Enrico Piconcelli
N. Menci
A. Grazian [OAPD]

L. Zappacosta, A. Travascio,
A. Luminari, F. Tombesi (Roma2)

WISSH


# BLACKOUT AT OAR

# OUTLINE OF THE ACTIVITES AT OAR+Roma2

## WP1 – BH feedback at the epoch of the formation of the largest BHs
## Task1.1 Luminous quasars at z=3-4

✪The WISSH Project
The  Big Bros (the most luminous QSOs at the highest redshifts)

## WP4 – BH wind and Cosmological models
## Task 4.1 BH nuclear wind models

✪The WINE model: latest results
Improvements of the Menci+19 SAM

## WP3 – Local laboratories for ISM and BH wind/jet physics

PDS 456: **MUSE** + ALMA investigation
Location & Energetics of UFOs in nearby AGN with WINE

## GOAL: Studying the AGN-driven feedback at its extreme

### Guidelines for the design of the WISSH Project

- **Sampling the brightest end of the AGN LF**

  ✪ Unique testbed for the models of co-evolution and wind acceleration
  ✪ "Caught in the act" approach: QSOs shining at cosmic noon
  →Redshift range z~1.5-3.5 peak of vigorous star-formation and QSO activity
  ✪ Opportunity of extending all the empirical relations involving $L_{BOL}$

- **Bright targets! → Cheap & easy for spectroscopic follow-ups**

  ✪ 2MASS sources with K~14 [ ~30 min @LBT-LUCI ]
  ✪ X-rays [ ~2ks detected, ~30 ks spectrum ]
  ✪ ALMA [~ 2h for kinematics of [CII] emission line at 158μm ]

## Looking for the Quasars T-ReX:

**~90 WISE/SDSS Selected Hyper-luminous (WISSH) Quasars**

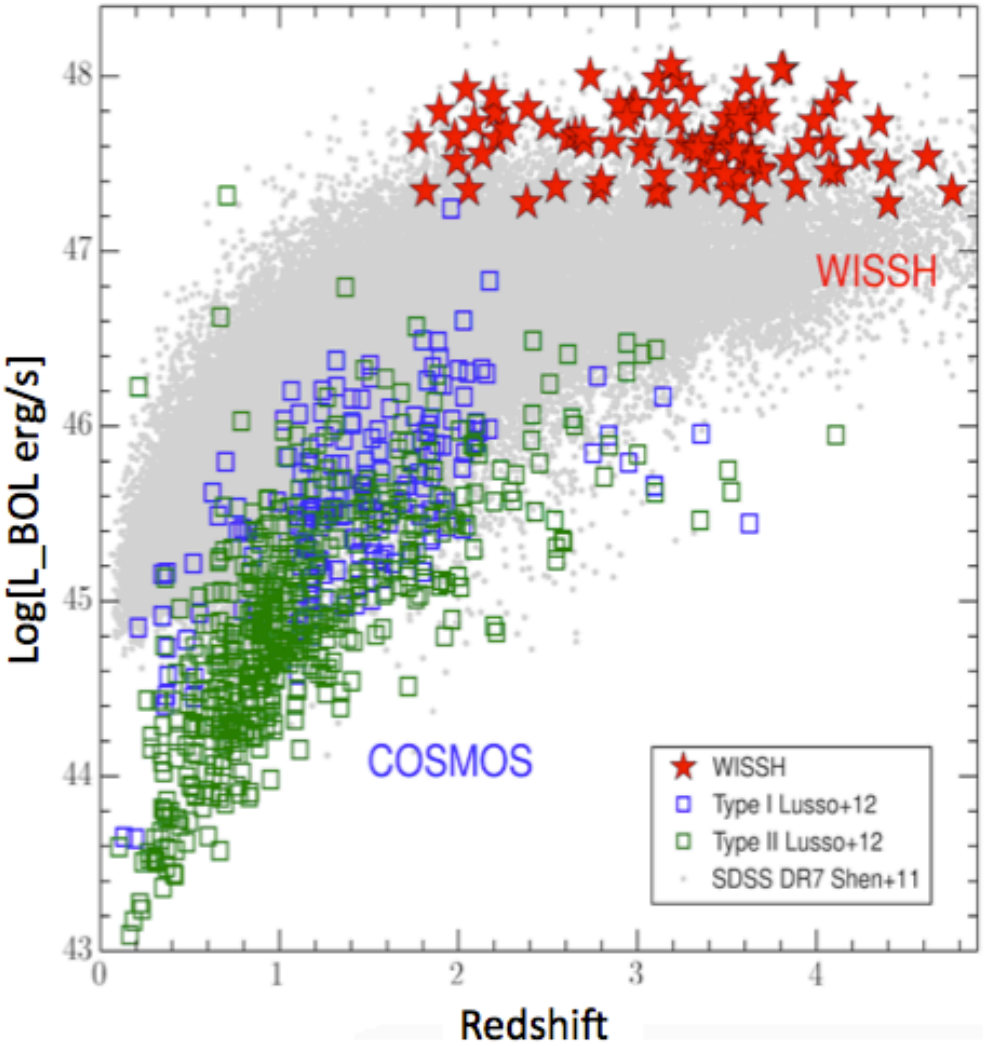
- SDSS broad-line quasars at $z > 1.5$ **AND** All-sky WISE(22μm) > 3 mJy
- Bolometric Luminosity > $10^{47.2}$ erg/s
- Redshift range $1.9 < z < 4.5$
  Peak at z~3

**Large amount of archival data!**

✓ SDSS spectroscopy [UV range]

✓ SDSS+2MASS+WISE photometry

✓ Good Chandra+XMM coverage



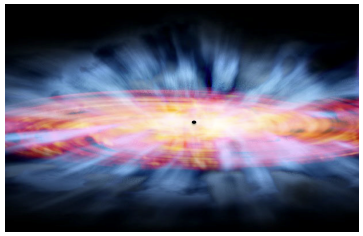
# THE WISSH QUASARS PROJECT

"Holistic" approach: AGN/Winds/Host/CGM

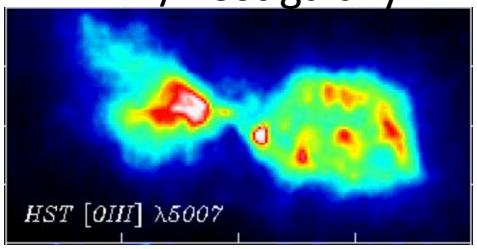
WISSH Tasks:

- ✓ Probing widespread presence of outflows from different gas phases
- ✓ ...and different distances [micro→meso→macro scales]
- ✓ Constraining the properties of the central engine
- ✓ Studying the ISM and SFR of quasars host galaxies
- ✓ Exploring the CGM of hyper-luminous QSOs

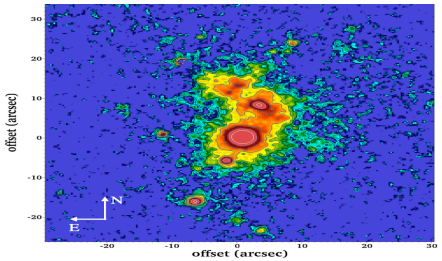
Nuclear/BLR



NLR/Host galaxy




Dozen kpc / CGM




Extensive multi-band coverage from radio to X-rays

- ✓ Backbone programs: LUCI@LBT [EP] + MUSE [Fiore] + Chandra [EP]
- ✓ Archival & Proprietary data: ALMA, NOEMA, JVLA, HERSCHEL, WISE, UKIDSS, 2MASS ESO/VLT/MUSE SINFONI X-shooter, LBT/LUCI, TNG, SDSS, HST CHANDRA, XMM → **PIs: Bischetti, Bruni, Gavignaud, Testa, Zappacosta**

# PUBLICATION BREAKDOWN [2017-2020]

Astronomy & Astrophysics

WISSH

I. "Powerful ionised outflows in hyper-luminous quasars" *Bischetti, EP +17*

II. "Giant star nurseries in hyper-luminous quasars" *Duras, Bongiorno +17*

III. "X-ray properties of hyper-luminous quasars" *Martocchia, EP +17*

IV. "BLR- vs. kpc-scale winds" *Vietri, EP +18*

V. "ALMA reveals the assembly of a giant galaxy around a z=4.4 hyper-luminous QSO" *Bischetti, EP +18*

VI. "Fraction and properties of BAL quasars in the hyper-luminous regime" *Bruni, EP +19*

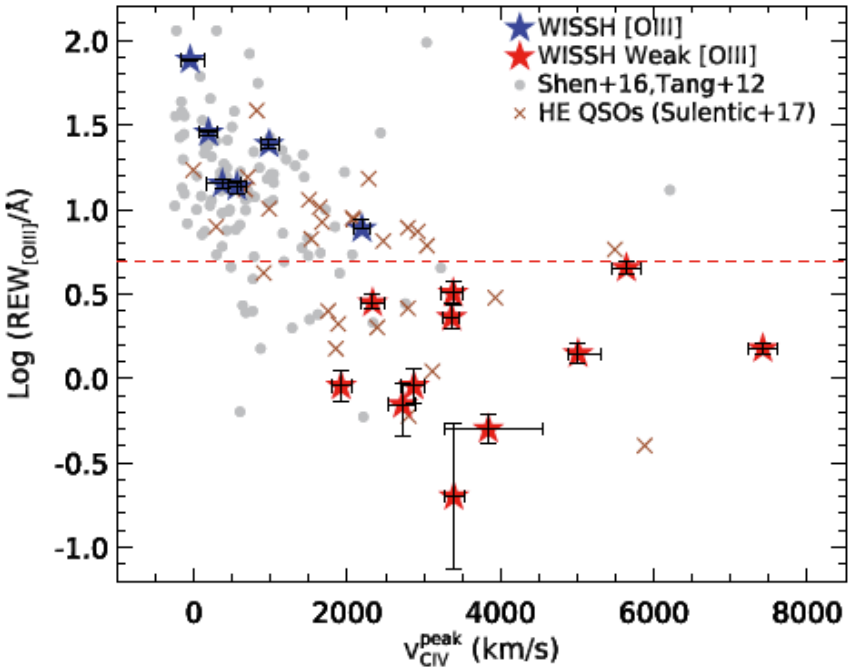
VII. "Outflows and metals in the CGM around the hyper-luminous z~3.6 quasar J1538+08" *Travascio, Zappacosta +20*

VIII. "The impact of extreme radiation field in the accretion disk & corona interplay" *Zappacosta, EP +20*

IX. "Cold gas content & environment of luminous QSOs at cosmic noon" *Bischetti, Feruglio +20*

# WIDESPREAD PRESENCE OF WINDS AT DIFFERENT SCALES

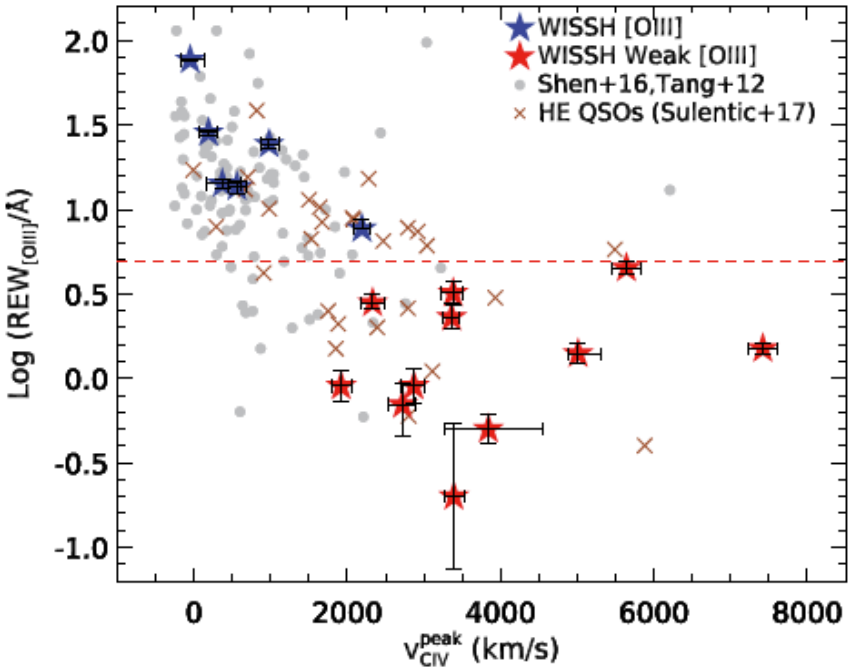
- ✓ Winds in the BLR (sub-pc) traced by CIV blue wings: intermediate between SMBH and pc-scale

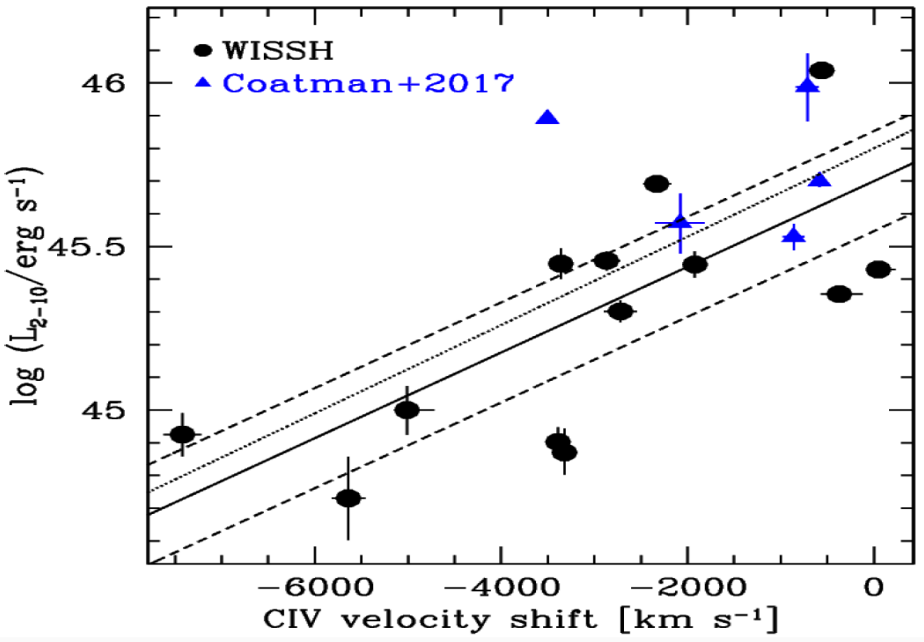



- Powerful, large-scale ionized outflows M >1000 $M_\odot$/yr  $\dot{E}$ ~$10^{45-46}$ erg/s
- 1/3 of LBT/LUCI spectra show broad [OIII]
- 2/3 DO NOT show [OIII] but show large CIV shifts **[NLR vs BLR winds!]** Vietri+18 Bischetti+17

# WIDESPREAD PRESENCE OF WINDS AT DIFFERENT SCALES

- ✓ Winds in the BLR (sub-pc) traced by CIV blue wings: intermediate between SMBH and pc-scale

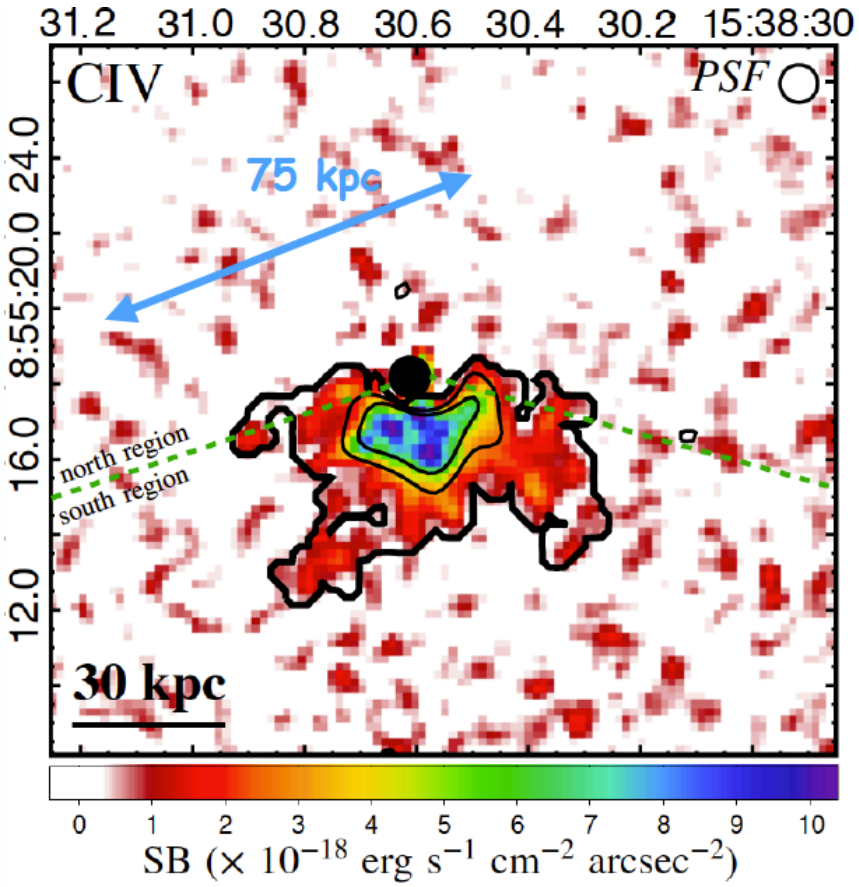


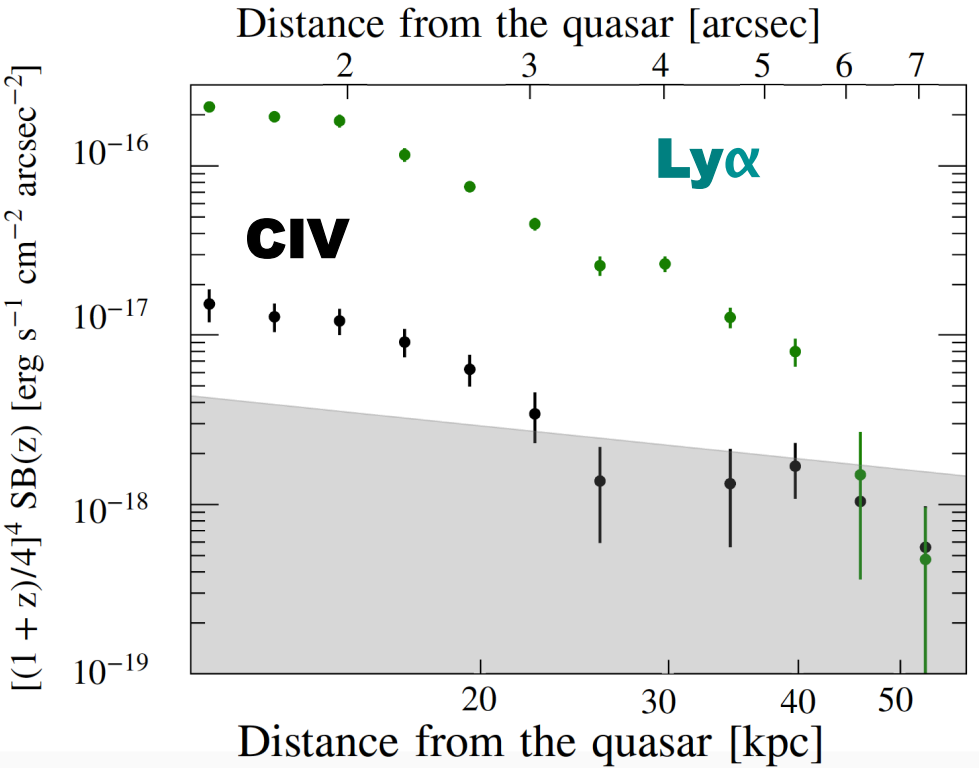




- A non-negligible fraction show low $L_X$ compared to $L_X$-$L_{UV}$ relation
- Discovery of a relation $L_X$ and $\alpha_{OX}$ with CIV shift
- CIV winds favored by low $L_X$→ these winds limit the corona X-ray production? Zappacosta+20

# WISSH VII: IMAGING METALS IN THE CGM AT Z~3.5

## Discovery of the first CIV nebula around a single radio-quiet quasar



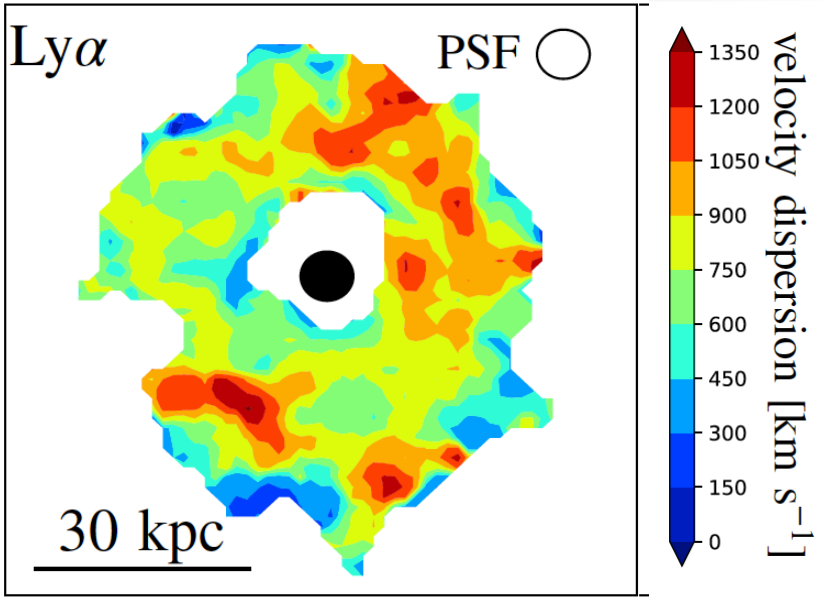



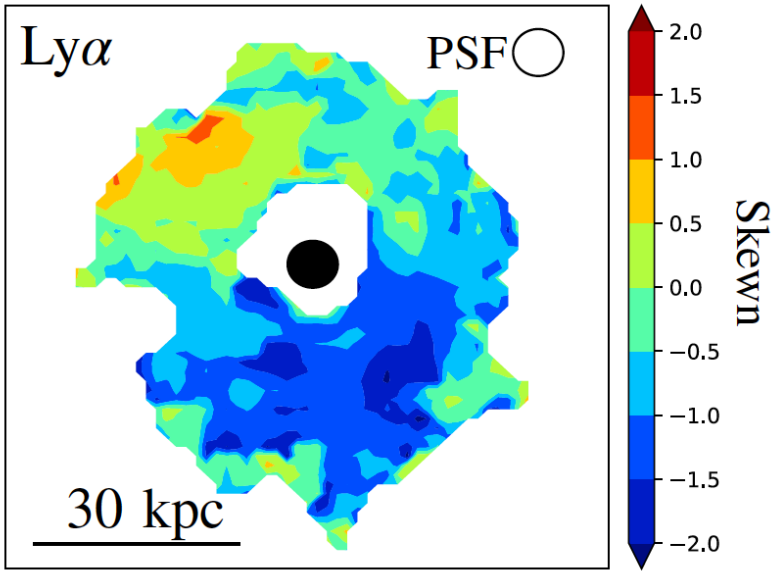

Non pristine gas in the CGM

Ratio CIV/Lyα~0.1 constant up to 25 kpc
→ Same emitting gas

Travascio +20

# FIRST IMAGING AN OUTFLOW IN THE CGM

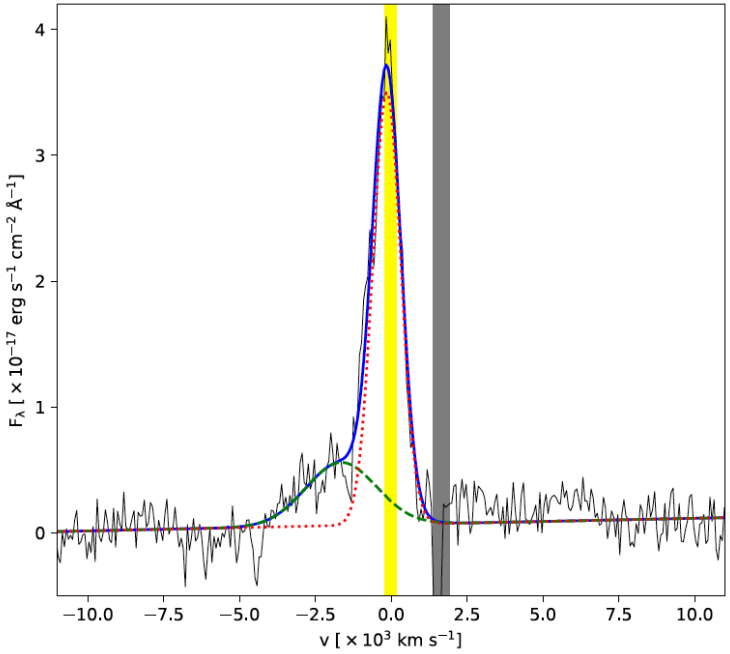


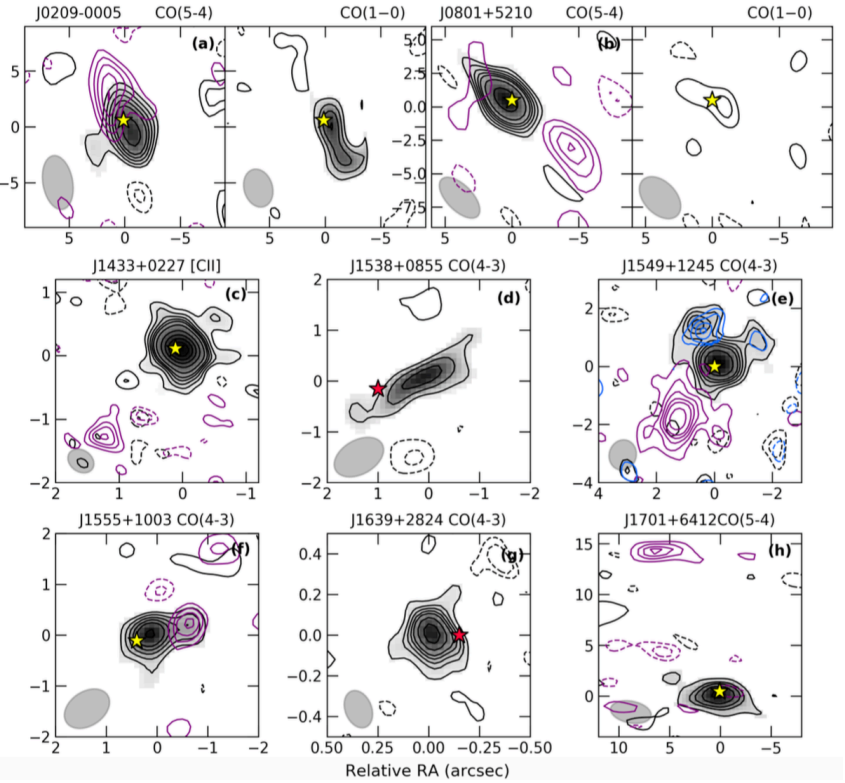

- Huge dispersion ~750 km/s (typically observed ~200-400 km/s)
- Skewness map: asymmetry of the line profile

- Presence of a broad (σ~1200 km/s) and blueshifted (- 1500 km/s) component as indication of outflowing gas over ~30 kpc

Travascio +20



# WISSH IX: Cold gas & environment of luminous QSOs




- 7 out of 9 QSOs show one (or more) nearby line emitter (Merger fraction 80%)
- Typical project distance 6-40 kpc (J1015 companion at 2.2 kpc!!)

- High CO excitation (also in the companions)

- Large velocity residuals (data-disk model)
- High dispersion offset from the nucleus

- SFR ~200-1200 Msun/yr
- Large SFE ~SFR/L_CO >100

Bischetti +20 arXiv:2009.01112

- **Concurrent intense growth of both SMBH and host galaxy**
- **Molecular gas will be used up in few tens of Myr**

- **Hyper-luminous QSOs are progenitors of "red&dead" giant ellipticals**
- **Mergers significantly contribute to the final mass of the galaxy**

# Winds in the nuclear environment (WINE) model

## Modelling UFOs in X-ray spectroscopic data

### Current status

i. Spectral analysis is done mainly through simulated absorption/emission spectra (e.g. *Cloudy, XSTAR*). P-Cygni profiles are **modeled *ad hoc*** combining emission and absorption spectra.

ii. Simulated spectra rely on several assumptions on the **geometry** and the **kinematics** of the **wind**

iii. The wind is modeled as a **layer of gas at rest** with turbulent broadened features, which are a posteriori blue-shifted to account for the wind velocity smearing

### WINE model

WIN*d Emission/absorption*

i. WINE is a **self-consistent model** for absorption and emission from disk winds. It is highly customizable and can mimic different launching scenarios.

ii. The **physical, kinematical and geometrical parameters** are determined fitting the model to the observed spectra and minimizing the $\chi^2$ statistic

iii. **Relativistic effects** are taken into account in the radiative transfer calculations. Absorption and emission profiles are directly built according to the geometry and velocity profiles.

# On the importance of Special Rel. effects in modelling UFOs

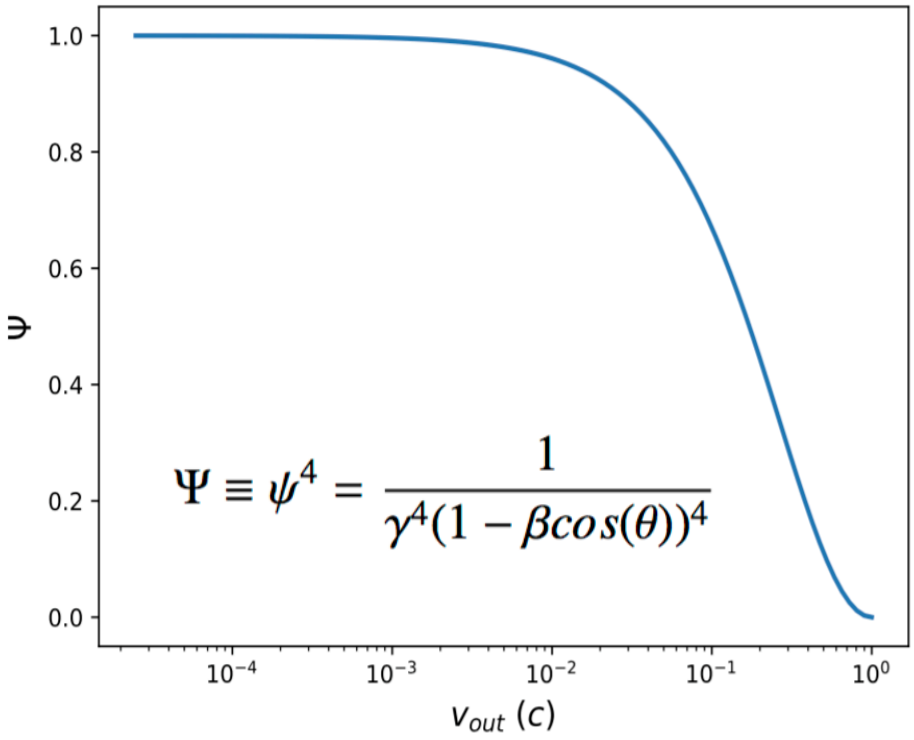



Fig. 1: Deboosting factor $\Psi$ in the gas reference frame $K'$ as a function of $v_{out}$ assuming $\theta = 180$. For speeds lower than 0.1 the speed of light the radiation intercepted by the outflow and the (rest-frame) observer at infinity are virtually the same. For higher speeds, the fraction of intercepted radiation drops dramatically due to special relativistic effects.

$$L' = L \cdot \Psi$$

Beaming effect:

- Wind with (sub)relativistic velocity
- back-illuminated by the AGN

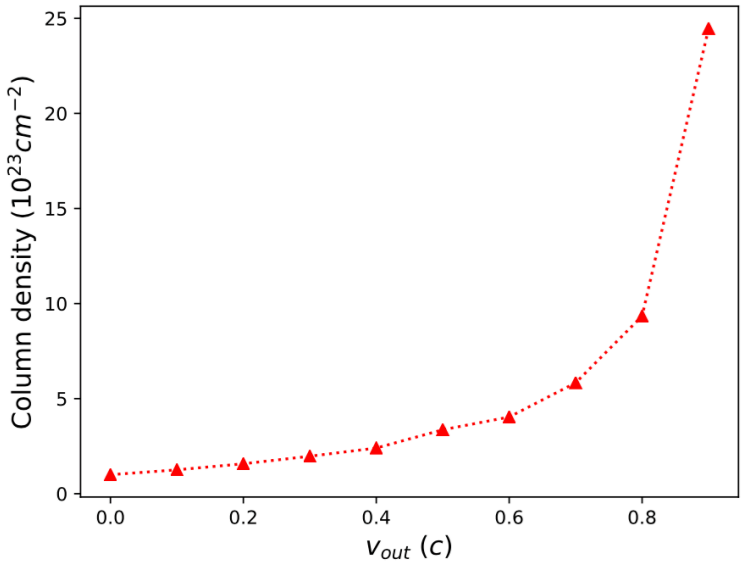
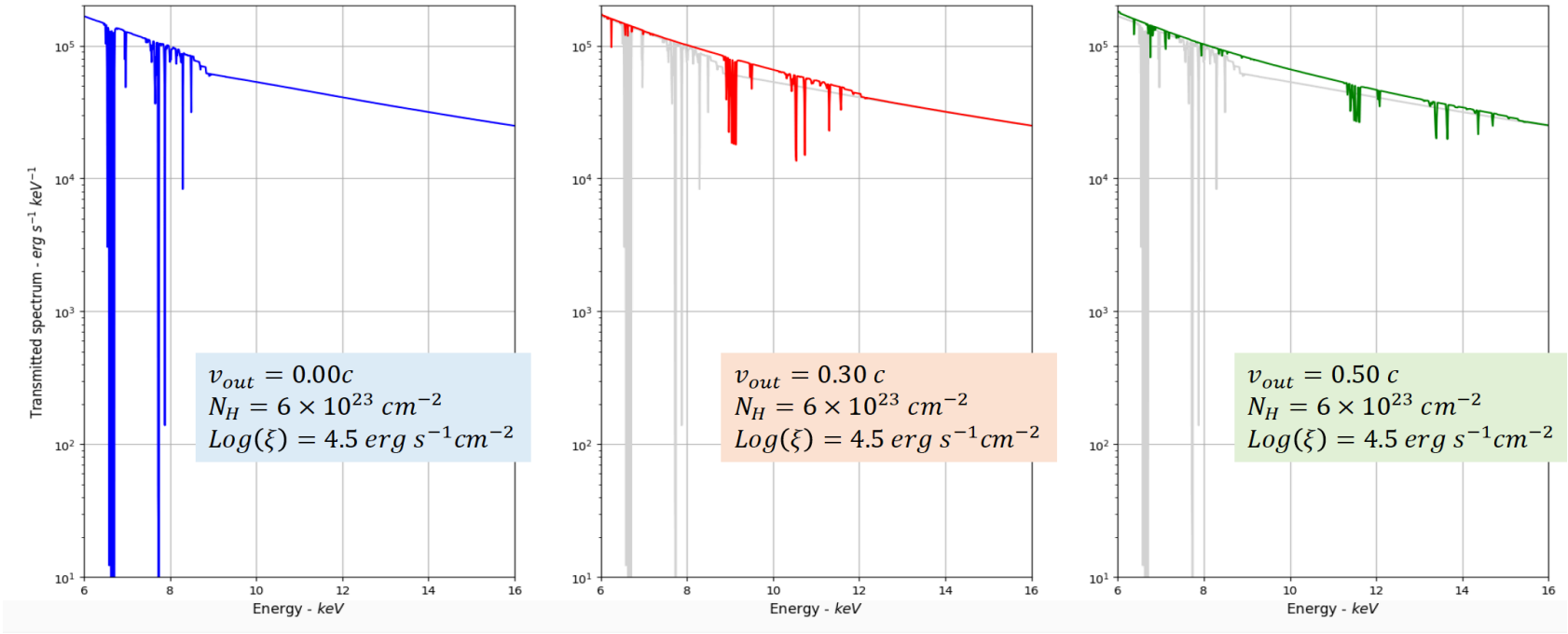



Fig. 3: Absorbing gas $N_H$ required to reach a given value of the optical depth as a function of $v_{out}$. Spectral parameters are as in

**Luminari et al. 2020, A&A**

# On the importance of Special Rel. effects in modelling UFOs




- ✓ **Optical depth of the wind depends on $N_H$ and v_out**
- ✓ **Estimating $N_H$ from optical depth needs a velocity-dependent correction**
- ✓ **This correction nearly propagates to Mout and Ekin**
- ✓ **Correction of 20 – 120% for the observed range of v_out ≈ 0.1 – 0.3c**

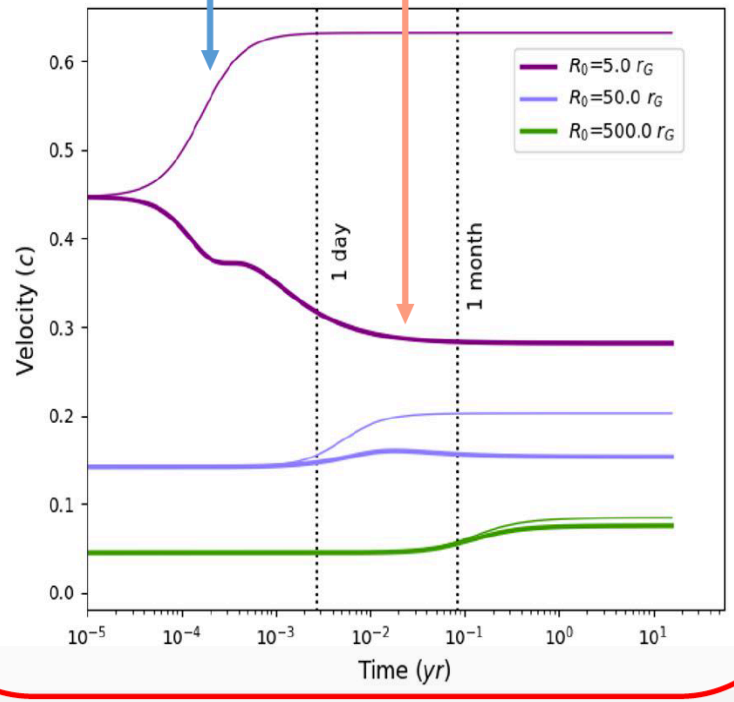
# Relativistic effects reduce the radiative driving

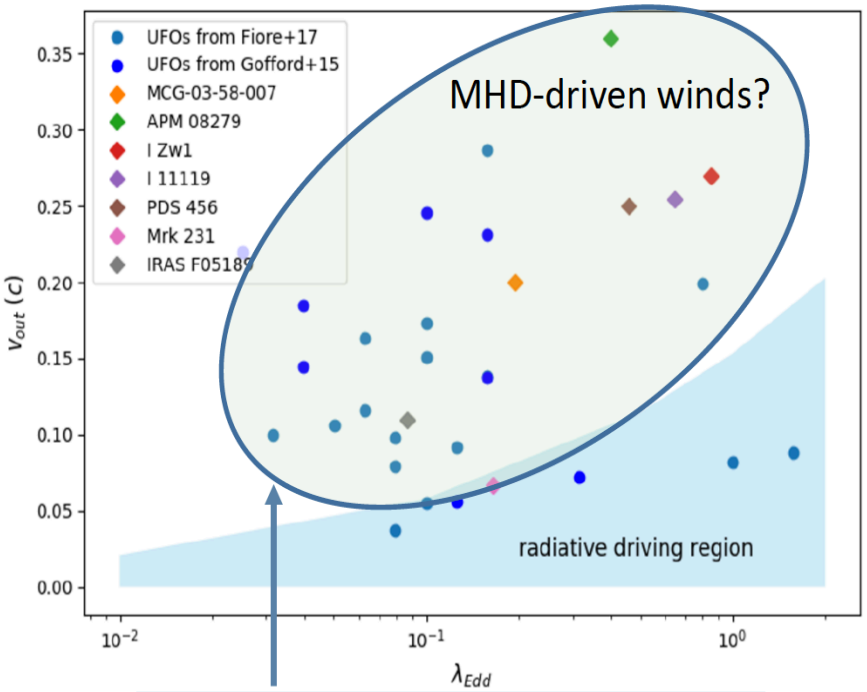
Wind opacity is reduced for increasing v_out → reduced radiative pressure

Radiation driven winds have limited velocity

Non-relativistic treatment: average $v_{out} = 0.6\ c$

Relativistic treatment: average $v_{out} = 0.3c$




Observed $v_{out}$ are sistematically higher than radiation-driving velocities

Additional interesting results, i.e failed winds are a natural outcome in any radiative driven scenario (expected to be ubiquitous). We show that successfull winds can be launched only through very high launching velocities (~v_rot ) or extreme Eddington ratios (>1).

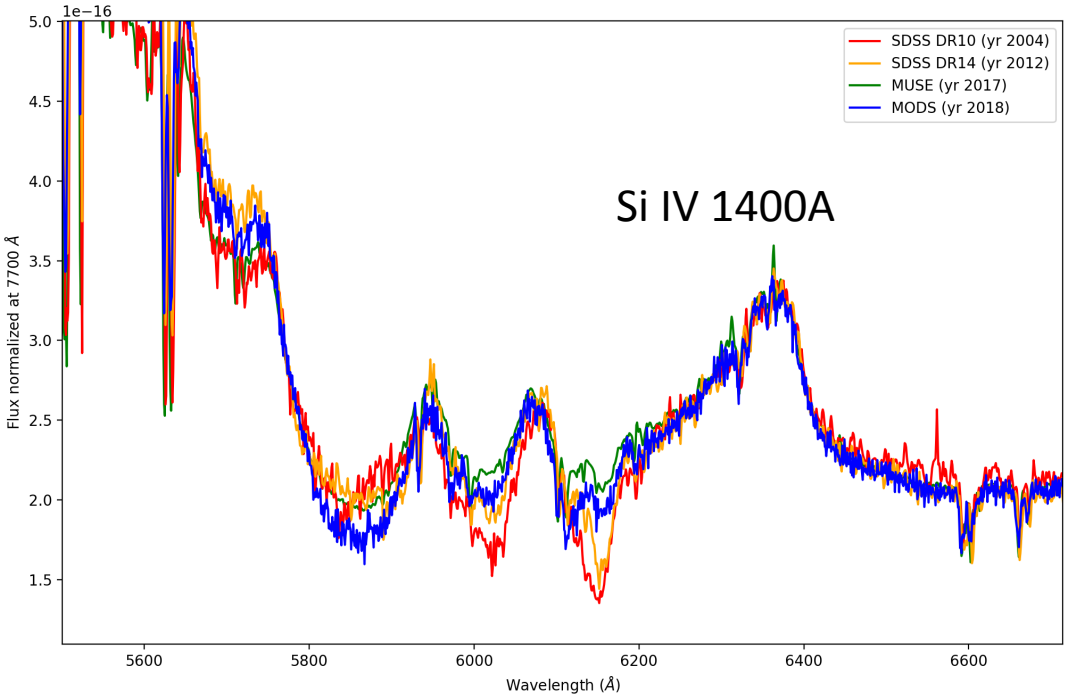


Luminari et al. 2020 ~submitted

# PERSPECTIVES ON THE MOST LUMINOUS QSOs

## Activities led by EP (OAR)

- MUSE view of WISSH QSOs (Blackout Fellowship)
- ALMA+NOEMA view of WISSH (M. Bischetti)
- Study of ultra-fast BAL winds (G. Vietri)




Two WISSH QSOs exhibit BALs bluewards SiIV (and no features redwards) →
Explained in terms of highly-blueshifted CIV absorption

→ **outflow speed of ~45,000 – 50,000 km/s [0.15-0.17c]**

**Bruni +19**
**Vietri in prep.**

✗ **ULTRA-FAST BAL SYSTEMS DISAPPEAR and VARY IN CONCERT**

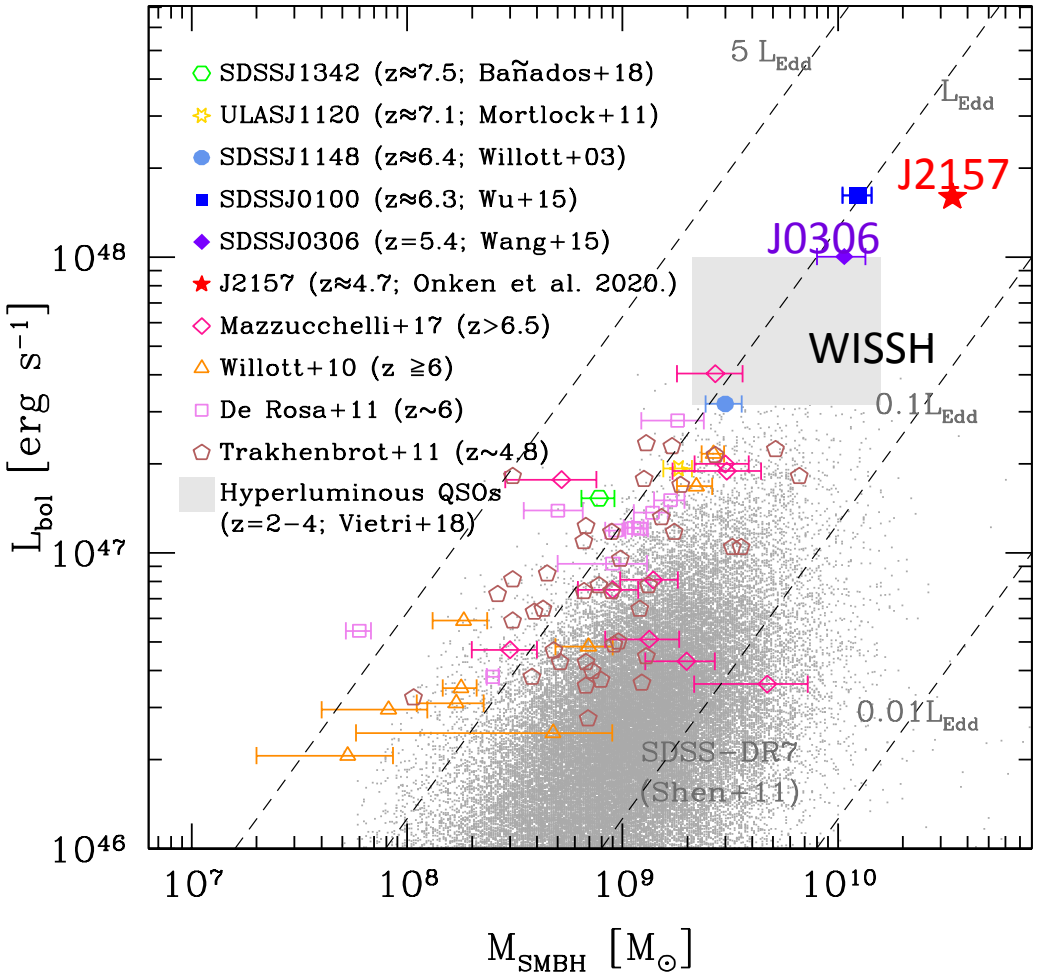
# PERSPECTIVES ON THE MOST LUMINOUS QSOs

## Activities led by L. Zappacosta (OAR)

## X-ray + X-shooter data of the Big Bros, i.e. two hyper-lum QSOs at z~5

**Aims:**
measure X-ray parameters, SMBH mass, luminosity, & winds parameters (blueshifts and BAL)

Zappacosta et al. in prep.



# PERSPECTIVES ON BH WINDS & COSMOLOGICAL MODELS

## Activities led by A. Luminari (Roma2, OAR)

- Paper presenting the WINE MODEL
- Application(s) of the WINE model to the data
  PG1448 (Laurenti et al. in prep.) + Hi-Edd QSO (EP in prep.)

## Activities led by N. Menci (OAR)

- Improving the Menci+19 SAM by
- (i) including a 2D description of the outflow in order to accurately measure its impact on the host galaxy properties
- (ii) including the stellar velocity dispersion of the bulge to study the evolution of the MBh-Sigma relation

# END