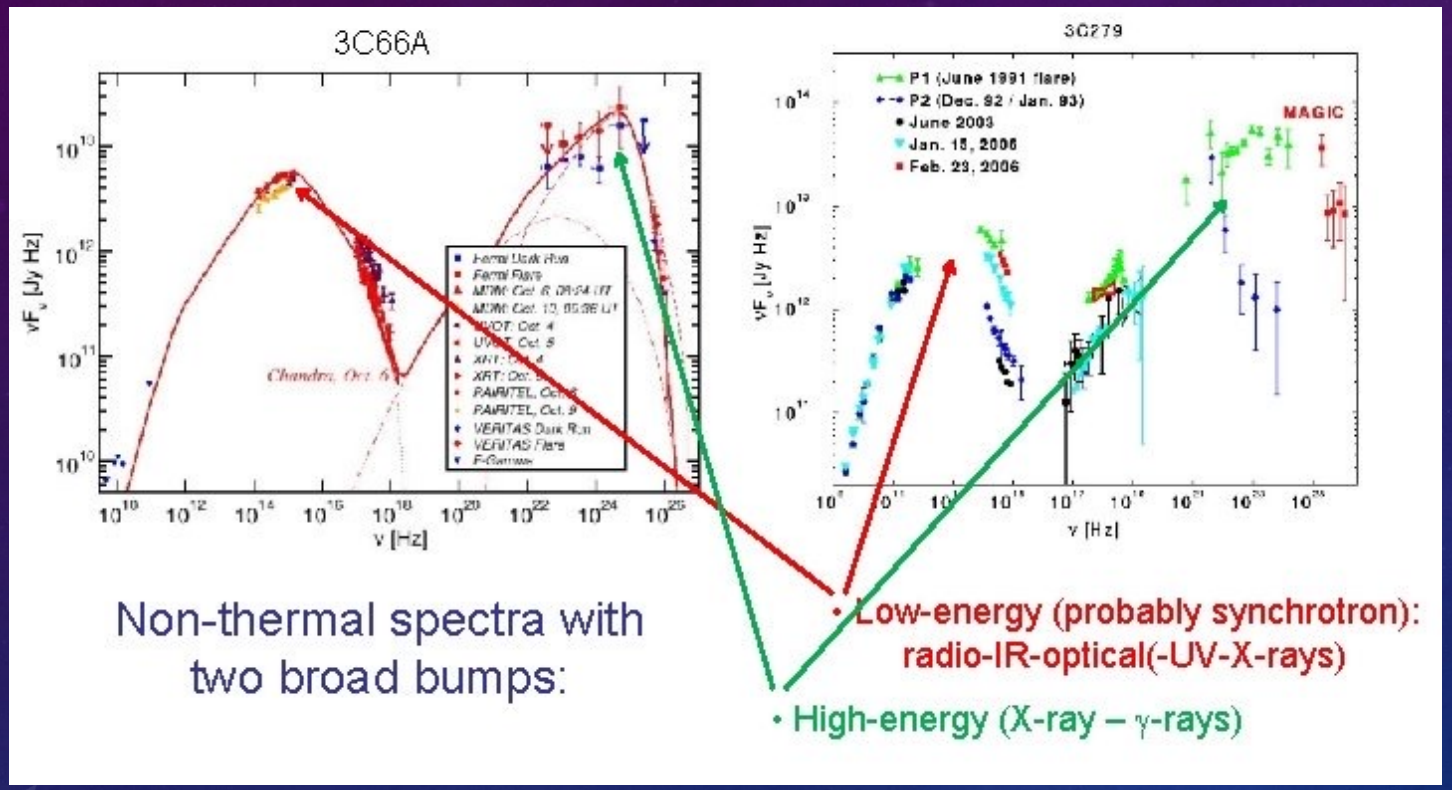
Jet Reorientation:

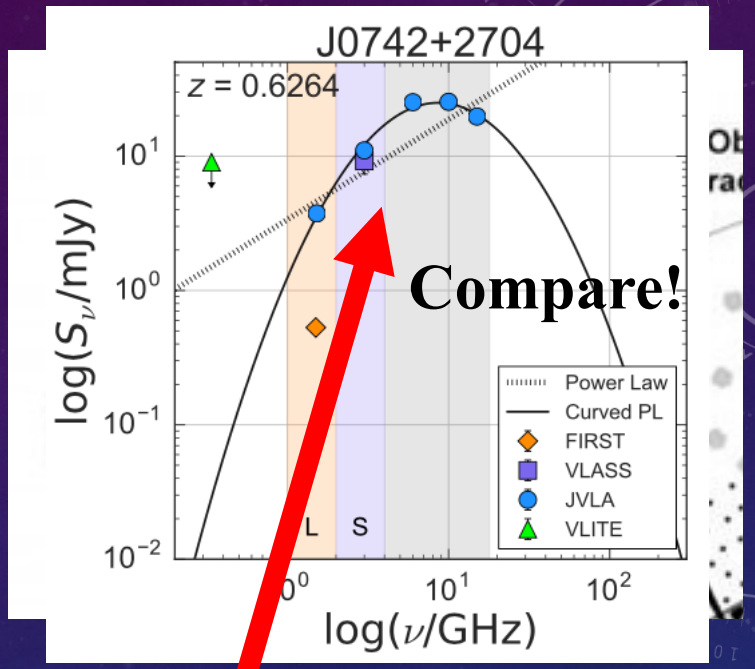
- Jets aligned at small angles to our LOS – relativistically beamed
- E.g. – rapid relocation of jet over 20 year timescale of our sources
  - Would lead to apparent brightening of our sources

- Underlying causes:
  - Helical magnetic fields
  - Flaring blazars
  - Jet-ISM interactions
  - SMBH orbital motion

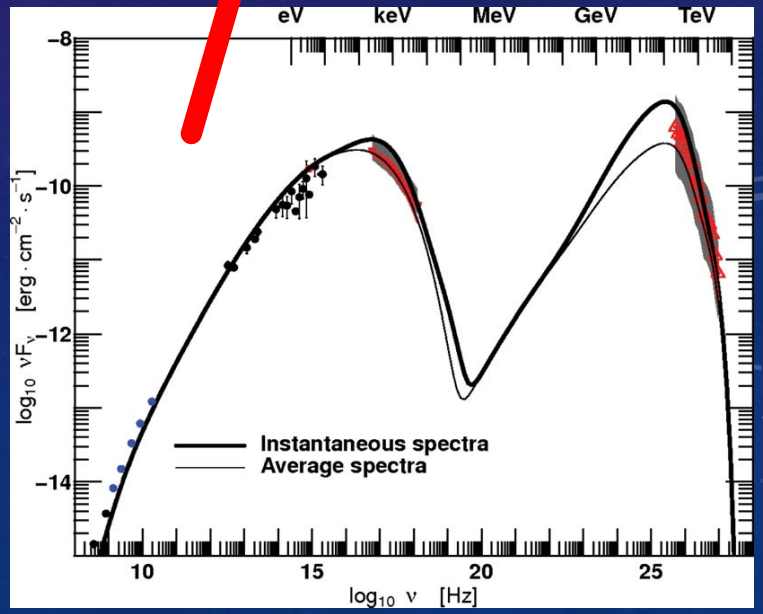


Blazar Contamination:

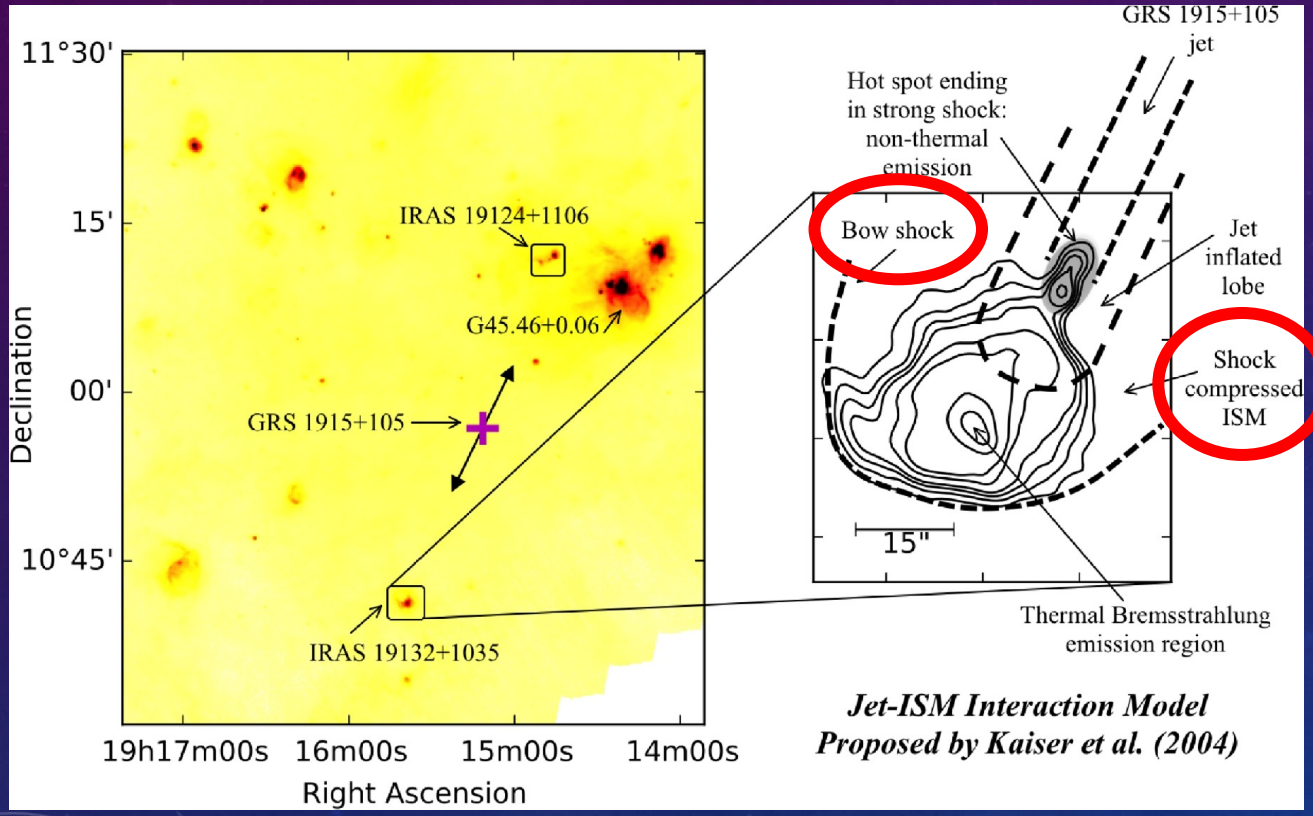


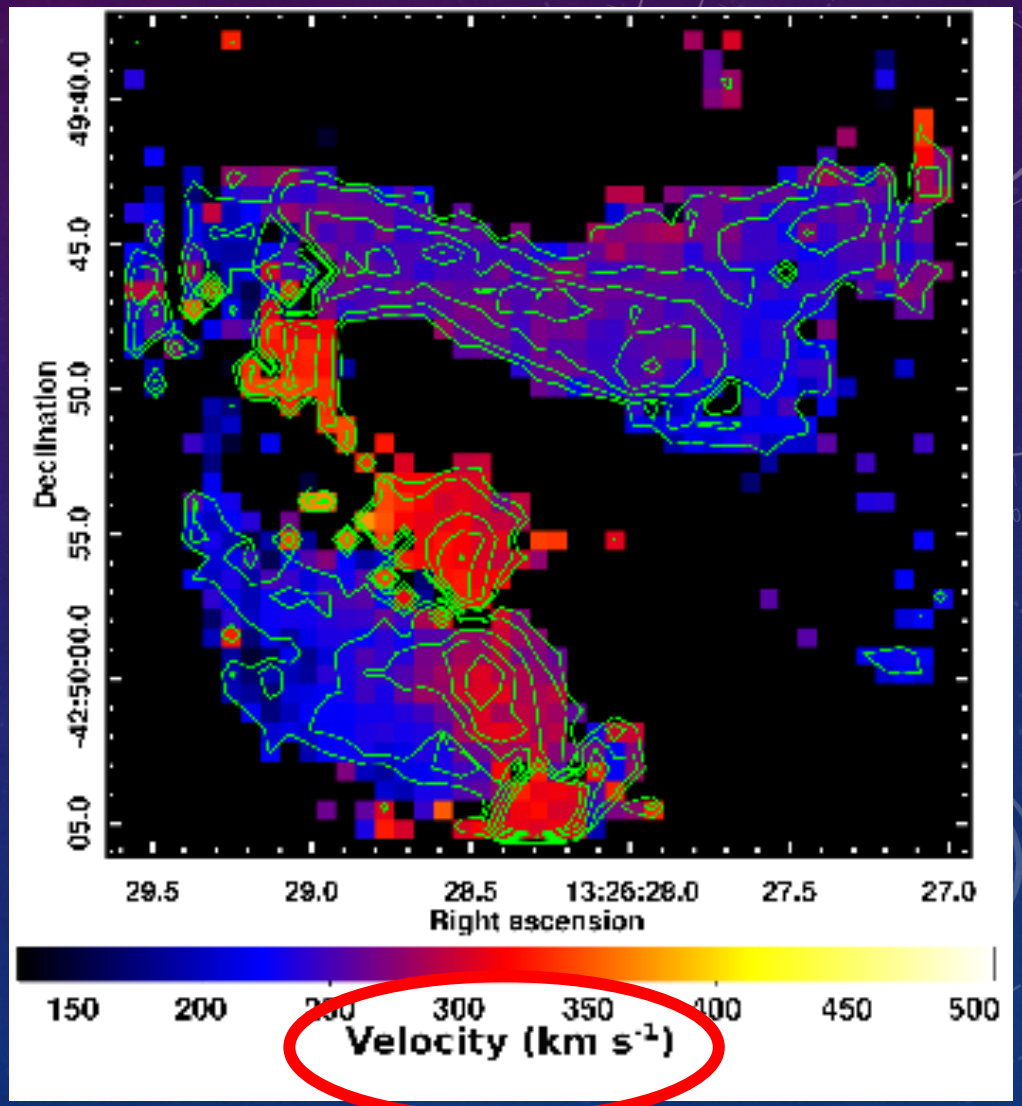


Compare!



Jet-ISM Interaction:



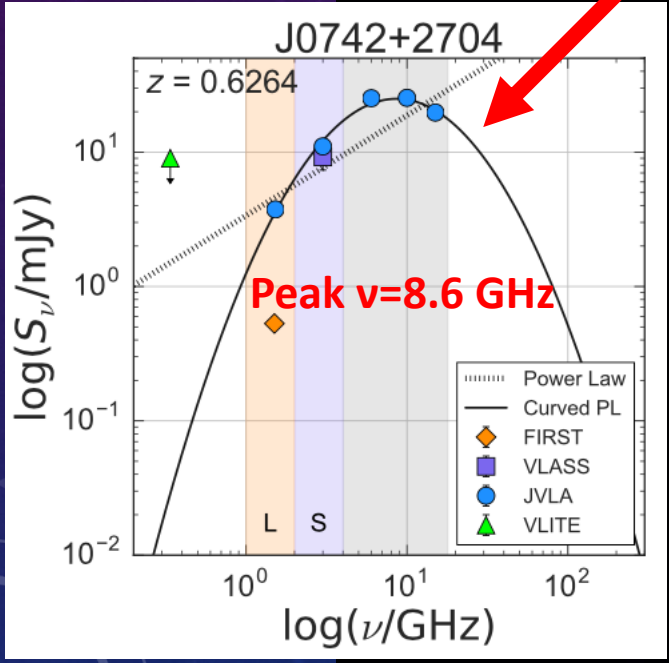


Young Radio Jets:

Exhibit:

- GHz peaks
- Compact morphologies
- Inverted SEDs

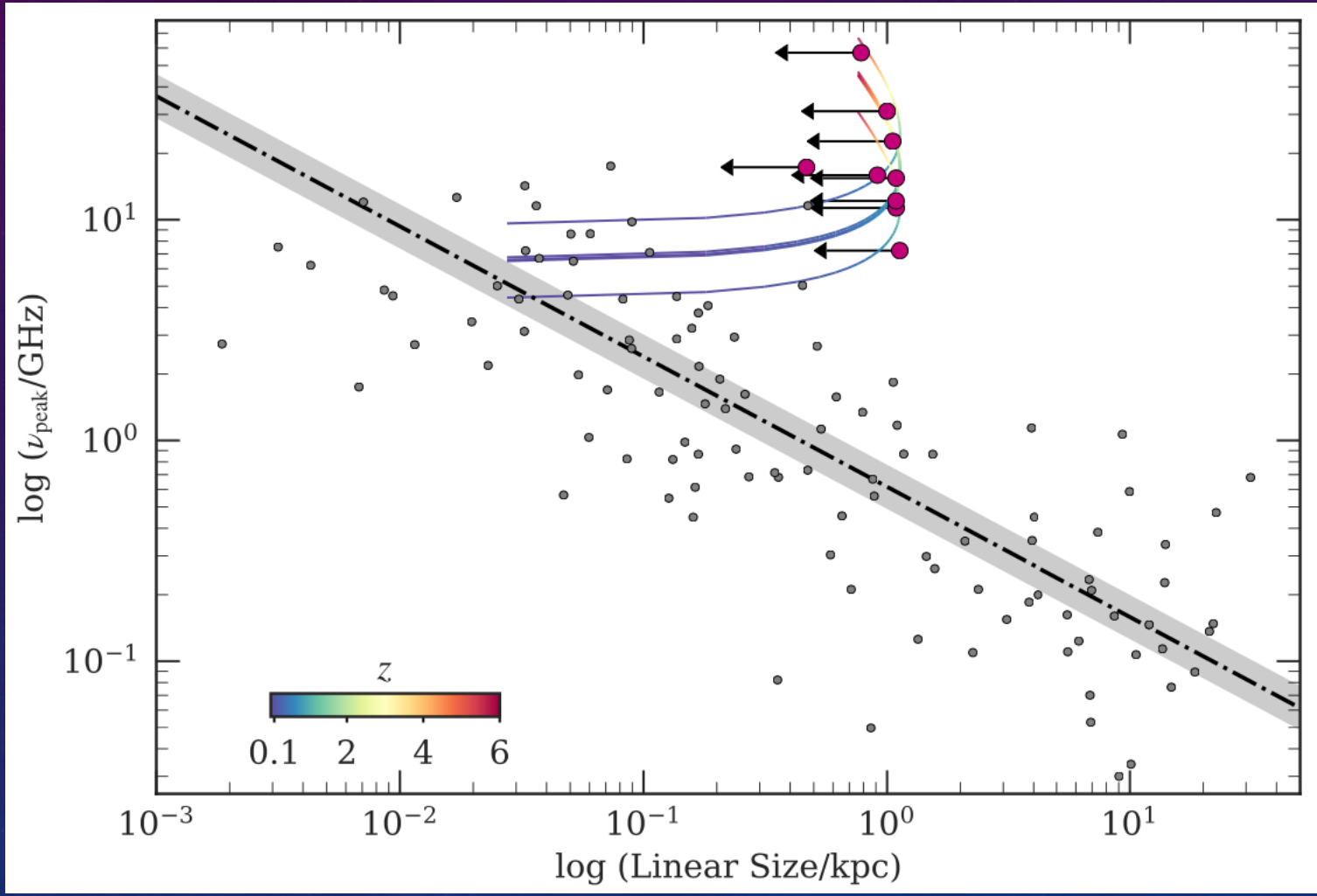
Example: J0742+2704



VLBA image of young jets originating near SMBH (triggered ~80 years ago)

Adiabatic -> Synchrotron

Young Radio Jets:



~~Extrinsic~~ vs. Intrinsic

Large variability amplitudes
Months-decades timescales
Source size constraints
GHz-peaked sources
Inverted SEDs

Young and compact radio AGN and jets

Multiple possible sources of variability for any one sources

CONCLUSIONS

As always… better telescopes and more data! ☺


QUESTIONS?