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

Makoto Kishimoto

Kyoto Sangyo University, KSU

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

- Image
- Fourier transform
- Fringe amplitude & phase

- Brightness
- Total flux
- Correlated flux
- Unity
- Visibility
- Spatial frequency (cycles / radian)

Angle (radian)
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 \( R_{\text{reverb}} \) - “Brighter-Steeper” trend
- several more (Burtscher+13) + new data: to be uniformly analyzed
Visibilities in mid-IR and near-IR

- Power-law thin-ring
- $r^{-2.6}$
- $r^{-2.0}$
- $r^{-1.5}$

Spatial wavelength ($R_{\text{in}}$)

Visibility amplitude

Spatial frequency (cycles per $R_{\text{in}}$)

Color-coded on Log $L_{\text{UV}}$ (erg/sec)

- 11 $\mu$m
- 2.2 $\mu$m
- 1 $R_{\text{in}}$
- 2 $R_{\text{in}}$
Edge-on, Type 2 studies

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

- Gallimore+04
- Wittkowski+04
- Raban+09

- NGC1068
- Circinus
- NGC424

- Tristram+12
- Hoenig+12

- polar extended at ~20-30 Rsub
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
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

![Graph showing surface brightness in $\nu L_\nu$ versus rest wavelength (\(\mu m\)). The graph includes data points for NGC4151, ESO323, and others, with temperature contours at 350K, 700K, and 1400K.](image)
Visibility variability
Evidence for receding sublimation region

- Brightest Type 1 AGN NGC4151
- visibility monitoring: $V_{\text{down}} = R_{\text{up}} = \text{dust destruction}$
delayed response to brightening central engine

timescale for destruction/reformation of dust distribution ~ several years
Evidence for receding sublimation region

- **micro. dest. time ~ 10s of days**
  
  \[
  t_{micro} \sim t_{dist} / \tau_{UV}
  \]
  
  \[\propto P_{vap}^{-1} \propto n_{gas.dust}^{-1}\]

- **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 !!
Differential visibility

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

![Graphs and diagrams related to differential visibility.](Petrov+12)
Differential visibility

- Relative size measurement, BLR vs torus
- In 3C273, it looks like: BLR > torus!!
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 $\sim 10^9$ cm$^{-3}$

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