COLUMBUS STATE COMMUNITY COLLEGE

THE OHIO STATE UNIVERSITY

AGN Outflows: Probing an Unexplored Parameter Space

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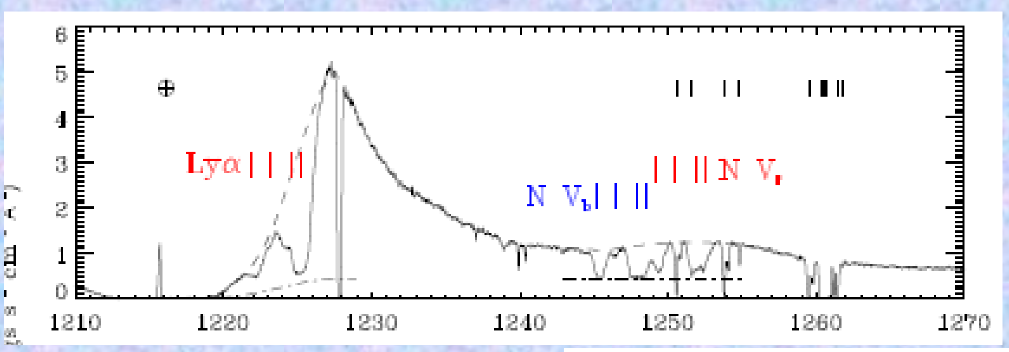
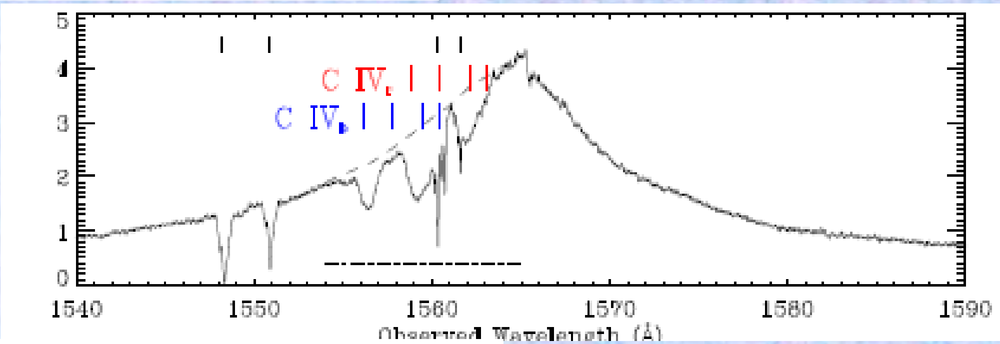
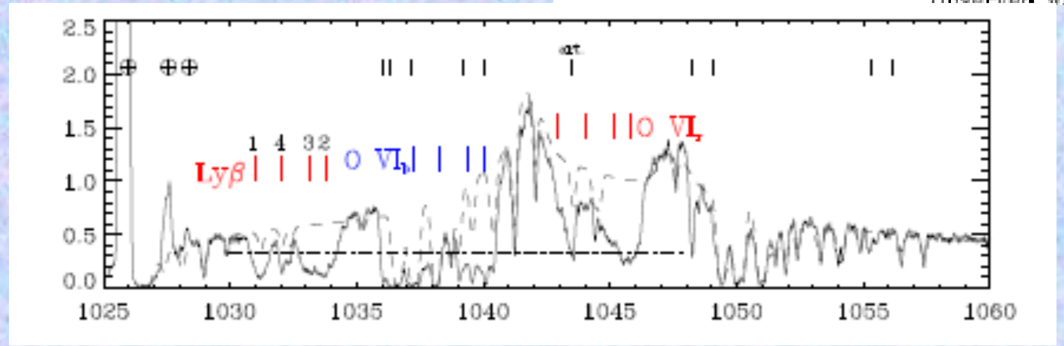
Low velocity outflows are ubiquitous

Seen in 50% of Seyfert galaxies.

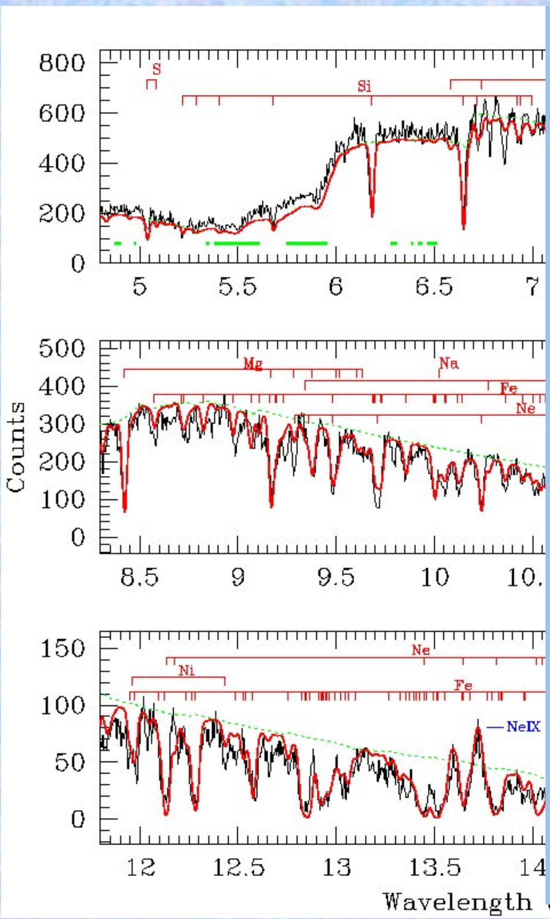






NGC 3783 HST and FUSE

Warm Absorbers

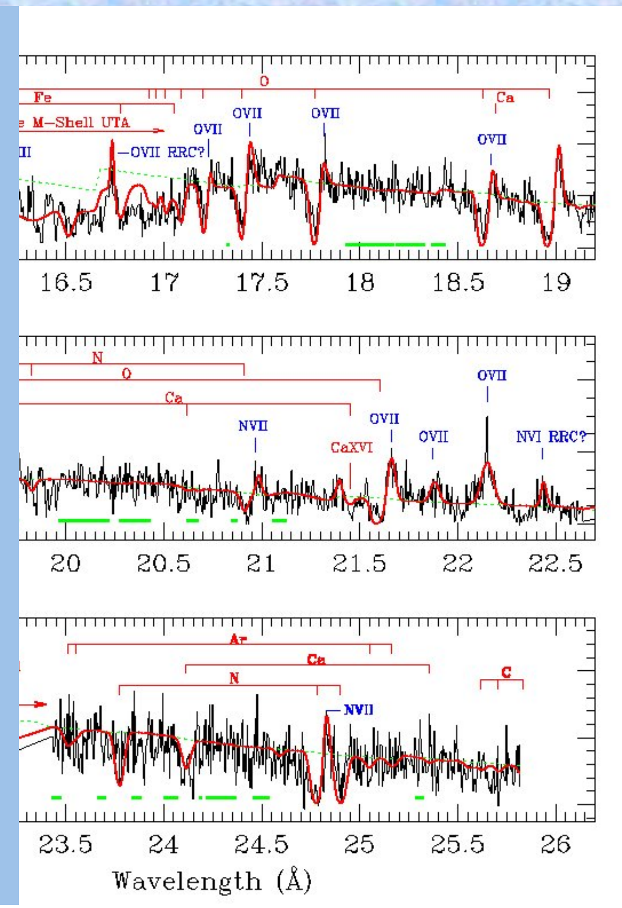


Log ξ = 0 – 2 erg s^{-1}

$N_H = 10^{20}$ - 10^{22} cm^{-2}

Outflow Velocity

100 – 1000 km s^{-1}



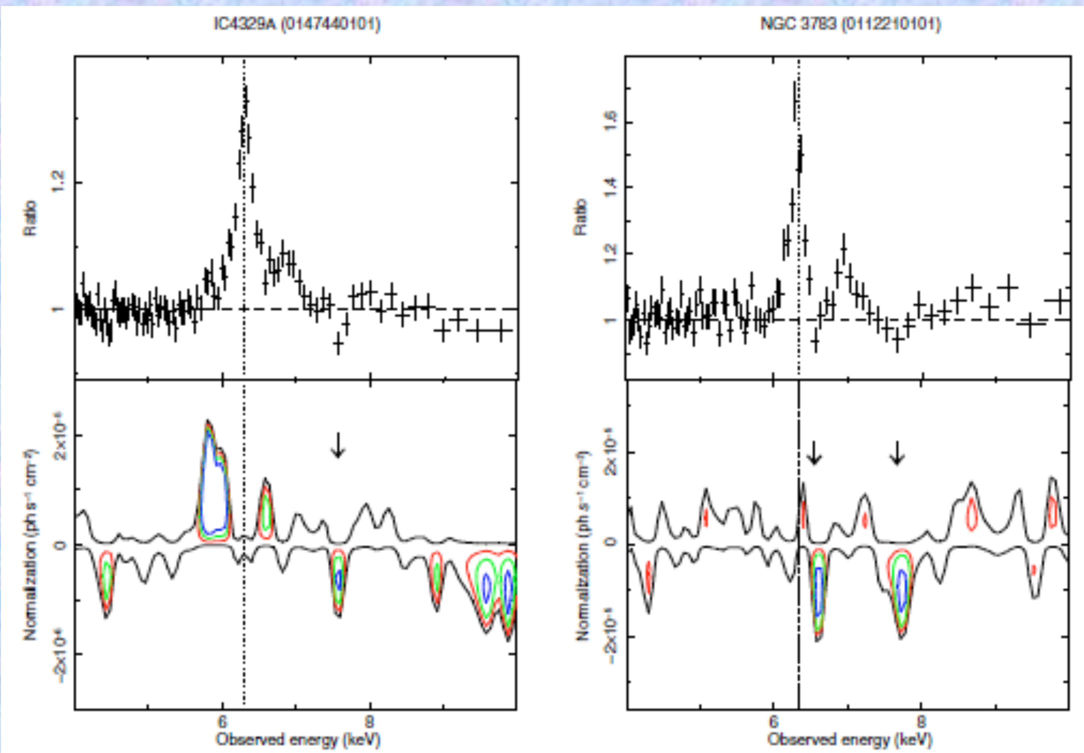
Krongold et al. 2003

Warm Absorbers

- **LIP: a low ionization parameter component, Fe UTA, UV lines**
- **HIP: a high ionization parameter component, seen only in X-rays**
- **In pressure equilibrium**
- **Not efficient agents of feedback**

Krongold et al.2003, 2007; Netzer et al. 2003

Ultra-Fast Outflows (UFOs)



Log ξ = 3 – 6 erg s^{-1}

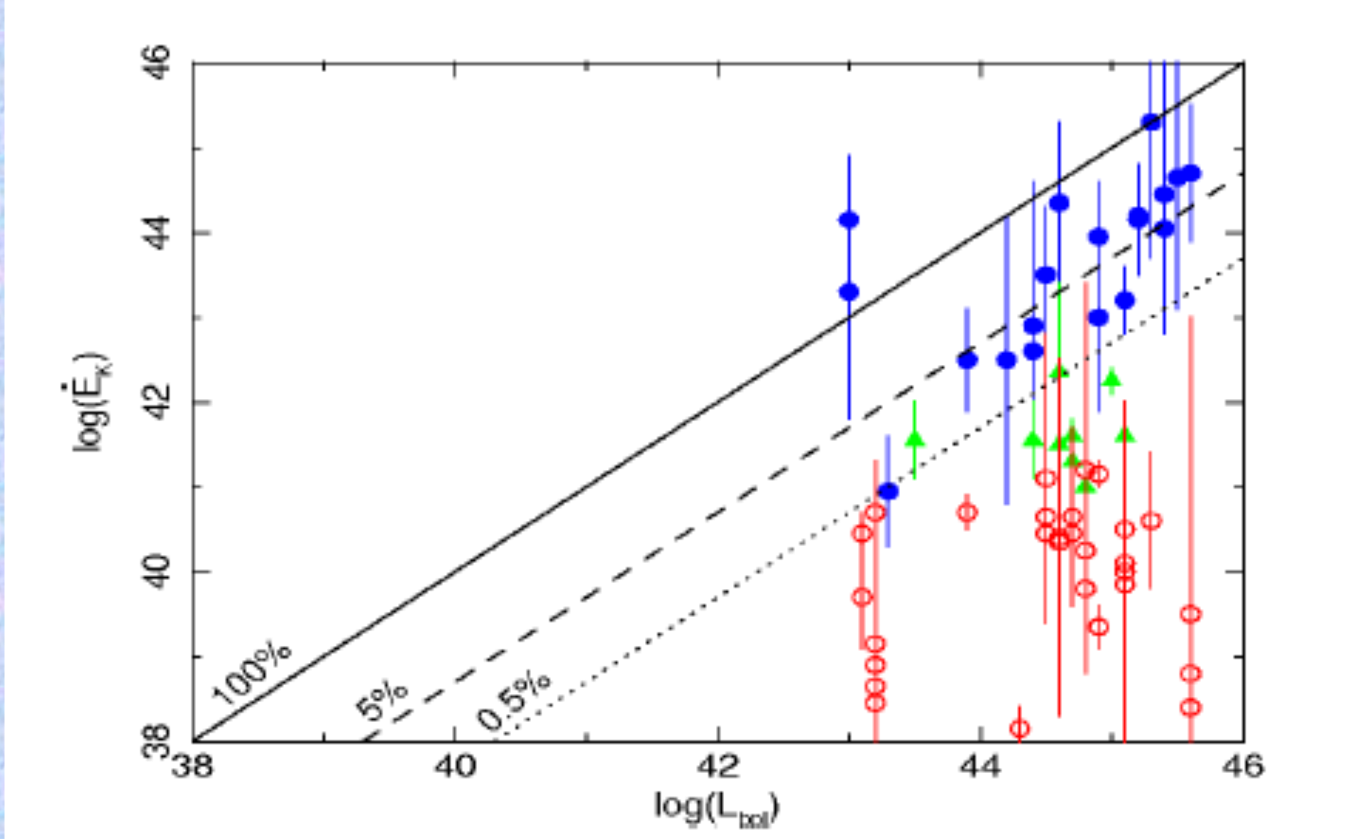
N_H = 10^{22} - 10^{24} cm^{-2}

Outflow Velocity

0.1c – 0.3c

Tombesi et al. 2010

Kinetic Luminosity



UFOs

Warm Absorbers

From Tombesi et al. 2013

Issues with detected UFOs

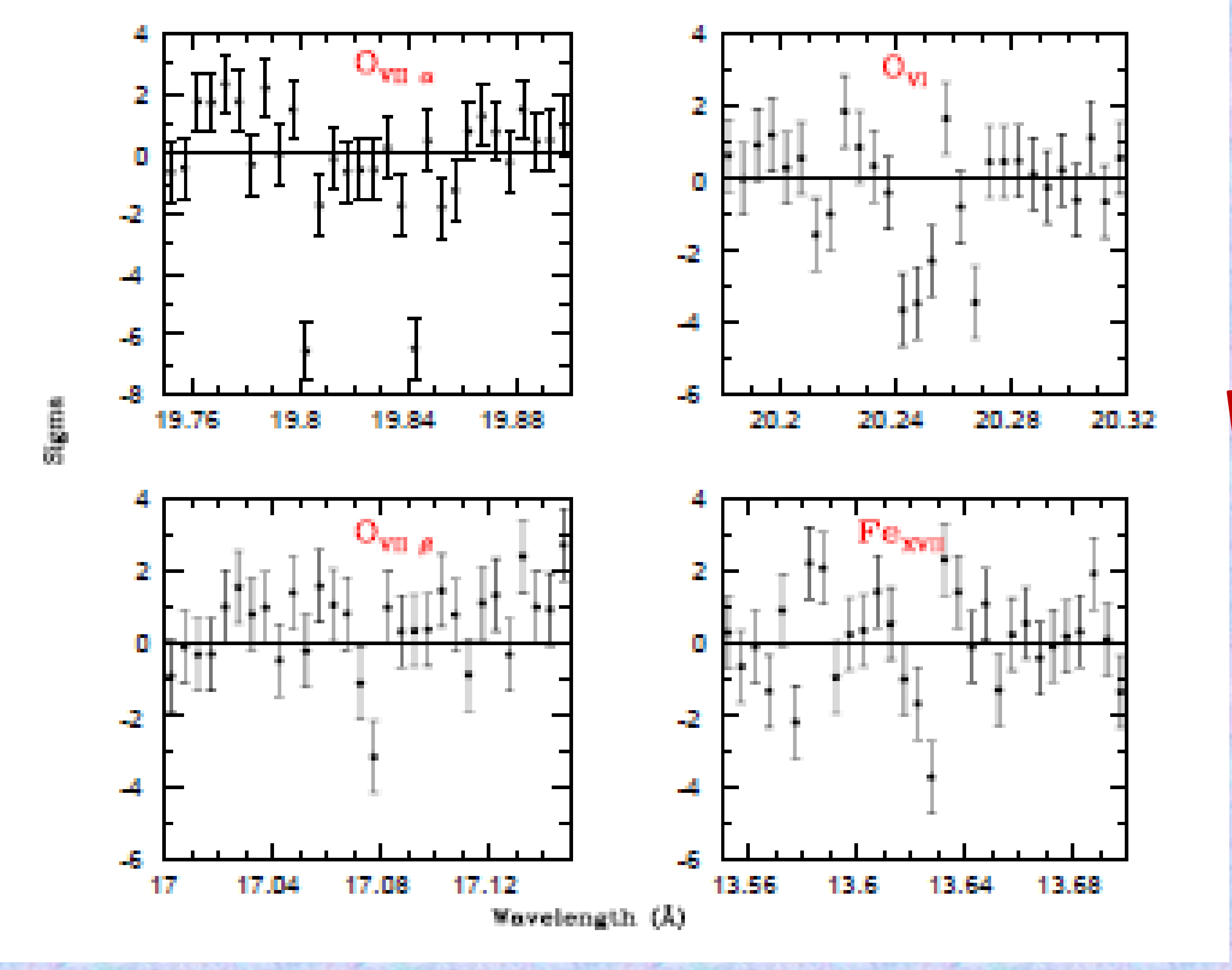
- Identified through blueshifted FeXXV and/or FeXXVI absorption lines only
- All in low resolution CCD spectra.
- Low significance absorption lines.
- Parameterization of photoionized plasma becomes difficult

Discovery of Relativistic Outflows in the Seyfert Galaxies

Ark 564, Mrk 590 and Mkn 1044

Gupta et al. 2013; 2015
Krongold et al. 2018 (in preparation)

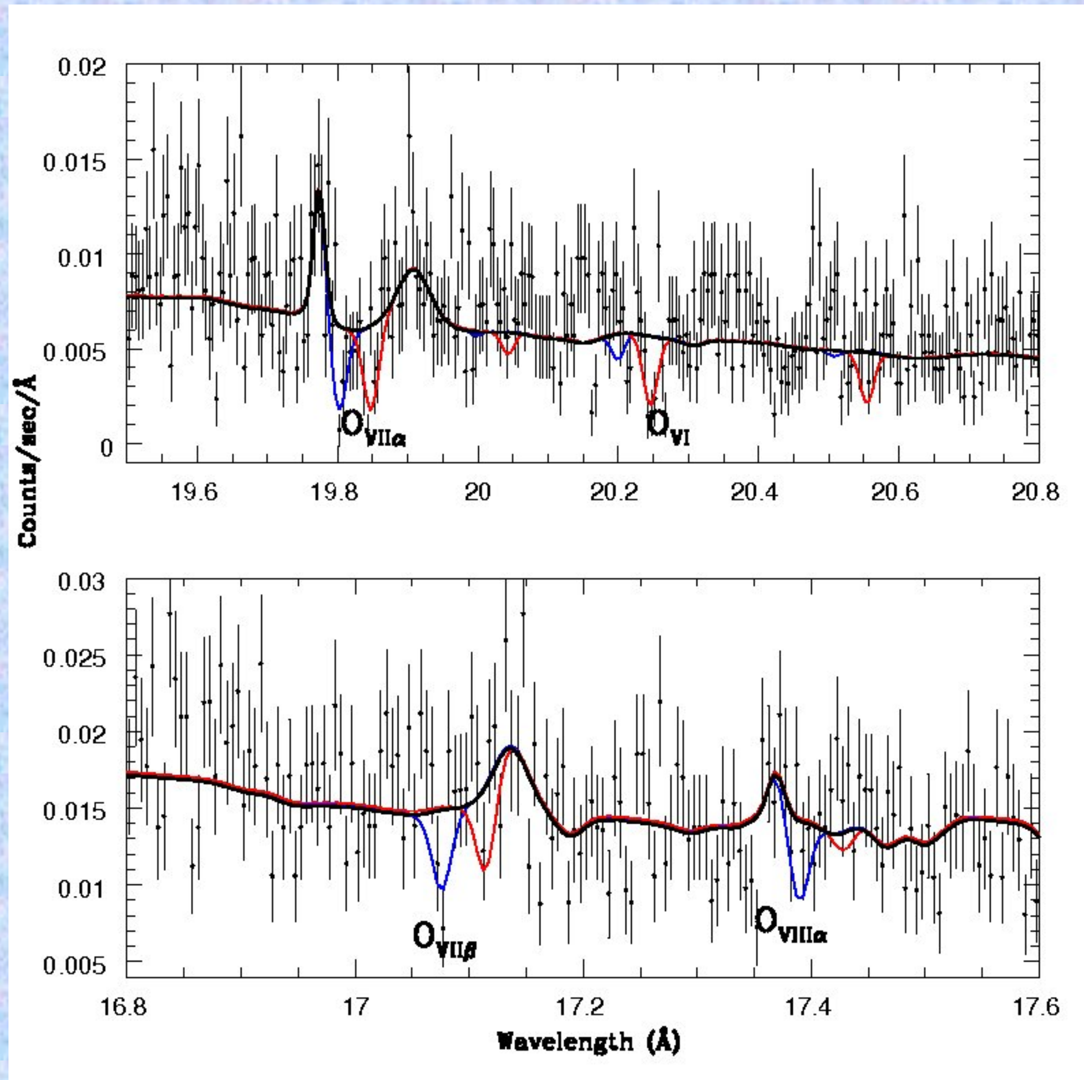
Discovery of relativistic outflow in Ark 564



Velocity >0.1c

Gupta+2013

….well fit with photoionization model



Log ξ = 1.25/0.65 erg s^{-1}

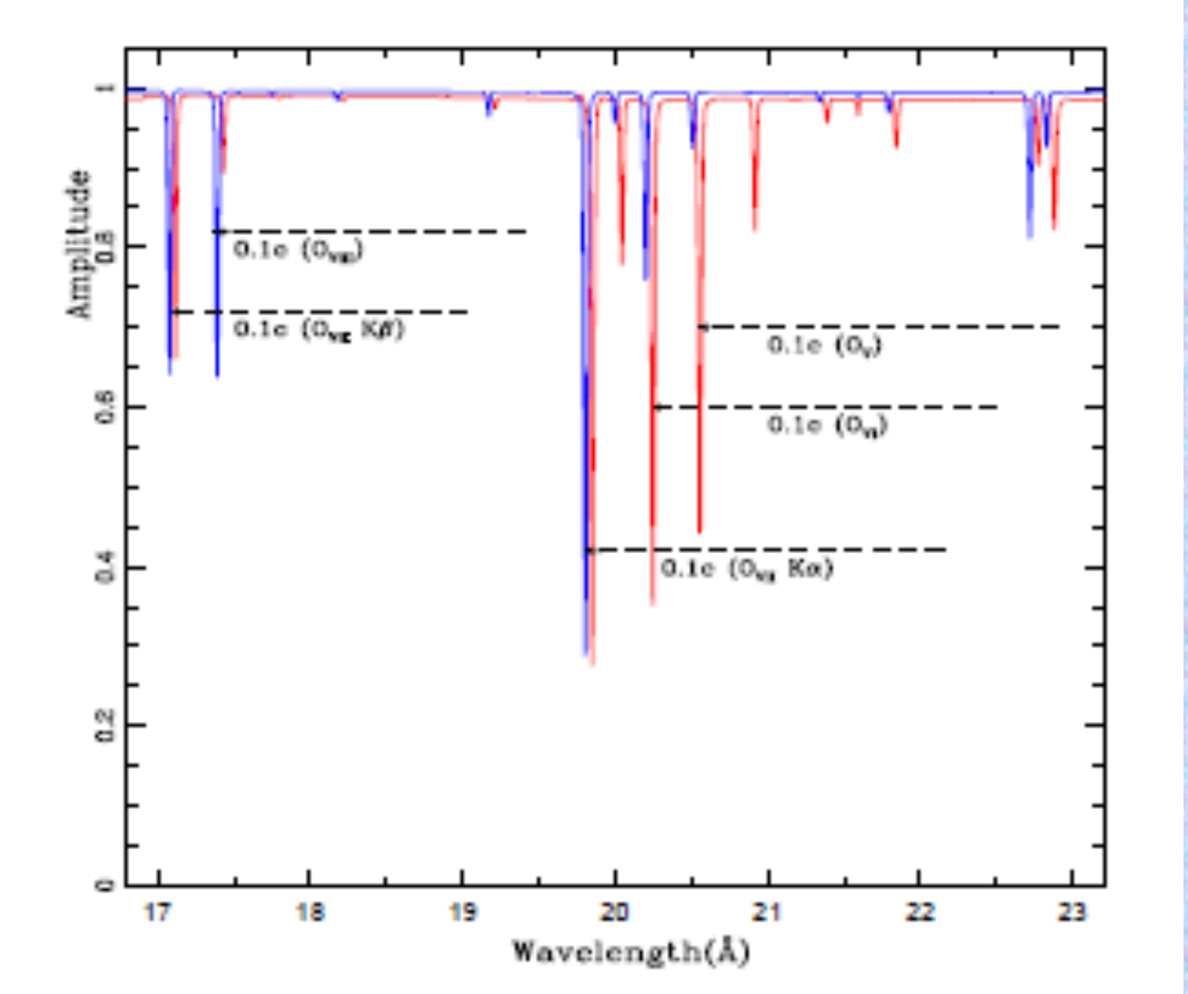
$N_H = 10^{19.8}/10^{20}$ cm^{-2}

Outflow Velocity

0.105c/0.103c

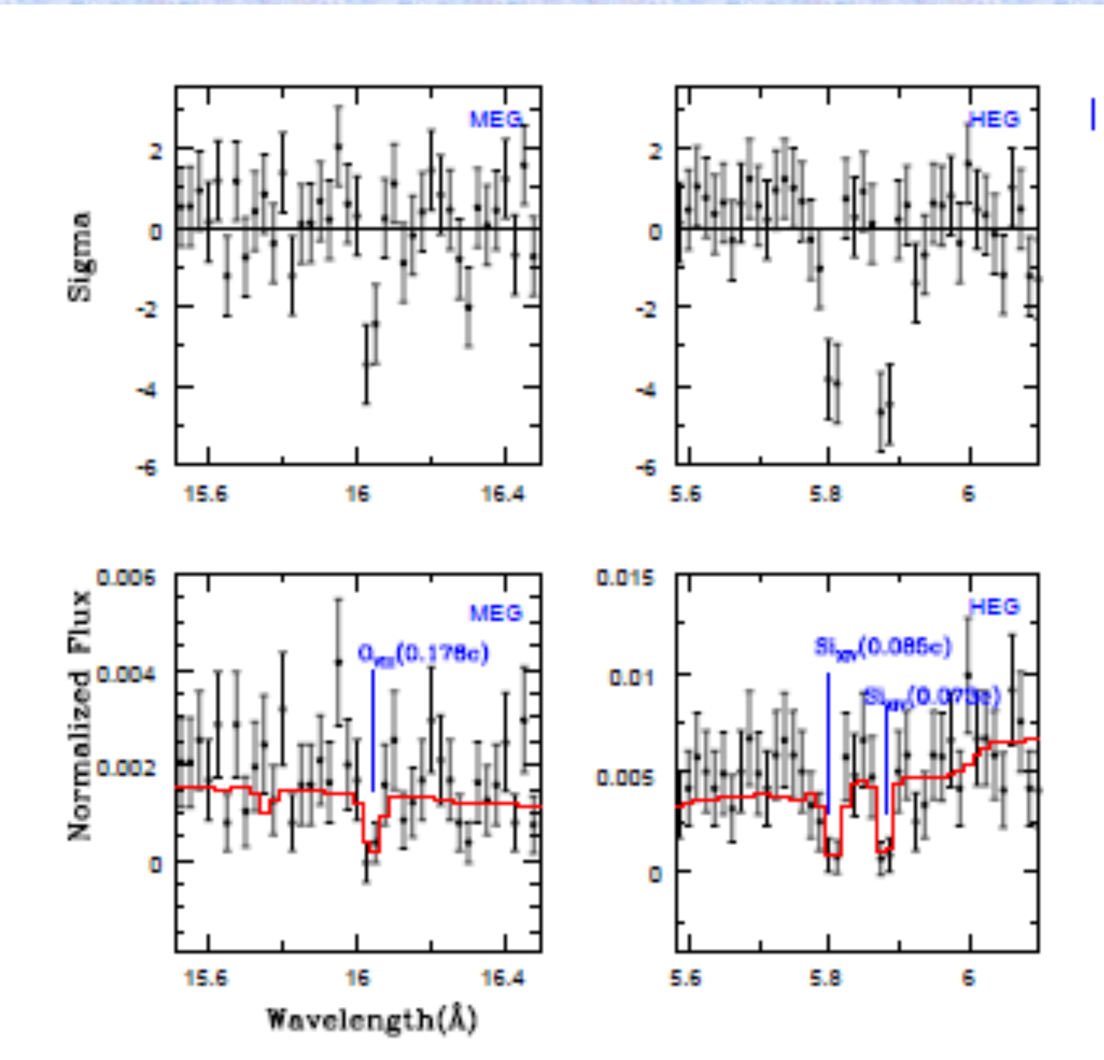
Gupta+2013

Two component photoionization model



Gupta+2013

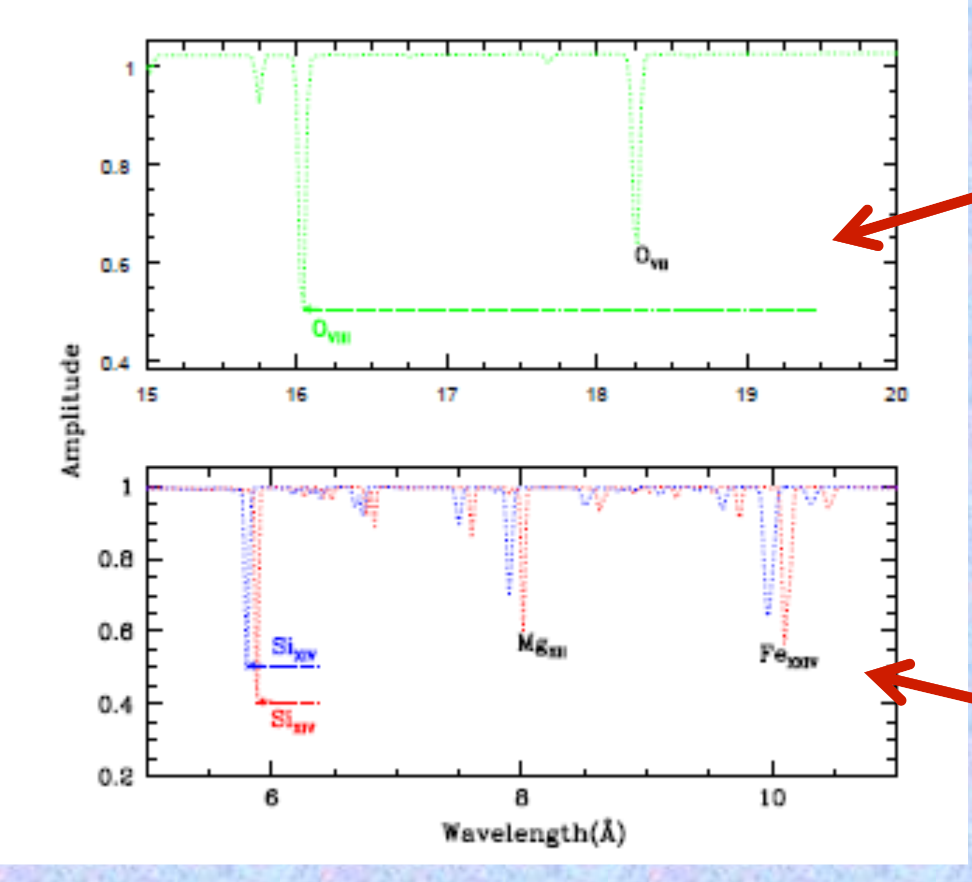
Relativistic outflow in Mrk 590



V = 0.081c - 0.176c

Gupta+2015

….and its photoionization model



HV-LIP

Log ξ = 2.24 erg s^{-1}

$N_H = 10^{20.94}$ cm^{-2}

Outflow Velocity *= 0.176c*

HV-HIP

Log ξ = 4.5 erg s^{-1}

$N_H = 10^{23.5}$ cm^{-2}

Outflow Velocity = *0.0867c/0.0738c*

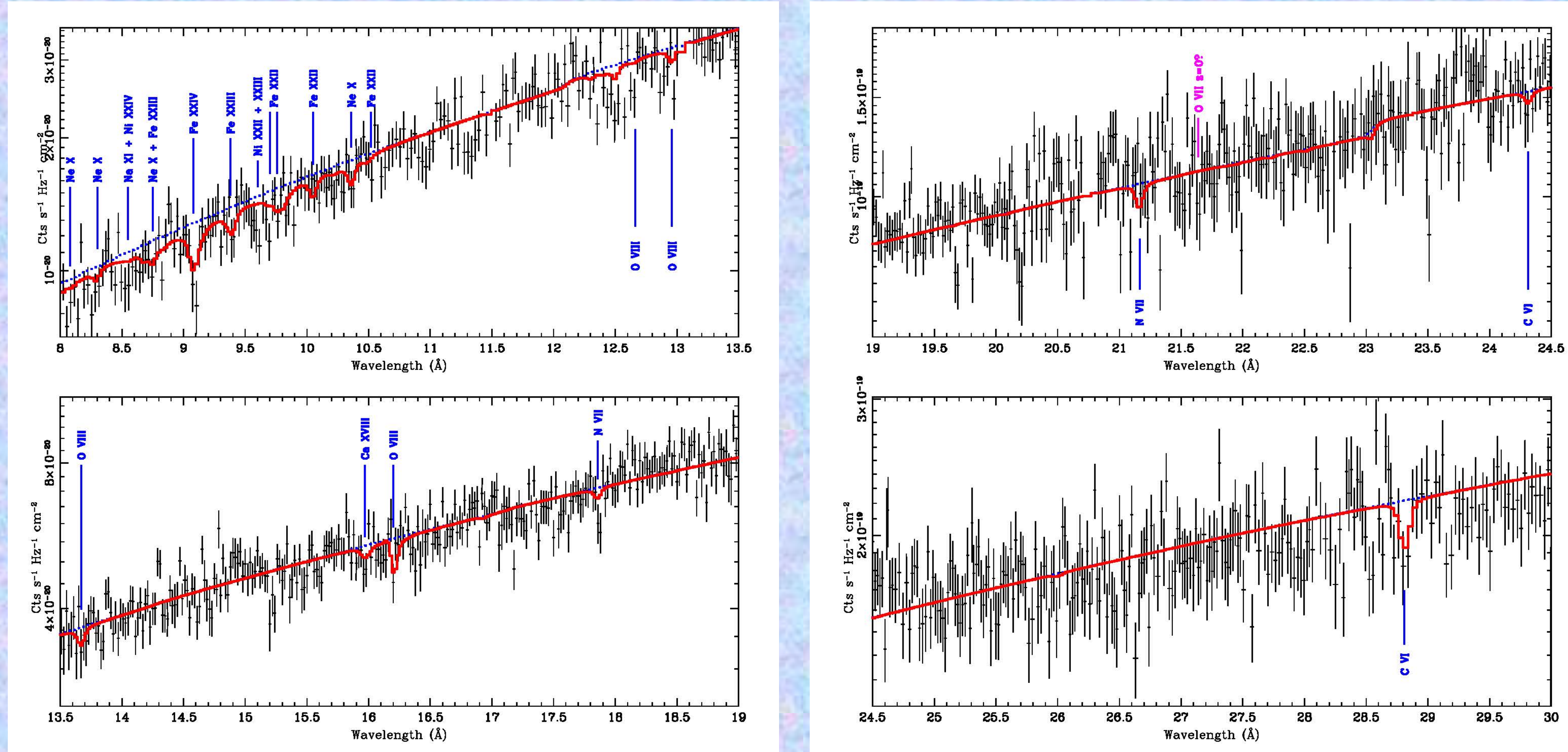
Kinetic Luminosity of Relativistic Outflows

HV-LIP Kinetic luminosity > 10^{41} erg/s

HV-HIP Kinetic luminosity > 10^{44} erg/s

c.f. X-ray luminosity: 7.0×10^{42} erg/s

Relativistic Outflows : Mkn 1044



Krongold+2017 (in preparation)

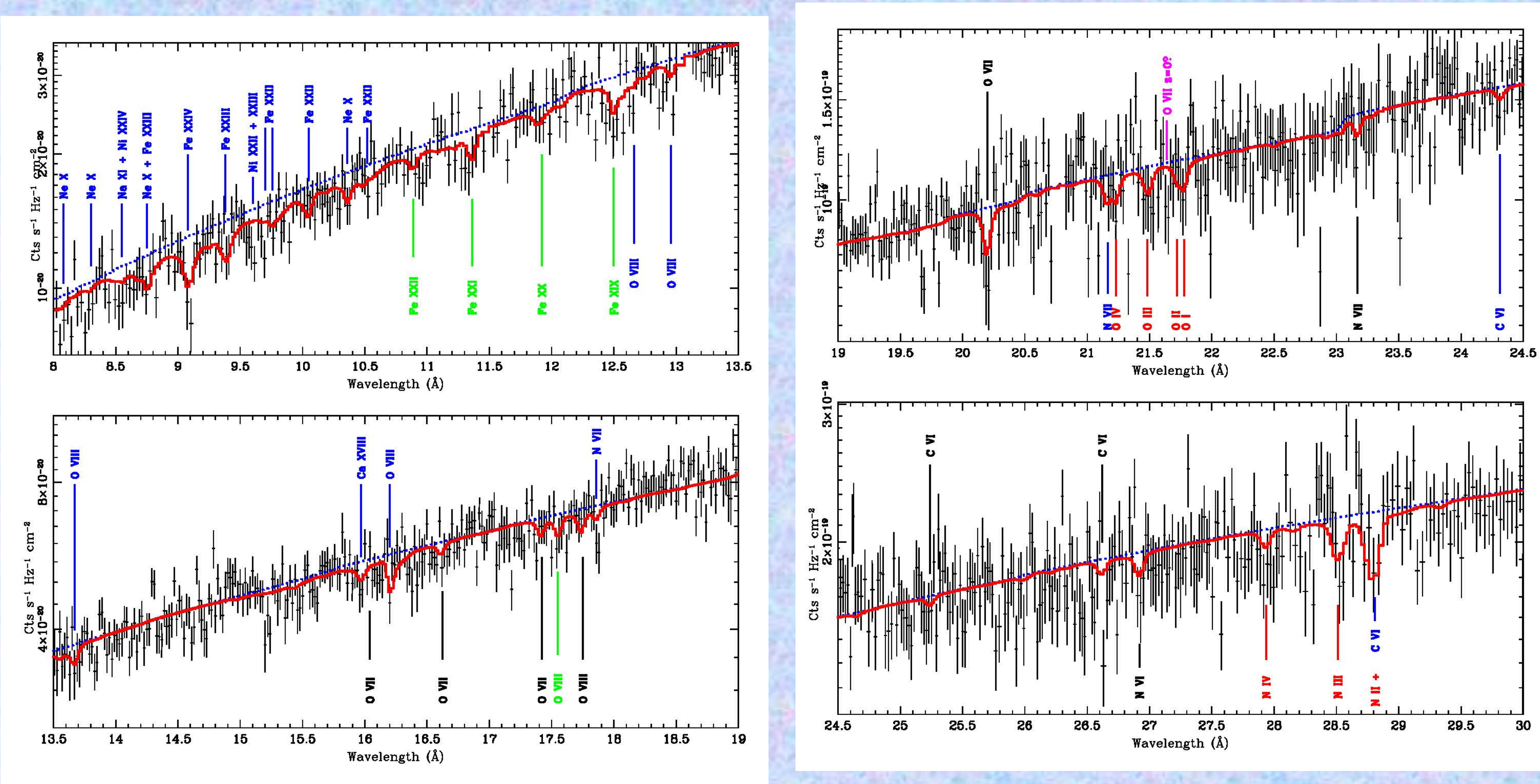
Comp 1

Log ξ = 2.12 erg s^{-1}

N_H = 10$^{23.32}$ cm^{-2}

Outflow Velocity = *47800 km/s*

Relativistic Outflows : Mkn 1044



Krongold+2017 (in preparation)

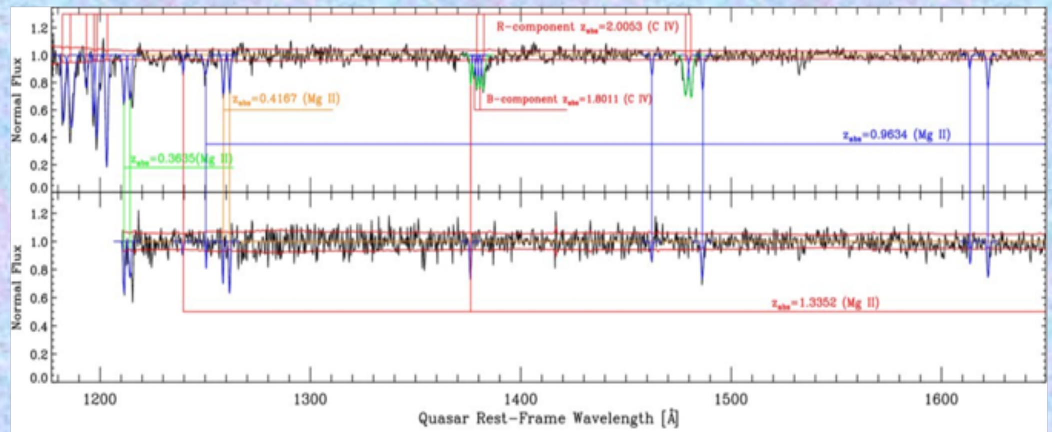
Comp 2, 3, 4

Log ξ = 1.14, -0.882, -2.938 erg s^{-1}

$N_H = 10^{21.56}$, $10^{20.09}$, $10^{20.39} cm^{-2}$

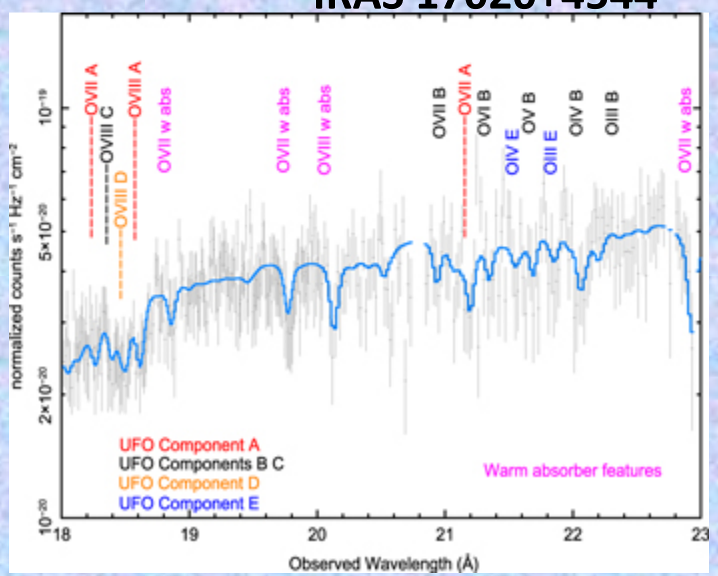
Outflow Velocities = *27400, 24700, 24900 km/s*

SDSS J095254.10+021932.8



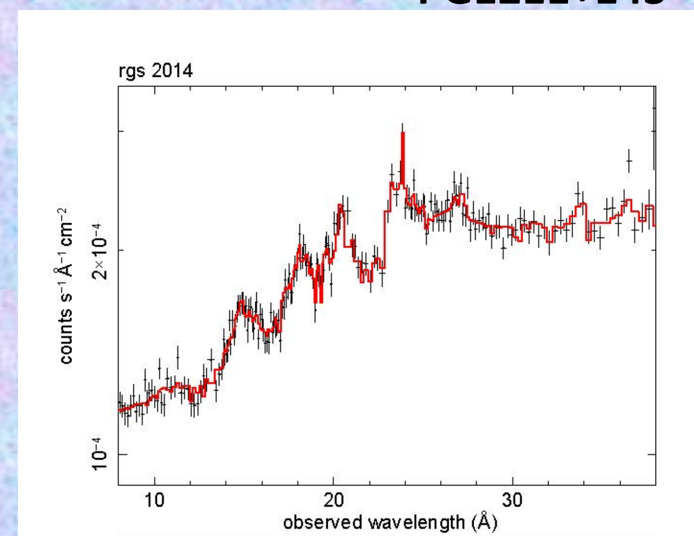
Chen+2013

IRAS 17020+4544



Longinotti+2015

PG1211+143

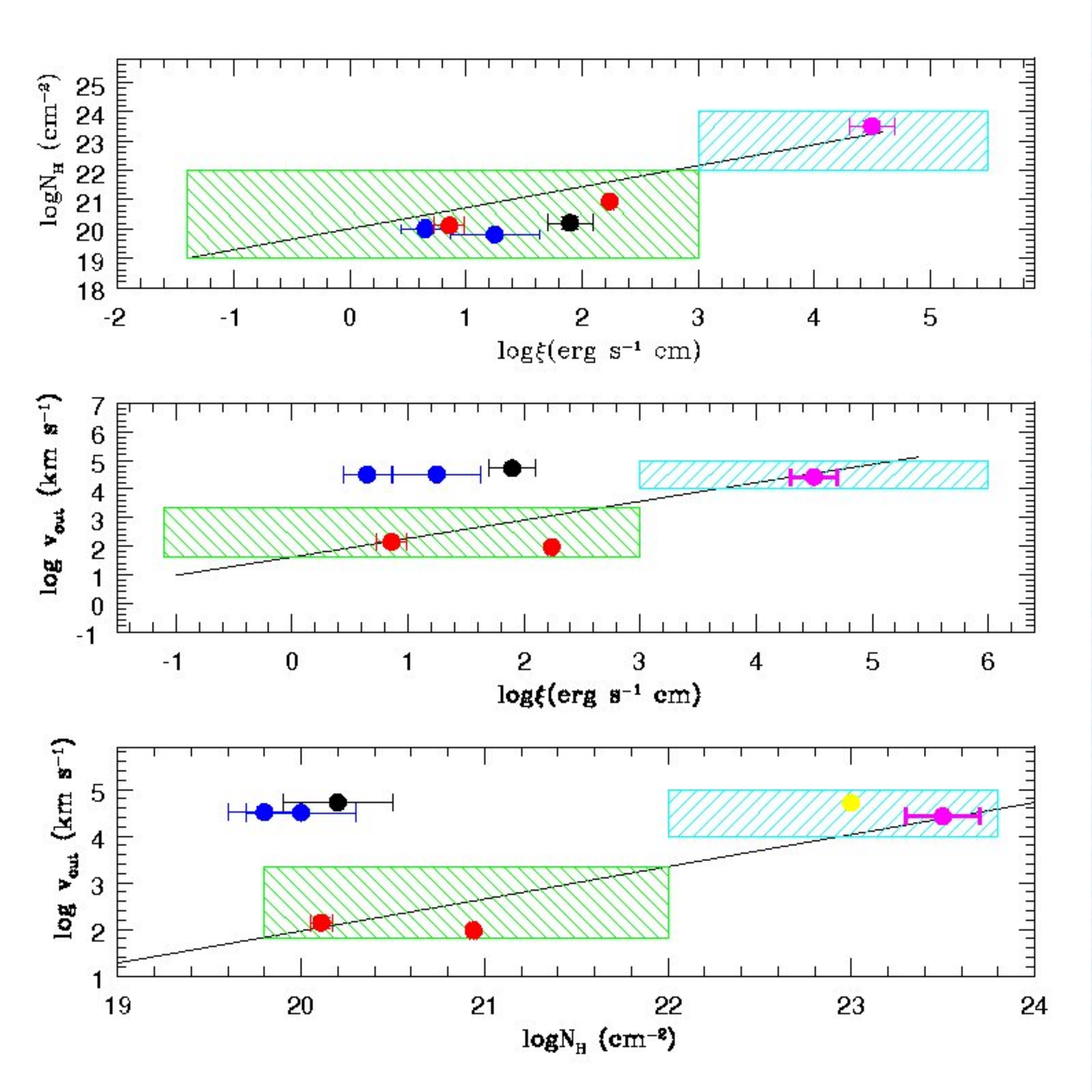


Pounds+2016

These are remarkable discoveries

- Relativistic outflows known only in luminous quasars
  - -- BALQSOs in UV
  - -- Few in hard X-rays: Fe line
- Examples in soft X-rays: Robust!
  - -- better instrumental response
  - -- multiple lines at the same velocity
- Physical parameters well determined.

…..WA and UFO connection ?



What is the launching mechanism of relativistic outflows?

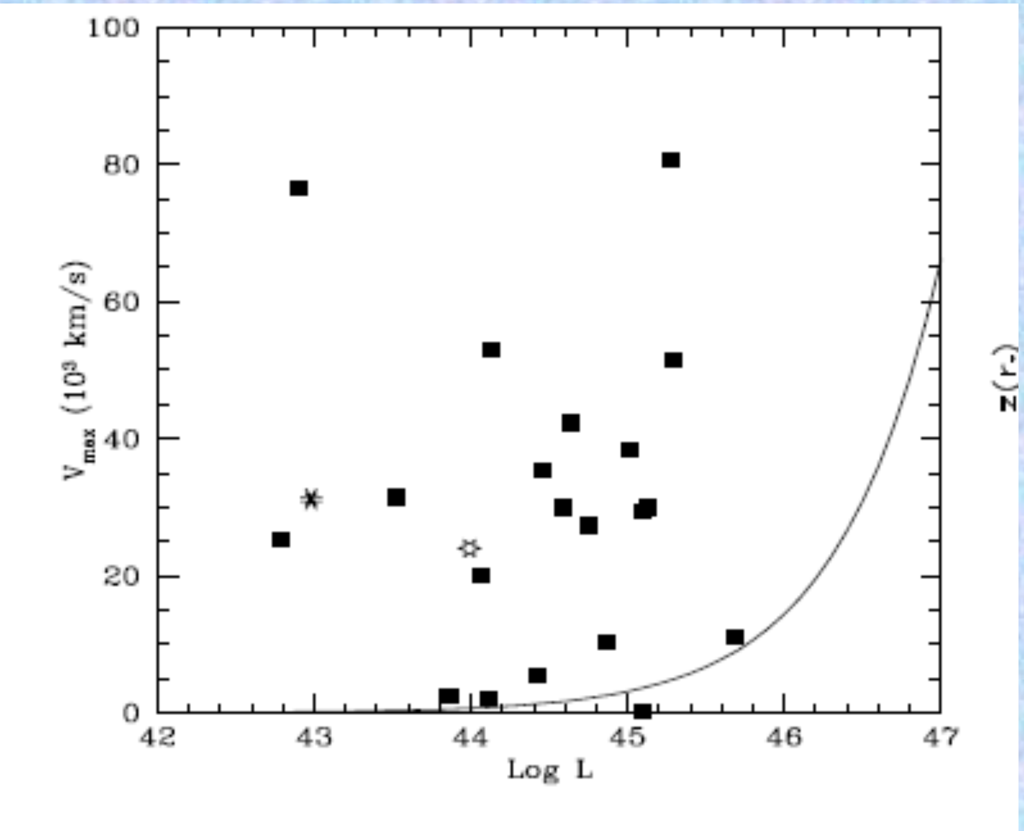


Figure: Outflow velocity plotted as a function of AGN luminosity. The solid line represents the upper envelope relation from Ganguly et al. (2007).

What is the driving mechanism?

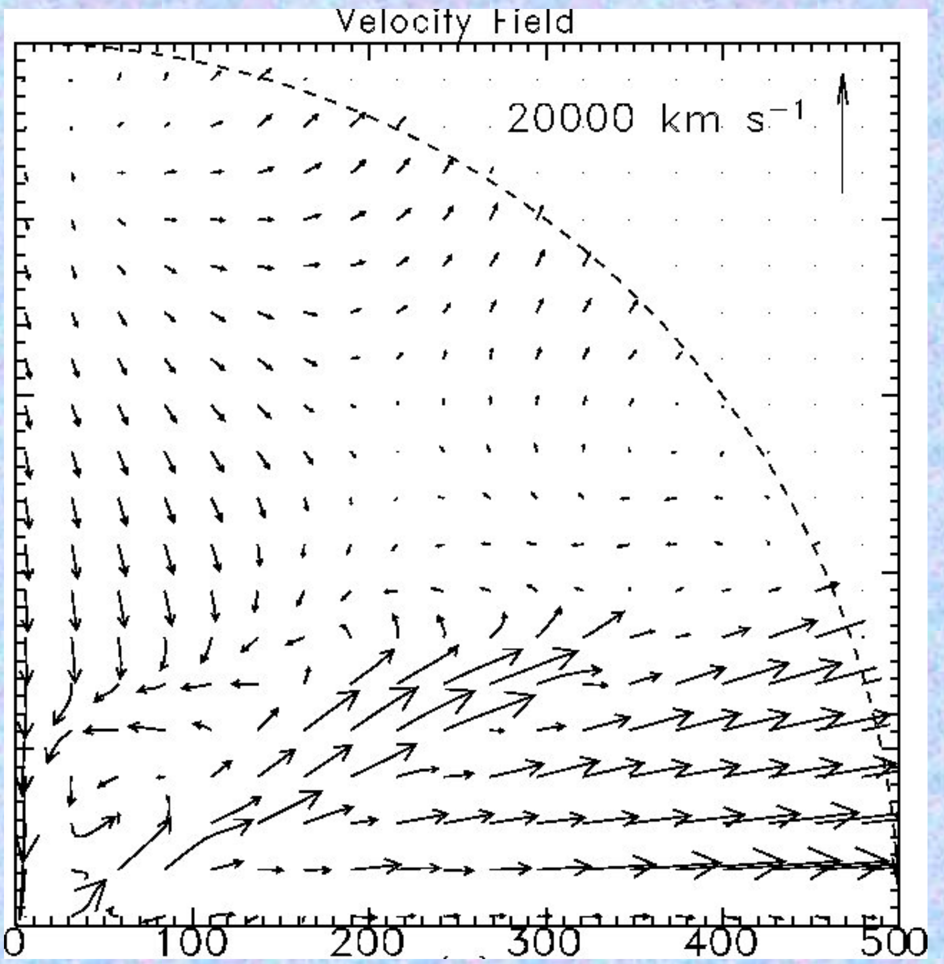
- Radiation pressure doesn't work
- Magneto-hydrodynamics?
- Failed jets?

New Physics

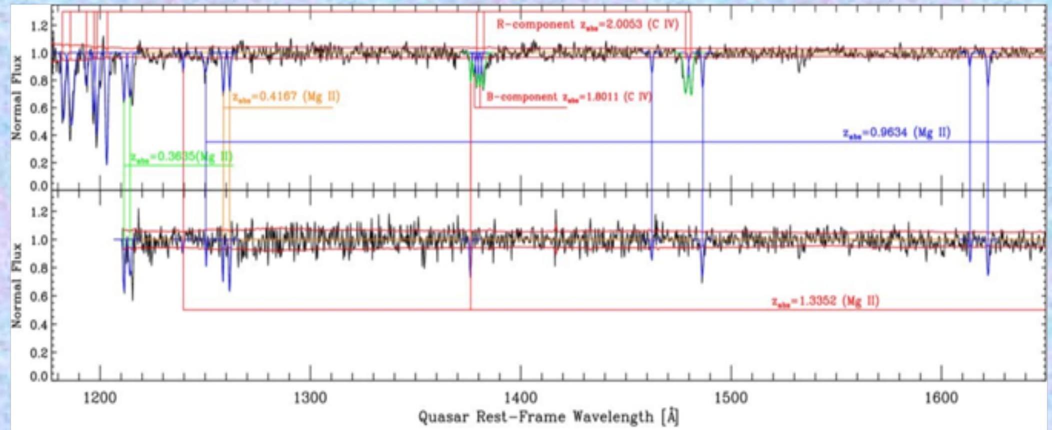
Thank You

Disk-wind models of AGNs

Proga & Kallan 2004

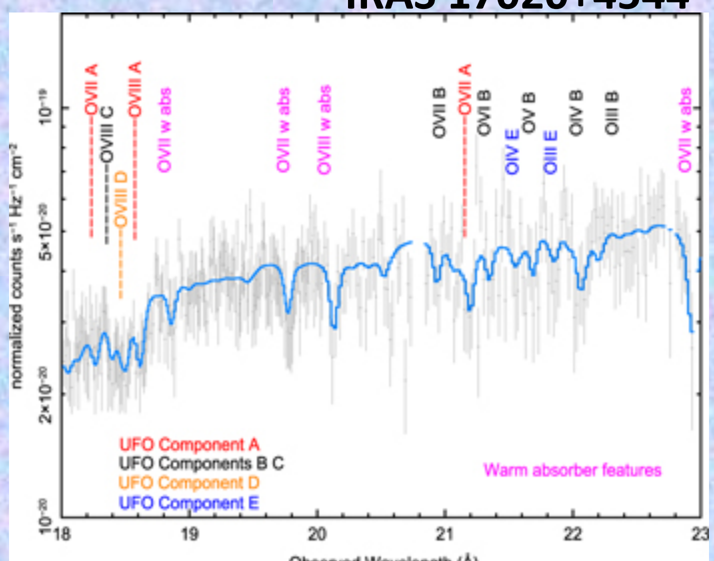


SDSS J095254.10+021932.8



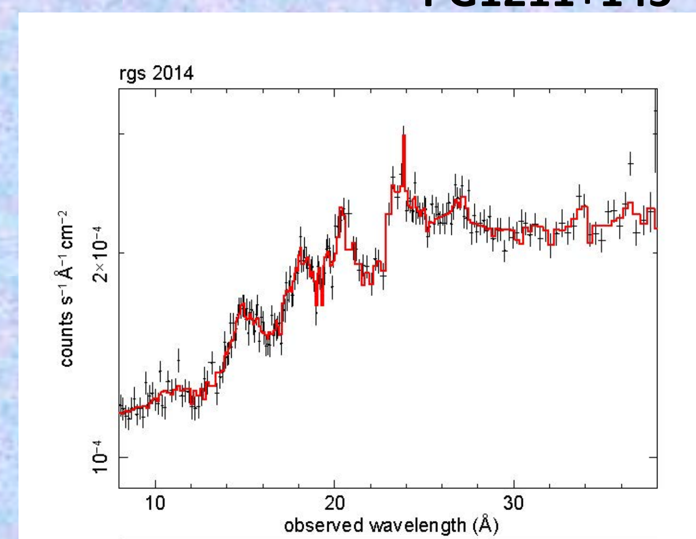
Chen+2013

IRAS 17020+4544



Longinotti+2015

PG1211+143



Pounds+2016

Theoretical Models

- King (2012) shock wind models produce winds with velocities v~0.1c, but in quasars accreting at Eddington limits. In this model a high velocity ionized outflow collides with the ISM of the host galaxy, losing much of its energy by efficient cooling resulting in a strongly shocked gas.

- The magneto-hydrodynamic accretion-disk wind models of Fukumura et al. (2010a;b) predict high-velocity ($v_{out} \leq 0.6c$) outflows. These models, how-ever, explain only the high-ionization high-velocity outflows, similar tothose observed byTombesi et al. (2012). In these models, ultra-high velocities are produced when UV to X-ray spectral slope is steep ($\alpha OX \leq -2$), i.e. the AGNs are relatively UV bright (or X-ray faint).

What is the distance of the absorber from the nucleus?

Proposals span a factor of > 10^6

from accretion disk to Kpc scale

narrow line region

$n R^2$

Variability

Density → Distance

$$t_{eq}^{x^i,x^{i+1}} \sim \left[\frac{1}{\alpha_{rec}(x^i,T_e)_{eq}\;n_e}\right] \times \left[\frac{1}{[\alpha_{rec}(x^{i-1},T_e)/\alpha_{rec}(x^i,T_e)]_{eq} + [n_{x^{i+1}}/n_{x^i}]}\right]$$

XMM Observations of NGC 4051

- RGS → High resolution spectrum
- EPIC → Variability

Krongold et al. 2007

Energy outflow rates

Kinetic power released: ~10^{38} erg/s

c.f. bolometric luminosity: 2.5 x 10^{43} erg/s

Energy injection rate in the surrounding medium is significantly smaller than that in feedback models

Scannapieco
Silk