The innermost dusty region and the BLR : Constraints from IR interferometry

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AGN interferometry in the IR : what is possible now

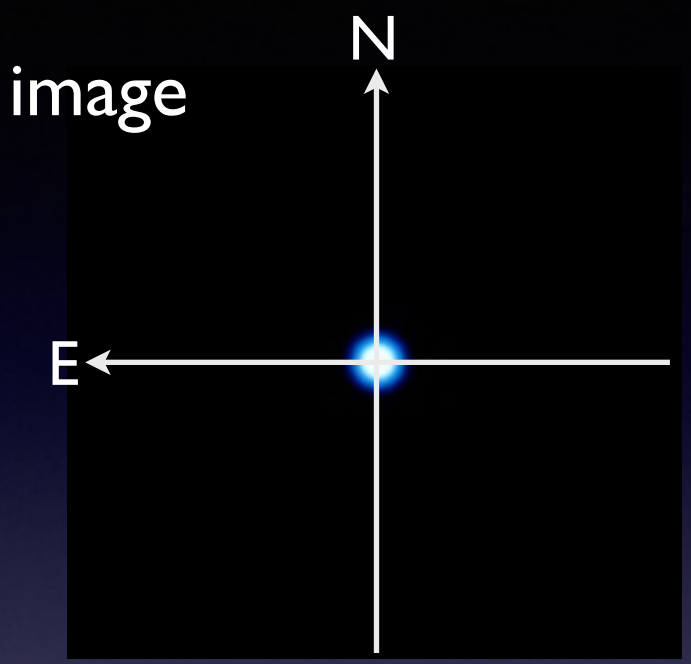
Optical/IR interferometers

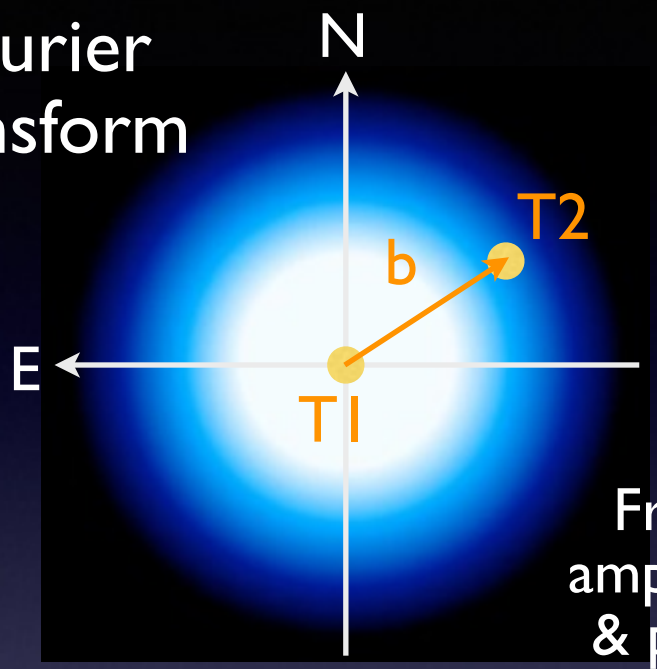
- Keck & VLT interferometers

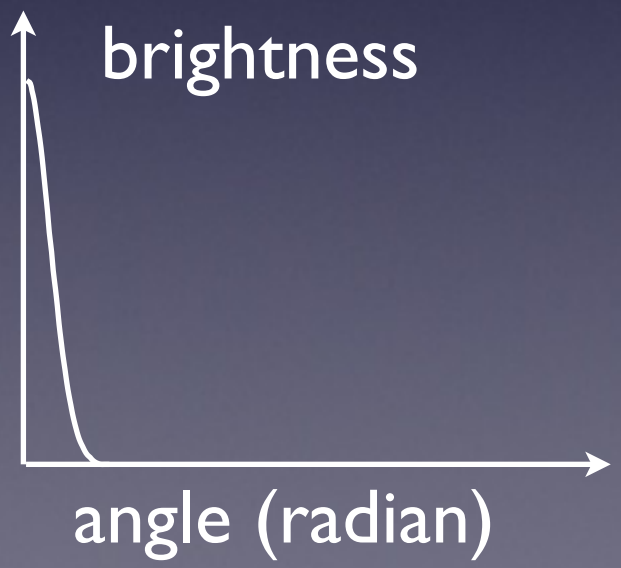
near-IR
max 85m
2 telescopes

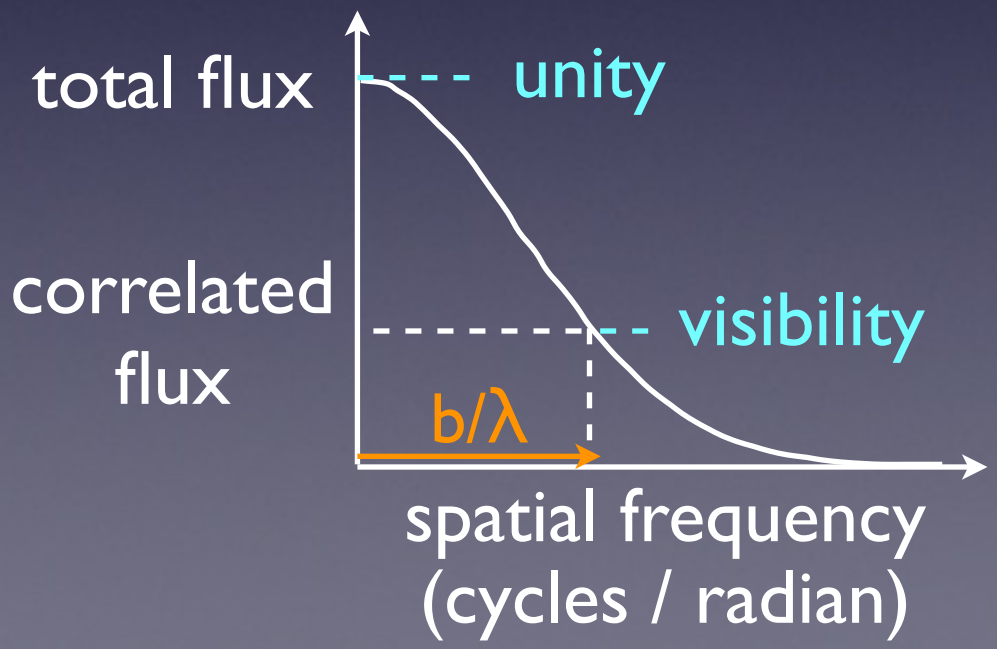
near-IR / mid-IR
max 130m
4 telescopes

Interferometry / Visibility science







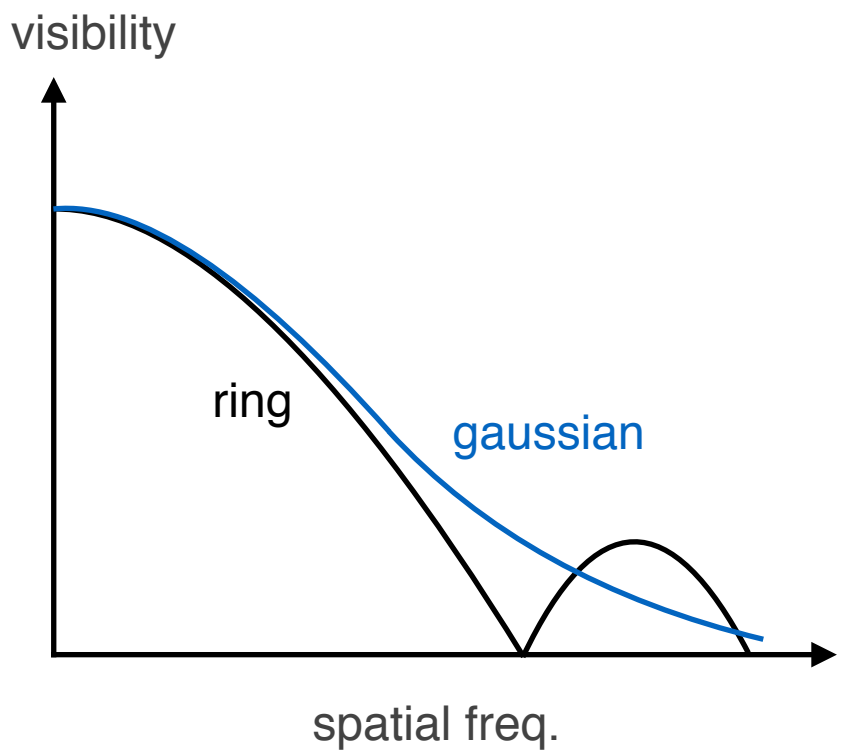


What we can do now with IR interf. on AGN:

- Dealing with only the "first lobe"
  - only partial resolution at the moment.
  - can't even distinguish Ring vs Gaussian

- Almost no phase info
  - two beams, or
  - zero closure phase at low spatial freq.

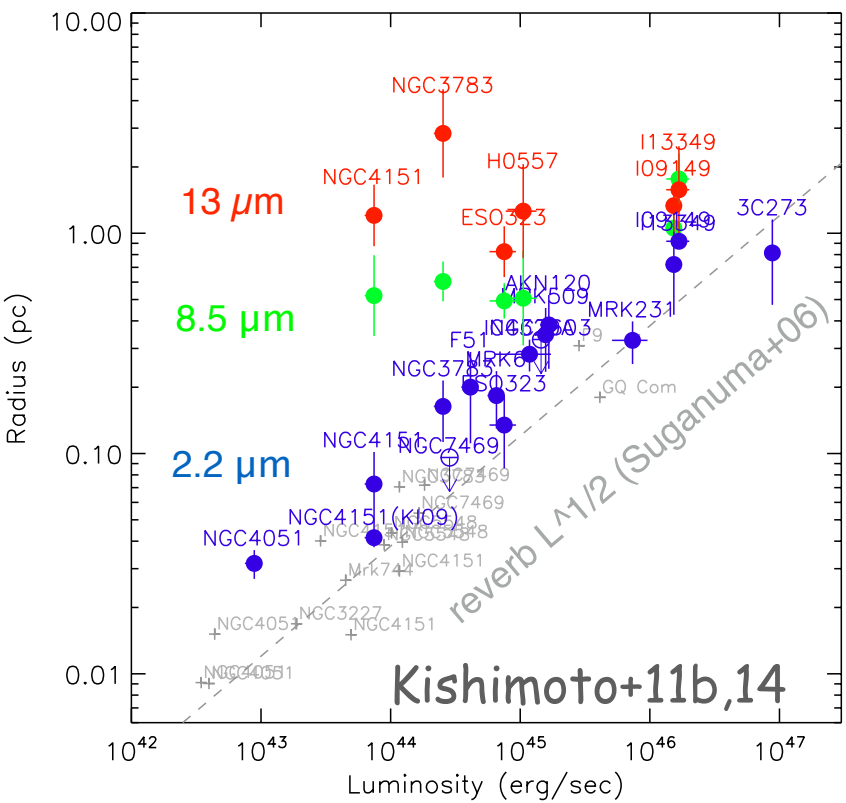
- We can still measure:
  - overall size
  - radial profile in mid-IR

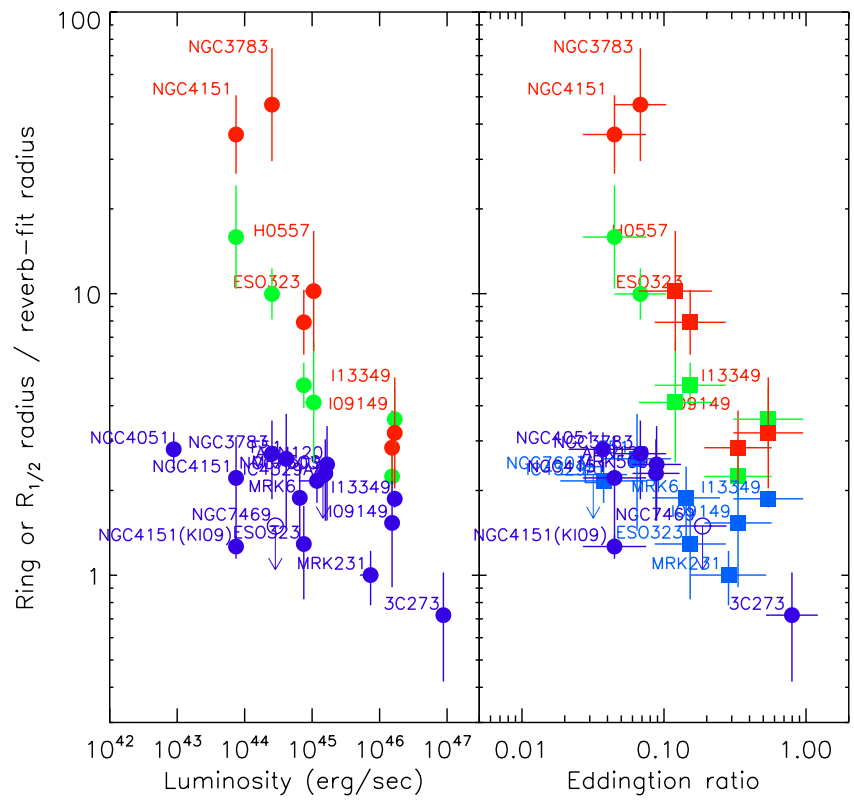


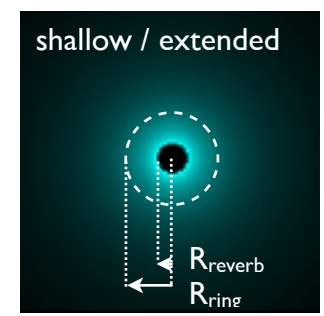
IR size-luminosity relation

Size & radial profile from face-on objects

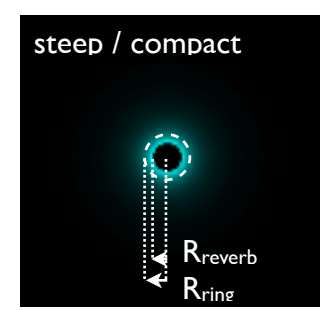
- near-IR: 15 Type 1s, resolving dust sub region, $\propto L^{1/2}$
- mid-IR: systematic obs of 6 Type 1s
- normalize by R_{reverb} - "Brighter-Steeper" trend
  - several more (Burtscher+13) + new data : to be uniformly analyzed





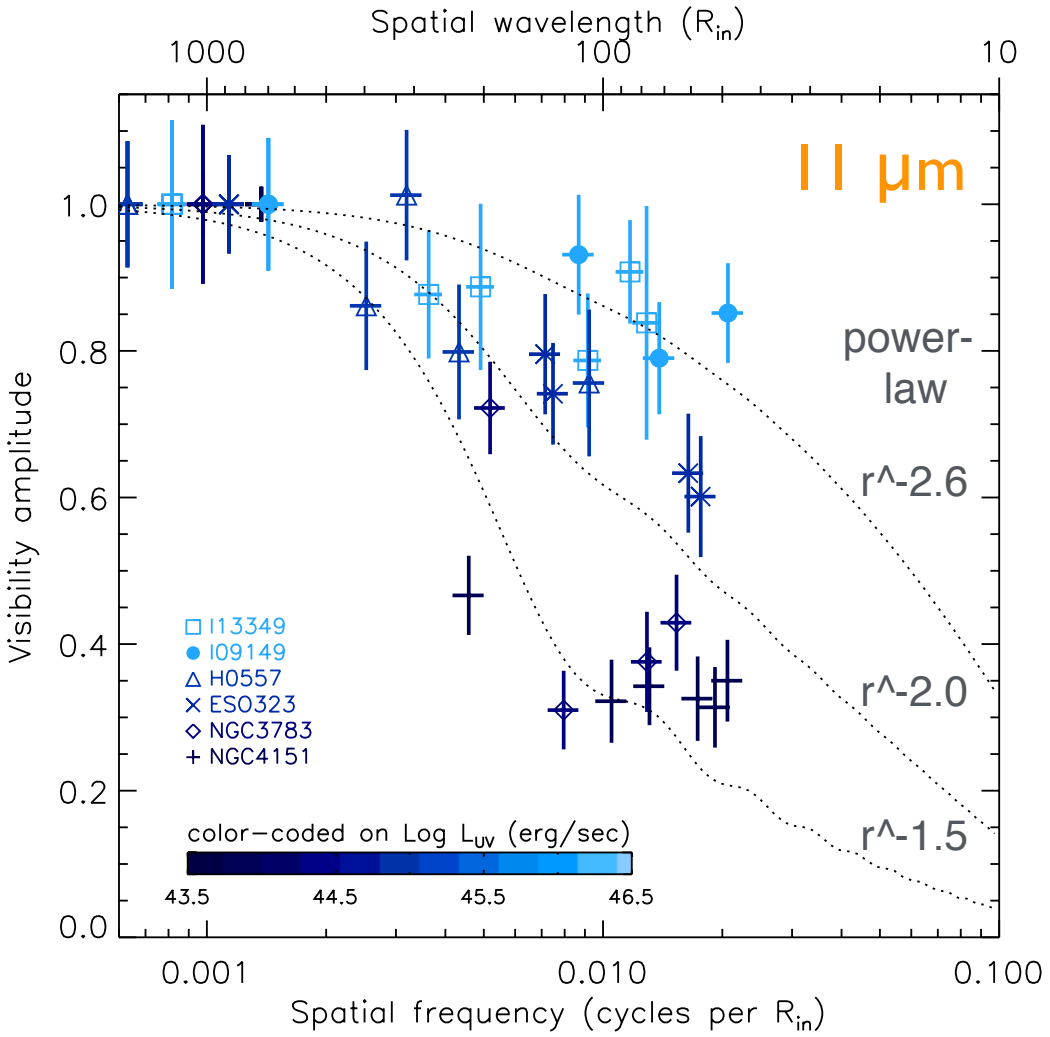


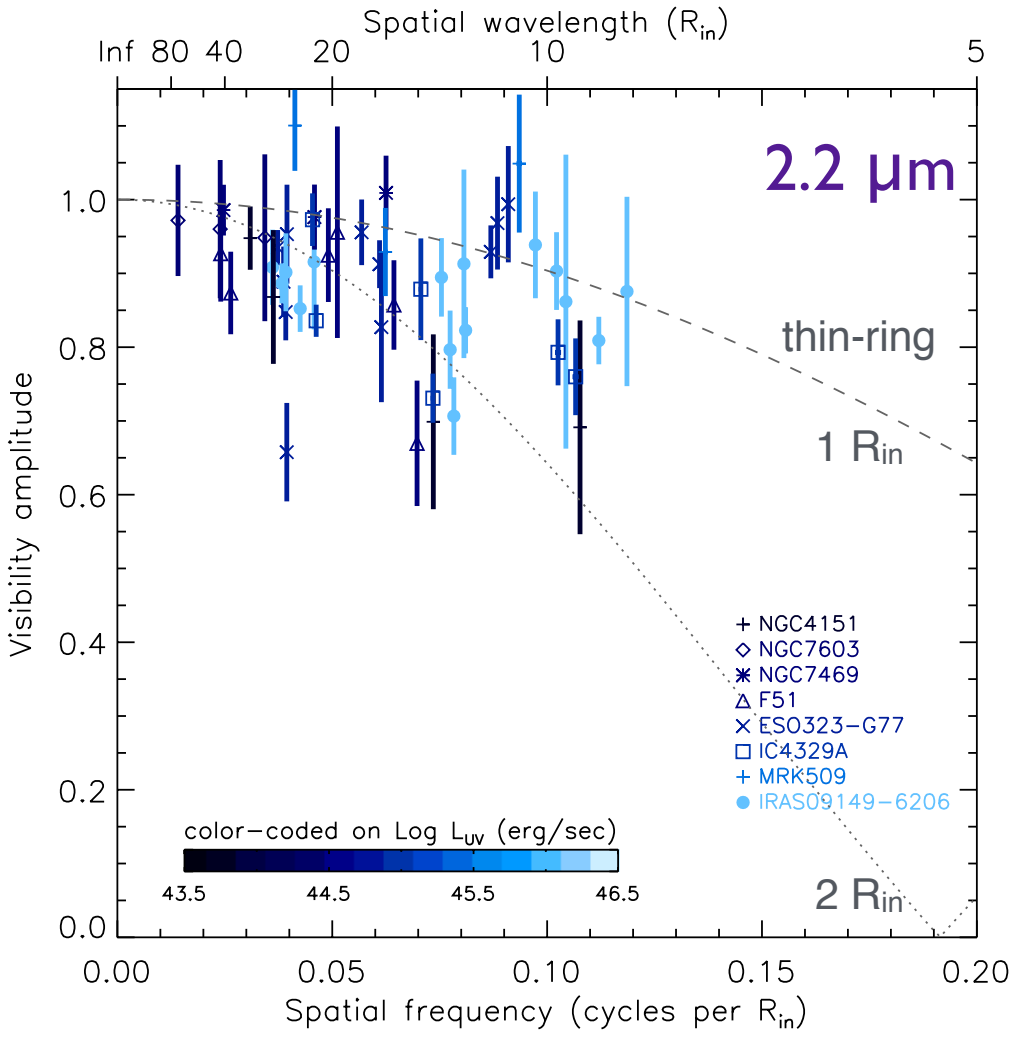
$R_{ring} / R_{reverb} >> 1$



$R_{ring} / R_{reverb} \sim 1$

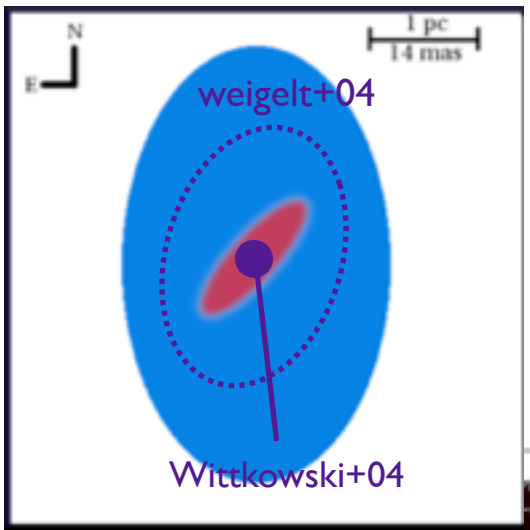
Visibilities in mid-IR and near-IR





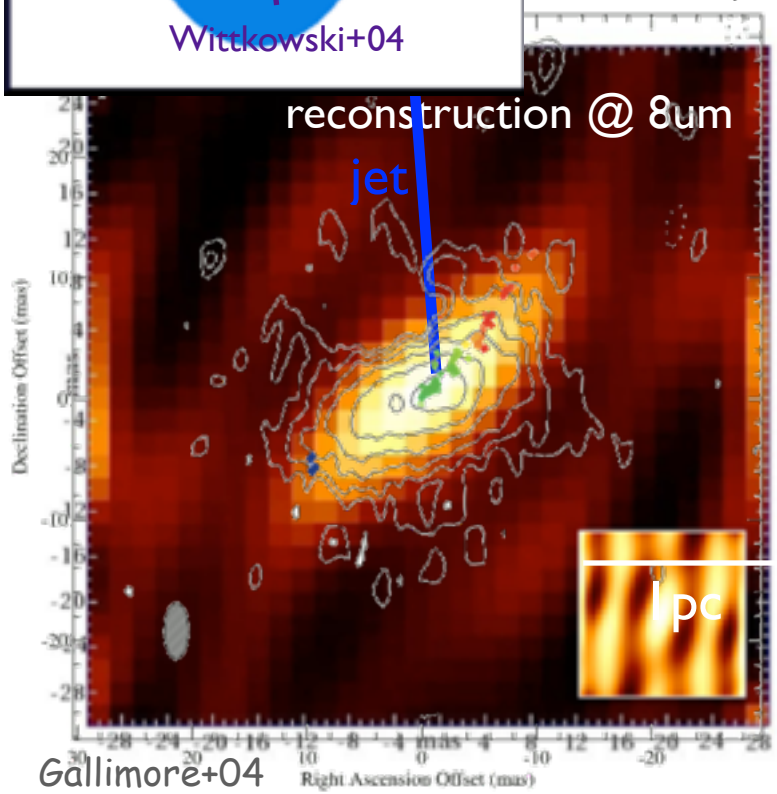
Edge-on, Type 2 studies

- 2 obj in early studies, + 1 obj in recent study



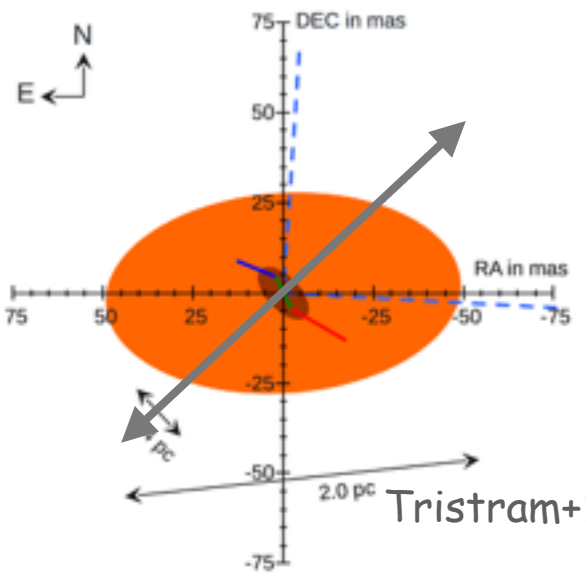
NGC1068

Raban+09



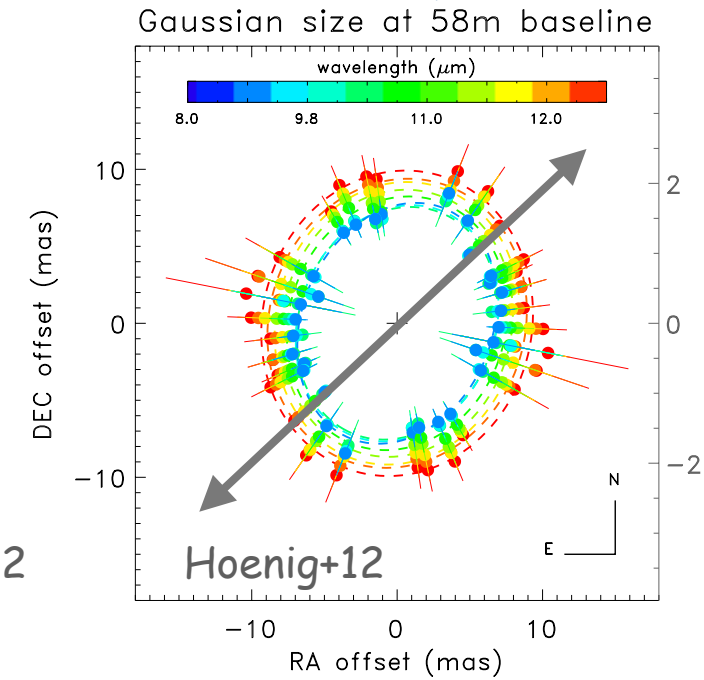
Gallimore+04

Circinus

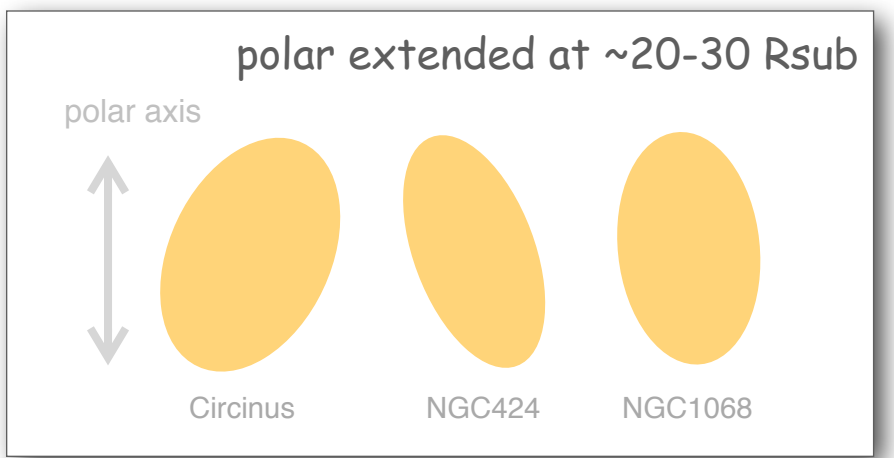


Tristram+12

NGC424

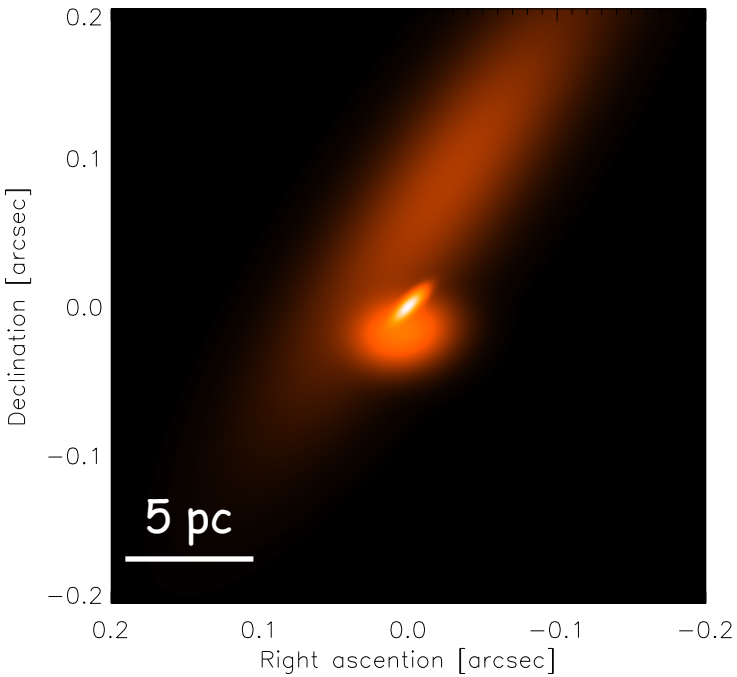


Hoenig+12



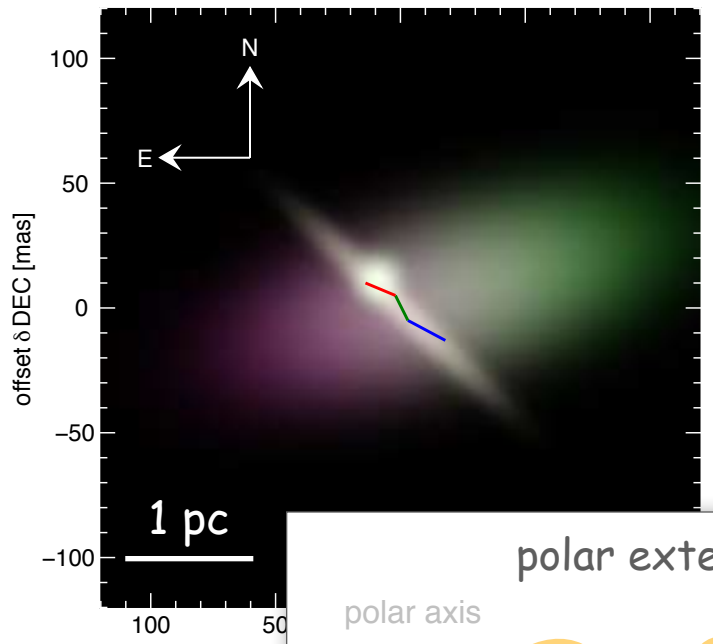
More recent studies on the two brightest 2's

- Differential / chromatic phase
  - multiple-comp. model, more complicated 'image'
  - but the bottom line is still the same...



NGC1068

Lopez-Gonzaga+14



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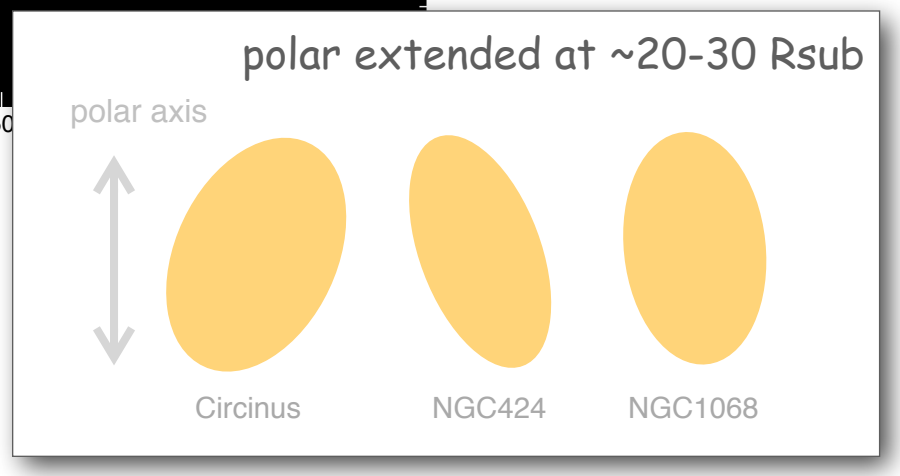
Tristram+14



Summary of what we have

- Observational facts:
  - Brighter-steeper trend in face-on
  - Eq. concentration & polar elongation in edge-on

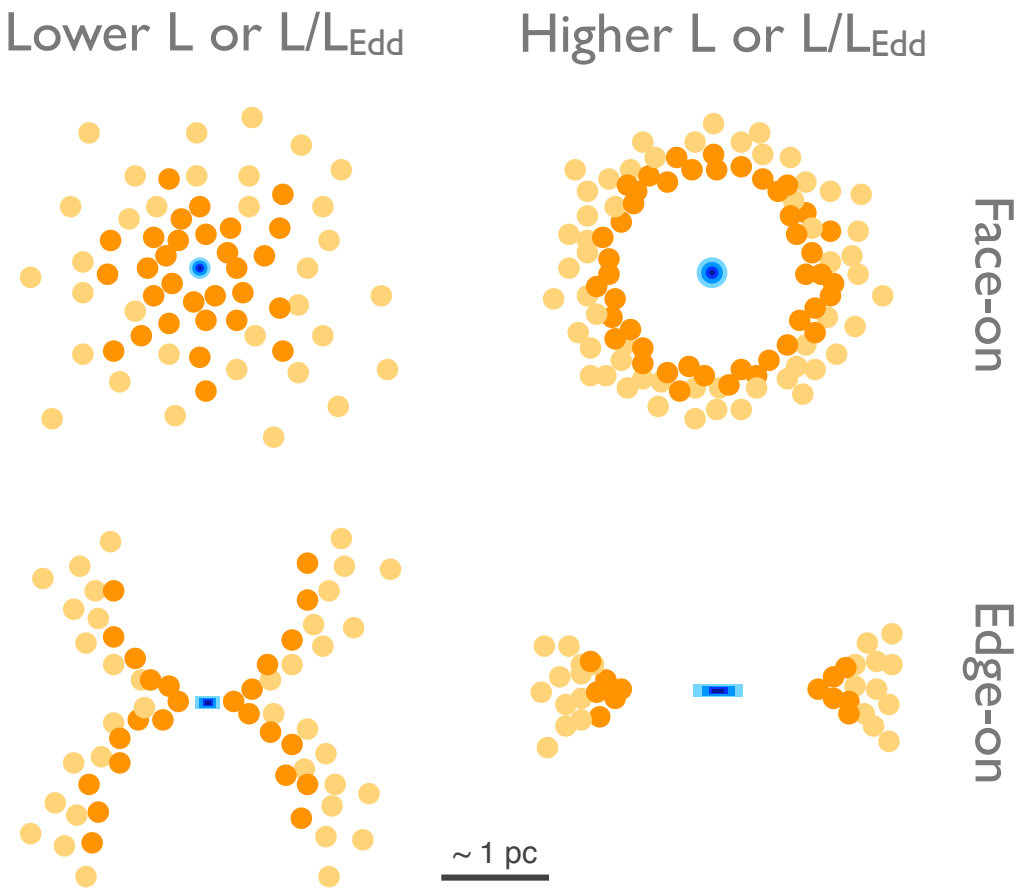
- Consideration on dust illumination
  - near-/mid-IR from directly illuminated material

  - radiation pressure on dust grains (e.g. Semenov+03)
    - eff. L/Ledd potentially > 1

  - possible anisotropic illumination
    - anisotropy of acc. disk (Netzer+85; Kawaguchi+11)

Possible picture

- Lower acc.rate:
  - eff. polar flaring, generally extended
- Higher acc.rate:
  - polar region cleared, equatorial steep struct.

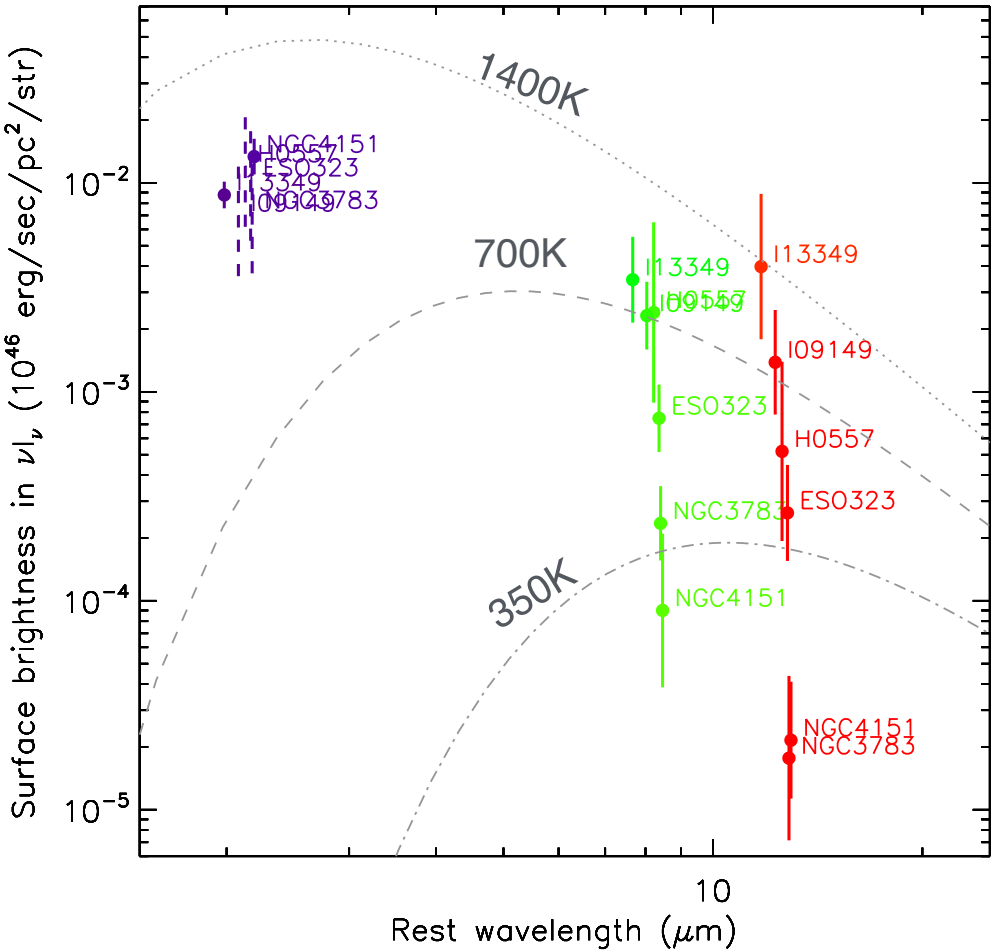


- Intrinsically steeper str. required for higher acc. rate?
  - need to be sensitive to colder material

Emissivity arguments

Emissivity estimation

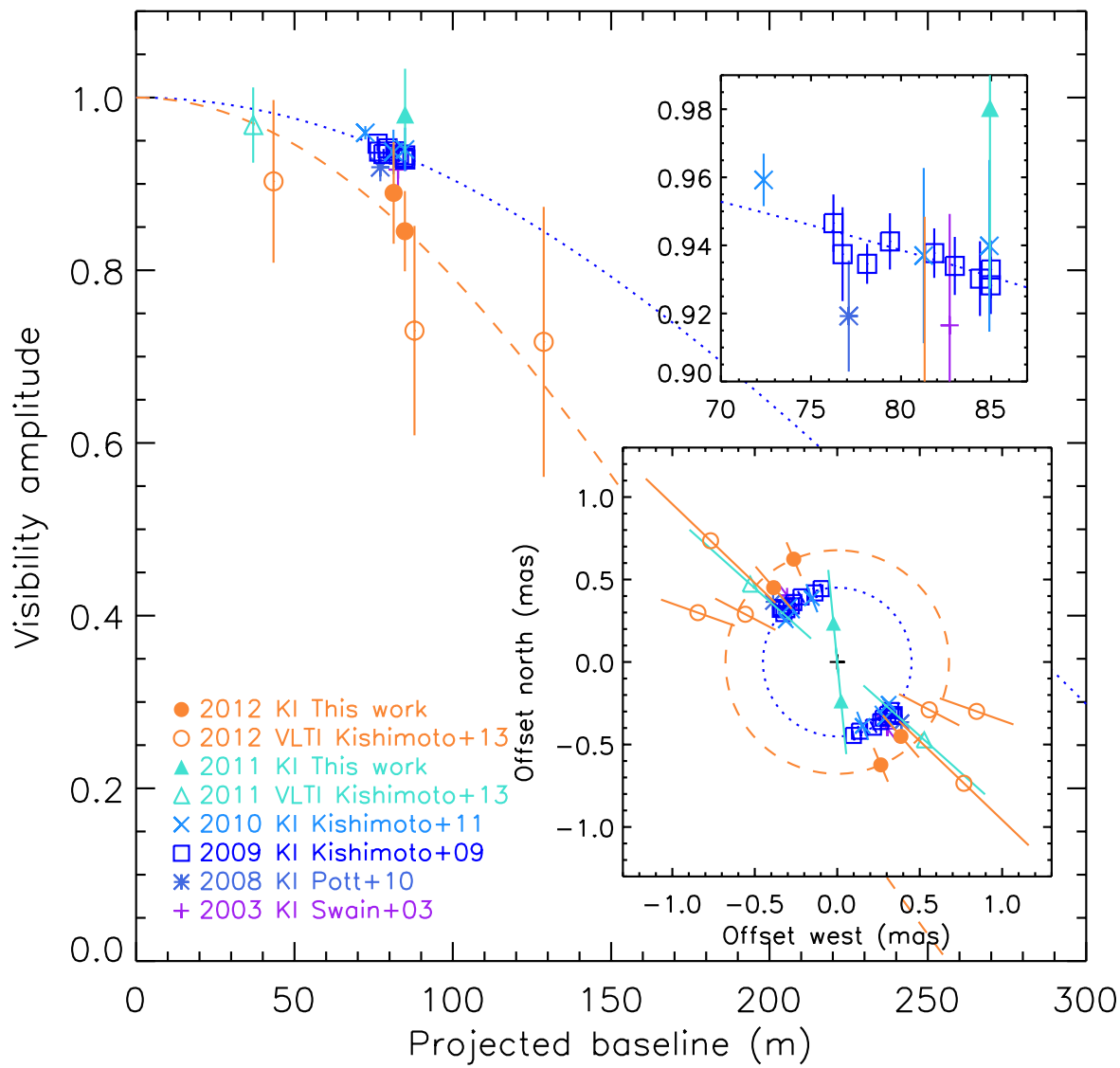
- Surface brightness from measured $R_{1/2}$ and flux
  - comparison to BB indicate emissivity of "sub-unity"
  - consistent with directly-illuminated UV-opt-thick surface
  - participating in obscuring the nucleus
  - very different from resolved NLR clouds



Visibility variability

Evidence for receding sublimation region

- Brightest Type 1 AGN NGC4151
- visibility monitoring : V down = R up = dust destruction



Kishimoto+13

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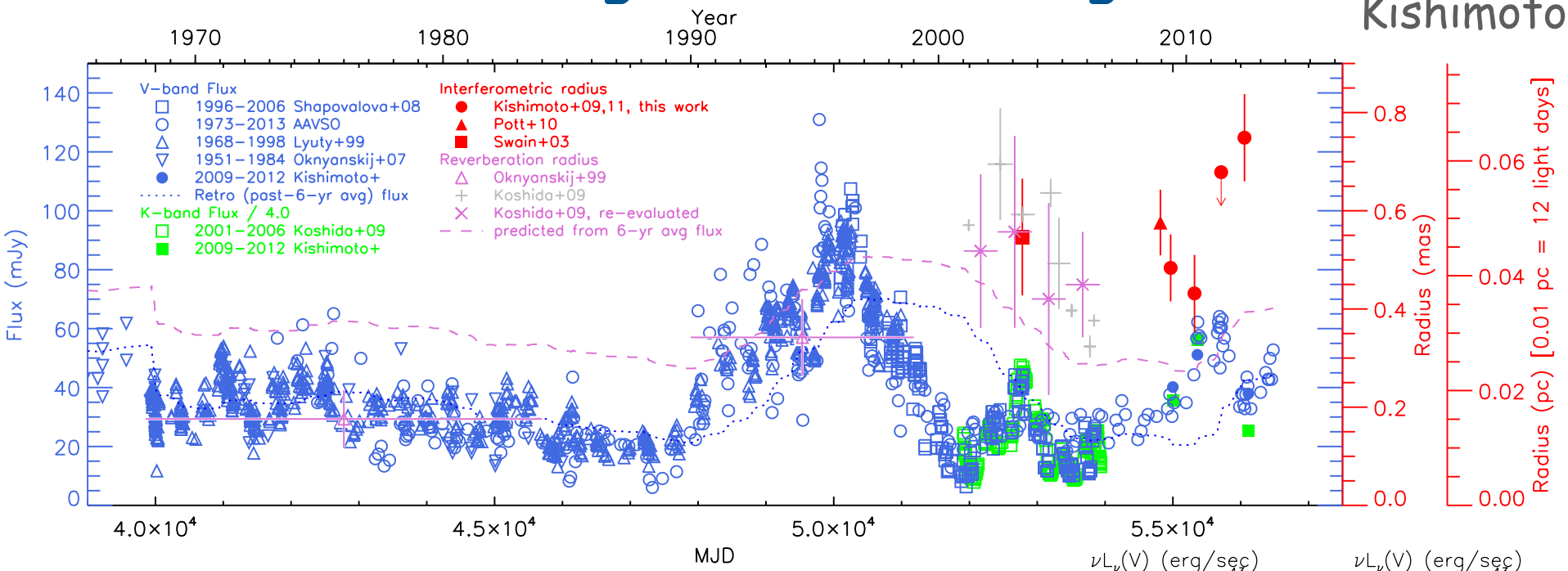
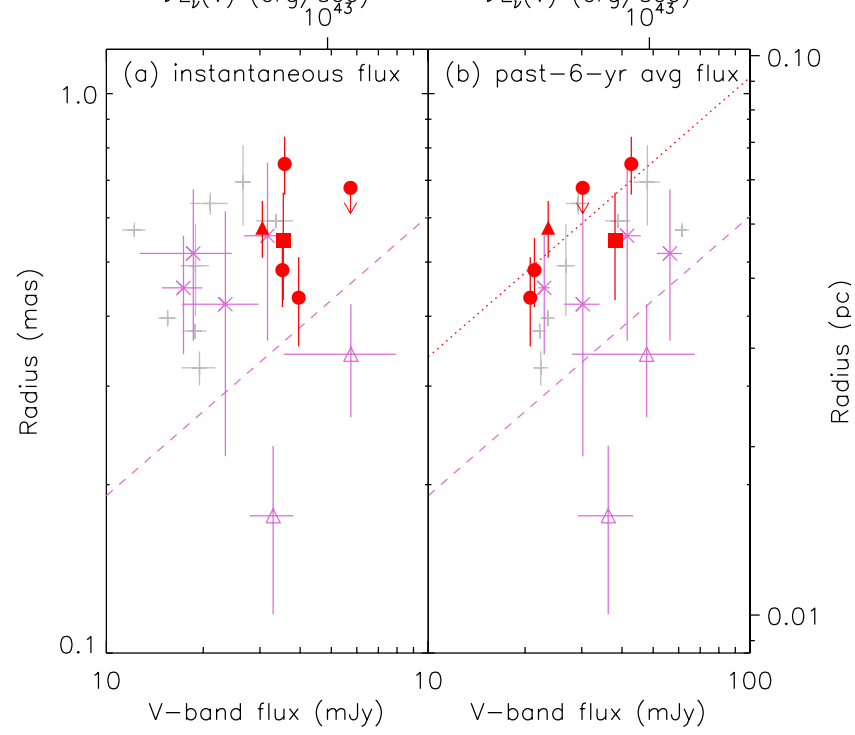
Kishimoto+13



- delayed response to brightening central engine
- timescale for destruction/ reformation of dust distribution ~ several years



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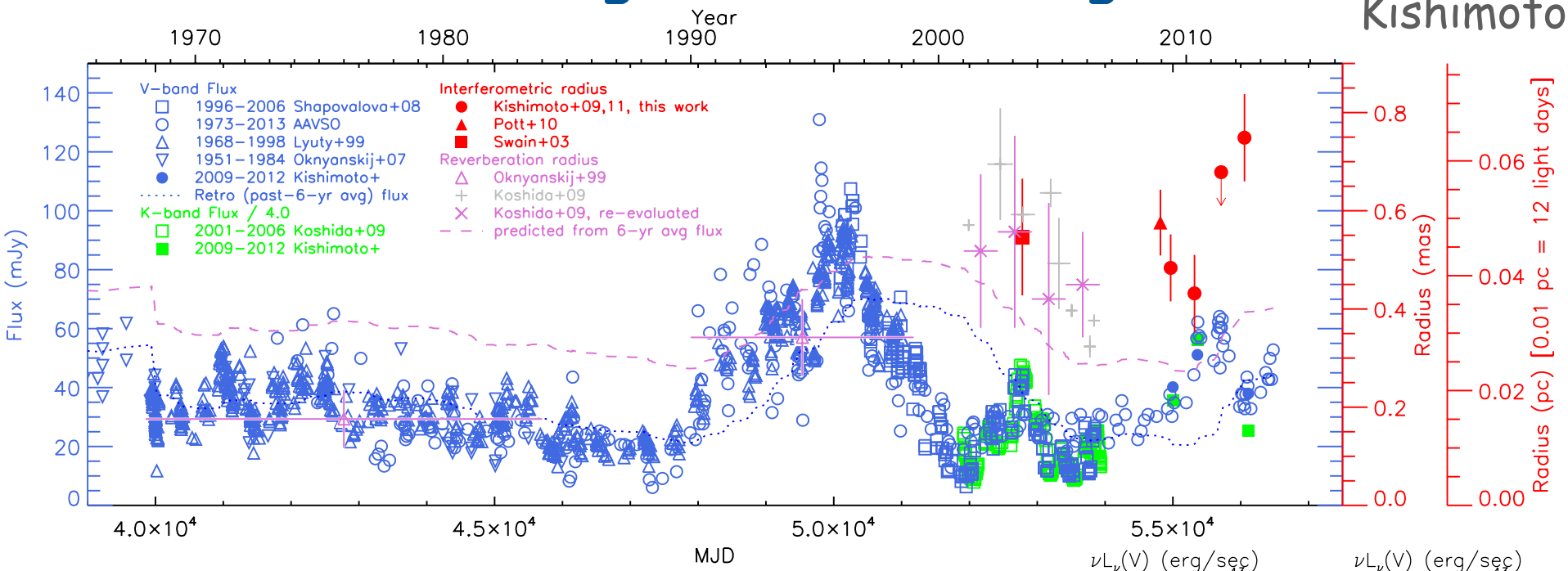
Kishimoto+13

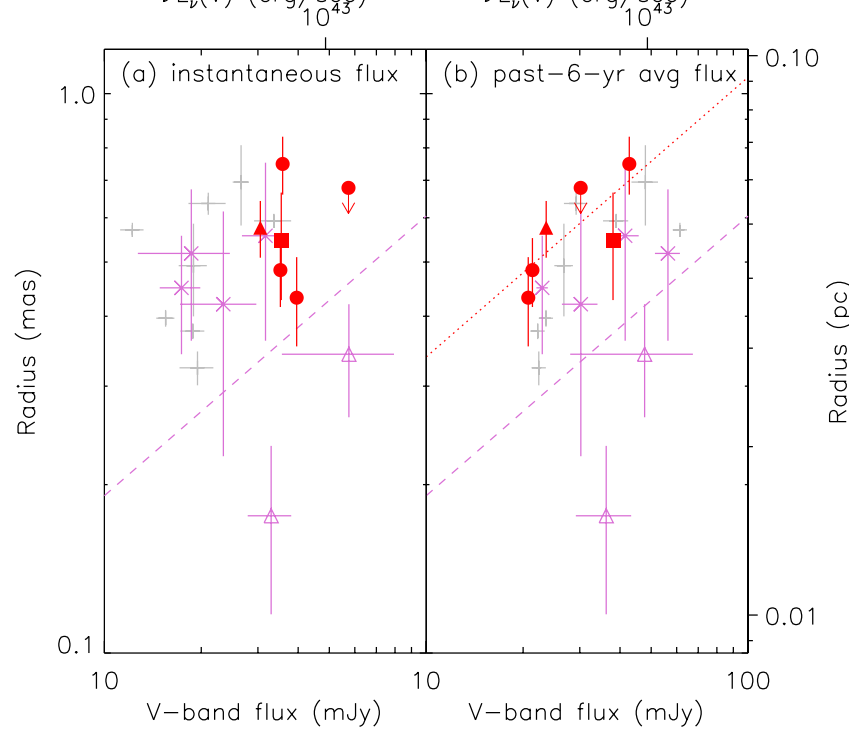


- micro. dest. time ~ 10s of days

$$t_{\rm micro} \sim t_{\rm dist}/\tau_{UV}$$

$$\propto P_{\rm vap}^{-1} \propto n_{\rm gas.dust}^{-1}$$

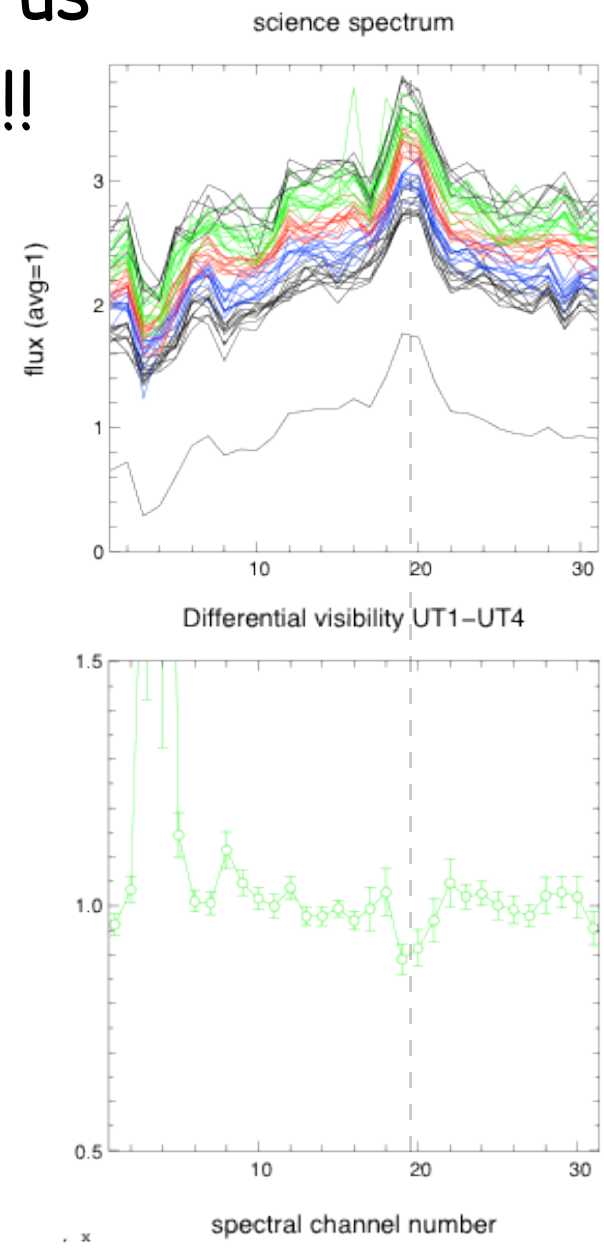
- gas density ~ 10^9 cm^{-3}



BLR vs dusty region

Differential visibility

- Relative size measurement, BLR vs torus
  - in 3C273, it looks like: BLR > torus !!



Petrov+12

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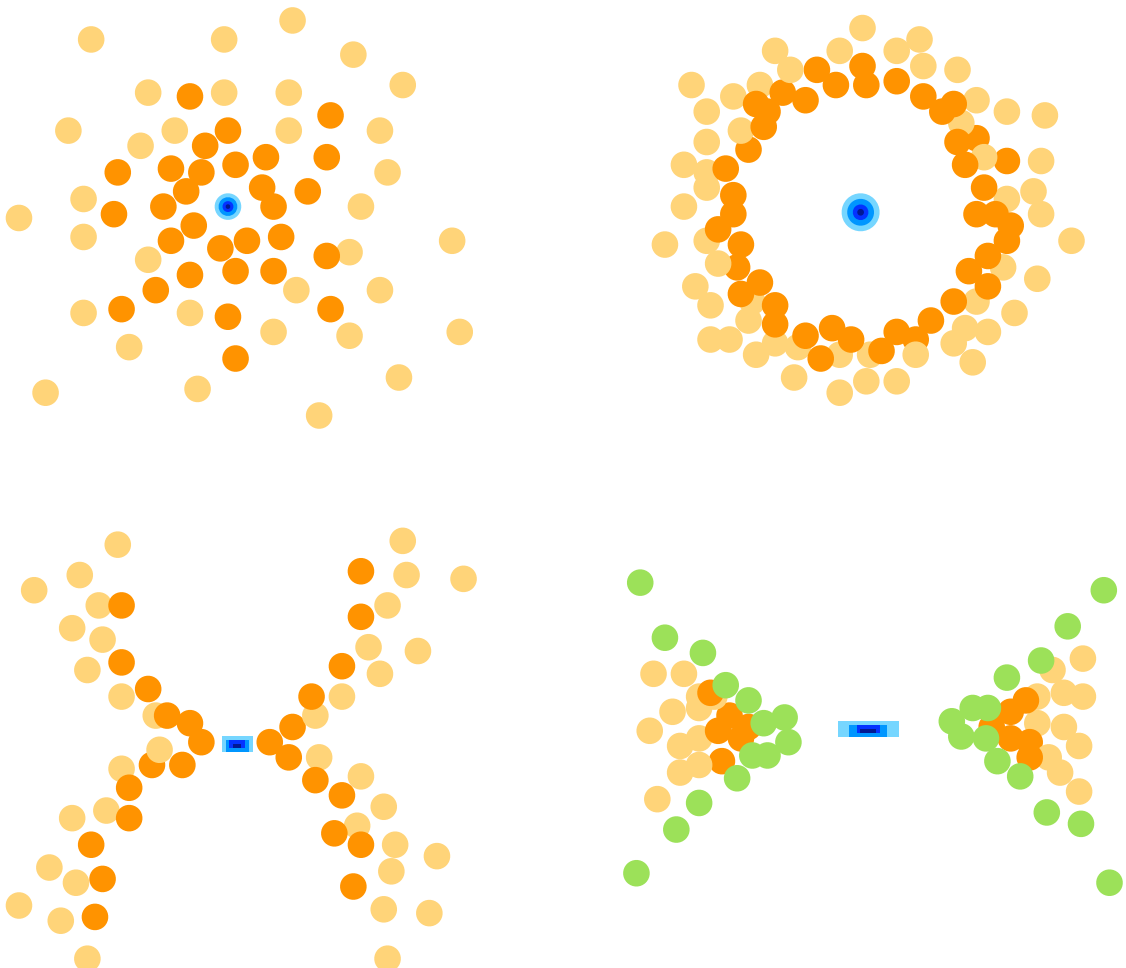

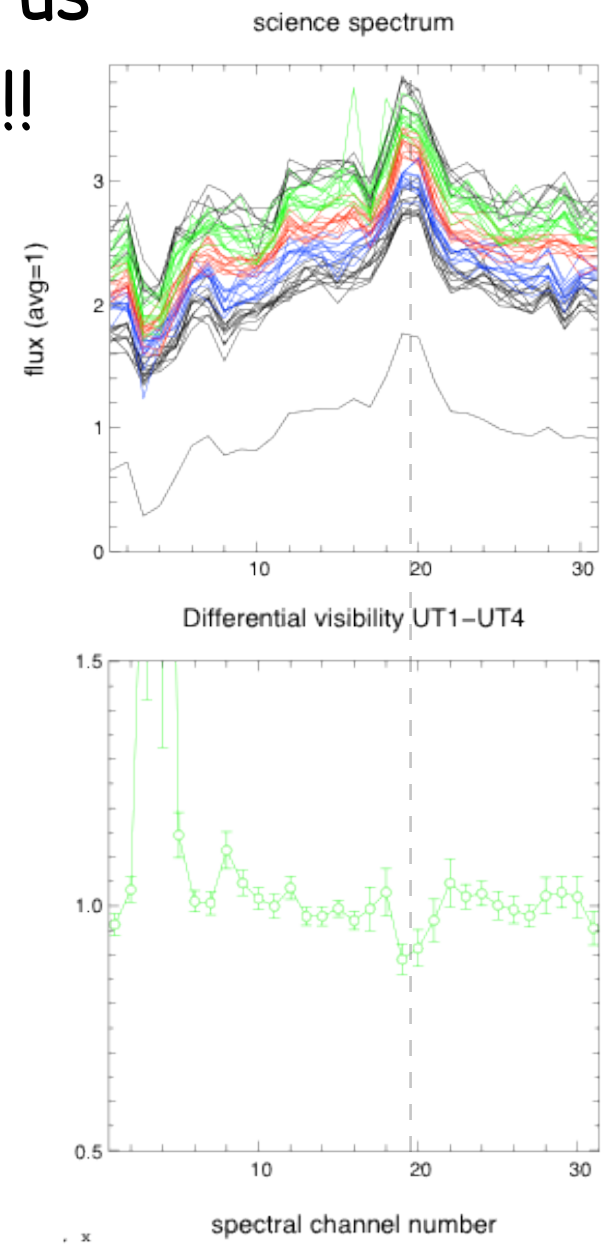

Petrov+12

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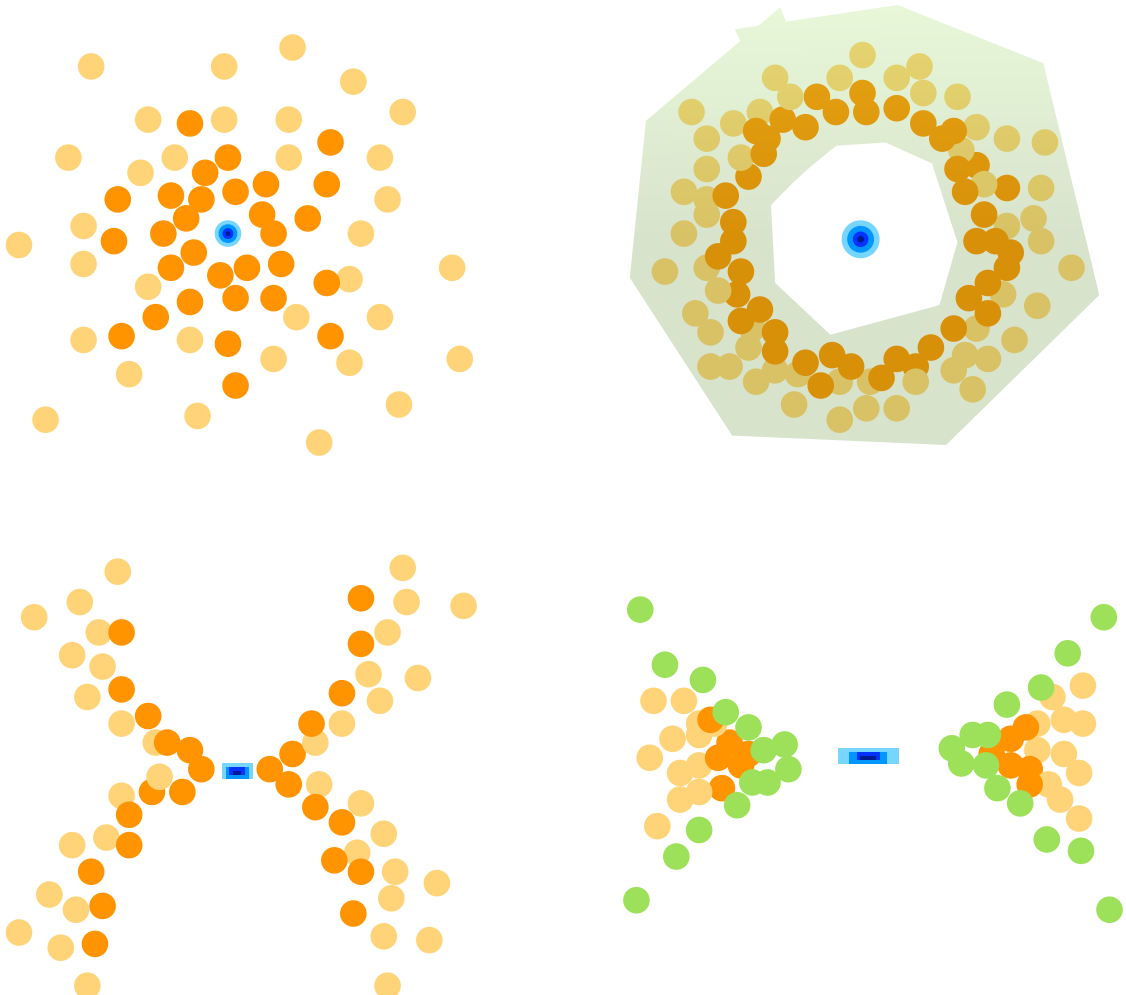

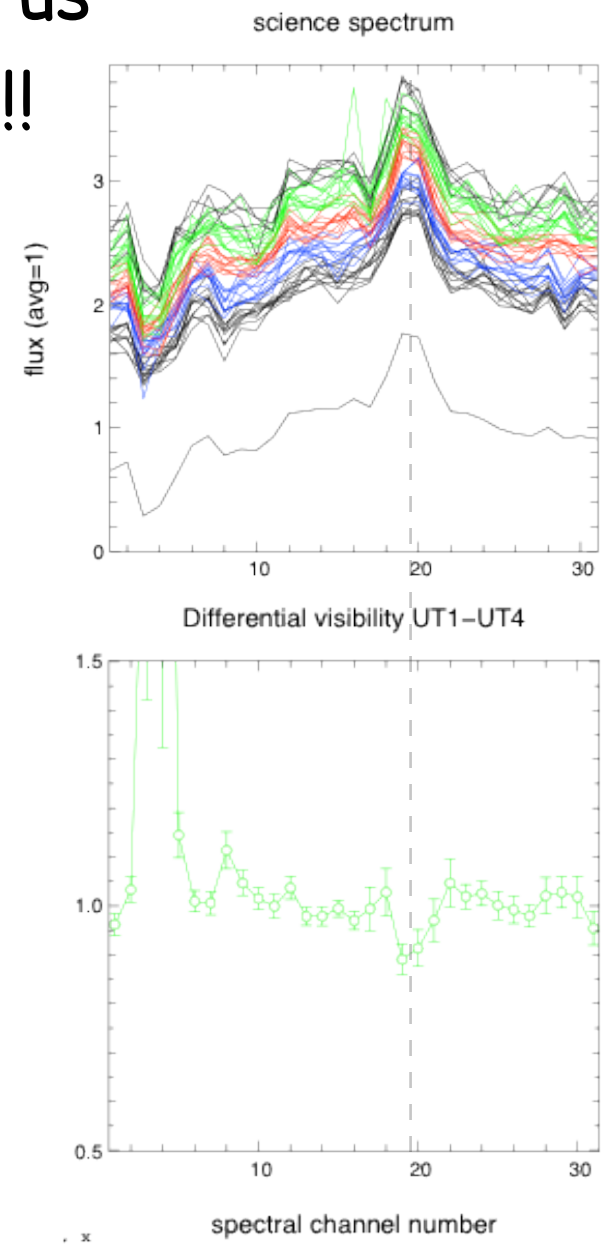

Petrov+12

Summary

- Spatially-resolved view of the innermost dust:
  - Face-on: rad. steeper structure at higher acc.rate, edge-on: eq. conc., polar extension at low acc.
  - polar clearing at higher acc.rate, wider open. angle?

- Emissivity: polar stuff at low acc.rate being opt.thick

- Evidence for receding dust sub region, taking several years: microscopically 10s of days, density ~10^9 cm^{-3}

- Overall BLR can look larger than the inner dust ring...?