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JWST's little red dots: an emerging population of young, low-mass AGN cocooned in dense ionized gas

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Little Red Dots (LRDs)
- Compact galaxy
- Broad hydrogen/Helium lines
- Extremely weak X-ray and radio emission

⇒ SMBH (overmassive compared to the host galaxy) or intense star formation

Current challenge for LRDs
(1) Too massive SMBH compared to host galaxies
(2) Too high number density in the early universe for there high inferred SMBH mass
(3) Lack of x-ray / radio emission

May be covered by Compton-thick ionized gas (Balmer absorption features are often observed in broad lines) ?

⇒ H α lines profile may be broaden by electron scattering of the thick ionized gas

Data:H α broad line(1000km/s) galaxies with R~1000 spectra
- 12 galaxies at z=3.4-6.7
- stacked spectra of 18 galaxies at z=2.32-6.76
- Additional 2 galaxies with R~2700

Many show compact morphology with typical LRD spectra

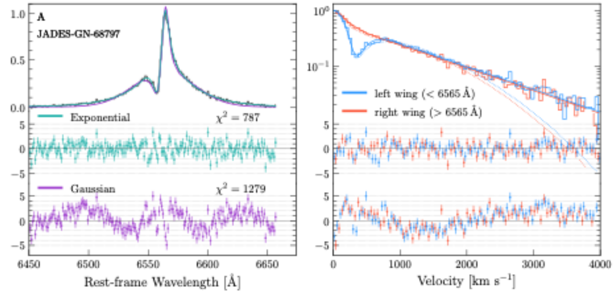

Figure 1: The Hα line profile for GN 1181-68797 (object A) showing the exponential shape of the line. The models in the figure compare the fiducial best-fit model that includes a scattered

Profile shape:
- Electron scattering => Double-sided exponential profile
- Doppler broadening due to gas motion : Gaussian profile
- Raman scattering or turbulence : Lorentzian profile

⇒ All the spectra are better fit by exponential profile (Figure 1)

⇒ Electron scattering, not bulk Doppler motion !

⇒ Not high-mass SMBHs !

Intrinsic line width : 300 km/s for 10 objects (Figure 3)

Ionized gas properties:
- Electron scattering optical depth : tau_e=0.5-2.8
- Column density : N_e=0.7-4.2 e24 (/cm^2)
- No [OIII] : n_e> critical density / 1e6.5 (/cm^2)
  => region size < few hundred light days
  => M_gas<1e5 Msun

Some show P Cyg profile => spherical gas distribution + mild outflow (few 100km/s) : Feedback from starburst?

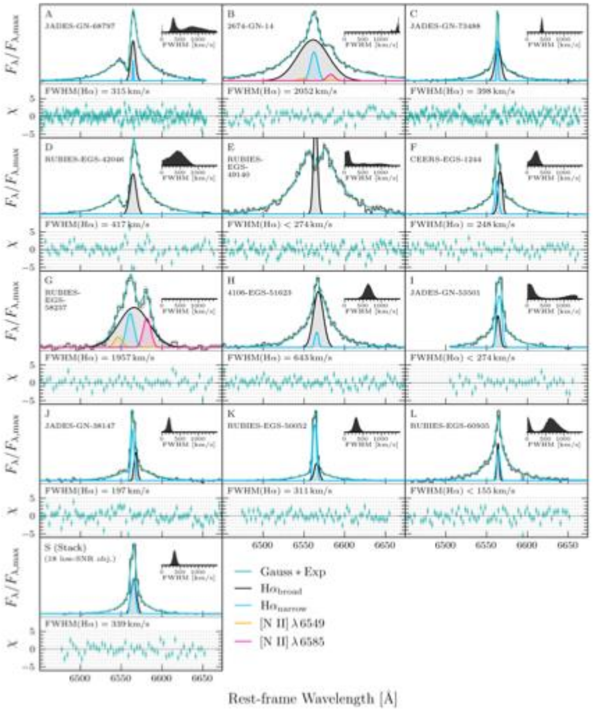

Figure 3: Hα line profiles for the full sample fit with the fiducial scattering model. The total model (cyan line) is the broad scattered and non-scattered components of the intrinsic gaussian line (black line and grey fill), and a narrow Gaussian Hα component from the host galaxy (blue line), as shown in the legend. In

Ionizing luminosity:
- ~1e45 erg/s (⇔ more than 4 order of magnitude higher than known system of 1e41erg/s/pc^2)
- Requires > 1e9 Lsun to keep the above gas ionized
- Impossible for starburst, only AGN is capable (e.g. H α BLR of five light days radius can reproduce above luminosity)

Discussion:
- SMBH mass becomes smaller by ~100 (M_BH=1e6-8Msun) => solves (1) and (2) (Figure 4)
- Compton thick ionized gas
  =>suppress X-ray and radio, but factor of a few
  => intrinsic X-ray spectra of SMBH should be steep
  ⇔ NLS1 (which is believed to be the low-mass / high accretion SMBH) has that property
- Other Implictions
  - There may be a population with higher obscuration, having more suppressed line emission and seen only in absorption
  - young AGNs may universally grows in spherical gas cocoon (instead of well defined accretion disk) with Eddington accretion
  - Gas is not at case B, so hydrogen line ratios cannot be a measure for dust extinction

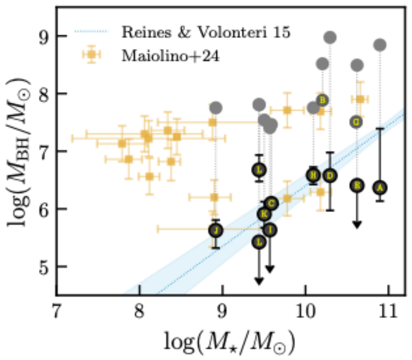

Figure 4: Black hole masses compared to the stellar mass of the host galaxy inferred from SED fitting. The SMBH masses are determined from the Doppler components of our fiducial model