Strongly-lensed background sources and their “contaminants”

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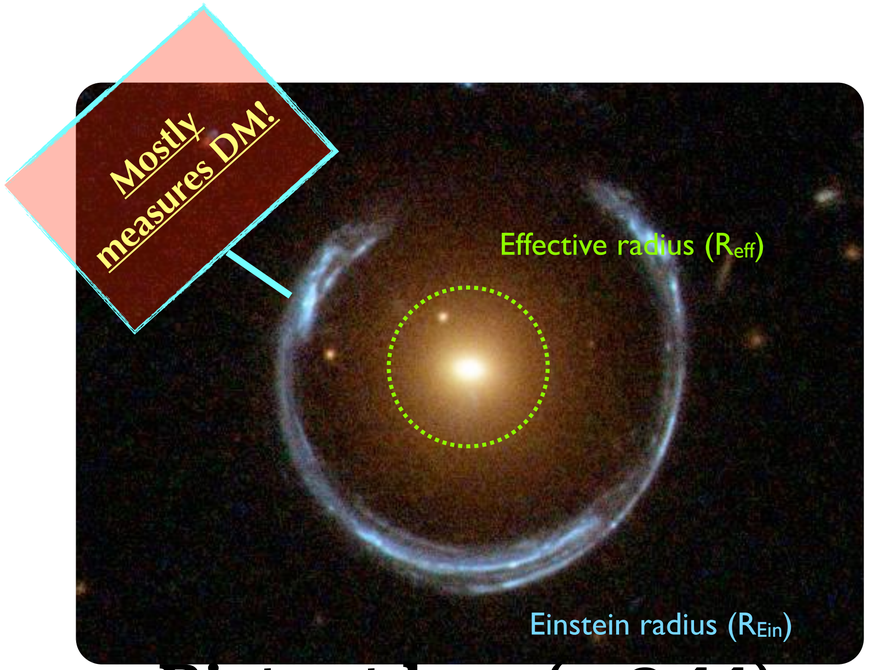
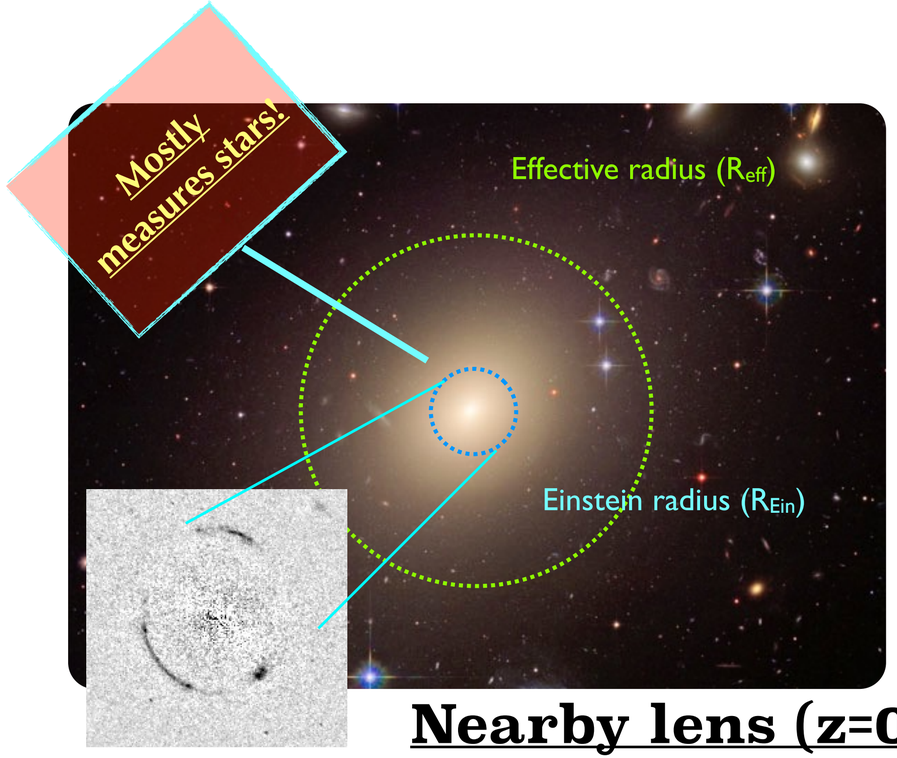
Nearby Strong Lens Search with MUSE

Gravitational lensing by <u>nearby</u> galaxies:

- **Arcs form at smaller radius in kpc terms than in distant lenses.**
- **Dark matter contributions to lensing mass are smaller than in distant lenses.**
- **Lensing mass reliably dominated by stars :— weighing the IMF in ellipticals.**
- **Challenge: to detect faint sources behind very bright lens emission <- IFUs**



<u>Distant lens (z=0.44)</u>



<u>Nearby lens (z=0.03)</u>

Nearby Strong Lens Search with MUSE

Use IFUs (MUSE, but also SINFONI, Subaru-FOCAS, MaNGA etc), to detect lensed background line emission sources.

Combination of spatial and spectral contrast detect rich screen of background sources unreachable with broad-band imaging.

And immediately get the redshifts which are required for the mass estimate.

Collier et al. MUSE search : new observations in “filler” mode supplemented with archival search programme.

J0403-0239:

Collier, RJS & Lucey (2020);
Galbany et al. (2018)

Bright lensed sources are very rare …

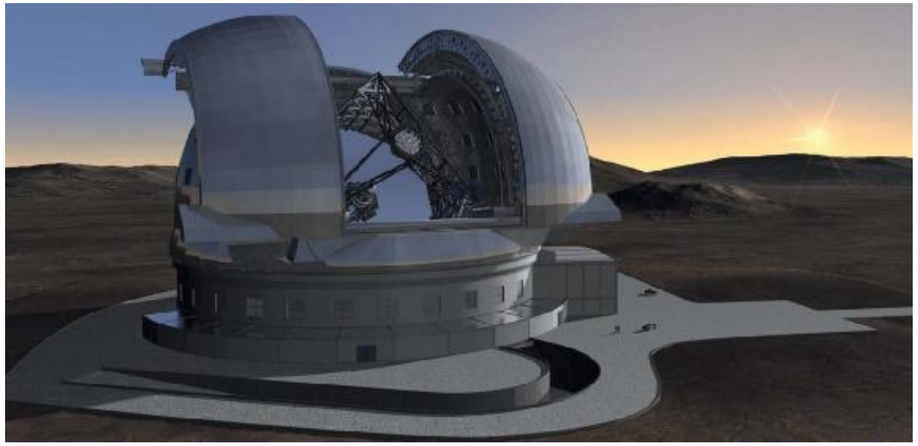
Nearby Strong Lens Search with MUSE

Bright lensed sources are very rare …

… but faint sources are everywhere.

Every galaxy is a strong lens if we observe for long enough.

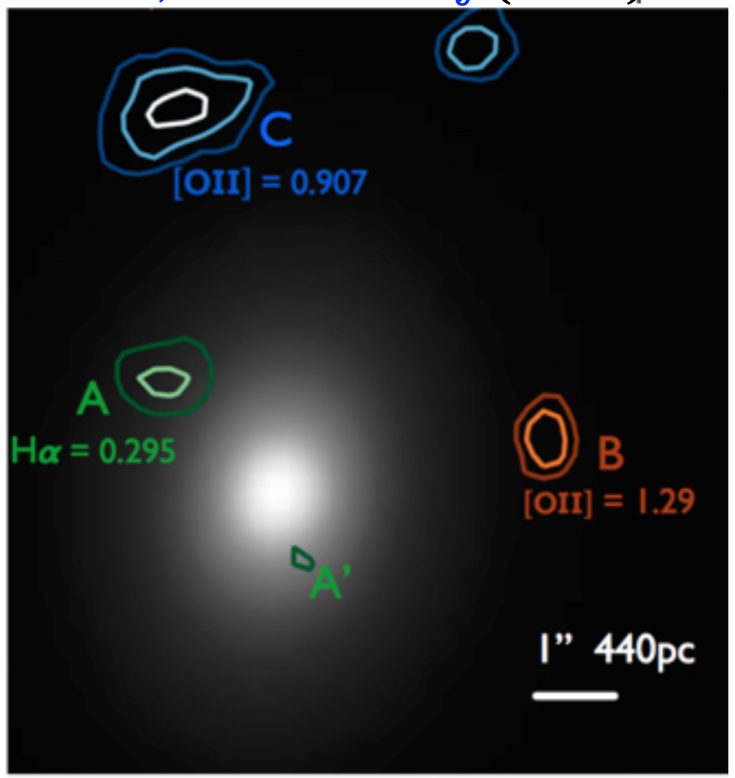
- Already demonstrated: MUSE deep fields (10-30h) have one emitter per ~24 arcsec²… = 1 per multiple-imaging cross section for a 300 km/s isothermal lens.
- (And this does not include boost from lensing magnification.)

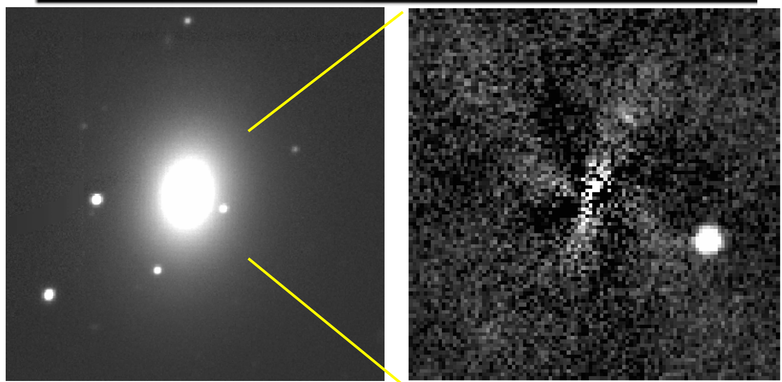


- *10-30h VLT => ~1hr exposure with ELT.*
- In IFU observations with ELTs, all massive galaxies should be surrounded by lensed background sources.

J0202-5055: z=0.021

Collier, RJS & Lucey (2020)

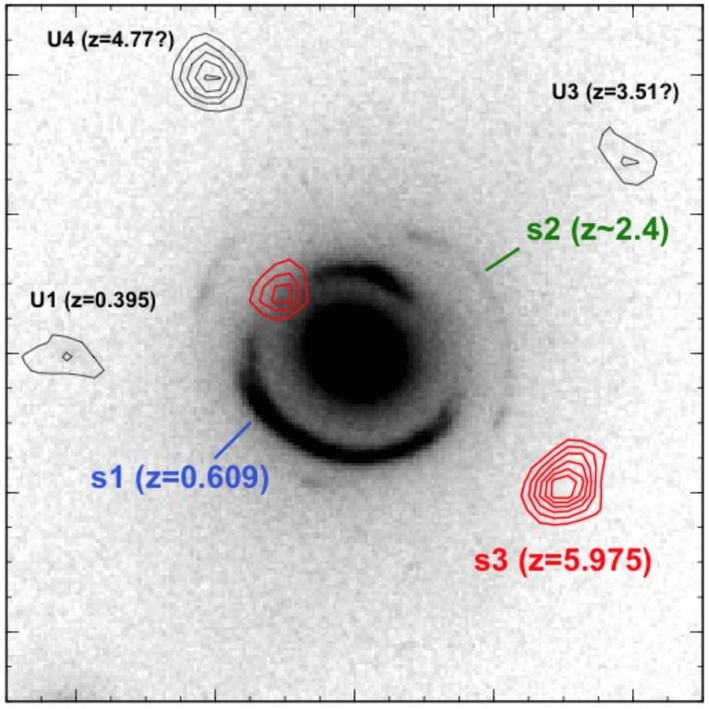




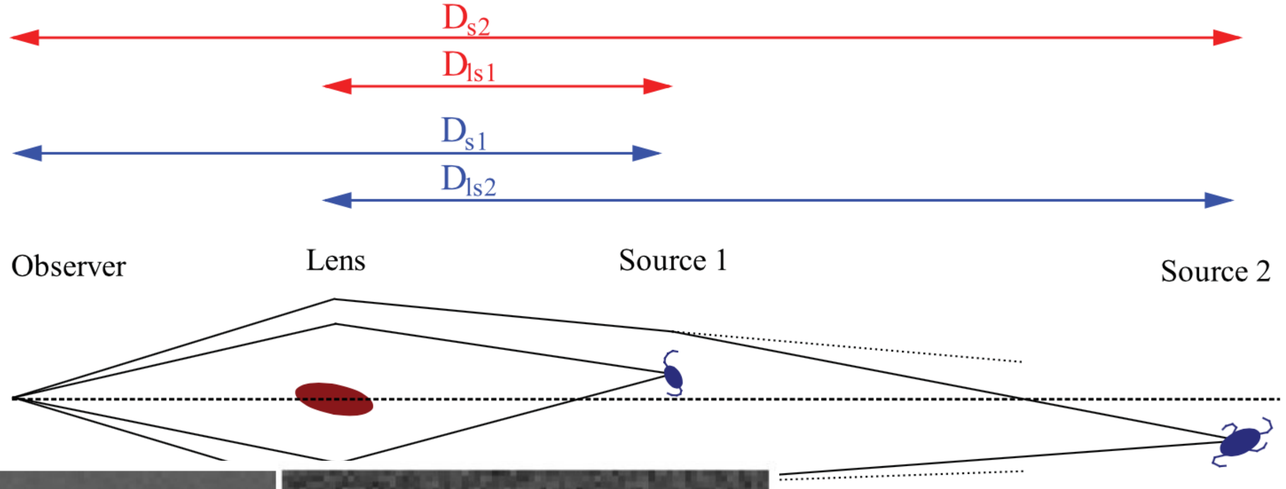
The Double-Source-Plane Lens Factory

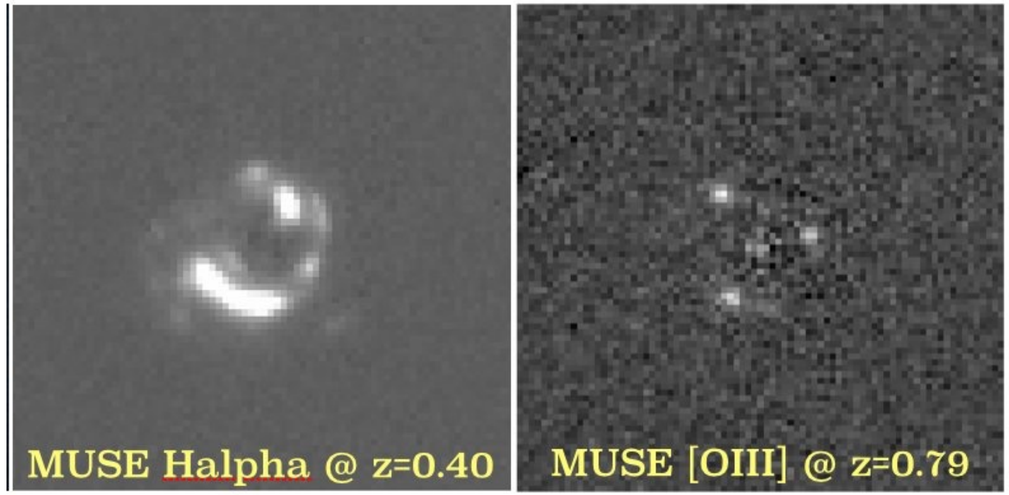
Can convert any galaxy into a lens, but also find new sources behind any existing lens. For suitable z configurations, this gives geometric measurement of cosmological parameters, e.g. w_{DE}, with sensitivity comparable to other methods; independent systematics.

Collett & RJS (2020)



A *third* source-plane at z~6 in Jackpot lens (from 5hrs w/WFM-AO)





… And more examples coming from MUSE DSLP Factory programme P106

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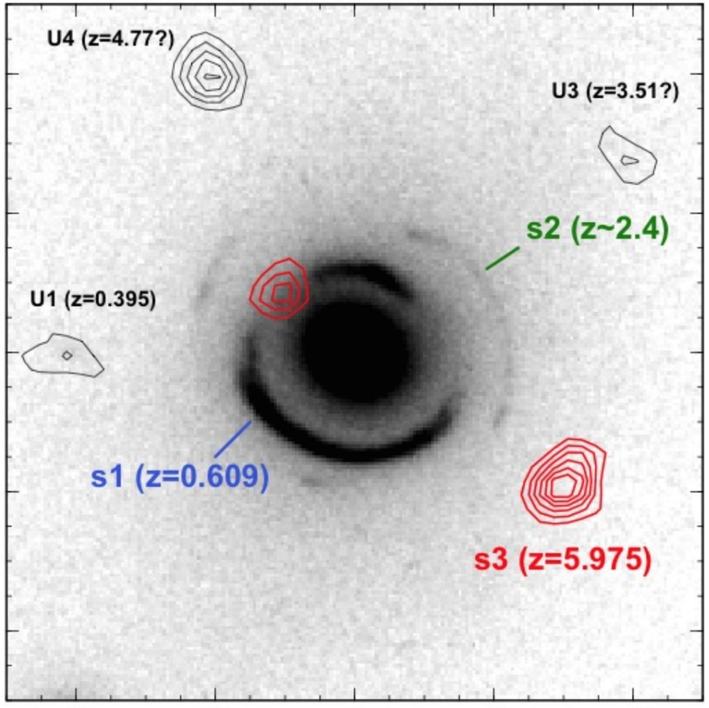

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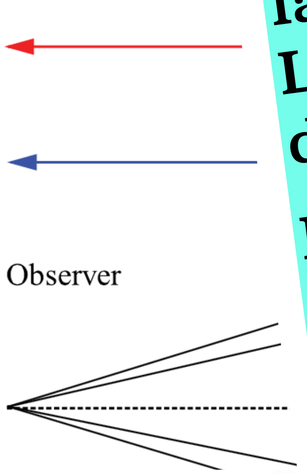


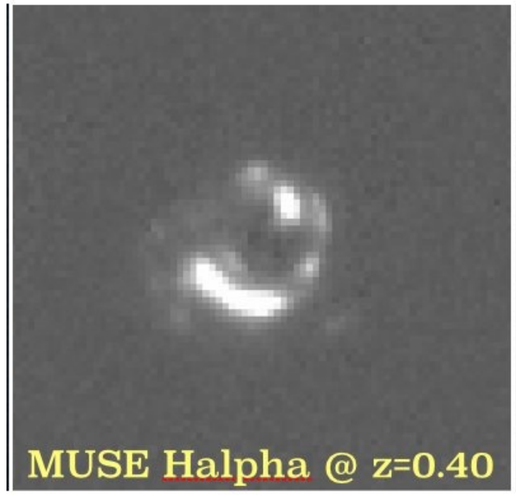
BlueMUSE?

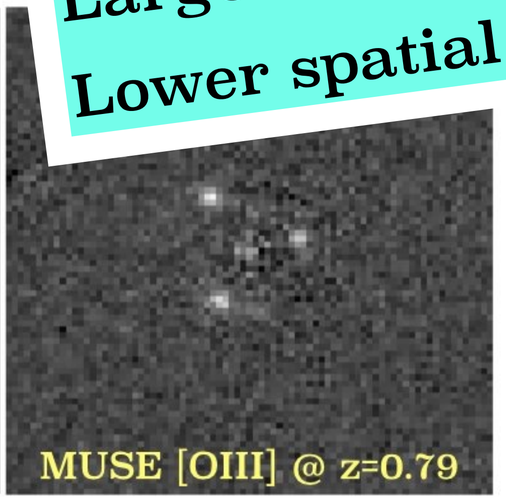
Bluer wavelength range probes large volume at z = 2—3 through Ly-alpha (though much could be done with redder lines in IR).

Higher spectral resolution helps contrast of source lines against lens continuum.

Larger FoV is not required.

Lower spatial resolution is a loss.





… And more examples coming from MUSE DSLP Factory programme P106

Cold gas around galaxies

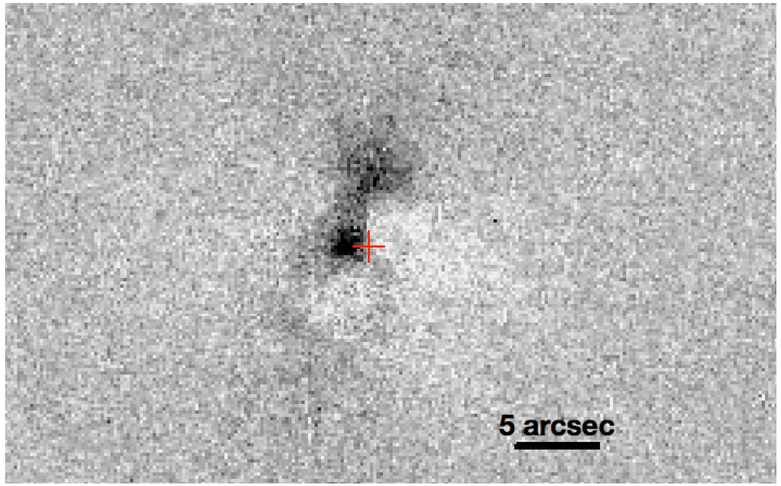
Brightest Cluster Galaxy of Abell 3716 (z=0.047)

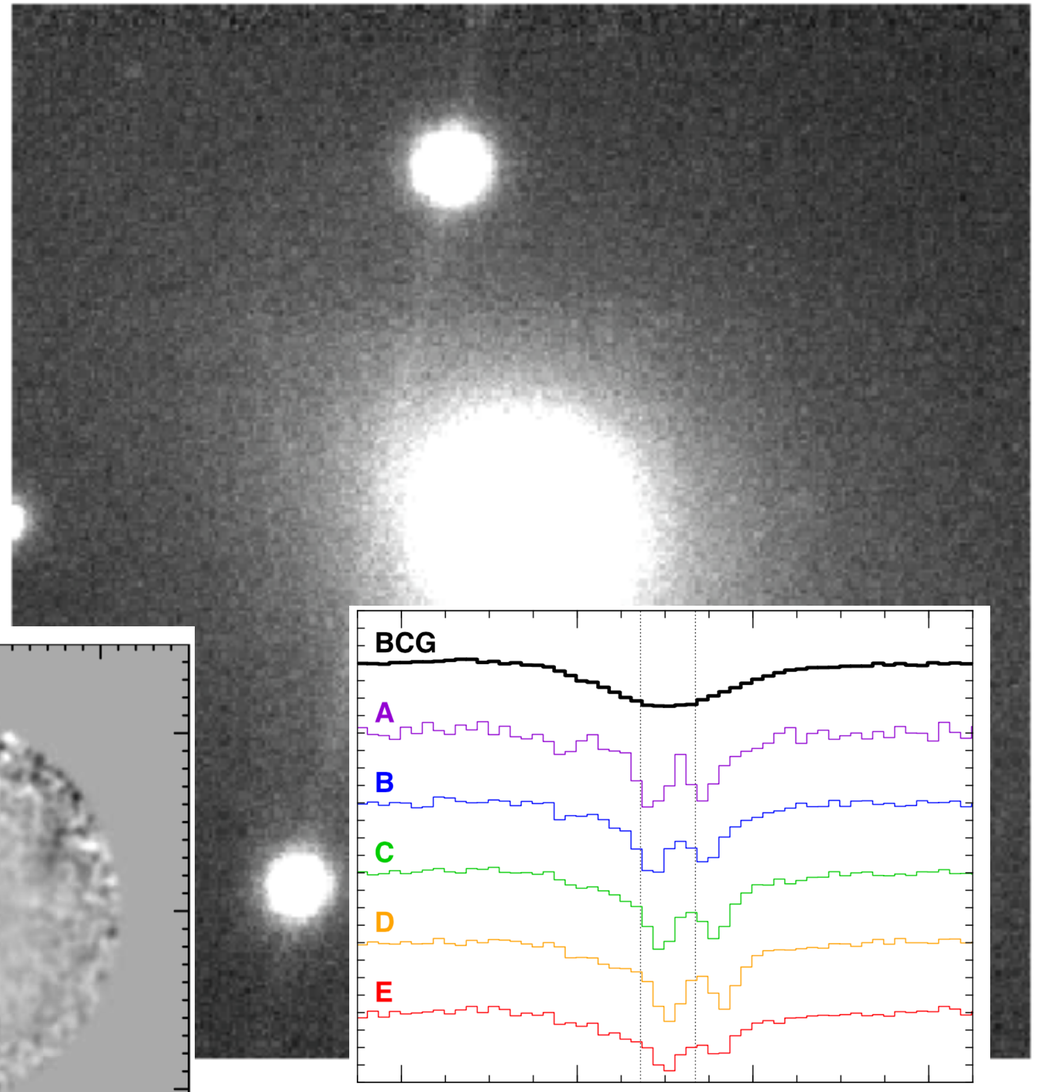
Looking for: spatially compact emission (lensed background galaxies)
Found : spatially diffuse absorption … ?

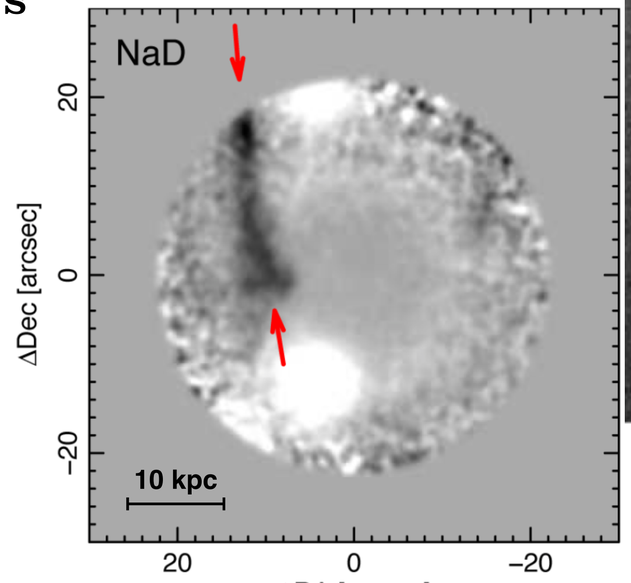
Extended cold gas stream seen in NaD absorption backlit by BCG stars.

A new spatially-resolved probe for the coolest phase of gas in intracluster medium.

Archival search shows this is not unique… but also not common. Sometimes, but not always accompanied by dust lanes (or vice versa).







RJS & Edge (2018)

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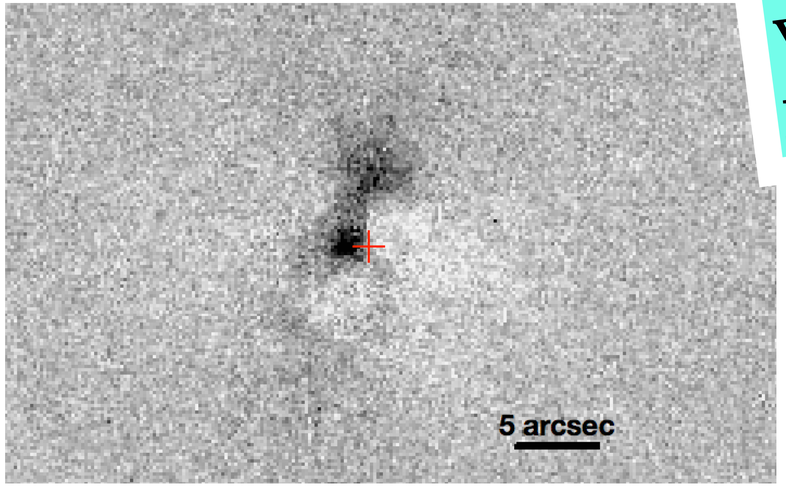


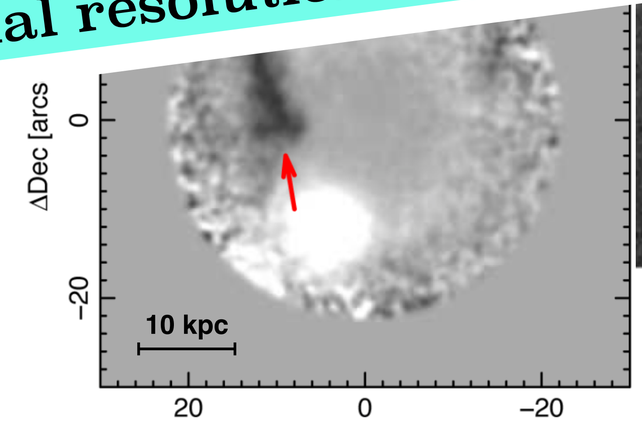
BlueMUSE?

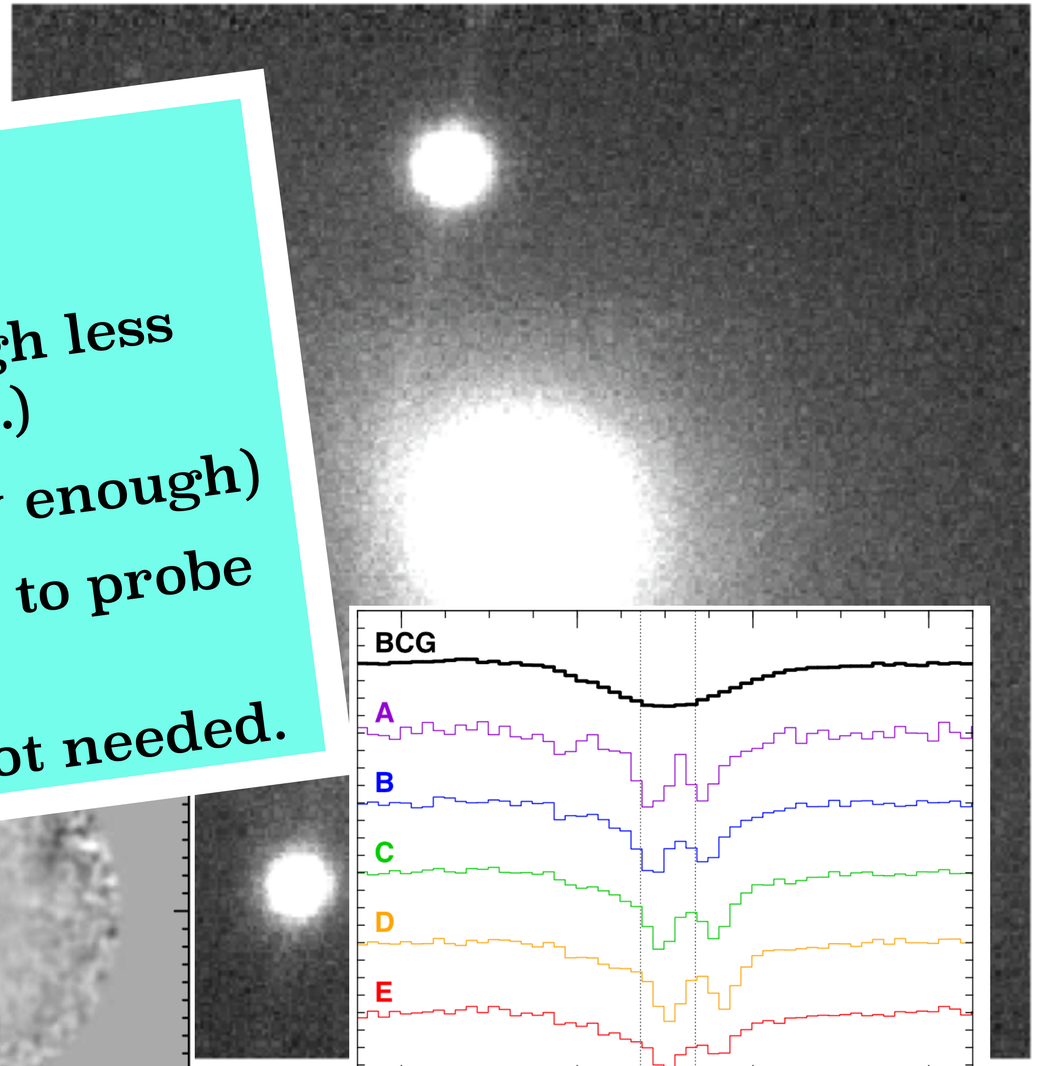
No NaD coverage, but CaII absorption instead? (Though less starlight to absorb against.)

FoV useful (but 1' probably enough)

Spectral resolution useful to probe velocities.

High spatial resolution not needed.

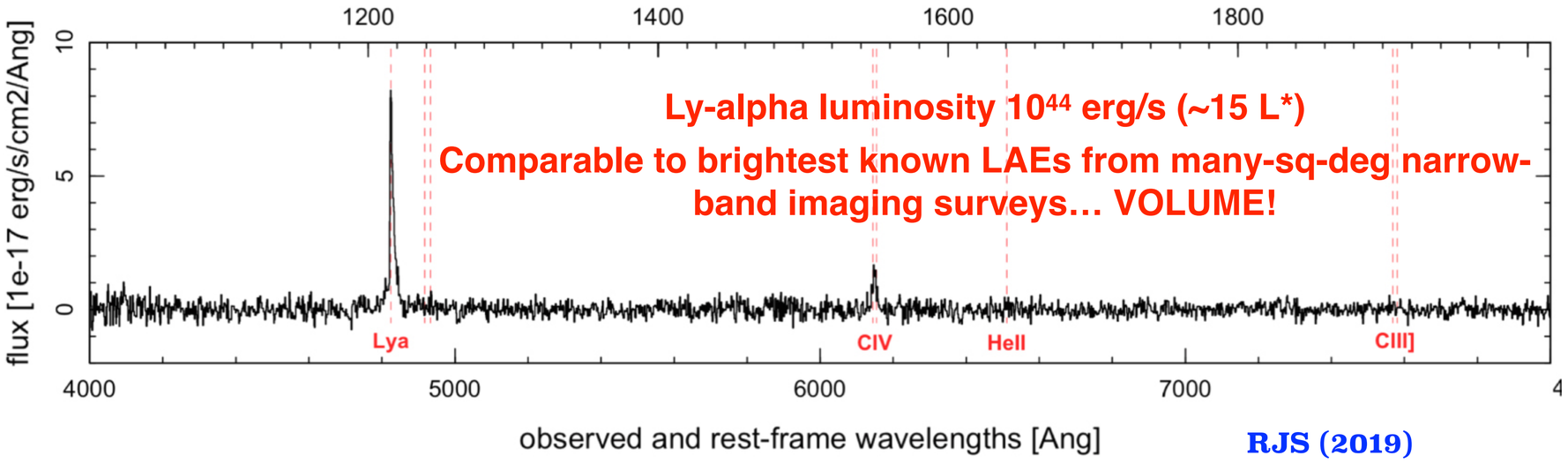




RJS & Edge (2018)

A contaminant: A hyper-luminous Ly-a emitter at z=3

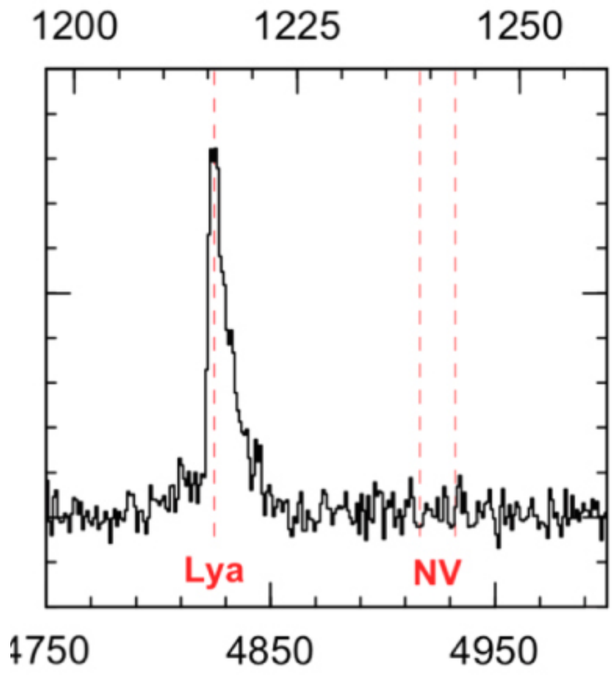
Looking for lensed background emitters in MaNGA … found something else



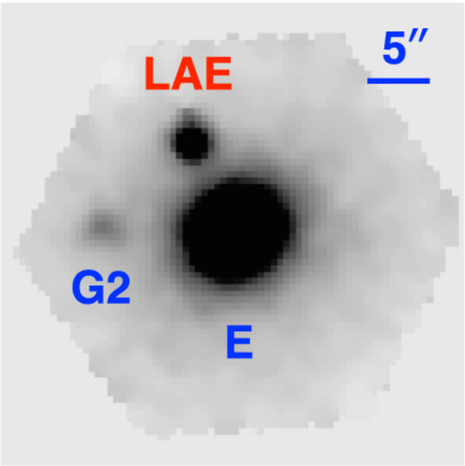
Ly-alpha luminosity 10^{44} erg/s (~15 L*)

Comparable to brightest known LAEs from many-sq-deg narrow-band imaging surveys… VOLUME!

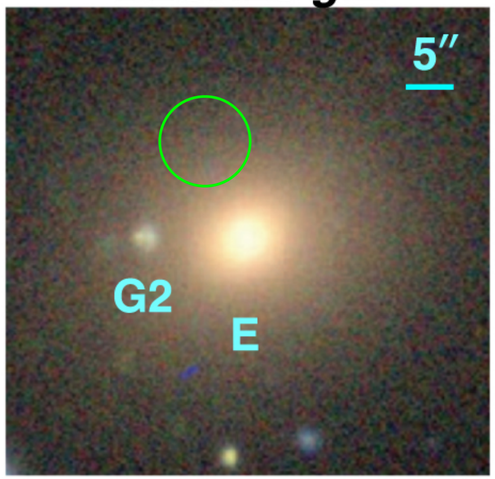
RJS (2019)



MaNGA (on Ly-α)



DECALS *grz*



How many interesting high-z emission-line sources are lurking behind our <u>targeted</u> MUSE observations?

In anyone cataloging them systematically…?

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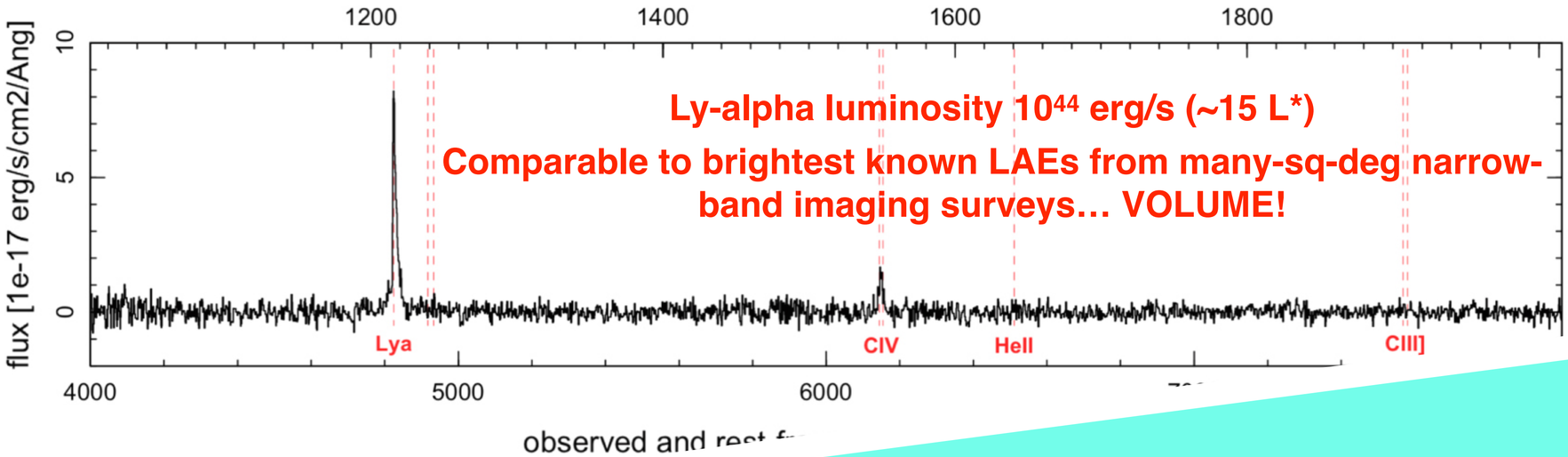

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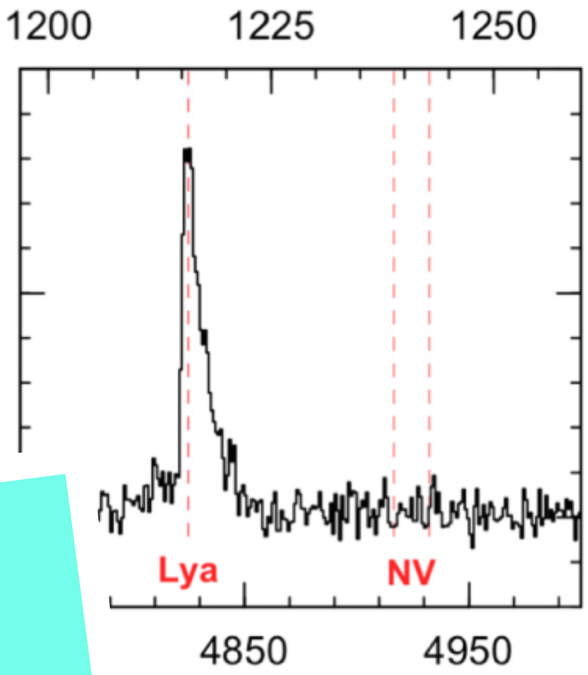
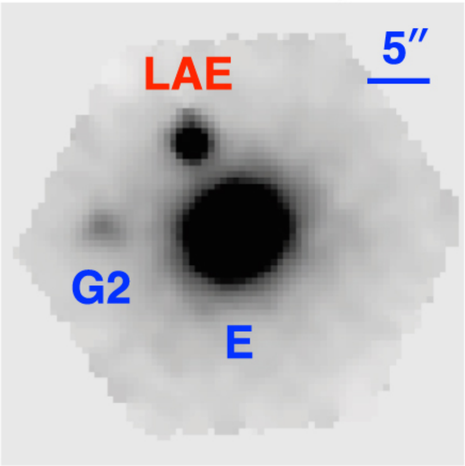


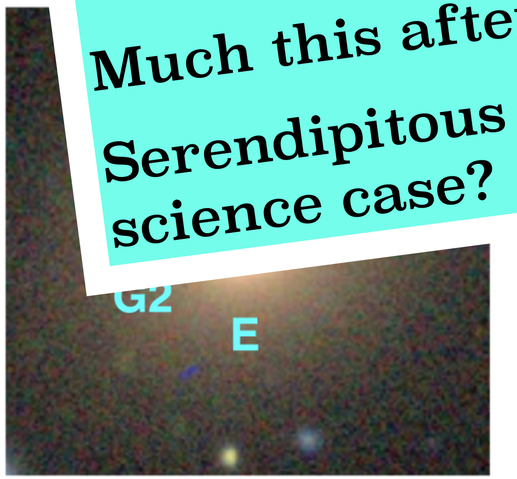
BlueMUSE?

Much this afternoon on high-z Ly-alpha.

Serendipitous high-z emitter catalogue as a science case?

MaNGA (on Ly-α)





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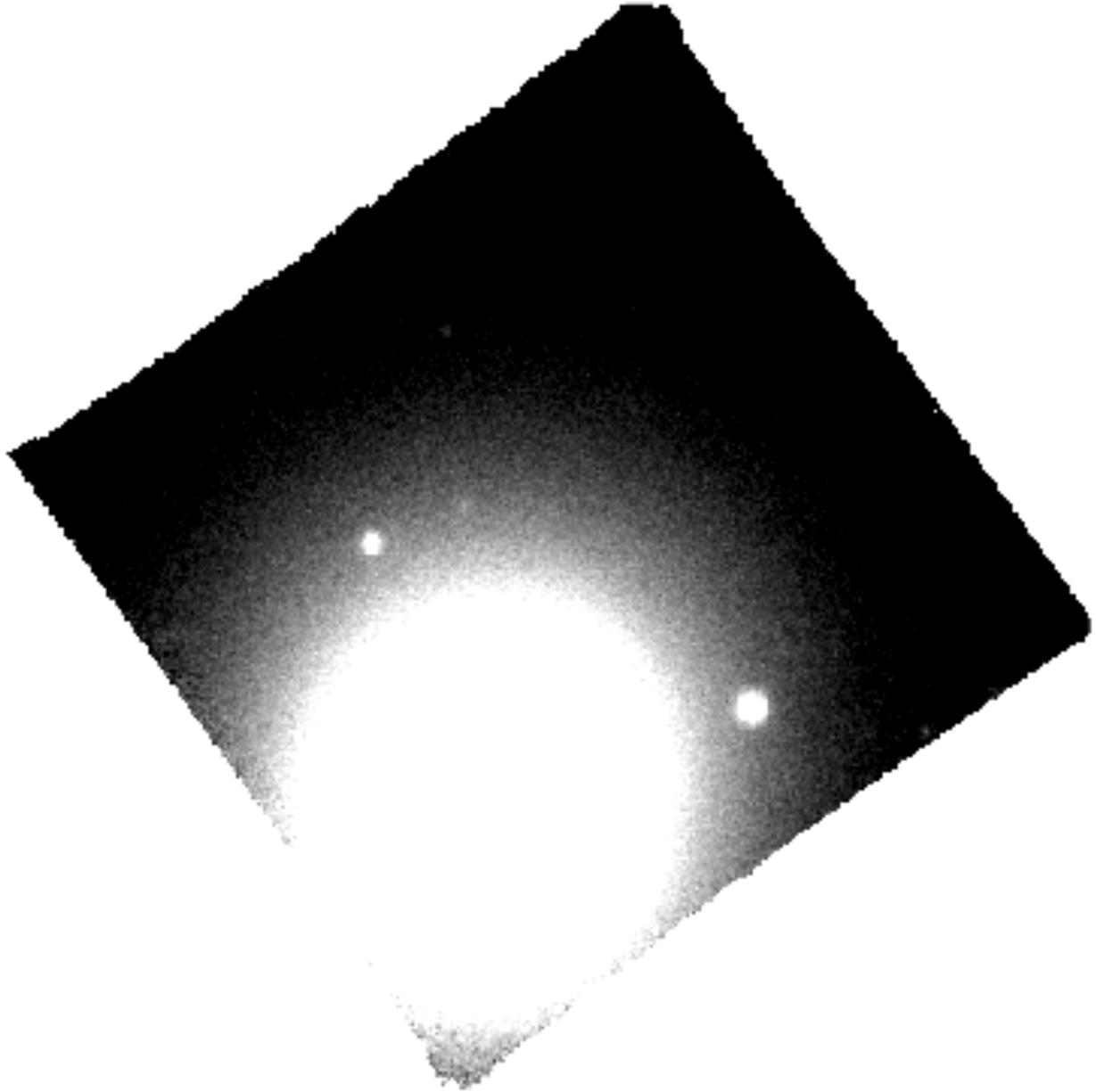
Planetary Nebulae in Nearby Ellipticals

Take the nearby lens search to the extreme…

Look for multiply imaged sources behind <u>really</u> nearby galaxies e.g. NGC 1404 at ~20 Mpc.

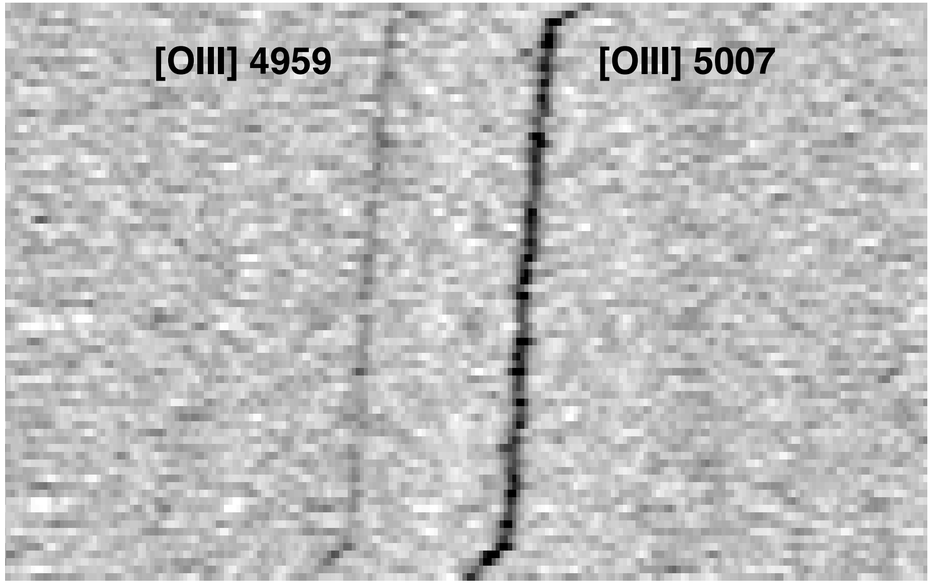
Wait … what are all those?



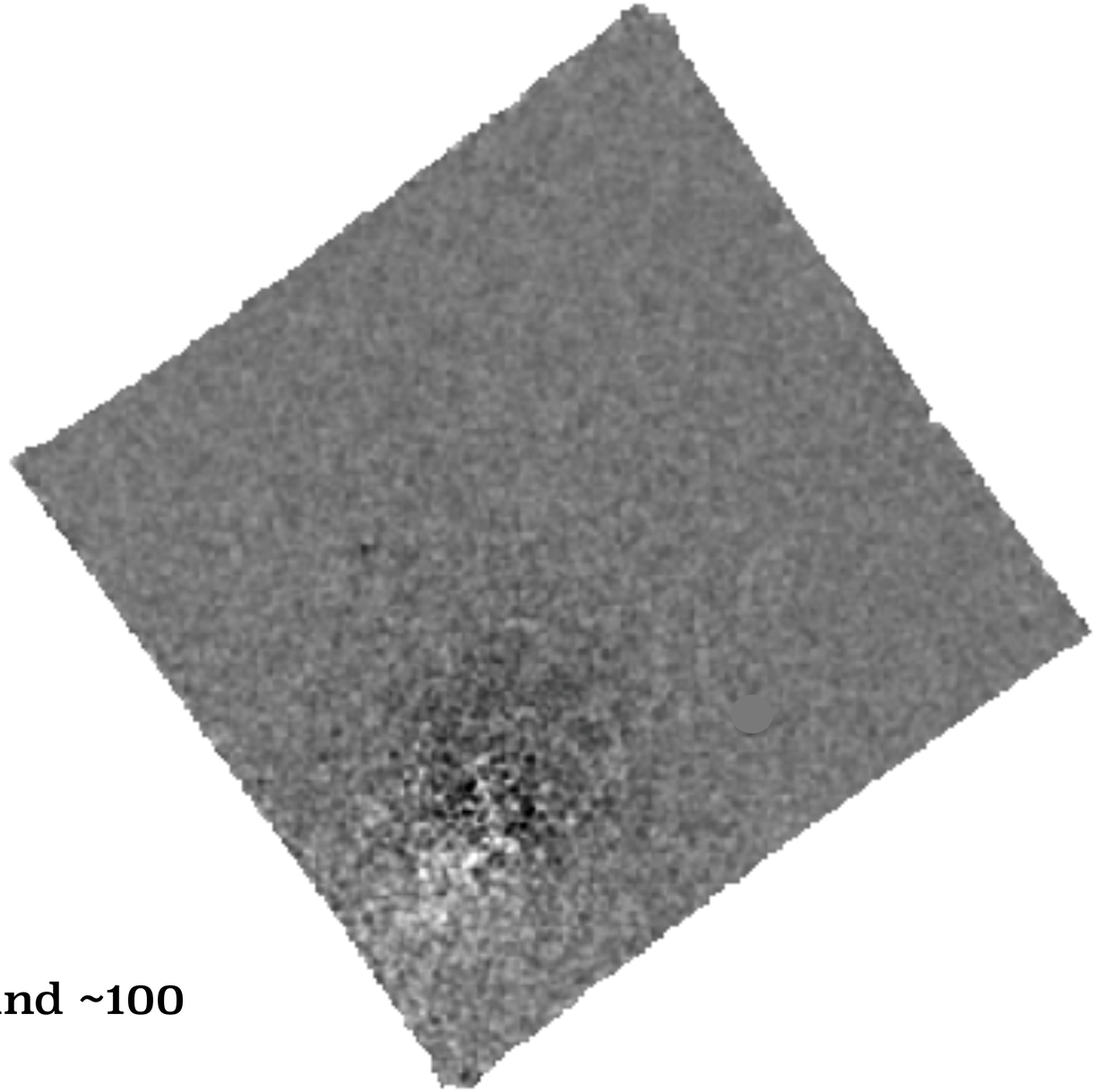
Planetary Nebulae in Nearby Ellipticals

Narrow [OIII] 5007 line from PNe

PN spectra ordered by velocity



wavelength



NGC 1404 — Spriggs et al. (2020) report ~50 PNe from this field.

(My undergrad project student George Carter found ~100 including a few from a second field further out.)

Extragalactic Planetary Nebulae with MUSE/BlueMUSE

Does N(PNe) per stellar mass change at small radius (= high metallicity) ?

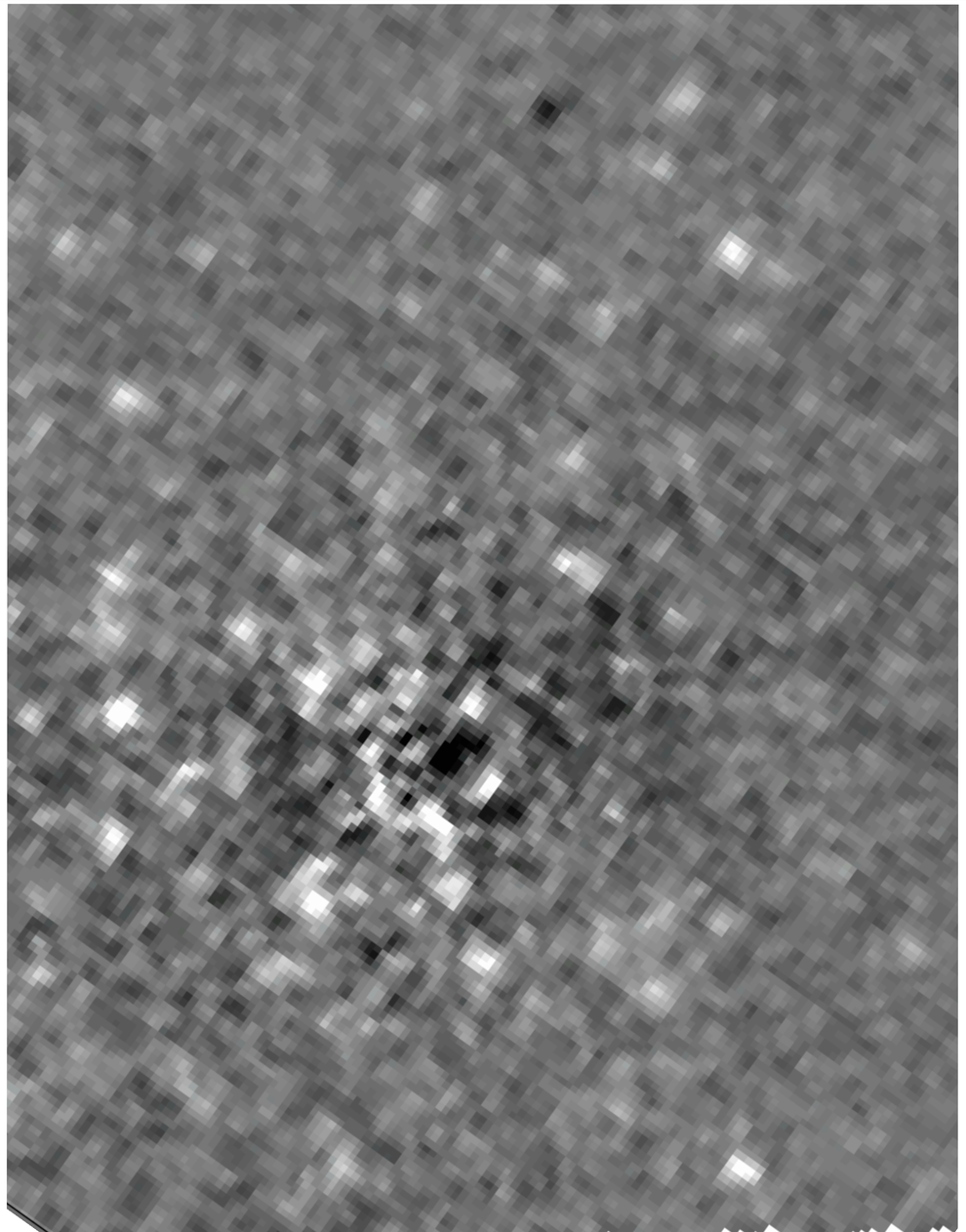
— best application for IFUs is finding PNe at small radius where other methods (narrow-band photometry / counter-dispersed slitless spectroscopy) fail.

— At 20 Mpc, easily find PNe to ~$R_{eff}/2$ with MUSE.

Why do this? Probe elliptical galaxy weirdness.

Central stellar pops of massive ellipticals show several peculiarities (UV excess; high Na enhancement; spectral signature of bottom-heavy IMF).

(How) are these linked? **PNe give us another probe of low-mass stellar evolution at high metallicities.**



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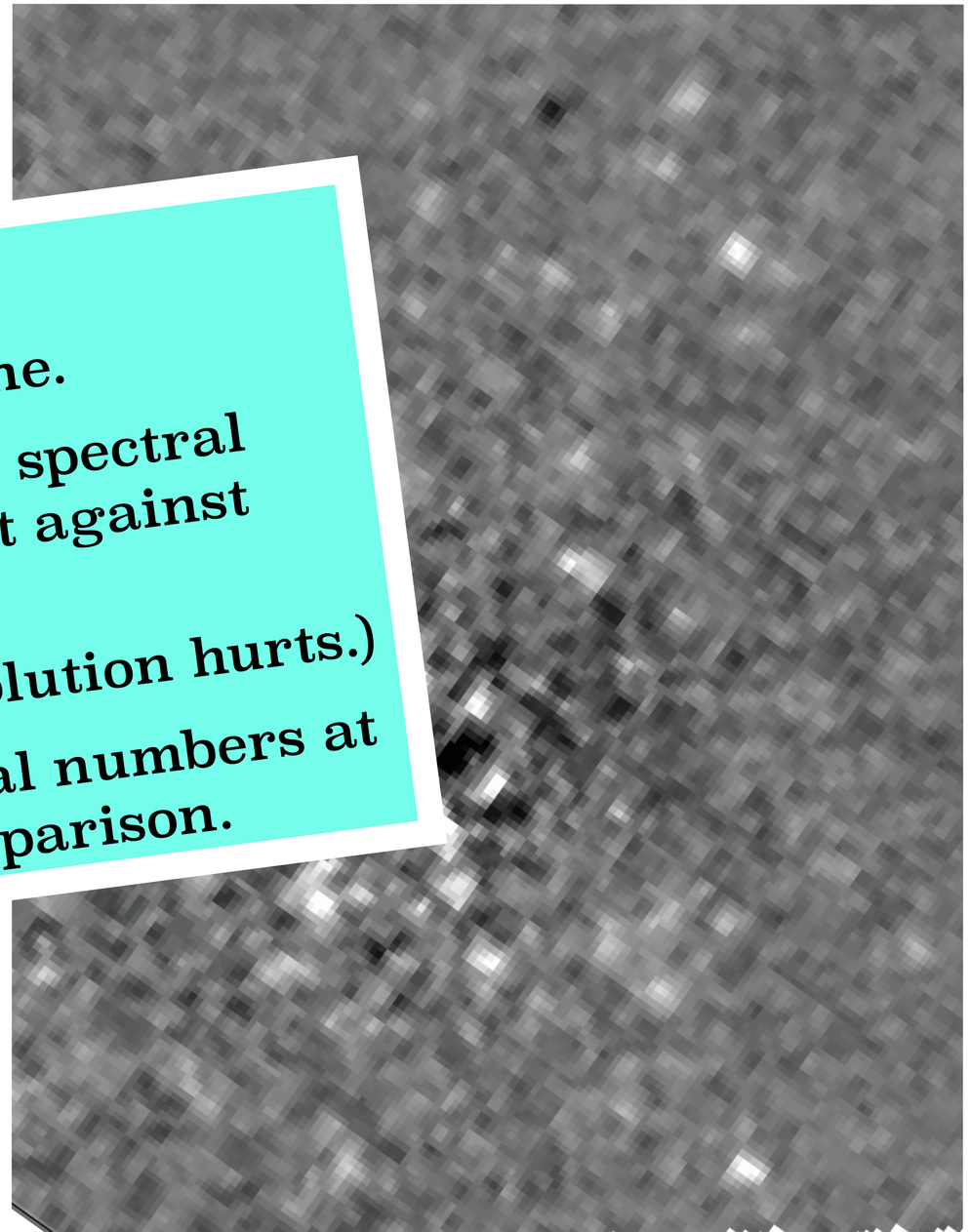
BlueMUSE?

Still covers 5007 Ang line.

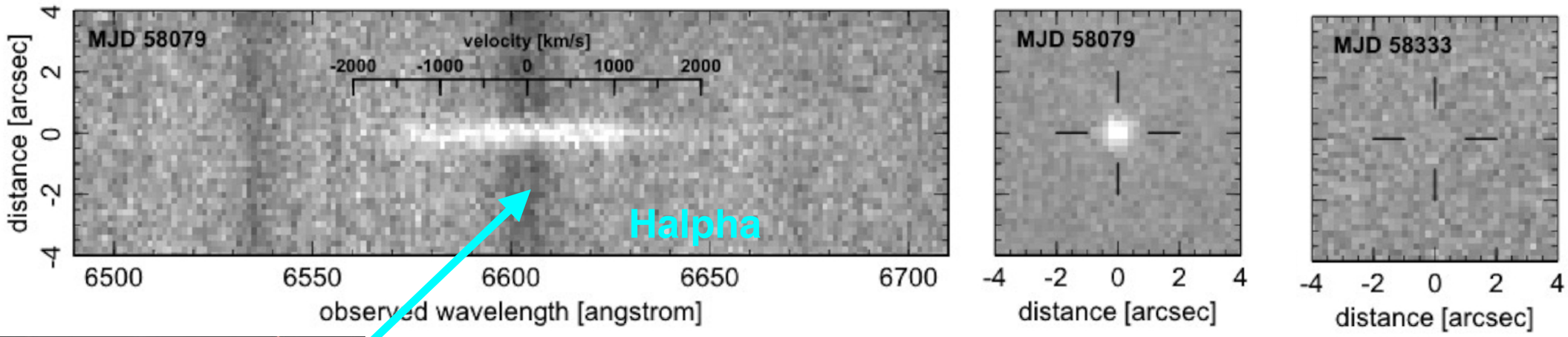
Higher throughput and spectral resolution aids contrast against high-SB continuum.

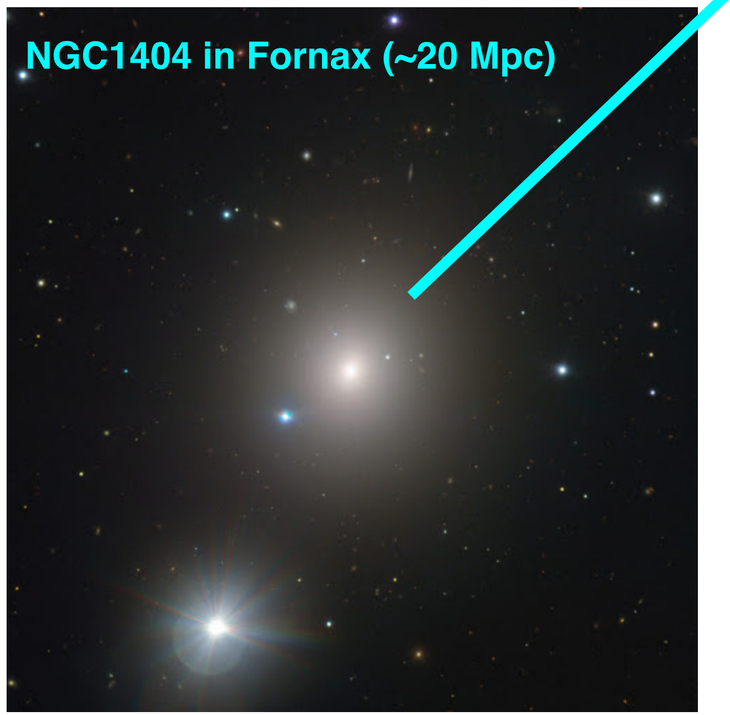
(But lower spatial resolution hurts.)

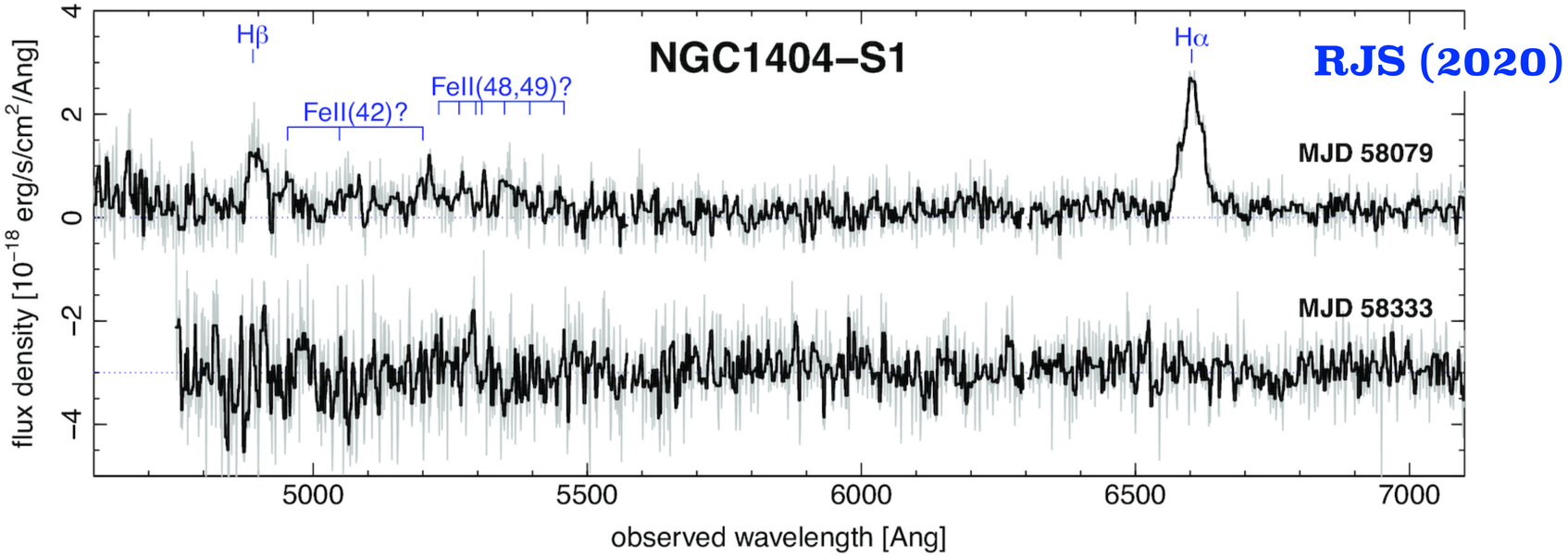
Larger field helps total numbers at larger radius for comparison.



Transient broad emission sources… = Novae







RJS (2020)

Archival search for similar sources finds another 12 of these in galaxies at ~20 Mpc, approx 1 per galaxy searched.

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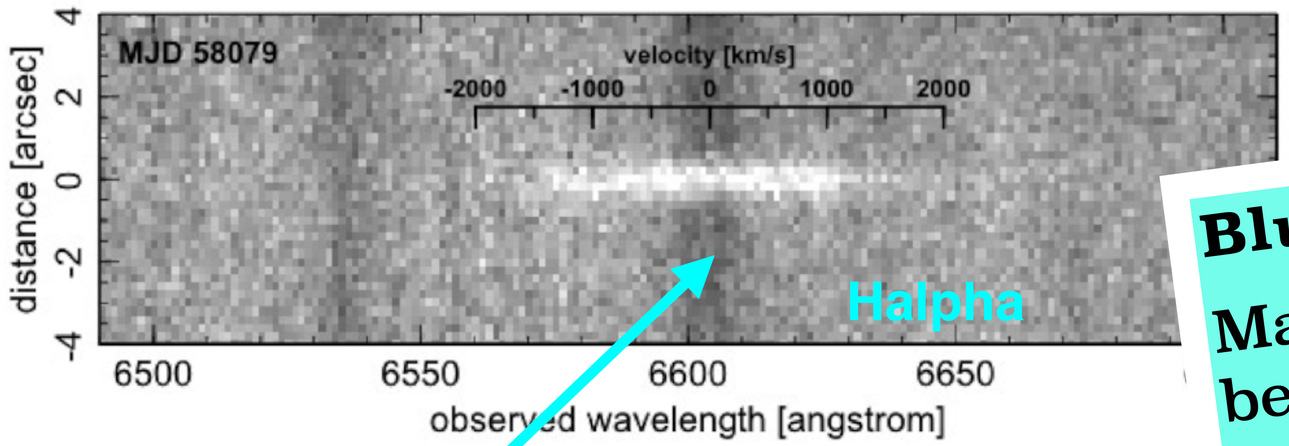
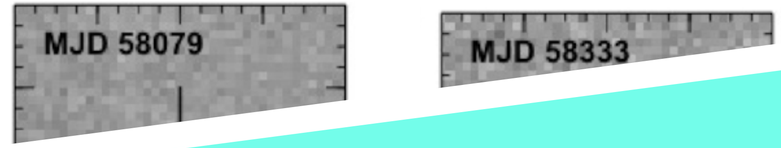
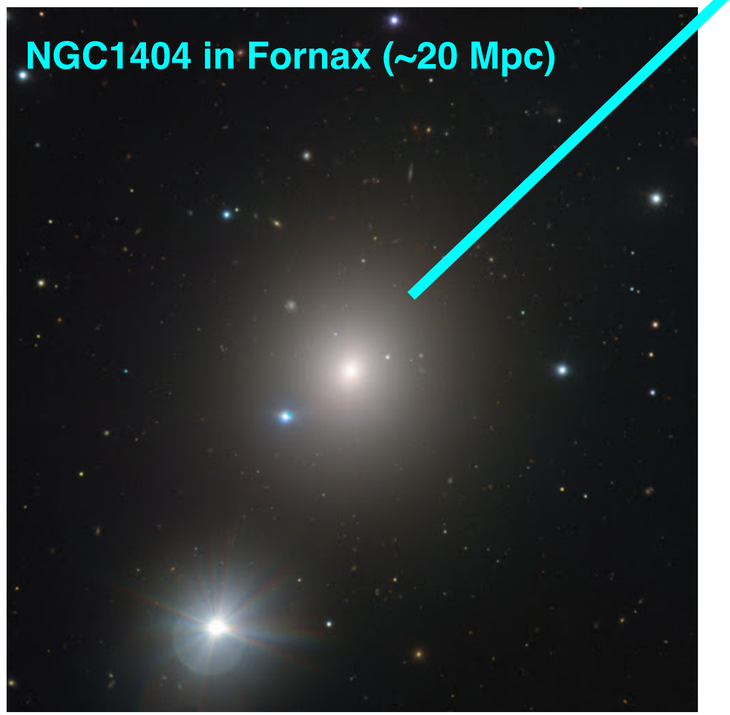


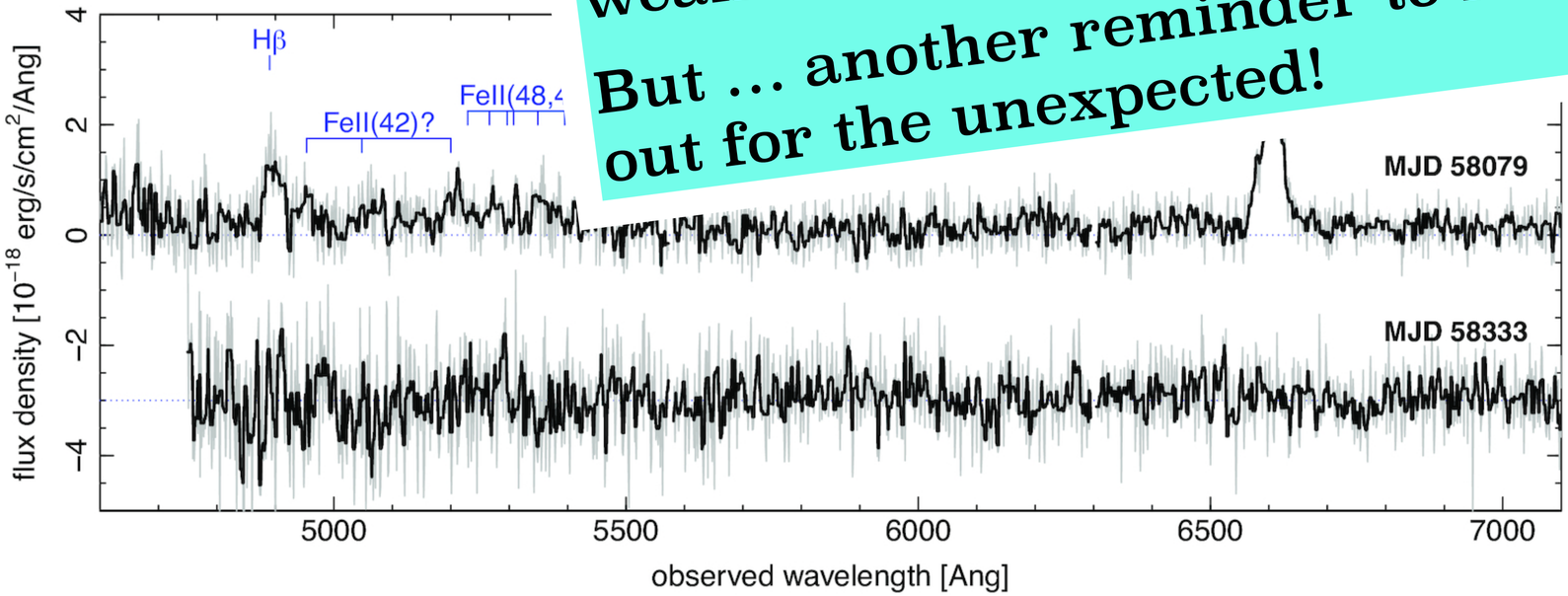


BlueMUSE?

Maybe not … Halpha line will not be covered. Other nova lines are weak.

But … another reminder to look out for the unexpected!





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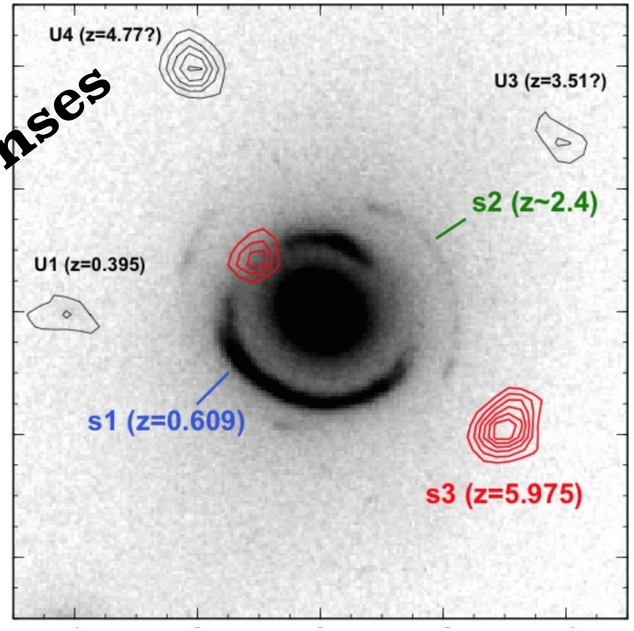
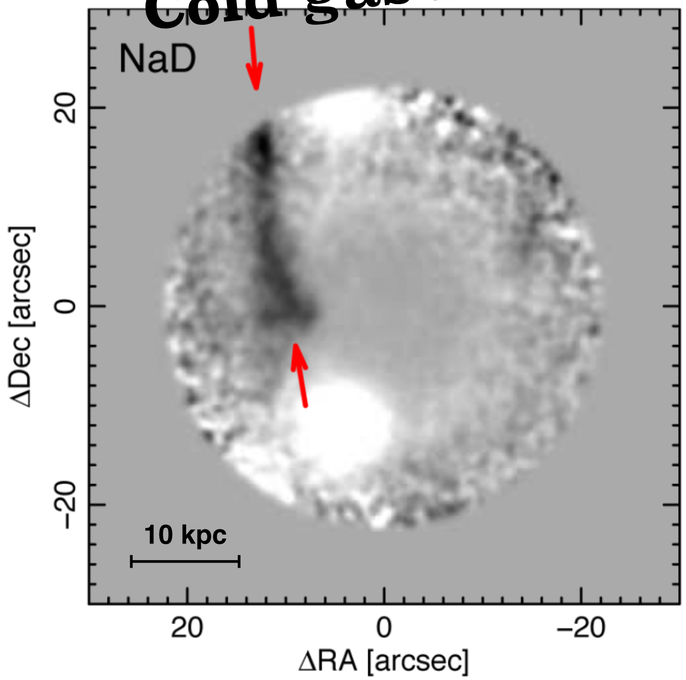
A visual summary

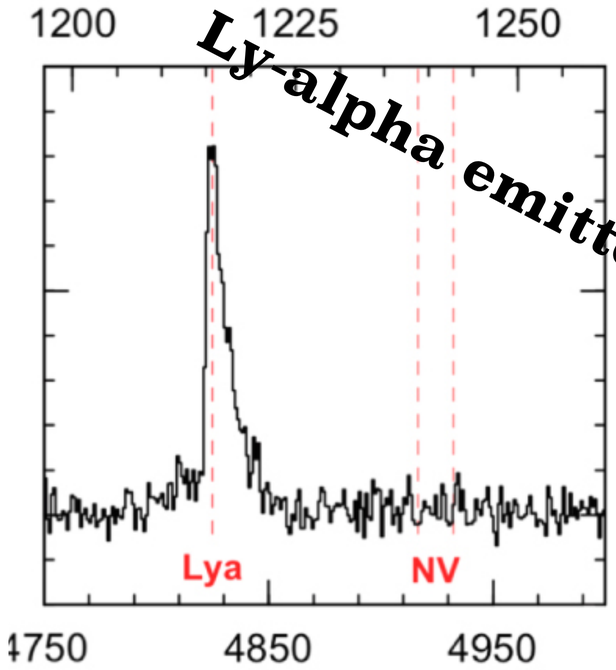
Lenses



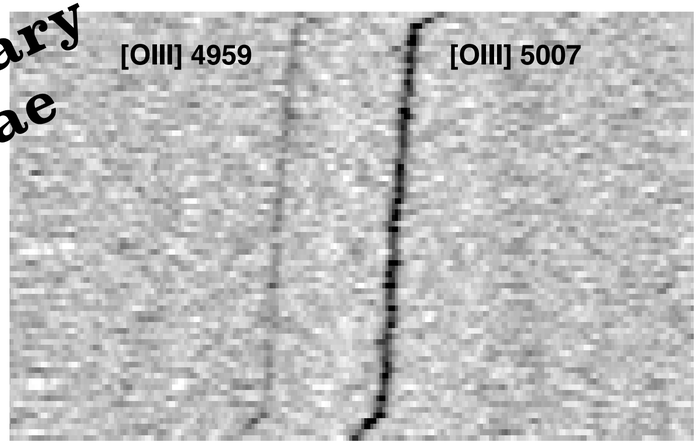
Cold gas streams



Ly-alpha emitters



Planetary nebulae



Novae