Origin of the X-ray Narrow Line Region

SAM GRAFTON-WATERS

MSSL

THANKS TO: GRAZIELLA BRANDUARDI-RAYMONT, MAT PAGE, MISSAGH MEHDIPOUR, JUNJIE MAO, JELLE KAASTRA, EHUD BEHAR, STEFANO BIANCHI, YIJAN WANG

sam.waters.17@ucl.ac.uk

Where does the X-ray NLR originate from?

- Warm absorbers (WA) are generally thought to be thermally driven winds
- Originating from the torus or outer accretion disk
  - **e.g. Krolik & Kriss 2001; Proga 2007**
- Is the X-ray NLR part of the WA, or is it separate?
- Does the X-ray NLR originate from the torus as well?

How do I answer this question?

- Results from photoionisation modelling of the soft X-ray spectra
- Obtained WA and X-ray NLR component parameters
- Compared the column density (N_H), ionisation parameter (ξ), and turbulent (v_{turb}) and outflow (v_{out}) velocities of each component
- Calculated their distances to infer possible locations of each wind type

Warm Absorbers

AGN	$\log\xi$ (10^{-9} W m)	N_H (10^{25} m^{-2})	v_{turb} (km s^{-1})	v_{out} (km s^{-1})	No. of Comps.	References
NGC 7469	1.9 - 3.3	0.7 - 2.3	42	(-370) - (-1830)	4	Mehdipour et al. (2018)
	1.6 - 3.0	1.0 - 5.2	11 - 35	(-630) - (-1960)	3	Grafton-Waters et al. (2020)
	(-0.6) - 2.7	0.01 - 2.2	35 - 70	(-650) - (-2050)	6	Behar et al. (2017)
	0.8 - 3.6	0.03 - 2.9	–	(-580) - (-2300)	3	Blustin et al. (2007)
NGC 3783	(-0.7) - 3.0	0.1 - 12	50 - 800	(-460) - (-1600)	9	Mao et al. (2019)
	0.3 - 2.4	0.5 - 28	300	-800	2	Blustin et al. (2002)
NGC 5548	0.3 - 2.7	0.2 - 6	20 - 210	(-250) - (-1150)	6	Kaastra et al. (2014)
NGC 3227	(-1.1) - 3.3	1 - 23	20 - 260	(-110) - (-1270)	4	Wang et al. (in Prep)

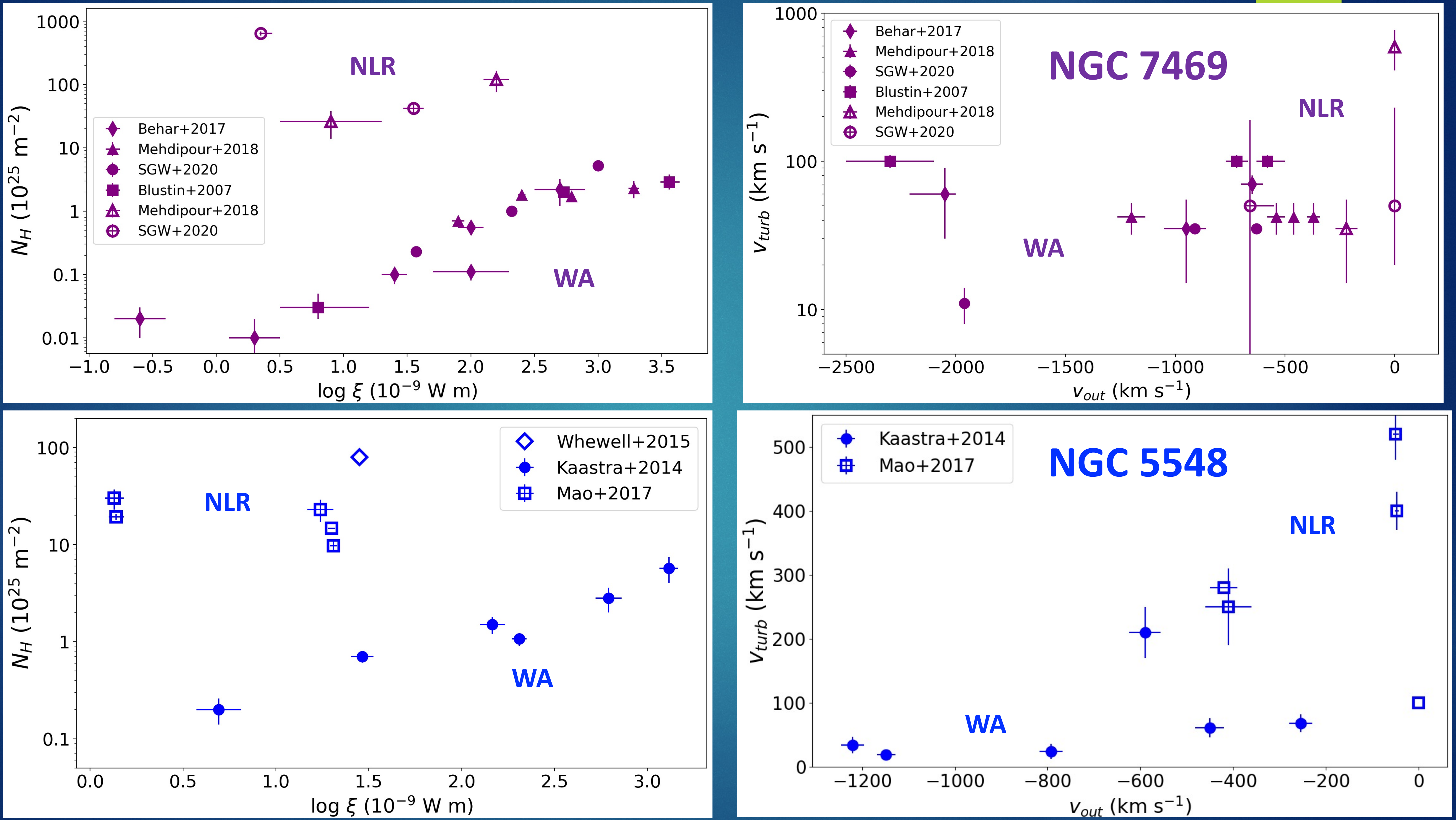
I also include the WA components of the type 1 AGN survey studied by **Blustin et al. 2005**

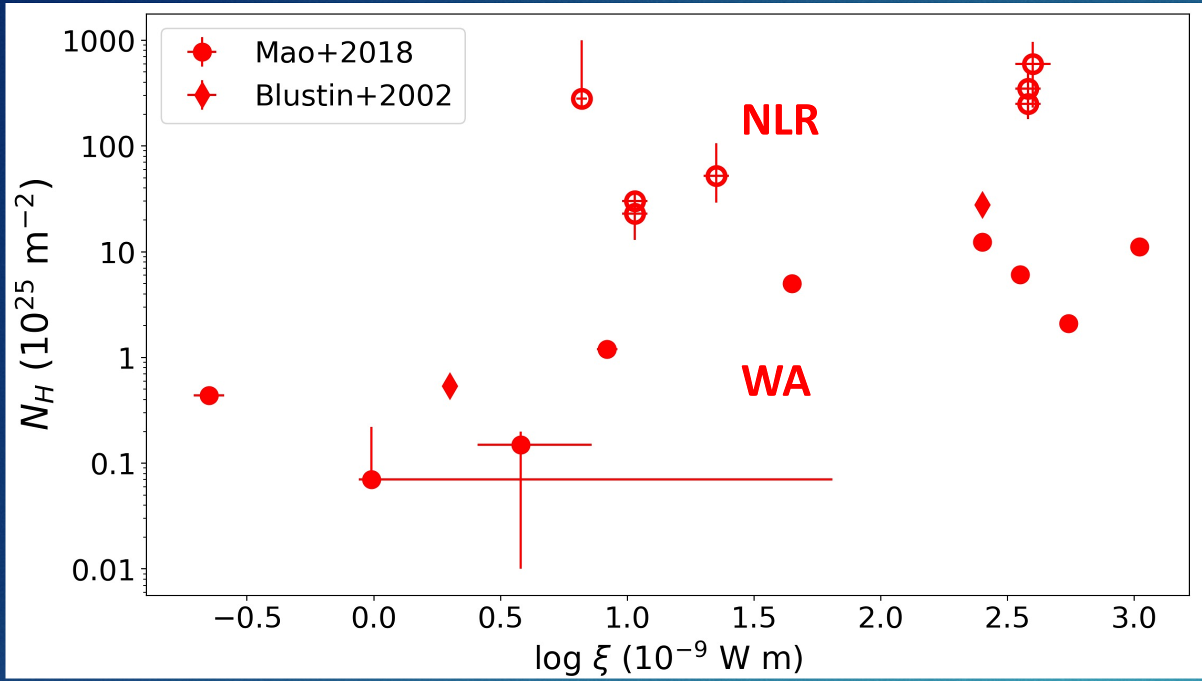
X-ray Narrow Line Region

AGN	$\log\xi$ (10^{-9} W m)	N_H (10^{25} m^{-2})	v_{turb} (km s^{-1})	v_{out} (km s^{-1})	No. of Comps.	References
NGC 7469	0.9 - 2.2	26 - 120	35 - 590	(-220) - 0	2	Mehdipour et al. (2018)
	0.2 - 1.6	42 - 780	50	(-660) - 0	2	Grafton-Waters et al. (2020)
NGC 3783	1.0 - 2.6	3 - 60	140 - 600	–	3	Mao et al. (2019)
NGC 5548	0.1 - 1.3	10	250 - 520	(-50) - (-420)	2 - 3	Mao et al. (2018)
NGC 3227	0.8 - 2.5	0.3 - 0.8	840 - 1790	–	1 - 2	Mao et al. (in Prep)
NGC 1068	0.6 - 4.0	18 - 51	410 - 2910	(-110) - (-610)	4	Grafton-Waters et al. (2021)

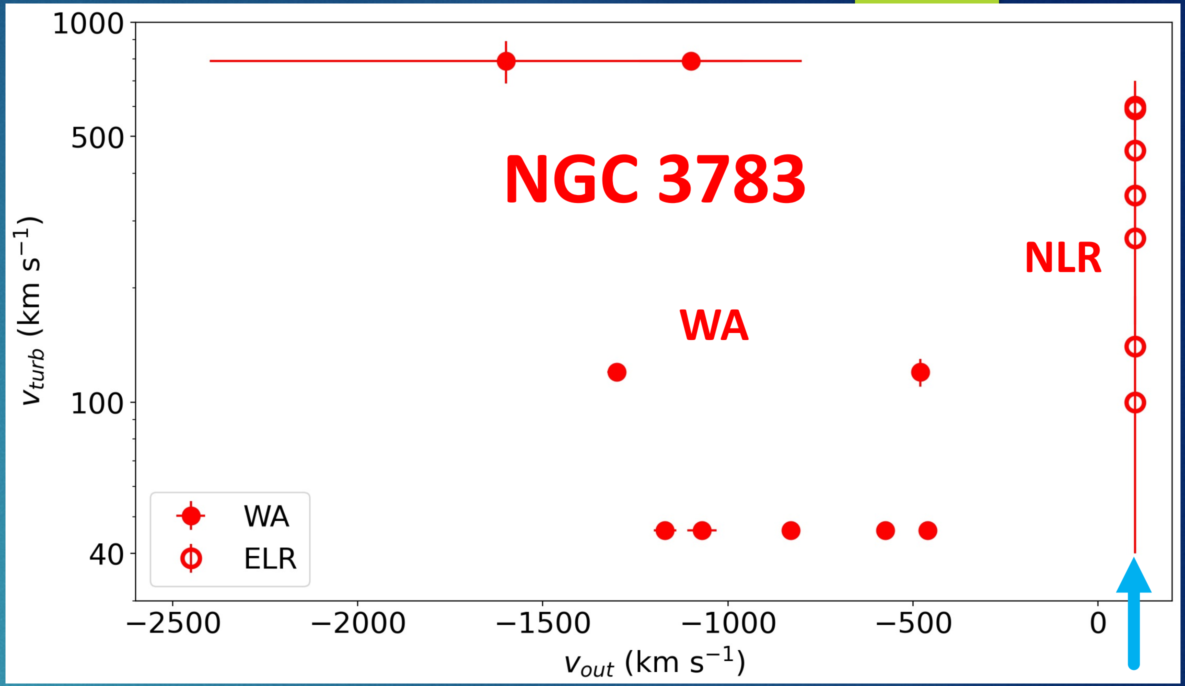
PION model in SPEX – Mehdipour et al. 2016

- Only model currently that uses the ionising continuum (SED) to simultaneously calculate the X-ray spectrum and ionisation balance
  - Other models require pre-calculated grids
- Computes the ionisation/thermal solutions for both absorption and emission lines

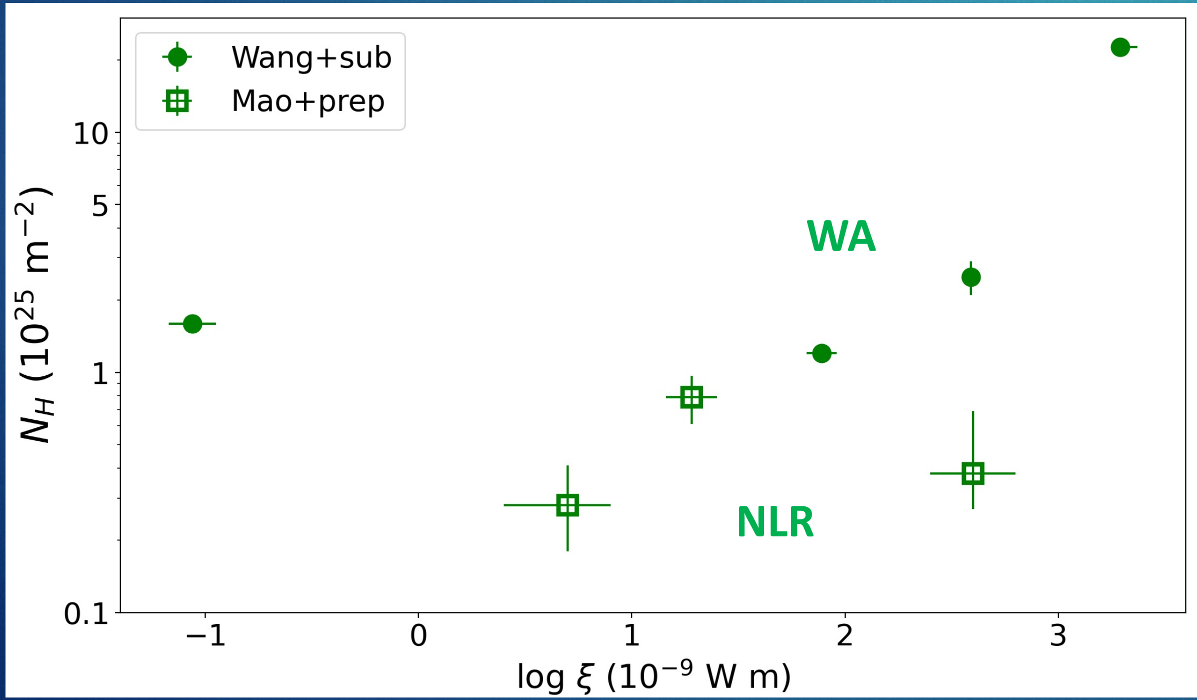

NGC 7469
NLR
WA
Behar+2017
Mehdipour+2018
SGW+2020
Blustin+2007
Mehdipour+2018
SGW+2020
N_H (10^{25} m^{-2})
log ξ (10^{-9} W m)
v_{turb} (km s^{-1})
v_{out} (km s^{-1})
NGC 5548
Whewell+2015
Kaastra+2014
Mao+2017



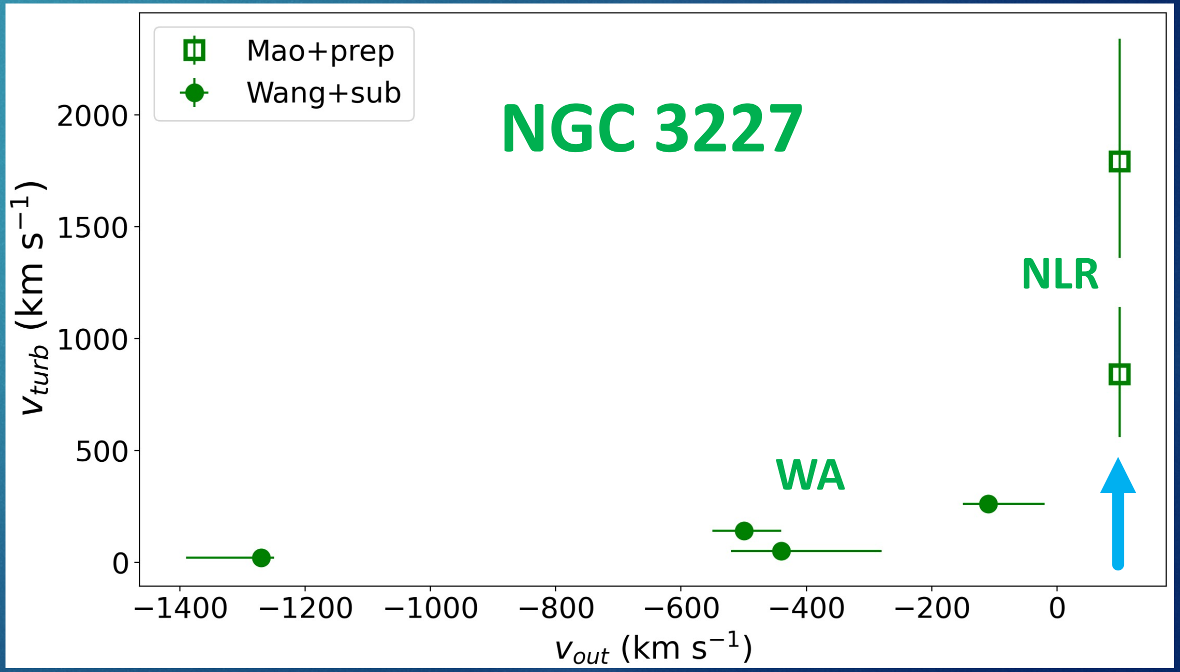
Mao+2018
Blustin+2002
NLR
WA
N_H (10^{25} m^{-2})
log ξ (10^{-9} W m)



NGC 3783
NLR
WA
WA
ELR
v_{turb} (km s^{-1})
v_{out} (km s^{-1})

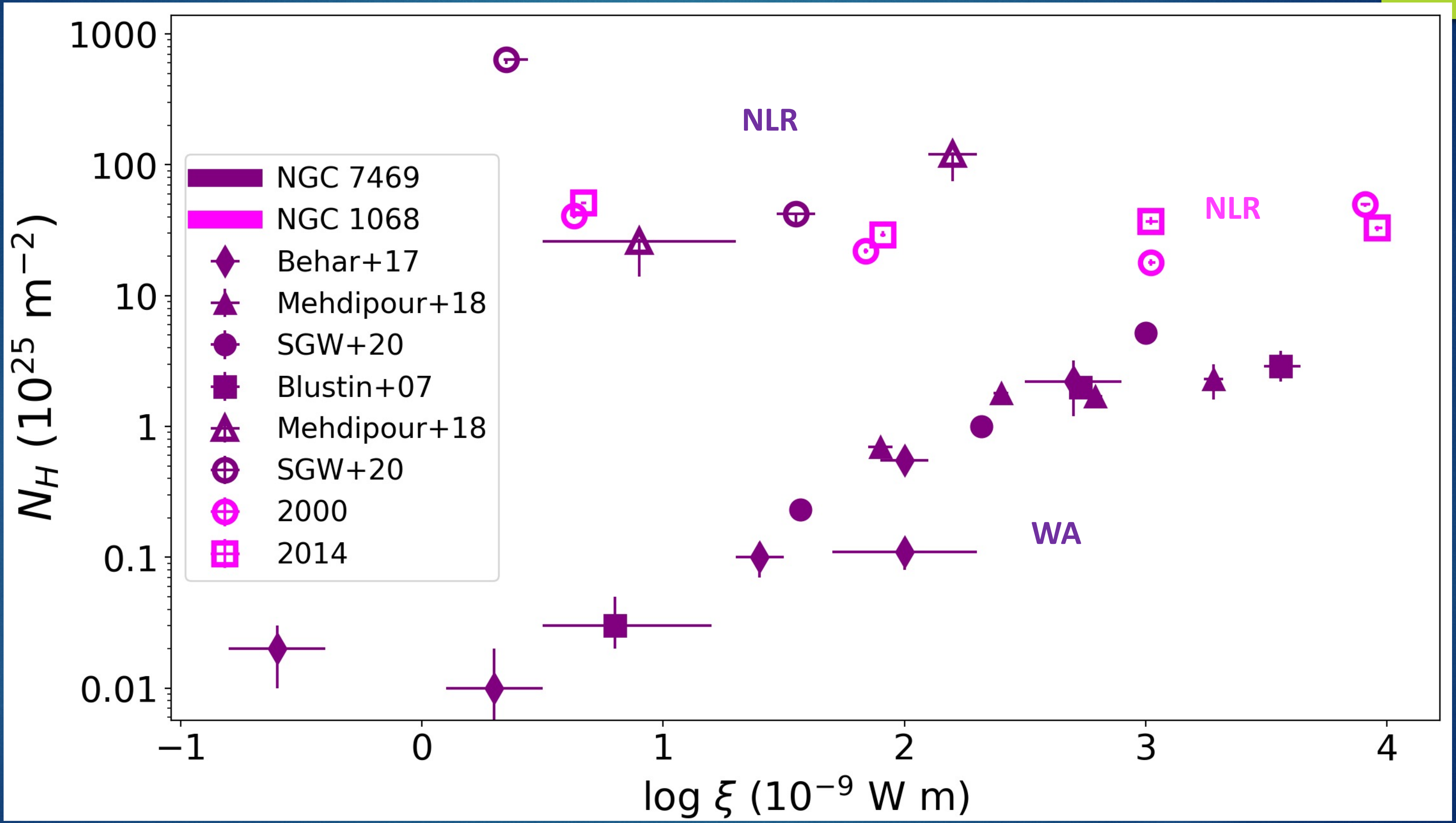


Wang+sub
Mao+prep
WA
NLR
N_H (10^{25} m^{-2})
log ξ (10^{-9} W m)

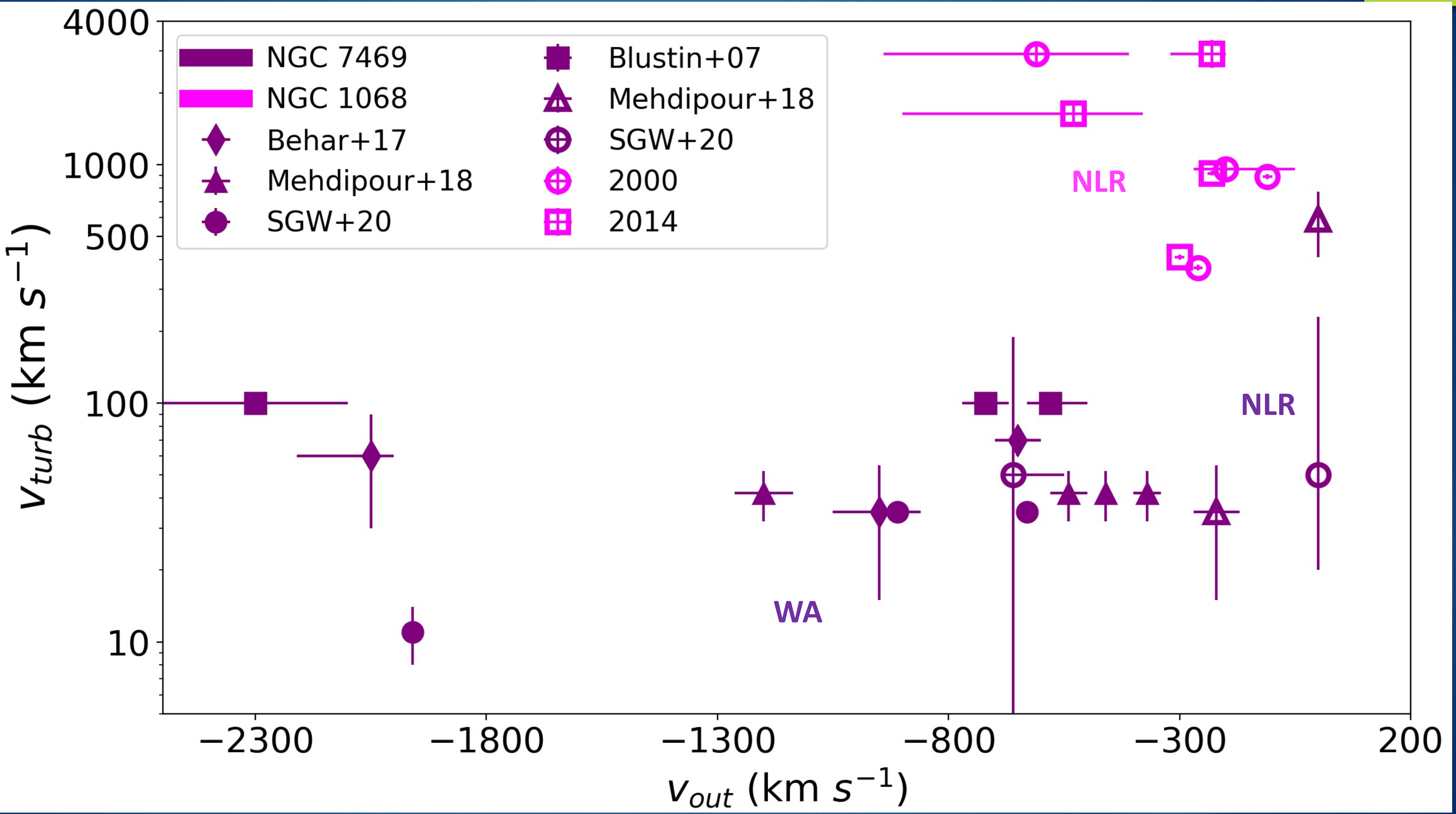


Mao+prep
Wang+sub
NGC 3227
NLR
WA
v_{turb} (km s^{-1})
v_{out} (km s^{-1})

NGC 7469 & NGC 1068



NGC 7469 & NGC 1068



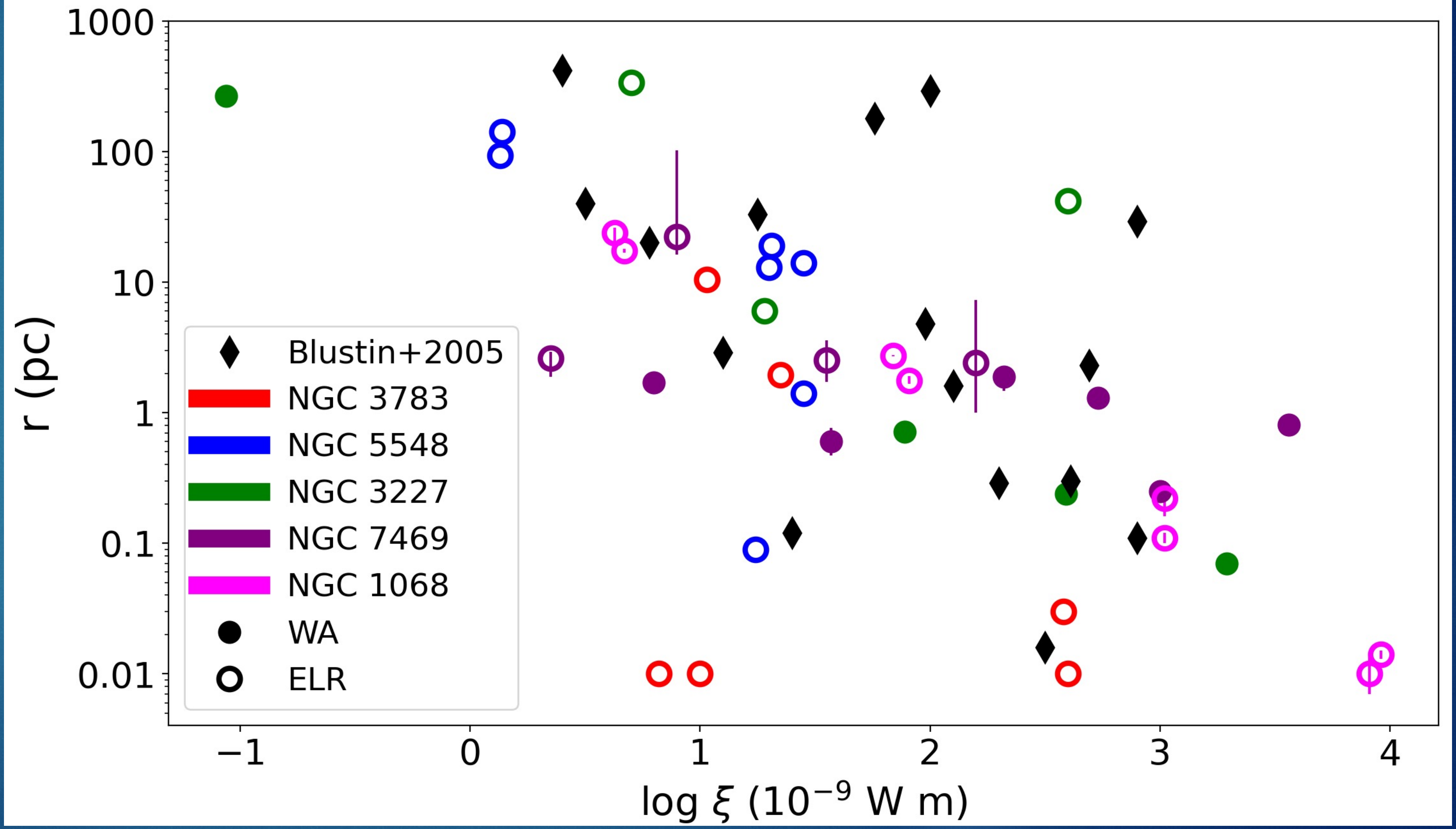
Distances

Ionisation Parameter Method

$$r \leq \frac{L_{ion} f_v}{\xi N_H}$$

f_v : volume filling factor

L_{ion} : ionising luminosity
(13.6 eV – 13.6 keV)

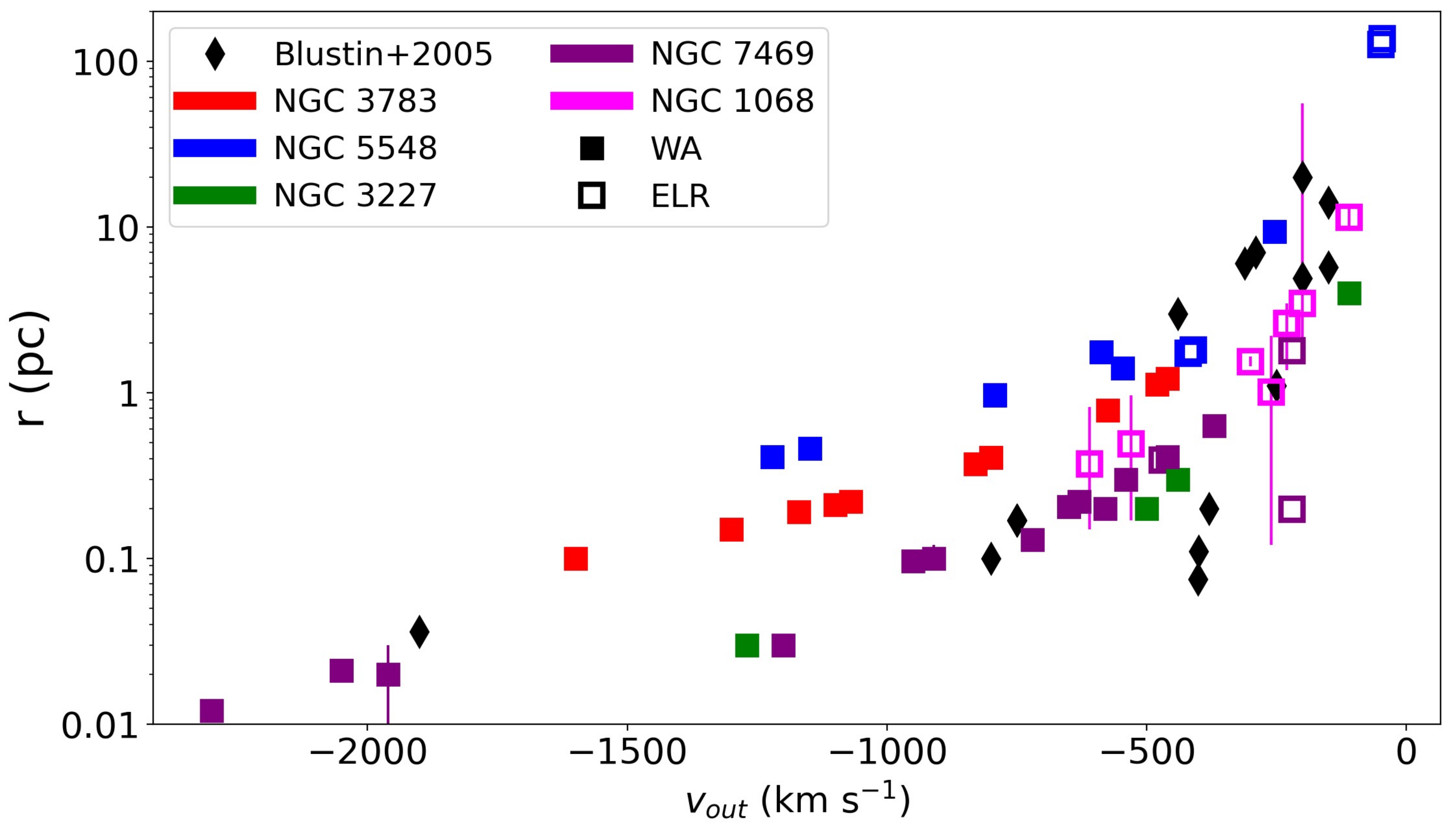


Blustin+2005

Outflow Velocity Method

$$r \geq \frac{2GM_{BH}}{v_{out}^2}$$

$(v_{esc} = v_{out})$



Blustin+2005

Caveats

- Volume filling factor, f_v
  - Can be calculated for the WA
  - Arbitrary for X-ray NLR
- Outflow velocity in type 2 AGN is a component of the true value
- Distance estimates are upper and lower bounds

Summary

- **We observe the WA and X-ray NLR to be …**
  - Similar in terms of ionisation parameter and distances
  - Different in column density and kinematics
    - Limited by the observed LOS
- There is evidence to suggest that the WA and X-ray NLR are part of the same outflowing wind
- **Therefore, the X-ray NLR could originate from the torus, launched through thermal driving**