The Near-Infrared Broad Emission Line Region of AGN

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**Why near-infrared?**

excellent instruments at excellent sites (<1 arcsec seeing): SpeX on IRTF 3 m, GNIRS on Gemini North 8 m, ISAAC on VLT 8 m

unknown broad emission line region physics
(geometry, kinematics, density, state of ionization)

- near-IR reverberation mapping campaign
- several near-IR lines for photoionization codes
  - unblended hydrogen profile shapes
  - near-IR continuum properties
Near-infrared spectroscopy

SpeX on IRTF 3 m, Mauna Kea, Hawaii
cross-dispersed (0.8 – 2.4 µm)
slit 0.8 x 15 arcsec (R~750)

• 23 well-known broad-line AGN (7/23 NLSy1, FWHM_Paβ<2000 km/s)
• continuum S/N >100
• J<14 mag, on-source ~1 – 1.5 hrs
• 4 observing runs (2004 May – 2007 Jan); ~2 epochs/object
• quasi-simultaneous optical spectra
Near-infrared broad emission lines  

hydrogen:  11 Paschen lines (Paα to Pa14); 5 Brackett lines (Brγ to Br11)
helium:    He I 1.08 µm; He II 1.16 µm and He II 1.01 µm
oxygen:    O I 1.13 µm, O I λ8446, O I λ7774
iron:      several Fe II (Fe II 1.05 µm and Fe II 1.11 µm unblended)
calcium (Ca II triplet) and molecular hydrogen H₂
steps for deriving pure AGN SEDs (0.4 – 2.4 µm)
• relative near-IR photometry using [S III] λ9531
• host galaxy flux subtraction (optical/near-IR aperture ~5)
• accretion disc spectrum used for spectral alignment
The one-micron continuum

accretion disc spectrum dominates at ~1 µm
BB curvature apparent in near-IR after acc. disc subtraction
Hot dust properties


- **Total sample**: $<T_{\text{hot}}> = 1365\pm18$ K, $<C> = 0.07\pm0.02$
- **NLSy1 (7 obj.)**: $<T_{\text{hot}}> = 1354\pm32$ K, $<C> = 0.013\pm0.002$ (higher $\lambda L_{\text{acc}}$)
- **Sy1 (14 obj.)**: $<T_{\text{hot}}> = 1369\pm22$ K, $<C> = 0.09\pm0.02$
The near-infrared virial product

accretion disc dominates at ~1 µm
Paα and Paβ broad-line profiles unblended

near-IR virial product:
\[ M_{\text{BH}} \approx v^2 r/G \]
surrogates:
v: width of broad Paα or Paβ
r: 1µm continuum luminosity

14 obj. with reverberation \( M_{\text{BH}} \)
The near-infrared R-L relationship

slope of logarithmic near-IR radius-luminosity relationship $\sim 0.5$
(independent of host galaxy flux subtraction)
intrisic scatter $\sim 50\%$ (small sample of 14 obj.)
The broad-line region outer radius

Are **all** broad-line profiles intrinsically flat-topped?
If yes, and gravitation dominates, there is an outer radius!
The “disappearing” narrow-line region

higher-order Paschen lines are intrinsically flat-topped

narrow-line can “reappear” in higher AGN state

magenta: Pa9 (3-9)
A broad-line region limited by dust?

- Logarithmic slope $0.56 \pm 0.08$
- Outer radius at same ion. flux $\Phi$
- Broad-line outer radii similar to average hot dust radii