IFU Synergies with Athena: the energetic view

Credits: ESA & Marcella Brusa

Marcella Brusa

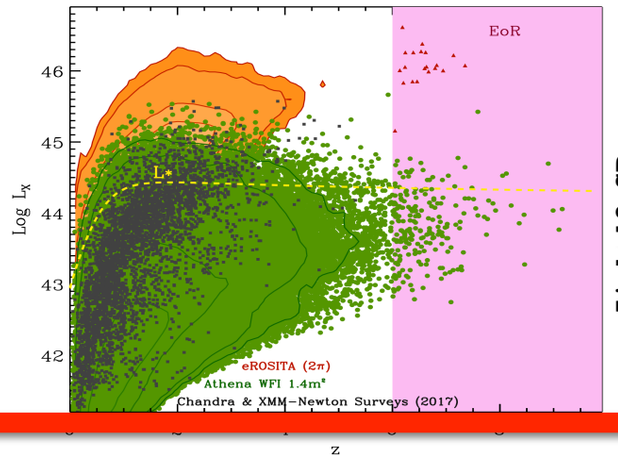
1) DIFA-Dipartimento di Fisica e Astronomia / Università di Bologna

2) OAS-Osservatorio di Astrofisica e Scienza dello Spazio di Bologna / INAF

The Energetic Universe

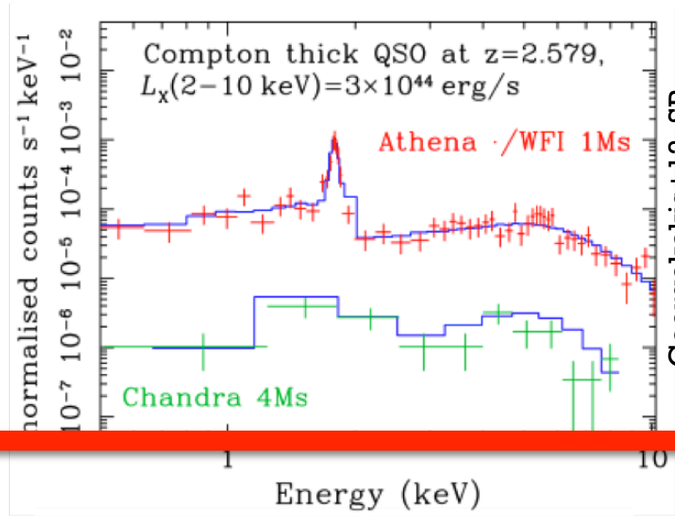
- How do black holes grow and influence the Universe?
  - The history of SMBH growth
  - Obscured AGN census z~1-3
  - AGN winds and outflows z~0-3
  - SMBH growth: accretion vs. mergers
  - BH & SMBH physics
  - Luminous extragalactic transients

Typical AGN z~6-8

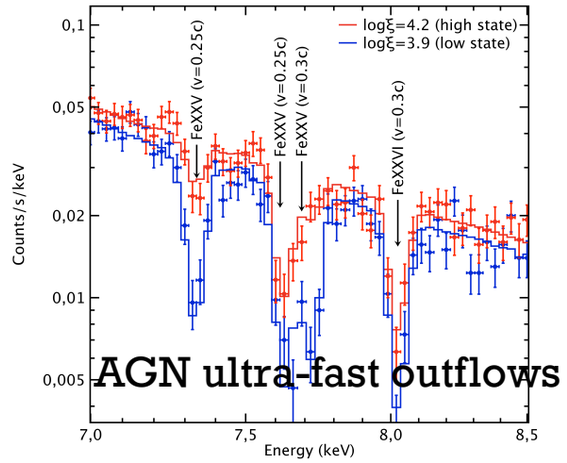


Aird+13, SP

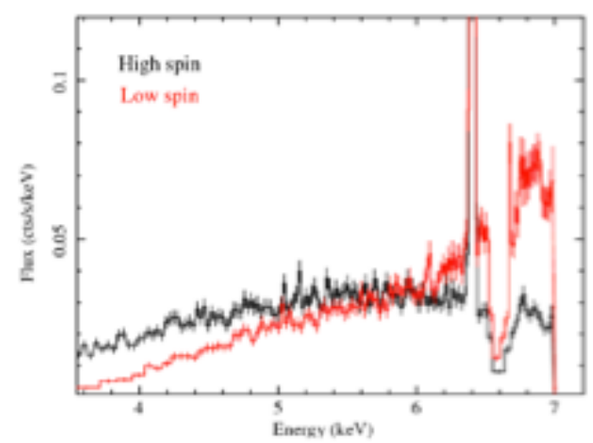
Compton-tick AGN census



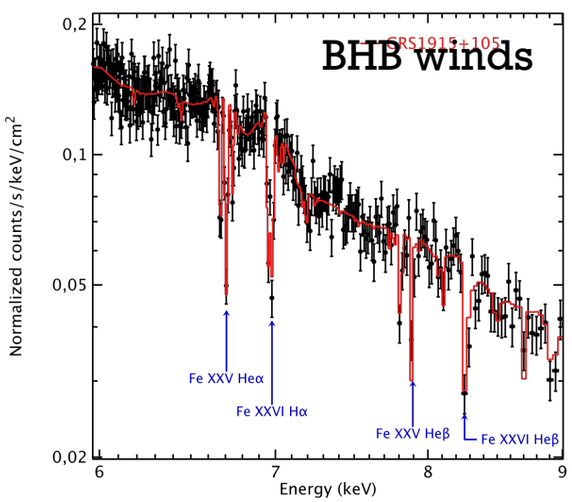
Georgakakis+13, SP



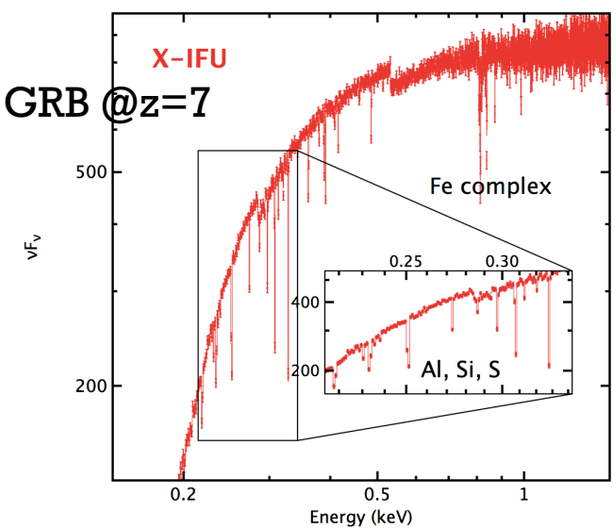
Cappi+13, SP



Dovciak+13, SP



J.M. Miller+16



Jonker, +13, SP

N.B: Slide taken from the "Athena Master Short presentation" template available on the Athena website

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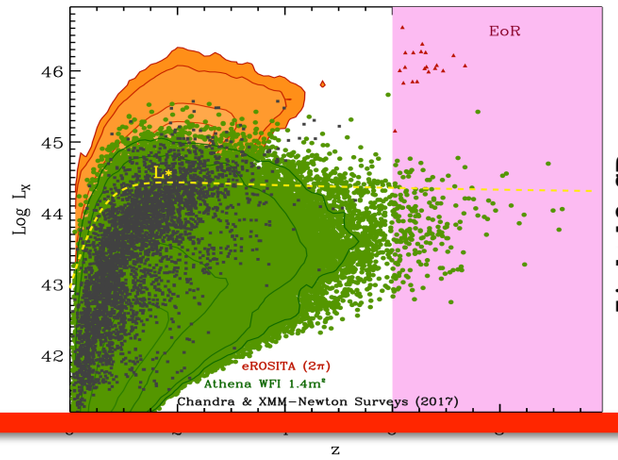

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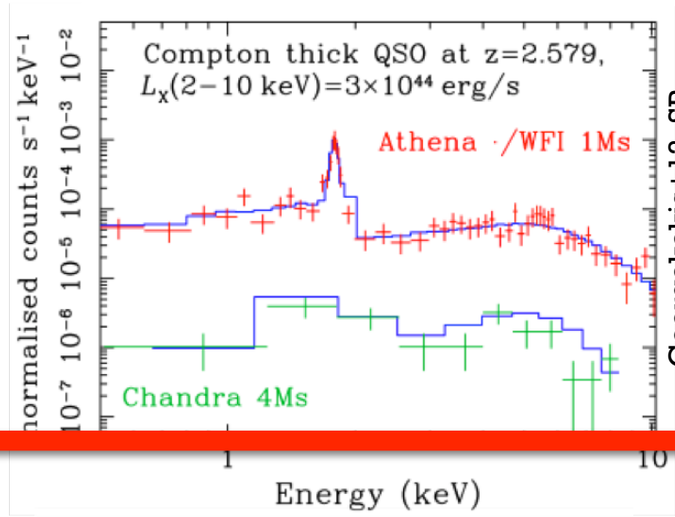

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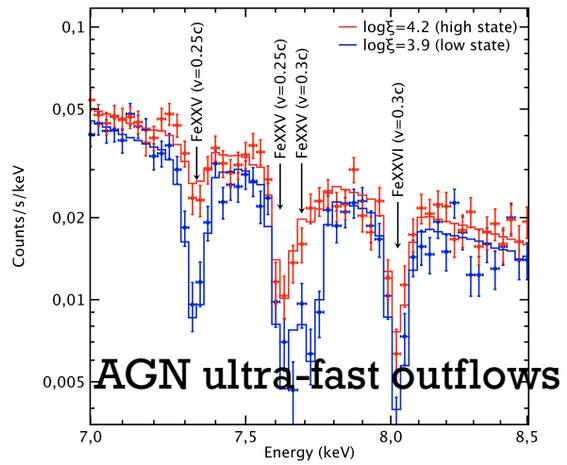

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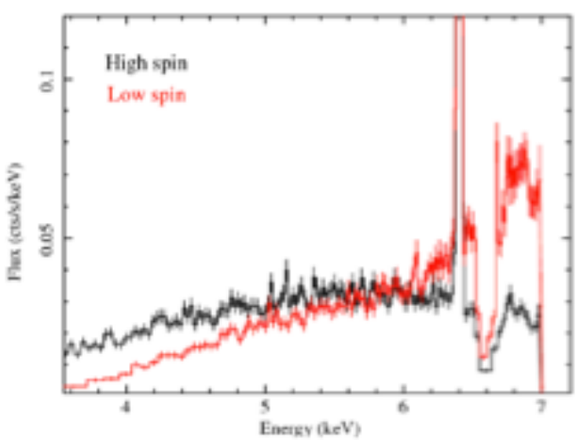

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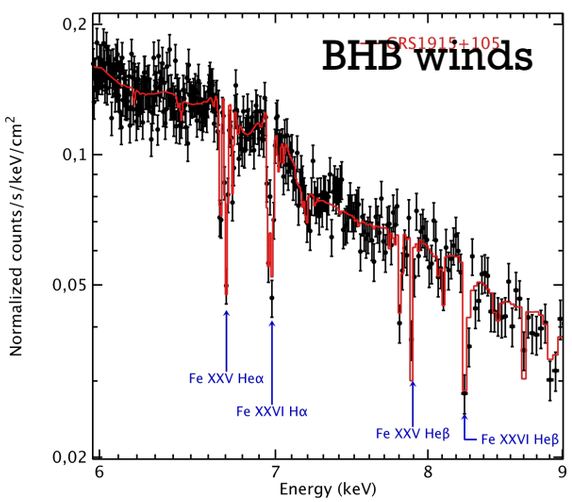

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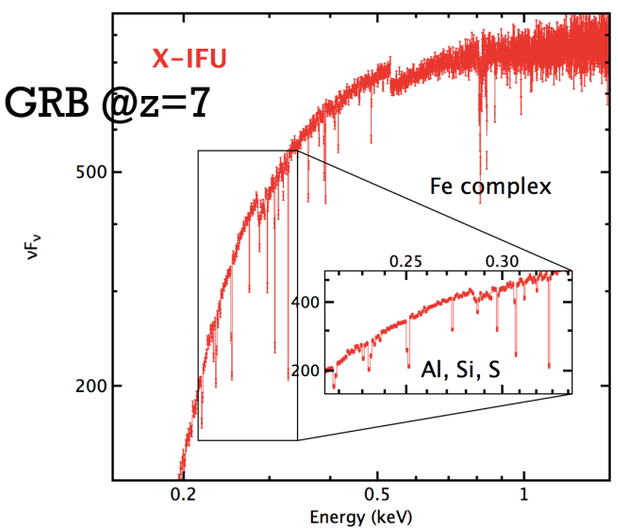

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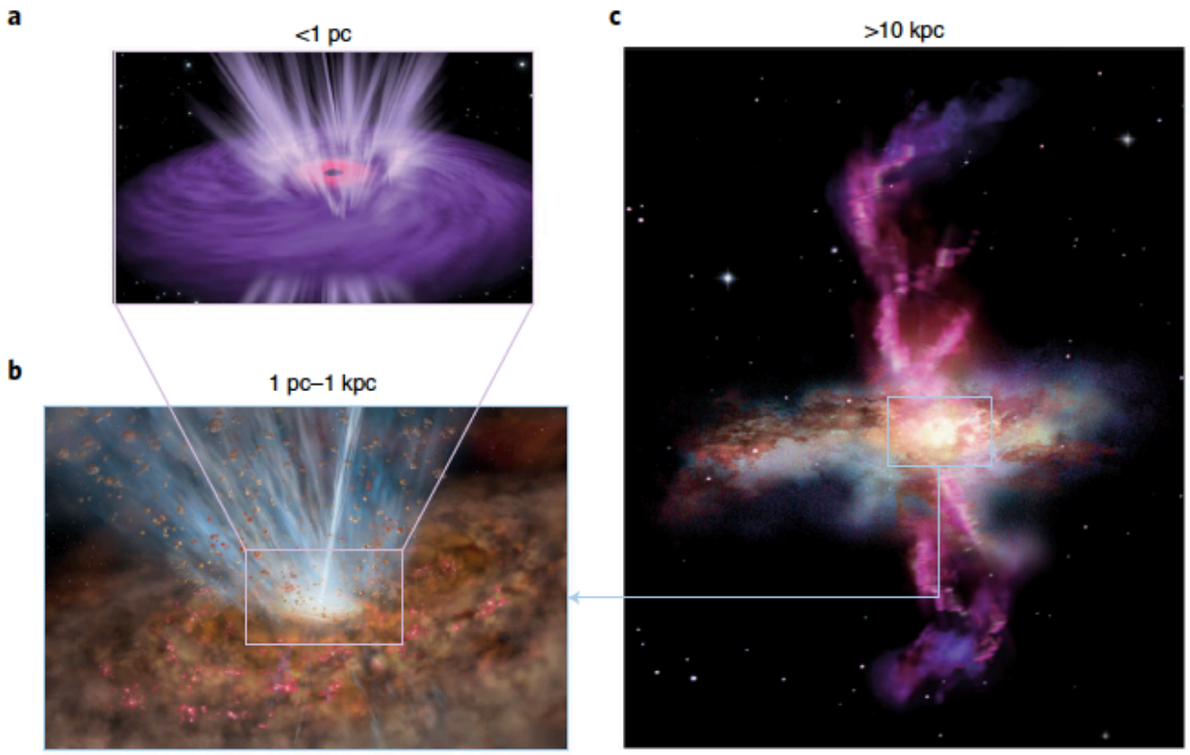
FEEDING AND FEEDBACK CYCLE



Expectations:

The activity of the SMBH influences the life of the galaxy

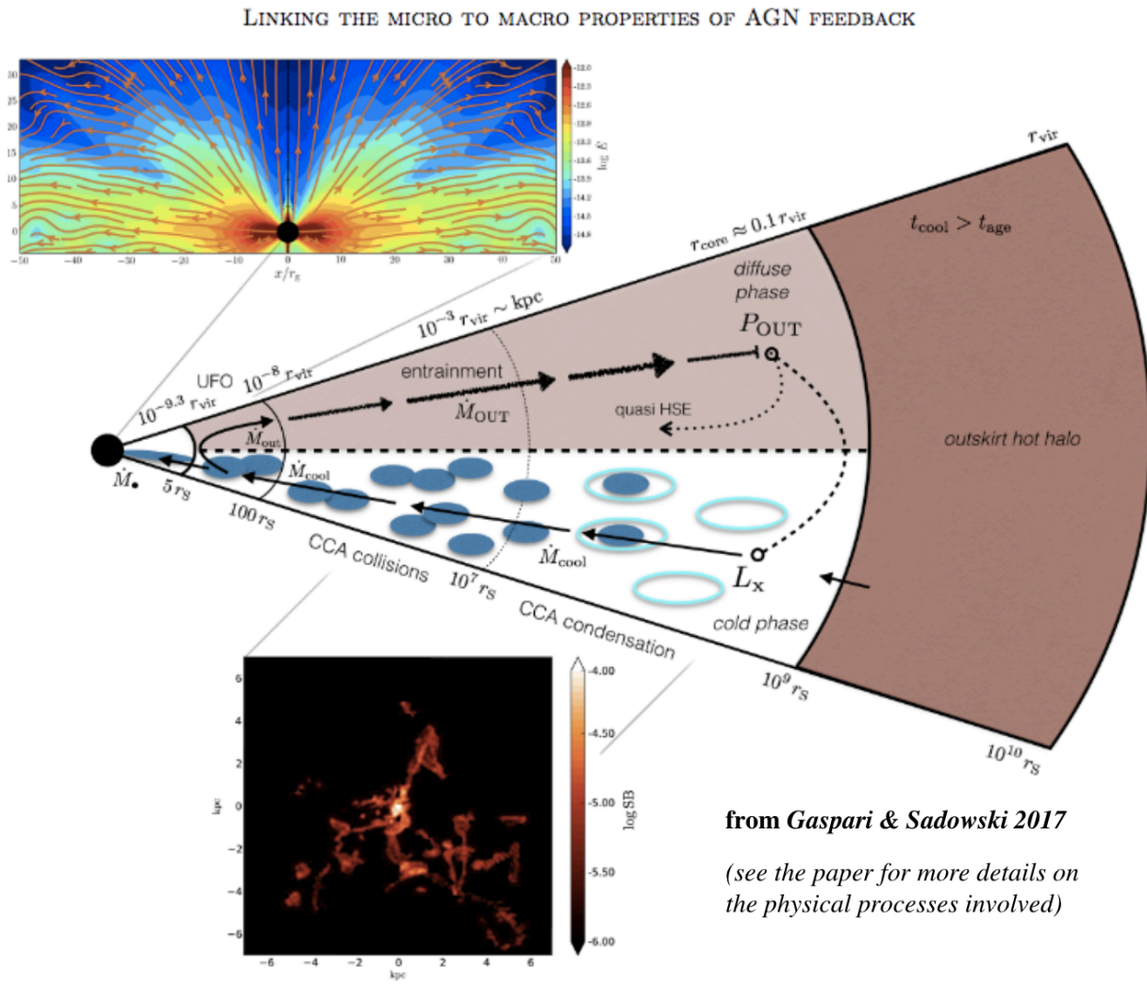
MICRO vs. MACRO

Heating vs. Ejecting

e.g. Croton+2006, Ciotti&Ostriker2007

Radiative vs. Kinetic

e.g. Zubovas&King 2012, Tadhunter+2014



from *Gaspari & Sadowski 2017*

(see the paper for more details on the physical processes involved)

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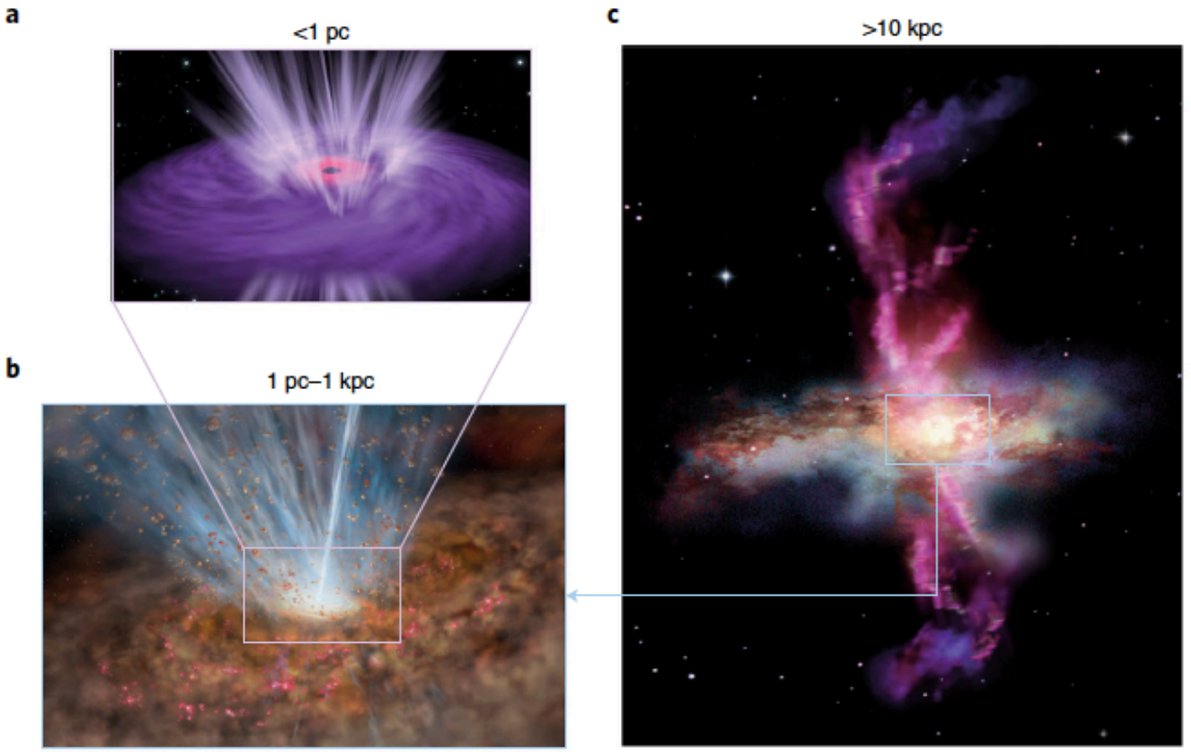
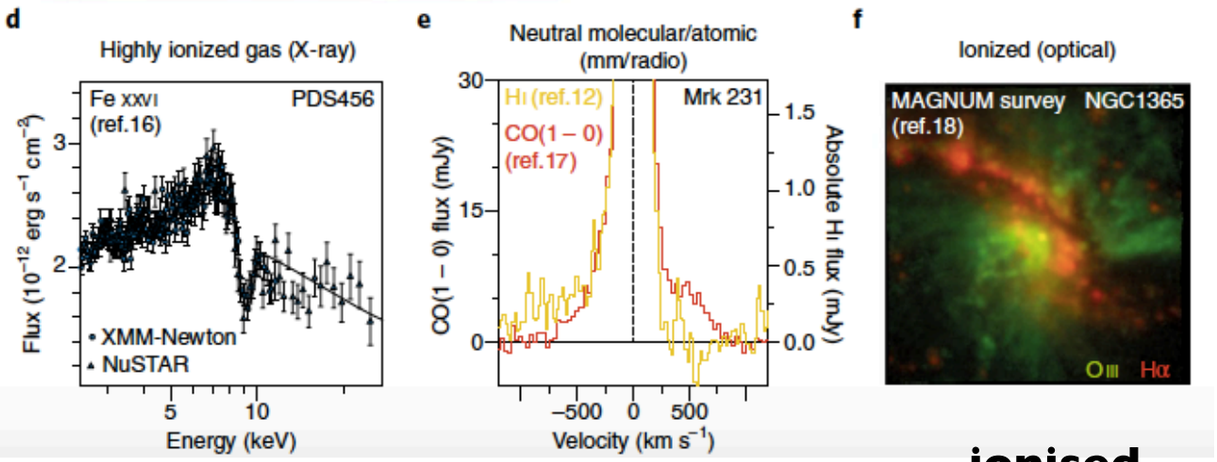
AGN FEEDBACK AS OUTFLOWS

Cicone, Brusa et al. 2018 (Nature Astronomy)





highly-ionised gas (UFOs)

Nardini+2015

neutral gas molecular and atomic

Morganti+2016, Cicone+2012

ionised gas

Venturi+2018

Expectations:

The activity of the SMBH influences the life of the galaxy
Winds from central SMBH propagate into the host galaxy

Wide-angle, wind-driven outflows, launched from the accretion disk

Observations:

Winds are seen across the electromagnetic spectrum
(ionization state, redshift…)

Different tracers probe different phases and different scales
(+warm molecular, warm absorbers etc.)

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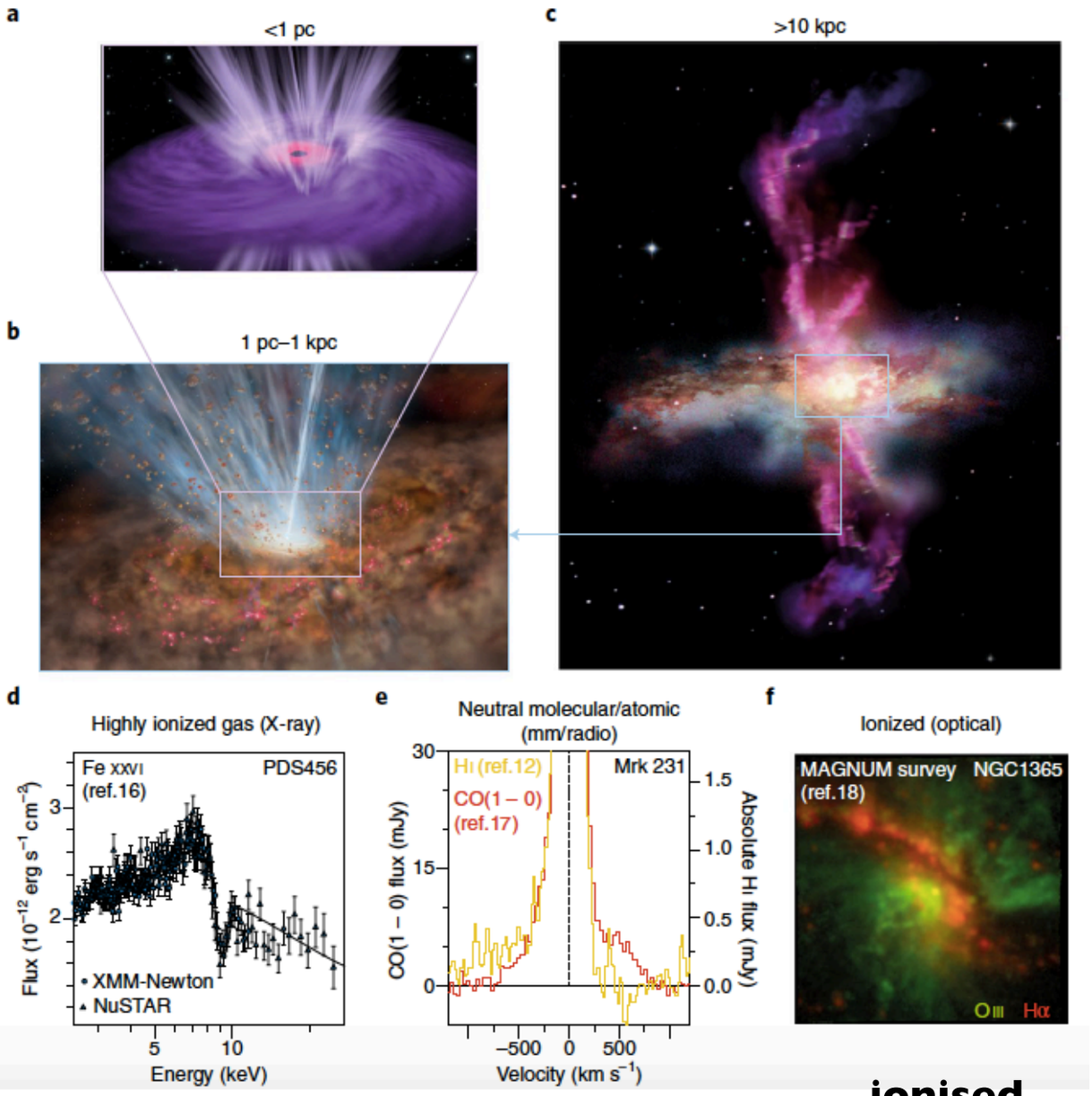

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momentum conserving vs.
energy conserving vs.
radiation pressure on dust

Fauchere-Giguere+2012, King2012, Fabian2012
Zubovas&King 2012…2016, Costa+2014, 2018

Main quantities needed to constrain models and propagation mechanisms

outflow mass rate:

$$\dot{M}_{out} \propto M_{out} V_{out} / R$$

kinetic power:

$$\dot{E}_{out} \propto \dot{M}_{out} V_{out}^2$$

momentum flux:

$$\dot{P}_{out} \propto \dot{M}_{out} V_{out}$$

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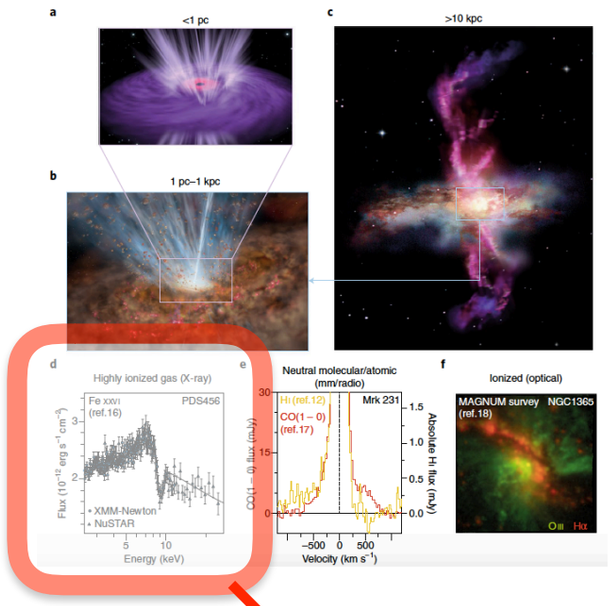
THREE KEY FACTS FOR (X)-IFU

Cicone, Brusa et al. 2018 (Nature Astronomy)



1) Role of ULTRA FAST OUTFLOWS (UFOs)

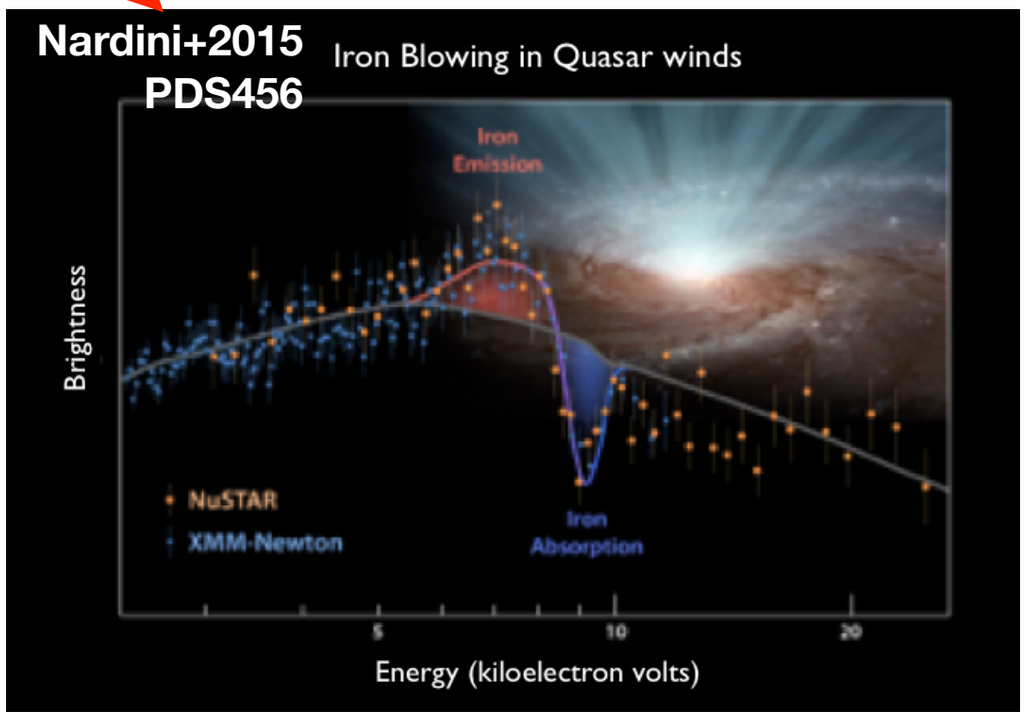
accretion disc winds of highly ionised hot gas with v~0.05-0.5c

local Universe: e.g. Reeves+03, Pounds&Reeves09, Kaastra+14, Tombesi+10,15, Longinotti+16

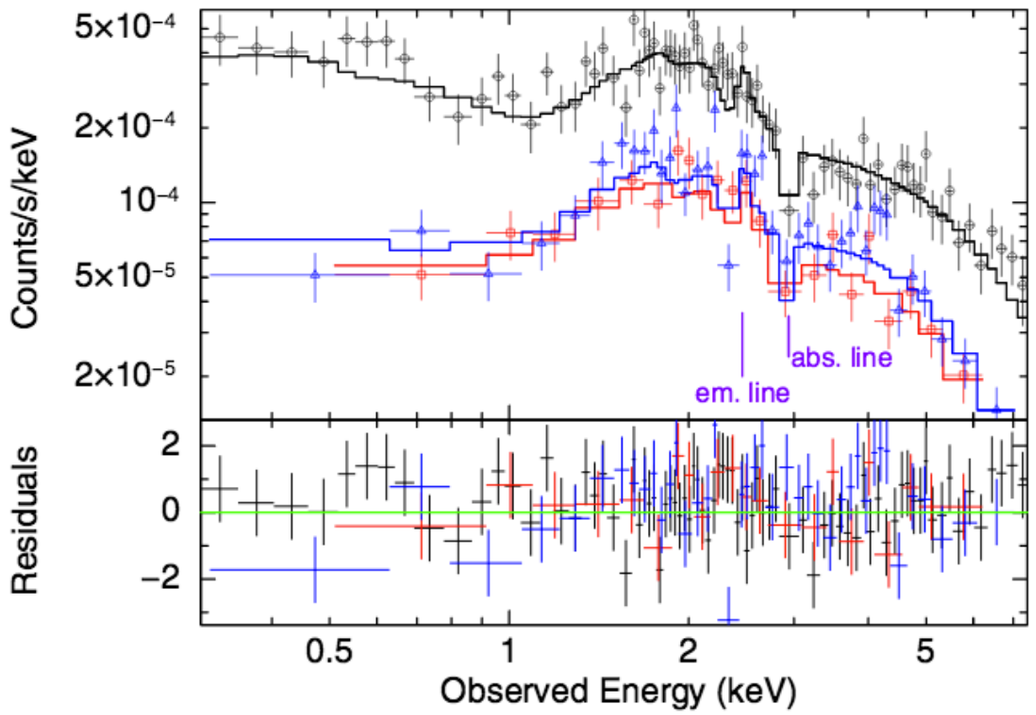
high-z: e.g Chartas+03,09, Lanzuisi+12,16, Dadina+18 (mostly lensed)

⟶ **X-rays**

$$\dot{M}_{out} = 4\pi r N_H m_H C_g v_r$$



Vignali+2015, XMM-CDFS
z=1.6 obscured QSO



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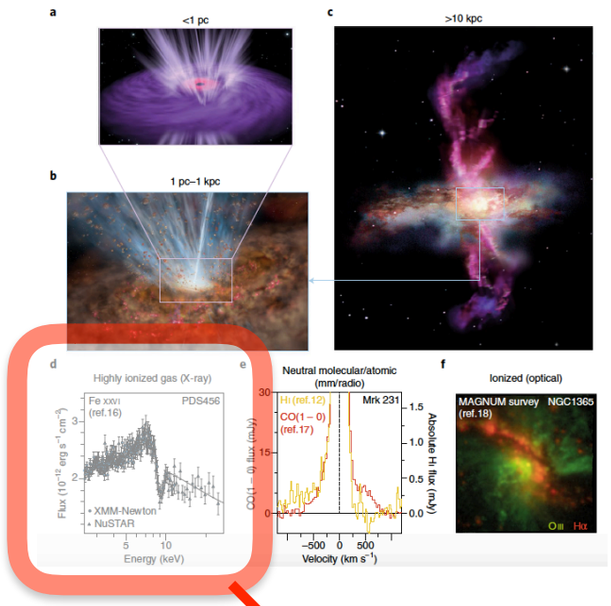

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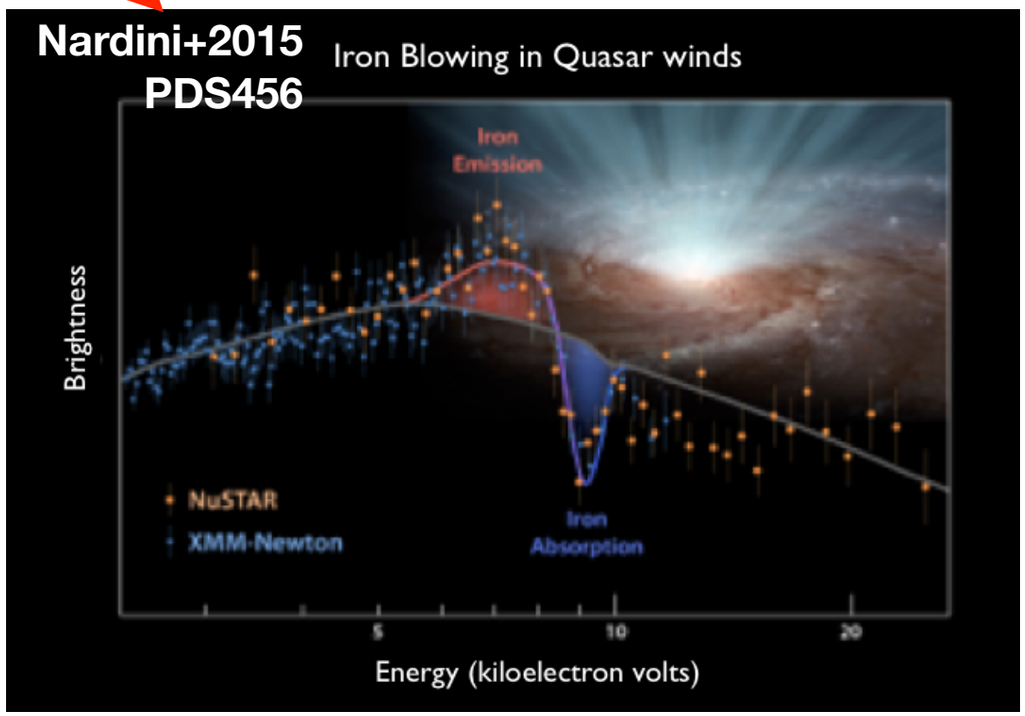

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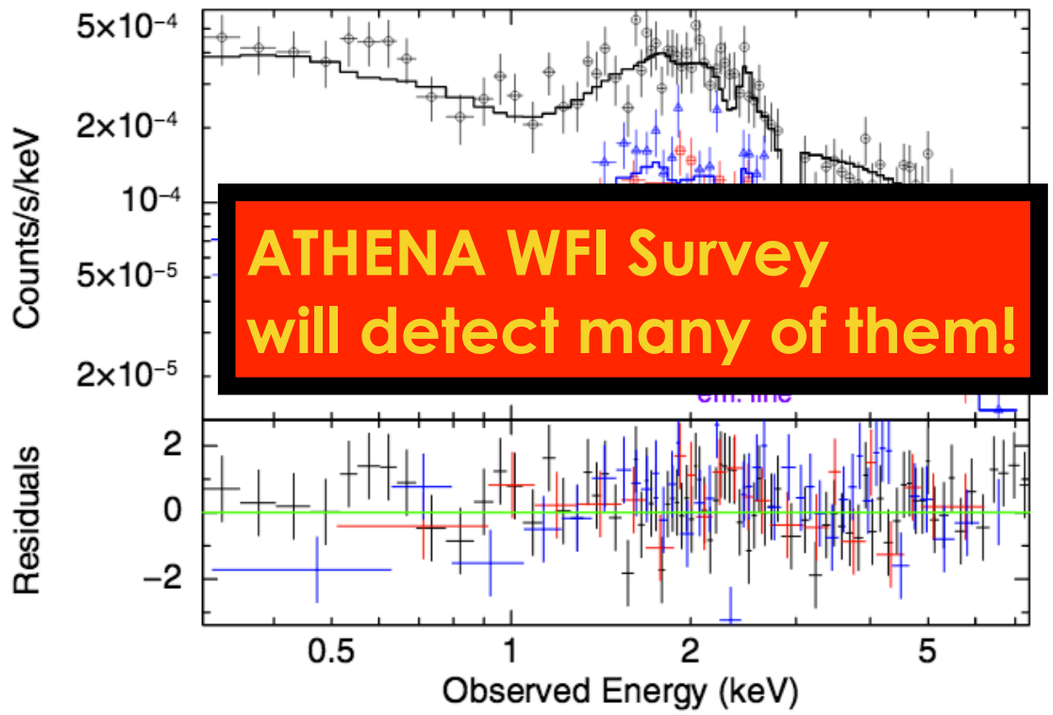

ATHENA WFI Survey will detect many of them!

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"EWASS SS31", Lyon, 28 June 2019

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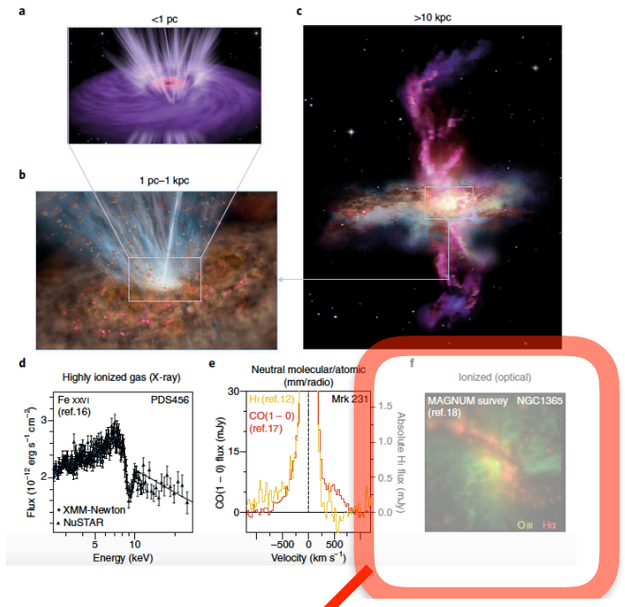
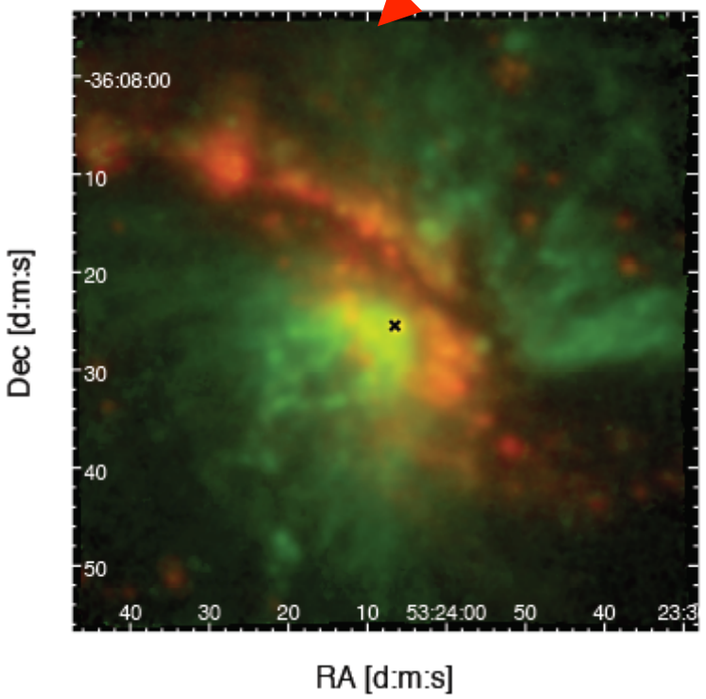


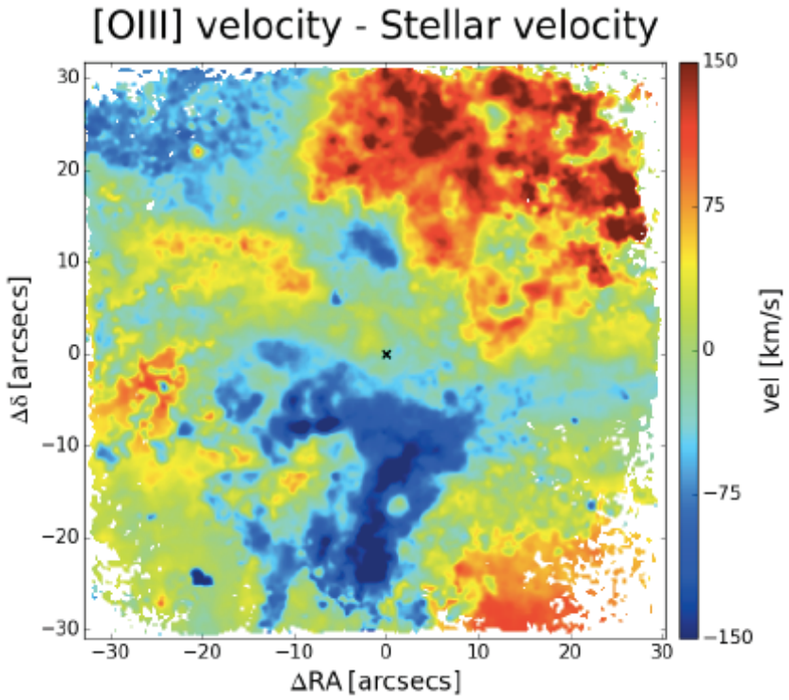


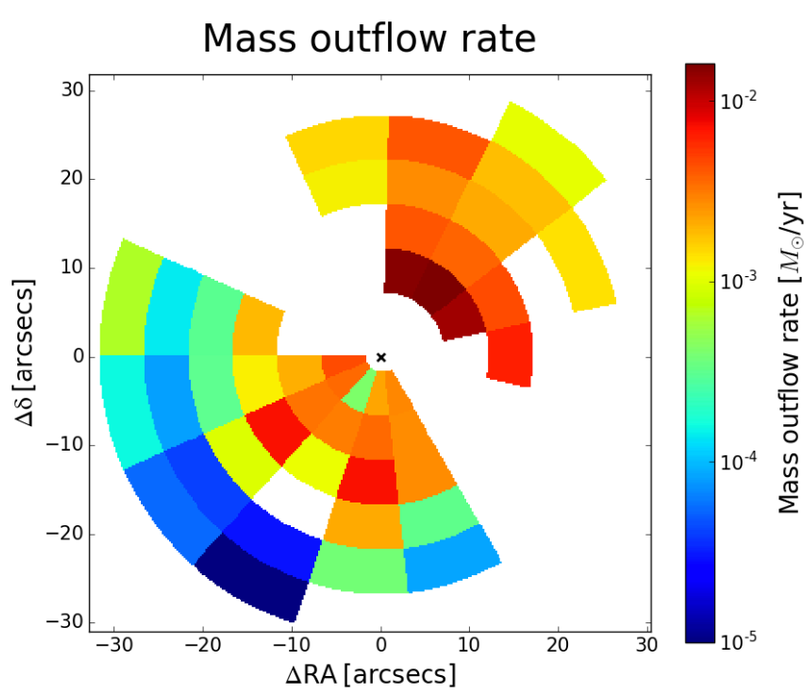
2) Importance of spatially resolved spectroscopy revolution of MUSE, ALMA, SINFONI/AO, MaNGA, CALIFA ++

—> **Integral Field Units !**

$$\dot{M}_{out} \propto M_{out} V_{out} / R$$

MUSE observations of NGC1365
(MAGNUM sample; Venturi+2018)





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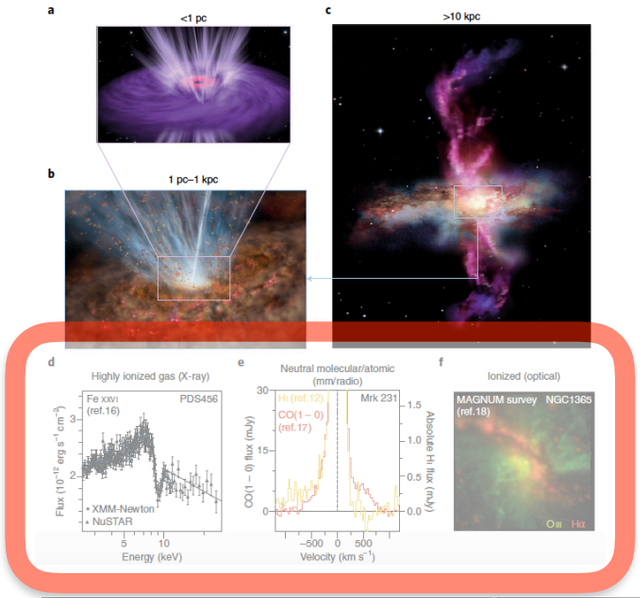


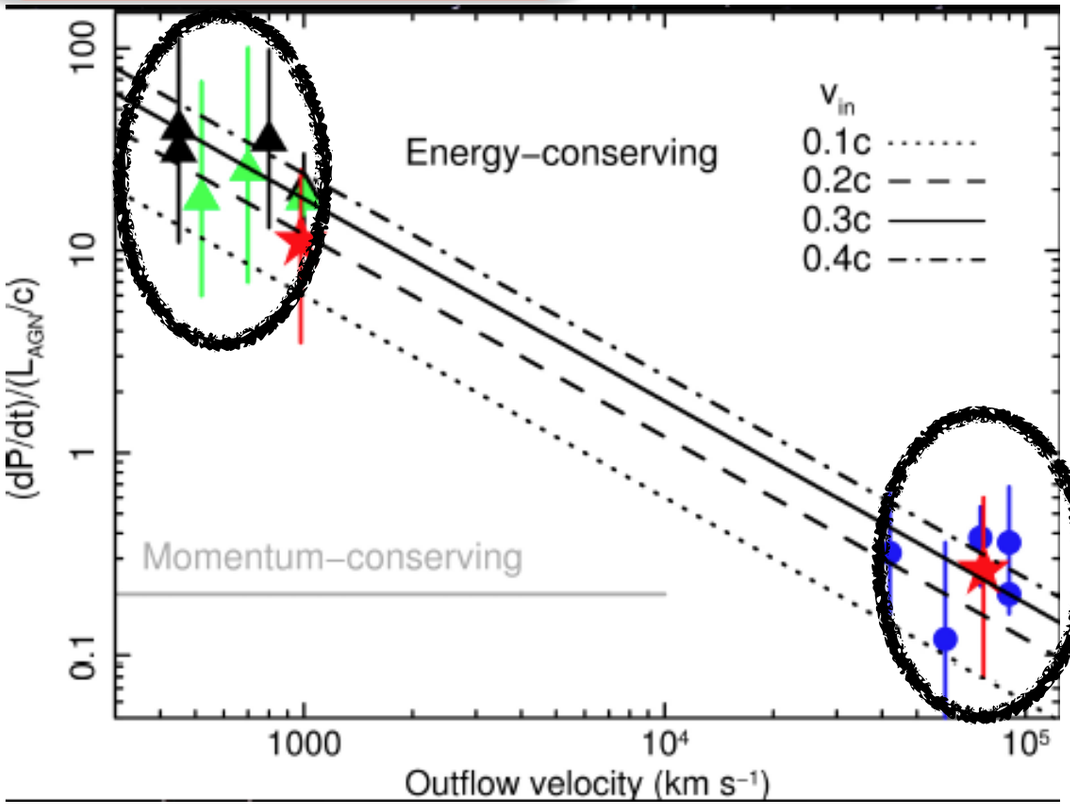
3) Importance of multiphase characterisation

Multiphase investigation is needed to get the full picture - otherwise highly incomplete

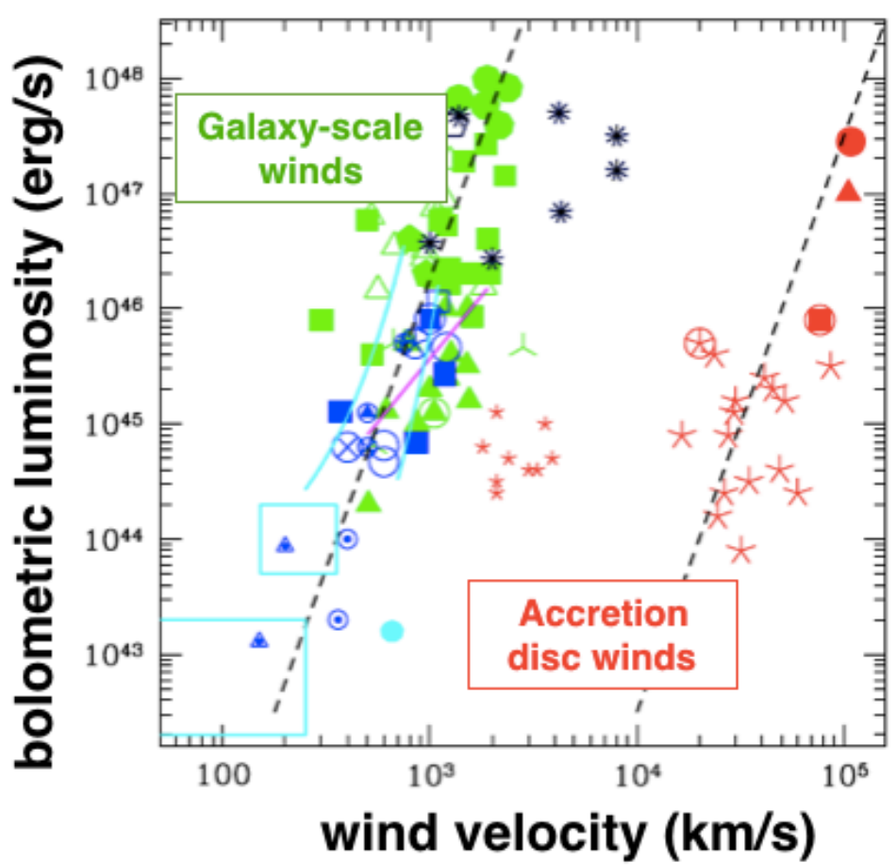
—> Perfect science topic for synergies

Padovani+2018 (ATHENA+ESO Synergies)

Tombesi+2015



Fiore+2017



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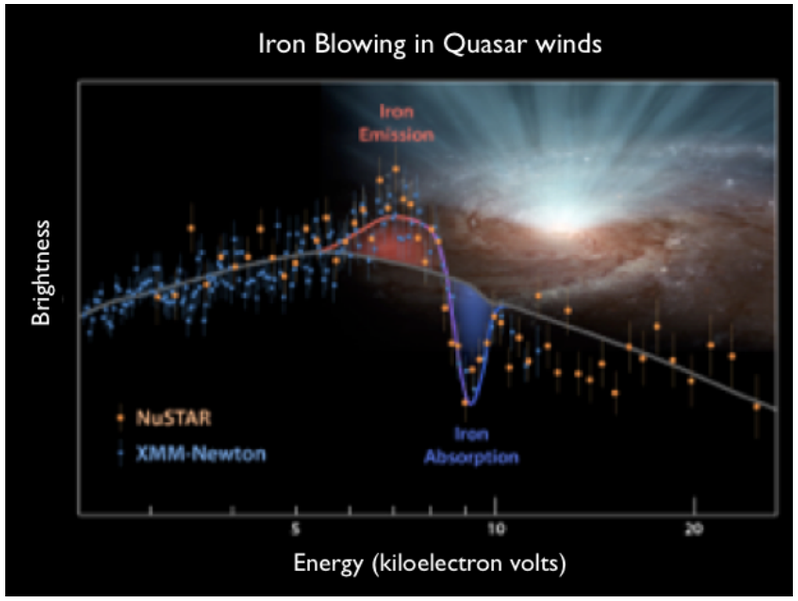
WINDS ARE MULTI-PHASE & MULTI-SCALE

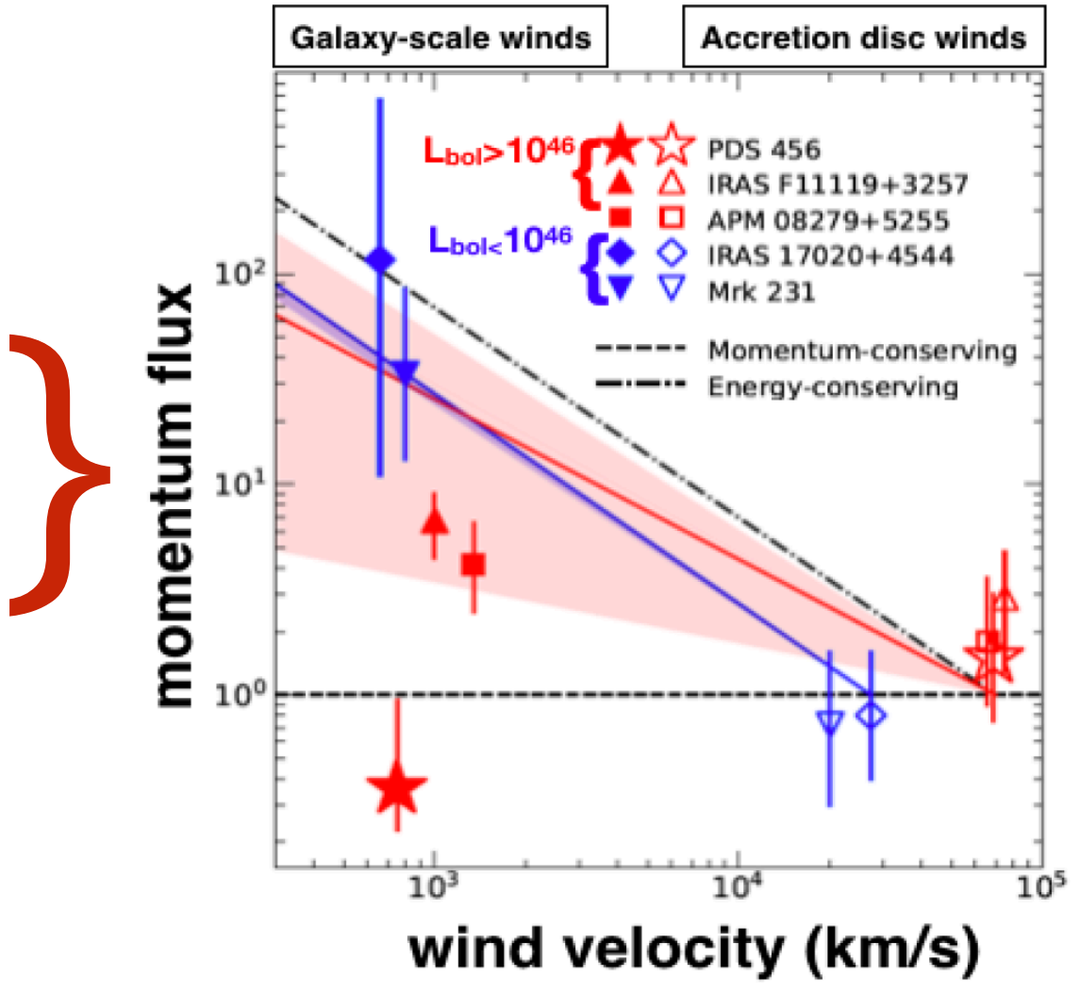
ultra fast outflow

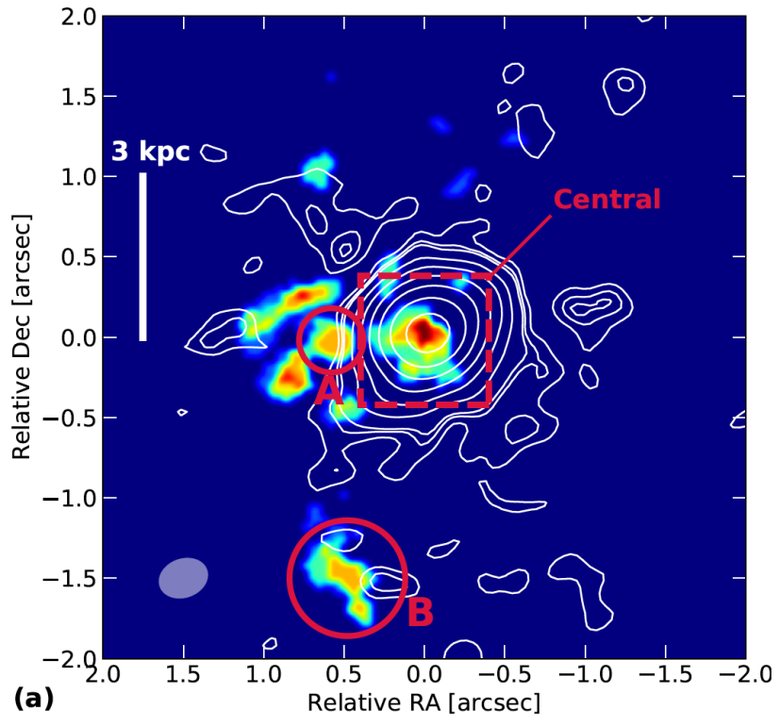
PDS456
z=0.18

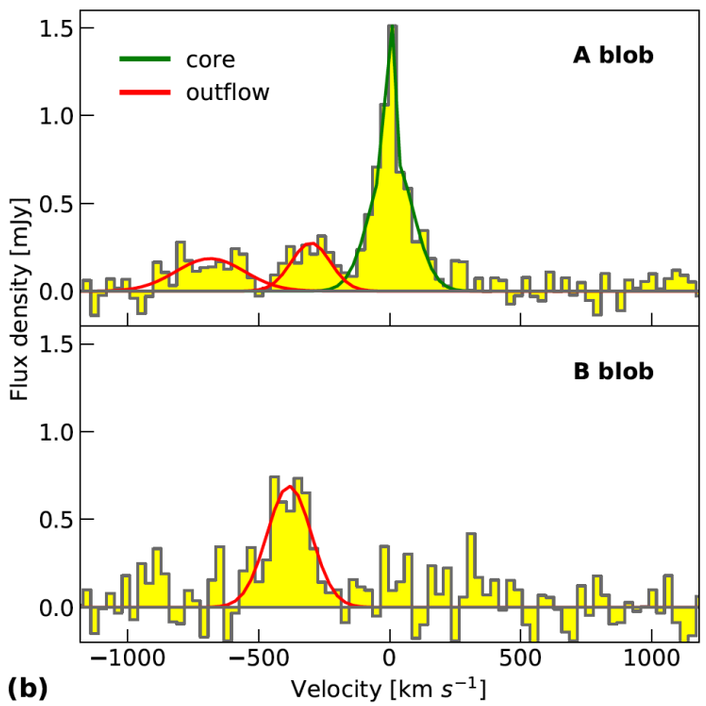
Reeves+03,09,14,18
Nardini+15
Luminari+18
Bischetti+19

XMM+Nustar+ALMA









molecular winds (CO(3-2))

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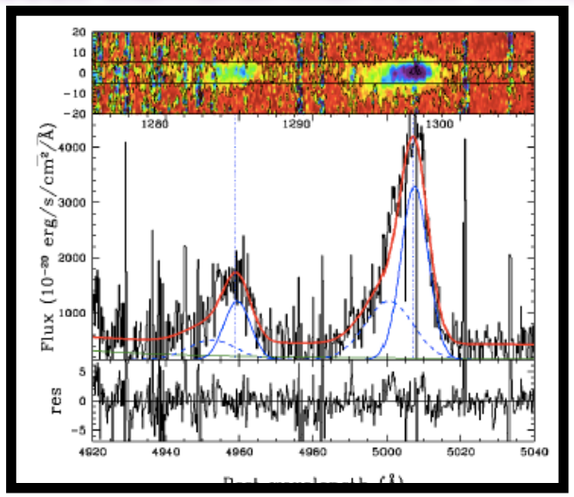
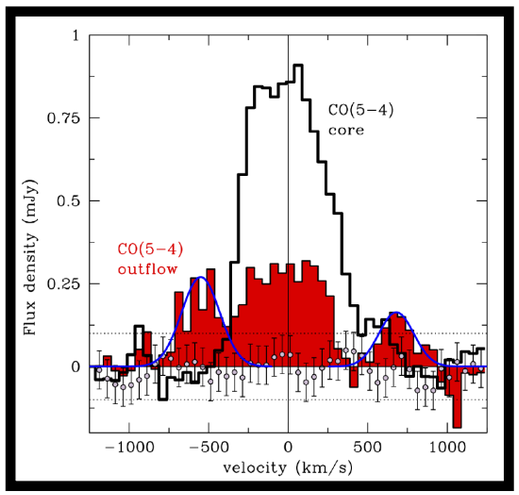
WINDS ARE MULTI-PHASE & MULTI-SCALE

XID2028
z=1.592

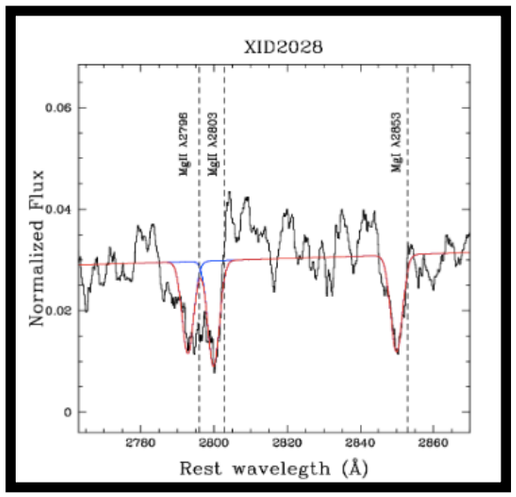
Brusa+2015a,b
Perna+2015
Cresci+2015
Brusa+2018



Ionised outflow ([OIII])

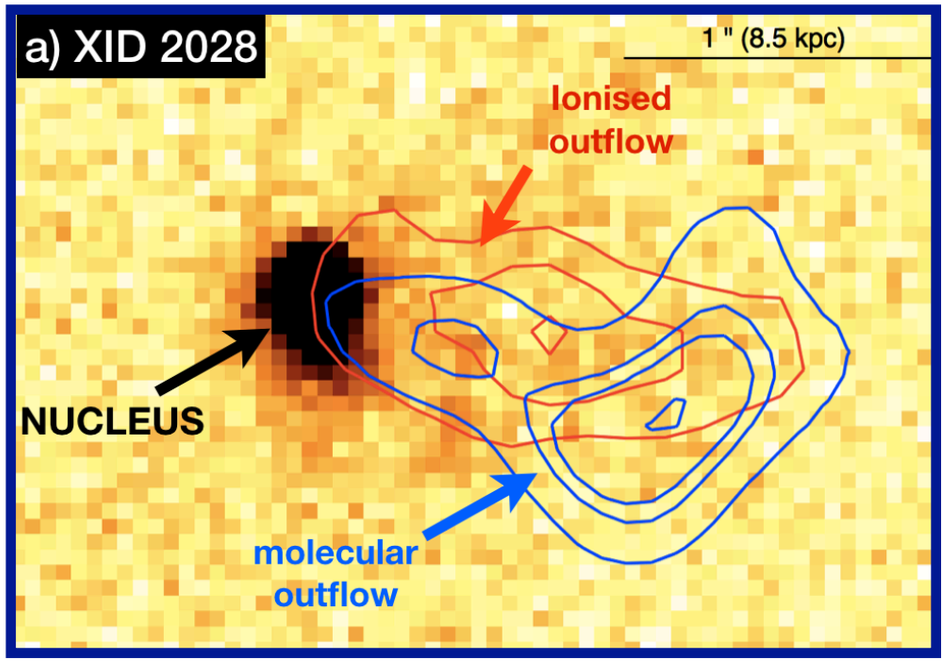


molecular outflow (CO(5-4)

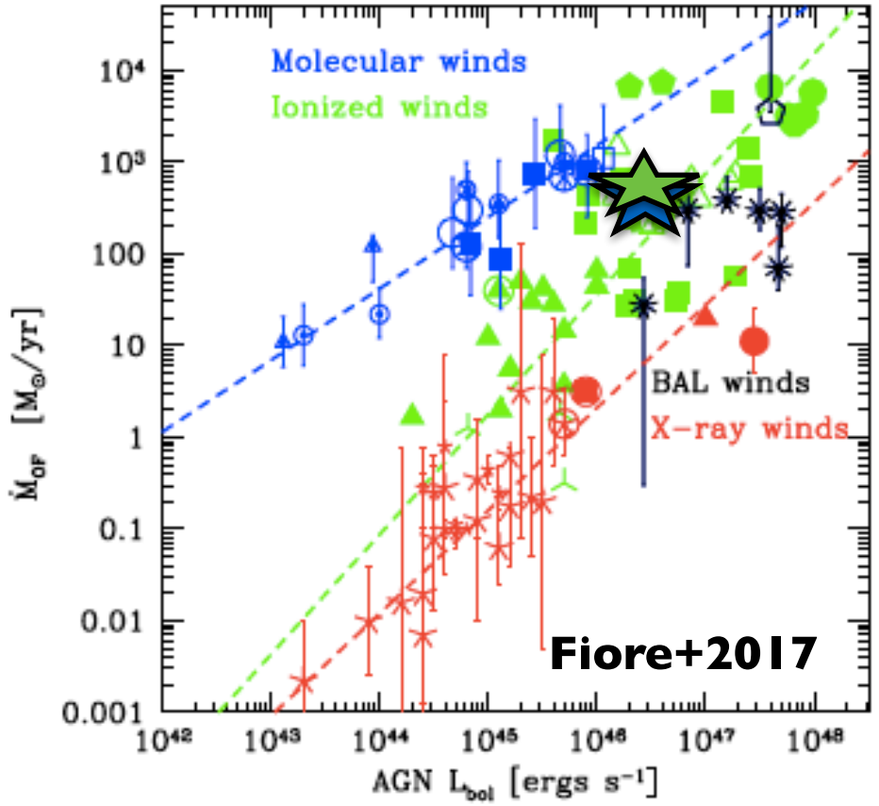


neutral outflow ([MgII])

X-shooter+
Deimos+
ALMA+
SINFONI



cospatial molecular and ionised winds



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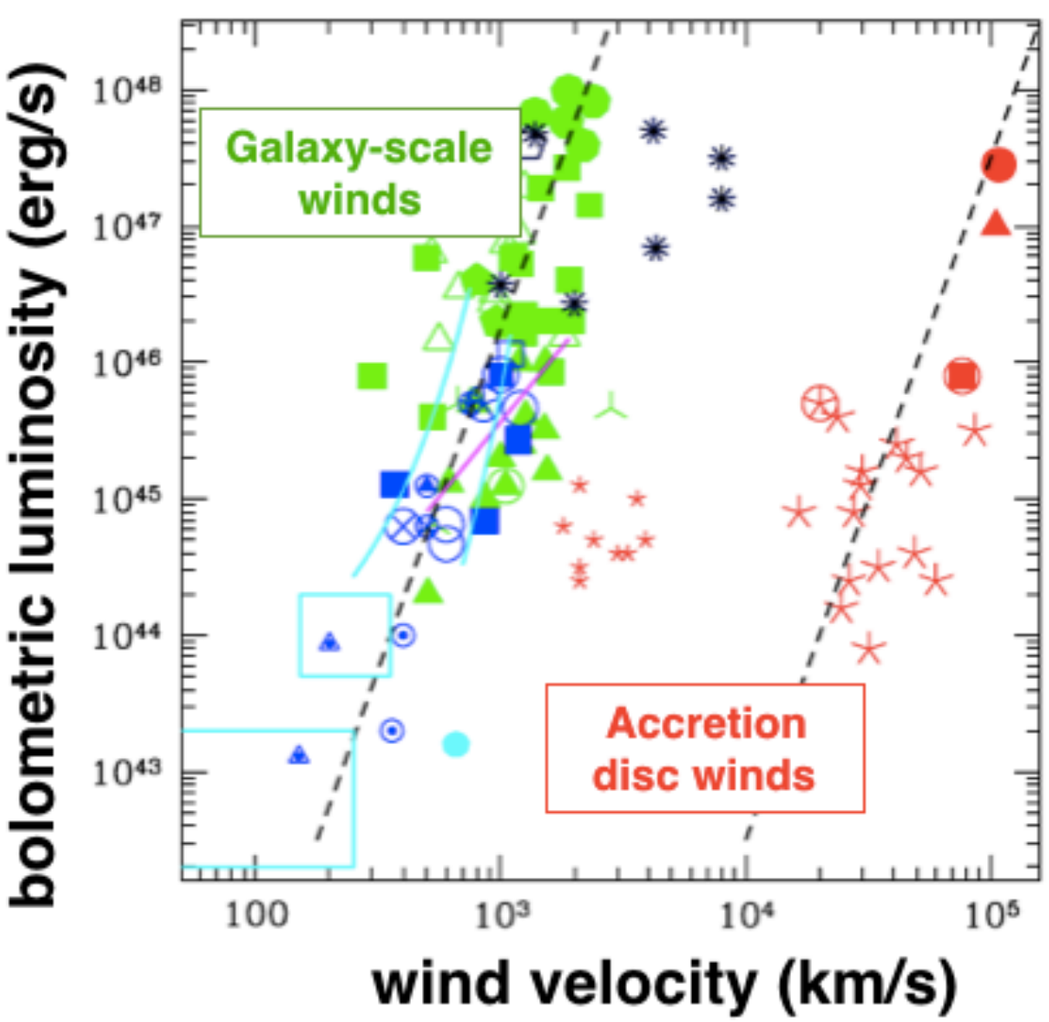
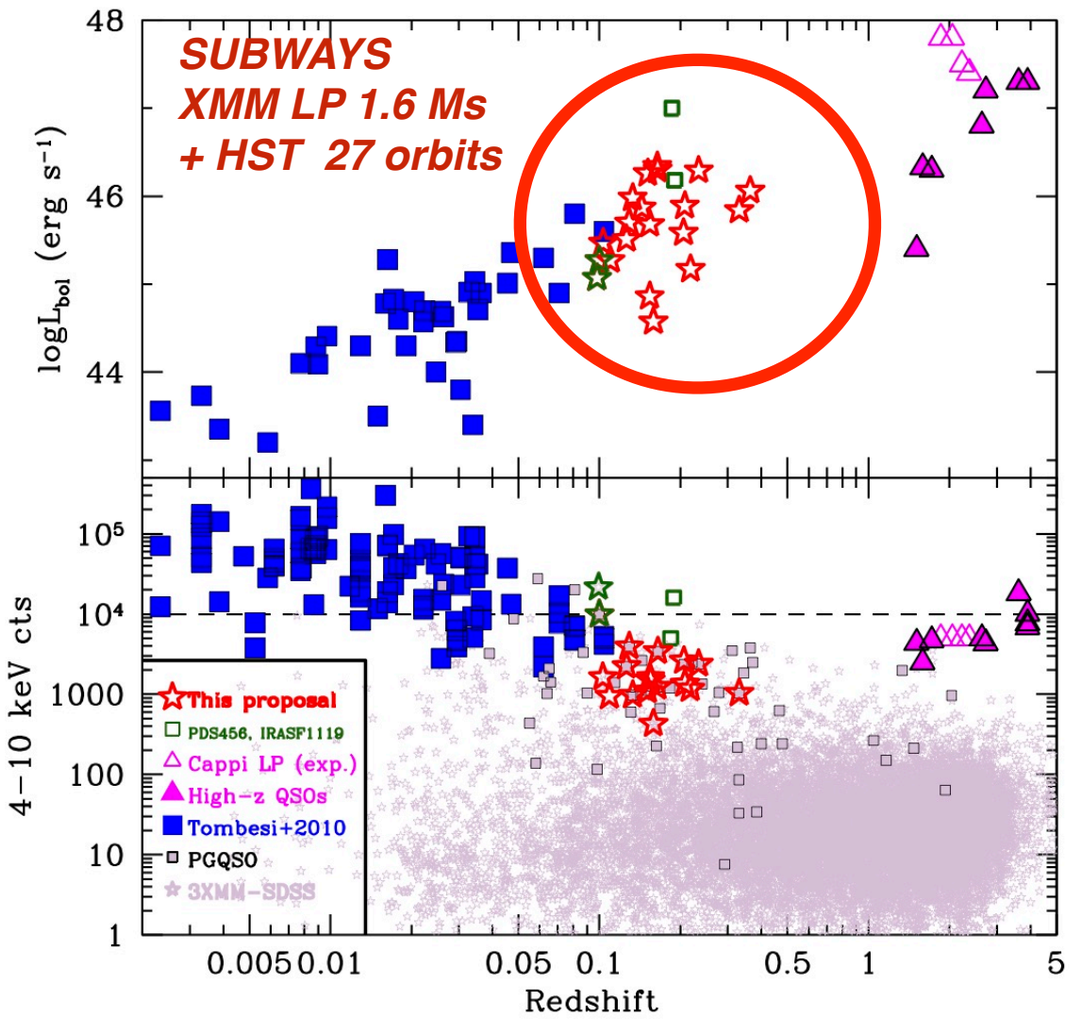
MAIN LIMITATIONS OF CURRENT STUDIES

Ultra Fast Outflows studied mostly low-z/low-L and at CCD resolution

need high counting statistics to detect absorption lines (>10.000 counts)
+ velocity (0.05-0.5c) usually known with large uncertainties

Fiore+2017





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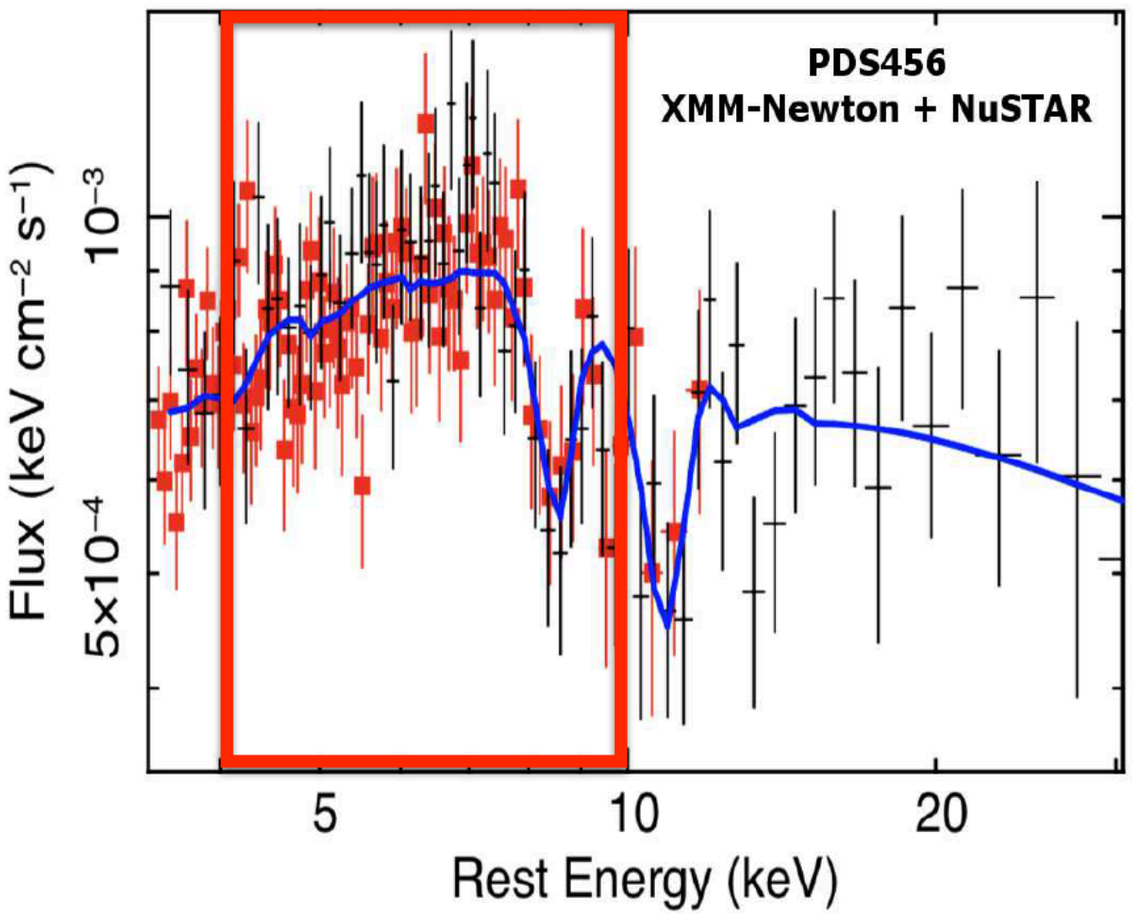
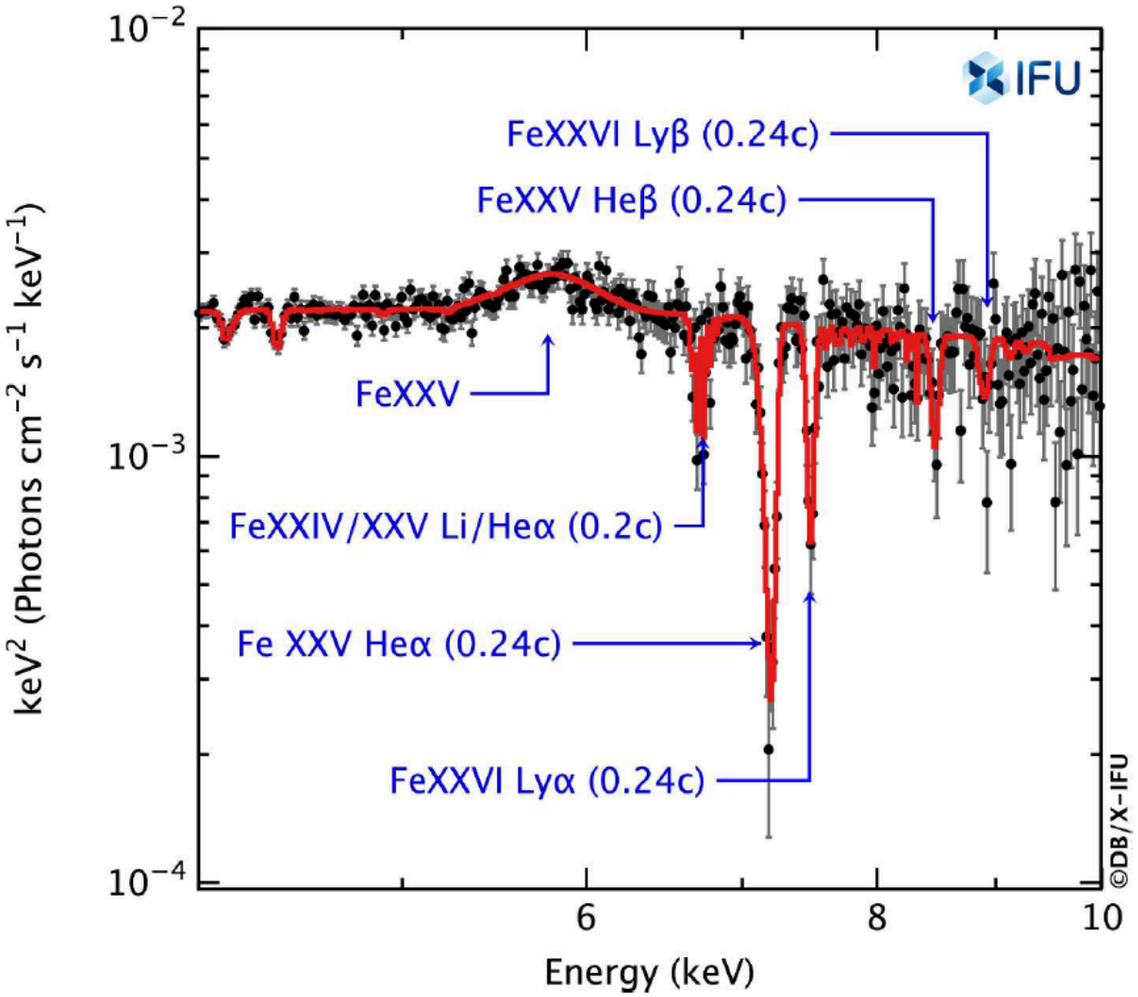
ATHENA REVOLUTION

Tombesi+2019, Astro2020 decadal paper; Cappi+2013 Athena SP; Barret & Cappi 2019

Reeves+2018





The accretion disc scale is unresolved (would need <<mas spatial resolution)
UFOs velocity will be characterised with errors of few km/s (!!)
Athena will map the stratification and complexity of the accretion disc wind
(see also Serafinelli+2019)

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Marcella Brusa
"EWASS SS31", Lyon, 28 June 2019

MAIN LIMITATIONS OF CURRENT STUDIES

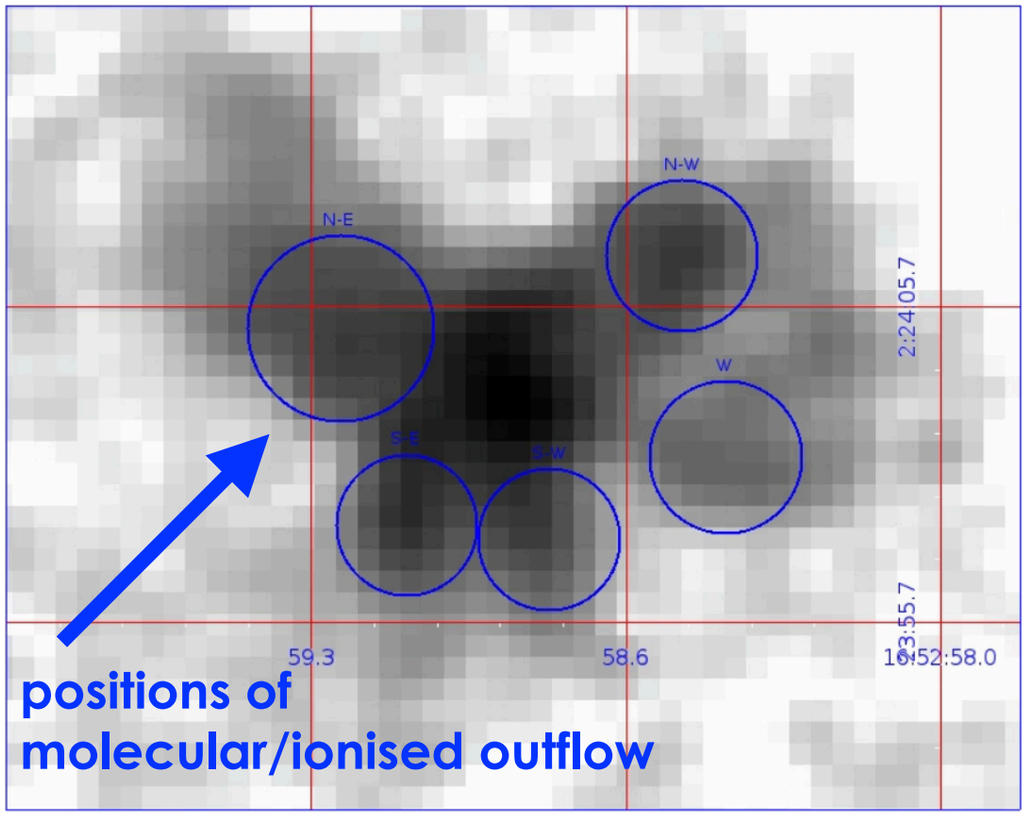
Hot component of QSO winds basically not explored

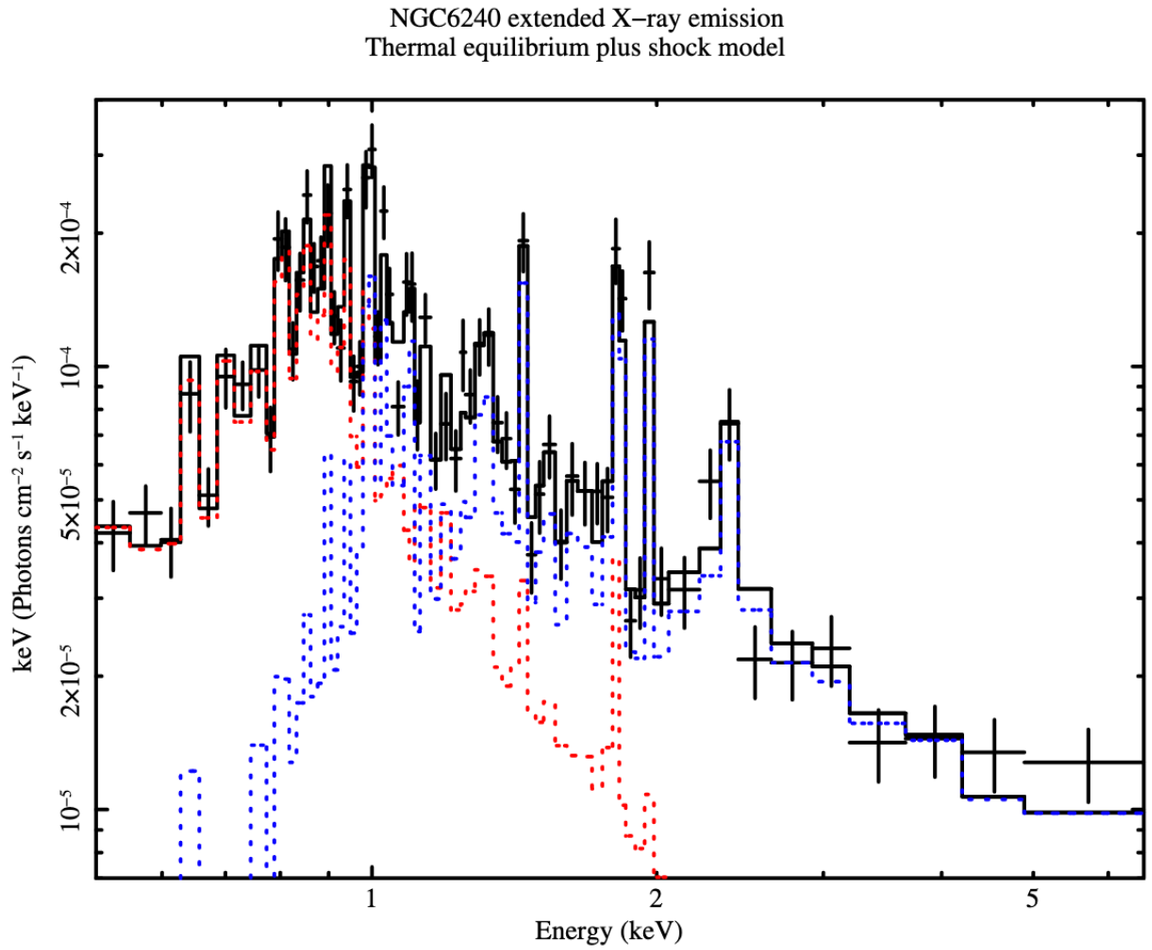
X-ray observations offer a unique window to probe the physical properties and state of the ISM (e.g. presence of shocks)

Provide a direct/independent constraint on the outflow energy + halo heating *(see Roberto's talk, Barret+19)*

Need high spectral and spatial resolution

Feruglio+2013, NGC6240





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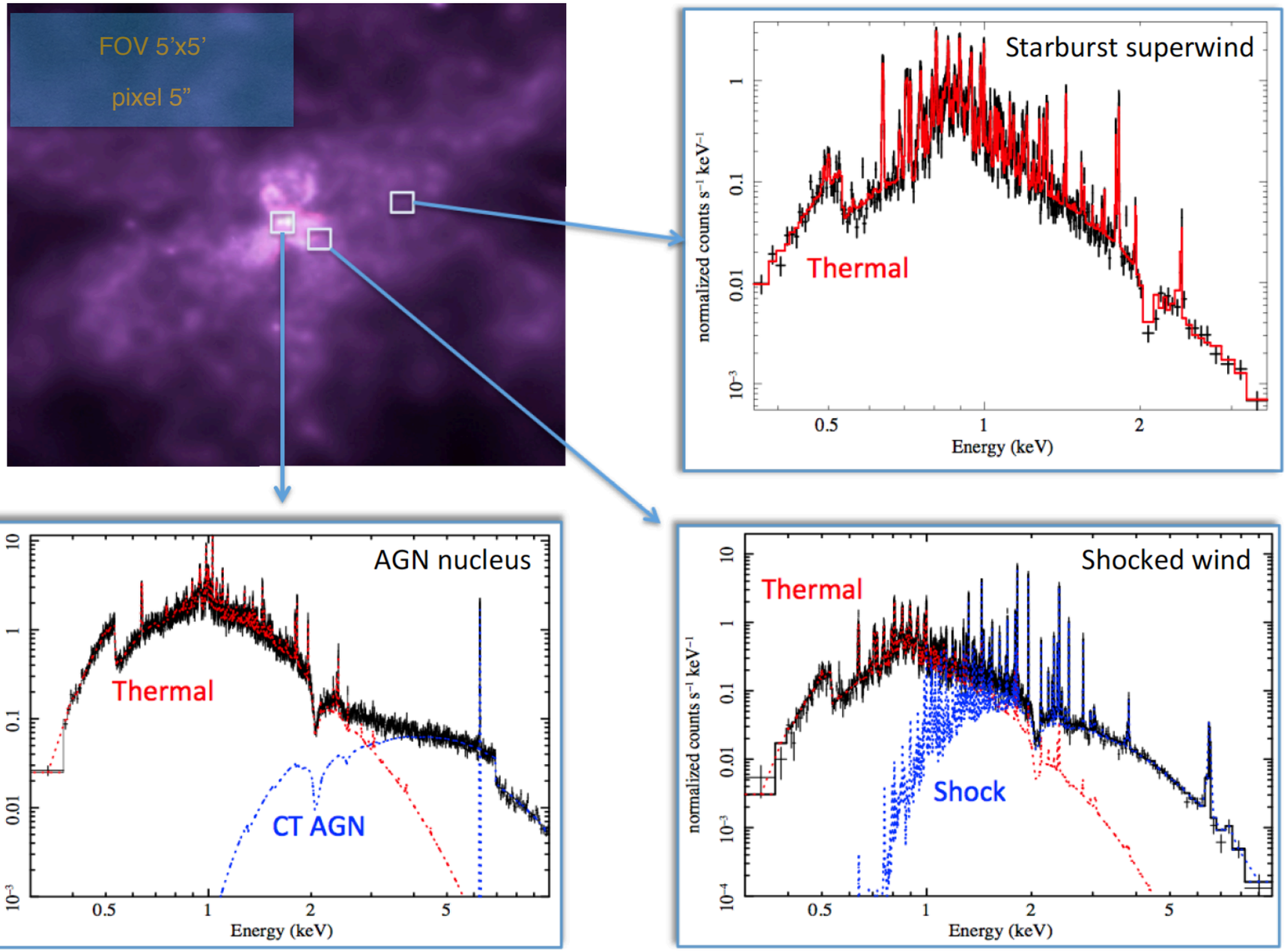
ATHENA REVOLUTION

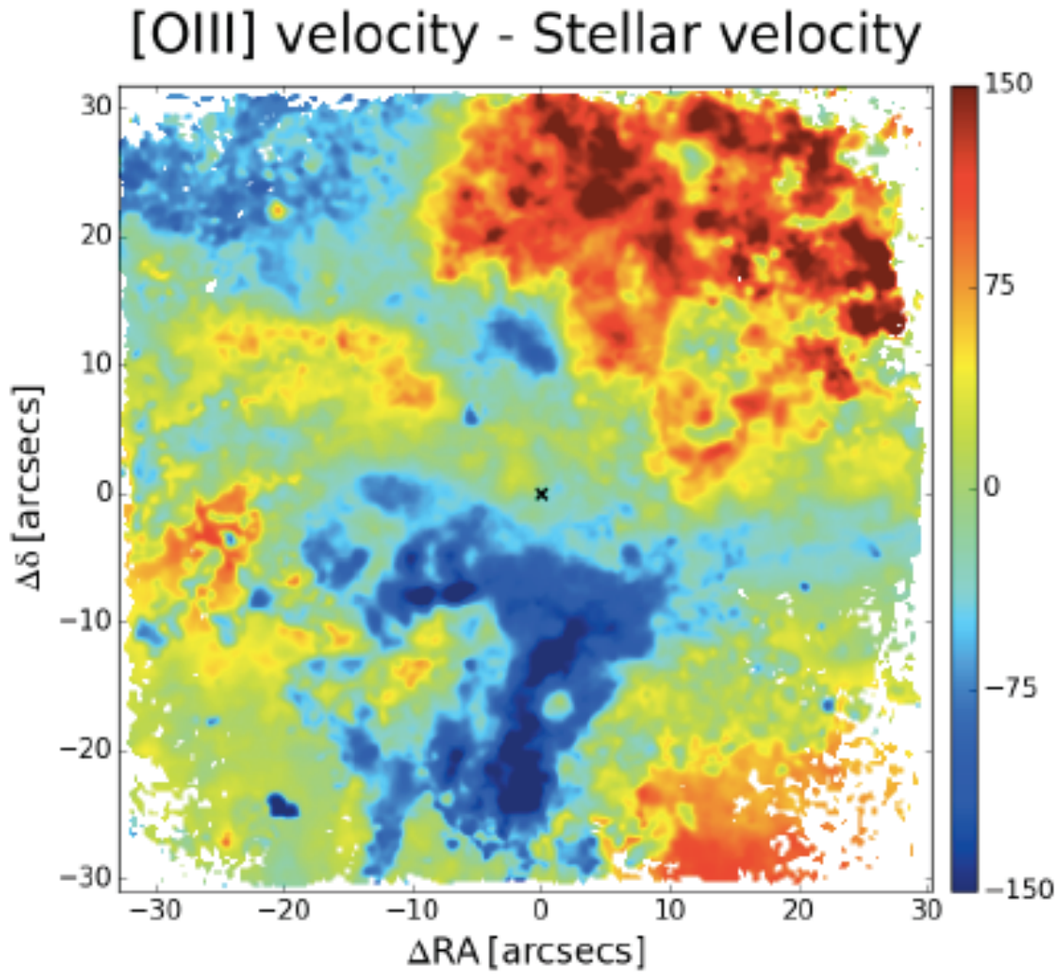
Cappi+2013 Athena SP

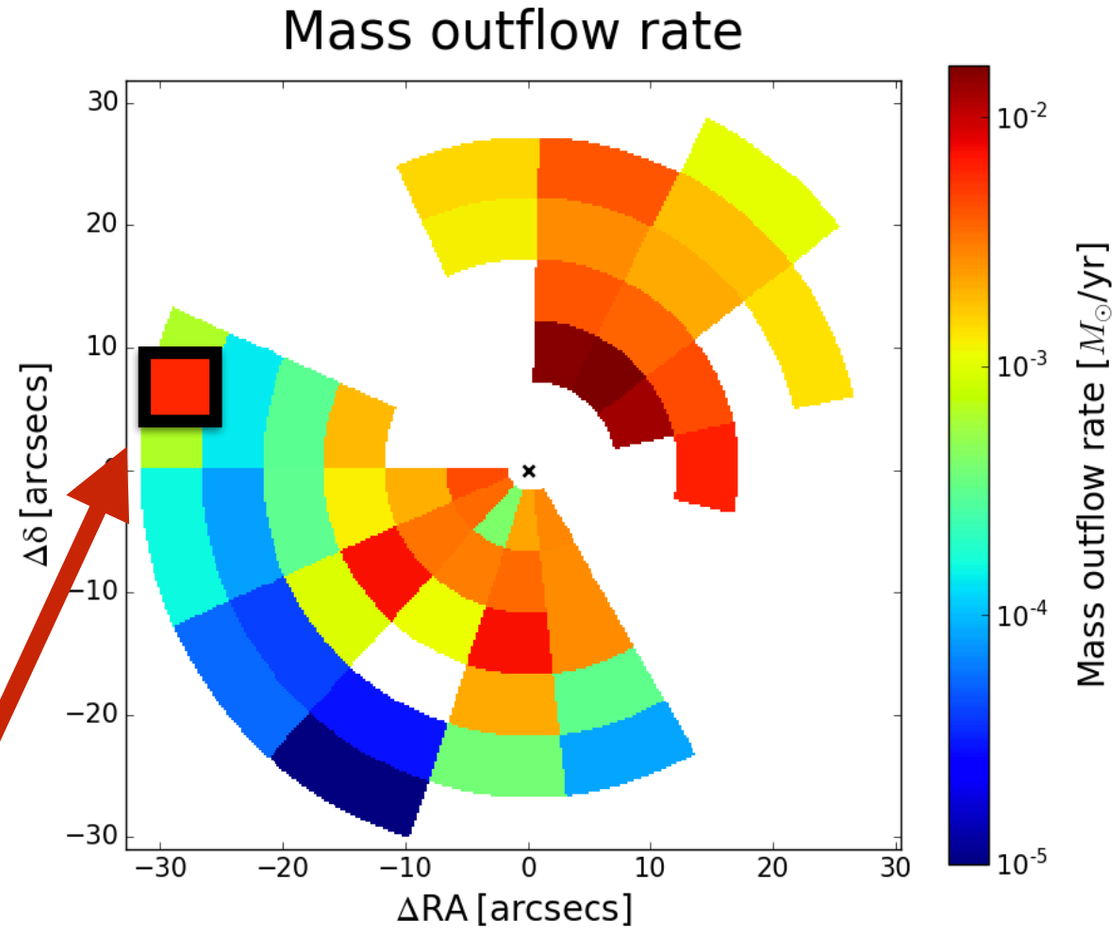


Importance of high resolution at hard energies

ATHENA REVOLUTION

NGC1365 (Venturi+2018)





XIFU Pixel

shocks can be mapped and spatially resolved in local AGN

Relation between hot gas properties/shocks and wind properties can shed light on the origin of the multi-phase structure and constrain models

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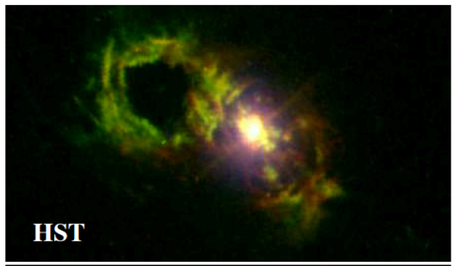
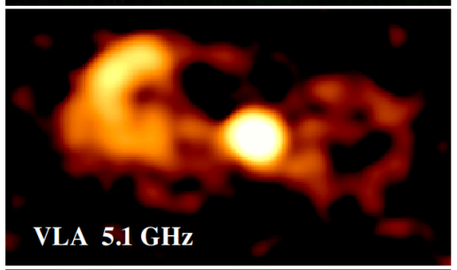
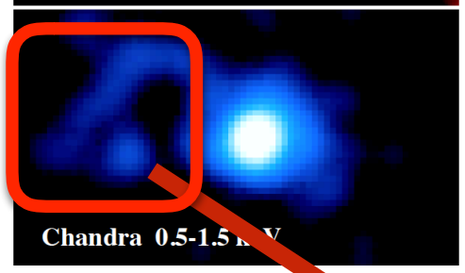
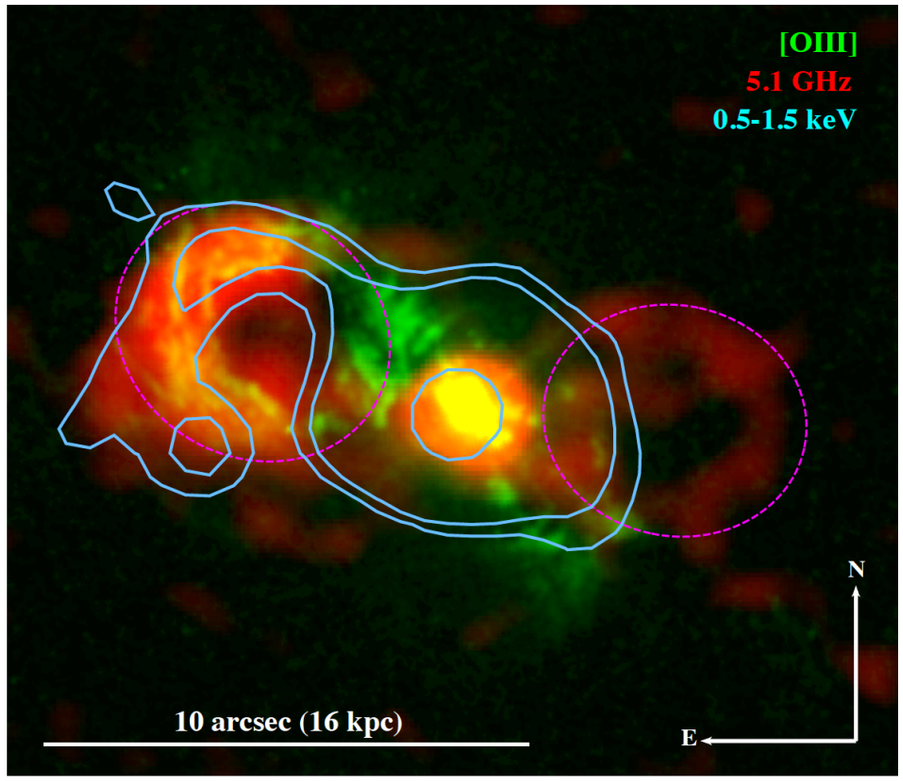
ATHENA REVOLUTION

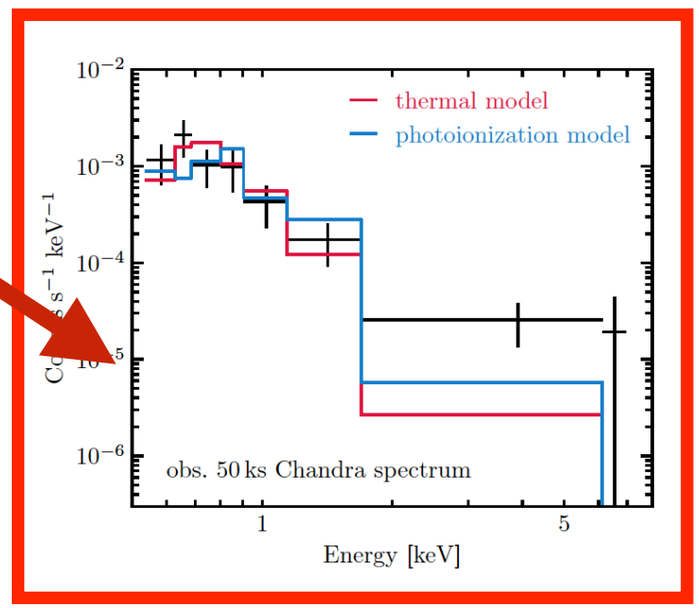
Teacup (Harrison+2015, Lansbury+2018)



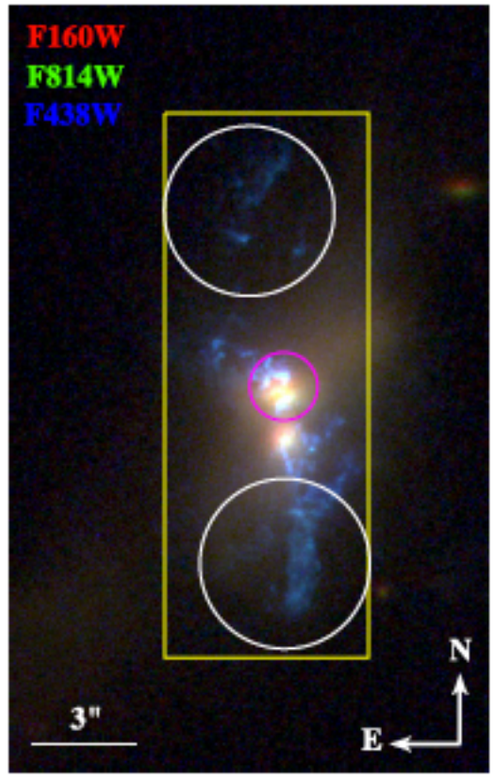


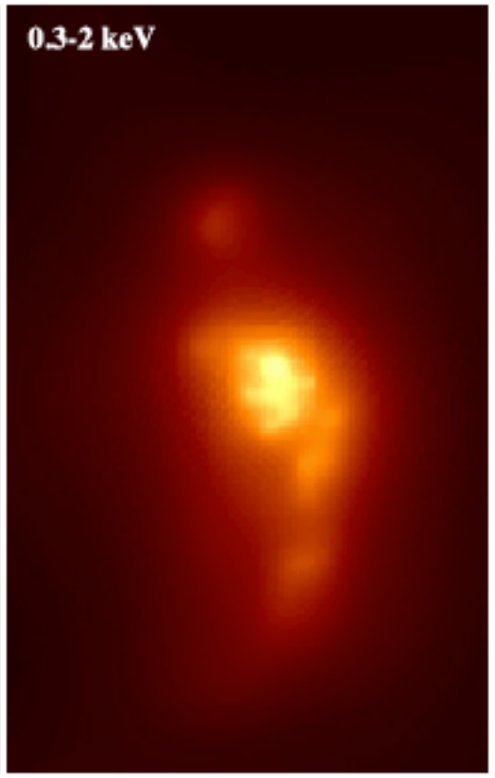






SDSS1356 (Greene+2014)





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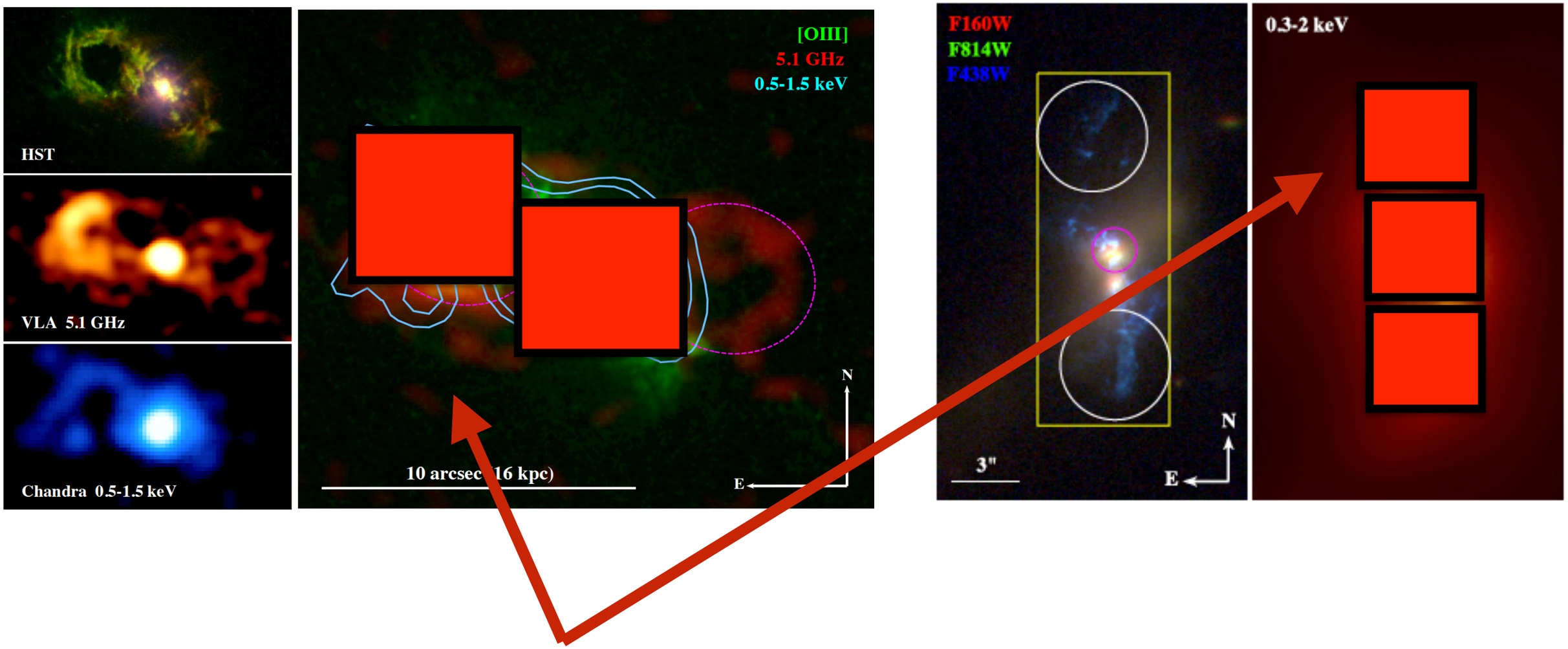

XIFU Pixel

shocks can be mapped and spatially resolved up to z~0.2

Relation between hot gas properties/shocks and wind properties can shed light on the origin of the multi-phase structure and constrain models

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MAIN LIMITATIONS OF CURRENT STUDIES

Detailed characterisation of single objects

outflows have been studied in great details but this has been limited to single objects and few phases (both at low-z and high-z)

low-z

Nardini+15/Bischetti+19 (PDS456)
Feruglio+10,15 Mrk231)
Longinotti+18 (IRAS17020)
Tombesi+15 (IRASF1119)
Greene+12/Sun+14 (SDSS1356)
Tadhunter+15 (IC 5063)

Serafinelli+19 (PG1114+445)
Feruglio+19 (ESO 428-014)
Perna+19 (Mrk 848)
Ramos Almeida+19 (J1509+0434)
+ MR2251, PG1126 (PI: Cresci),
Circinus, NGC1068, MCG-03-58-007…

high-z

Chartas+2003/Feruglio+2017 (APM0279)
Brusa+2018 (XID2028)
Herrera-Camus+2018 (zC400528)
Vayner+2017 (3C298)
Carniani+2017 (2QZ J0028)
+ SINFONI, ALMA (PI: Cresci, Chartas)

The 2030s will witness a revolution in this field
multi-phase outflows will be routinely studied in thousands of sources

Our understanding of SMBH energy-ISM coupling may change dramatically

Key role of Athena / XIFU

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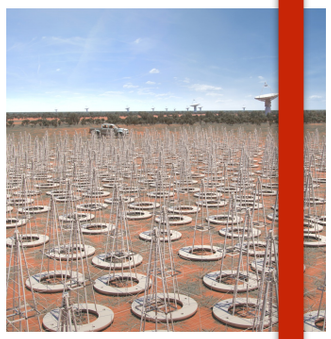
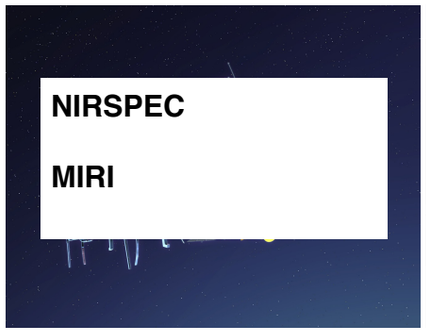
Athena in the framework of the 2030s

SKA

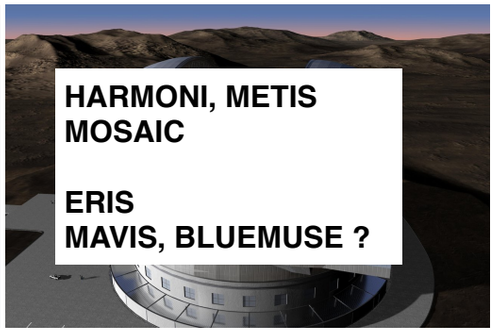


ALMA

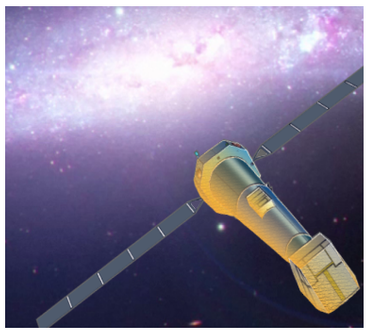
JWST



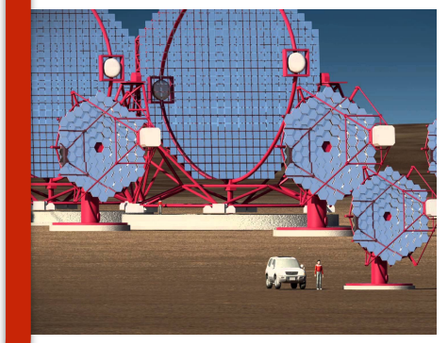
VLT/ELT

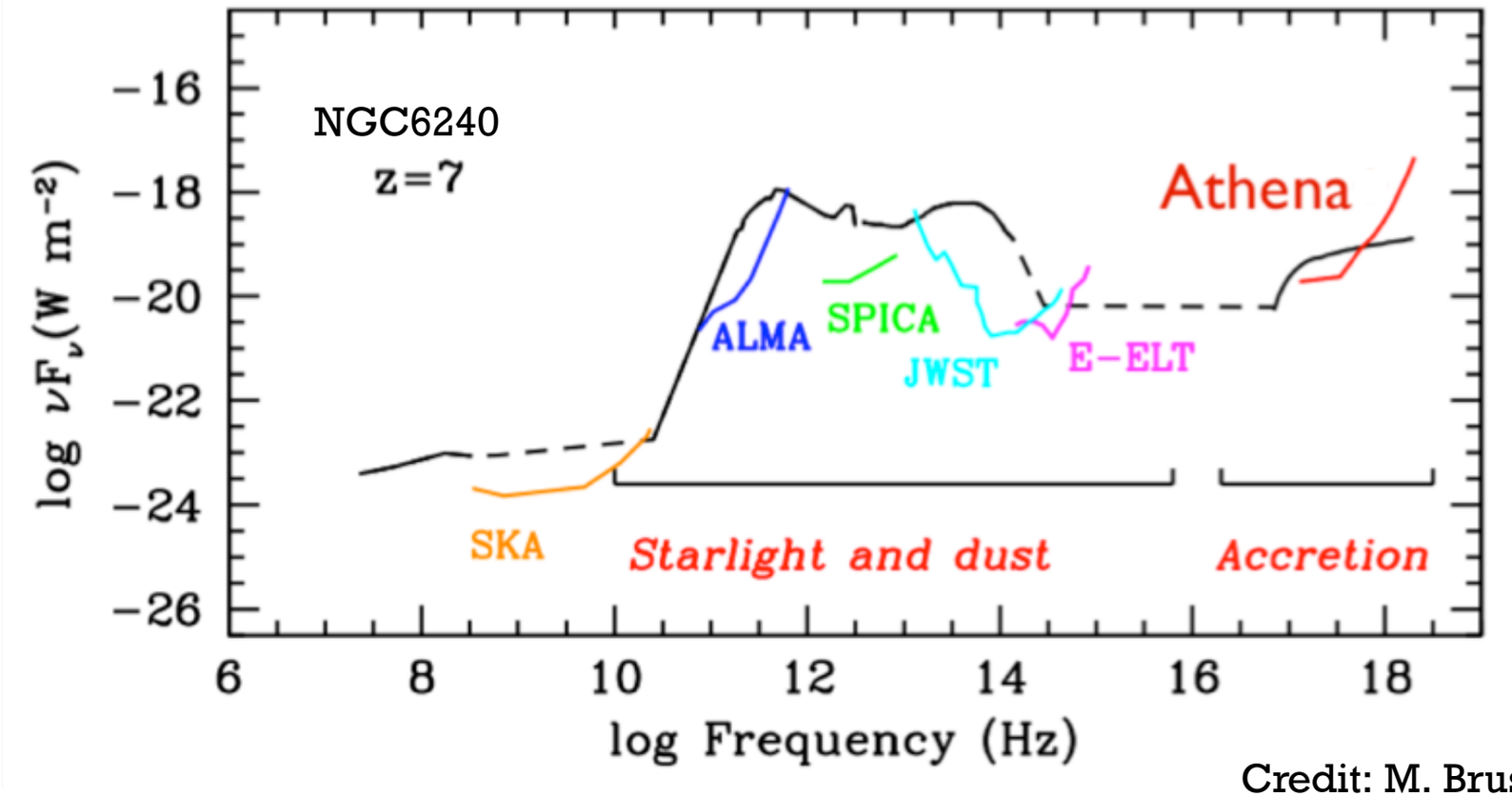


Athena



CTA





Athena XIFU will bring <u>spatial (5")</u> and <u>spectral (2 eV)</u> resolution <u>simultaneously</u>

Credit: M. Brusa & Athena team

SUMMARY

Ultra Fast Outflows:

—> key *observables* to constrain AGN feedback models but…

- ⋆ duty cycle/energetics vs. AGN properties (e.g. L_{Edd}) unexplored for sources with L~L*
- ⋆ relation between larger scale (molecular/ionised) outflows to be explored on *statistical samples*

Athena will revolutionise this field (in ~12+ years)

—> at z~0: factor of 10 lower and unique energy resolution (X-IFU)

—> extend up to z~3-4 (WFI survey + X-IFU pointings)

***Natural* Synergies with longer wavelengths facilities in the 2020-2030 landscape**

—> X-ray detected UFOs primary targets for ALMA & NOEMA (molecular gas)
this already happened with APM08279, PDS456, IRASF1119, Mrk231…
from z=0 to z=3+

—> X-ray detected UFOs primary targets for VLT, E-ELT and JWST IFUs
(ionised and warm molecular gas)

—> AGN/QSOs with molecular/ionised outflows primary targets for Athena (XIFU)

—> Hot components of QSO winds to be explored from scratch (XIFU)

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