AGN Jet Workshop 2020

The relation between the accretion process and the Faraday rotation of the jet of blazars

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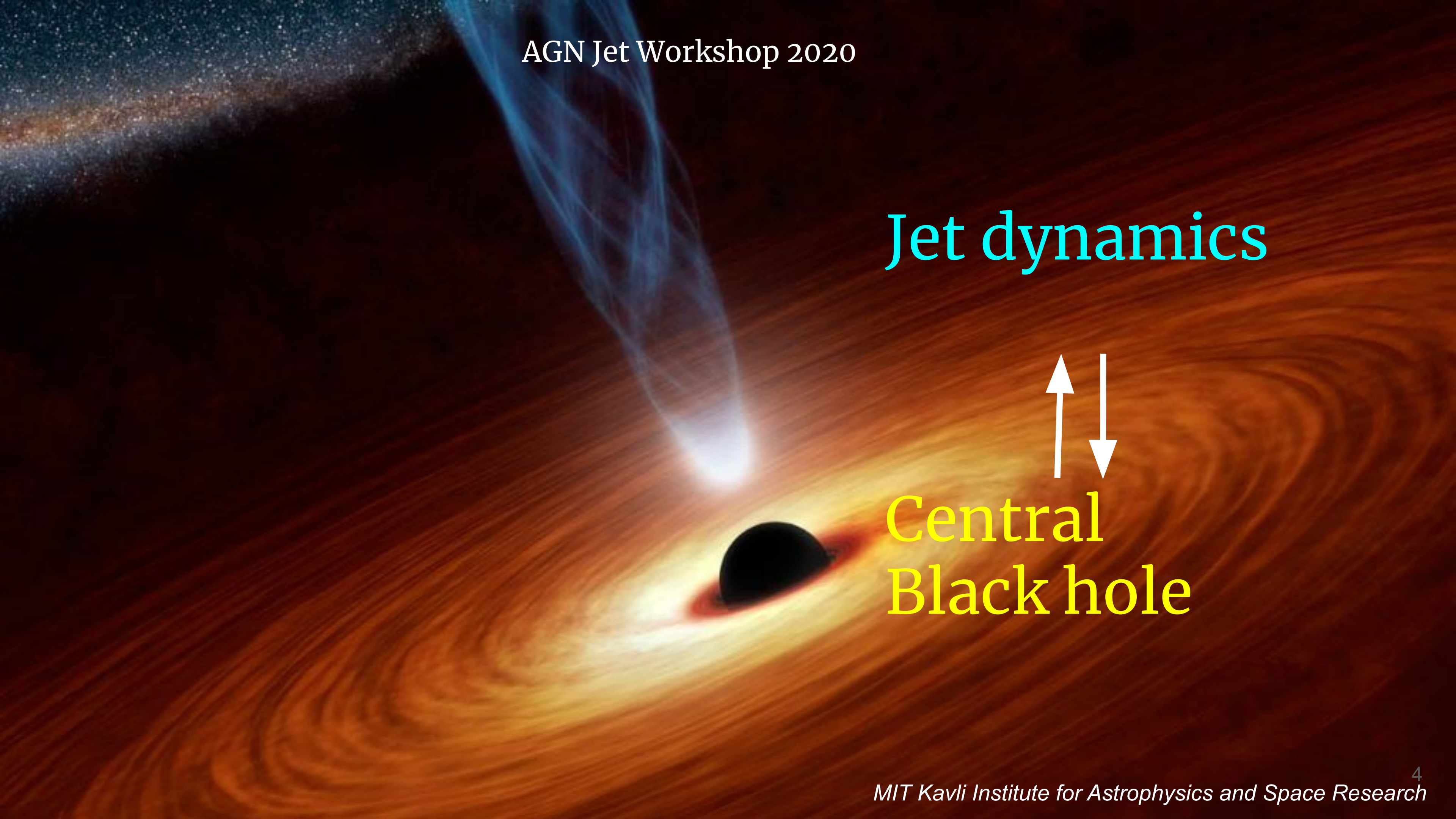
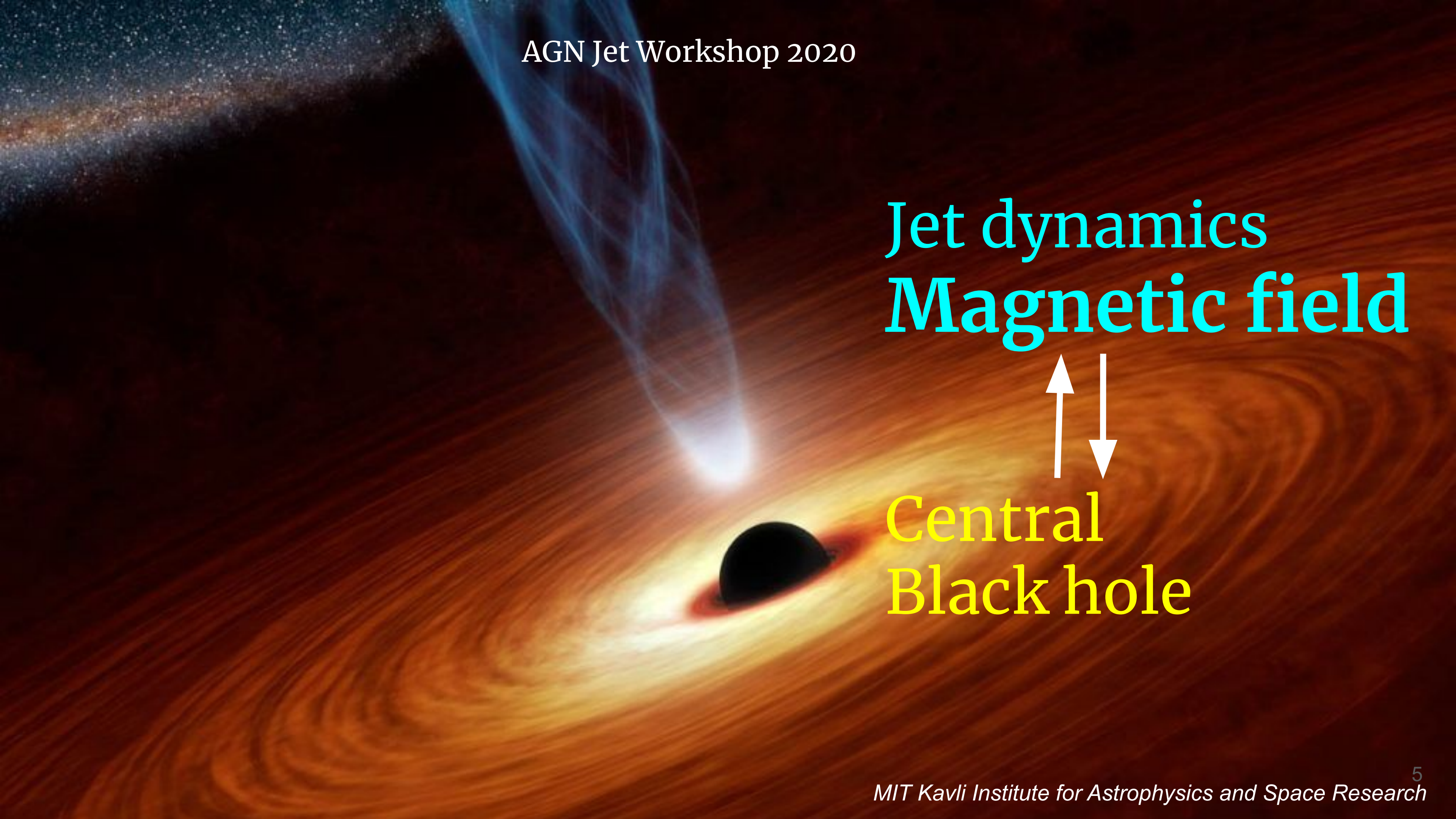
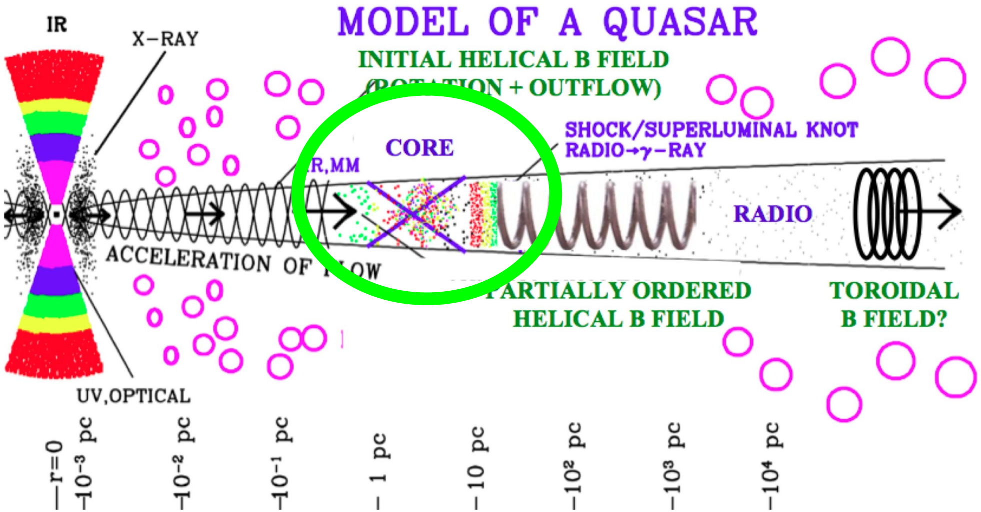
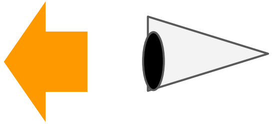
Introduction


Jet dynamics
Central
Black hole


Jet dynamics
Magnetic field
Central
Black hole

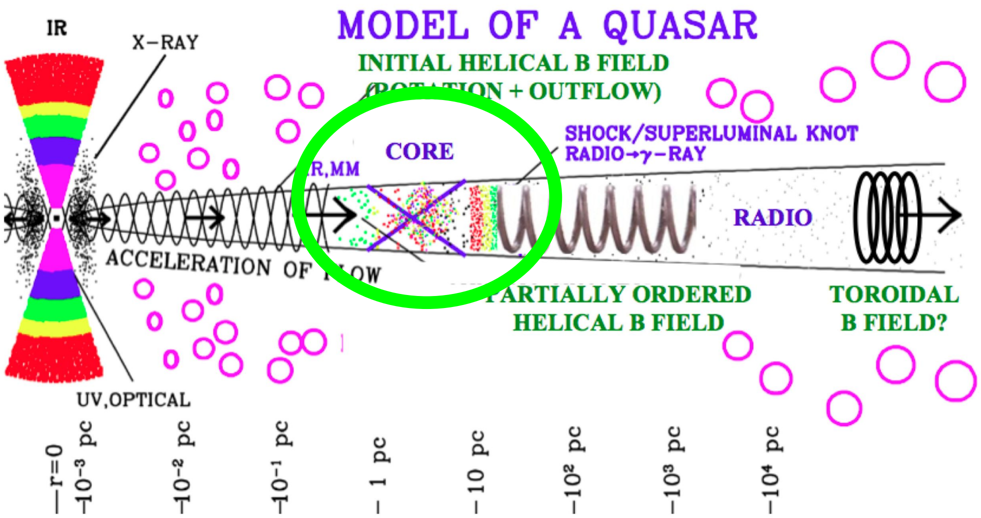
Gabuzda, 2017

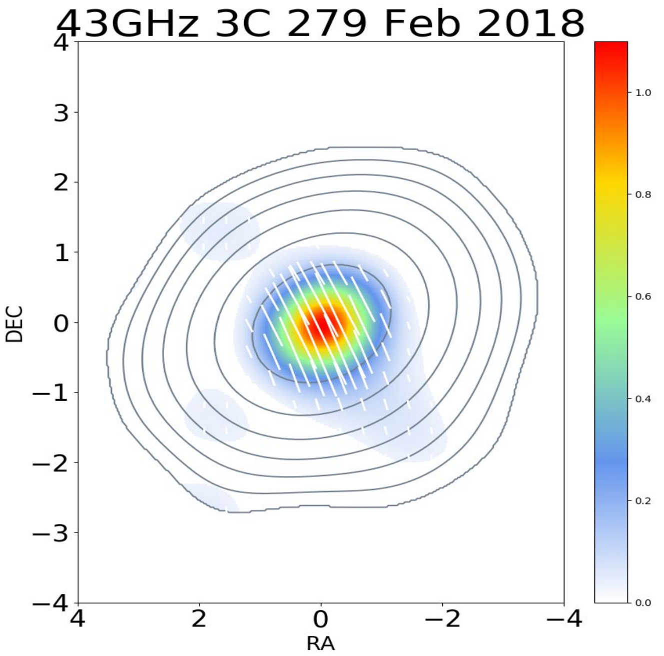




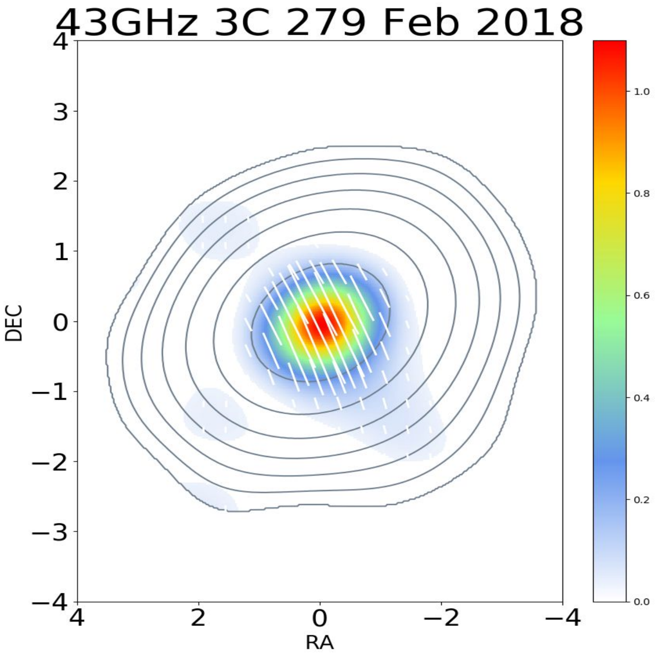
Blazars

Gabuzda, 2017





Multiwavelength Observation of Blazars



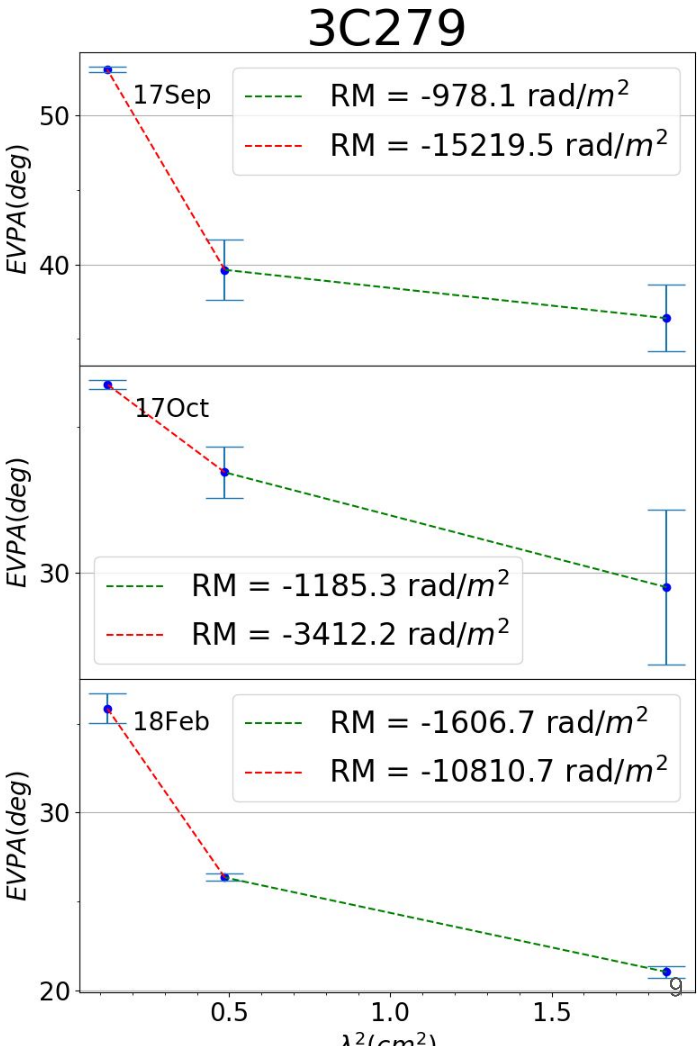
$$\chi_{obs} - \chi_o = \frac{e^3\lambda^2}{8\pi^2\epsilon_o m^2 c^3}\int n_e \mathbf{B}\cdot \mathbf{dl} \equiv RM\lambda^2$$

Rotation measure(RM) is integrated electron density and magnetic field along the line of sight.

$$RM \sim \int_0^l n_e(l) \cdot B_{\parallel}(l)\, dl$$

$$\mathrm{EVPA_{obs}} = \mathrm{EVPA_{int}} + \underline{\mathrm{RM}\lambda^2}$$

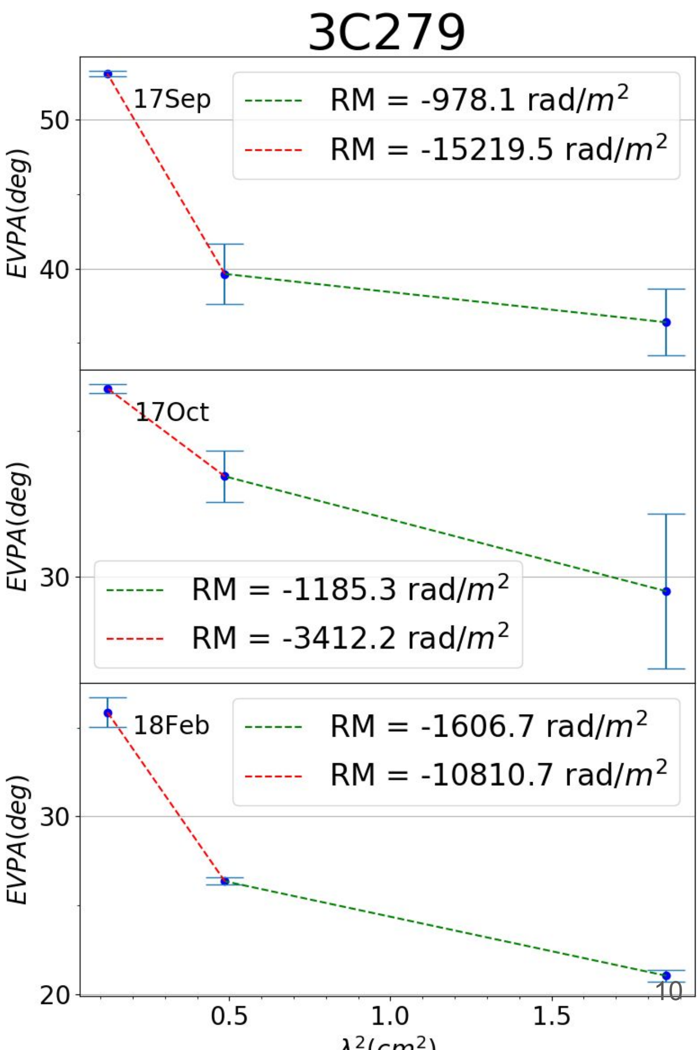
Inclination between two EVPAs
= Rotation Measure



N. Shin @ SNU, Korea

$$RM \sim \int_0^l n_e(l) \cdot B_{\parallel}(l)\, dl$$

$$\mathrm{EVPA_{obs}} = \mathrm{EVPA_{int}} + \mathrm{RM}\lambda^2$$



EVPAs change even in one month -> Multi-frequency data needed to obtained in similar period

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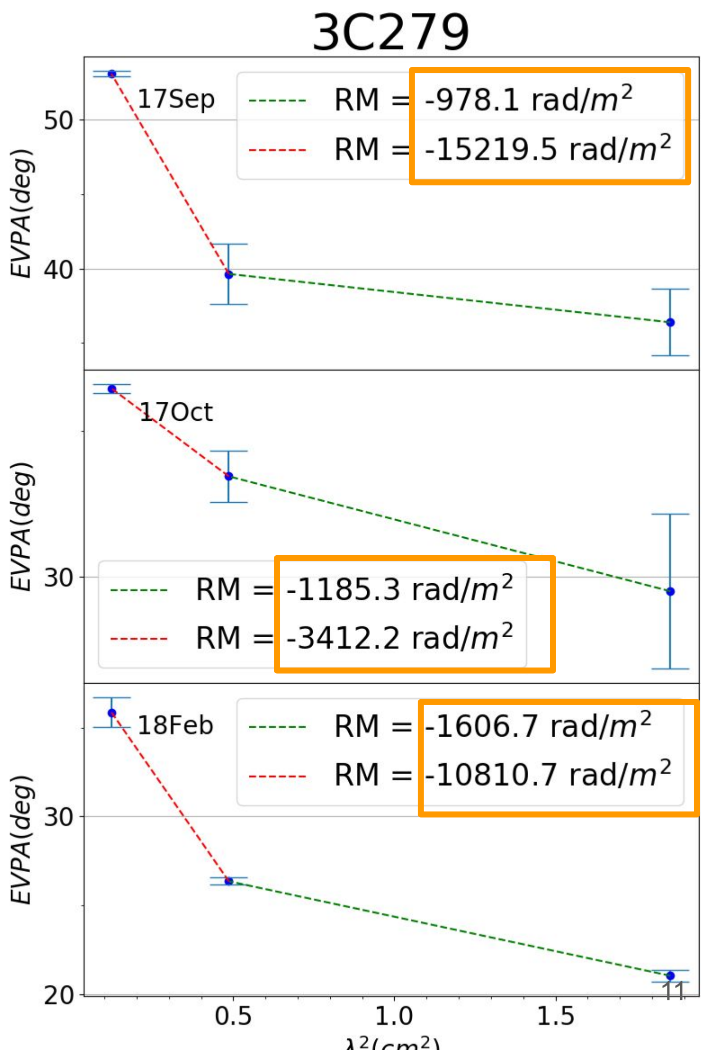
$$RM \sim \int_0^l n_e(l) \cdot B_\parallel(l)\, dl$$

$$\mathrm{EVPA_{obs}} = \mathrm{EVPA_{int}} + \mathrm{RM}\lambda^2$$

Variability of the AGN jet
-> Multi-epoch observation is needed



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Find the relation between the jet and the accretion rate

The jet power ~ **Accretion rate** ~ **Rotation Measure**

↓

Electron density

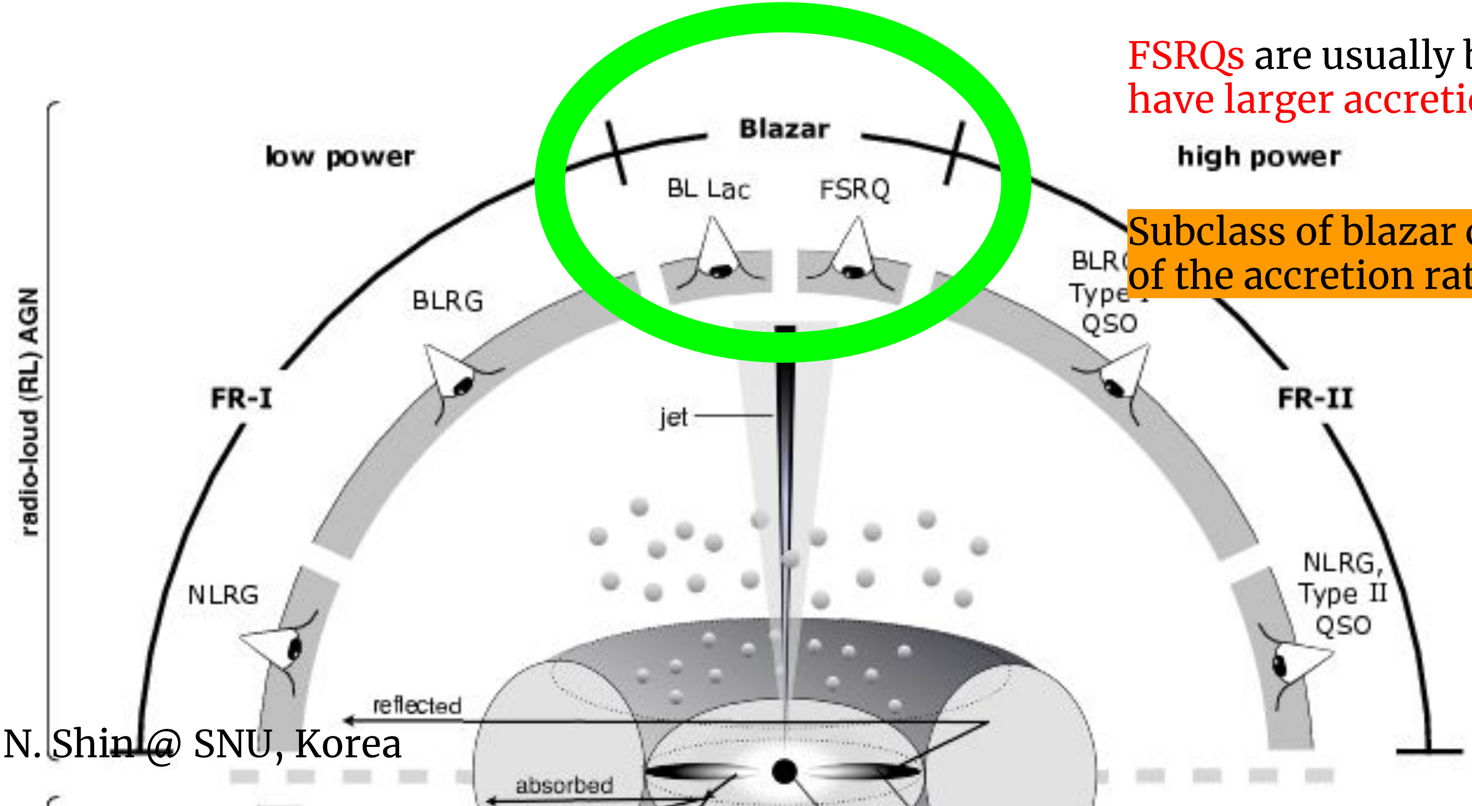
Magnetic field strength

Optical Subclass of Blazar

Flat spectrum Radio Quasar (FSRQ)
& BL Lac Object (BLO)

FSRQs are usually bright and believed to have larger accretion rates than BLOs

Subclass of blazar can be a information of the accretion rate!



Find the relation between the jet and the accretion rate

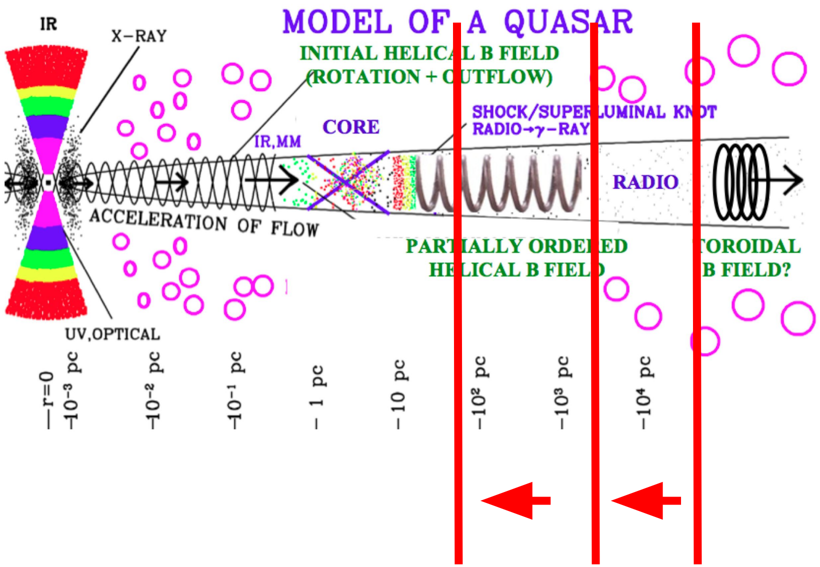
The jet power ~ **Accretion rate** ~ **Rotation Measure**

Accretion rate ↓ **FSRQs** / **BLOs**

Rotation Measure ↓ **Electron density** / **Magnetic field strength**

Statistical studies of FSRQs & BLOs using rotation measure

8~15GHz (Hovatta et al. 2012, Zavala & Taylor, 2004)



The inner region of the jet near the core
Can be observed **with higher frequency**

Data & Targets

KVN monitoring program

We used monthly monitored data observed simultaneously at 22 (K), 43 (Q), and 86 (W) GHz by the Korean VLBI Network (KVN) from the Plasma-physics of Active Galactic Nuclei project (PaGaN).

7 FSRQs and 5 BLOs

FSRQs	BLOs
3C279	BL Lac
3C345	OJ287
3C454.3	0235+164
NRAO150	0716+714
NRAO530	1749+096
CTA102	
1633+38	

In 6 epochs from 2016 to 2018

Results

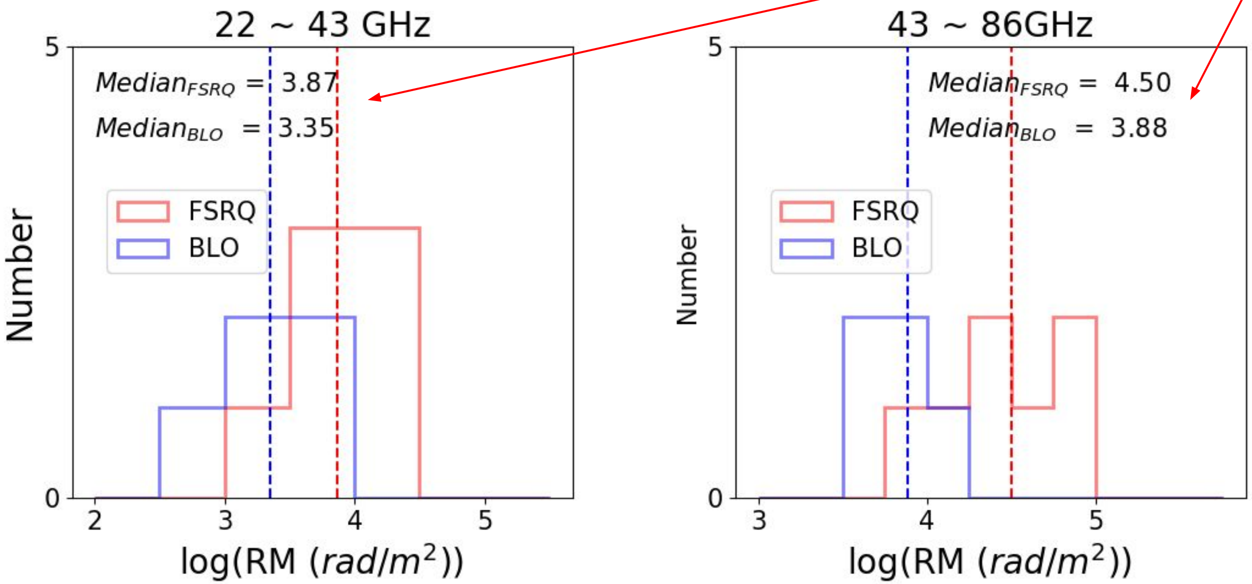
Result 1:
FSRQs have larger RMs than BLOs

Result 2:
Similar slope between FSRQ & BLO in freq - RM figure

Result 3: High accretion with large RM in FSRQ

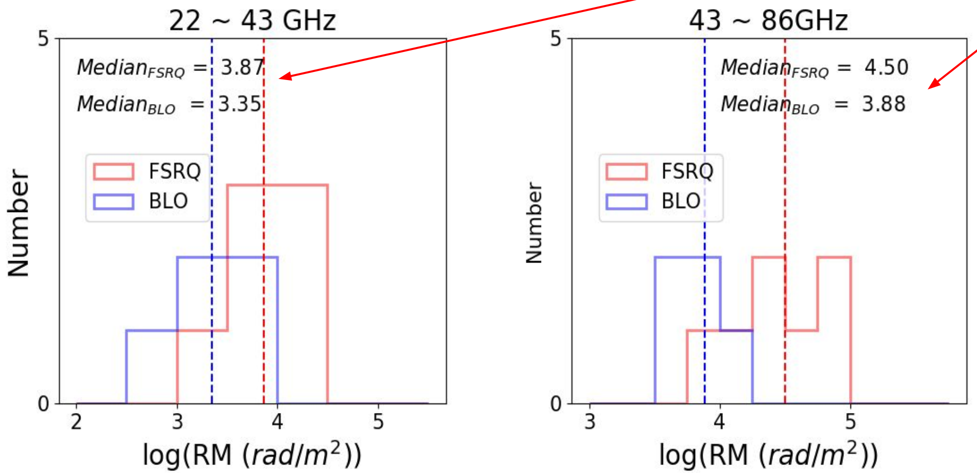
RM of optical subclasses

In logarithmic scale



RM of optical subclasses

In logarithmic scale

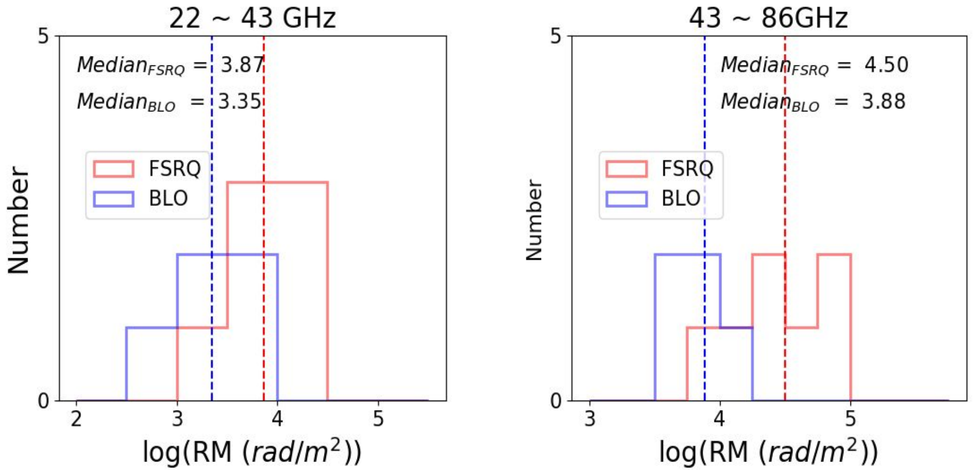


The median value of RM of FSRQs is larger than BLOs

22 ~ 43 GHz: 2.7 / 43 ~ 86 GHz: 4.7 times larger

BLOs have less surrounding materials -> less density, low B of the jet

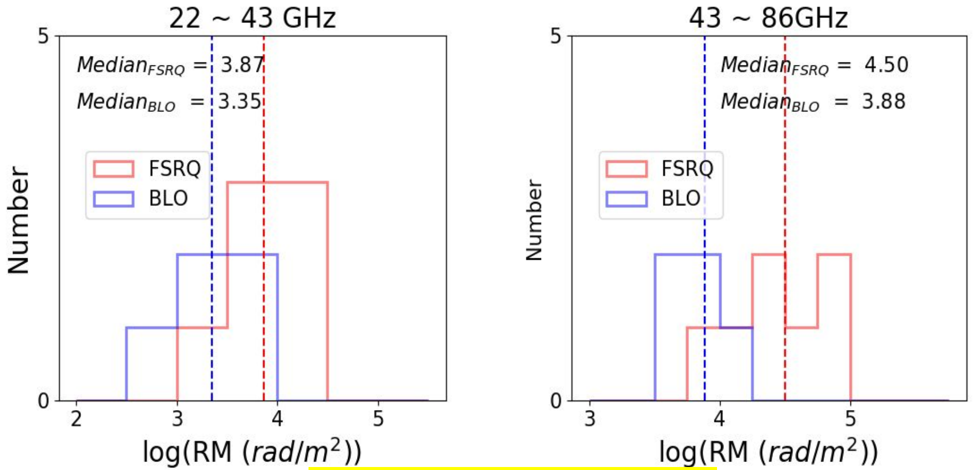
RM of optical subclasses



K-S test for 22 ~ 43 GHz: p value = 0.30
K-S test for 43 ~ 86 GHz: **p value = 0.02**

In higher frequency, the two groups are significantly separated!

RM of optical subclasses



The median value of RM of FSRQs is larger than BLOs

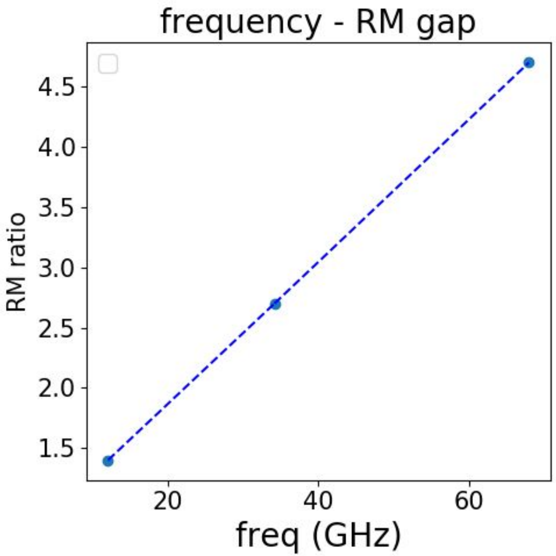
43 ~ 86 GHz: 4.7

22 ~ 43 GHz: 2.7

8 ~ 15GHz : 1.4 times larger (Hovatta et al. 2012)

The gap of two groups become larger in a higher frequency.

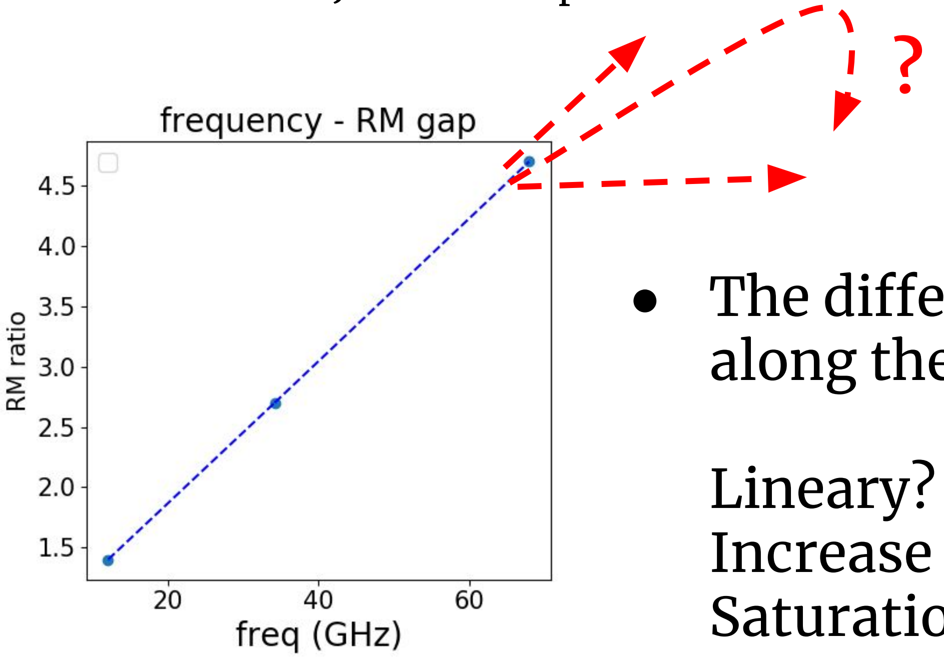
$$\frac{RM\_fsrq}{RM\_blo}$$



Observing frequency
(Geometric mean)

- The difference increase along the frequency
- With higher frequency, we can observe the deeper region of the jet

RM_fsrq
―――――
RM_blo



Observing frequency
(Geometric mean)

- The difference increase along the frequency

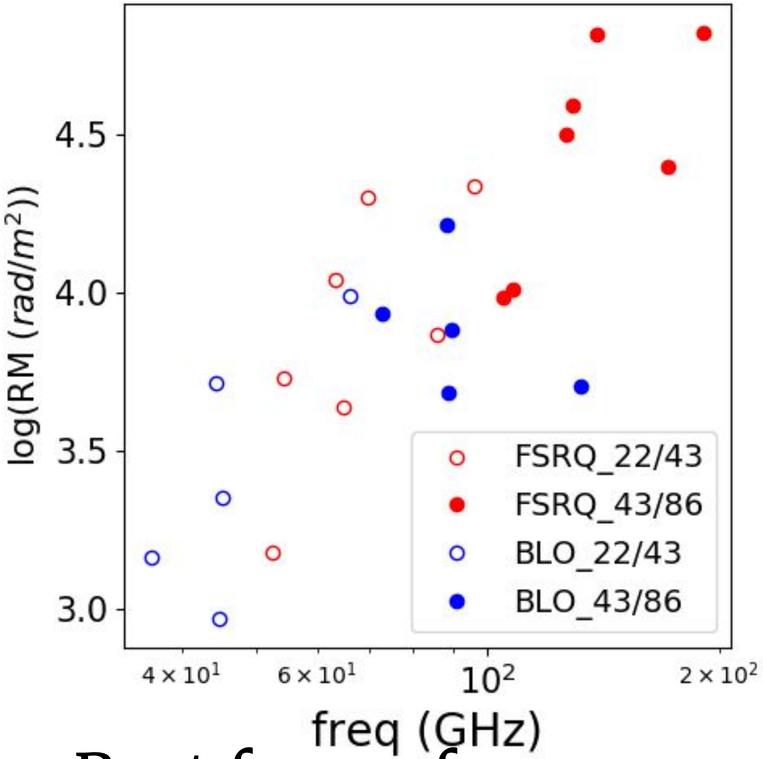
  Linear?
  Increase continuously?
  Saturation?
  Decrease in high freq?

- **High frequency data is needed**

Result 1:
FSRQs have larger RMs than BLOs

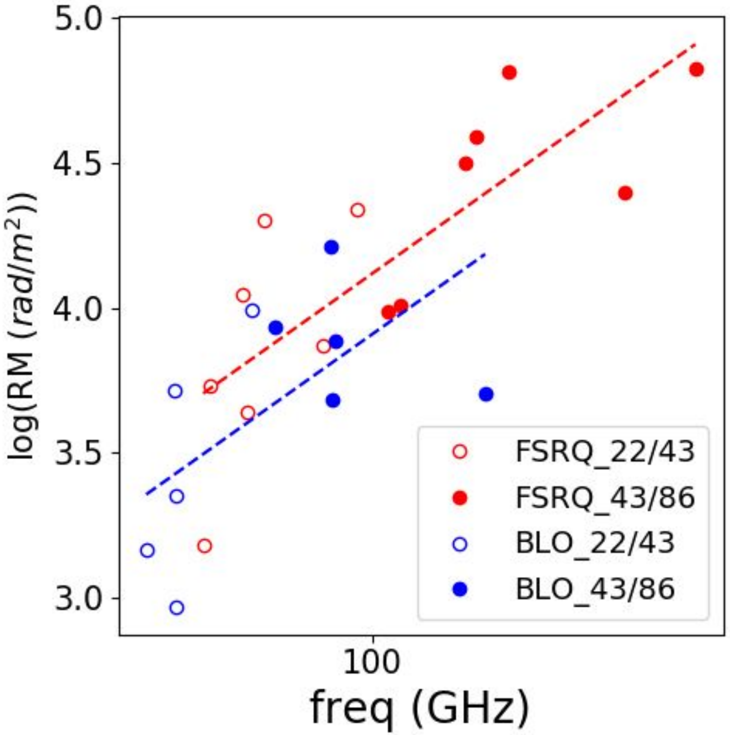
Result 2:
Similar slope between FSRQ & BLO in freq - RM figure

Result 3: High accretion with large RM in FSRQ



Rest frame frequency

- RMs of each targets are averaged for 6 epochs.
- Both show the increasing RMs with higher rest frame frequencies.



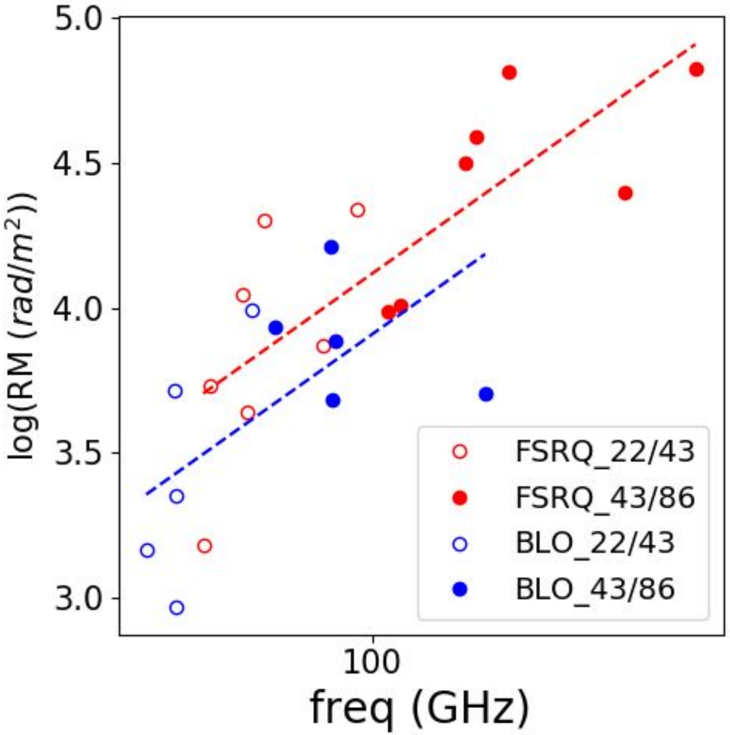
FSRQ: 0.0087 x + 3.25

Error: 0.018, 1.89

BLO: 0.0087 x + 3.04

Error: 0.03, 2.27

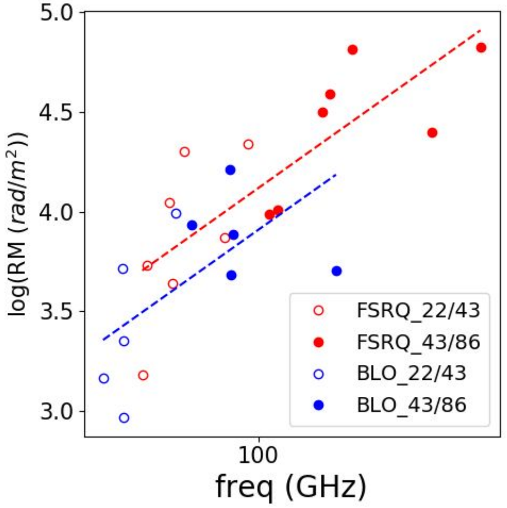
- **FSRQs and BLOs show similar increase of RM as a function of frequency. (with large scatter)**
- **Need more data points!**



FSRQs usually have larger RMs than BLOs
-> because of a high redshift?

FSRQs are usually brighter than BLOs
-> can be observed in higher redshift

Observed in higher rest frame frequency
Observing deeper region of the jet
-> have larger RM than BLOs



1) **FSRQs and BLOs have similar trend of increase in freq - RM relation**

-> FSRQs and BLOs have similar magnetic field structure of the jet

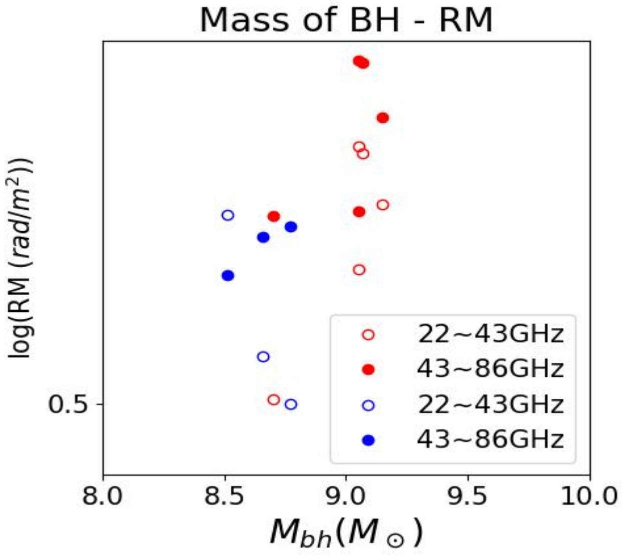
2) **Larger RM of FSRQs can be a red shift effect?**

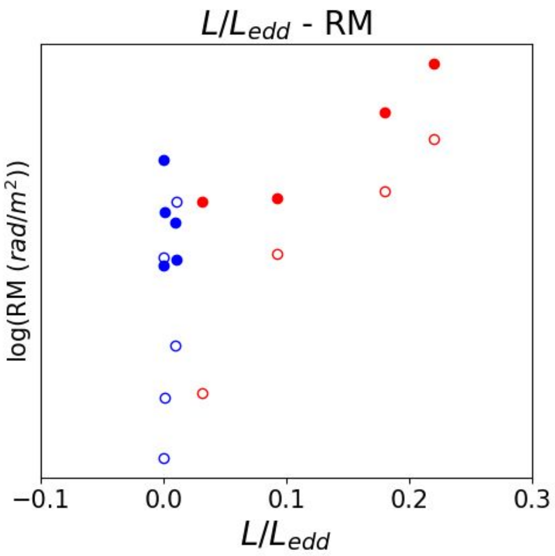
Result 1:
FSRQs have larger RMs than BLOs

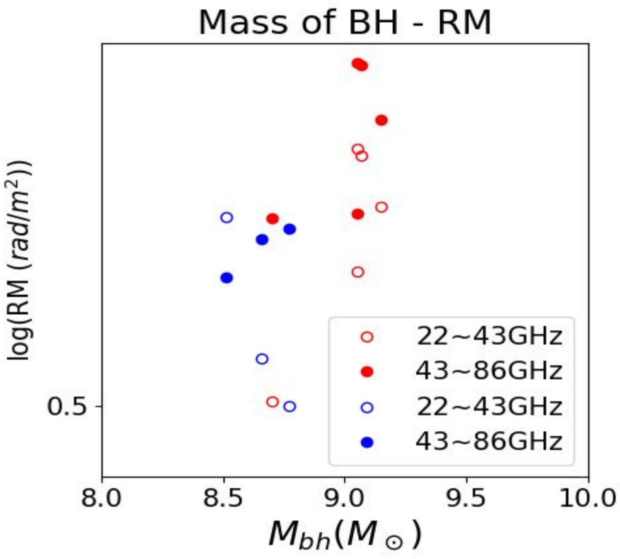
Result 2:
Similar slope between FSRQ & BLO in freq - RM figure

Result 3: High accretion with large RM in FSRQ

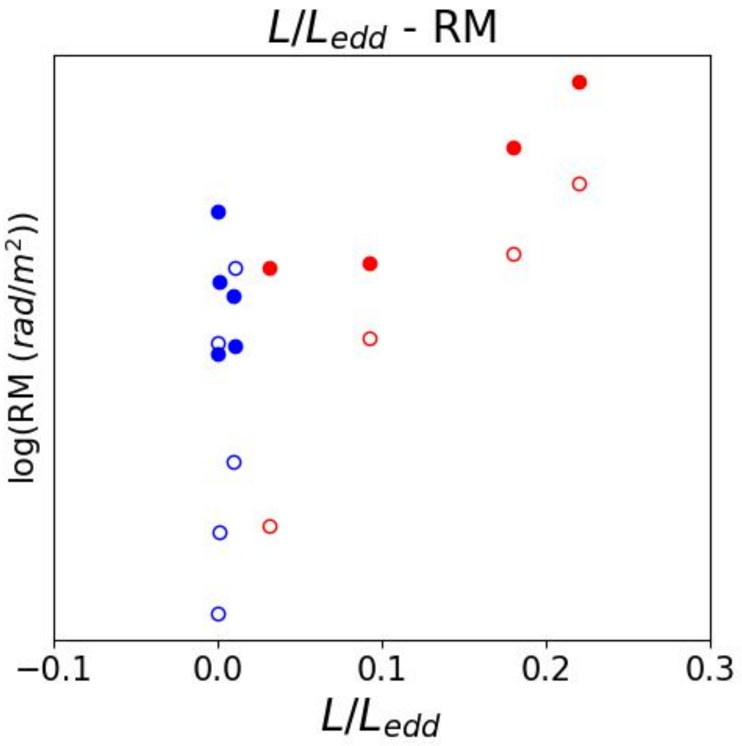
Compare RMs with optical properties







- Both FSRQs and BLOs show random distribution between RM and BH mass
- BH masses are obtained with various methods



The disk luminosities in a unit of Eddington luminosity (Park & Trippe 2017)

While BLOs show a random distribution but FSRQs show a positive relation between RM and L/Ledd

Discussion: FSRQ & BLO

Mass of the BH
: past accretion
history

Disk Luminosity
: current accretion rate

→

Electron density ↑
B strength ↑

Only in FSRQs

Future

Future 1: Increase the data frequency range

Sub-mm VLBI data is hard to get

Blazars are usually very compact

Most of polarization flux in the beam size

is originated from the core

Single dish data is also feasible

Future 1: Increase the data frequency range

Current KVN frequency band

22, 43, 86, 129 GHz

Calibration finished

MOJAVE Project Archeive

15GHz

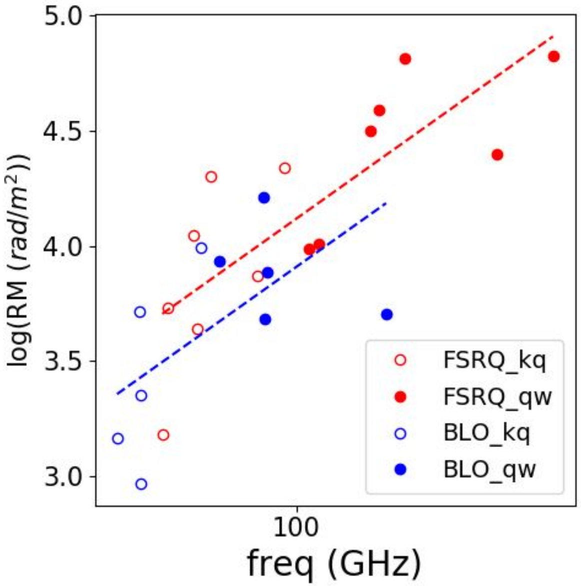
Future 1: Increase the data frequency range

22, 43, 86, 129 GHz

e-KVN: 230GHz

SMA: 230 & 345GHz
JCMT: 352GHz

Future 1: Increase the data frequency range



- Increased numbers of the data points
  -> get smaller scatter

- More data in higher frequency
  -> find the behavior of FSRQs and BLOs in wide frequency range

Future2 : The advanced sample set with limited z

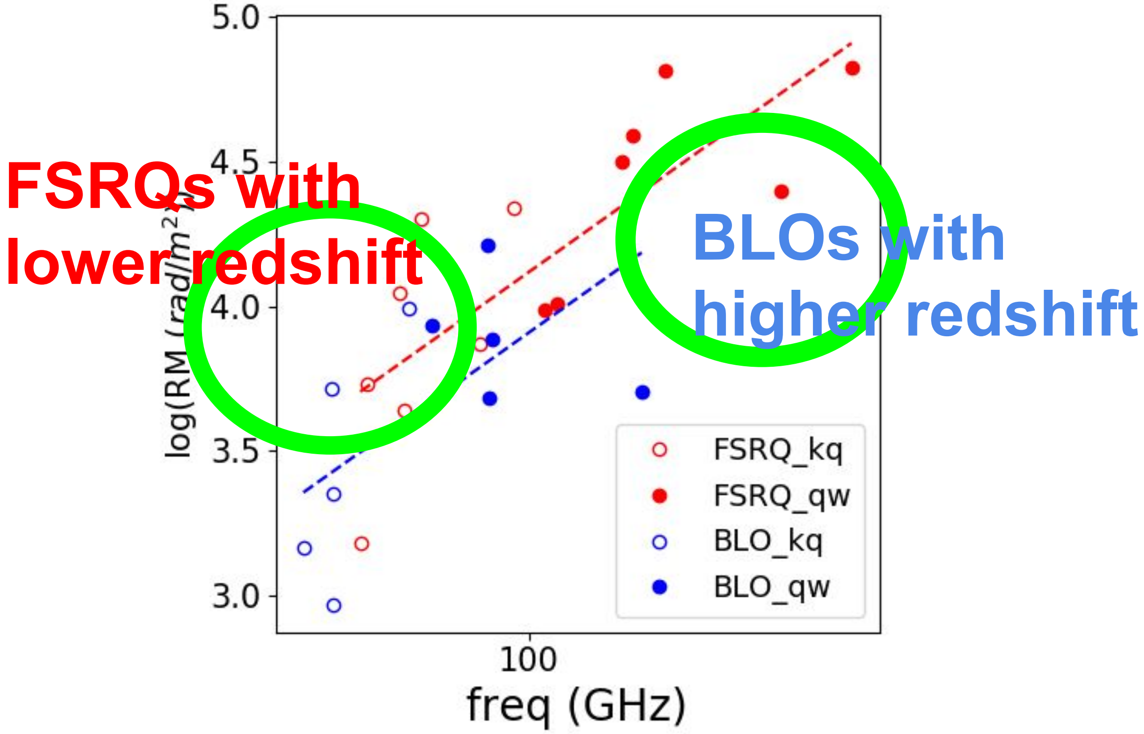
Previous

7 FSRQs $0.5 < z < 1.5$
5 BLOs $0.1 < z < 0.3$

	Total	$0.3 < z < 0.7$
FSRQ	20	8
BLO	12	9

- **Increase the sample set**
- **Select targets in similar redshift range**

Future2 : The new sample set with limited z



Summary

1. The study of RM of FSRQs and BLOs can find the relation between RM and the accretion states of central black hole
2. We used simultaneous multi-frequency data of 12 blazars from 22 to 86GHz using KVN
3. FSRQs show larger RMs than BLOs when compared in observing freq.
4. Both FSRQs and BLOs show similar trend in rest-frame frequency.
5. FSRQs with larger RMS have higher accretion rates.
6. We need more data points in higher frequency.

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