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CENTER FOR ASTROPHYSICS
HARVARD & SMITHSONIAN

Local Broad-Line Blue Compact Dwarf Galaxies, Which Resemble Distant Little Red Dots

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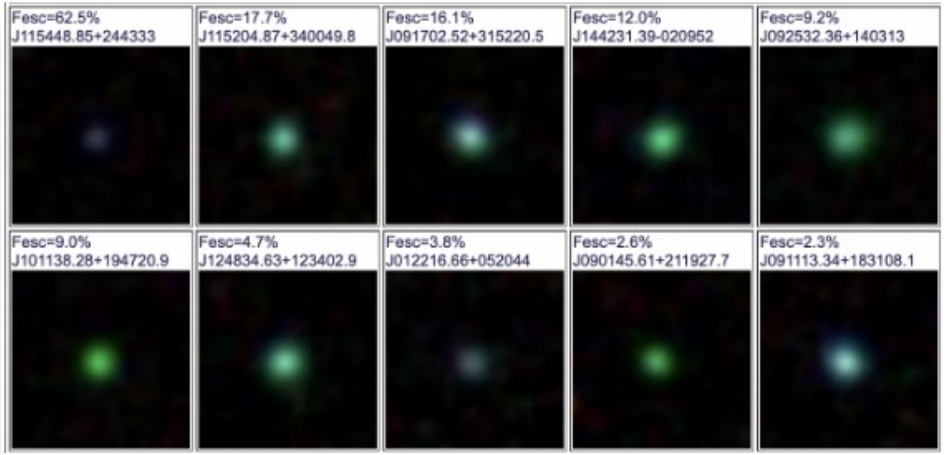
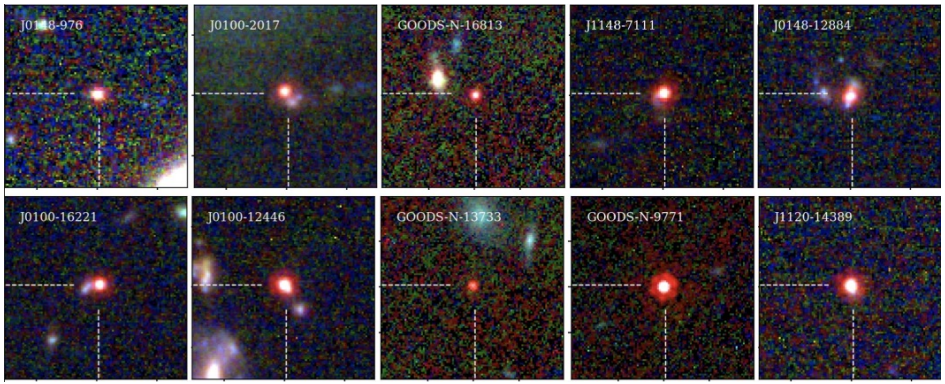
LRDs and BCDs

- BCDs: blue, compact, low-mass
  - Discovered in the 70s (Sargent & Sarle'70)
  - Hypothesized to be young galaxies but shown to be old (Papaderos+96)
  - Extremely high star formation rates and low gas metallicities
  - Re-discovered as "green peas" then "blueberries" in SDSS in the 2000s
  - Sometimes show broad emission lines
  - Ly-continuum leakers
- LRDs: also very compact (<0.2kpc)
  - Discovered in JWST imaging surveys (2023)
  - V-shaped spectral energy distributions
  - Sometimes show broad Balmer lines, large decrement indicative of internal extinction
  - Often thought to be AGN-powered but usually undetected in X-ray



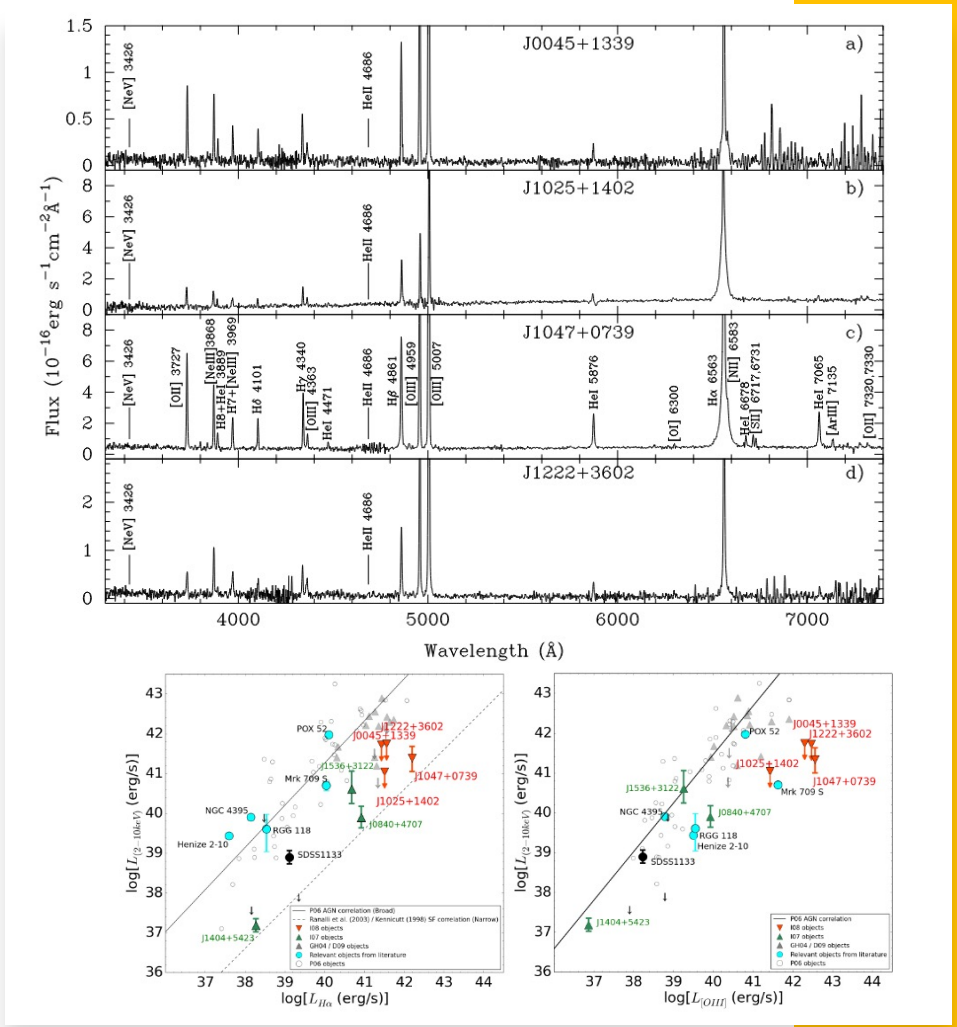
Amorin+2024; see also Lin+2025



Matthee+2024

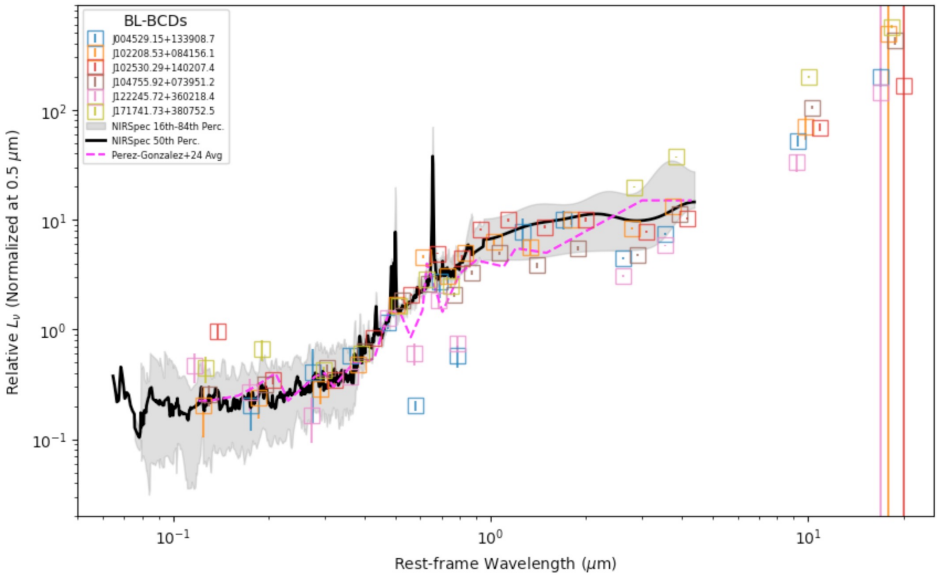
Broad-Line BCDs

- Izotov & Thuan 08:
  - 4 BCDs in SDSS at z=0.1-0.35 were found to have prominent broad Balmer lines; narrow line ratios place them on the star forming sequence in the BPT diagram (top-left corner)
  - Point sources
  - Hypothesized to be low-metallicity AGN in dwarf galaxies
  - CAVEAT: broad-lines in starburst galaxies can be transient (SN-IIn), see Baldassare+15
- Simmonds+16
  - Persistent broad Hα: not a supernova
  - No X-ray (upper limit at least 1 order of magnitude below the expected flux level from the optical/X-ray AGN correlations)
- We found two additional BL-BCDs in SDSS/eBOSS and DESI DR1
  - Follow-up spectroscopy (Magellan MagE/FIRE)



BL-BCDs vs LRDs: SEDs

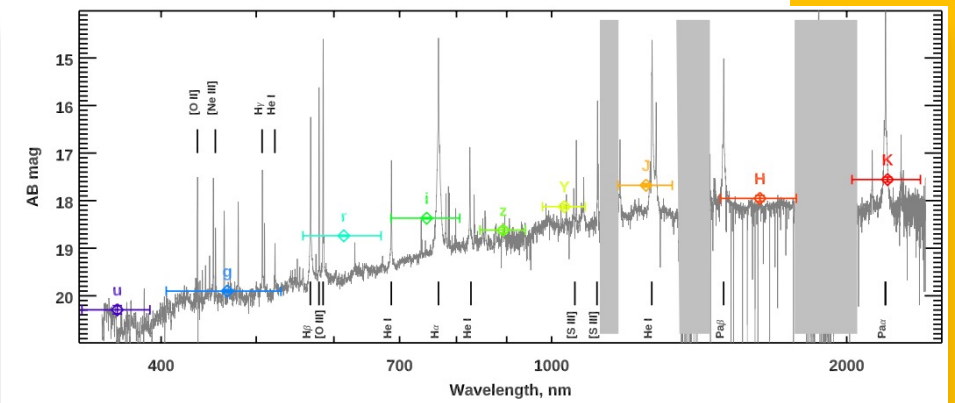
- Look very similar
  - V-shaped in F_λ
  - Strong mid-IR excess
  - Saw-like shape (because of high equivalent widths of emission lines)
- 2 out of 6 BL-BCDs are faint in the bands falling ”between” bright emission lines: low continuum level

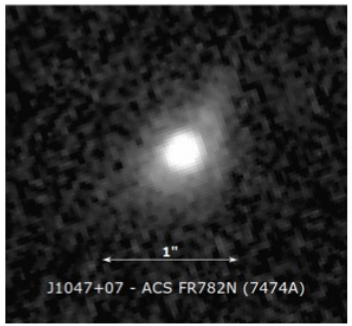


BL-BCDs: GALEX, SDSS/DECaLS, UHS, WISE

J1047+07 (z=0.17)

- Stellar absorptions: not detected
- "Regular" broad Hα
  - FWHM = 2600 km/s
  - $L_{H\alpha}=2*10^{42}$ erg/s
  - Hα/Hβ suggests A_V=1…2 mag
- Broad HeI lines (FWHM = 1000 km/s)
- HeI 1.083μm (metastable)
  - Narrow central absorption: slow gas inflow
  - Broad blueshifted absorption: fast outflow
- Paschen lines are strange
  - Broad blueshifted absorption
  - Paα/Paβ ~ 1: collisional excitation
  - Different abs. velocities in Paα and Paβ



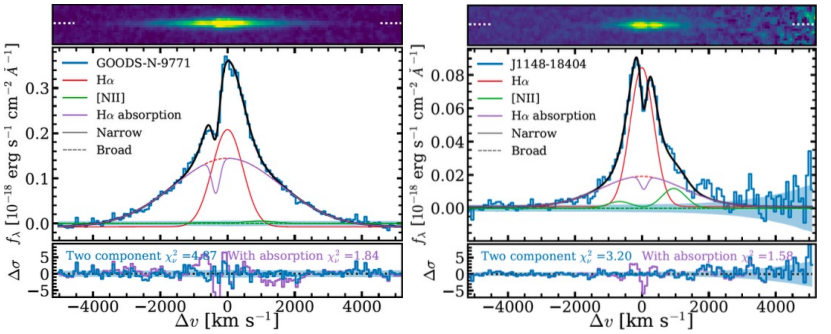


Size: <70 pc
95% of Hα unresolved

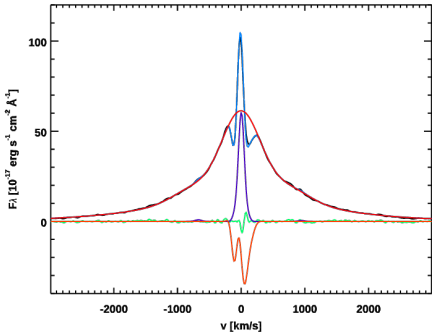
BL-BCDs vs LRDs: Hα

- Self-absorptions
  - Blue (P-Cyg like)
  - Both blue and red
- High gas densities (10^{10}-10^{11} cm^{-3}) are required
  - Forbidden lines are formed elsewhere
  - These BL-BCDs exhibit high Balmer decrements (~20) and display a NaD absorption feature

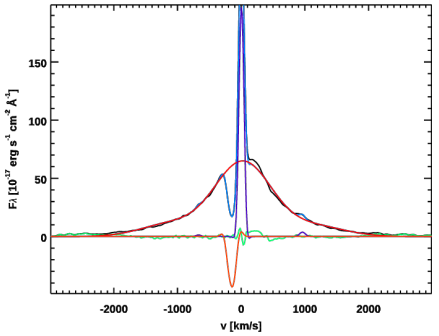
Matthee+2024



J1022+0841 (MagE)



J1025+1402 (MagE)



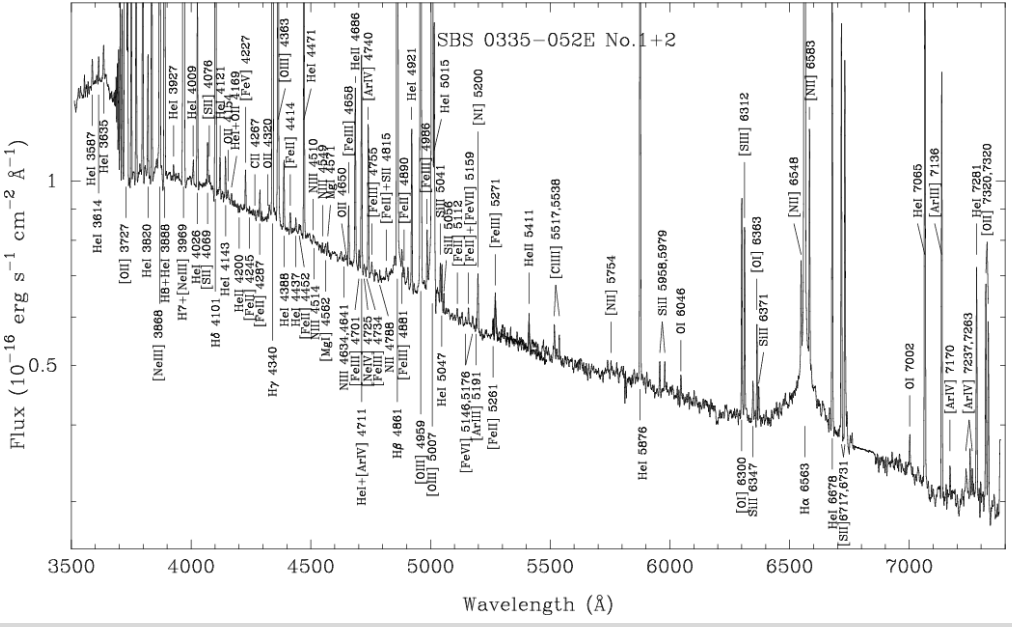
Summary (Jun/2025)

- Low-*z* BL-BCDs share most of their properties with high-*z* LRDs
  - X-ray weak/undetected
  - Very small sizes (unknown radius!)
  - BPT: top-left corner of the SF sequence
  - Non-detection of stellar absorptions
  - Often strange velocity structure of broad lines (blue self-absorption)
- BL-BCDs are rare unlike LRDs
  - Surveys select against them because of extremely weird optical colors
  - Those found were observed ”by mistake” as intermediate-redshift QSOs

- BL-LRDs are not normal AGN
  - HeI is expected to be broader than Hydrogen lines but it’s narrower
  - Self-absorptions in “narrow” lines require high densities (10^{10}-10^{11} cm^{-3})
- Possible models
  - BH with an accretion disk truncated inside
  - No BH at all: everything is a massive super-wind from a compact starburst (O/B stars can have outflows of 3000-4000 km/s)
- Path(s) forward
  - Far-UV spectroscopy: stellar/ISM features
  - Mid-IR spectroscopy: PAH or coronal lines

AGN or not?

- Not everything that has broad Balmer lines is an AGN!



BCG

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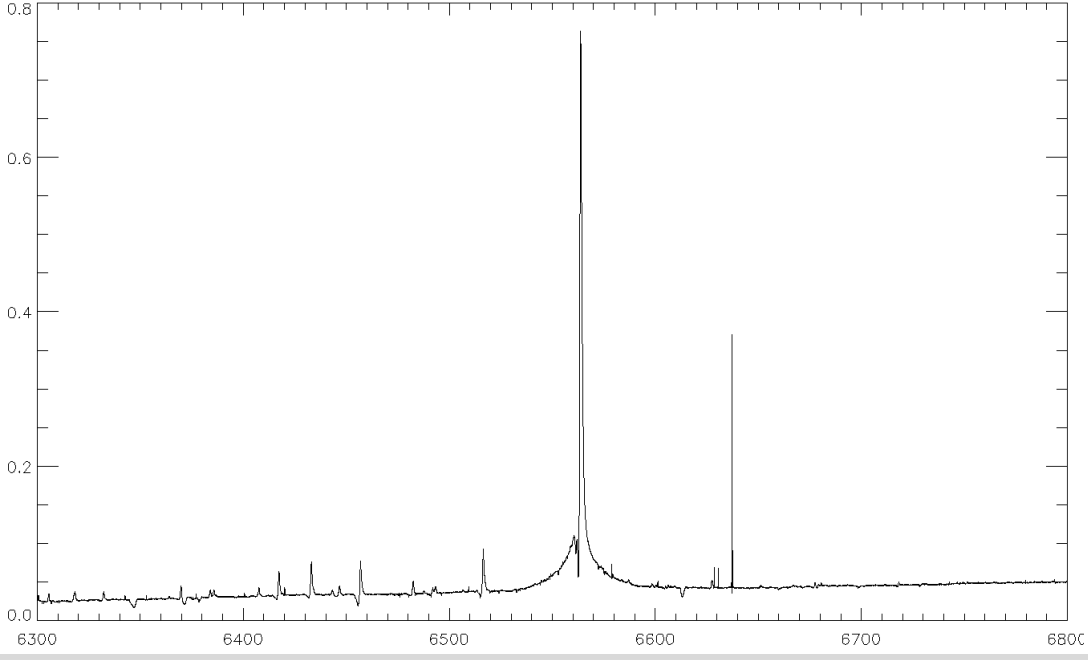
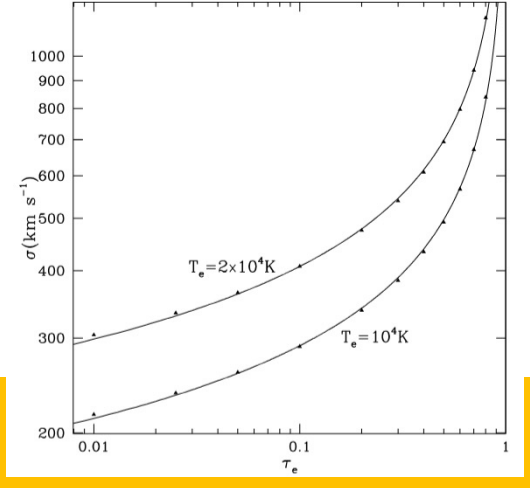


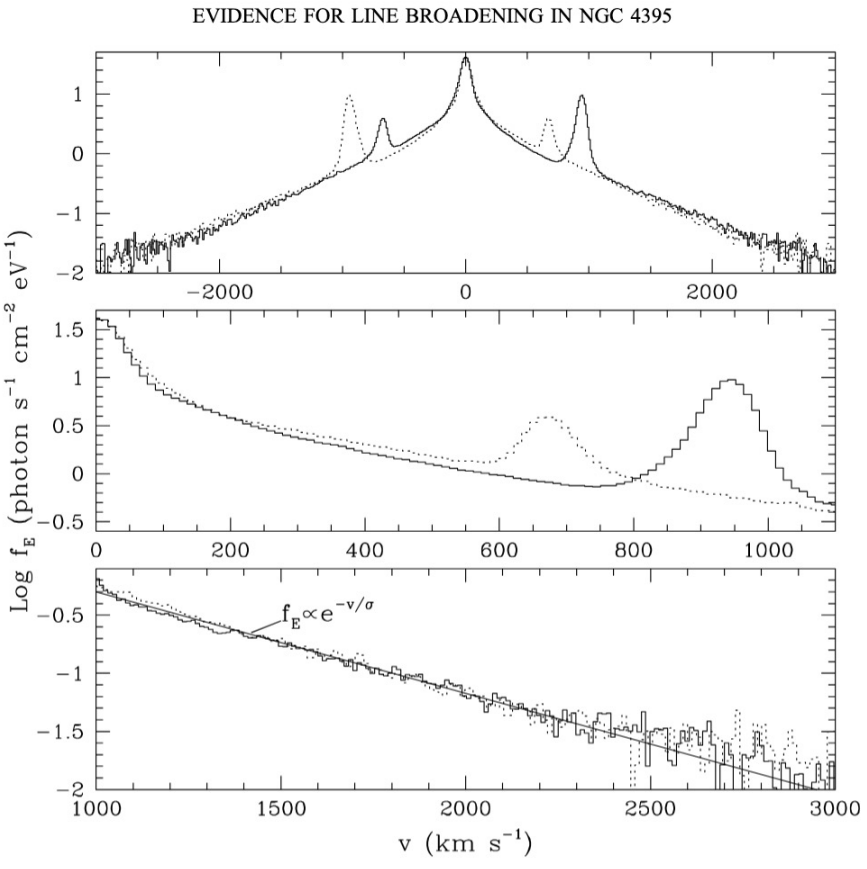
Evolved Yellow hypergiant IRAS17163-3907 (20-30 M_{Sun})

Ha flux + width naively plugged into an AGN virial relation for black hole masses yield… 100000 M_{Sun}

Origin of broad lines

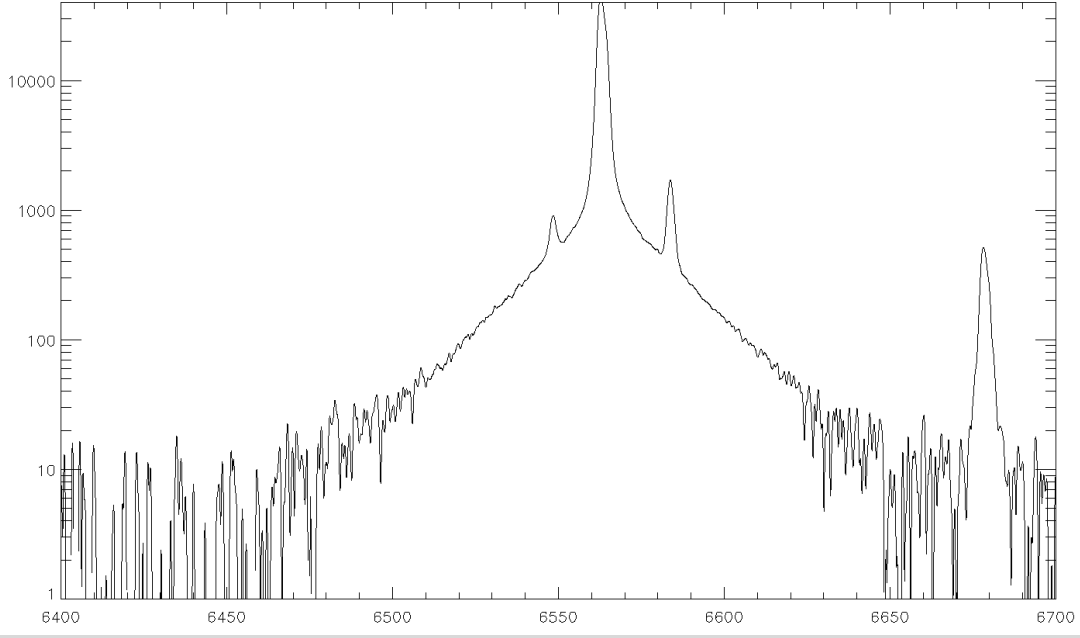
- Exponential wings from optically-thin electron scattering (Laor 06)
- Weak dependence on τ
- Strong dependence on T_e





Exponential wings in an “LRD”

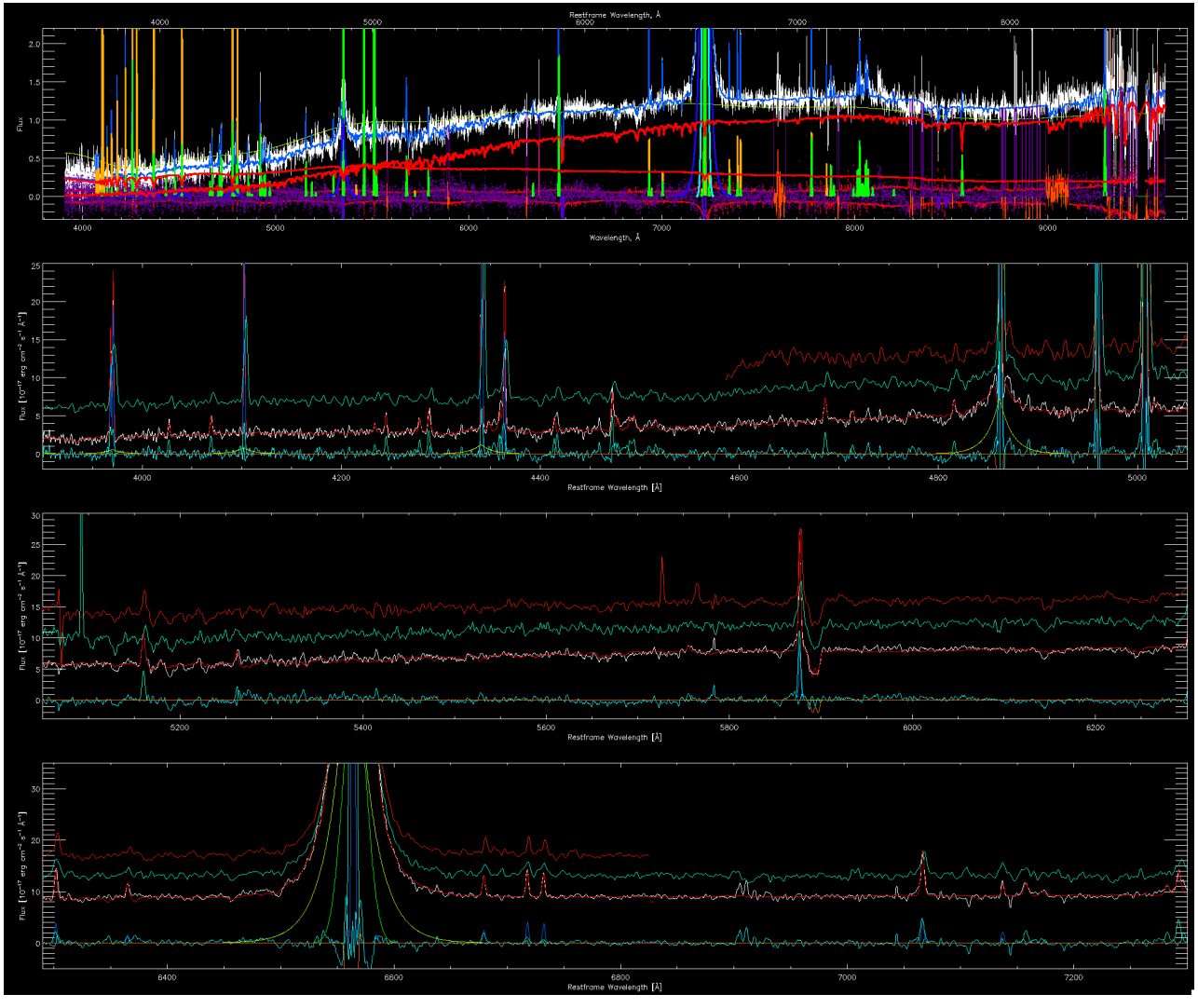
- Tol 2240-384 (also discovered by Izotov+09)



VLT UVES spectrum
T_e=7000-8000 K for
reasonable values of τ

J1025+14: photospheric absorptions

J1025+14 (see also Lin+25, Ji+25)



Absorption features in J1025+14

- NaD + KI: high column density on the line-of-sight ($N_H > 10^{22}$)
- Photospheric absorptions: no neutral lines, not even Mg*b*
- Most prominents features are FeII, some are (likely) BaII, TiII, SII, NeII
- No MgII lines; no carbon
- The spectrum looks like a moderately attenuated late-A/early-F star
- Working hypothesis: a supermassive star!

Z>0 supermassive stars

- Gieles+18: metal-enriched supermassive stars may exist and grow by runaway collisions in dense star clusters
- Nandal & Chon 26: growth by gas accretion; collisions play a minor role
  - >50000 M_{Sun} stars collapse because of GR instabilities
  - <50000 M_{Sun} stars reach core He burning

Metallicity	Accretion	Final Stage	Comments	X_{ini}	Y_{ini}	Z_{ini}	M_{final} ($M_\odot$)	t_{final} (Myr)
$10^{-5}\,Z_\odot$	Variable	GR inst.	Baseline model	0.751600	0.248400	1.4×10^{-7}	72,492	1.948
$10^{-4}\,Z_\odot$	Variable	GR inst.	Baseline model	0.751597	0.248402	1.4×10^{-6}	82,193	1.962
$10^{-4}\,Z_\odot$	Variable	GR inst.	$\dot{M}_{crit}$ test	0.751597	0.248402	1.4×10^{-6}	⋯	⋯
$10^{-4}\,Z_\odot$	Variable	GR inst.	Wind pres.	0.751597	0.248402	1.4×10^{-6}	⋯	⋯
$10^{-3}\,Z_\odot$	Variable	Core He-b	Baseline model	0.751568	0.248418	1.4×10^{-5}	32,629	2.029
$10^{-2}\,Z_\odot$	Variable	Core He-b	Baseline model	0.751284	0.248576	1.4×10^{-4}	2270	1.829
$10^{-2}\,Z_\odot$	Constant	Core He-b	Time avg. $\dot{M}_{acc}$	0.751284	0.248576	1.4×10^{-4}	⋯	⋯

Note. Each model starts from a 10 $M_\odot$ fully convective seed.

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