COLUMBUS STATE
COMMUNITY COLLEGE

Discovery of Relativistic Outflows in the Seyfert Galaxies Ark 564 and Mrk 590

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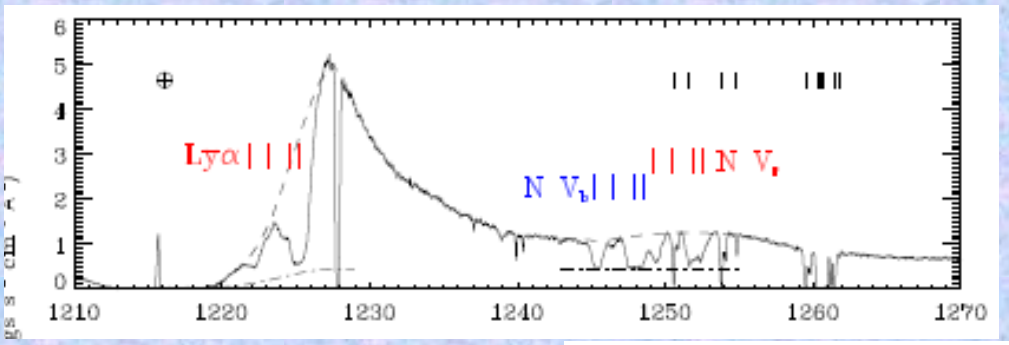
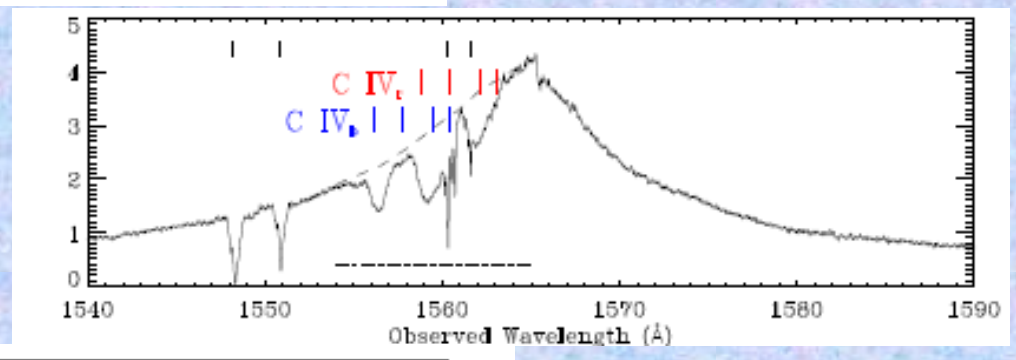
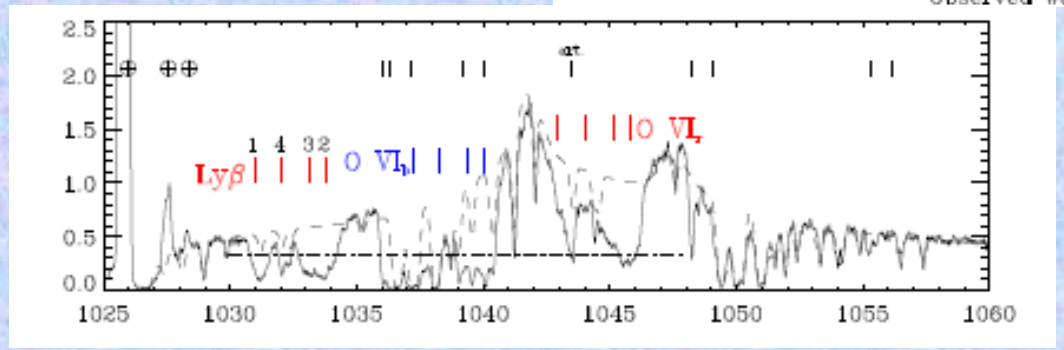
The X-ray Universe 2014, Trinity College Dublin, Ireland

Low velocity outflows are ubiquitous

Seen in 50% of Seyfert galaxies.

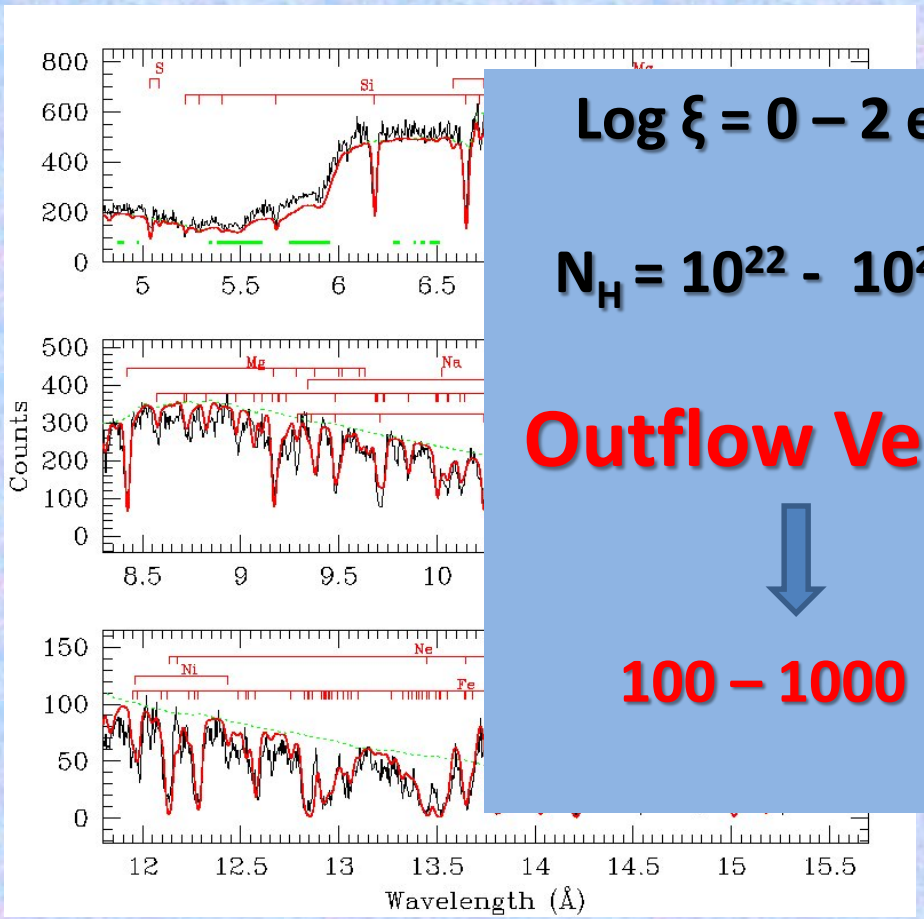






NGC 3783 HST and FUSE

Warm Absorbers

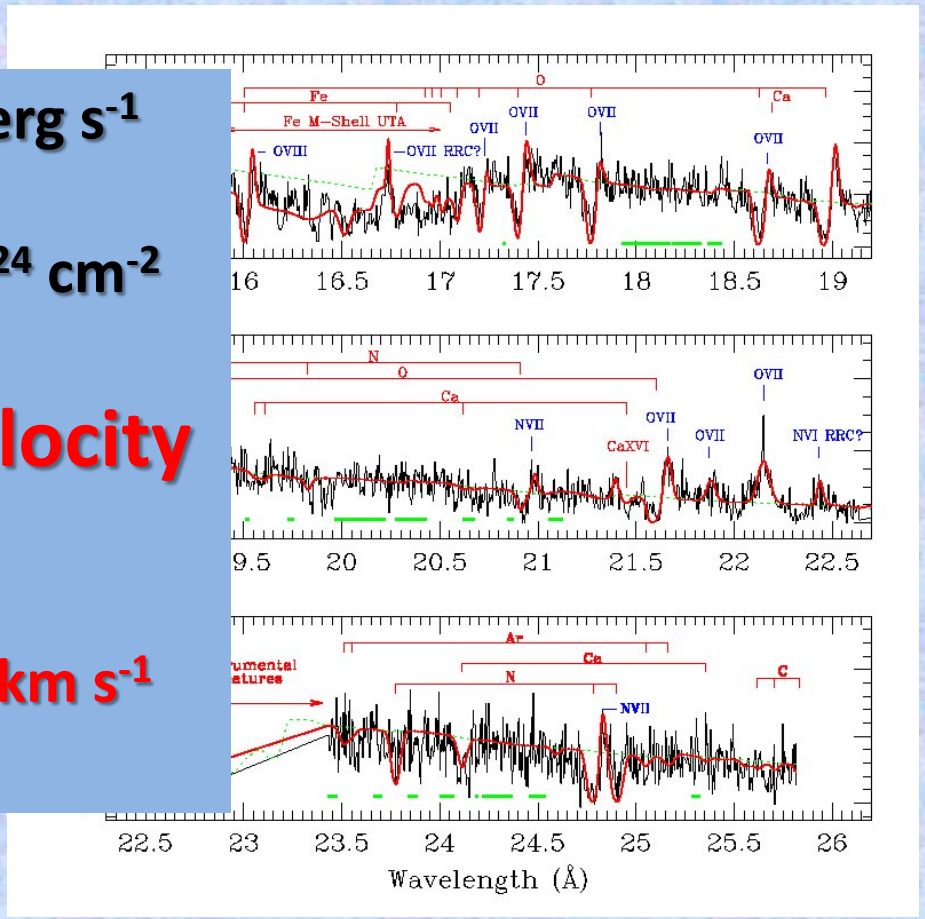


$\text{Log } \xi = 0 - 2 \text{ erg s}^{-1}$

$N_H = 10^{22} - 10^{24} \text{ cm}^{-2}$

Outflow Velocity

100 – 1000 km s^{-1}



Krongold et al. 2003

Do outflows carry sufficient energy and momentum to be effective agents of feedback?

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

Two-Phase Absorber

- **HIP: a high ionization parameter component: O VIII; Ne X**
- **LIP: a low ionization parameter component: Fe UTA, UV lines**
- **In pressure equilibrium**

Krongold et al.2003; Netzer et al. 2003

Energy outflow rates

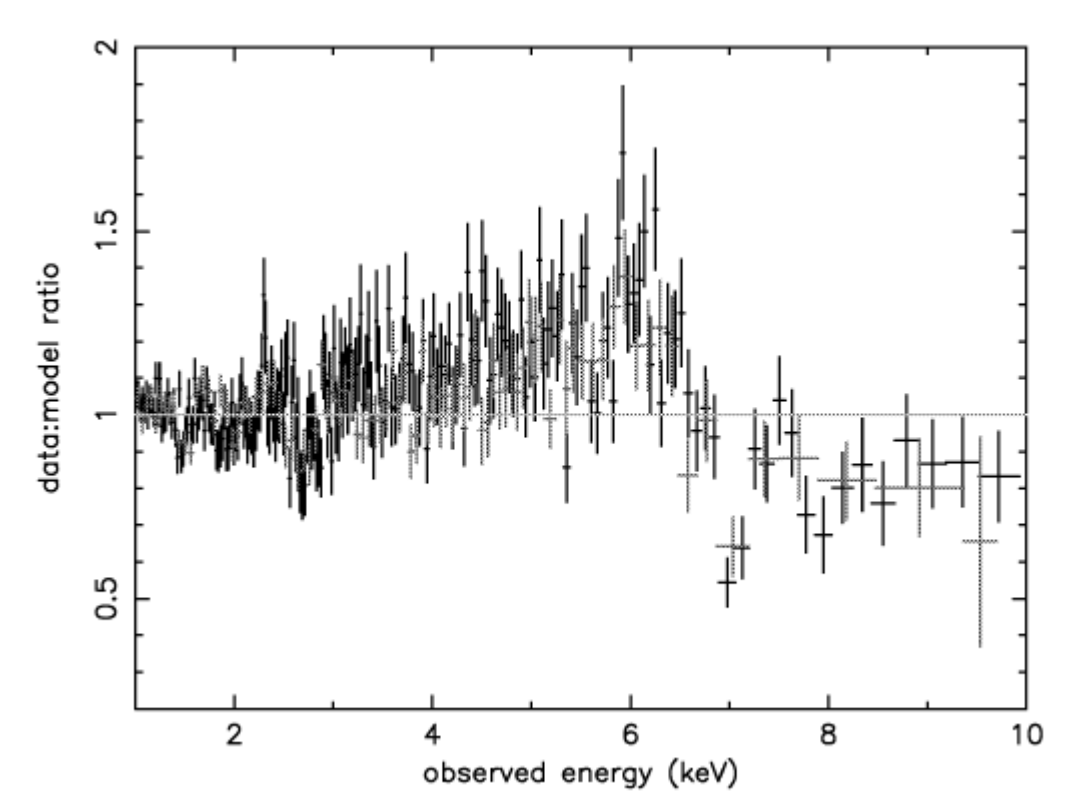
Kinetic power released: ~10^{38} erg/s

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

Discovery of UFOs



$\mathrm{Log}\ \xi = 3 - 6\ \mathrm{erg\ s^{-1}}$

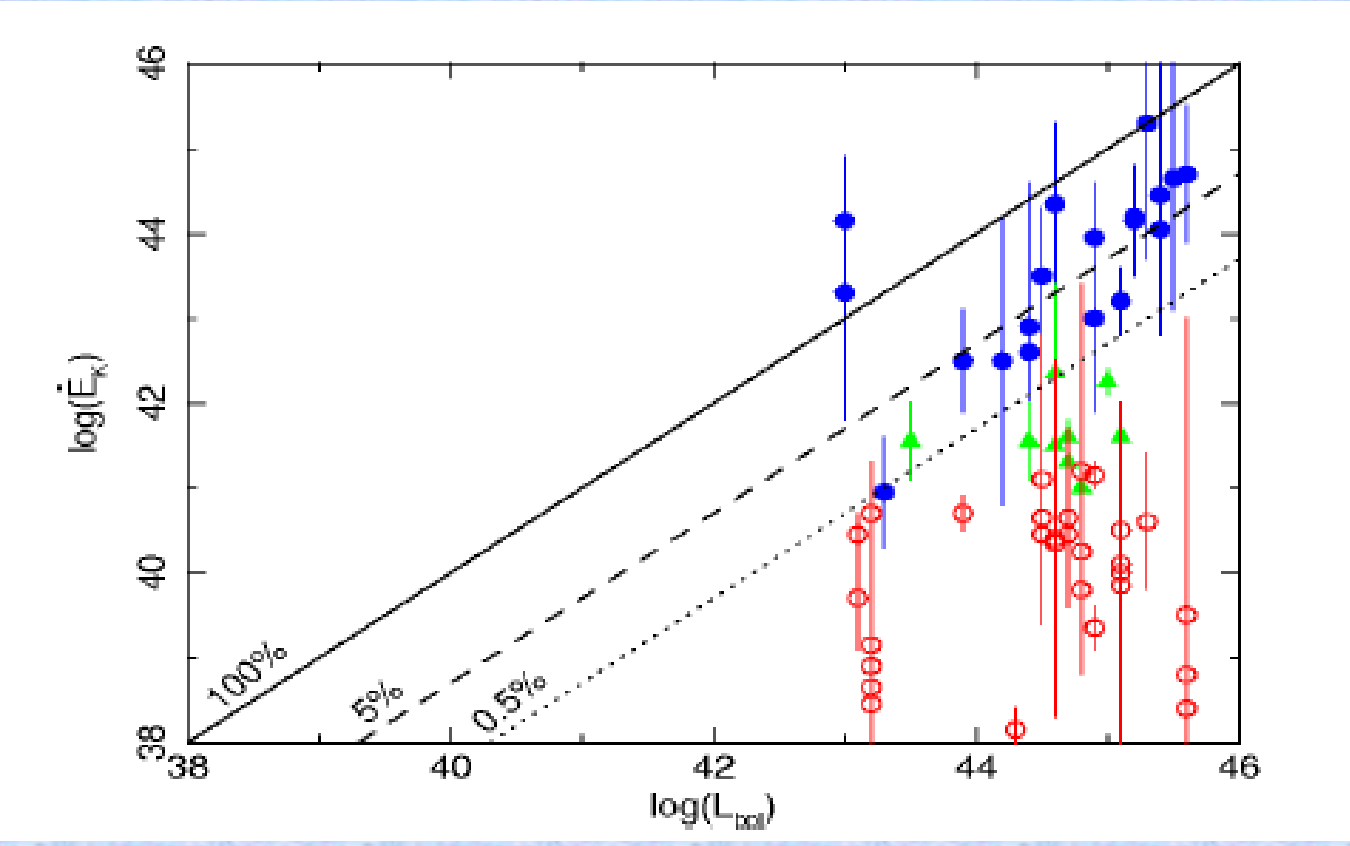
$N_H = 10^{22} - 10^{24}\ \mathrm{cm^{-2}}$

Outflow Velocity

0.1c – 0.3c

In PG1211+143: Pounds et al. 2003

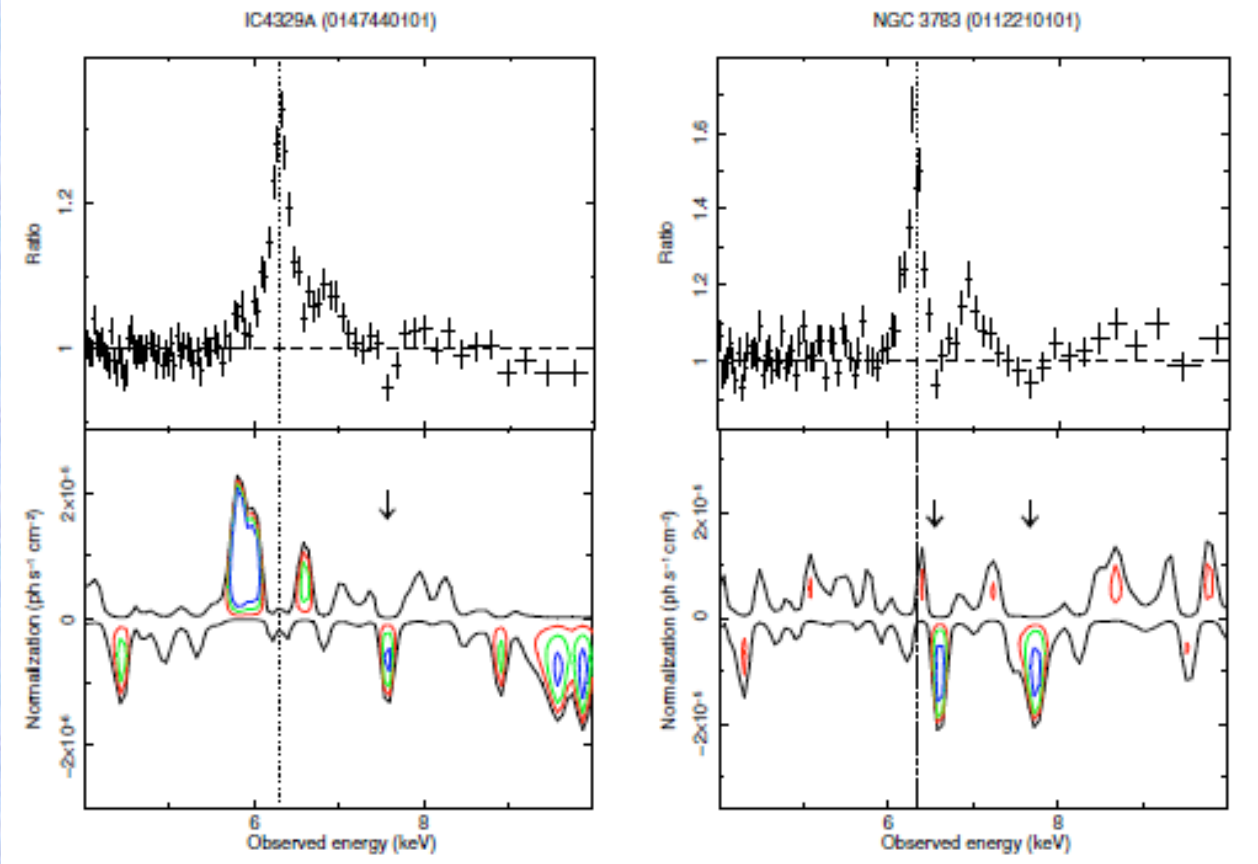
Kinetic Luminosity



- Warm Absorbers
- UFOs

From Tombesi et al. 2013

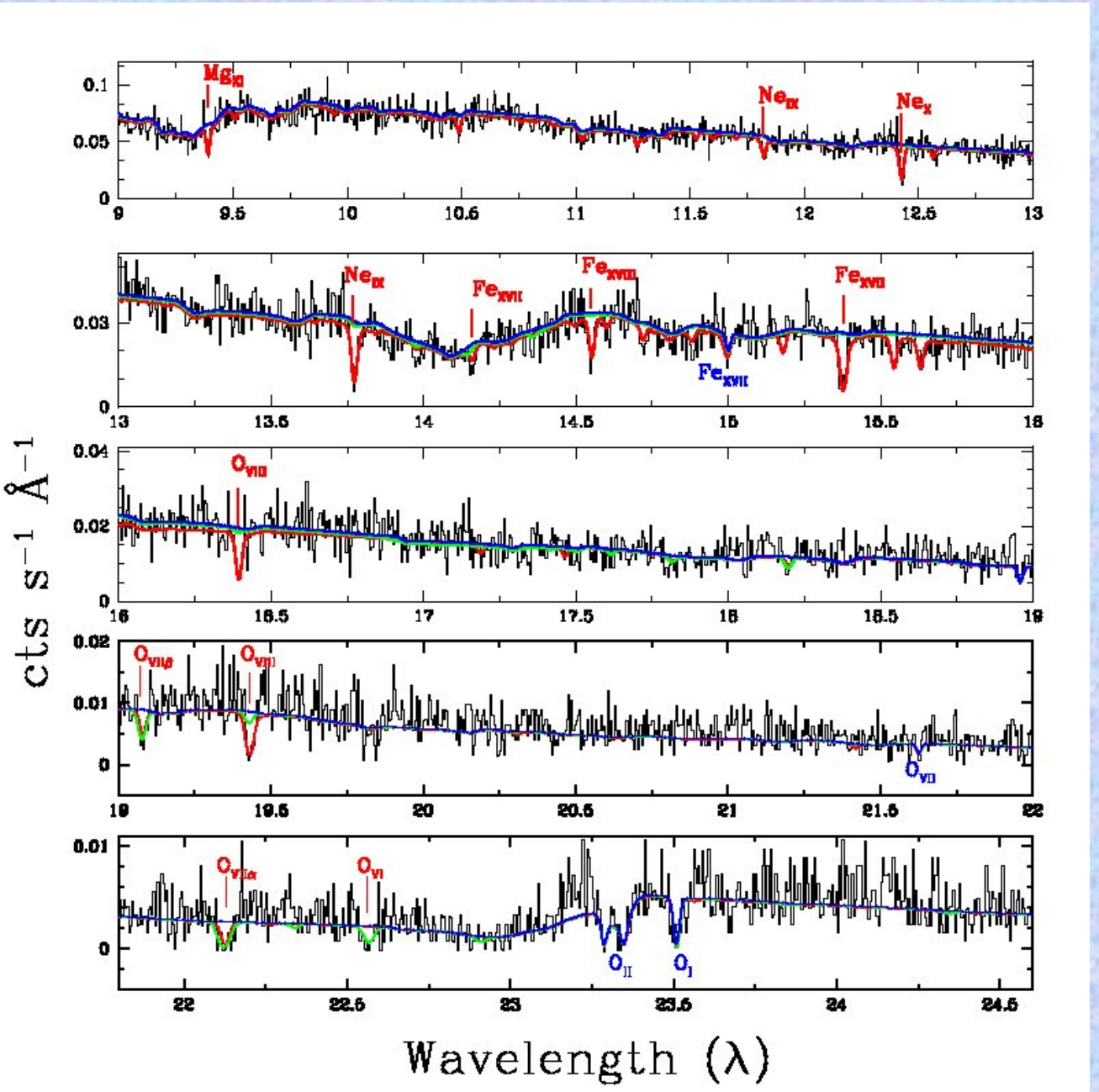
UFOs

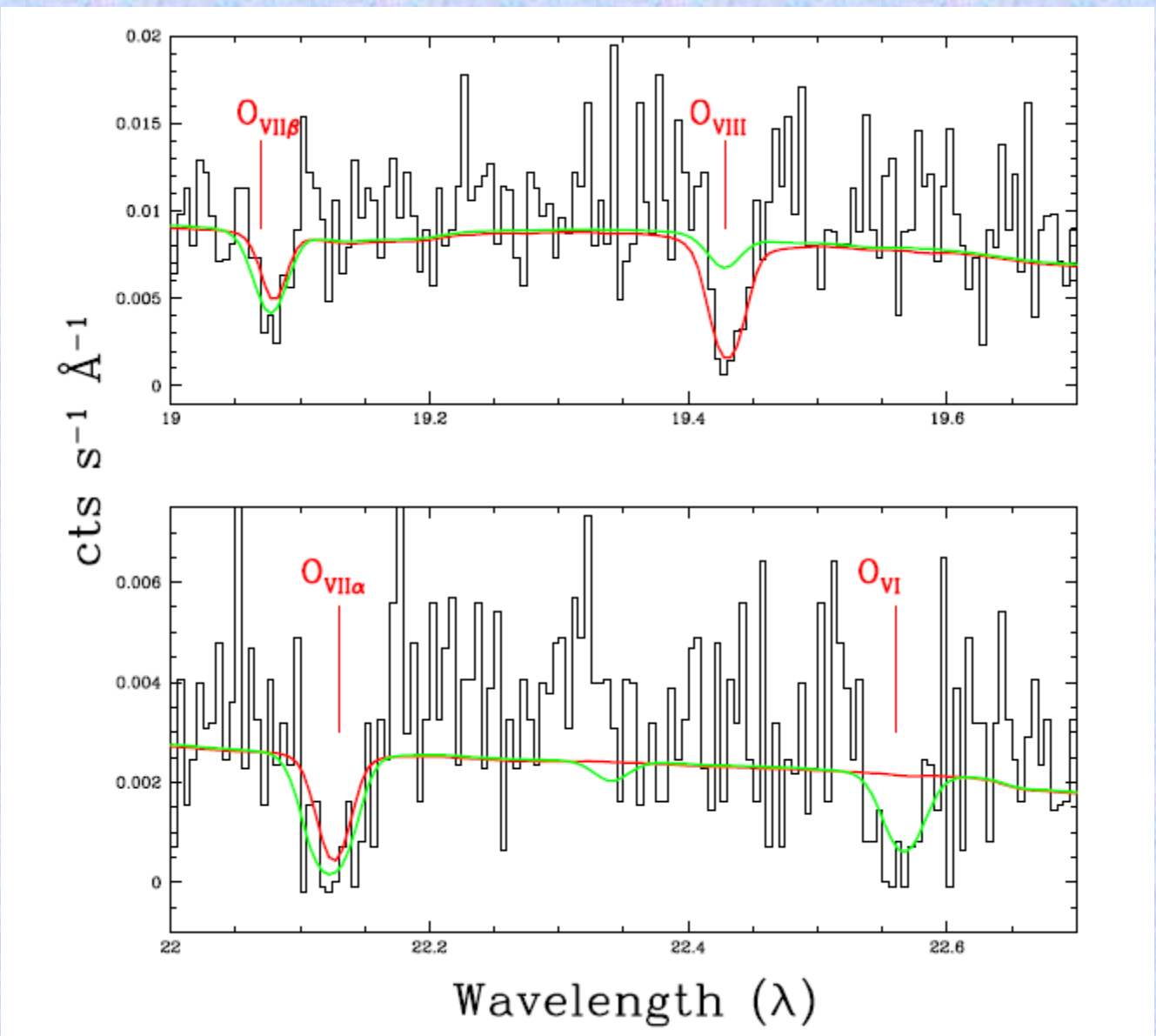


----- all in low resolution CCD spectra.

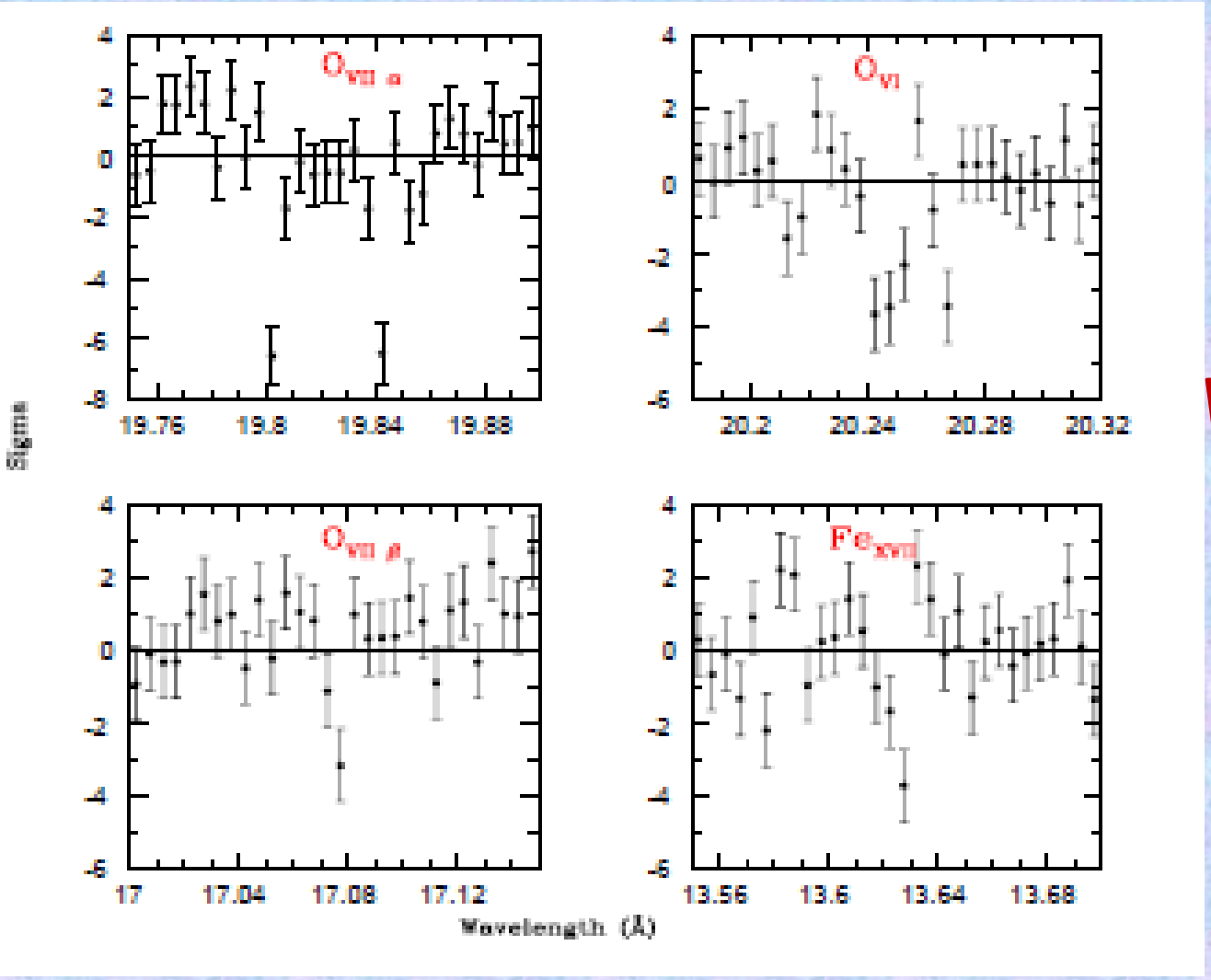
Tombesi et al. 2010

Low-velocity outflow in Ark 564

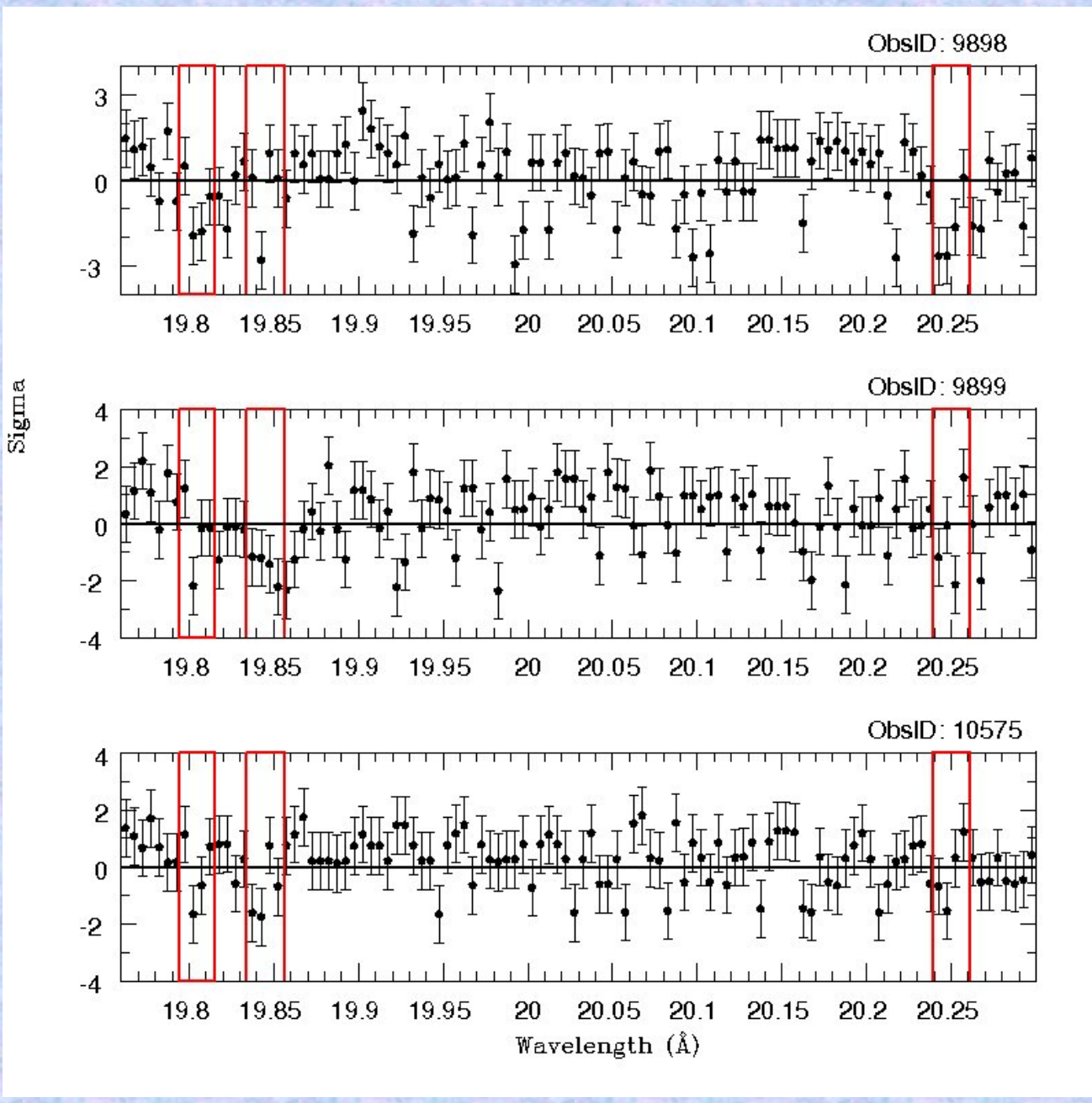



0.02
0.015
0.01
0.005
0
19
19.2
19.4
19.6
$O_{VII\beta}$
O_{VIII}
0.006
0.004
0.002
0
22
22.2
22.4
22.6
$O_{VII\alpha}$
O_{VI}
cts s^{-1} Å^{-1}
Wavelength (λ)

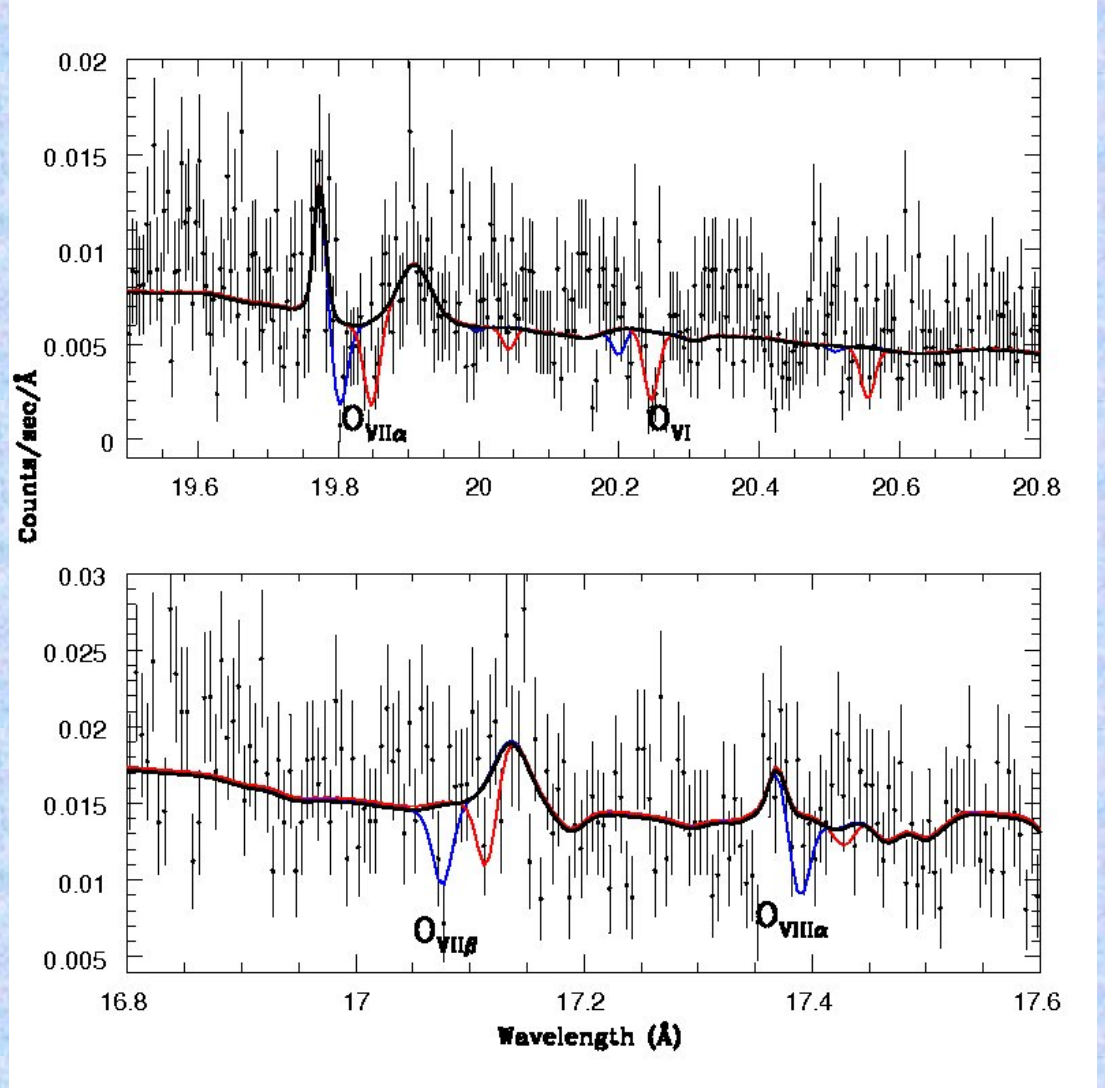
Discovery of relativistic outflow in Ark 564



Velocity = 0.1c


ObsID: 9898
ObsID: 9899
ObsID: 10575
Sigma
Wavelength (Å)
19.8
19.85
19.9
19.95
20
20.05
20.1
20.15
20.2
20.25

….well fit with photoionization model



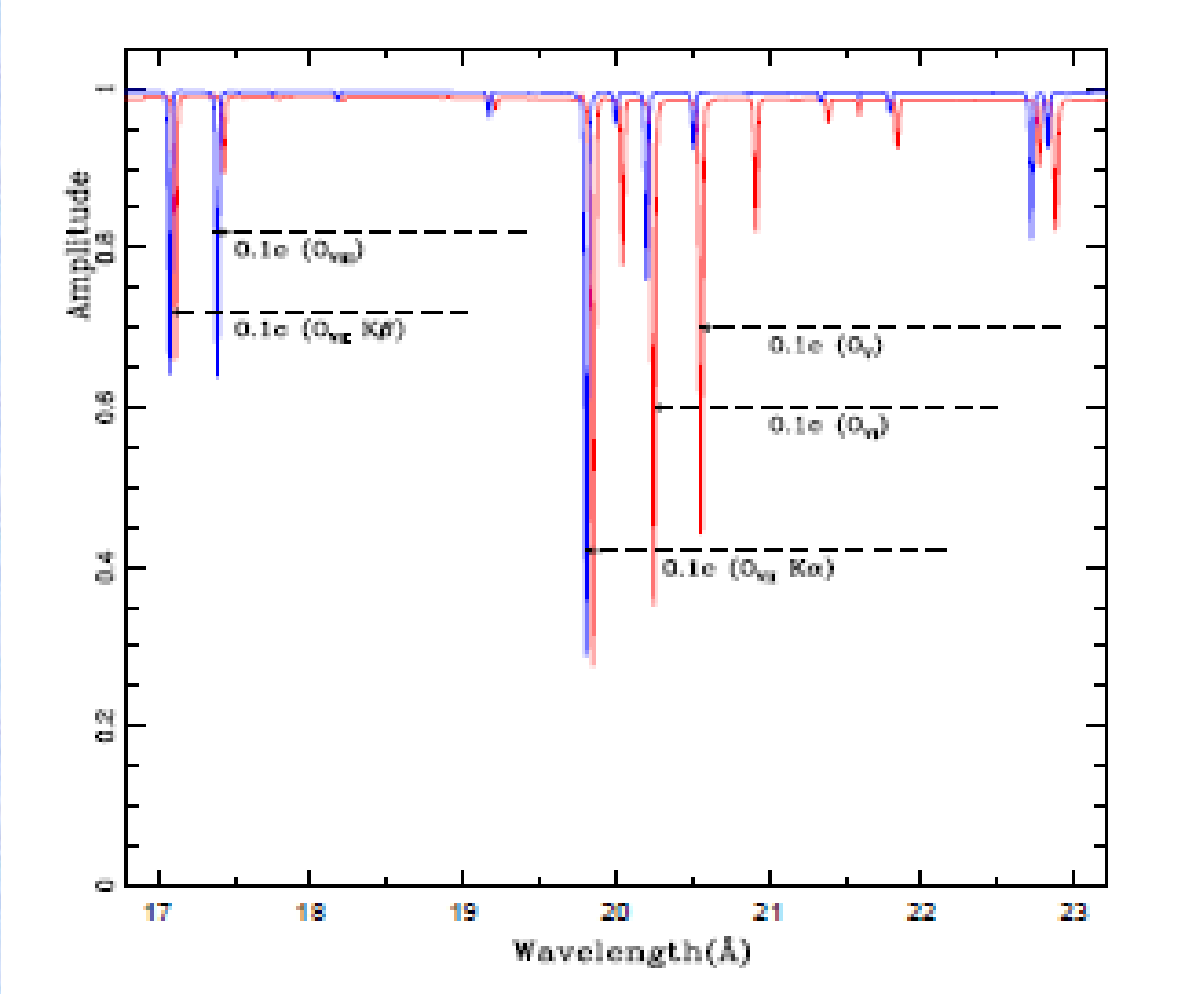
Log ξ = 1.25/0.65 erg s^{-1}

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

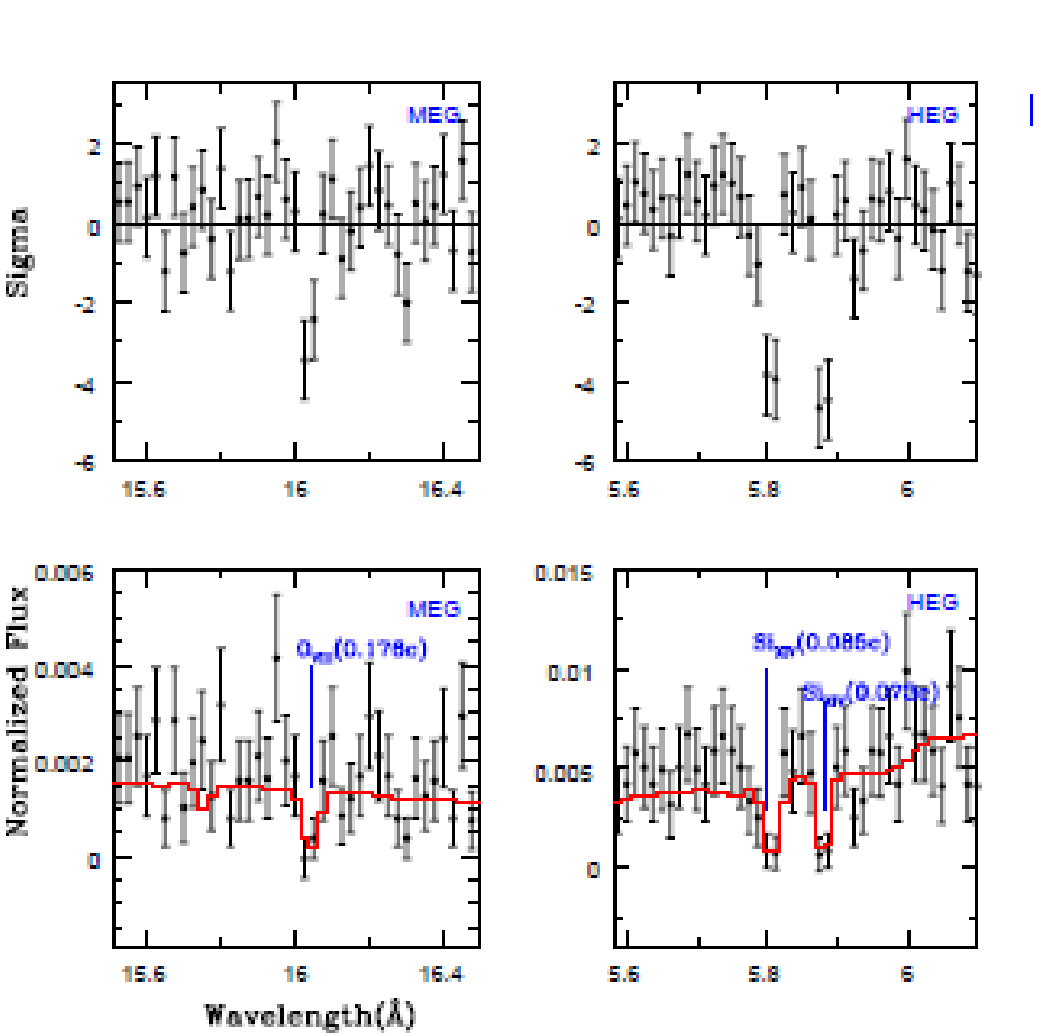
Outflow Velocity

0.108c/0.106c

Two component photoionization model

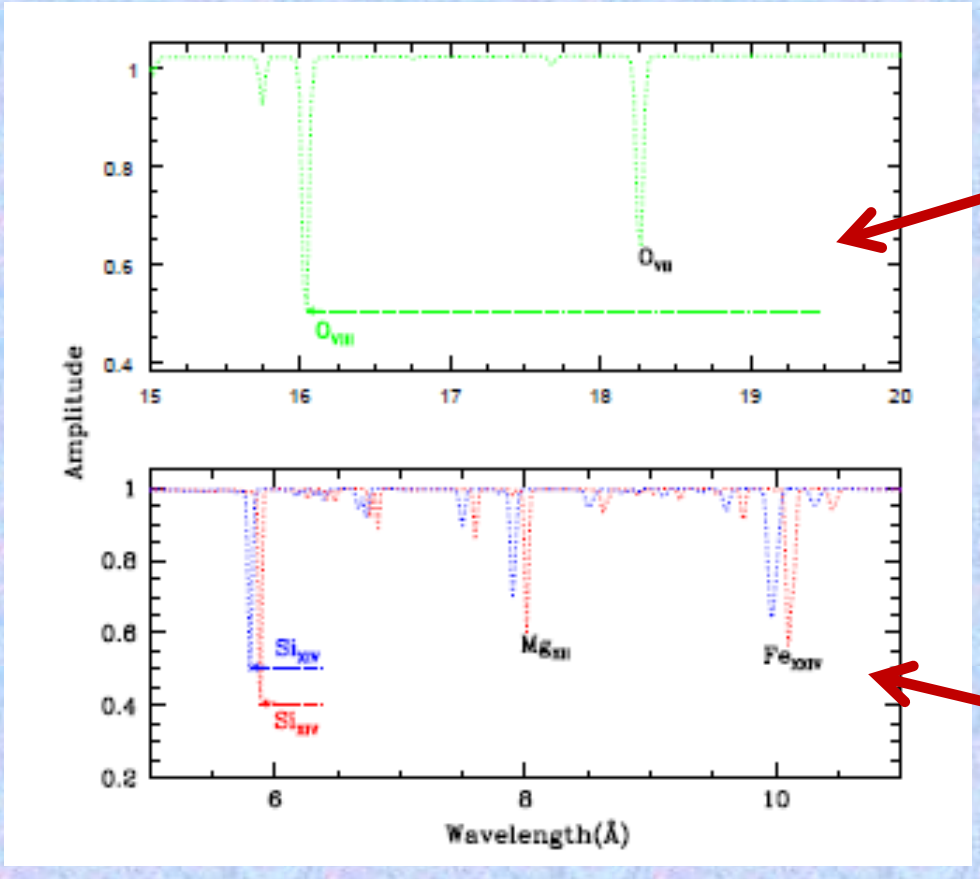


Relativistic outflow in Mrk 590?



V = 0.081c - 0.176c

….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

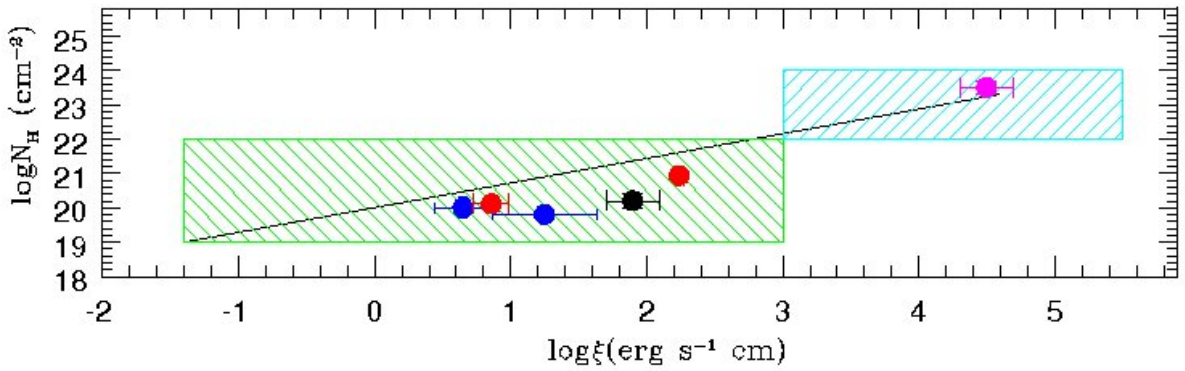
HV-HIP Kinetic luminosity > 10^{44} erg/s

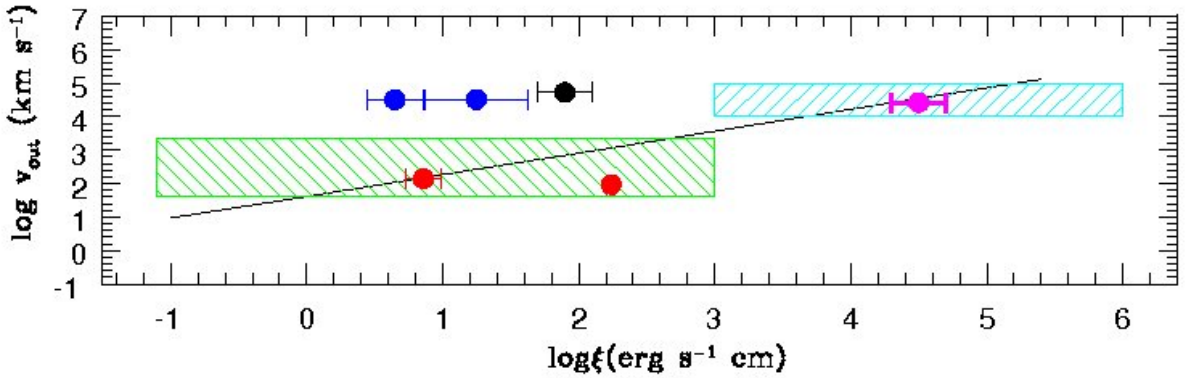
c.f. X-ray luminosity: 7.0 x 10^{42} erg/s

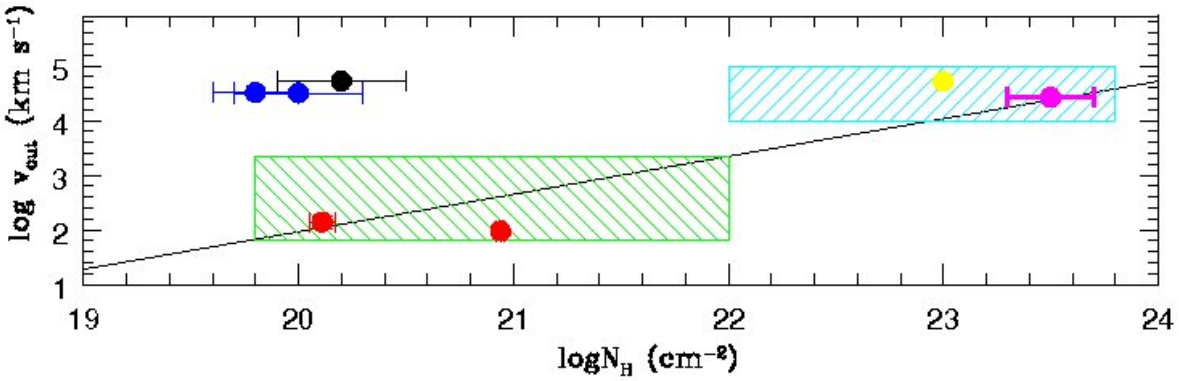
This IS a remarkable discovery!

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

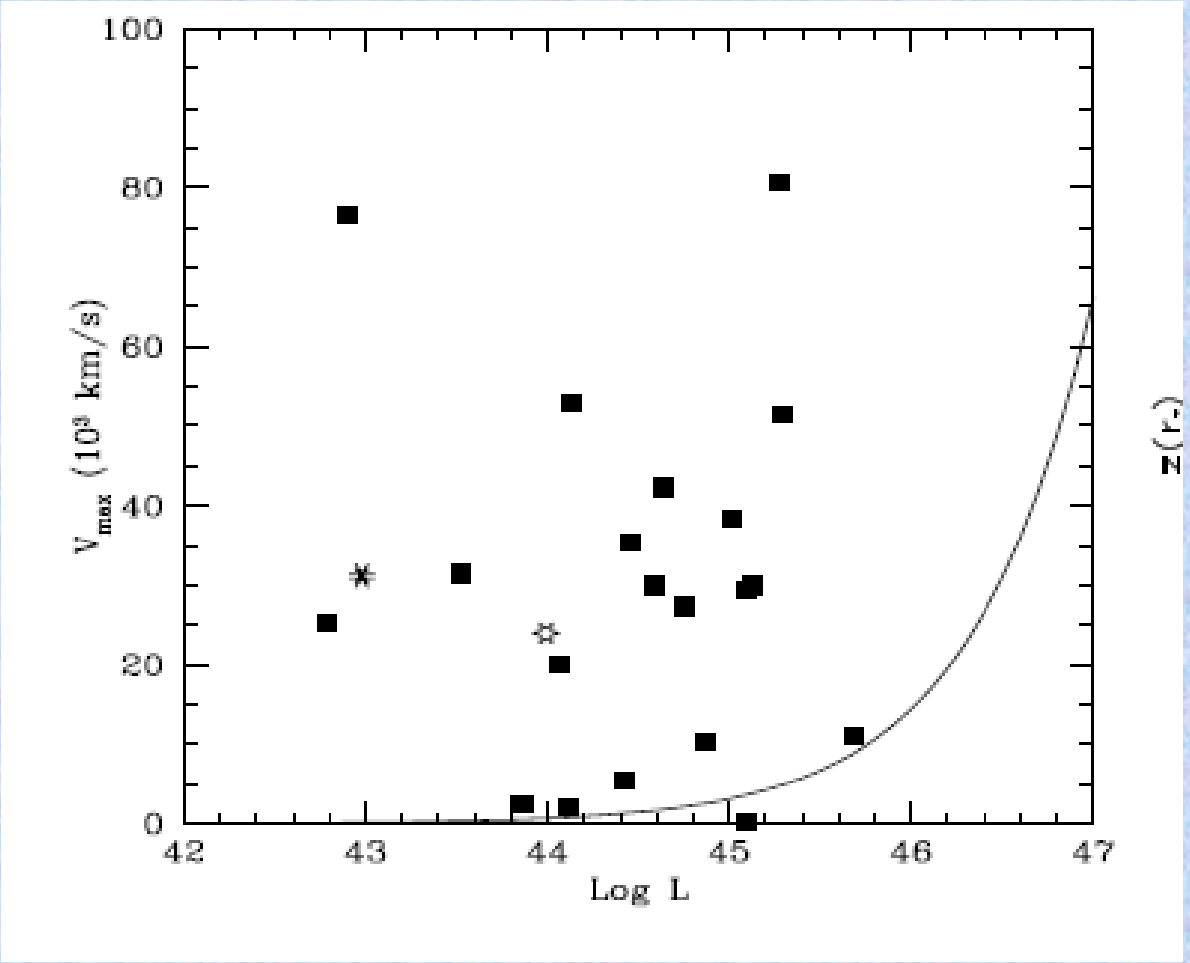
…..WA and UFO connection ?





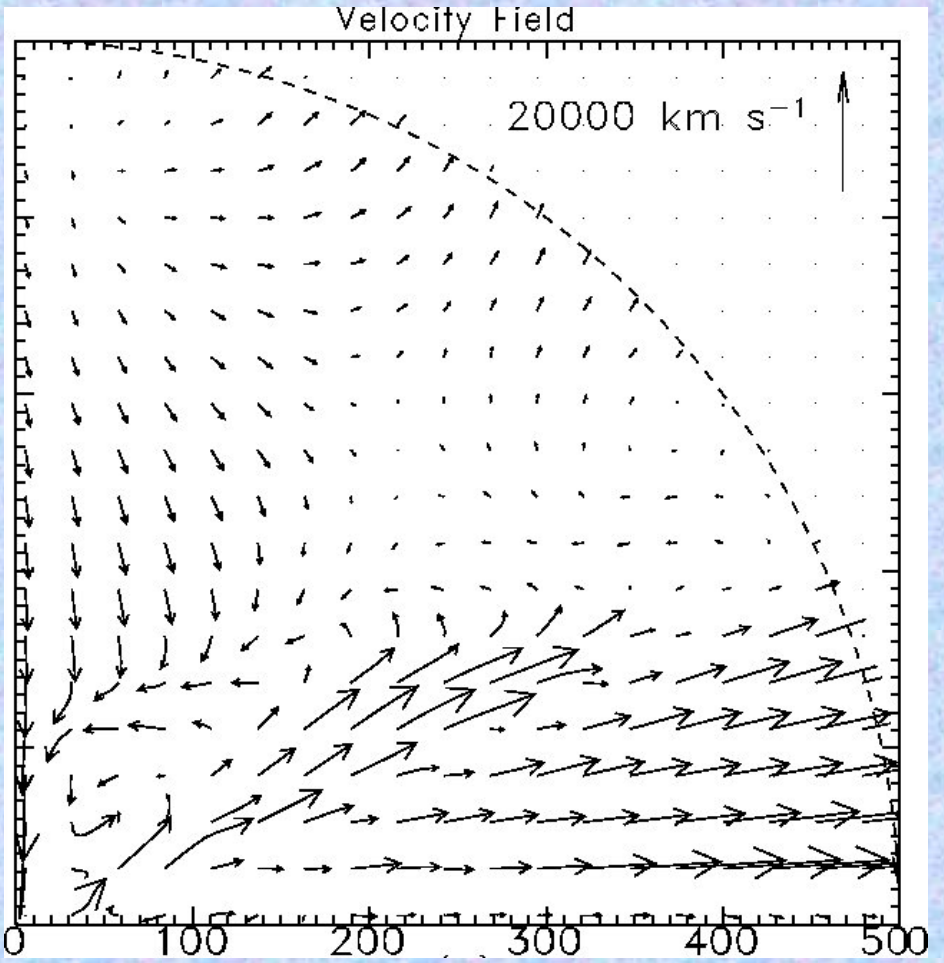


….unlike other AGN outflows



Disk-wind models of AGNs

Proga & Kallan 2004



What is the driving mechanism?

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

New Physics