Outflowing winds of Active Galactic Nuclei

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MSSL

Thanks to:

Graziella Branduardi-Raymont, Mat Page, Missagh Mehdipour, Jelle Kaastra, Ehud Behar, Junjie Mao, Stefano Bianchi, Myrto Symeonidis

Leicester lunch-time talk

10 Dec 2020

Image Credit: Jennifer O’Kane

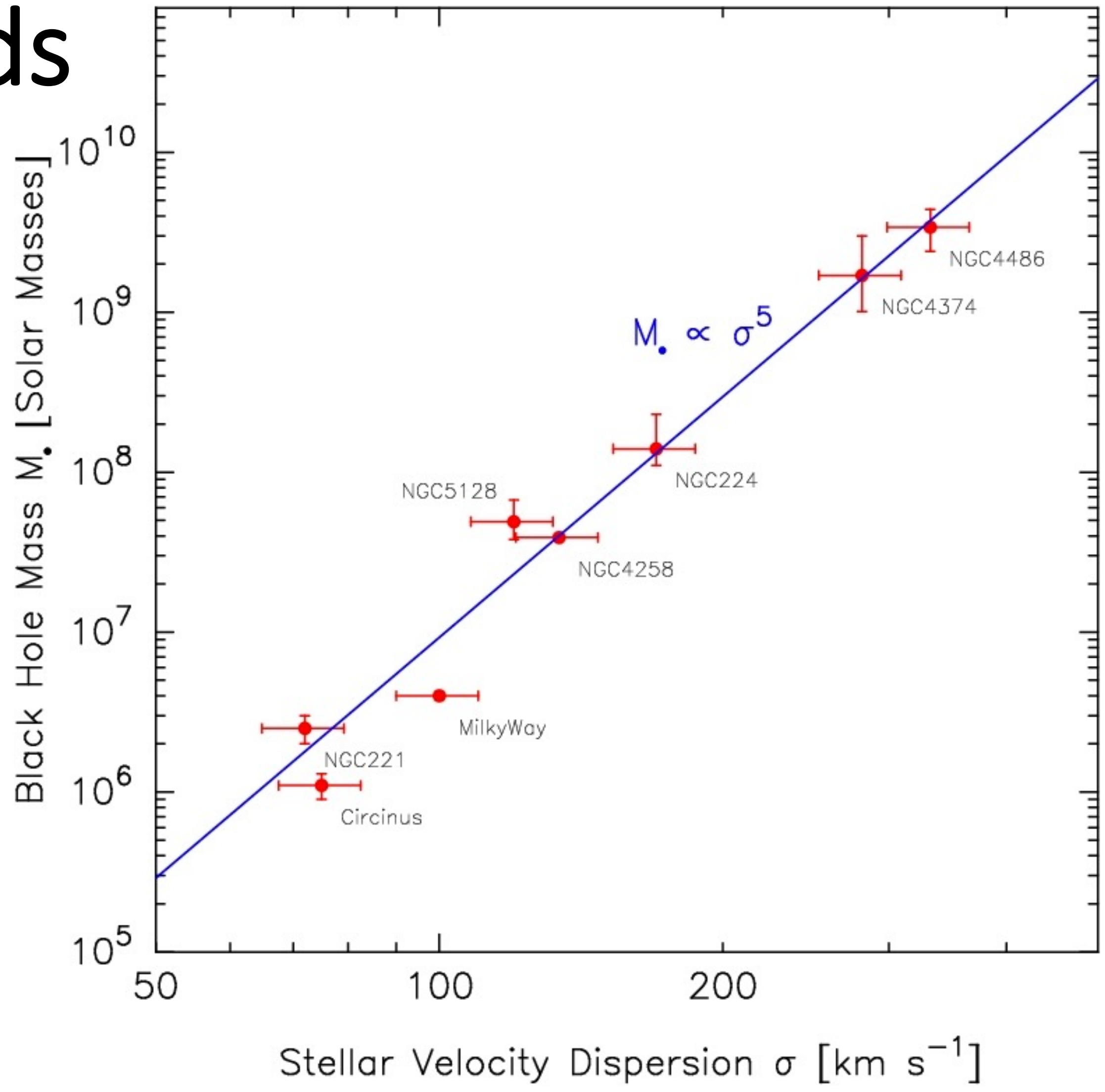
What Are AGN?

- Supermassive black hole at the centre of galaxies
  - $M_{BH} = 10^5 - 10^{10} M_{\odot}$
  - $L_{bol} = 10^{34} - 10^{41} W$
- Powered through the process of accretion
  - Material in the disk heats up as it orbits the black hole,
  - Radiates EM waves
- Process launches material away
- Outflow winds are ionised by the AGN radiation and the signatures are observed in X-ray/UV spectra

Image credit: MIT Kavli Institute for Astrophysics and Space Research

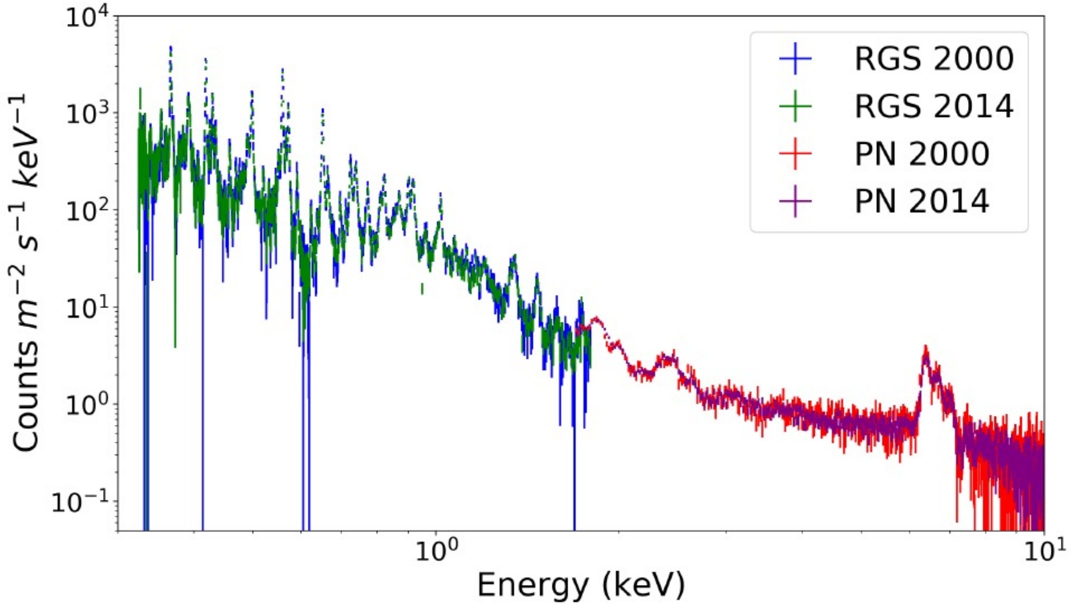
Motivation for studying Winds

- Main questions:
  - Origin of winds
  - Launching Mechanism
  - Location and Geometry
- M-σ relation
  - Galaxy impact
  - Co-evolution



Wikipedia

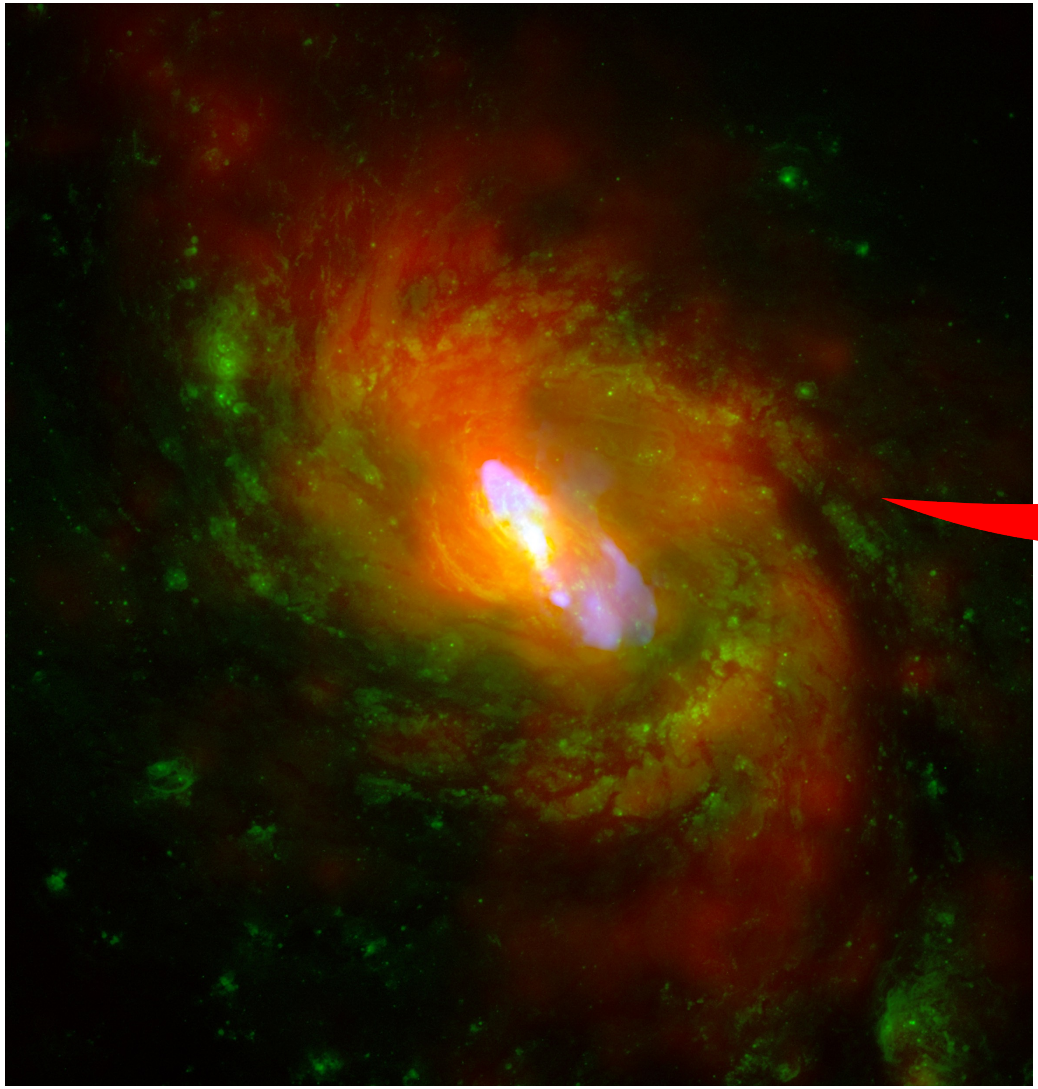
XMM-Newton



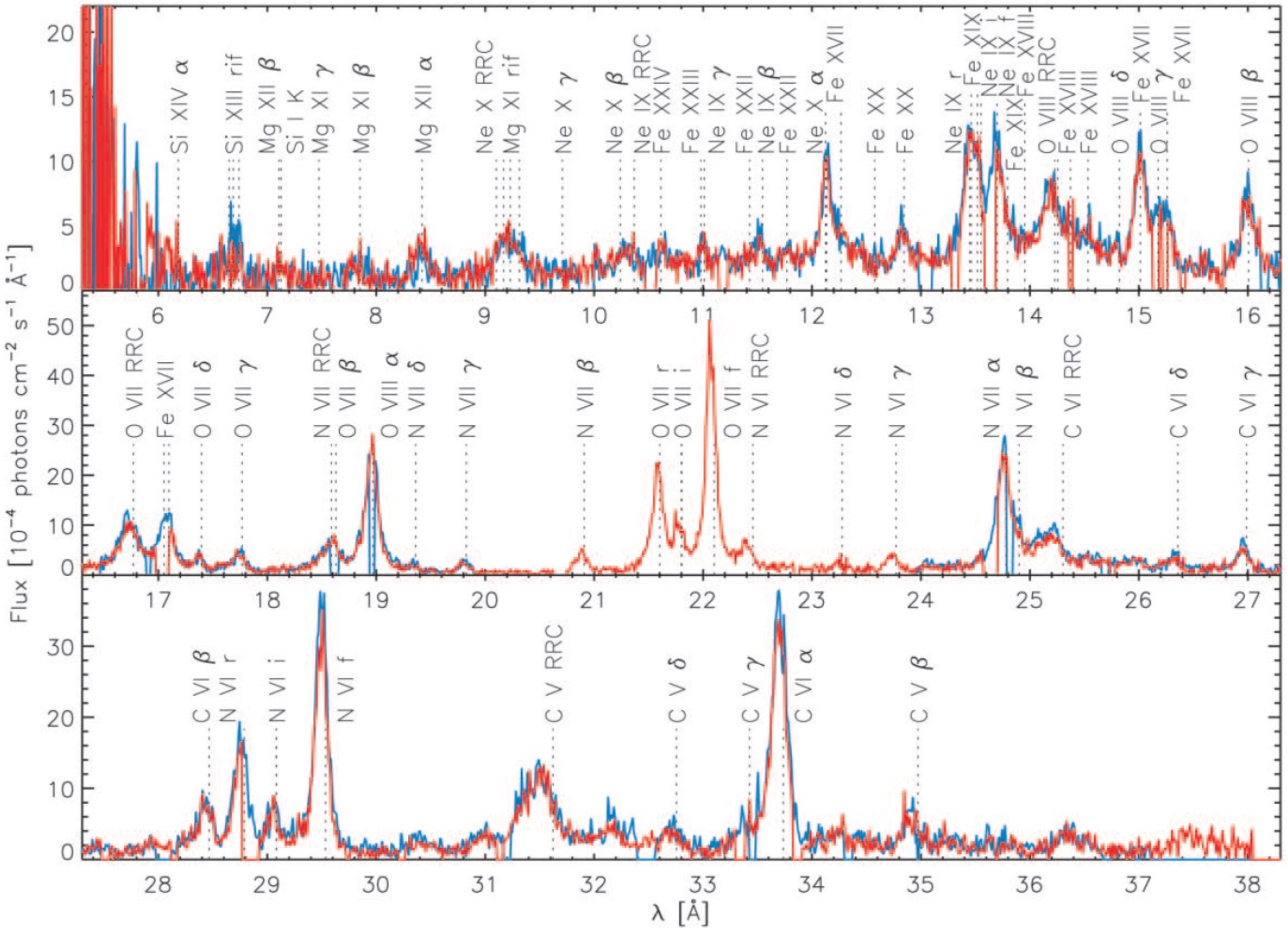
SGW et al. submitted

ESA

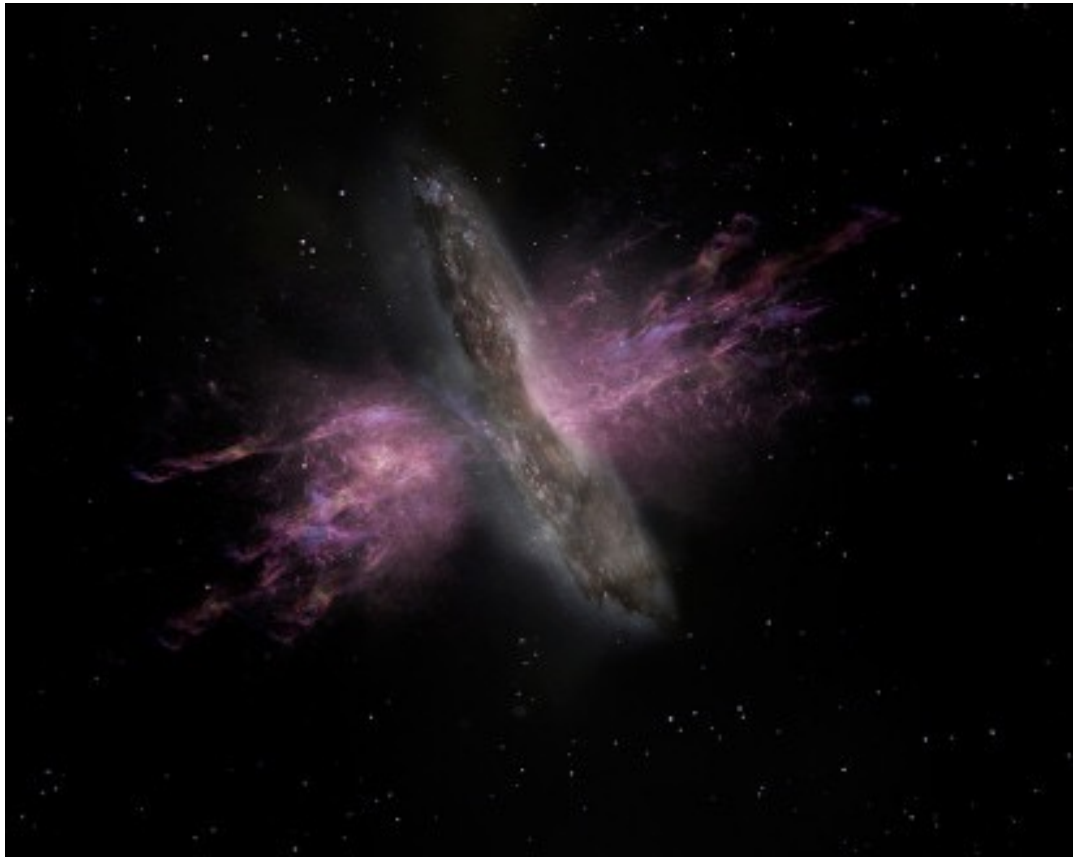
EPIC-pn/mos: 0.3 – 12 keV
RGS: 0.3 – 2.5 keV (6 – 38 A)
OM: UV/optical filters



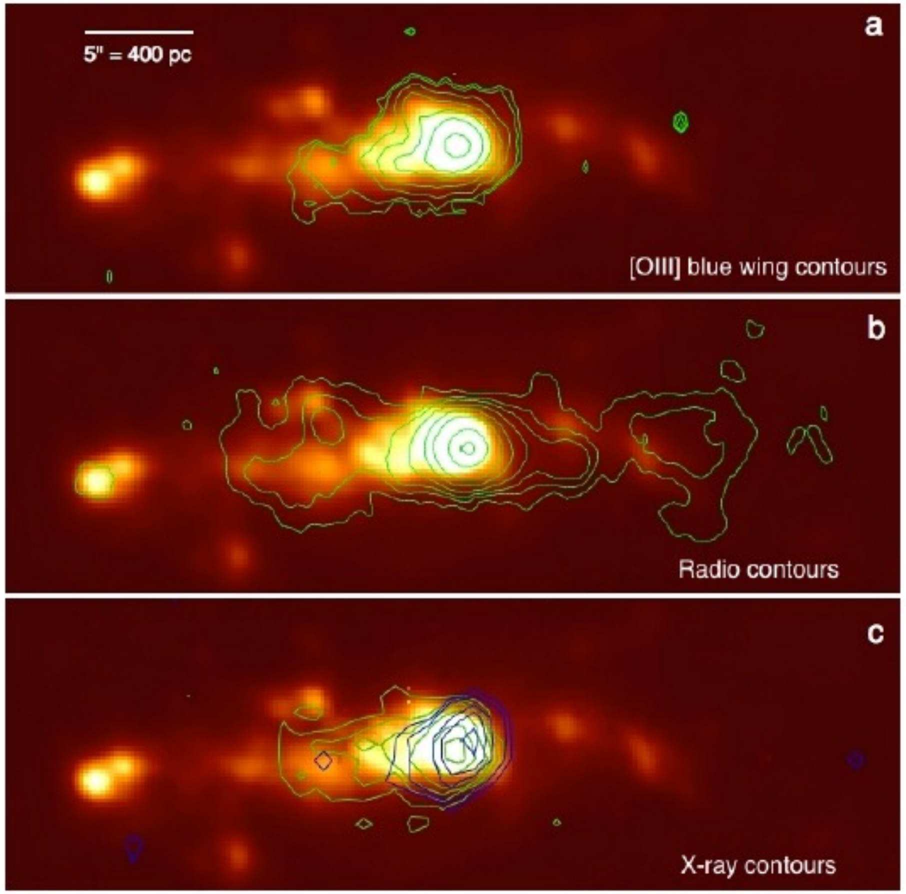
Chandra image of NGC 1068



RGS1 and RGS2 Spectra of NGC 1068 from 2000
Kinkhabwala et al. 2002



ESA

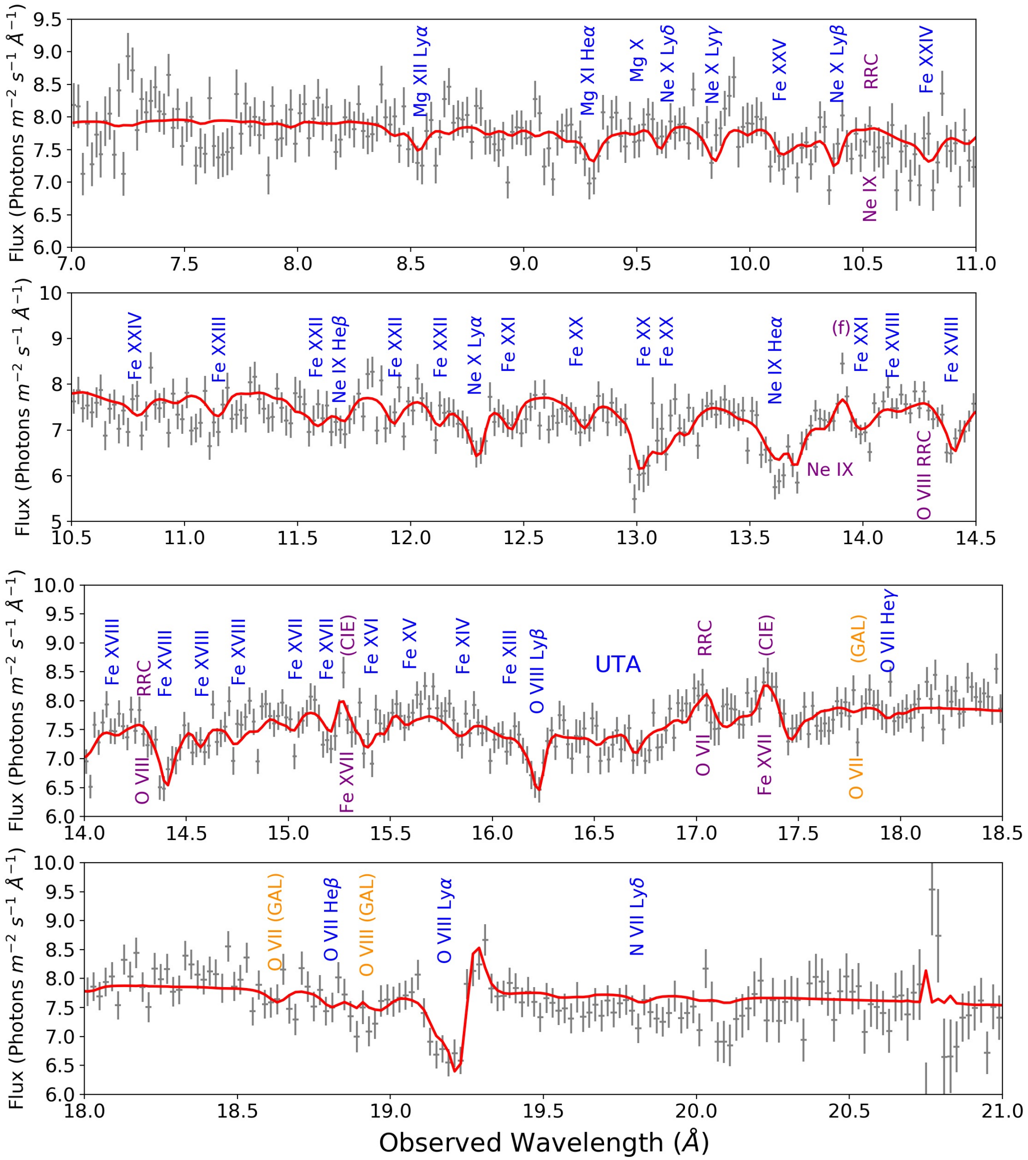


Hα map of NGC 5643
Cresci et al. 2015

Types of Outflowing Wind

1. Warm absorbers

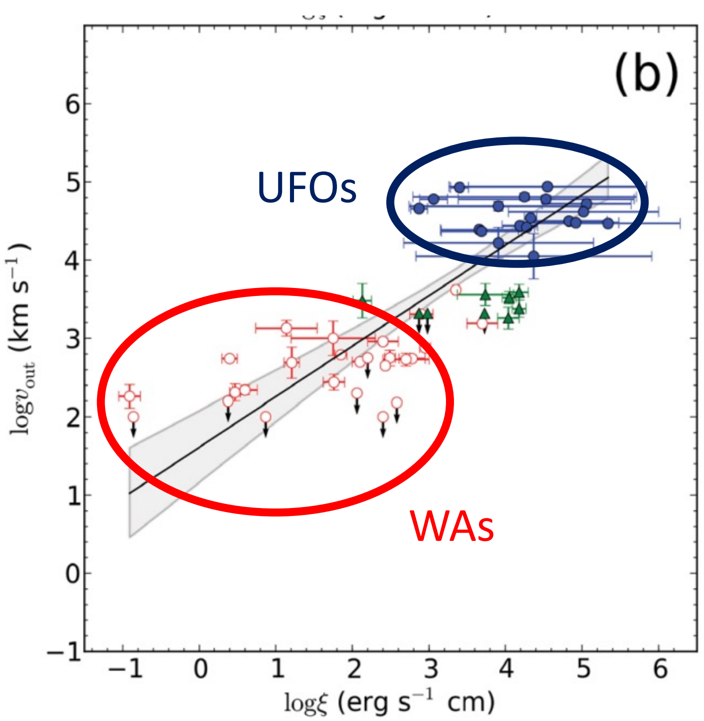
NGC 7469
SGW et al. 2020

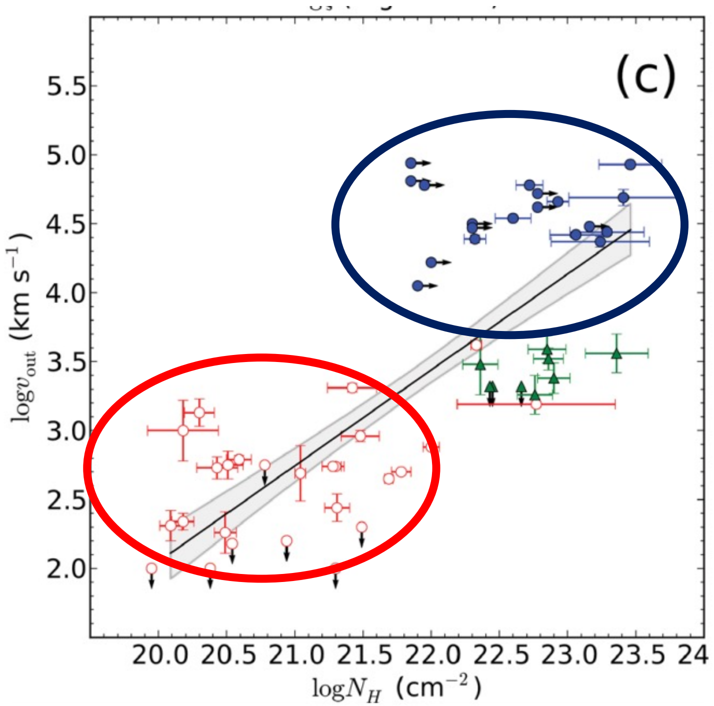


- **Narrow lines**
- **UV and soft X-ray bands**
- **Multiple components**
    - **Range of column density and ionisation state**
- **Outflow velocity > $10^2 – 10^3$ km s^{-1}**
- **Located between torus (origin?) and NLR**

2. UFOs (ultra fast outflows)

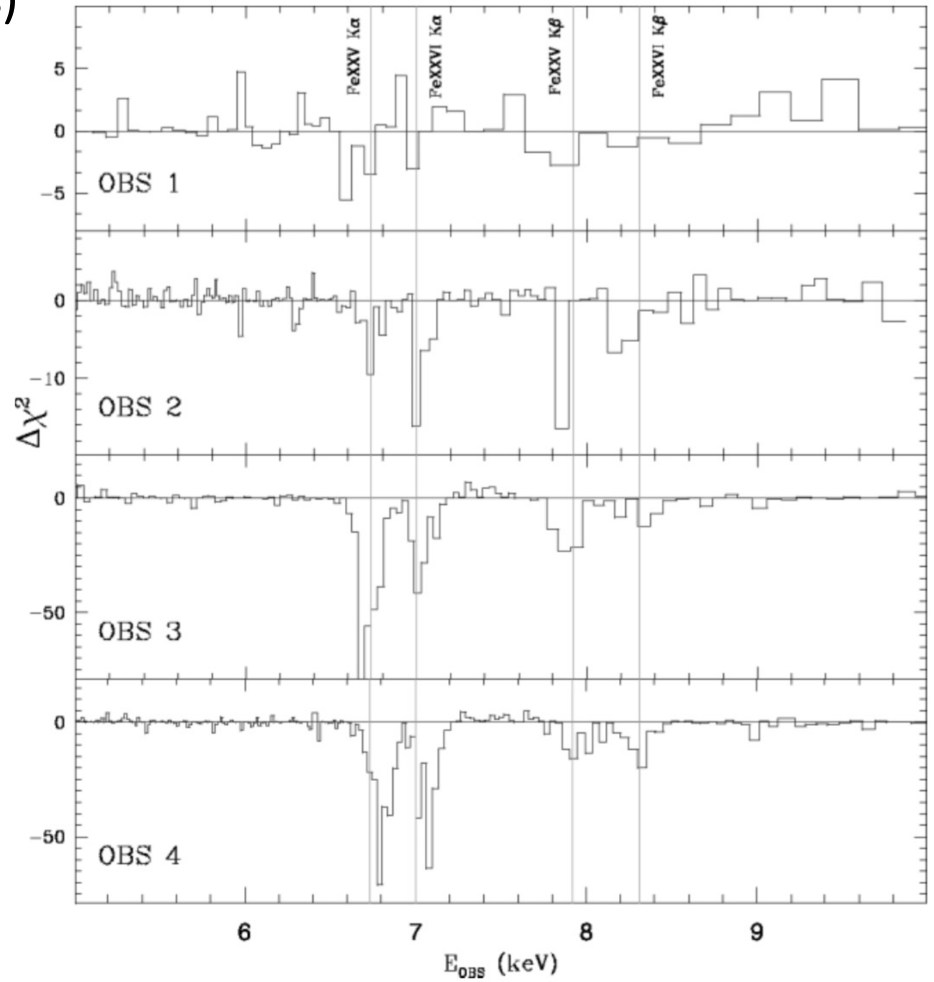
- **Fe XXV and Fe XXVI absorption lines**
- **v_{out} ~ 0.1 – 0.4 c**
- **Originate from the accretion disk**
- **Higher column density and ionisation parameter than the WA**



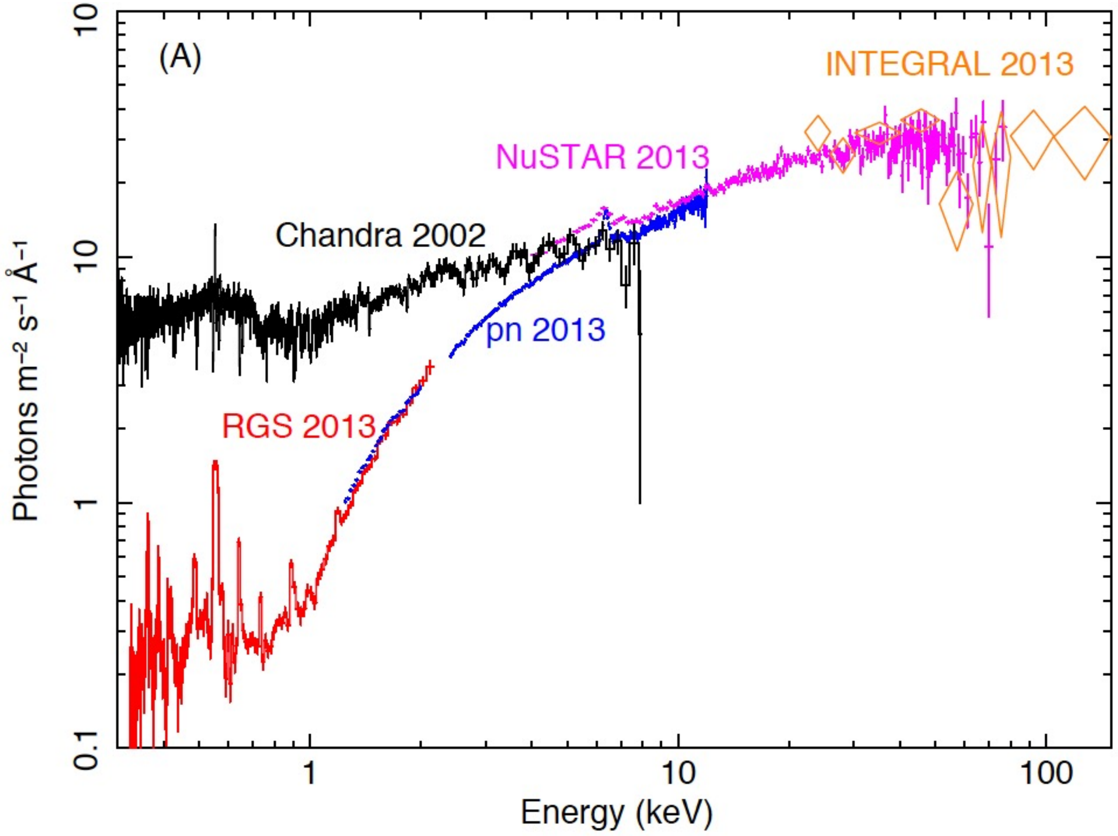


Tombesi et al. 2013

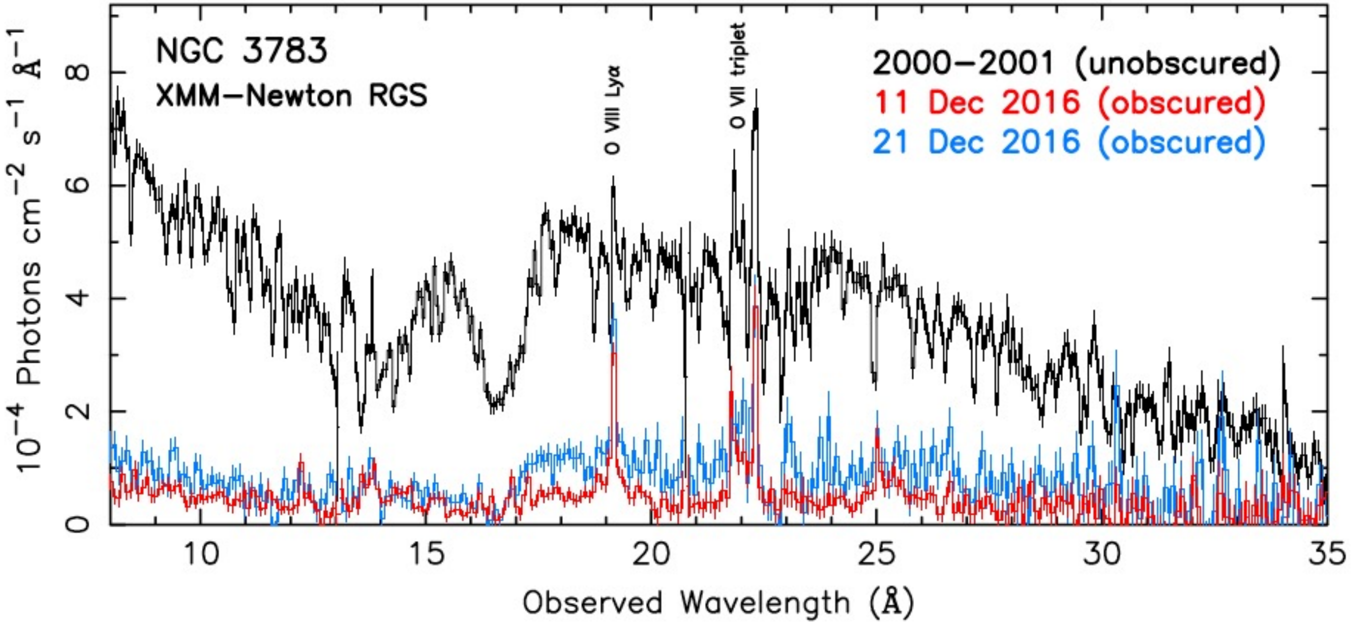
NGC 1365: Risaliti et al. 2005



3. Obscuring Winds

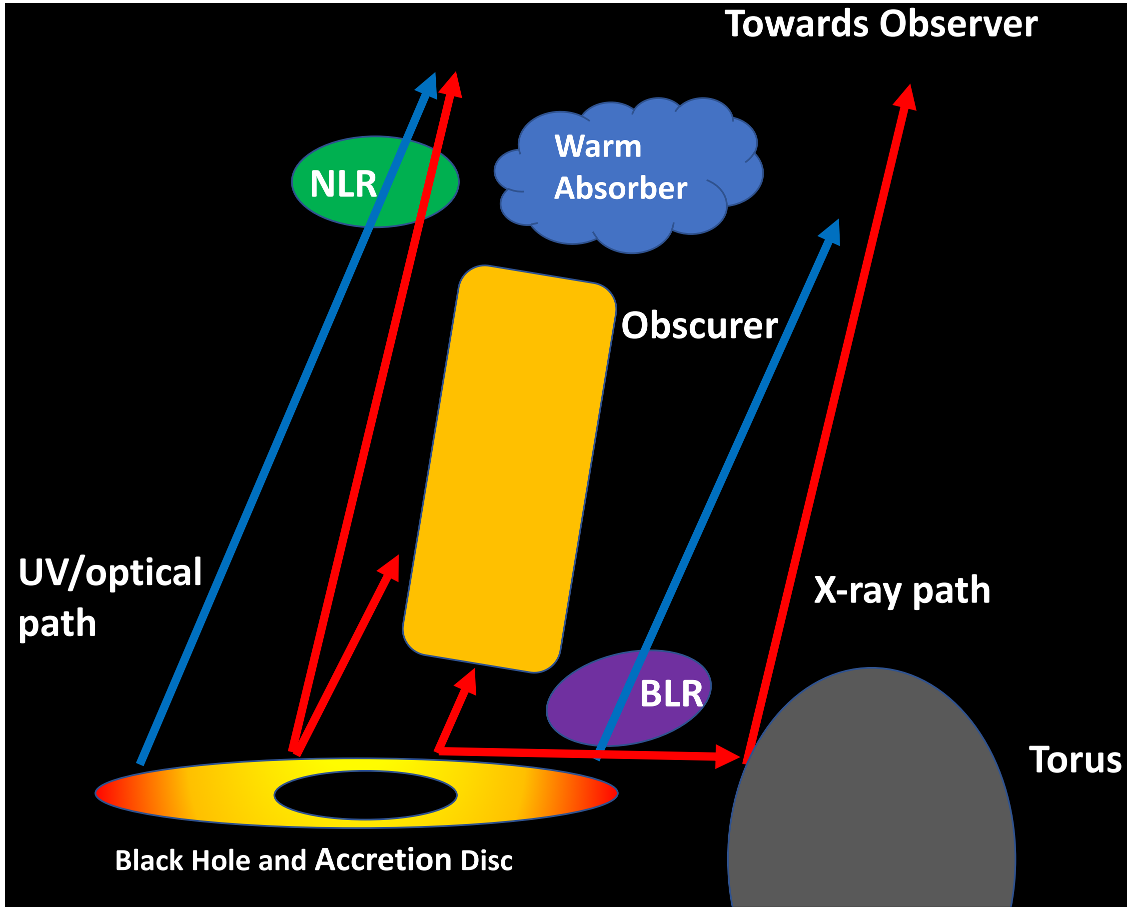


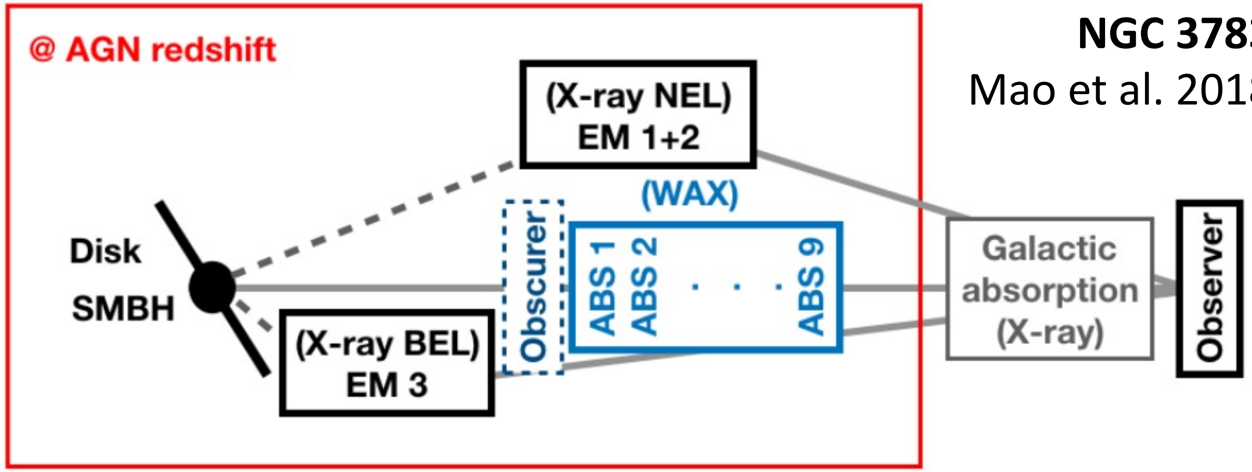
NGC 5548
J. Kaastra et al. 2014



NGC 3783
M. Mehdipour et al. 2017

Comparing Obscurers





NGC 3783
Mao et al. 2018

- **2 components**
- **Covers 40 – 80 % X-ray flux**
- **-1000 to – 5000 km s^{-1}**
- **Distances: few – 10 light days**
- **Duration: NGC 5548 > 8 years; NGC 3783 = 32 days**

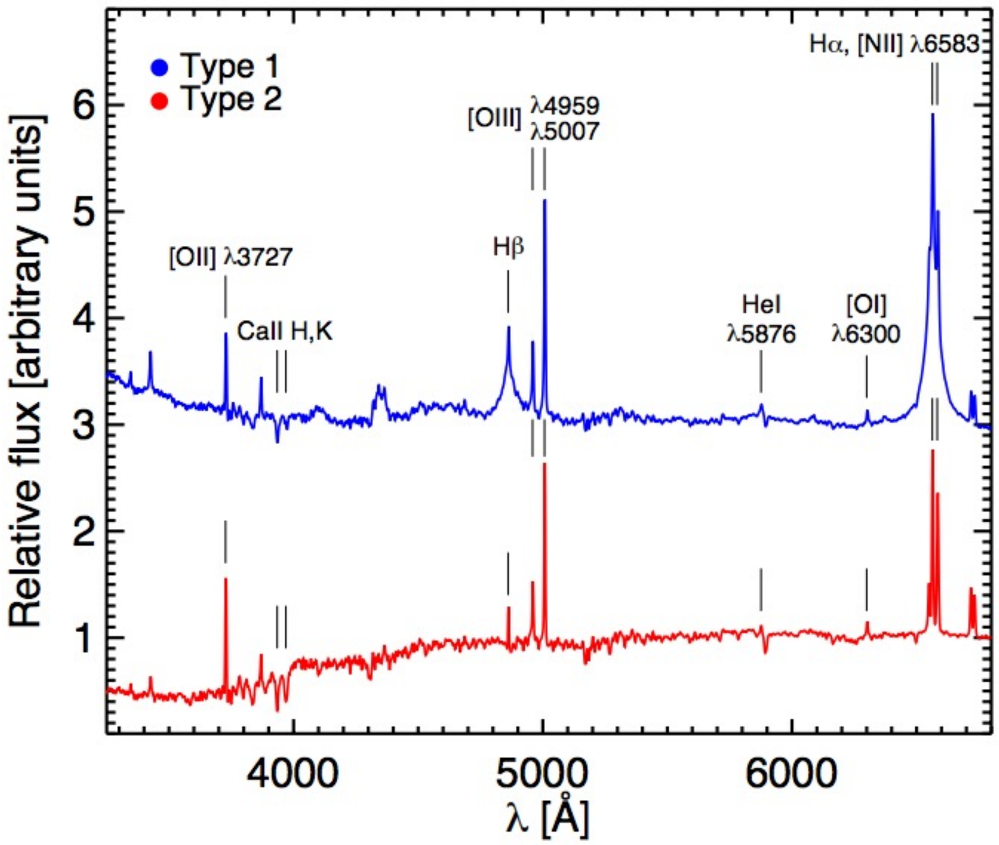
NGC 5548:

- $N_H \sim 12 - 100 \times 10^{25}$ m^{-2}
- $\xi \sim -1.2$ to 0

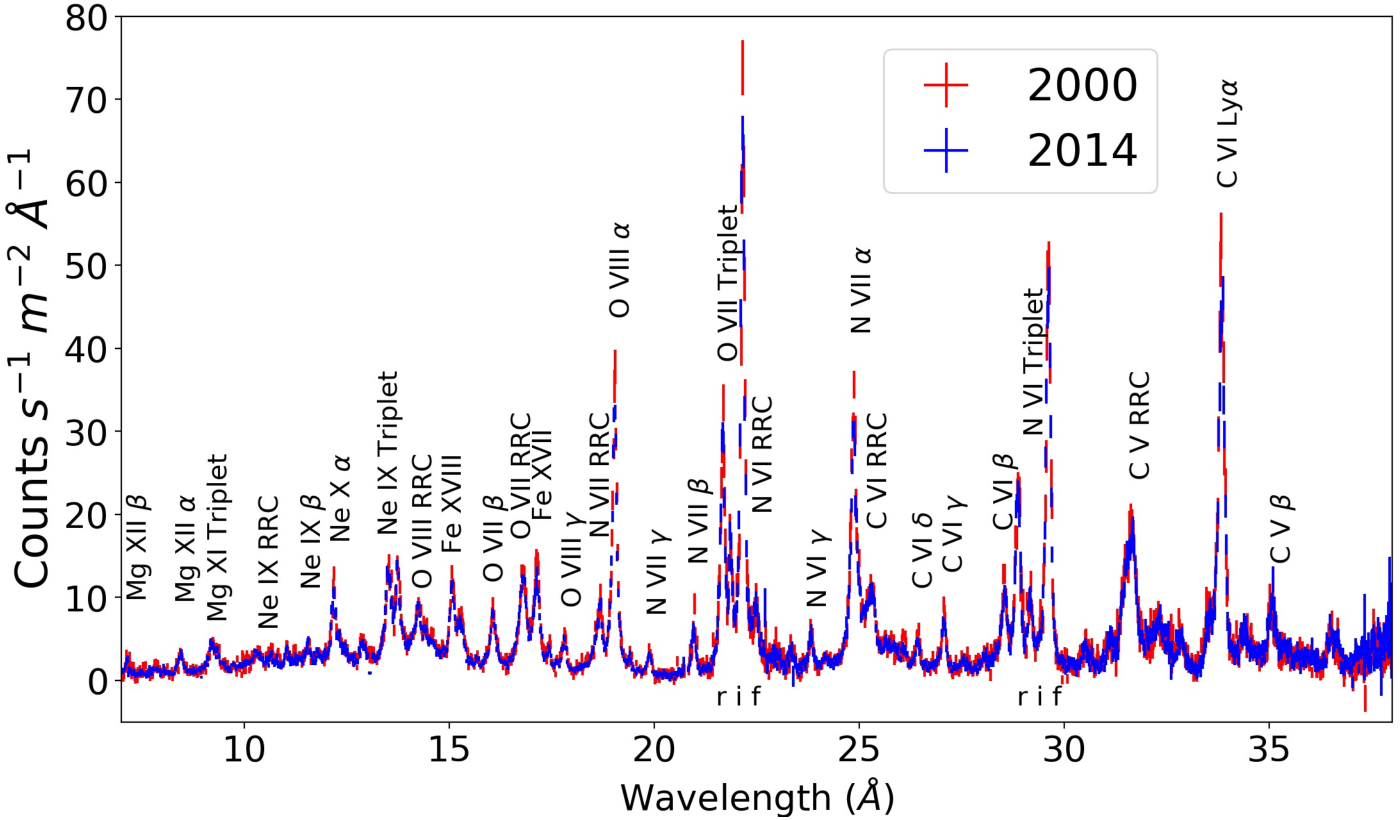
NGC 3783

- $N_H \sim 0.5 - 20 \times 10^{22}$ m^{-2}
- $\xi \sim 1.8$

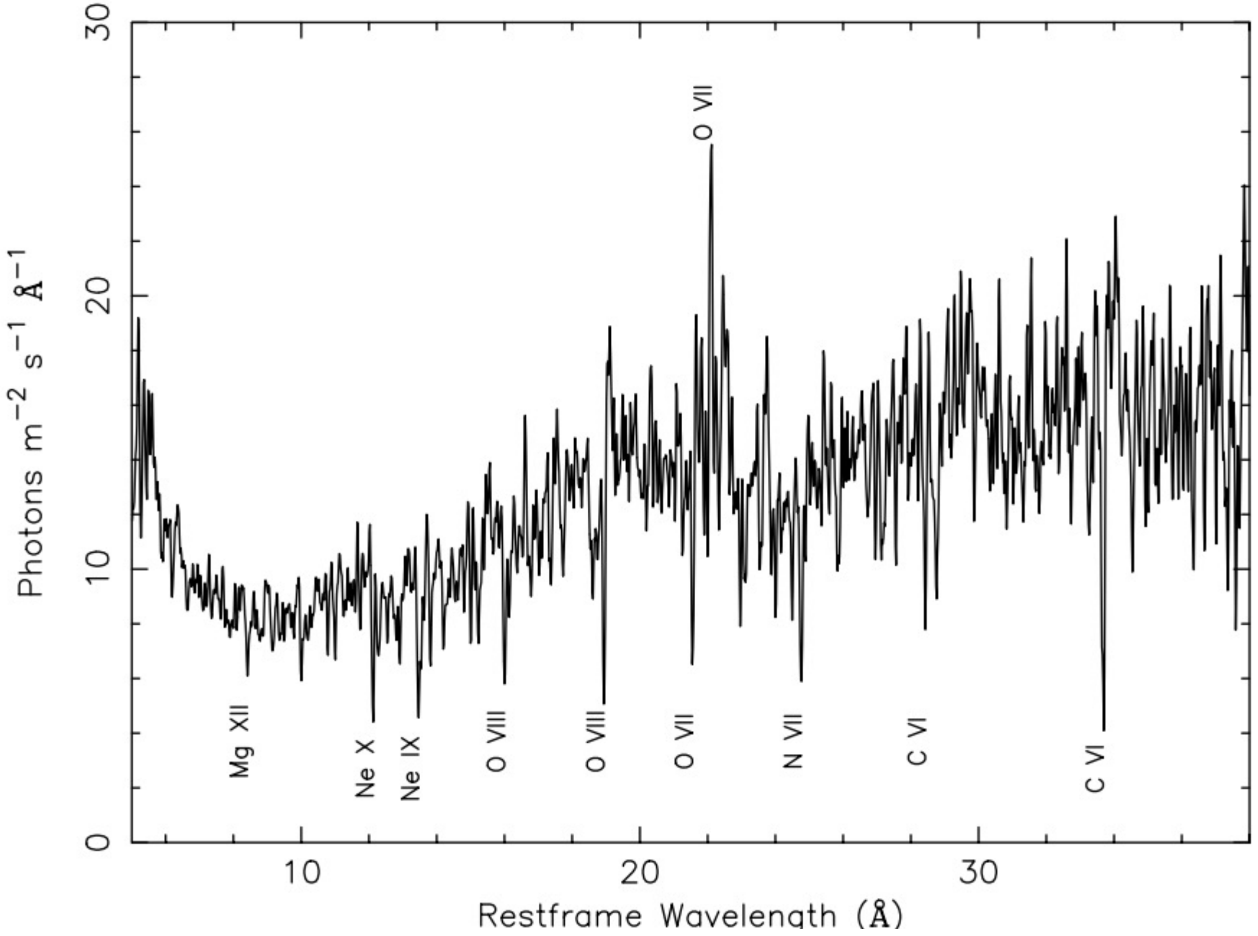
4. Emission Lines Regions



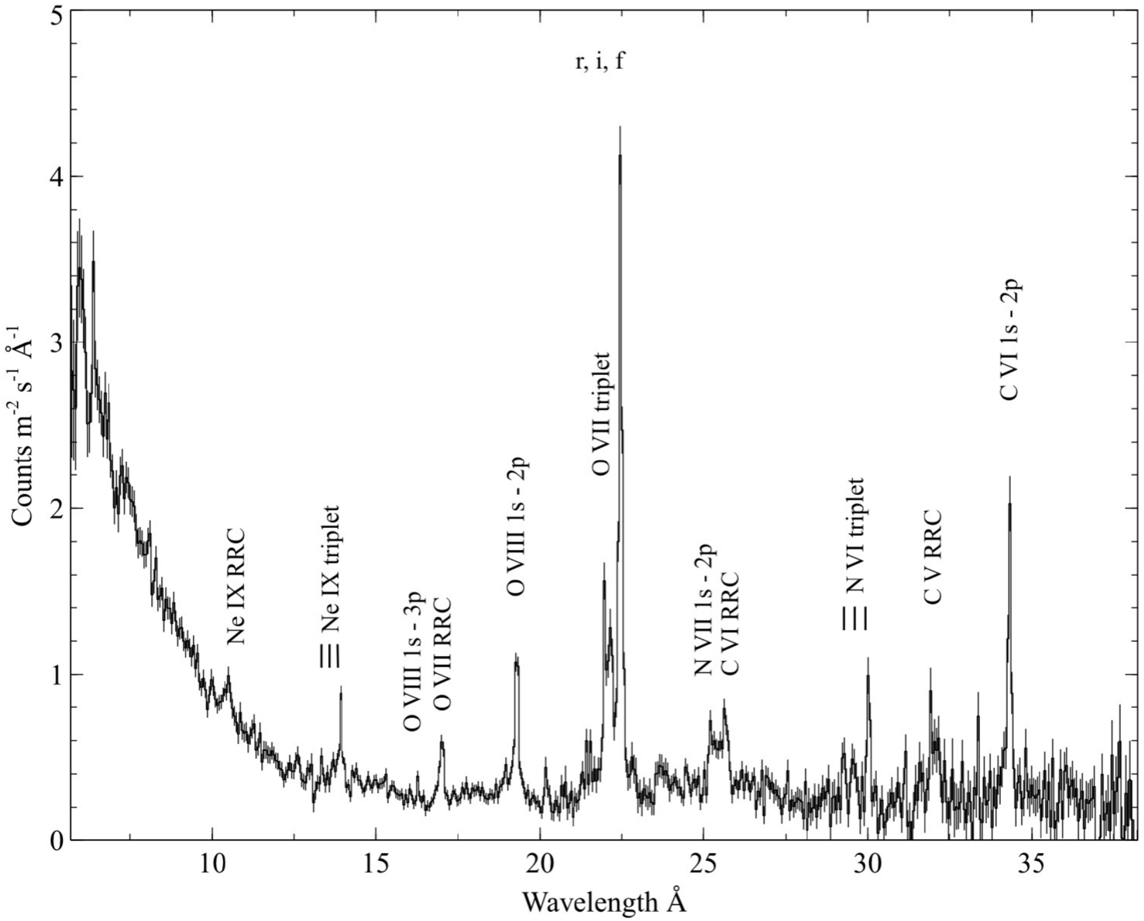
Adapted from DiPompeo et al. 2018
by Hickox & Alexander 2018



RGS Spectrum of **NGC 1068** from 2000 & 2014;
SGW et al. in Review

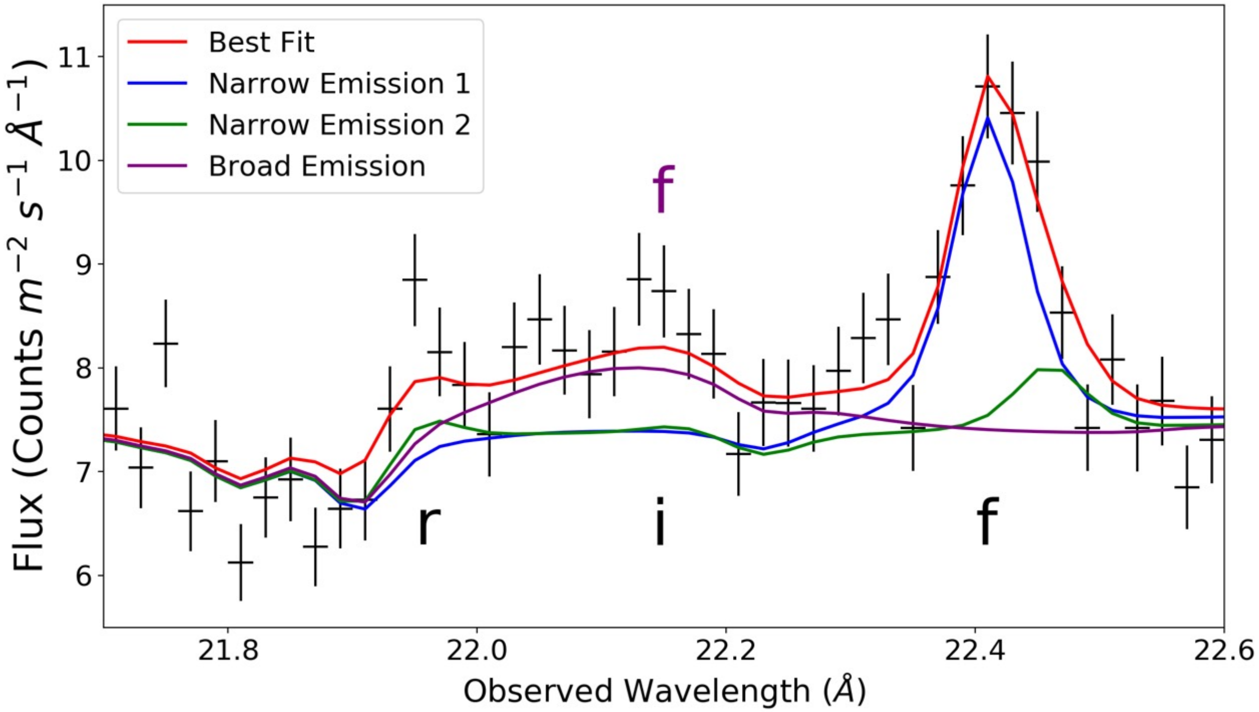


Chandra Spectrum of NGC 5548 in 2000;
J. Kaastra et al 2000



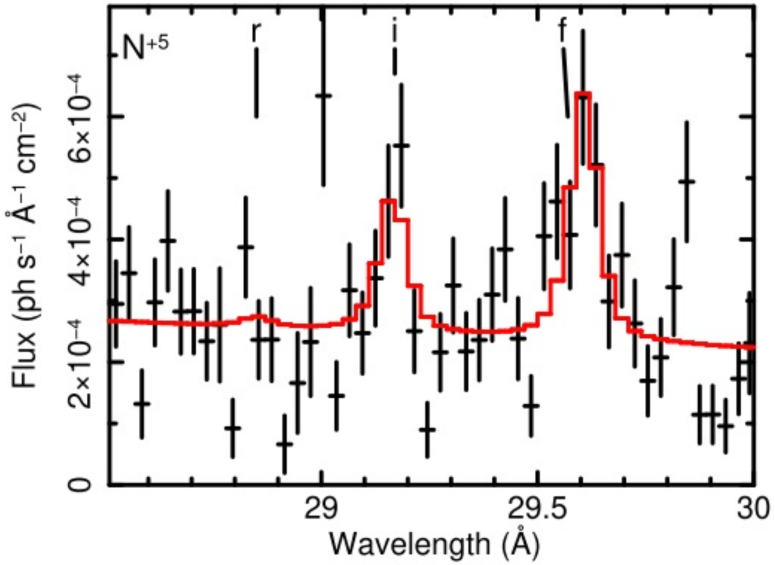
RGS Spectrum of NGC 5548 in 2013;
M. Whewell et al. 2015

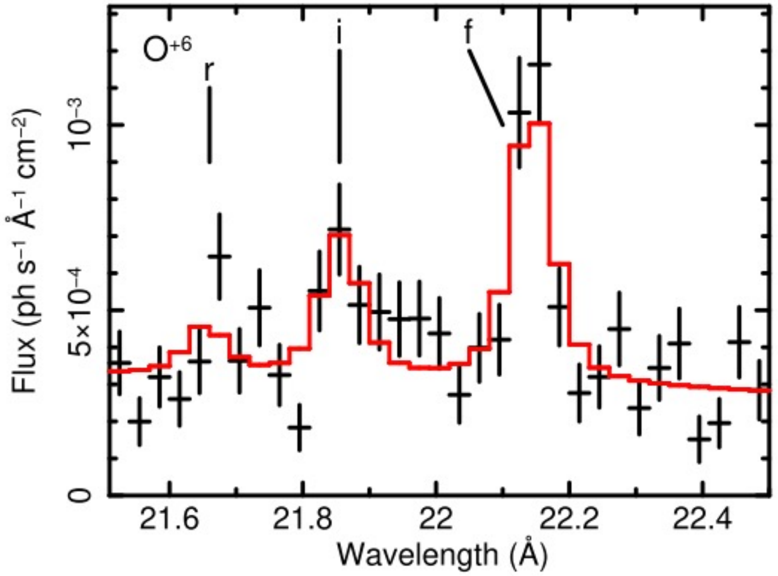
Evidence of Broad Line Emission



NGC 7469
SGW et al.2020

V_{turb} = 1360 km s^{-1}
V_{out} = -4460 km s^{-1}

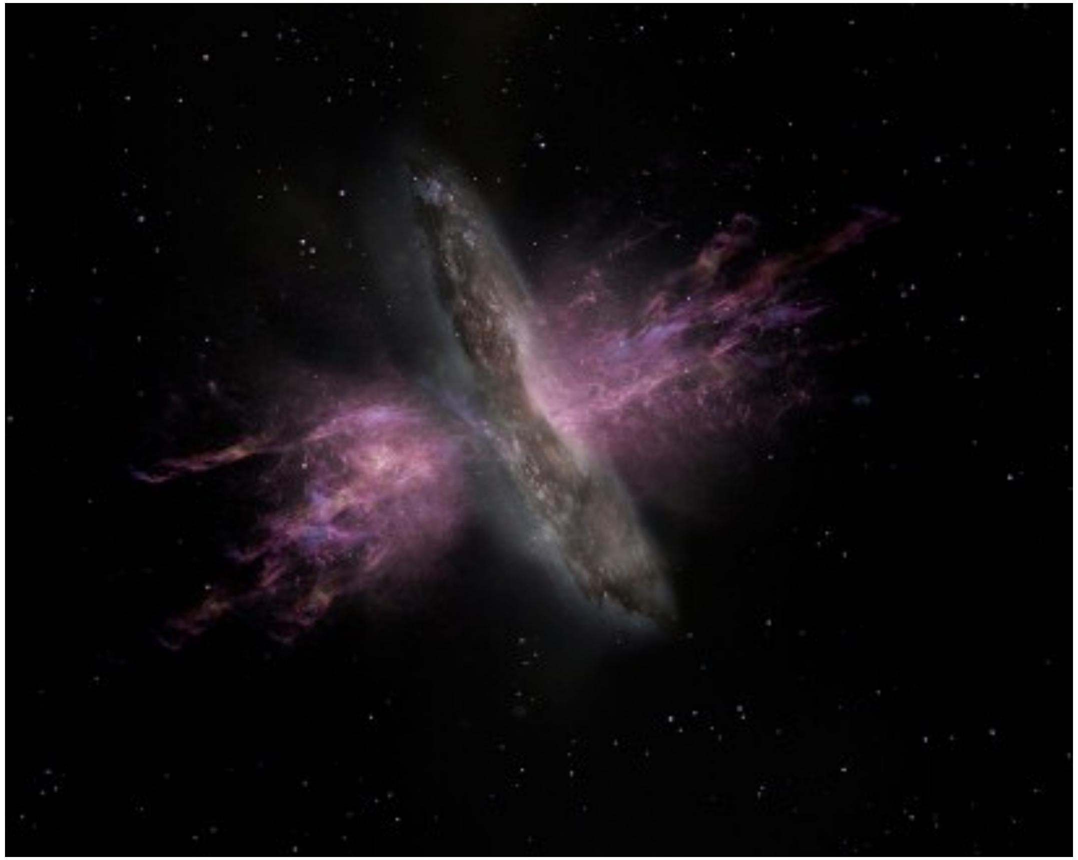




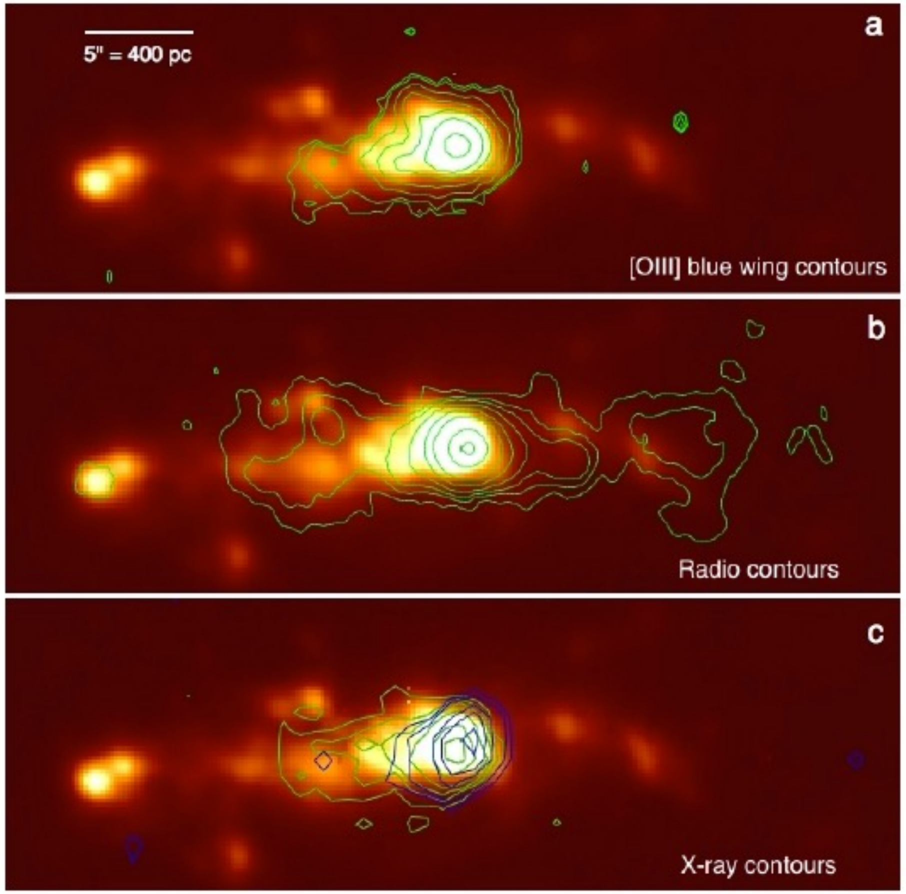
$n_e \sim 3 \times 10^{10}$ cm^{-3}
R = 10^{15} cm

NGC 4051
Peretz et al. 2019

Observed in its lowest ever state



ESA



Analysis of the Winds

Hα map of NGC 5643
Cresci et al. 2015

Photoionisation Modelling

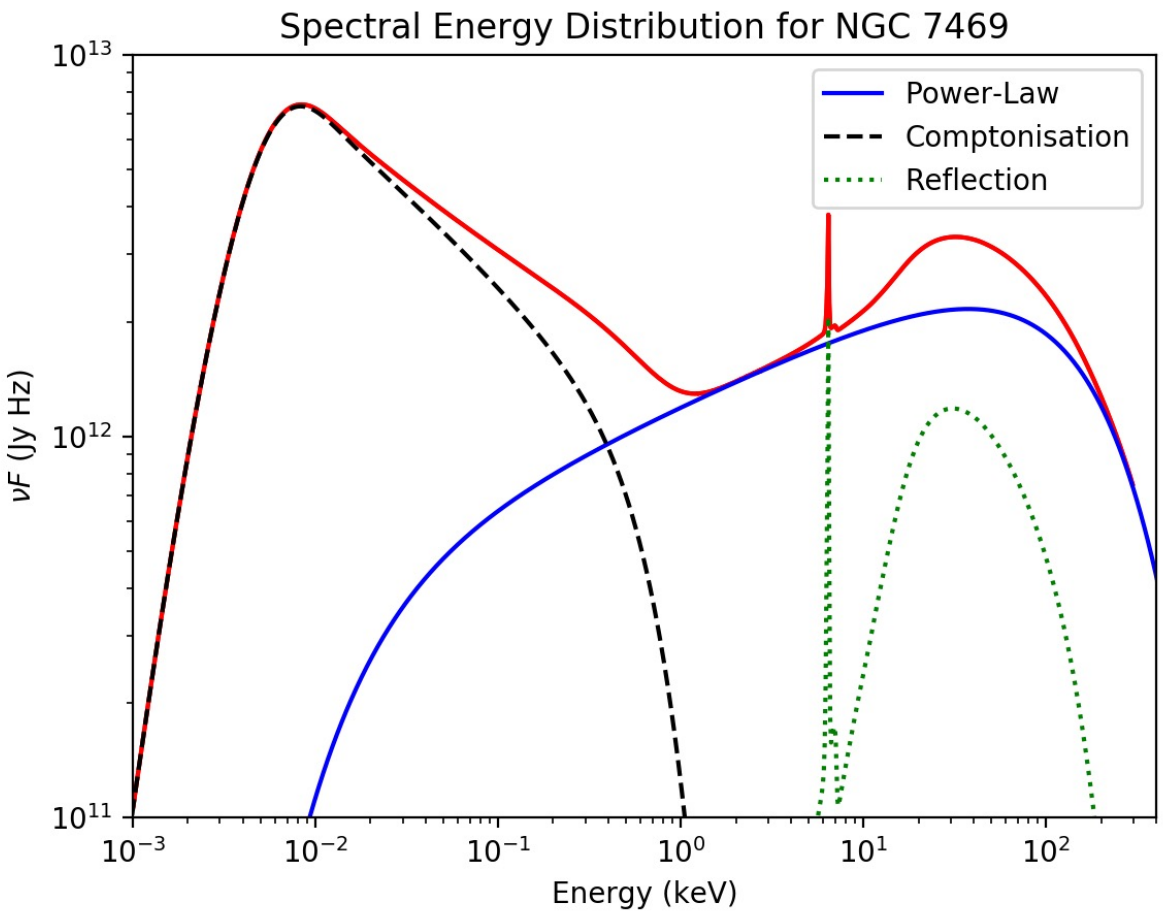
- Assume photoionisation equilibrium
  - Rate of ionisation = Rate of recombination
- State of the photoionised gas depends on the ionisation parameter ξ

$$\xi \equiv \frac{L_{ion}}{nr^2}$$

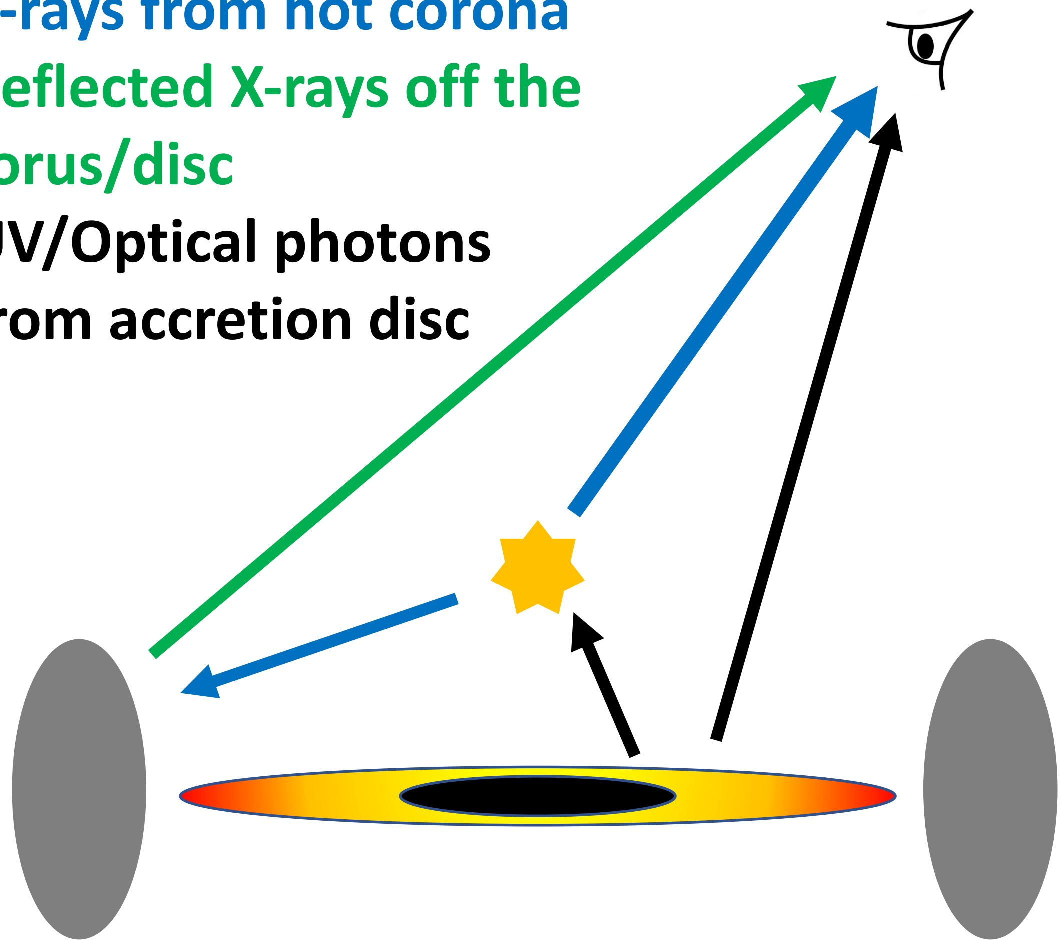
PION

- Self consistent model **(M. Mehdipour et al. 2016)**
- Simultaneously models the continuum and ionised plasma
- Requires SED of AGN
- As continuum varies, recalculates the ionisation balance
- Does not require an ionisation grid e.g. Cloudy or XSTAR

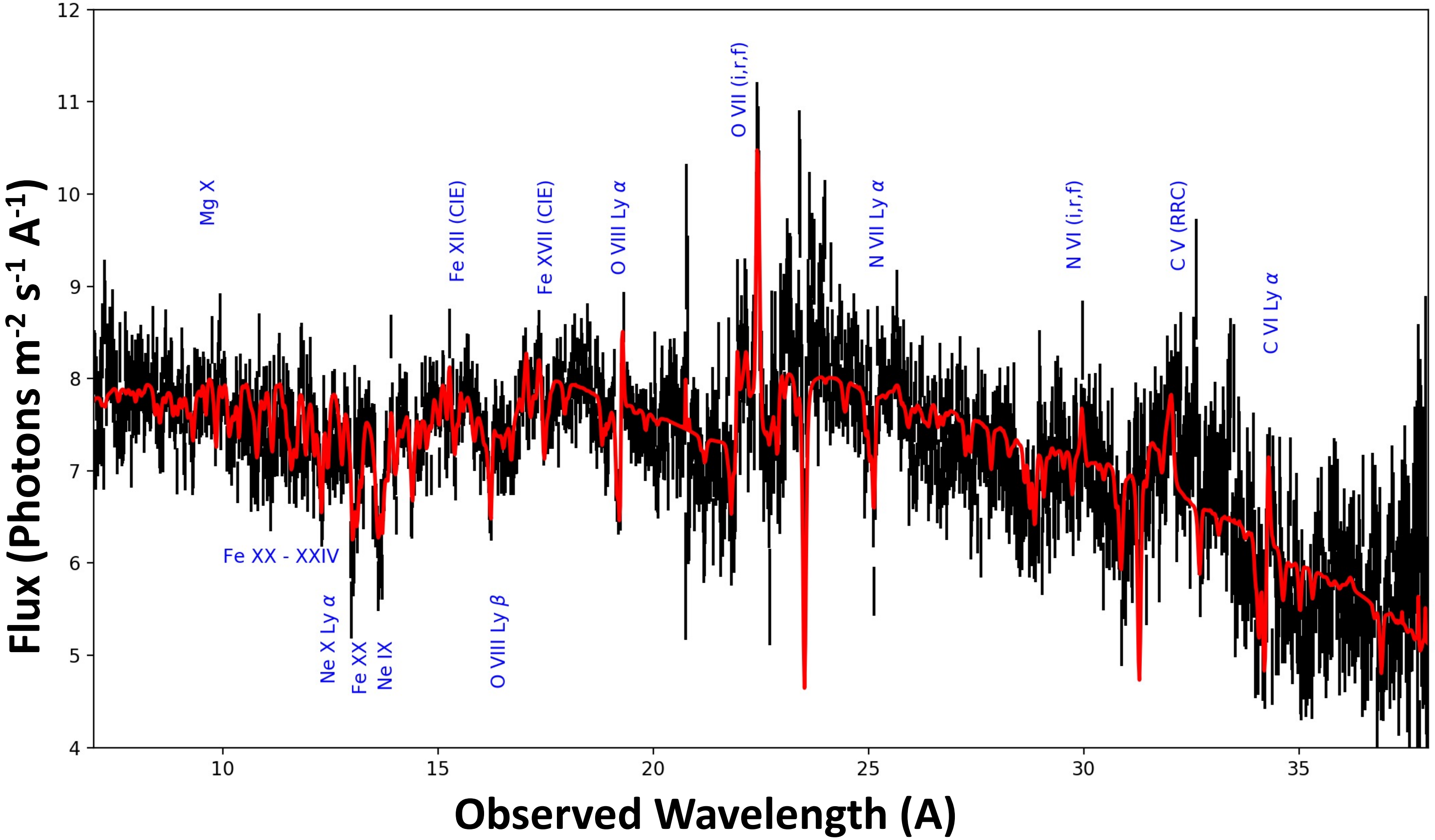
Spectral Energy Distribution (SED)



- X-rays from hot corona
- Reflected X-rays off the torus/disc
- UV/Optical photons from accretion disc



Spectral Modelling



- N_H - the line depth
  - $10^{24} – 10^{28}$ m^{-2}
- $\xi \equiv \frac{L_{ion}}{nr^2}$ - ionisation
  - log ξ = 0 - 3
- v_{turb} - line broadening
  - ~ $10^1 – 10^2$ km s^{-1}
- v_{out} - line centring
  - > $10^2 – 10^3$ km s^{-1}
  - Blueshifted
- Multiple components to fit all the emission/ absorption lines

Location of these winds

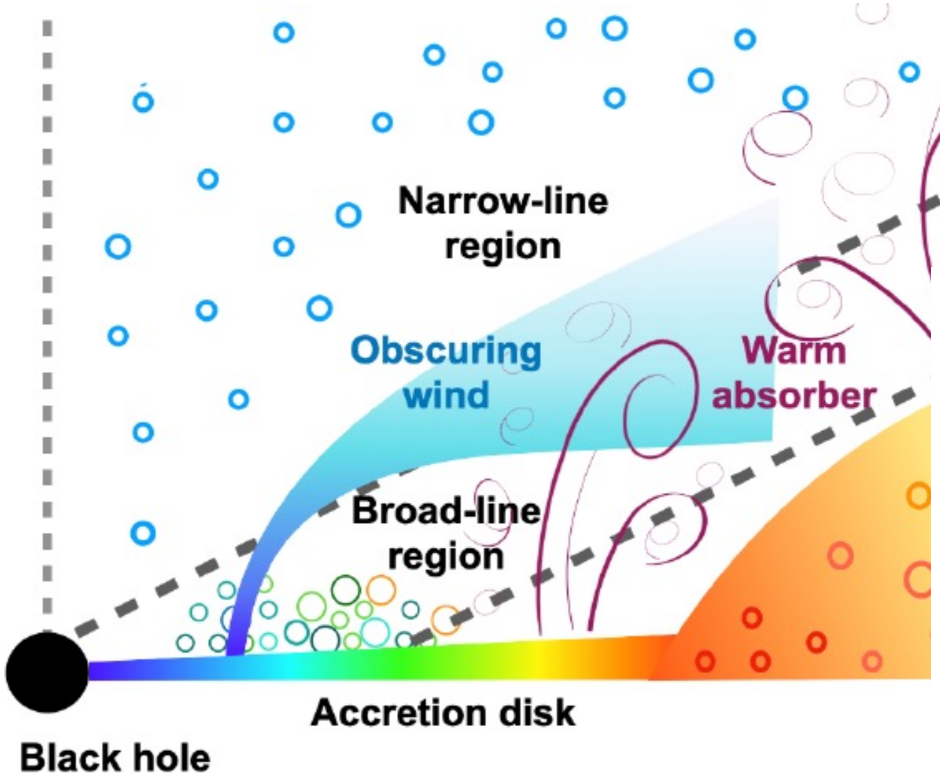
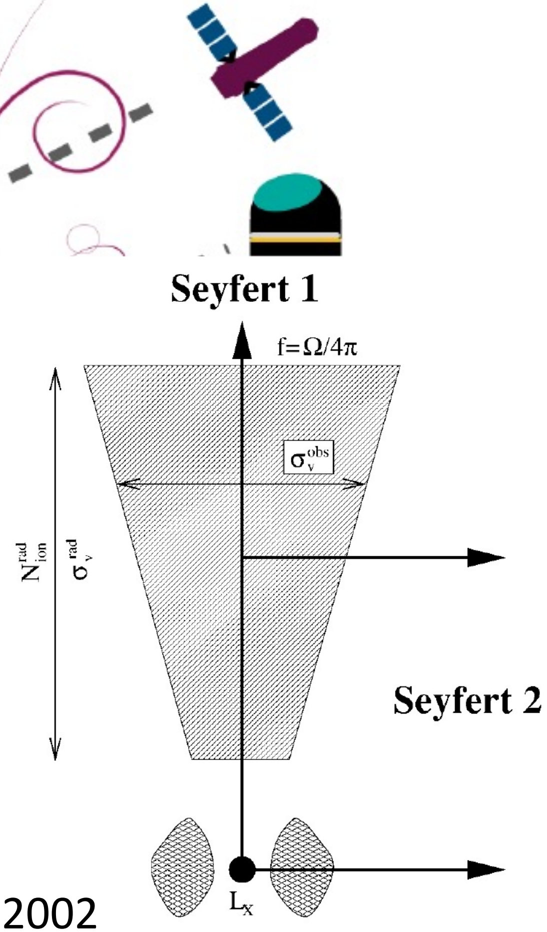


Image Credit: Junjie Mao



Kinkhabwala et al. 2002

- $\xi = \frac{L_{ion}}{n_e r^2}$
  - ξ from ionisation modelling
  - L_{ion} from SED (13.6 eV – 13.6 keV)
- n_e and r are degenerate!
- Plasma responds to changes in SED
- Causing changes in ionisation state and density
- Constrain density to obtain the distance

WA and NLR same component of the wind viewed differently?

See e.g. Kinkhabwala+02 and Blustin+05

Interaction with the Host Galaxy

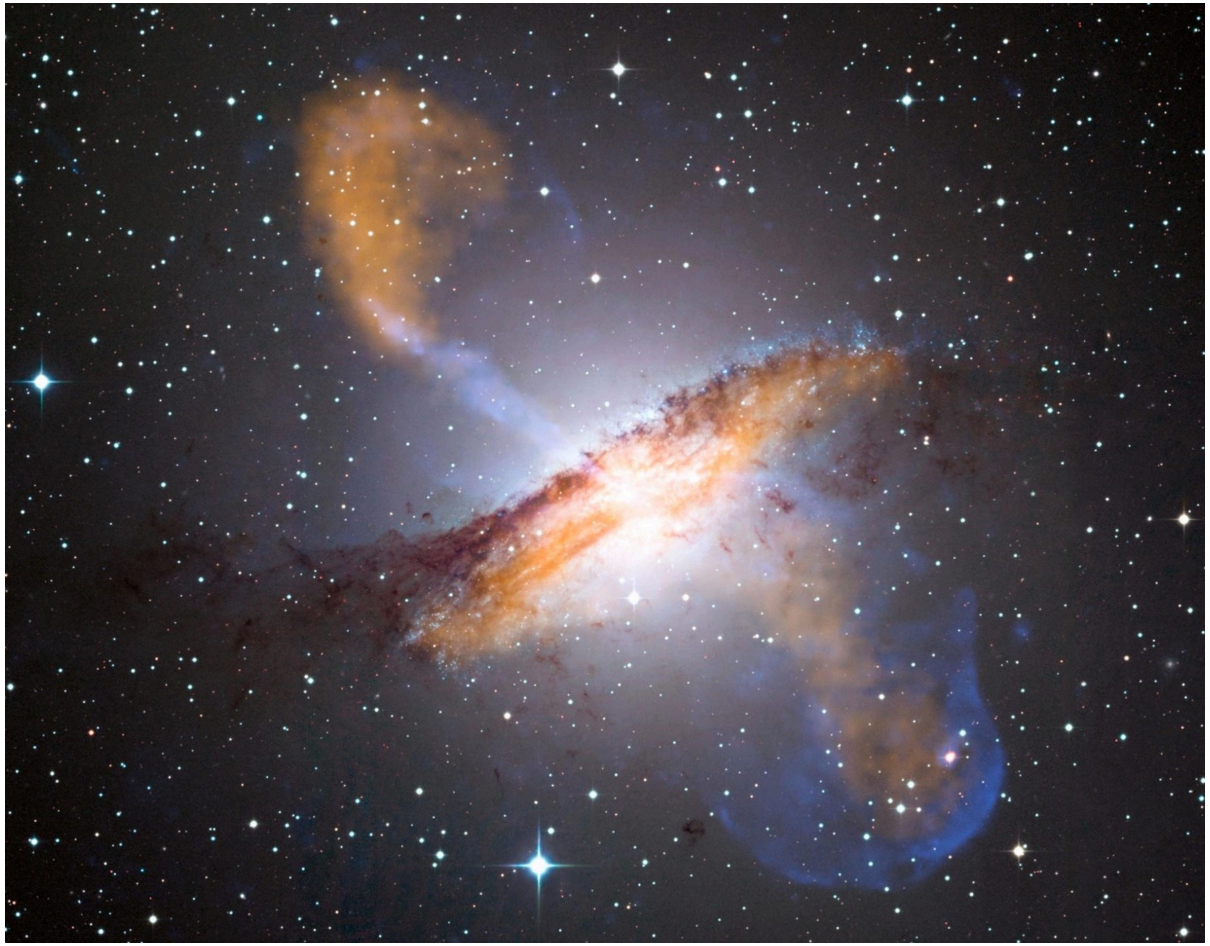
Mass outflow rate

$$\dot{M}_{out} \sim \frac{\mu\, m_p\, L_{ion} f v \omega}{\xi}$$

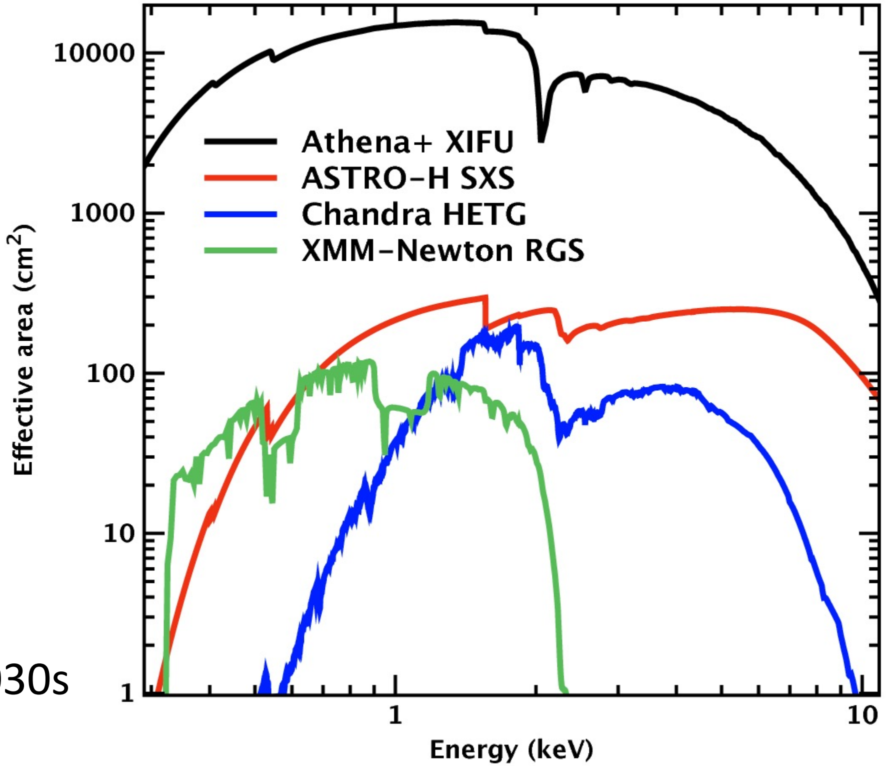
Kinetic luminosity

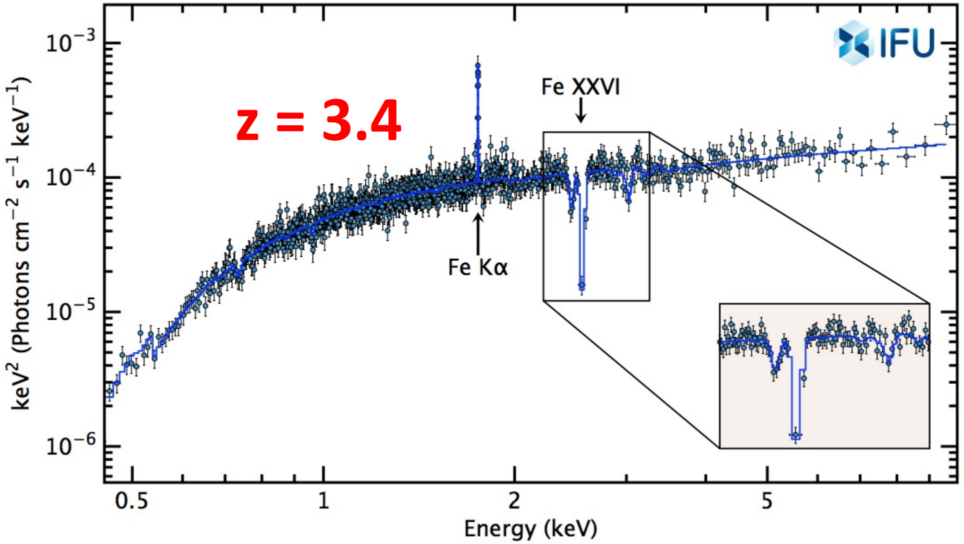
$$L_K = \frac{1}{2} \dot{M}_{out}\, v^2$$

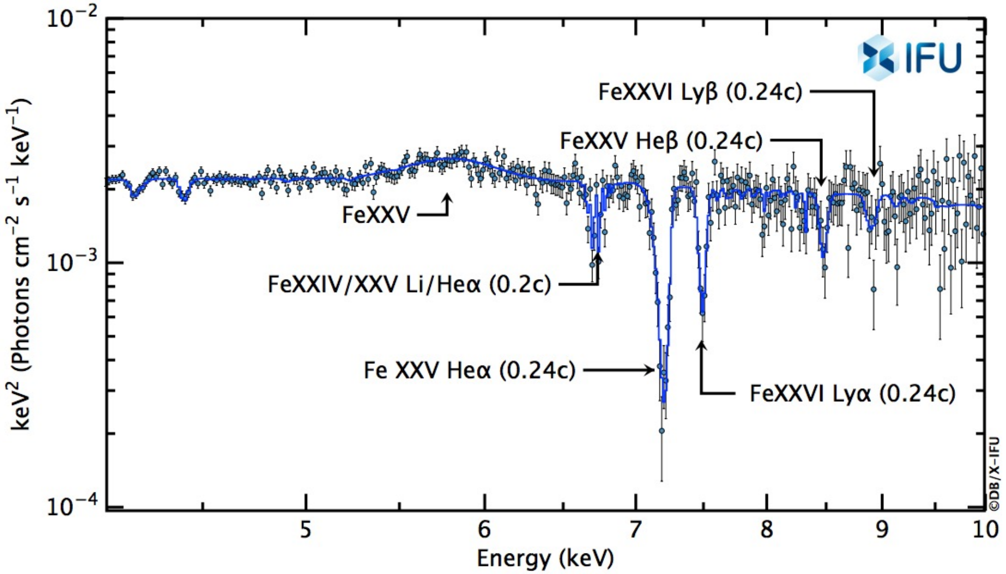
- If L_K < few % of L_{bol} then insignificant enough to affect host galaxy (Blustin et al. 2005)
- WA not energetic enough to influence host - but UFOs are (Tombesi et al. 2013)



SciTechDaily







IRAP, CNES, ESA & ACO

Launched 2030s

X-IFU consortium: Barrett et al. 2013; Nandra et al. 2013; Willingale et al. 2013

Summary

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- **Different types of outflowing winds:**
  - Depends on origin and therefore outflow velocity
  - Depends on how we view them (WA/NLR)
  - Part of same structure?
  - Varying ξ, N_H and $v_{out,}$ with different locations
- **Unanswered questions:**
  - Origin?
  - Launching mechanisms?
  - Locations?

  Poorly understood
- **To understand AGN and galaxy coevolution through feedback**