Session 4:
QSO/AGN, outflow and QALs

平成30年 11月25日

Inclination model for intrinsic NAL absorbers

クェーサー付随NALの角度依存性の調査

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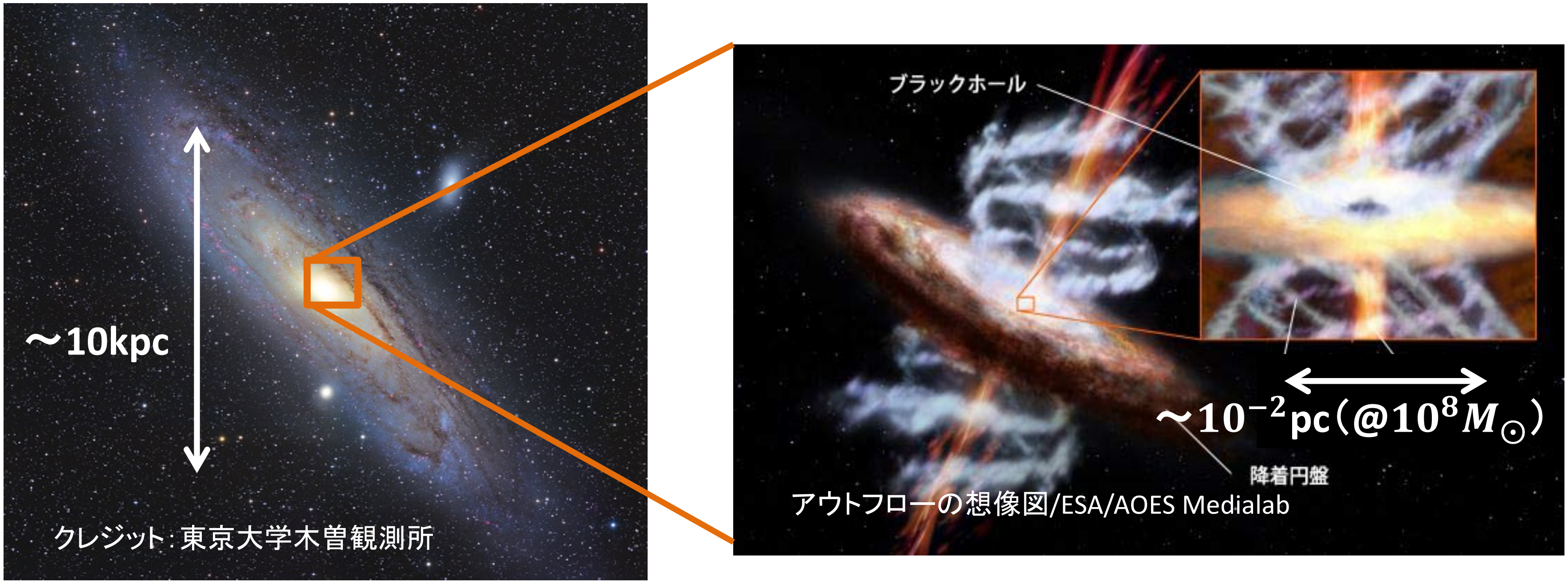
Introduction

AGN and Quasar Outflow

- **Gas flow launched from the AGN accretion disk.**



Why AGN/QSO outflow winds are important?

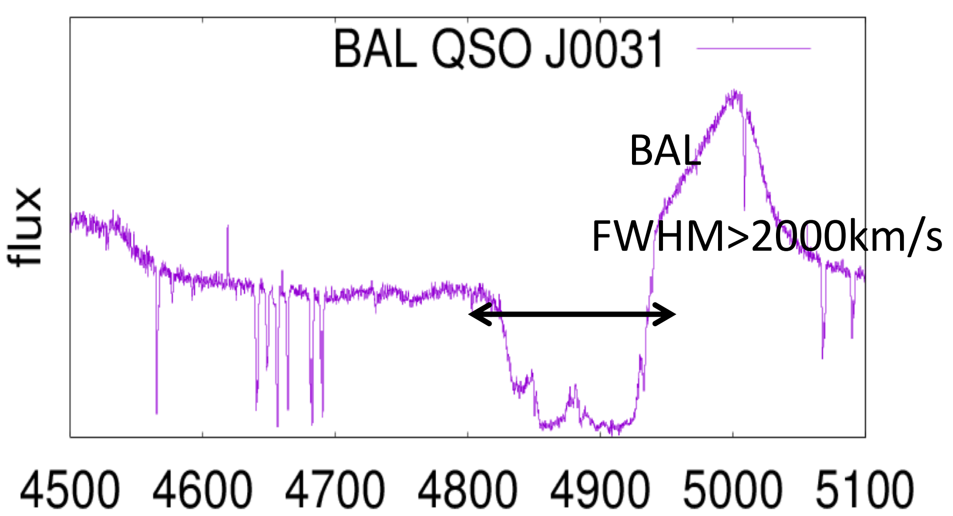
- They exclude angular momentum from accretion disk and promote the evolution of black hole(e.g., Murray et al. 1995).
- They eject metals and promote a chemical evolution of ISM pf host galaxies and nearby IGM(e.g., Dunn et al .2010).
- They eject energy and momentum and inhibit star formation (e.g., Di Matteo et al. 2005).

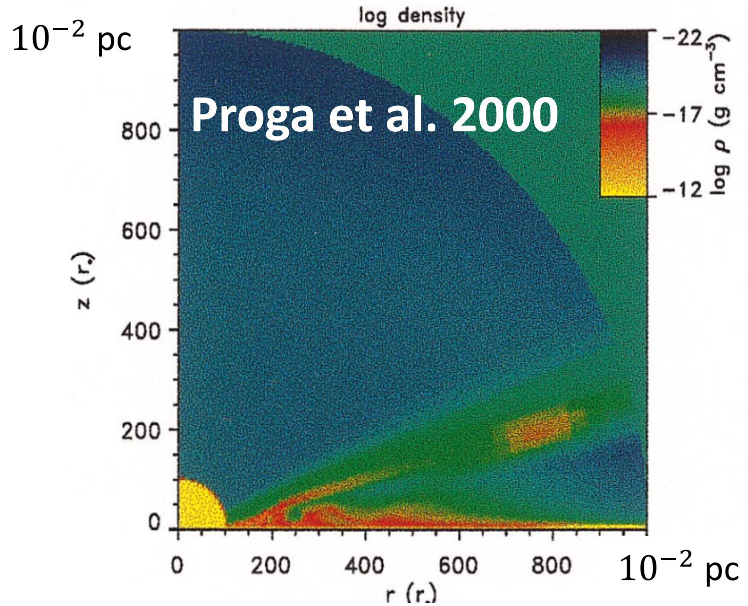
But difficult to observe directly

Inclination model for BAL outflow

- **B**road **A**bsorption **L**ine (BALs) with FWHM>2000km/s have frequently been used for outflow studies.
- But, Only a small fraction of quasars have BALs in their spectra (about 10-20%: e.g., Trump et al. 2006, Hamann et al. 2012).

Current results from observations and simulations support the inclination model.

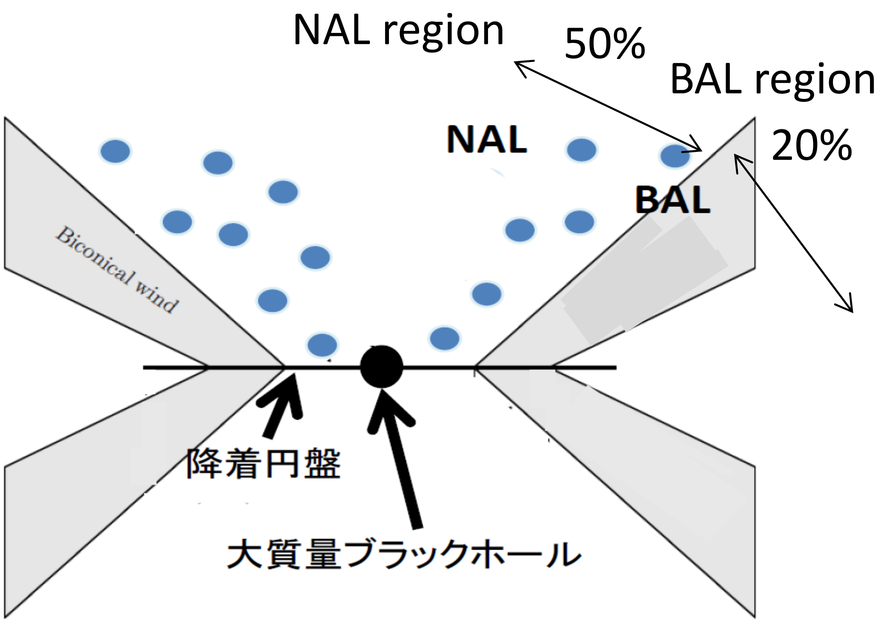




Properties of BAL outflow support "Inclination model"

Inclination model for intrinsic NALs?

- Outflow is also observed as Narrow Absorption Line (NALs) with FWHM<500km/s.
- They are detected in ~50% of all quasars (e.g., Misawa et al. 2007, Nestor et al. 2008, Hamann et al. 2012).



- NALs have not been statistically explored for BAL quasars.

- NALs may coincide with BALs in same quasars.

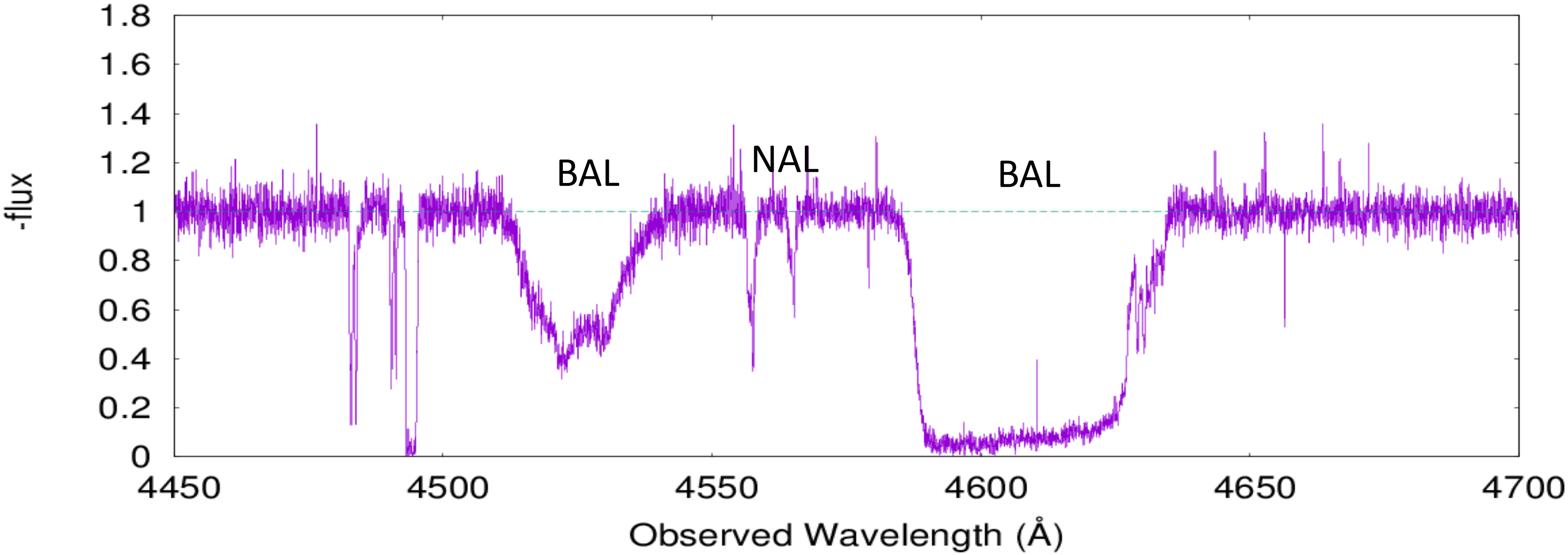
Open question

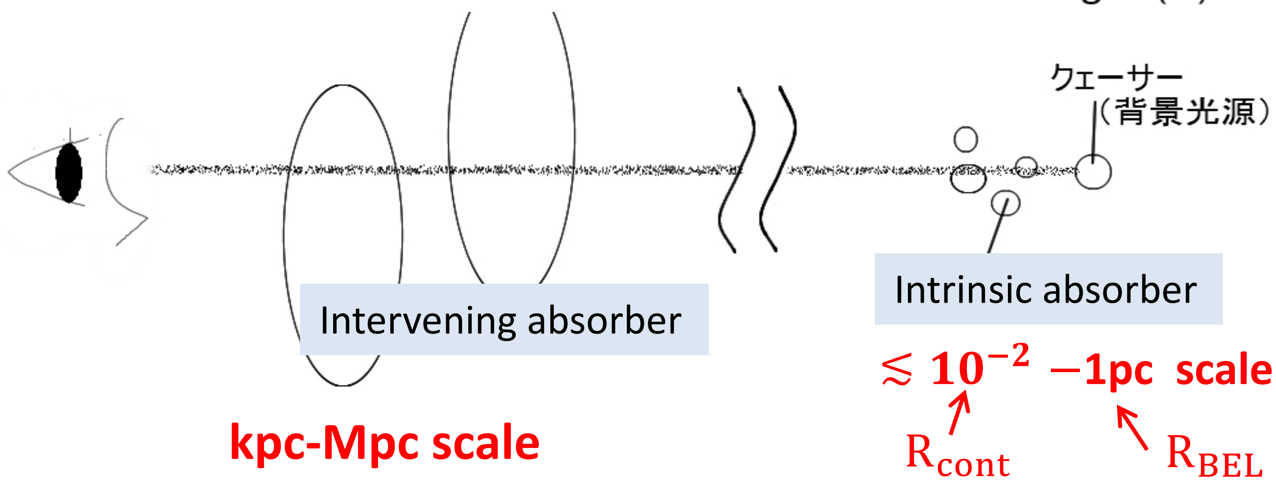
We should test if the inclination model is still acceptable when we consider intrinsic NALs as well as BALs.

Data & analysis

Partial coverage analysis

- **Distinguish intrinsic absorber from intervening absorber by Covering factor; C_f.**





If $C_f < 1$, intrinsic NAL

Sample data

- Partial coverage analysis requires high-resolution spectra with R > 30,000 .
  ⇒ We use archive data taken with VLT/UVES.

Credit:J.L. Dauvergne & G. Hüdepohl /ESO

- **Sample selection**

- SDSS DR5 BALQSO Catalog (Gibson et al.2009) containing 5039 quasars.
- **S/N($\geq$ 5.0) , Resolution($\geq$ 30000)**
- **Spectra covering from λ=1216Å-1550Å (at rest frame)**

→We chose 9 quasars for our targets.

QSO name	RA(deg)	DEC(deg)	z	mag	BI_0	R
SDSS J022844.09+000217.0	37.183	0.038	2.72	18.46	1962.9	42310
SDSS J024221.87+004912.6	40.591	0.82	2.06	18.67	896.2	40970
SDSS J115944.82+011206.9	179.937	1.202	2.00	17.59	937.9	40970
SDSS J120550.19+020131.5	181.458	2.025	2.13	17.45	403.9	40970
SDSS J120917.93+113830.3	182.324	11.641	3.11	17.62	323.5	42310
SDSS J121549.80−003432.1	183.957	-0.575	2.71	17.50	4807.7	51690
SDSS J122848.21−010414.5	187.200	-1.070	2.66	18.27	17.1	42310
SDSS J133701.39−024630.3	204.256	-2.775	3.06	19.06	2.3	37820
SDSS J143907.51−010616.7	219.781	-1.104	1.82	19.59	81.5	40970

Result & Discussion

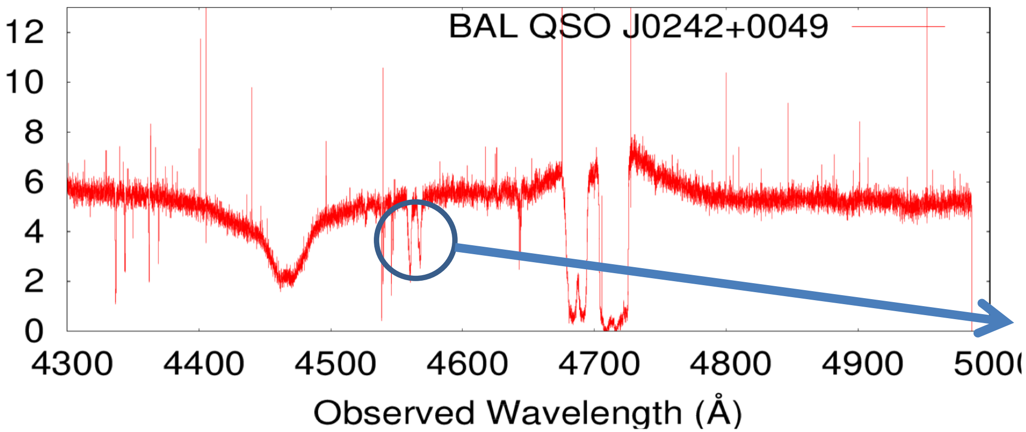
Result

Detectability of Intrinsic NALs in BAL quasar spectra

- 39 NALs are detected in 9 BAL quasar spectra, of which we identified 3 intrinsic NALs in 3 BAL quasars.

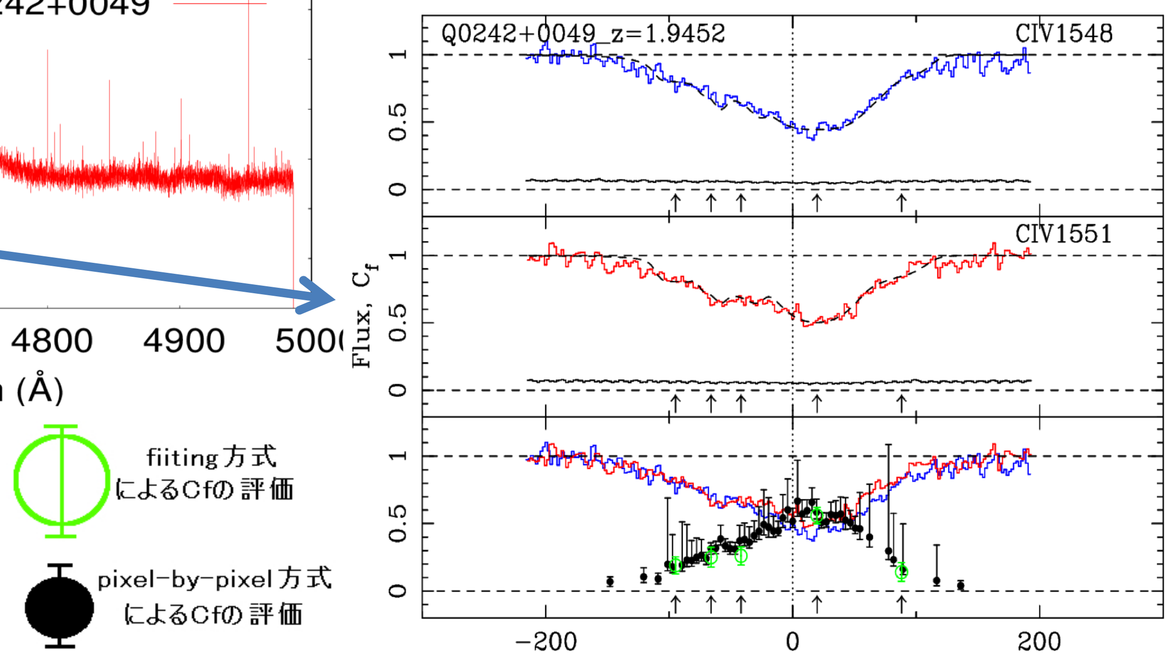
Intrinsic NAL absorbers locate
at least 30% of line of sight toward BAL quasars.

- An example of reliable (> 3σ significance) intrinsic NALs (SDSS J0242-0049).

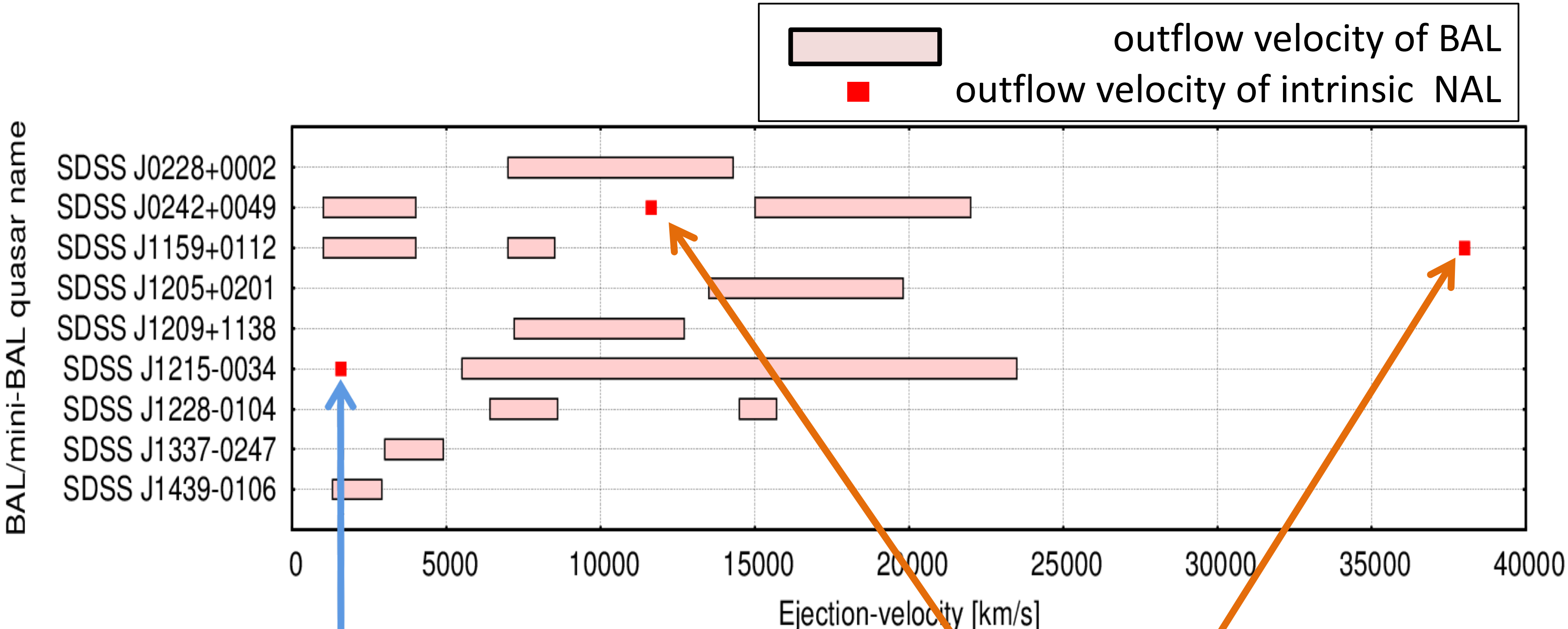


Covering factor

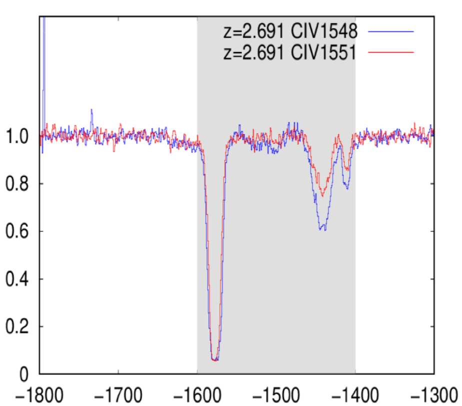
$C_f = 0.56 \pm 0.06$



Velocity distribution of intrinsic NAL



- **Low velocity intrinsic NAL**



v_ej≅1,600km/s

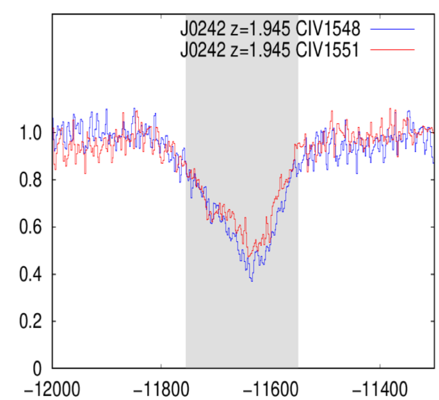
R ≅ kpc

low velocity

&

far away

- **High velocity intrinsic NAL**



v_ej ≳10,000km/s

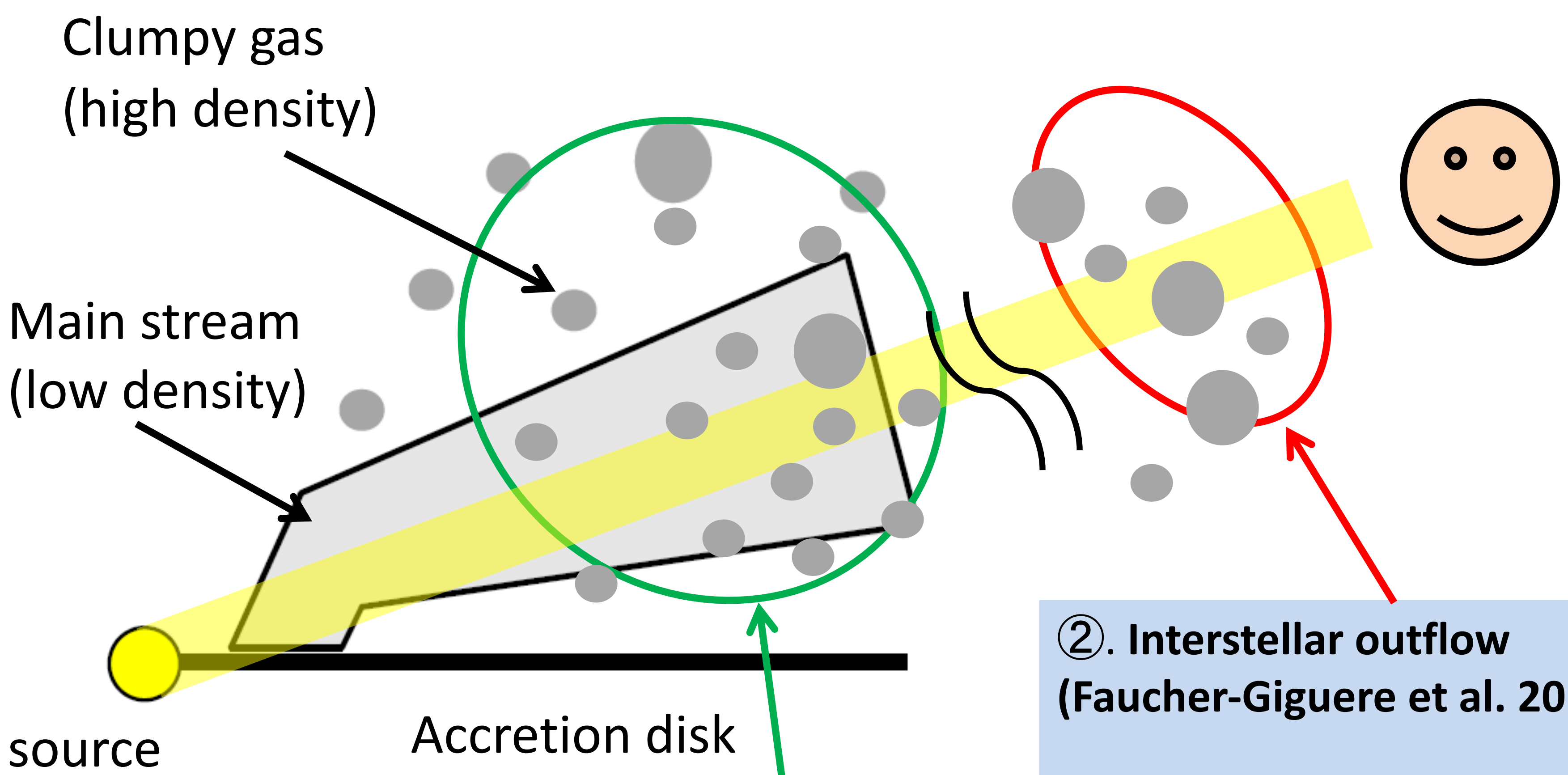
R ≲ pc

high velocity

&

inner region

Outflow model



①. **Clumpy outflow in a main gas stream**
(Takeuchi et al. 2013, Kobayashi et al. 2018)

- **Wide range of ejection velocity(≤90000km/s)**
- **locate at small distance from the source(~pc)**

②. **Interstellar outflow**
(Faucher-Giguere et al. 2012)

- **Low velocity(≤ 5000km/s)**
- **In a scale of ISM (~kpc)**

Some NAL absorbers are known to locate at kpc scale.
(e.g., Arav et al. 2013)

Summary

- To test the inclination model of AGN outflow wind, we searched for intrinsic NALs in **BAL quasar sight line** using partial coverage analysis.

- We detected 3 intrinsic NALs in 3 out of 9 BAL quasars, which suggests that the detectability of intrinsic NALs does not depend on the existence of BALs.
  ⇒**Existence of intrinsic NAL does not depend on inclination angle.**

- Intrinsic NALs in BAL quasars have a wide range of outflow velocity, **1500-38000km/s**.

- We proposed a possible model in which intrinsic NALs have origins at the main stream of the outflow and ISM host galaxies.

Future work

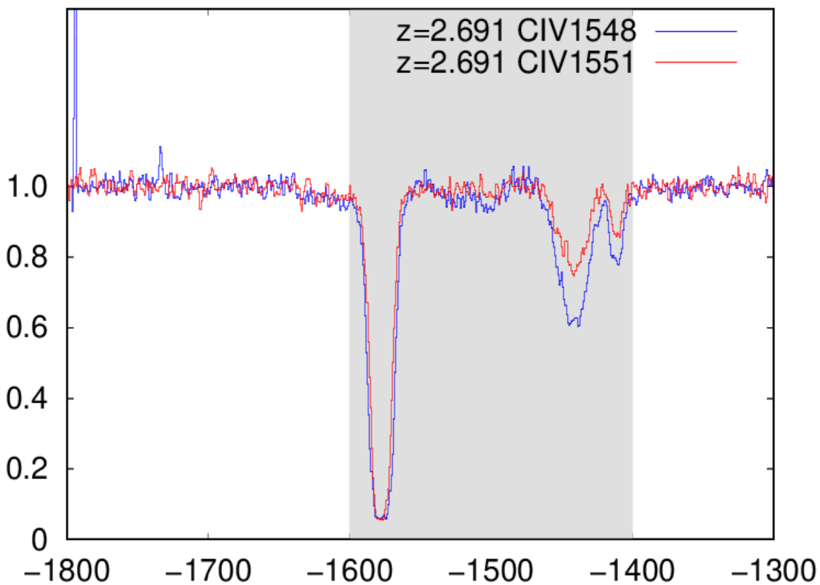
- We plan to increase a sample size to ~40 targets for reliable statistical analysis.

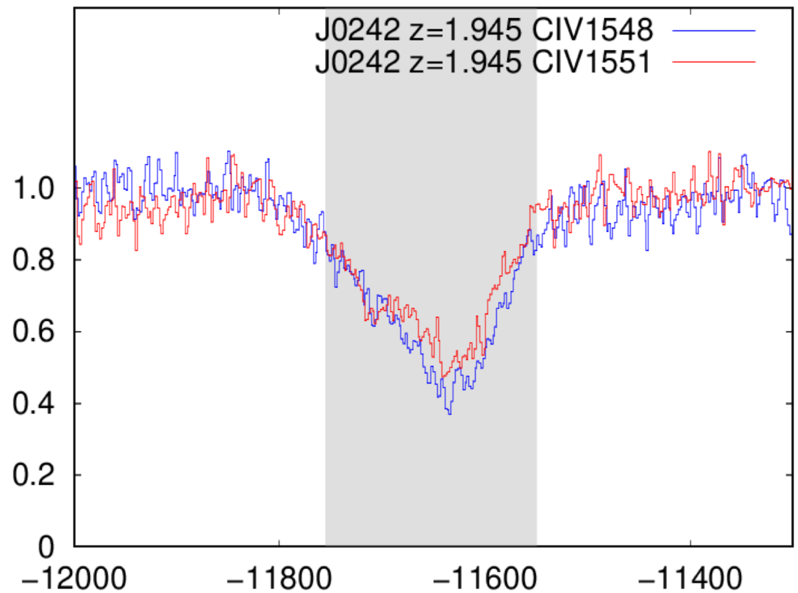
- We plan to perform photoionization models, to classify the origins of intrinsic NALs into absorbers at the main stream and those n ISM.

2種類のintrinsic NAL

補足1

性質の大きく異なる2つのNAL





<u>特徴</u>

V_ej~1600km/sと小さい

光電離モデルによる距離概算(Borguet et al. 2012)

⇒kpc(ISM)スケール

低速度かつ遠方

(Faucher et al. 2011, Kurosawa et al. 2009等のISM & outflow)

<u>特徴</u>

V_ej~11600km/sと大きい

ISMスケールより内側

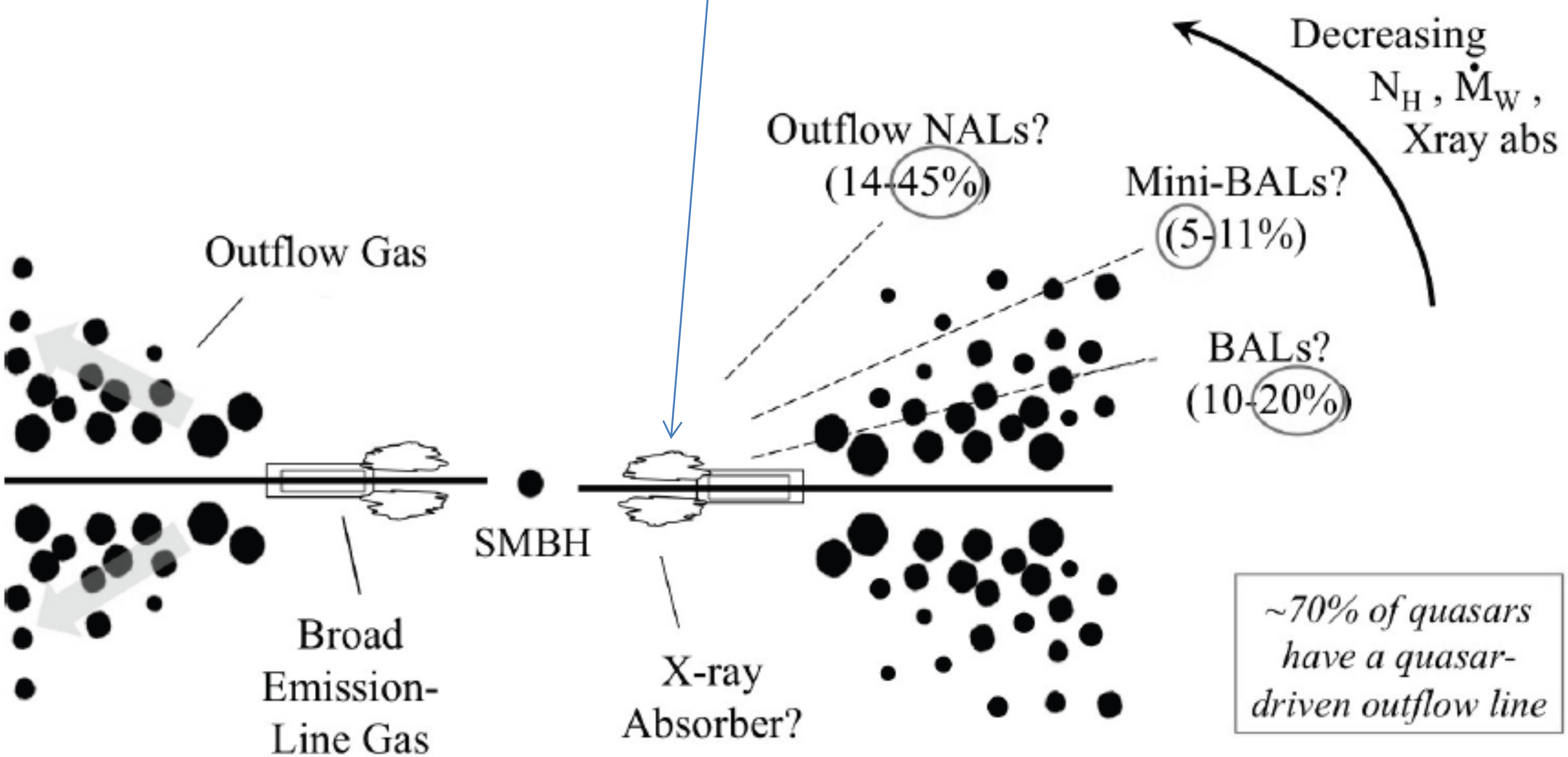
高速度かつ近傍

(Ohsuga et al. 2005, Takeuchi et al. 2013等のclumpy outflow)

補足2

BALクェーサーはX線吸収を強く受ける

- アウトフローの根元付近にX-ray absorberがあるため低緯度側ではX線吸収を受ける
- BAL クェーサーはX線吸収が強く、NALクェーサーはX線吸収が小さい⇒BALクェーサーは低緯度方向から観測している



吸収体の位置の見積もり

- 吸収体の位置情報を得て、intrinsic NALの起源、アウトフロー角度依存モデルを特定する。

- 手法⇒吸収線の電離パラメータと光源距離の関係を使う。

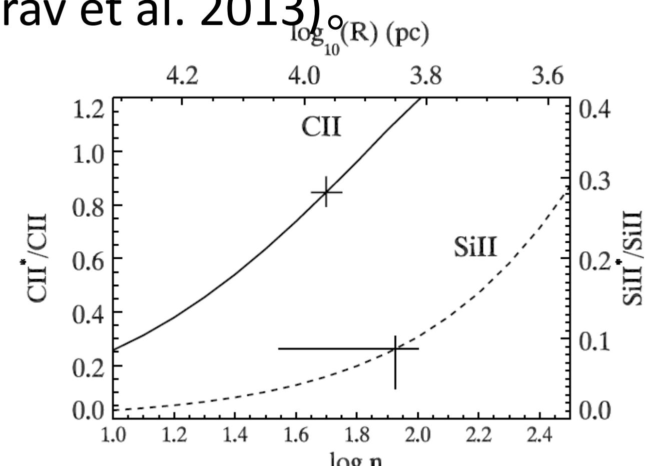
$$U = \frac{Q(H)}{4\pi r^2 c n_H}$$

電離パラメータと距離の関係式
U　：電離パラメータ
Q(H)　：電離光子数

➢ 吸収線のイオンから電離パラメータUは求まる。中性水素密度n_Hが求まれば、位置rを特定できる。

➢ 中性水素密度は励起状態のことなる二つの同種吸収線を使うことで求めることができる(Borguet et al. 2012 , Arav et al. 2013)。

励起状態の異なる吸収線の**等価幅比と中性水素密度は1対1の関係**にある。



励起状態の異なる2つの吸収線強度比と電子密度の関係