Review of the AGN central engine and its environments.

Overview of our recent works

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Based on few results from recent thesis by:

Vivek Jha, Vibore Negi, Vineet Ojha, Priyanka Jalan, Sapna Mishra

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- Scale ~10 MPC: dN/dz measurements
- Scale 1-10MPC: Quasars pairs Proximity
- Scale 100pc: BAL outflows
- Few dozen of light days: BLRs RM & intra-nights variabilities
- Scales <lightdays: X-ray emitting regions
- Hour like scale, continuum variability

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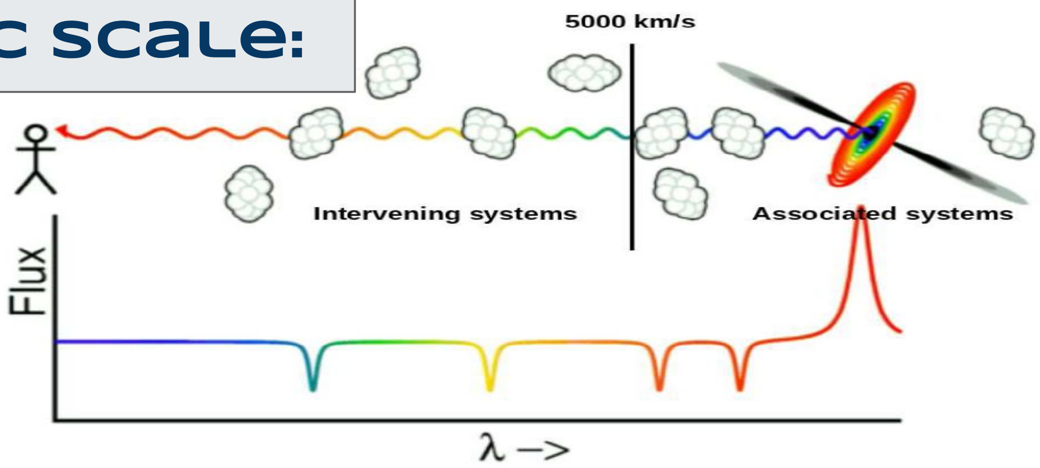
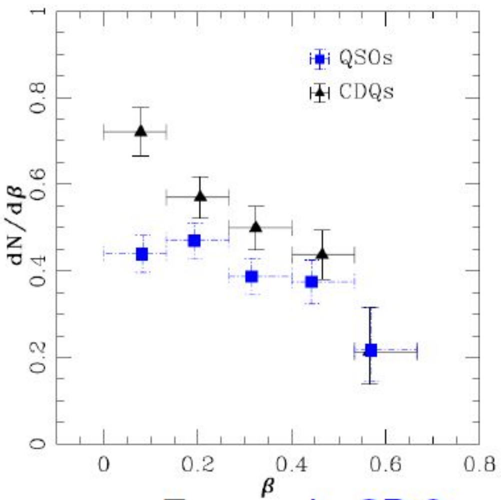
~ MPC scale:

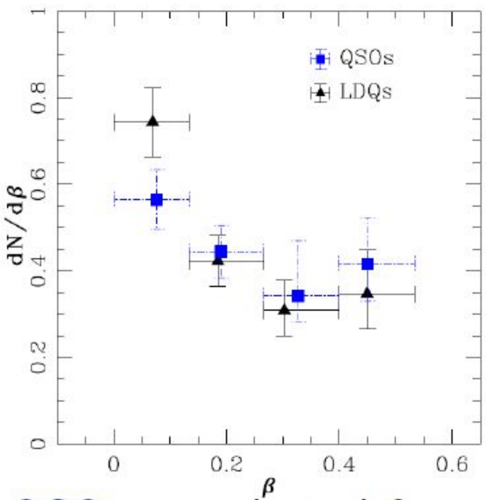


$$\beta \equiv \frac{v}{c} = \frac{(1+z_{em})^2-(1+z_{abs})^2}{(1+z_{em})^2+(1+z_{abs})^2}$$

- **Appealing scenario**, specially in case of **blazars**, if **material is** present(either in interstellar medium or in halo) and **swept up by the jet to high velocities**.
- Bergeron et. al 2011 proposed that a reasonable jet power can swept-up **column density as large as** $10^{20} cm^{-2}$,can attain an **expulsion velocity as large as 0.1c.**

The absorbers distribution in bin of relative velocity





$$\beta \equiv \frac{v}{c} = \frac{(1+z_{\rm em})^2 - (1+z_{\rm abs})^2}{(1+z_{\rm em})^2 + (1+z_{\rm abs})^2}$$

For CDQs an excess is seen at 3.75σ level

Joshi & Chand et al. 2013, MNRAS

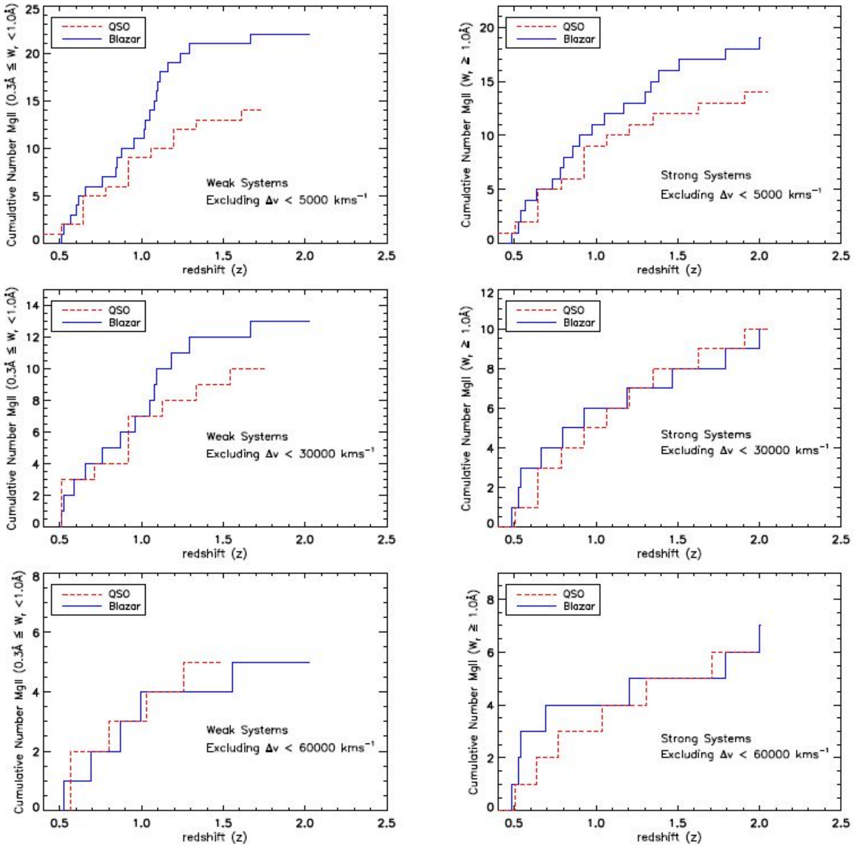
For unbiased comparison:

- For each CDQ, a QSO was selected from SDSS DR-7, matching in redshift and Luminosity resulting in 2919 CDQs having 473 with offset velocities of up to 40000 km s^{-1} .
- The 3.75σ excess supports that associated Mg II systems may well occur at velocity offsets that are an order of magnitude higher than the commonly adopted limit of 5000km s^{-1}.

Cumulative number of Mg II absorbers

Cumulative number of weak and strong intervening Mg II absorption systems detected towards blazars (blue solid line) and QSOs (red dashed line), after excluding the systems with offset velocity $(\Delta v) < 5000$ kms^{-1} (*top panel*), $\Delta v < 30000$ kms^{-1} (*middle panel*) and $\Delta v < 60000$ kms^{-1} (*bottom panel*). For QSOs the estimates for weak MgII systems are taken from Nestoret al. 2005 , and for strong systems these are adopted from Prochter et al. 2006.

Mishra et al. MNRAS,2018,473,5154



❖ Being extended for steep spectrum source now [Kumar et al. in prep.]

1. CAN RELATIVISTIC JETS CHANGE THE NUMBER DENSITY OF INTERVENING ABSORBERS (Δ V >5000 KMS^{-1} RELATIVE TO BACKGROUND SOURCE)?

On an avergae NO, however, associated MgII absorbers remain a significant contributor to dN/dz up to $\beta = 0.2$ relative to the background QSO (Mishra et al. 2018, MNRAS, 473, 5154).

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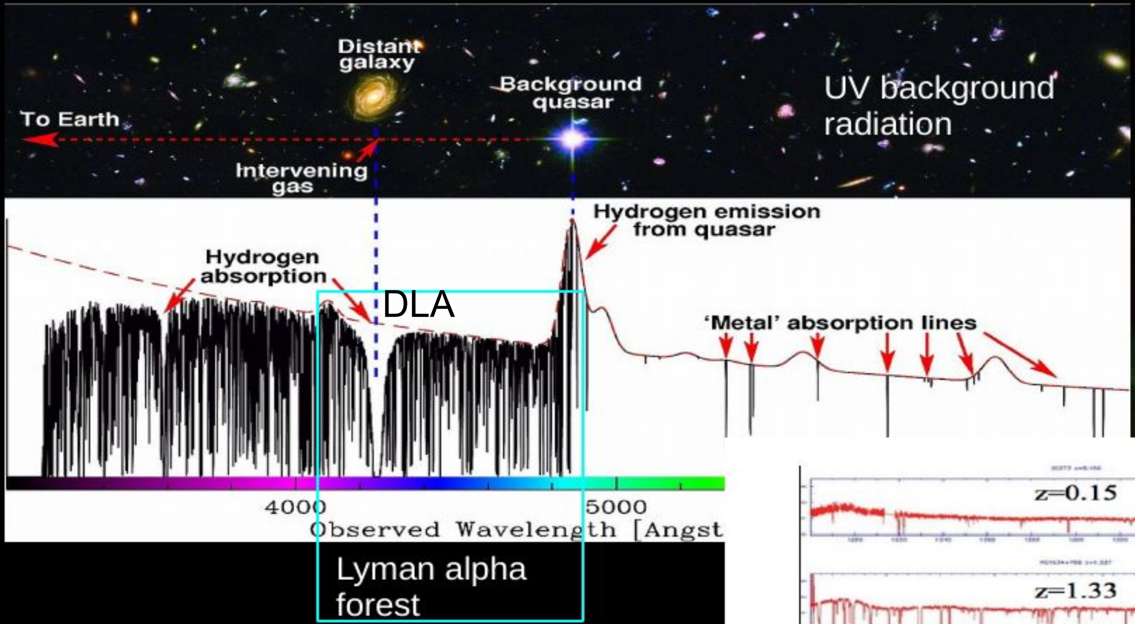
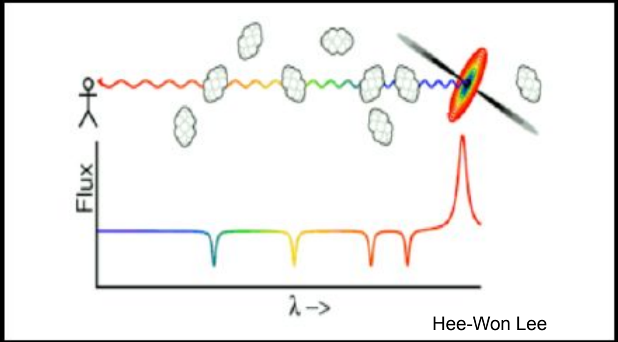
Hour like scale, continuum variability

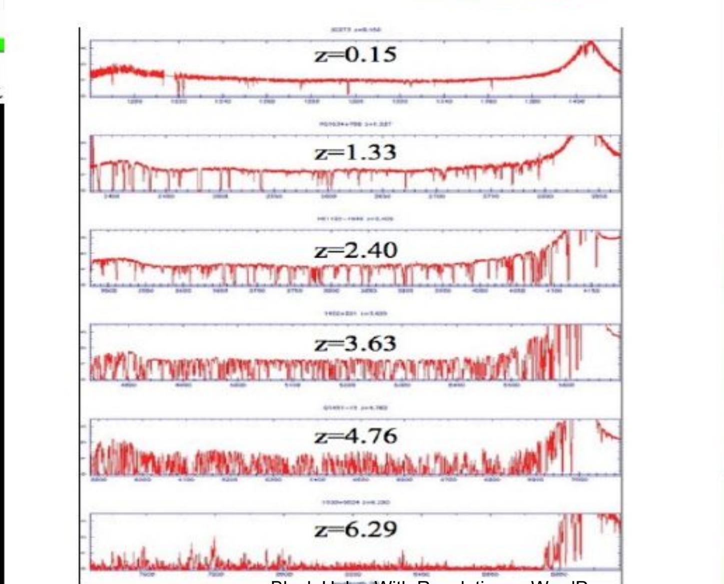
Lyα forest:

- Lyα optical depth evolves with redshift.
- Gunn-peterson trough at high-z
- Almost no absorption at low redshift.
- Proximity effect, due to Quasar's ionisations



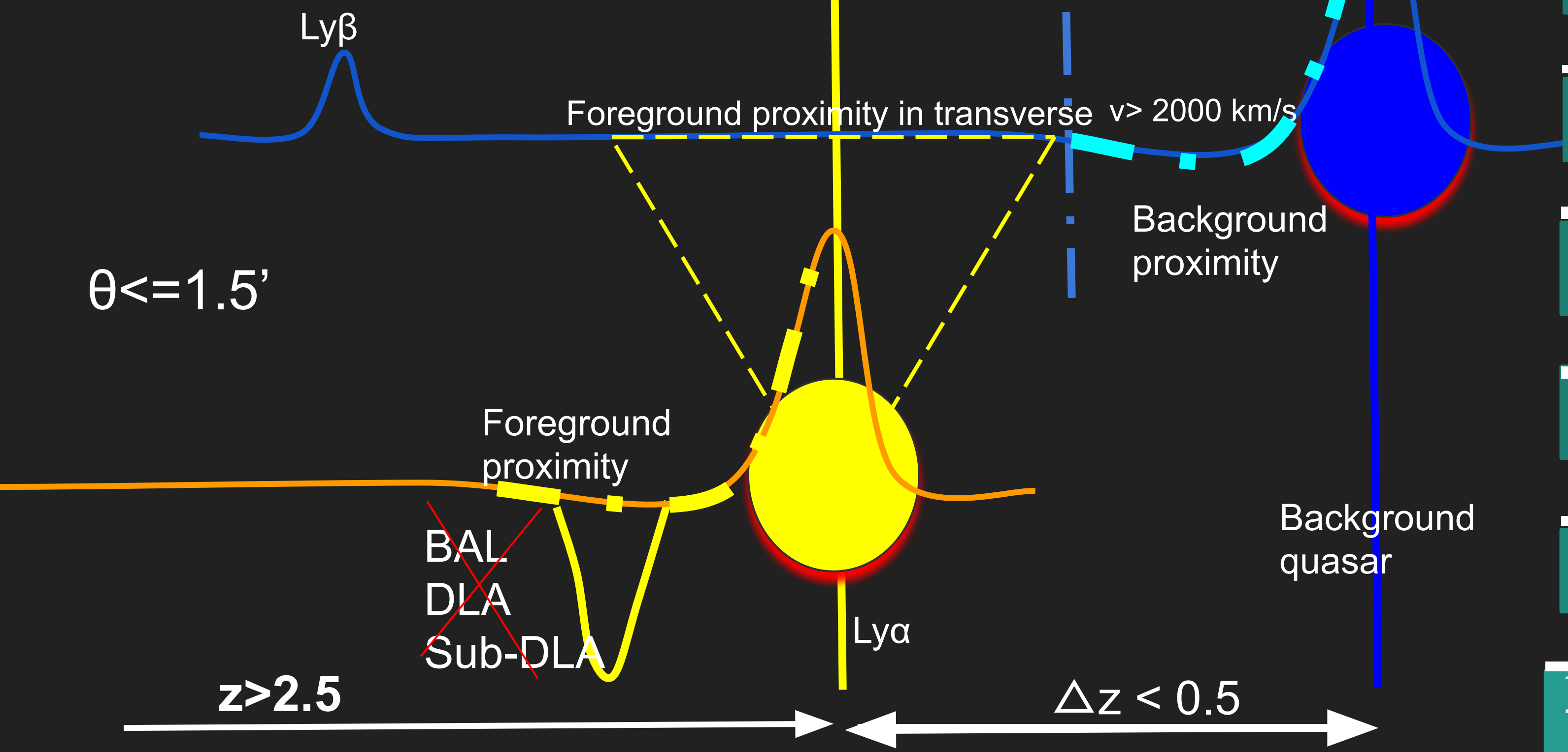
http://www.eso.org/~jliske/qsoal/qsoabs.jpg





Black Holes With Revelations - WordPress.com

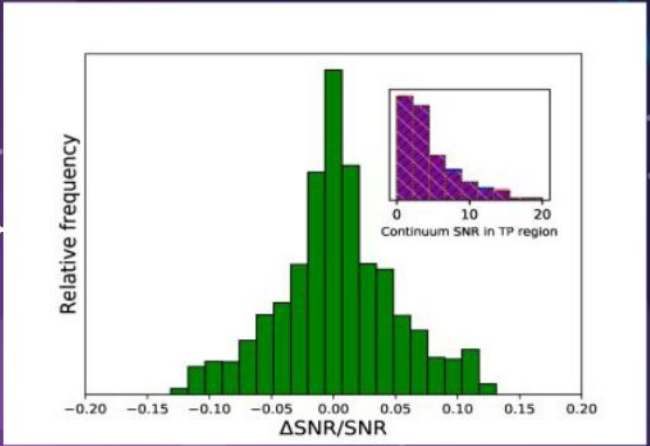
Experiment: HI density Radiation field around QSOs

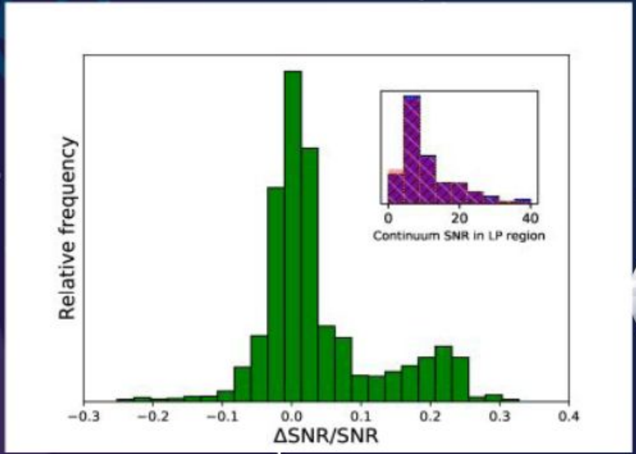


- 3 million quasars
- z> 2.5 ;83661 quasars
- θ<=1.5'
  △z < 0.5 ;380 pairs
- No BAL. DLA, Associated absorber ;237 pairs
- Correct redshift ;207 quasar pairs
- △v > 2000 km/s ;182 quasar pairs
- 1 zero flux quasar
  181 quasar pairs

Something to compare with :

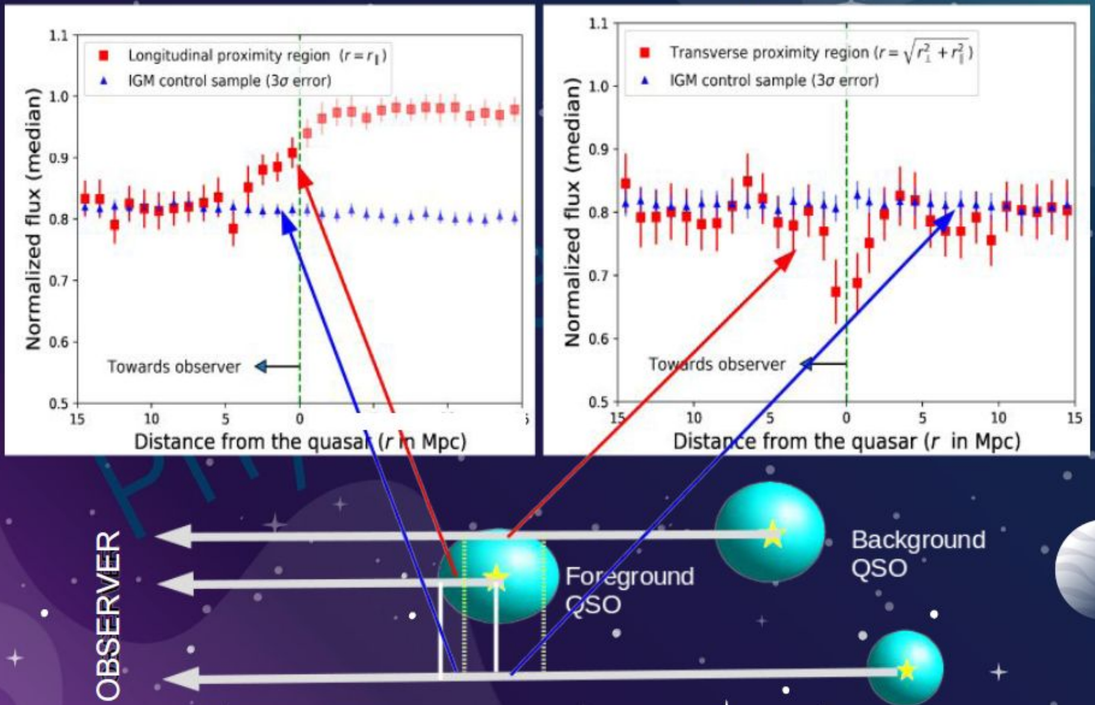
CONTROL SAMPLE





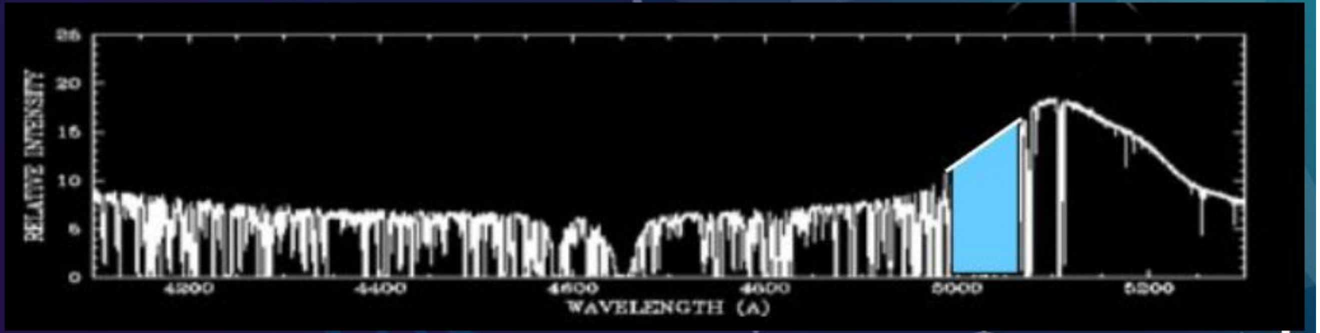
Jalan et. al 2019 ApJ, 884, 151

Transmitted flux distribution



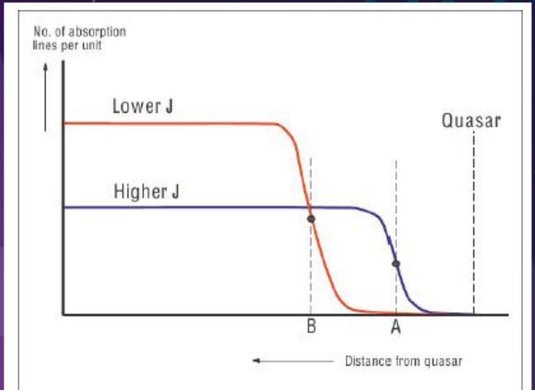
Jalan et. al 2019 ApJ, 884, 151

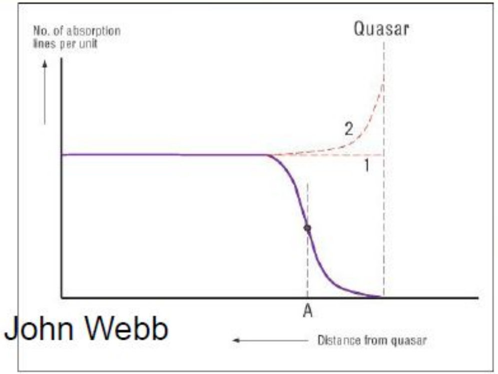
Quasar proximity effect



Longitudinal proximity effect

Depends on the UVB value





John Webb

Depends on the overdensity

Degeneracy between Ionization and overdensity

$$\tau_{IGM}^{exp} = \tau_{prox} \frac{1 + f^{\tau}(\omega_r)}{(\rho(r)/\bar{\rho})^{2-0.7(\gamma-1)}}.$$

$$\frac{\Gamma_{\rm uvb}(z_a) + \Gamma_q(r, z_a)}{\Gamma_{\rm uvb}(z_a)} \equiv 1 + \omega_r$$

For high resolution spectra $f^{\tau}(\omega_r) = \omega_r$,

$$\omega_{\rm r} \equiv \Gamma_{\rm quasar}(\mathbf{r}, \mathbf{z})/\Gamma_{\rm IGM}(\mathbf{z})$$

$$\Gamma_{quasar}(r) = \int_{\nu_{912}}^{\infty} \frac{L_\nu}{4\pi r^2} \frac{\sigma_{HI}}{h\nu} d\nu$$

$$\Gamma_{IGM}(z) = \int_{\nu_{912}}^{\infty} \frac{4\pi J_\nu}{h\nu} \sigma_{HI} d\nu$$

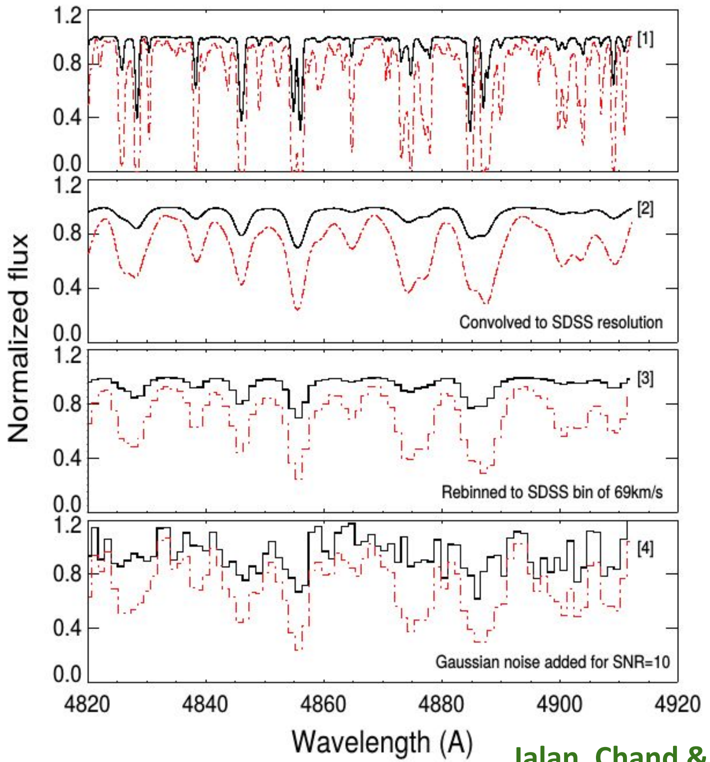
UVB⇒ Khaire and Srianand 2015,2019

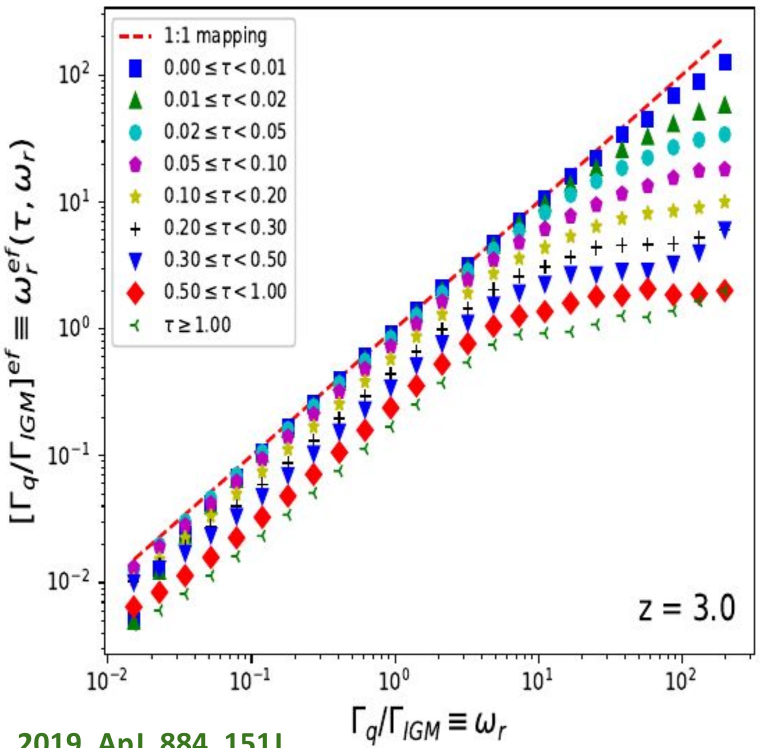
So the ratio of

$\tau_{prox}(1+\omega_r)$ / τ_{IGM} ⇒ overdensity

The average Overdensity around the quasar should be spherically symmetric

Simulations to get the scaling factor $f_\tau(\omega_r)$ at SDSS resolution

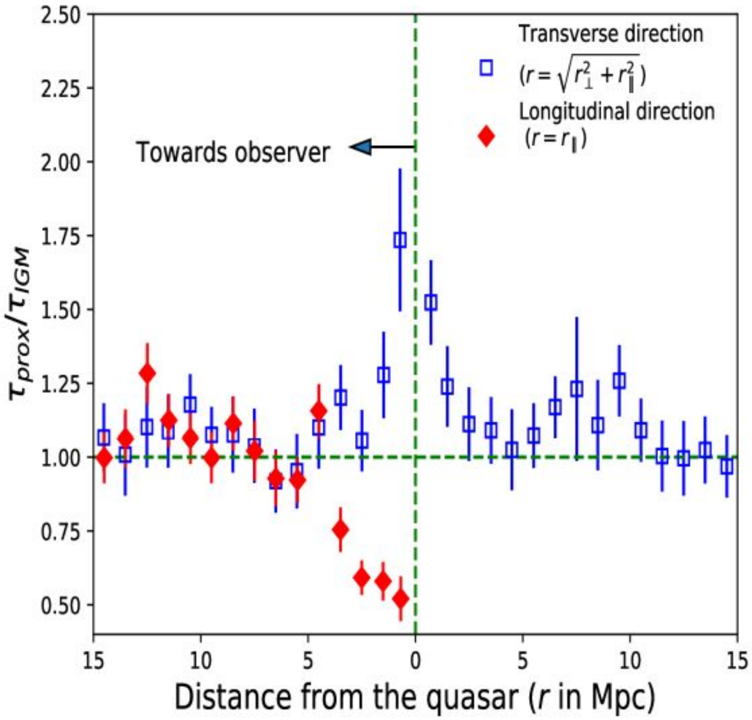


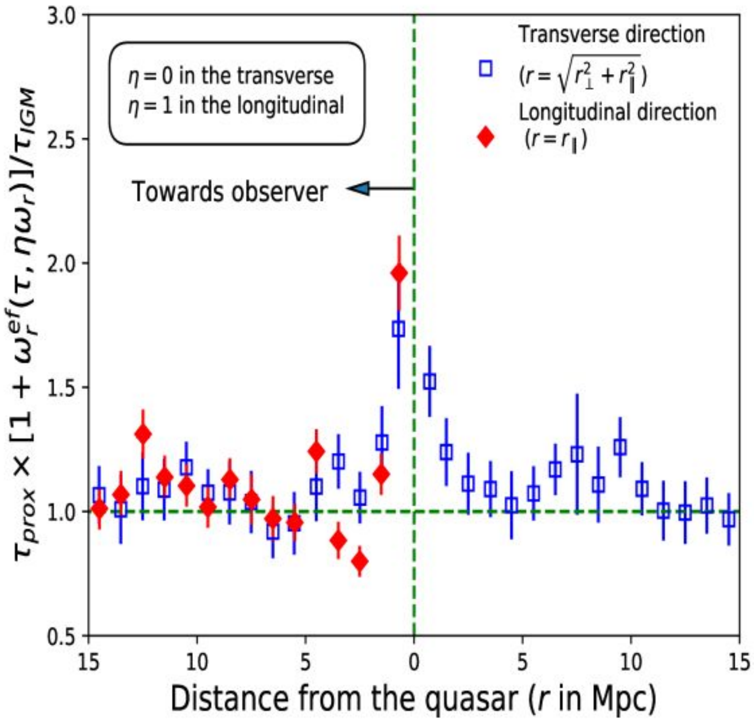


Jalan, Chand & Srianand, 2019, ApJ, 884, 151J

Transverse: No-quasar's radiation & Longitudinal: Quasar's radiation

Jalan, Chand & Srianand, 2019, ApJ, 884, 151J





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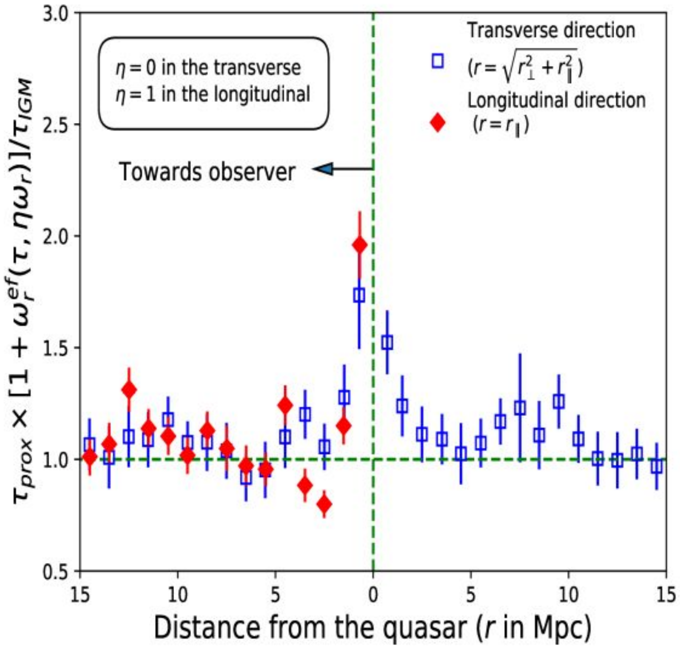
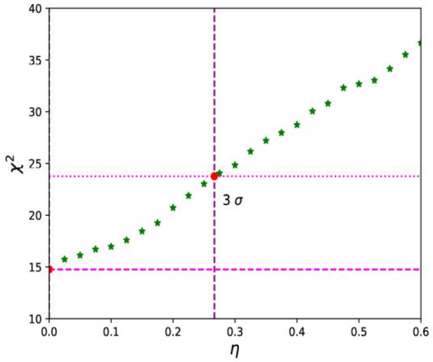
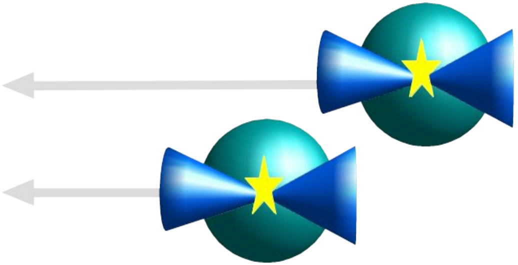
Jalan, Chand & Srianand, 2019, ApJ, 884, 151J







- ⇒ <27% Illumination in Transverse direction at 99% confidence level
- CIV width imply that most of foreground quasars are Type-1 AGN (perhaps selection bias in SDSS).
- ⇒ Evidence of dusty torus.
- NEW SAMPLE WITH DESI and SALT!!!

Results:

- Density profile is **radial.**
- Excess density to a distance of 6 Mpc at z~4.
- Significance doesn't vary much with the adopted UVB measurement or spectral index.
- Overdensity correlated with luminosity.
- Even after continuum systematics the density is evident till 6 Mpc.

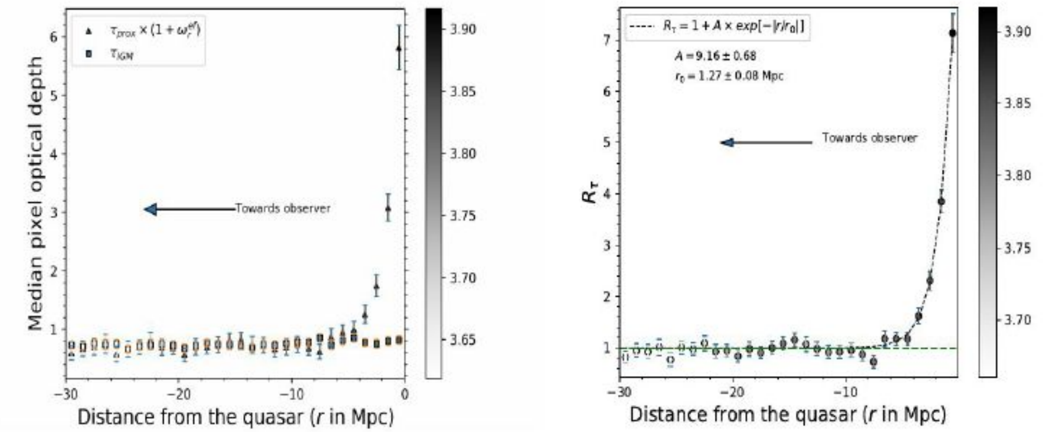


Figure 6. *Left panel:* The plot shows the median pixel optical depth corrected for quasar's ionization in the proximity region (triangle) and the median pixel optical depth of the general IGM (square) at different radial distance bin of 1 Mpc. The gray-shades represents the median value of the absorption redshifts (along the proximity sightline) in each radial distance bin. The resultant error bars consist of the flux error from photon counting statistics, redshift uncertainty, sightline-to-sightline variance and r.m.s statistical error within the 1 Mpc radial distance bin as also used in Fig. 4 along with the error propagation in $[1 + \omega_r^{ef}(\tau, \omega_r)]$ based on the uncertainty in the pixel optical depth. *Right panel:* The plot shows the ratio of median pixel optical depth shown as two curves in the left panel (defined as $R_\tau(r)$ in Eq. 7 and 8), in a radial distance bin of 1 Mpc.

Jalan et. al 2021, MNRAS, 505, 689

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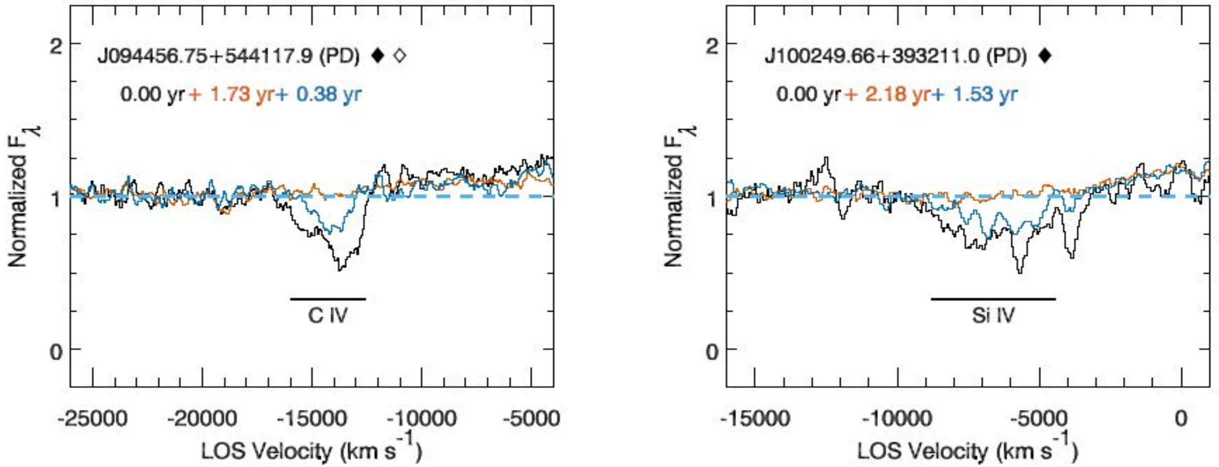
Broad absorption line quasars.... Why do we care?



McGraw et al. (2017)

Why variability study is important in BAL quasars?

1. To understand the location and physical condition of absorbing gas (wind lifetime, size, and geometry).
2. In constraining the kinetic power of the outflows.
3. In examining whether or not they are potential contributer to the AGN feedbacks.

APPEARING:

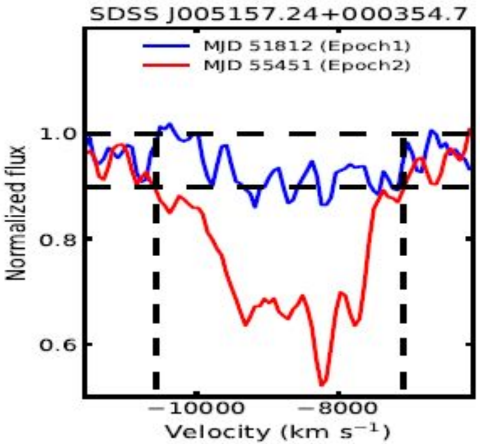
- Based on the compariosn between the SDSSDR-7, SDSSDR-12, and SDSSDR-14 quasar catalogs.

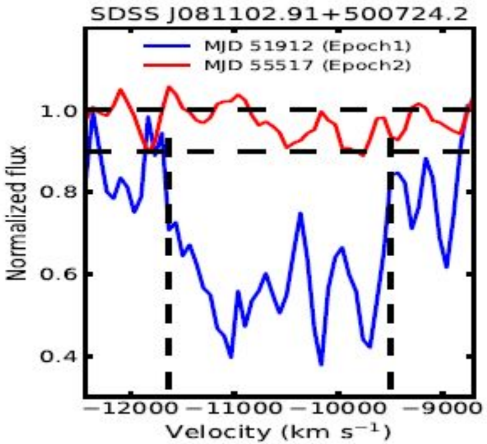
DISAPPEARING:

- Sample of 73 disappearing BAL quasars presented by De Cicco et al. (2018) is re-analyzed for comparison.

Table: Summary

Sample Type	Number of complexes	Number of BAL quasars	Comment
Appearing	123	118	BI = 0 in Ep1
Appearing pristine	60	60	BI = 0 in Ep1; No residual absorption in Ep1
Disappearing	55	53	BI = 0 in Ep2

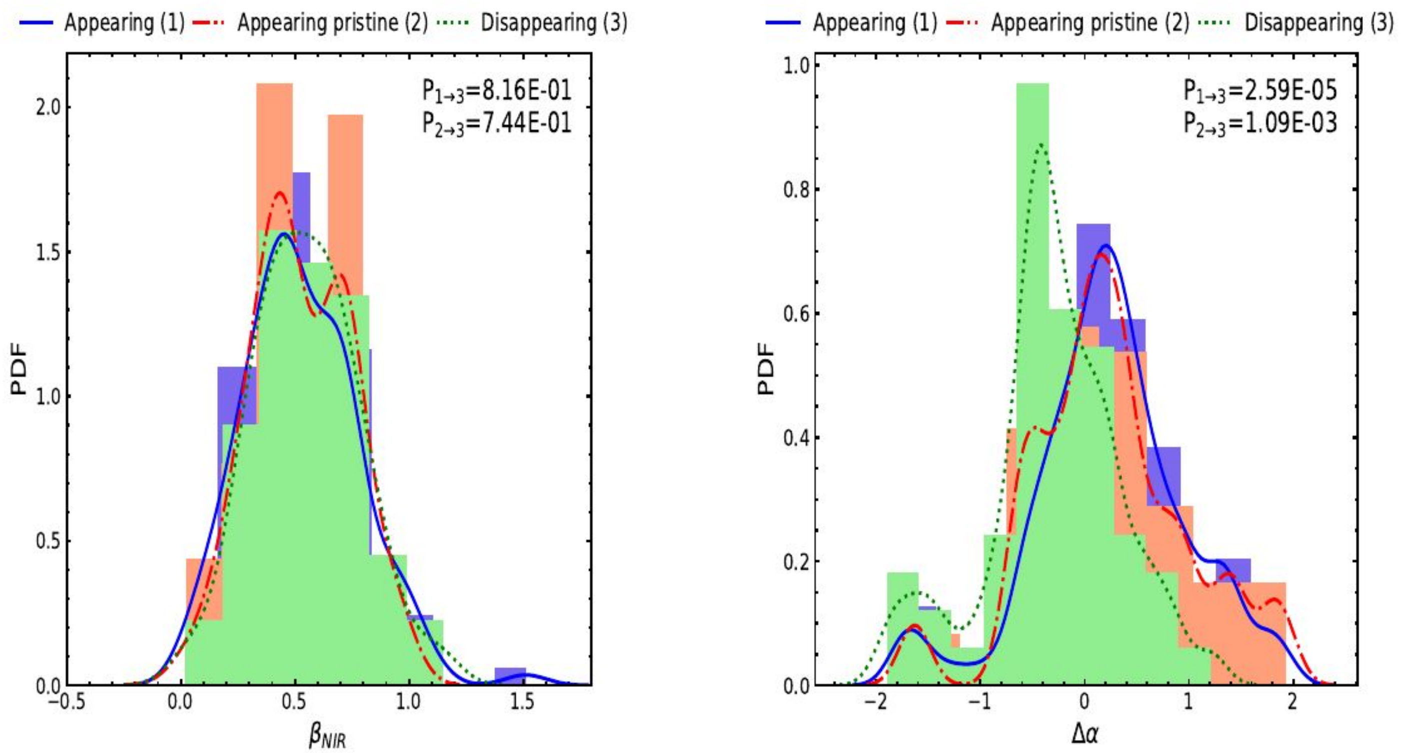




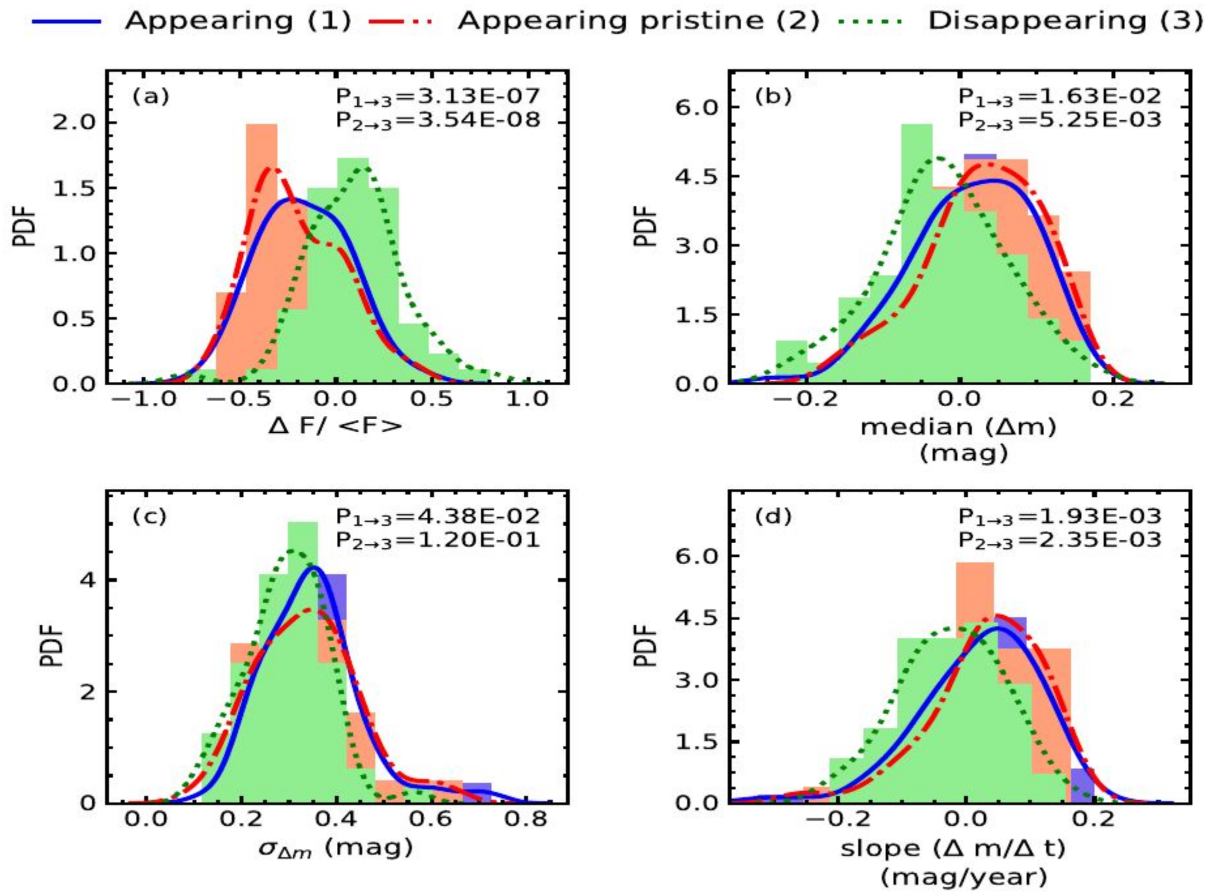
Mishra et al 2021, MNRAS

$L_\lambda \propto \lambda^{\beta_{NIR}}$ (from IR-WISE magnitudes)
Using w1, w2, and w3

$F_\lambda = b\lambda^{\alpha} e^{\tau_V k_\lambda}$ (from optical spectra)



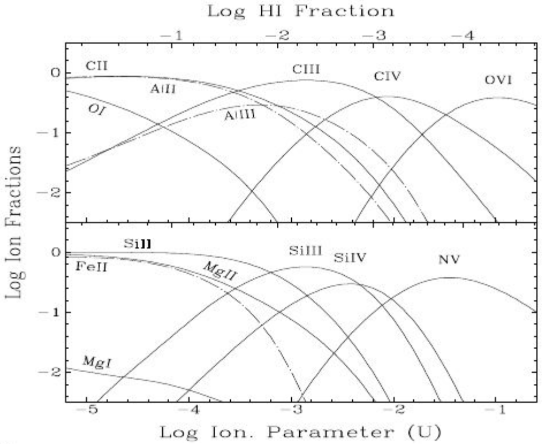
Mishra et al 2021, MNRAS, accepted

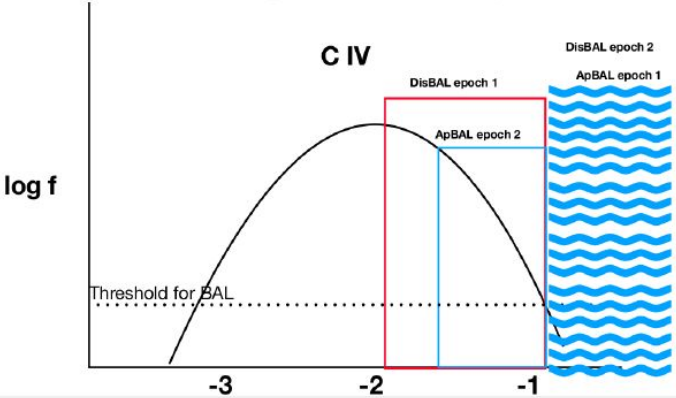


Mishra et al 2021, MNRAS, accepted

Recap

1. We present a new set of 94 appearing BAL quasars.
2. We rule out the intrinsic dust driven BAL variability scenario.
3. Continuum variations supports the bluer-when-brighter trend seen in normal quasars, implying fluctuations in continuum are related to the changes in the accretion processes.
4. **Appearing BAL quasars are brighter than the disappearing BAL quasars.**
5. **Appearing BAL troughs are shallower than the disappearing BAL troughs.**
6. **Appearance of a BAL trough is accompanied by the dimming of the continuum and vice versa.**
7. Our findings support the ionization change scenario.





Mishra et al 2021, MNRAS,504,3187

Appearing BAL VERSES Disappearing BAL

Mishra et al 2021, MNRAS in press

1. We have isolated a new appearing/emerging catalog of BAL absorption troughs over 1-5 yr(rest-frame).
2. We find appearance and disappearance of BAL troughs occur at similar redshifts over similar time scales.
3. Within a time span of 1-5 years the variations of BAL troughs are random (Gibson et al. 2010).
4. We find no significant difference between the variation in BAL trough properties of appearing and disappearing BALs except disappearing BAL troughs are deeper than appearing once.
5. Appearance of BAL troughs is followed by the dimming and disappearance is accompanied by the brightening of the continuum (intrinsic).
6. Disappearing BAL quasars are the low-luminous compare to appearing (check for extinction)
7. Central environment of appearing and disappearing BAL quasar is same.
8. Dust has no significant role in disappearance and appearance of BAL troughs.
9. Extreme variations of BAL troughs are mainly driven by change in ionizing photons.

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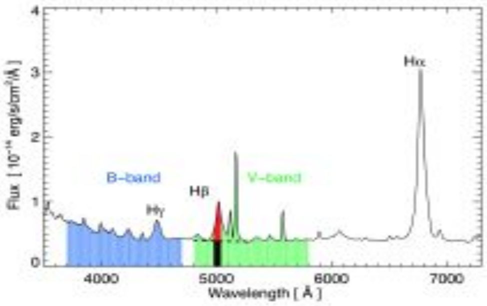
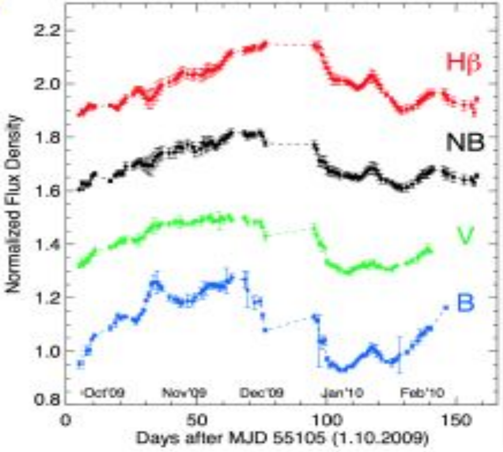
PHOTOMETRIC REVERBERATION MAPPING (PRM





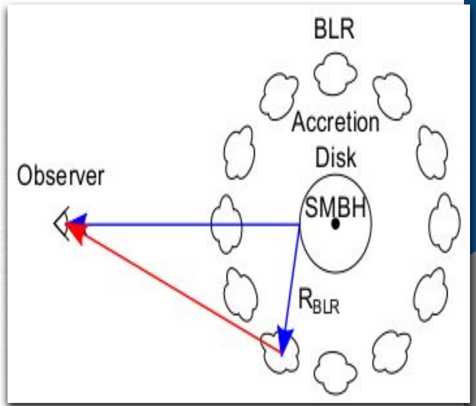
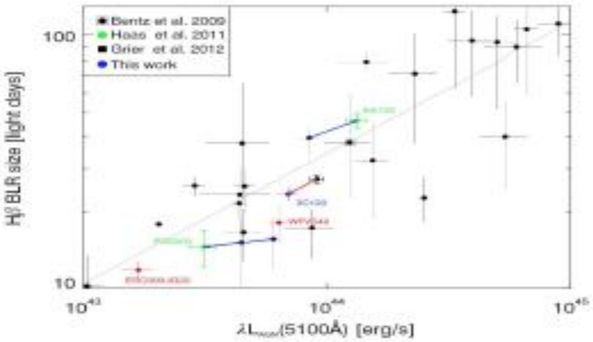


Figure: 3C120 (z=0.033) *Left*: Observed spectra *Right*: Light curve (e.g see Pozo et 2012)

- Using 1.3m DFOT(to afford large telescope time)
  - Continuum light curve using using broad band filter
  - Line intensity light curve using redshifted narrow band filter.
  - Cross-correlation will imply delay(τ_d) such that $R = c\tau_d$
- Using 3.6m DOT (to afford small telescope time)
  - Single epoch spectra $\Longrightarrow FWHM$ for $FWHM^2 = fGM_{bh}/(c\tau_d)$
  - Follow up for any very interesting case, e.g to do Velocity resolved reverberation mapping.

Present Status: Local RM projects



- Local RM project
  - Executed in a serial mode, observing one object at a time.
  - The source selection was also success oriented.
  - Mainly target bright and variable upto z< 0.8 using H-β and H-α line.
- Main drawback of Local RM project
  - lack of co-ordinated efforts
  - lack of un-bised sample to cover full parameter space.

What about $L < 10^{43} erg/s$: 1.3m and 3.6m photometric reverberation mapping (PRM) can help here.

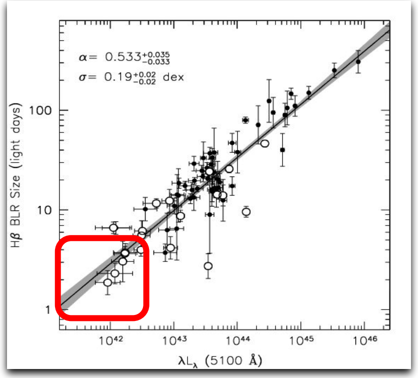
RM provides the scaling of luminosity and the BLR size (R-L) relation.

The low luminosity end of the RL relation, are these AGN different?

Photometric reverberation mapping, a cost effective and efficient way for RM with limited objectives.

1.3m and 3.6m telescopes at Devasthal perfectly suited for such projects.

This project aims to study the low luminosity AGN with H-alpha and/or H-beta emission line RM



Quite challenging, out of 700,000+ AGN only ~120 studied using this technique!!

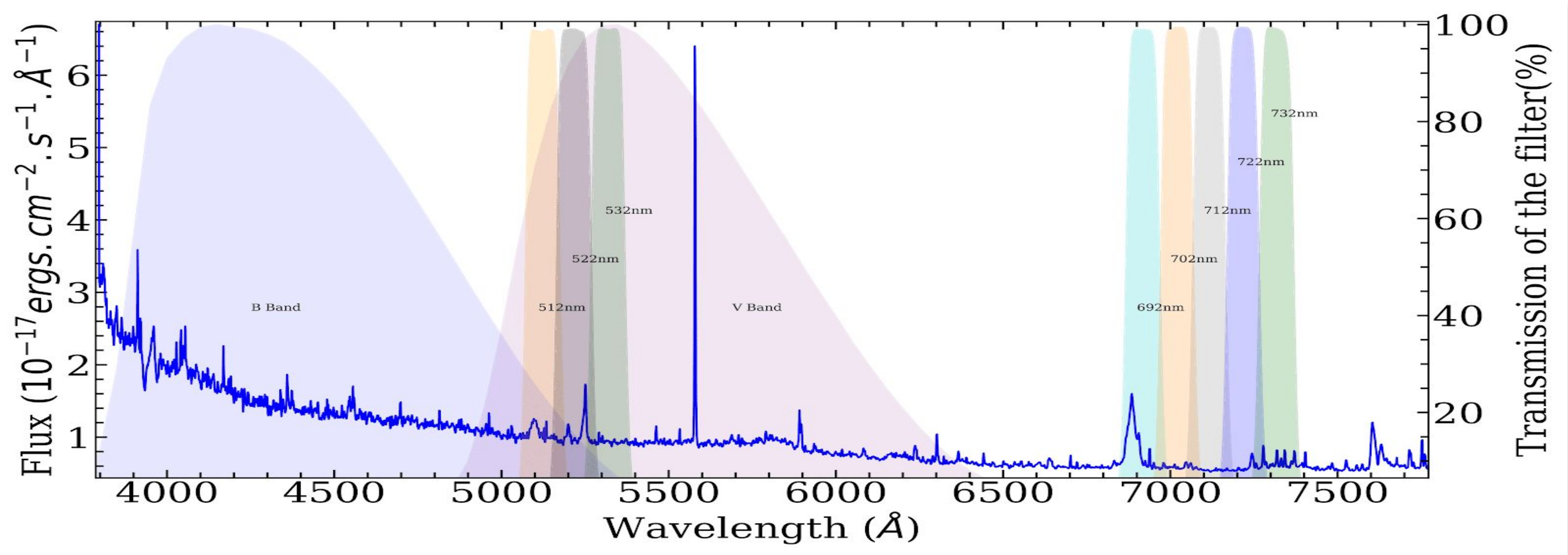
PRM < 10 so far

PRM requires narrow band filters, tuned to specific wavelengths (highly customized).
Very precise filters required: costly but save a lot of observing time.

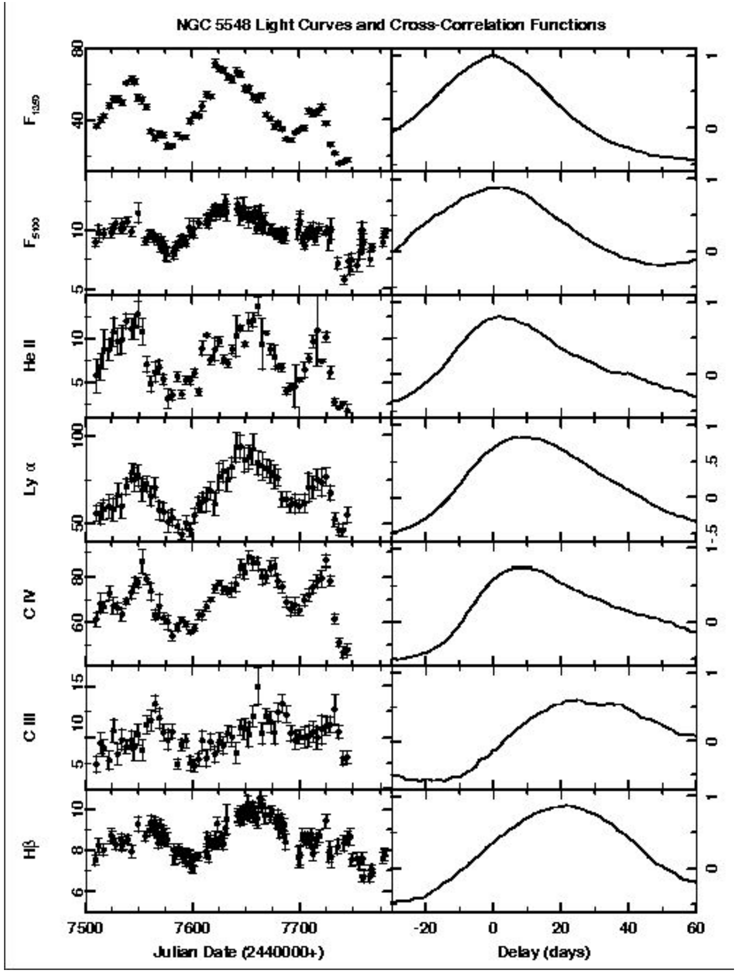
8 narrow band filters purchased: (Rs. 23,14,491 total cost) [July 2018!!!]

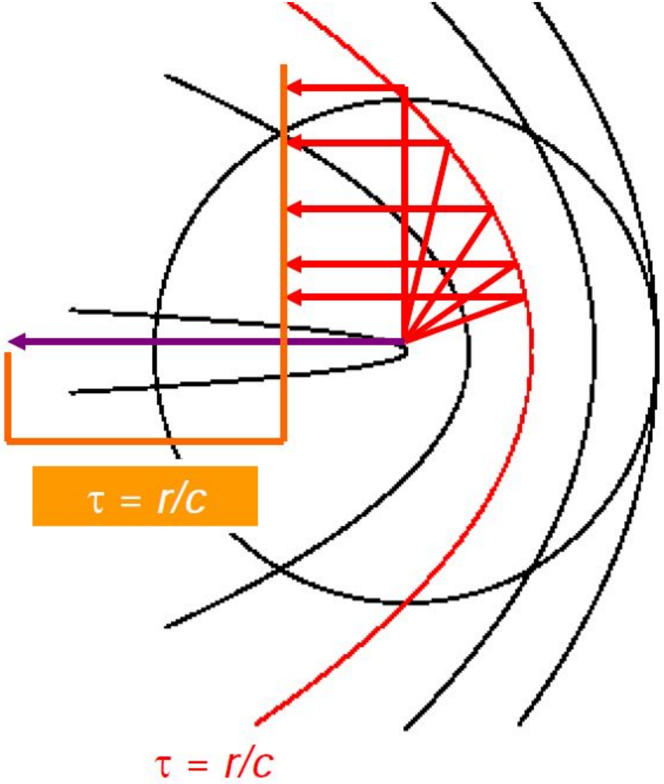
Very important asset for Devasthal observatory.

512, 522,532 nm for catching the H-beta flux at a rest frame of 4861A
692,702,712,722,732 nm for catching the H-alpha flux at 6562.8A



Continuum using the broad band B and V band filters.





Higher ionisation line respond more rapidly
⇒ ionisation stratification

Collaborative observations with NARIT, Thailand

3 Robotic telescopes ~ 0.7m aperture.

Continuum reverberation mapping using Thai Robotic Telescopes (TRT) operated by NARIT, Thailand.

- Sierra Remote observatory, USA.
- GMGO, China.
- Springbrook Observatory, Australia

Data for 5 AGN collected, analysis is in process.

Getting time at the telescopes has been challenging

Telescope	Cycle	Time allotted
1.3m DFOT	2018B,2019A, 2019B, 2020A, 2020B	~40 nights (total+partial)
1.04m ST	2019A, 2019B,2020A,2020B	~10 nights
0.7m NARIT	7C, 7D, 8C	270 (90*3) hours
0.8m Xinglong telescope	2019-20	25 partial nights
IIA GROWTH and 1.3m	Continued …	…..

A large scale RM campaign could not be successfully executed due to irregular time allocation and bad weather in 2018-19.

Now also continuing programme with IIA 1.3m, Thanks to Director ARIES and IIA to allow sharing the resources.

Origin of proposal

ISRO interest:

- 1-meter telescope in Himachal at latitude >30 degree will be very helpful for the detection and follow-up of space debris

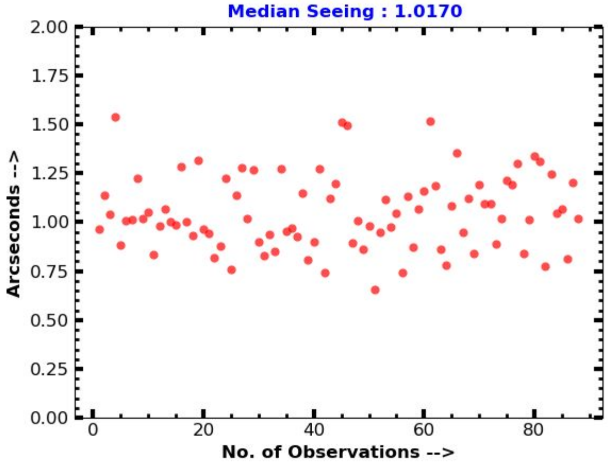
CUHP interest:

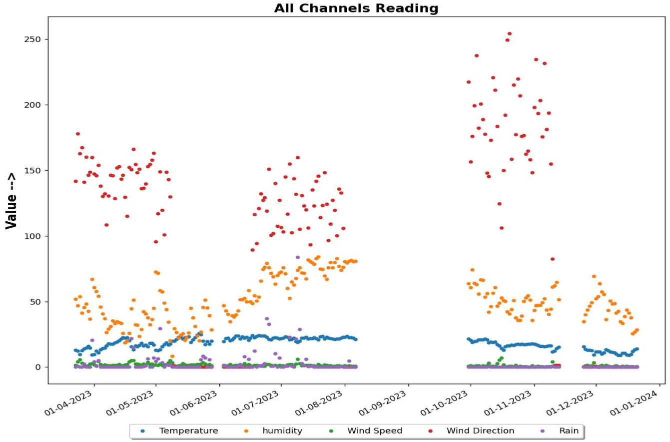
- Started Astronomy and space science at UG and PG level along with vibran research programs for master and PhD thesis.

Signing MoU between ISRO and CUHP on 8th April 2022 for "Astronomy & Astrophysics and Space Situational Awareness".

Site characterization for 1m-telescope at CUHP Dharamshala

Site with median seeing 1-arcsec





- **One this telescope setup, it an be a first ever attempt for a dedicated emission line RM campaign in this country.**

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Scales <lightdays: X-ray emitting regions

Hour like scale, continuum variability

NLSy1 galaxy detected in X-ray and gamma rays: where from X-ray emission comes?

An optical spectrum of Narrow-line Seyfert 1 galaxy, J22423934+2943312

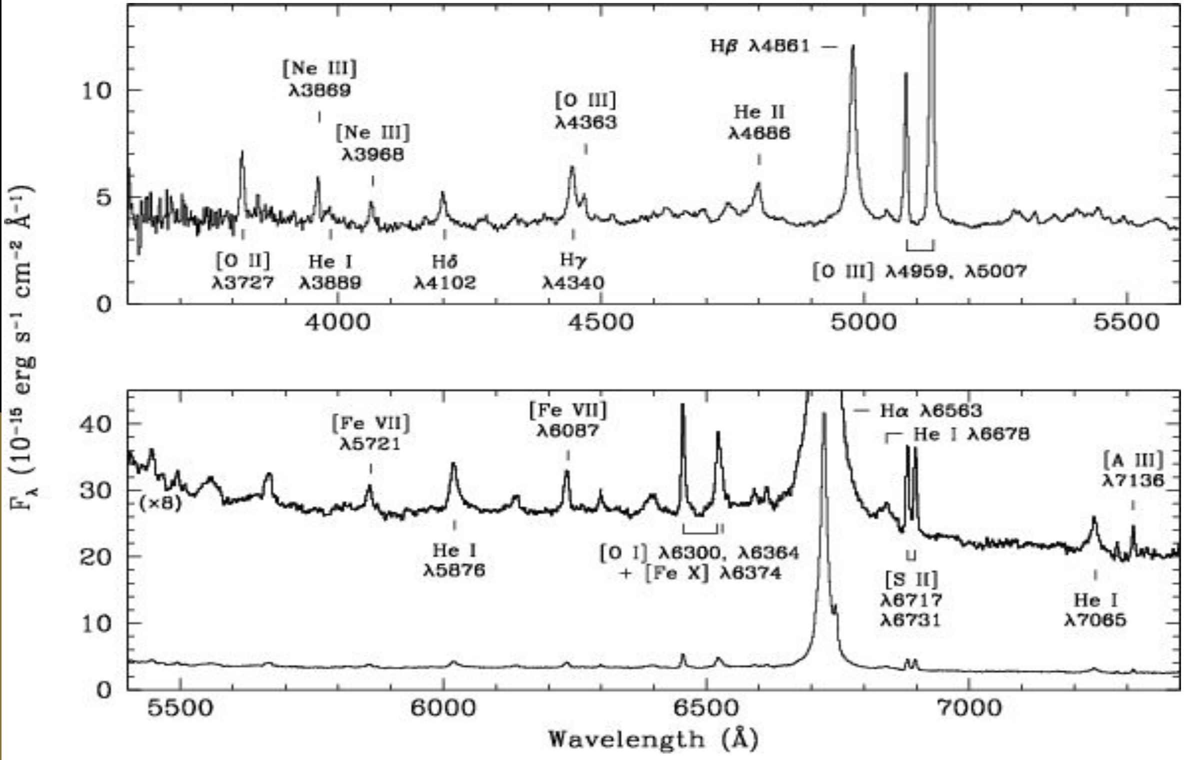


Image taken from Camastri et al. 2001, A&A,365,400.

Narrow-line Seyfert 1 galaxies (NLSy1s) are the special class of lower-luminosity AGNs defined by :

(i) Balmer emission line FWHM(Hβ)< 2000 km s^{-1}

(ii) flux ratio of [OIII] $_{\lambda5007}$/Hβ < 3 and

(iii) having strong permitted optical/UV **FeII emission** line in their spectrum.

A comparison of X-ray photon indices among the narrow and broad-line Seyfert 1 galaxies

Sample Selection:

(i) For the NLSy1s we have used recently a large catalog of 11101 NLSy1s given by Rakshit et al. (2017), along with, a control sample of broad-line Seyfert 1 (BLSy1) galaxies.

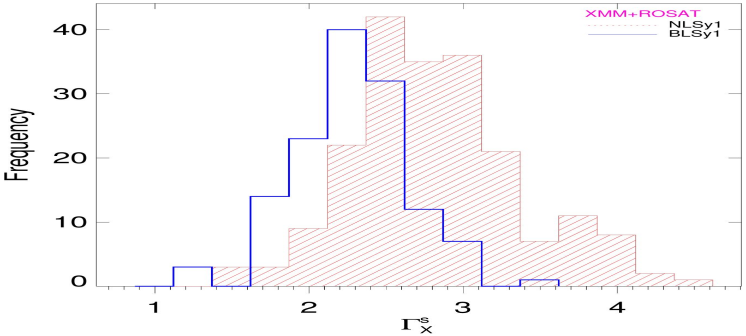
(ii) The average count rate of the source should be greater than 3 times to its background average count rate (i.e. 3σ detection).

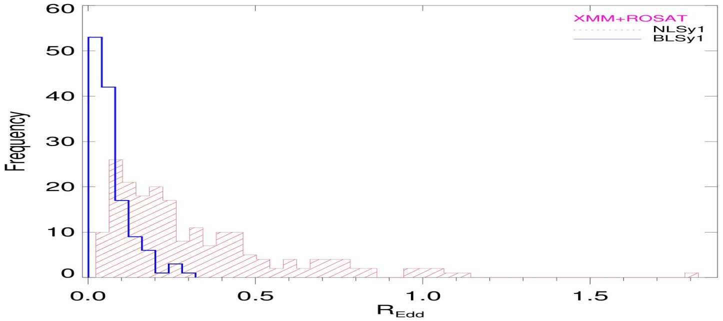
	Selected (taken*)					
	Soft		Hard		Total (Soft+Hard)	
	NLSy1	BLSy1	NLSy1	BLSy1	NLSy1	BLSy1
ROSAT	530(59*)	289(33*)	000(00*)	000(00*)	530(59*)	289(33*)
XMM-Newton	697(141*)	332(99*)	144(56*)	103(51*)	697(144*)	332(103*)
BOTH (XMM+ROSAT)	1227(200*)	621(132*)	144(56*)	103(51*)	1227(203*)	621(136*)

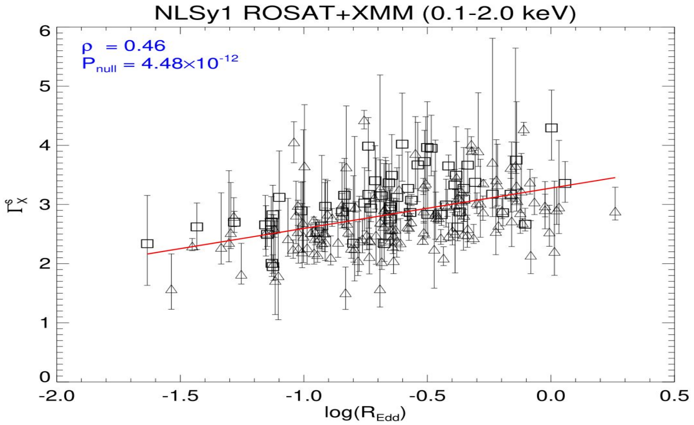
*After imposing minimum 3σ criterion and counting the repeated sources only once along with the exclusion of those sources which could not be fitted with the adopted models (e.g., see Sect. 4.2).

A comparison of X-ray photon indices among the narrow and broad-line Seyfert 1 galaxies

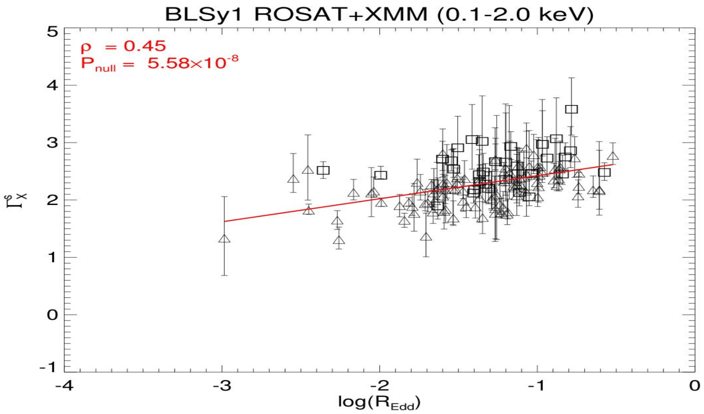
Comparison of soft X-ray photon indices (Γ^S_X) and Eddington ratios (R_{Edd}) between the samples of NLSy1s and BLSy1s





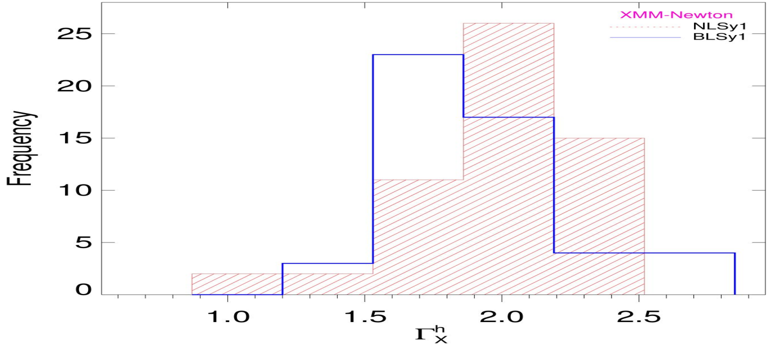


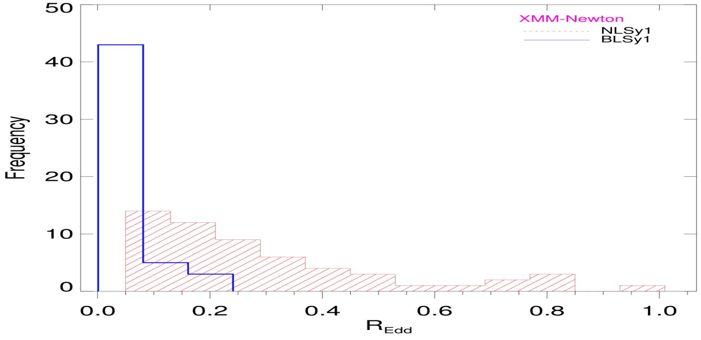
Comparison of Γ^S_X - R_{Edd} correlation between the samples of NLSy1s and BLSy1s

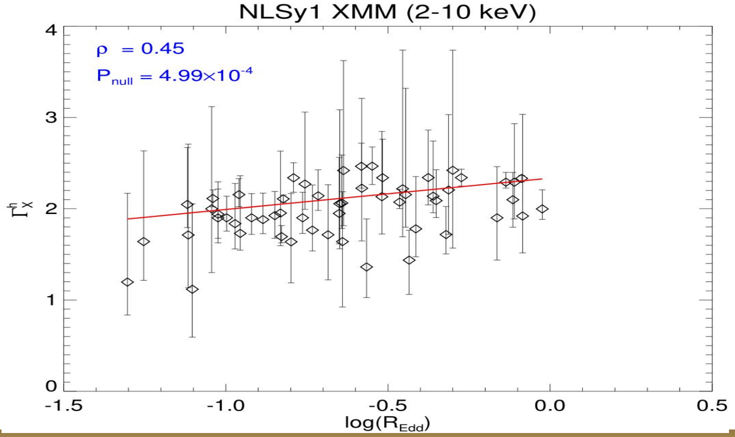


A comparison of X-ray photon indices among the narrow and broad-line Seyfert 1 galaxies

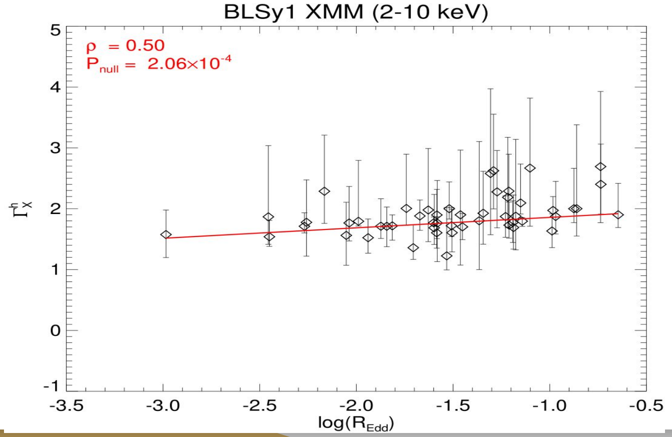
Comparison of hard X-ray photon indices (Γ^h_X) and Eddington ratios (R_{Edd}) between the samples of NLSy1s and BLSy1s







Comparison of Γ^h_X- R_{Edd} correlation between the samples of NLSy1s and BLSy1s



A comparison of X-ray photon indices among the narrow and broad-line Seyfert 1 galaxies

Results and conclusion: *Ojha & Chand et al. 2020, ApJ, 896, 95*

- We found the existence of bimodality in the Γ_x , R_{Edd} distributions among NLSy1 and BLSy1 galaxies, with steeper Γ_x for the NLSy1s.

- We found a strong positive correlation between Γ_x and log(R_{Edd}) in soft and hard X-ray energy bands for both the samples of NLSy1 and BLSy1 galaxies.

- The Γ_x- log(R_{Edd}) correlation found in the samples of NLSy1 and BLSy1 galaxies is intrinsic and independent of soft X-ray excess, inclination effect, and bolometric luminosity.

- Our intrinsic Γ_x- log(R_{Edd}) correlation found for both the samples of NLSy1 and BLSy1 galaxies is found to be consistent with the theoretical prediction of the disc-corona system as proposed for the case of luminous AGNs.

Statistical Approach to constraint BLR model

single epoch spectrum: multiple physical parameters

- FWHM/EW/Area of the emission lines.
- Luminosity of the AGN.
- FeII strength.
- Black hole mass (single epoch mass estimation technique).
- Eddington ratio.
- Emission line asymmetries.
- Size of BLR using R-L relationship.

Related to the Broad Line region

Combined with multi-wavelength observational data, potentially robust method for generating BLR models

The Sample

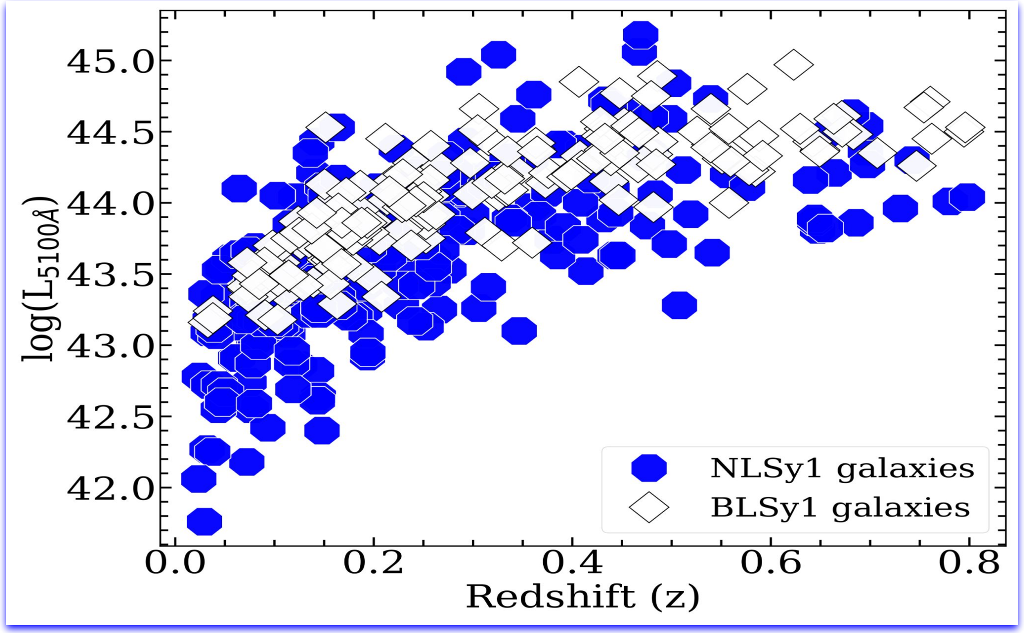
DR 16
spectrum used

Mostly Seyfert-1s, low luminosity end of AGN.

Around 400 total AGN

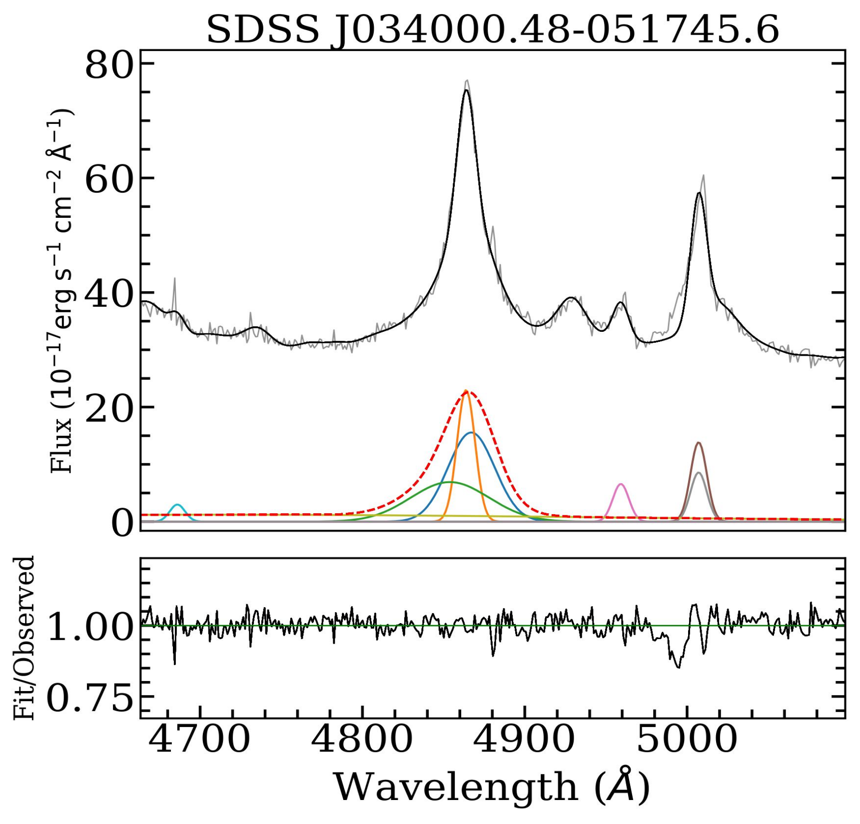
Limited to z=0.8 due to SDSS H-beta detection limit.

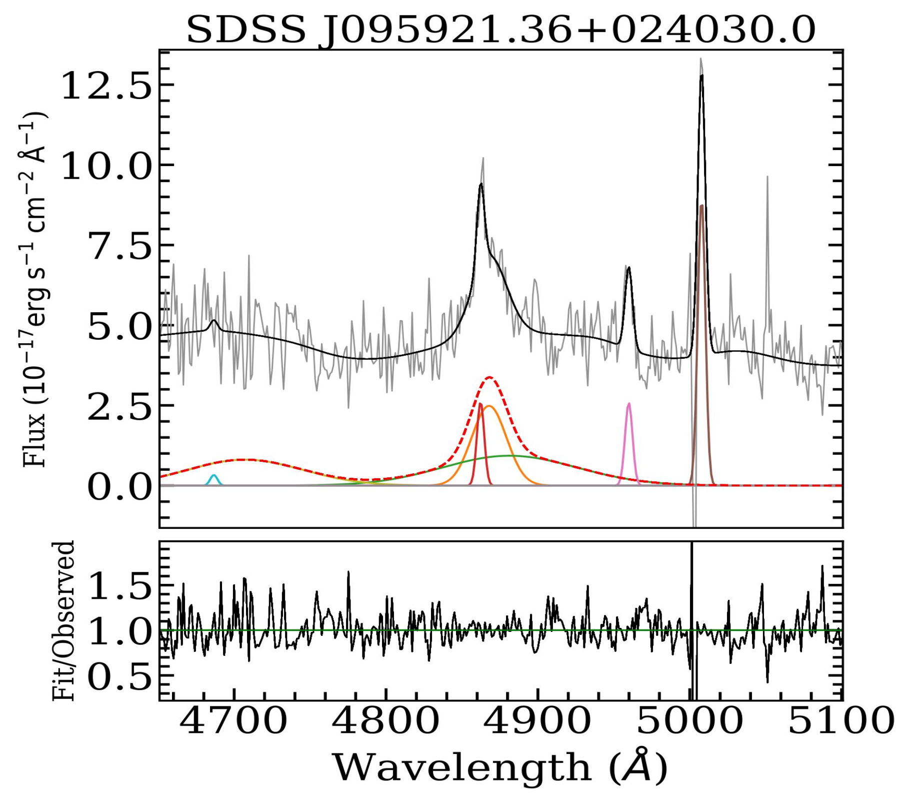
AGN spectral properties don't change much with redshift.



Sources are available in X ray ROSAT and XMM- Newton database as well.
(Ojha et al, ApJ, 2021)

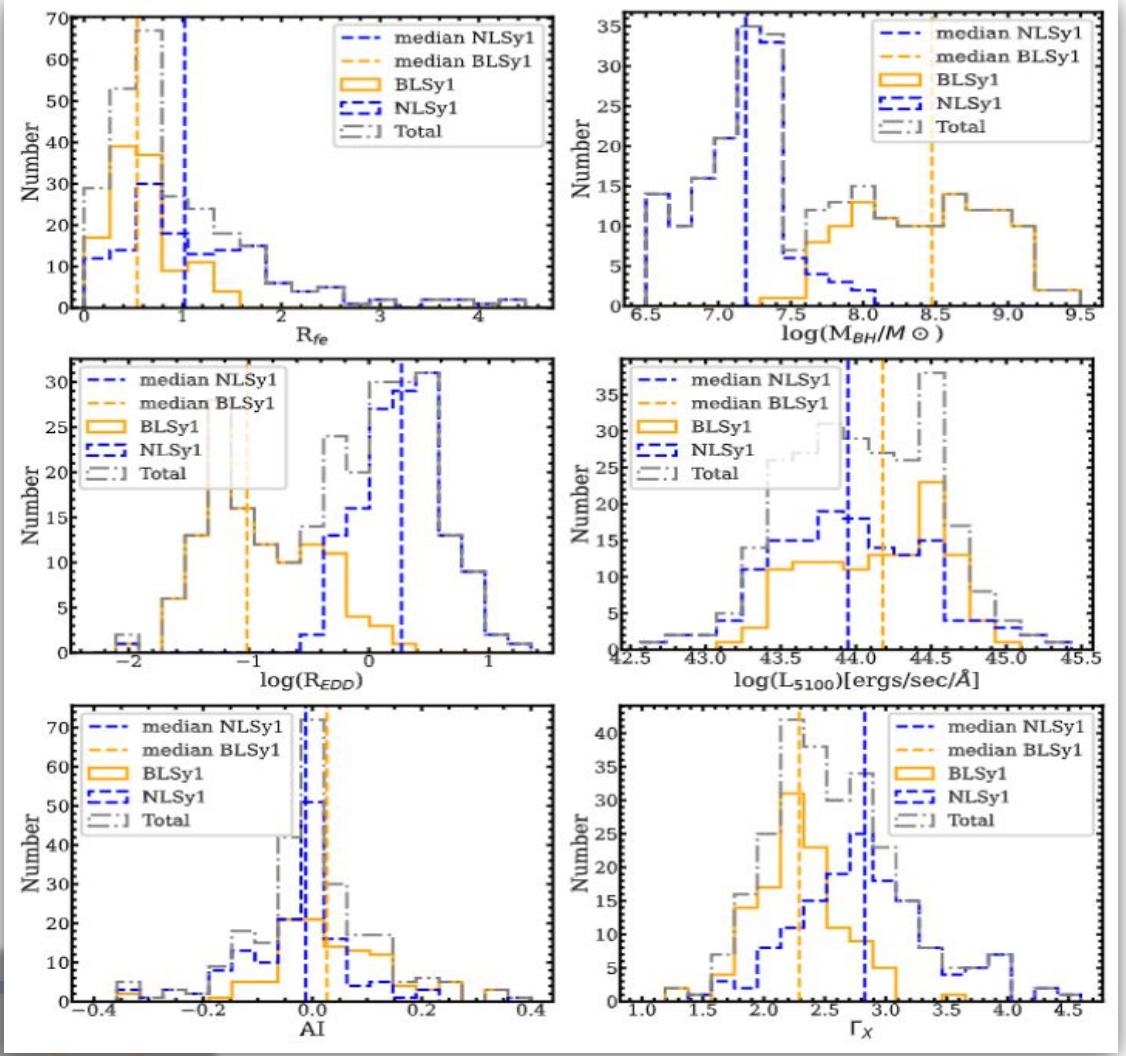
An assumption to be tested is that the Nlsy1 are a subclass of Blsy1. Thus, the emission line parameters must be correlated.





Asymmetric Hβ emission profiles

Jha et al. 2022, MNRAS (arxiv:2112.09150)

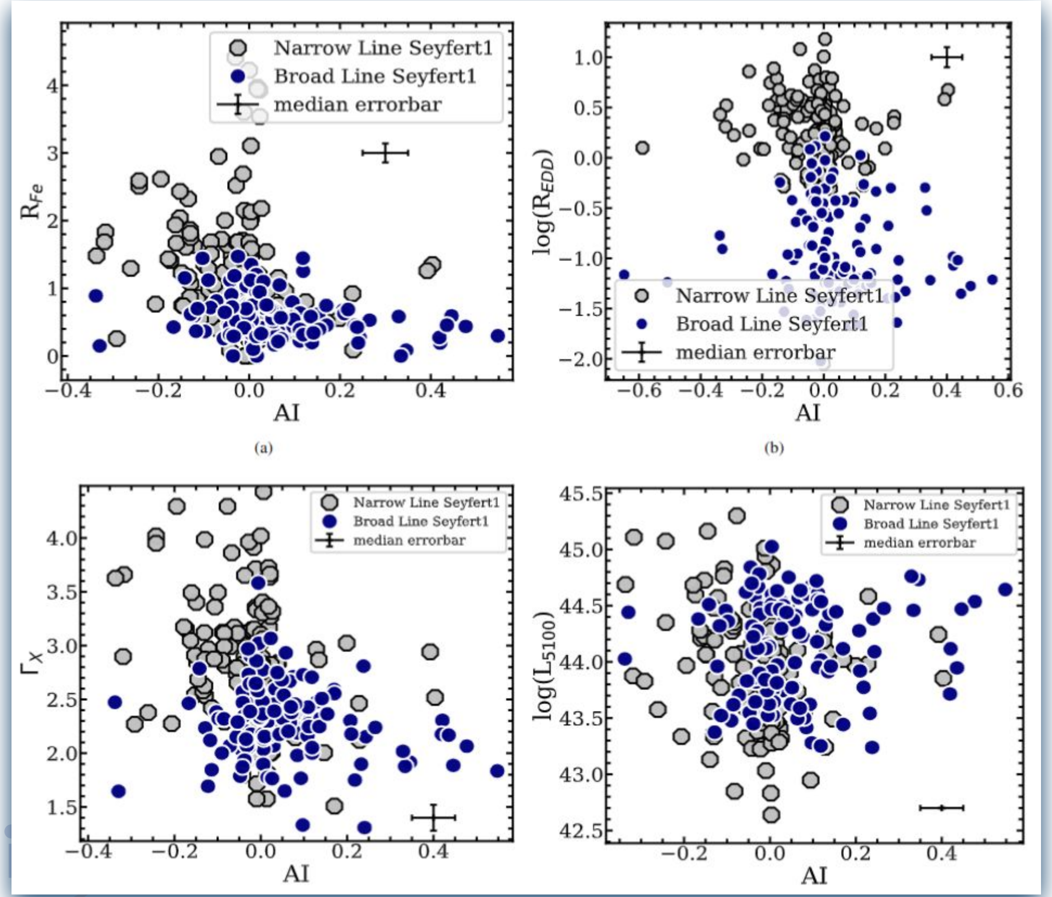


Distribution of parameters

- NLSy1 galaxies:
- Low SMBH mass
- Higher accretion rates
- High R-fe
- Higher X-ray Photon indices
- 3 time more likely to show blue asymmetries

Jha et al. 2022, MNRAS (arxiv:2112.09150)

NLSy1 compared with BLSy1 galaxies



How Asymmetry Index (AI) correlates with other parameters?

Surrogate for FWHM in the 4DE1 formalism, but slight correlation.

- No significant correlations/anticorrelations observed with other parameters

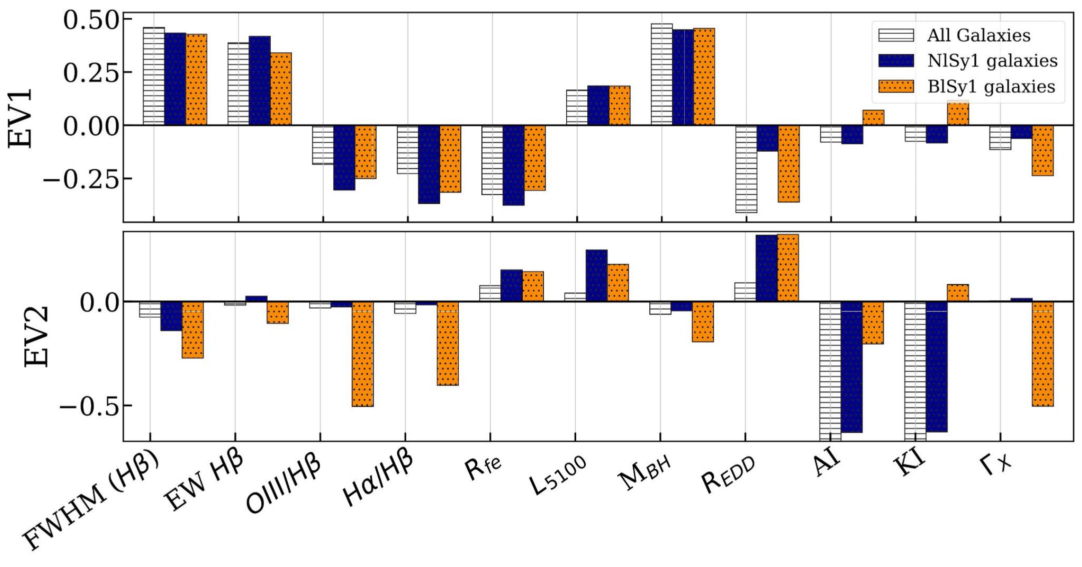
Jha et al. 2022, MNRAS (arxiv:2112.09150)

Principal Component Analysis (PCA)

Dimensionality reduction algorithm.

Only a few principal components can describe the data (Eigenvectors).

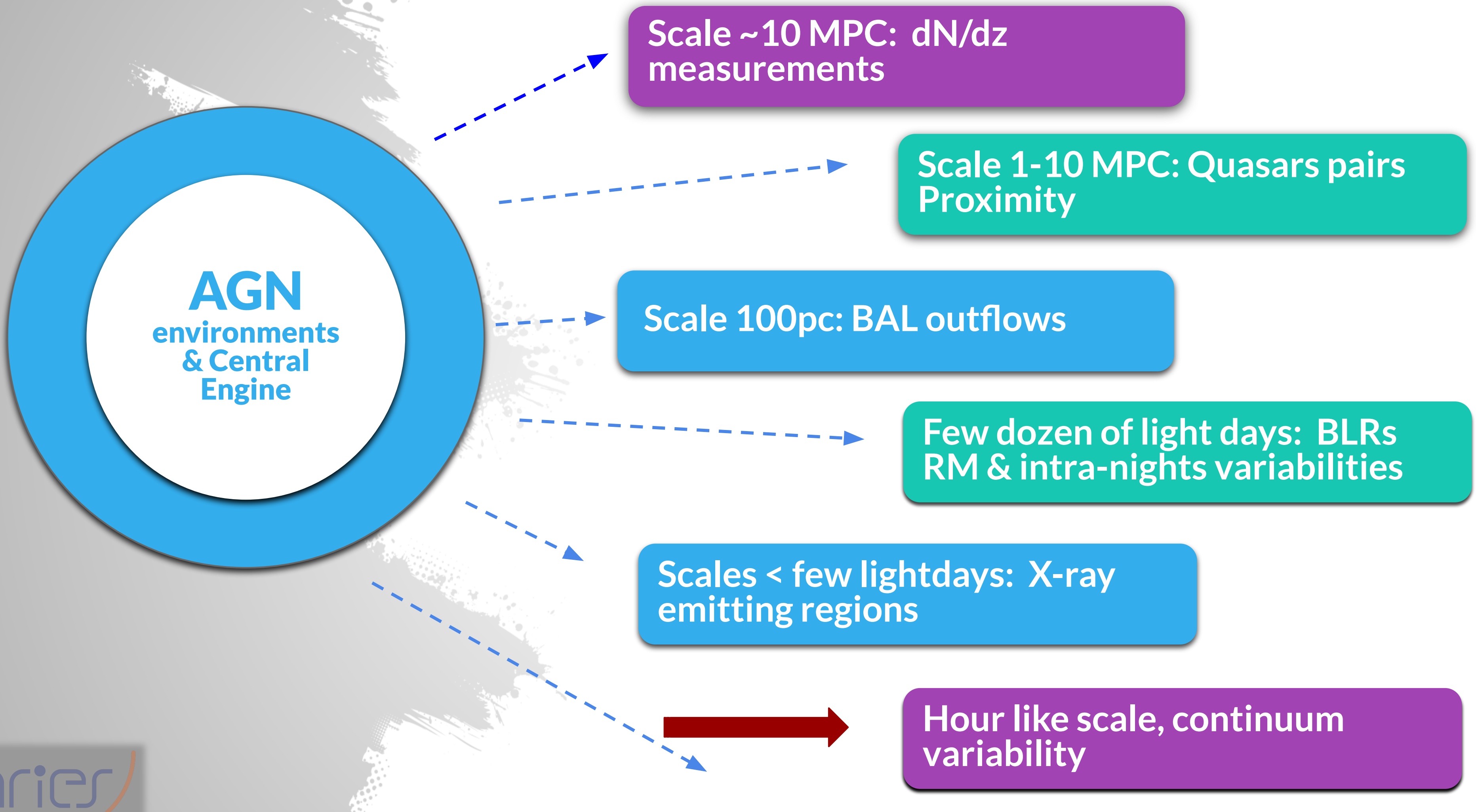
The 4DE1 formalism obtained by Boroson and Greene, 1992. Known as the "Quasar Main Sequence".



EV1 similar for both the types of galaxies but EV2 significantly different!

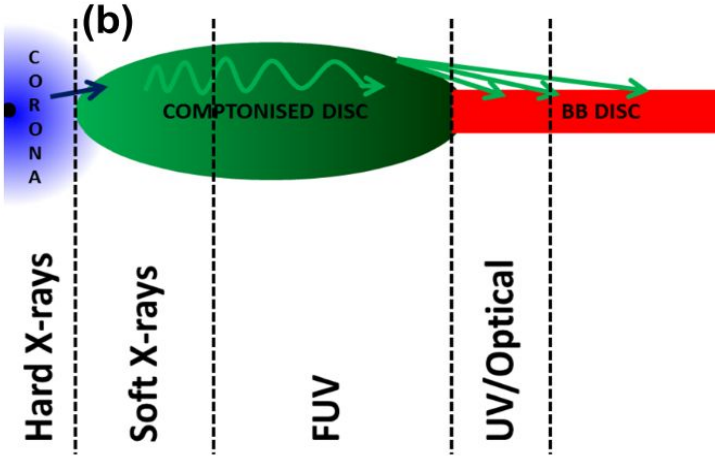
NLSy1 galaxies may not be a subclass of BLSy1 galaxies

Jha et al. 2022, MNRAS (arxiv:2112.09150)


AGN
environments
& Central
Engine
Scale ~10 MPC: dN/dz measurements
Scale 1-10 MPC: Quasars pairs Proximity
Scale 100pc: BAL outflows
Few dozen of light days: BLRs RM & intra-nights variabilities
Scales < few lightdays: X-ray emitting regions
Hour like scale, continuum variability

Shakura Sunyaev (SS) disk model. 4/3 scaling.

The lamp post reprocessing:



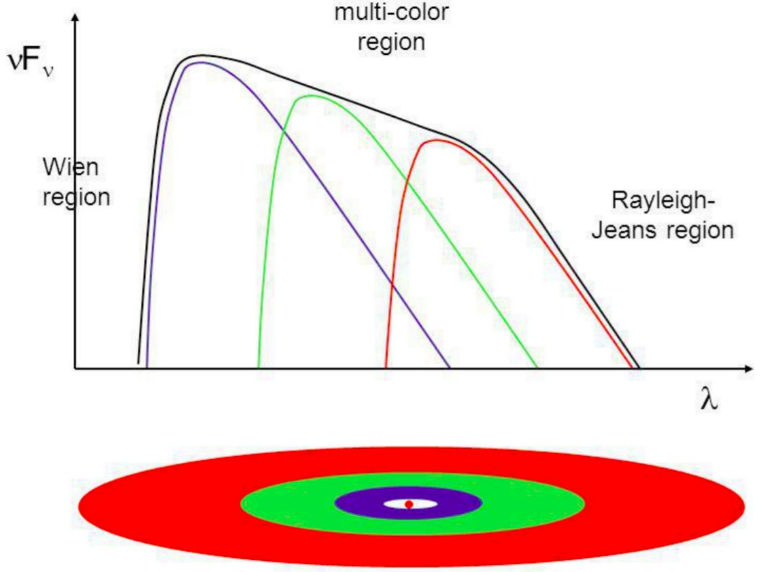
Gardner and Done, 2017, MNRAS

Black body assumption

$$T(R) = \left(f_i \frac{3GM_{\rm BH}\dot{M}}{8\pi\sigma R^3} \right)^{1/4}$$

Inter band lags

$$\tau = \tau_0 \left[\left(\frac{\lambda}{\lambda_0} \right)^{\beta} - 1 \right]$$



β=4/3 for SS disk

$$\left(\frac{\tau_0}{1.0\ \text{days}} \right) = \left(\frac{\lambda_0}{4800\ \text{Å}} \right)^{4/3} \left(\frac{M_{\rm BH}}{10^8\ M_\odot} \right)^{2/3} \left(\frac{\dot{m}_{\rm Edd}}{0.09} \right)^{1/3}$$

Extent of the disk

Multi band monitoring: correlated lags

Simultaneous Disk RM

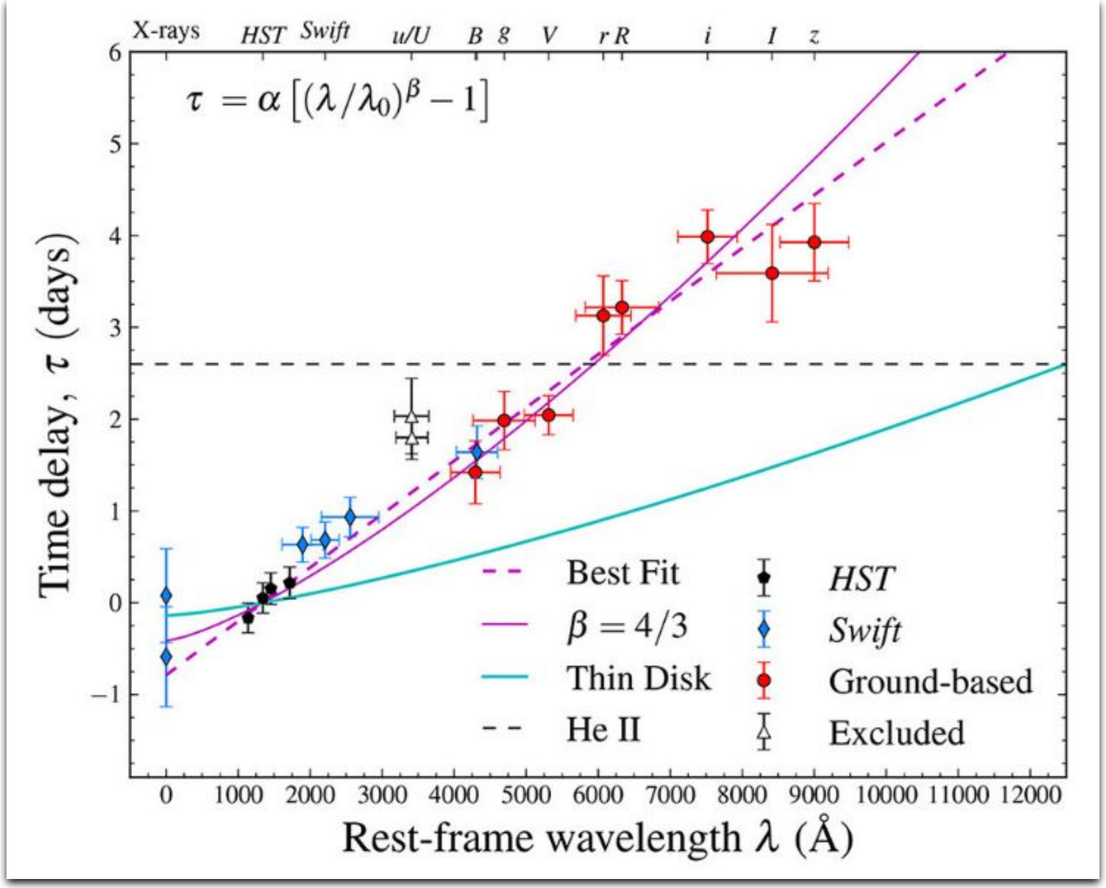
AGN STORM (2015)

6 month of synchronous observations: NGC 5548 (De Rosa et al, 2015 Fausnaugh et al, 2016 etc. 13+ papers so far.)

Disk size follows 4/3 scaling but, Lags 3x larger than predicted!

MRK 509 using SWIFT. (Edelson et al. 2019) and a few others

AGN STORM II (2020-ongoing): MRK 817 (Kara et al. 2021)



Fausnaugh et al. 2016

ZTF survey

Good cadence for upto 3 years (2018-2021) very unique!

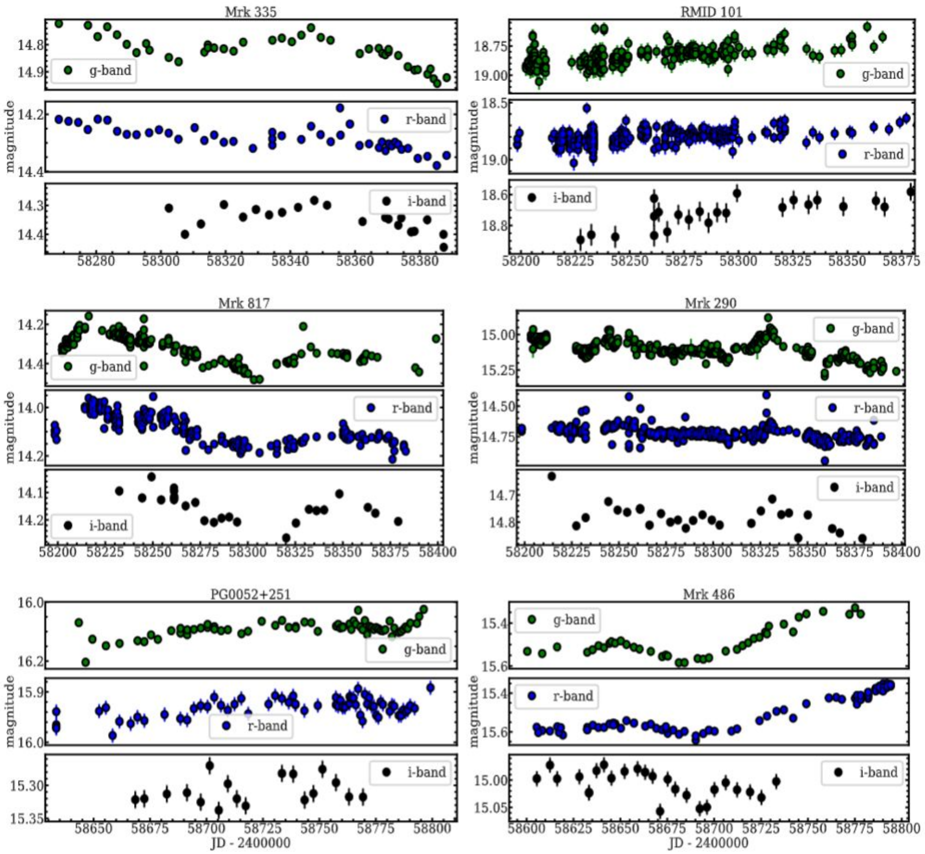
An all sky survey covering wide range of AGN population (unlike SDSS-RM or OzDES)

Is g-r lag shorter than g-i lag?

Accretion disk sizes scaling with BH masses ?

Difference in accretion mechanism between low and high luminosity AGN

RL relation for the disk??

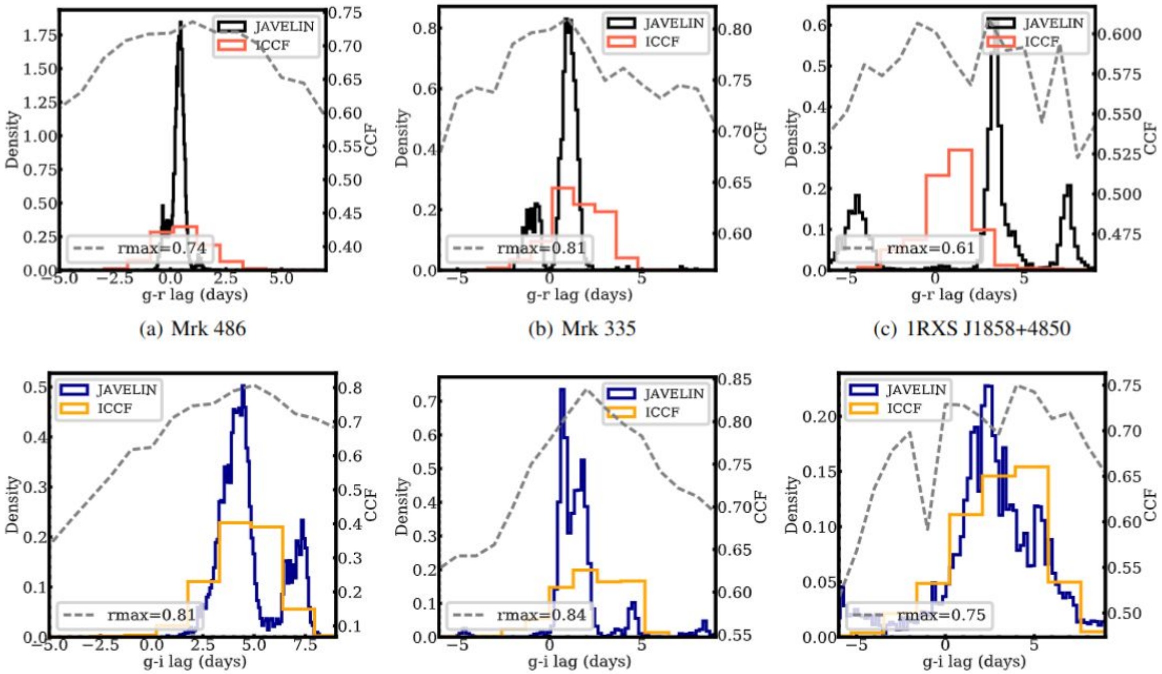


Entire reverberation mapped AGN collection ~120 AGN

Reverberation lags using ICCF/ JAVELIN methods.

19 objects with reliable lag estimate.

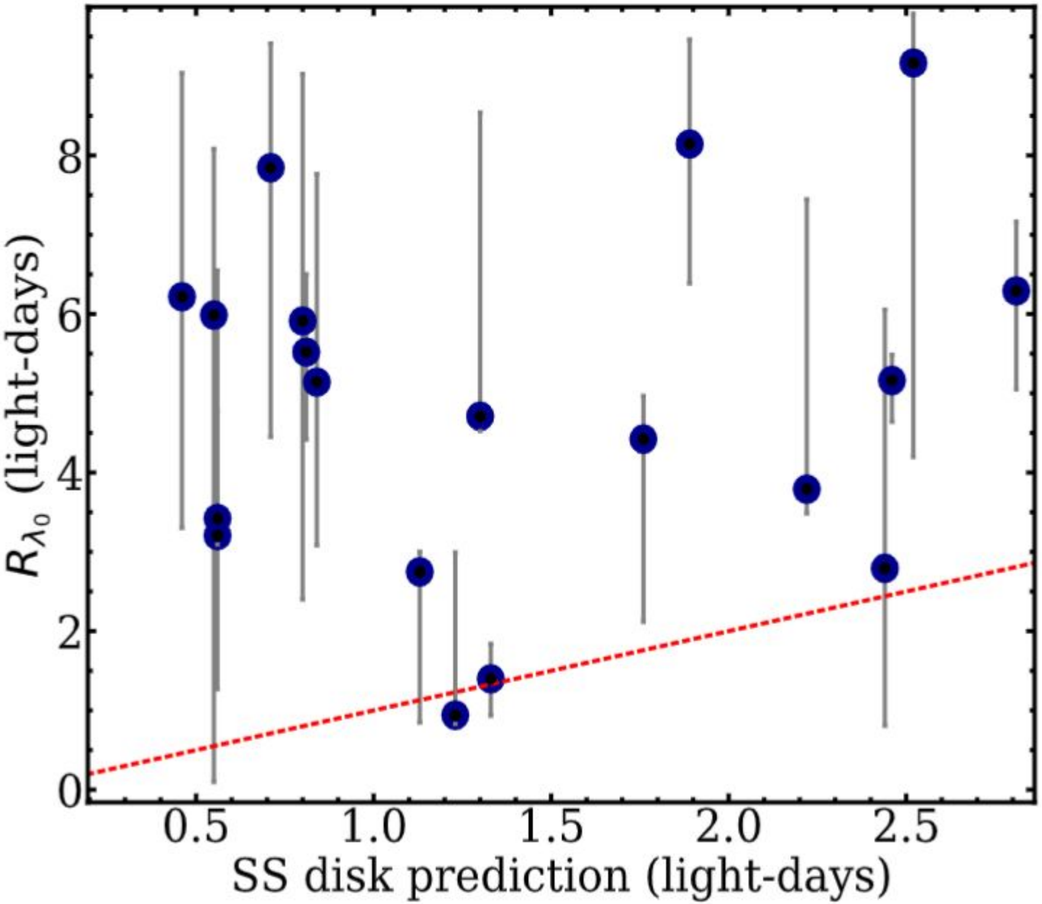
Lag estimation:
- JAVELIN
- ICCF



Shorter g-r lags as compared to g-i lags in most of the cases.

Jha et al. 2023, MNRAS (arxiv:2109.05036)

Comparison with the Shakura Sunyaev disk prediction



- Size of the accretion disk is larger than expected from the standard SS disk model.
- Fitting SS disk model using JAVELIN package (on light curve), reveals the disk sizes to be about 4 times larger than the prediction of the theoretical
- For further understanding, we continue to monitor the sample of SEAMBH AGN using GROWTH telescope.
- Facility like planned 1m-telescope at CUHP can run such long term project.

Long term flux and colour variability of blazars

Motivation:

- Searching for any universality in blazars colour behaviour: ‘Bluer when brighter (BWB)’ or ‘Redder when brighter (RWB)’ trends seen.
- Understanding the origin of the colour variability.

Caveats and Challenges:

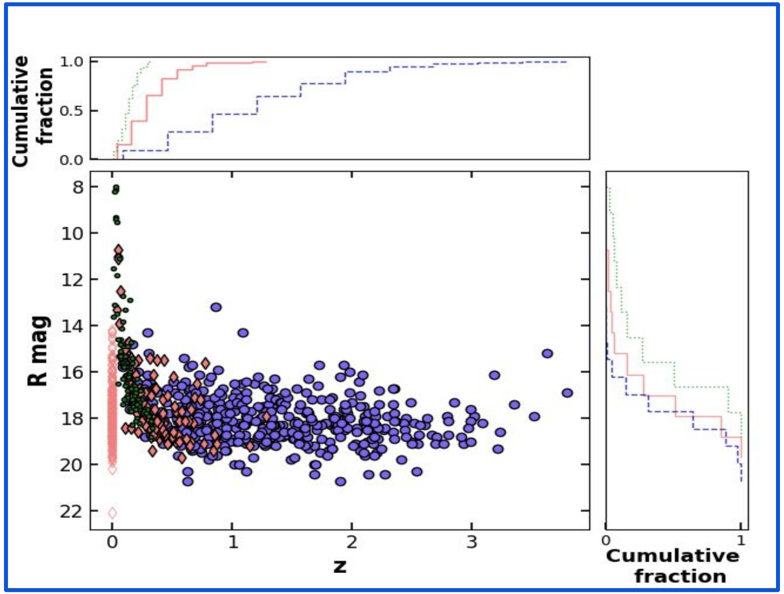
- Targeted observations: time expensive, requires (quasi) simultaneous observations.
- Biased towards brighter objects.

Large and unbiased samples required for checking universality in the colour behaviour.

Sample Selection:

Catalog Used: ROMA BZCAT, 1333 BL Lacs, 1909 FSRQs, 109 host galaxy dominated.

Light Curves data set : Zwicky Transient Facility.



Selection criteria:

- >= 10 quasi-simultaneous (30 min) data-points.
- Poor quality data excluded.

Final Sample:

BL Lacs 455 (109 being host galaxy dominated).

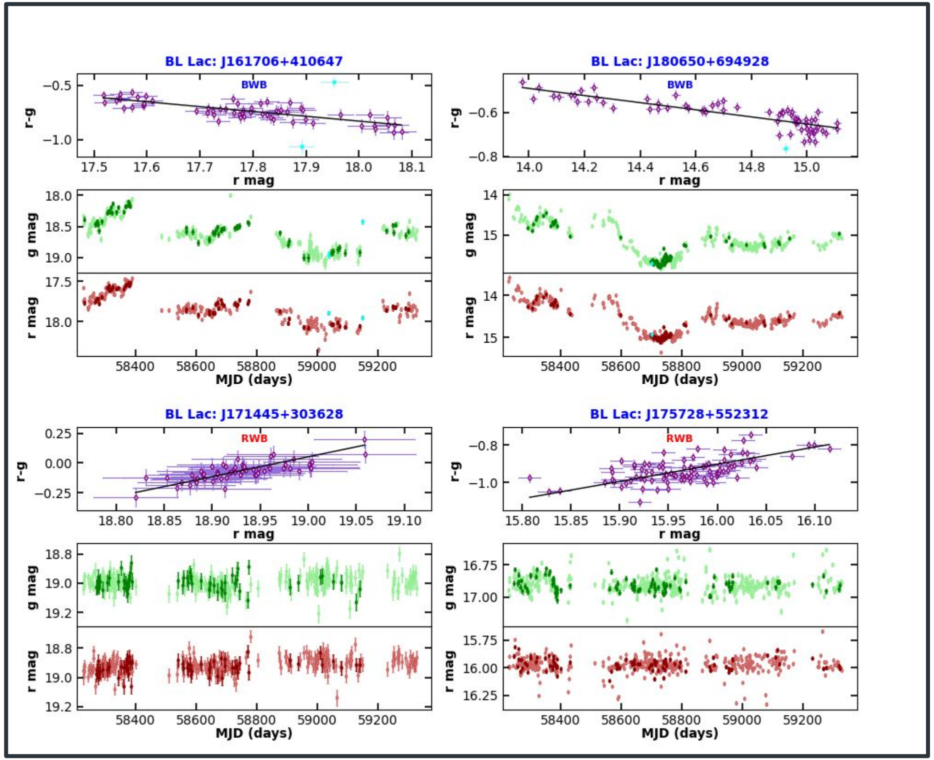
FSRQs 442.

An order of magnitude larger than previous samples.

Analysis and Results:

Variability Amplitude:

- BL Lacs found to be more variable than FSRQs with Ψ_{median} 0.47 and 0.30 mags.
- Excess variability in BL Lacs: larger contribution of the jet.



Colour Variability:

- **Bootstrapped Pearson correlation** coefficient used to find robust BWB or RWB trends.
- Correlation coefficient $\rho \geq 0.5$ and $p_{null} < 0.05$, BWB; $\rho \leq -0.5$ and $p_{null} < 0.05$, RWB.

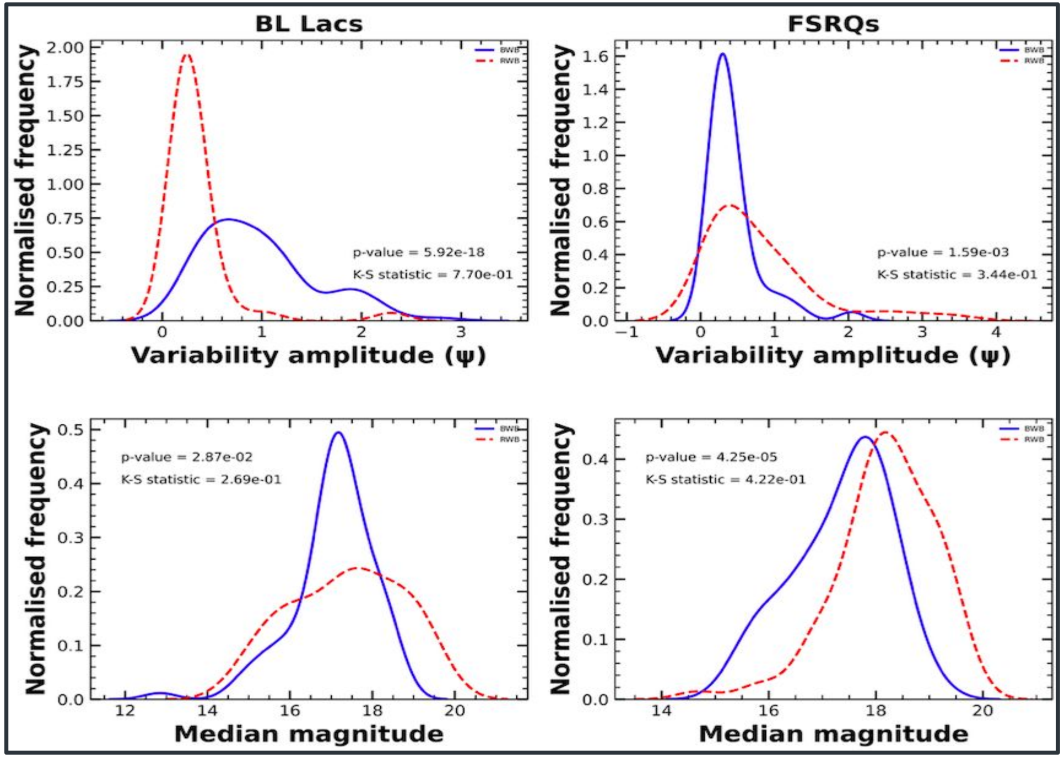
Results of the final sample of BL Lacs and FSRQs showing BWB and RWB trend:

Trend	**Strong** **$\mid \rho \mid \geq 0.5$ & $p\_null < 0.05$**	**Weak** **$\mid \rho \mid \geq 0.2$ & $p\_null < 0.10$**	**Partial** **$\mid \rho \mid \geq 0.5$ & $p\_null < 0.05$**
BWB BL Lacs	84(10)	135(11)	54(1)
RWB BL Lacs	41(29)	66(46)	72(21)
BWB FSRQs	45	81	29
RWB FSRQs	78	118	120

*Numbers in bracket show the host galaxy dominated targets.

Dependence of colour behaviour on blazar state:

- BL Lacs showing BWB behaviour tend to show Ψ as compared to those exhibiting RWB trends.
- Median magnitude for FSRQs with BWB trends is smaller than the ones following RWB trends.
- Brighter FSRQs, likely to be in more active states, follow a BWB trend, whereas the fainter ones follow an RWB trend.



Results:

Negi et al 2022 MNRAS 510, 1791-1800

- Sample Size: 897 blazars, Duration: as large as 2 years,

- Results BL Lacs:
  - **84/455** BL Lacs showed a **BWB** trend
  - 41/455 showed a RWB trend, with 71 % being host galaxy dominated.
  - Extremely variable BL Lacs are most likely to show the BWB trend ⇒ shock-in-jet model, electrons accelerated to high energies make high energy bands more variable.

- Results FSRQs:
  - Only 45/442 systems showed a BWB trend.
  - **78** evinced a **RWB** trend ⇒ strong contributions from the accretion disc.
  - RWB FSRQs are found to be fainter in magnitudes as compared to the BWB FSRQs.

- Multiple partial trends: transitions between jet-dominated and disc-dominated states.

AGN
environments
& Central
Engine

- Scale ~10 MPC: dN/dz measurements
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- Scale 100pc: BAL outflows
- Few dozen of light days: BLRs RM & intra-nights variabilities
- Scales < few lightdays: X-ray emitting regions
- Hour like scale, continuum variability

THANKS