ATHENA solution for the cooling flow problem in clusters of galaxies

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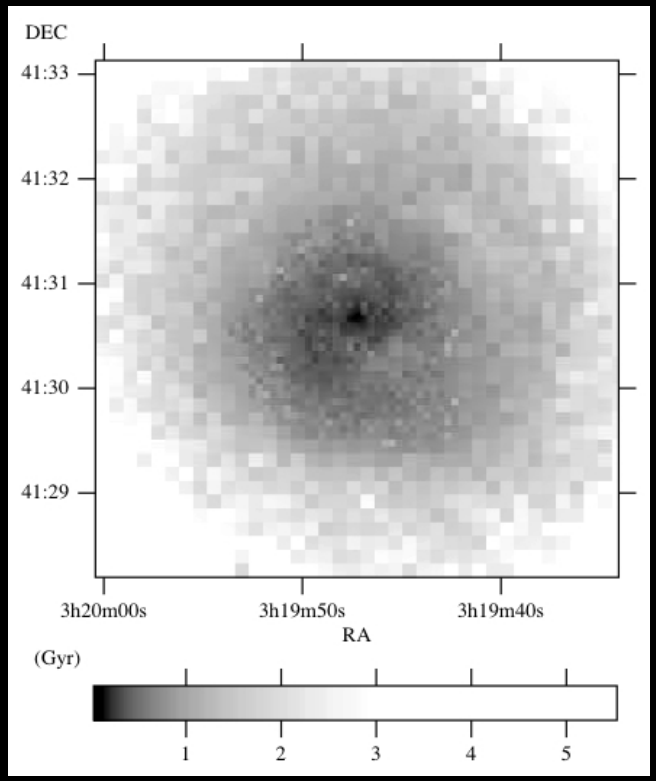
Cooling flows in clusters core

Cooling time shorter than Hubble time

→ mass deposition towards core

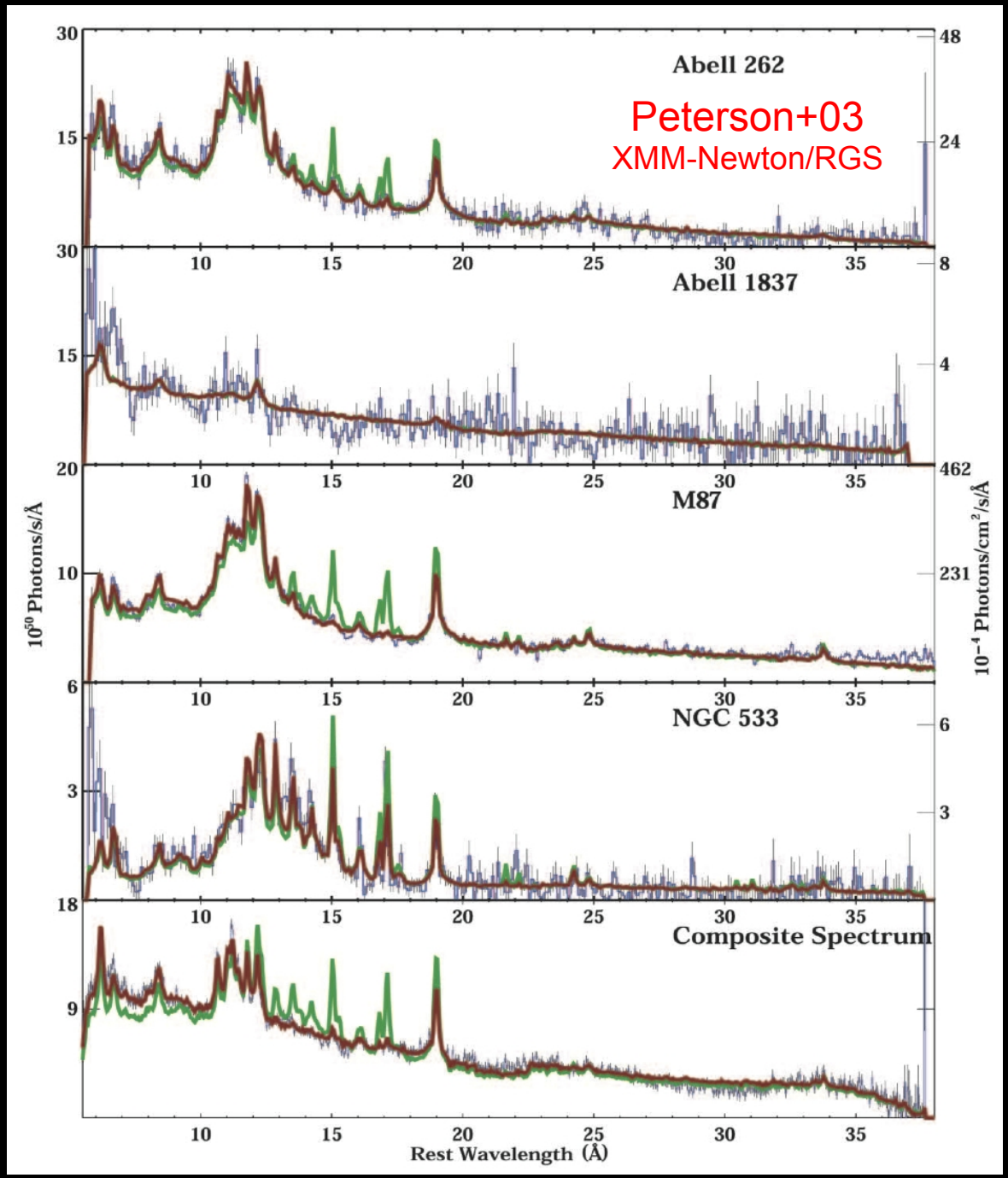
100-1000 M_{sun} yr^{-1} for clusters

0.1-1 M_{sun} yr^{-1} for ellipticals & groups



Fabian'02 – Perseus
Cooling time

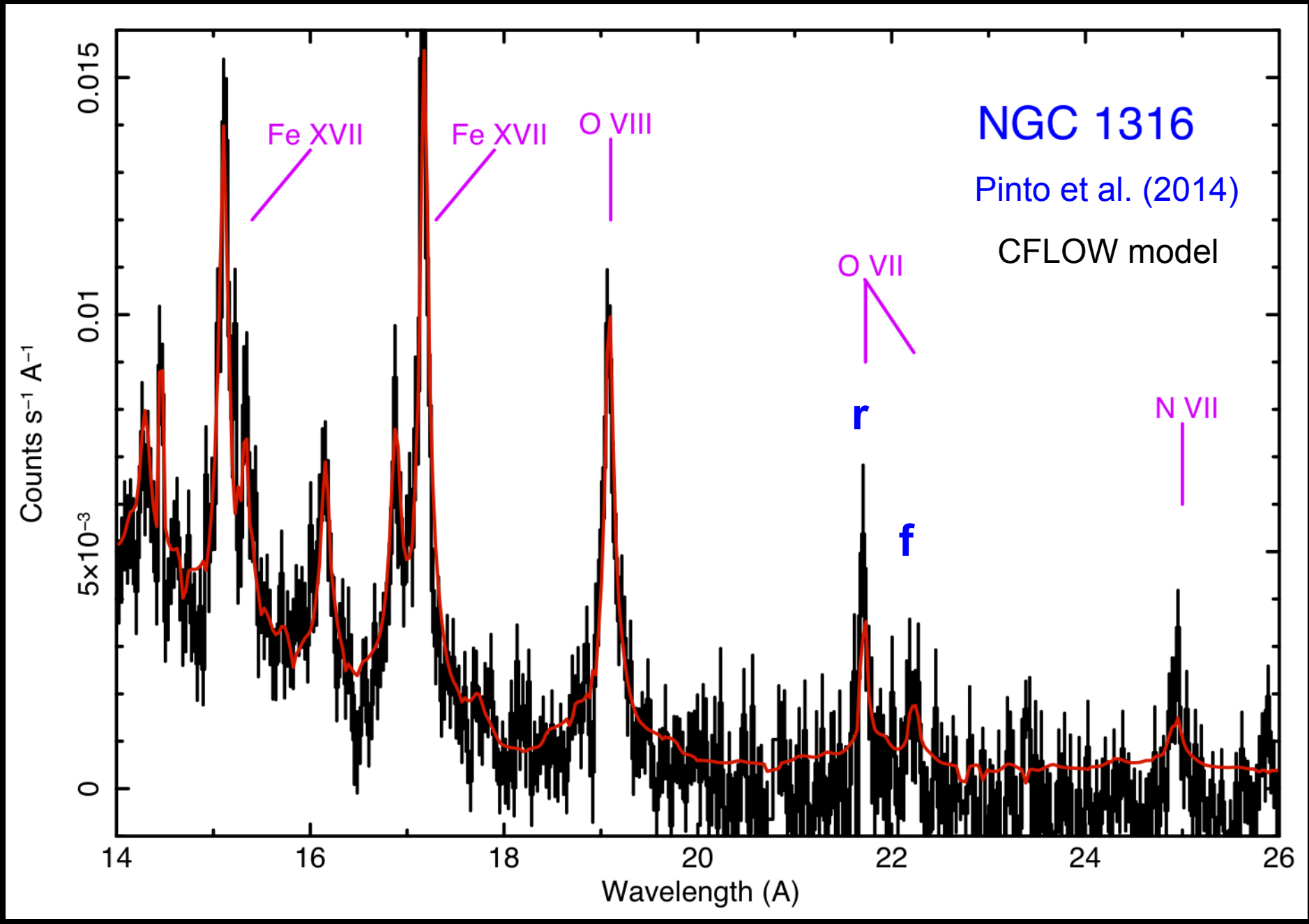
Clusters: lack of cool (< 0.4 keV) gas



Fe XVII weak,
O VII missing

- Heating ?
- Absorption ?

Ellipticals / groups: O VII cooling gas



AGN feedback may offset cooling

MS 0735.6+7421

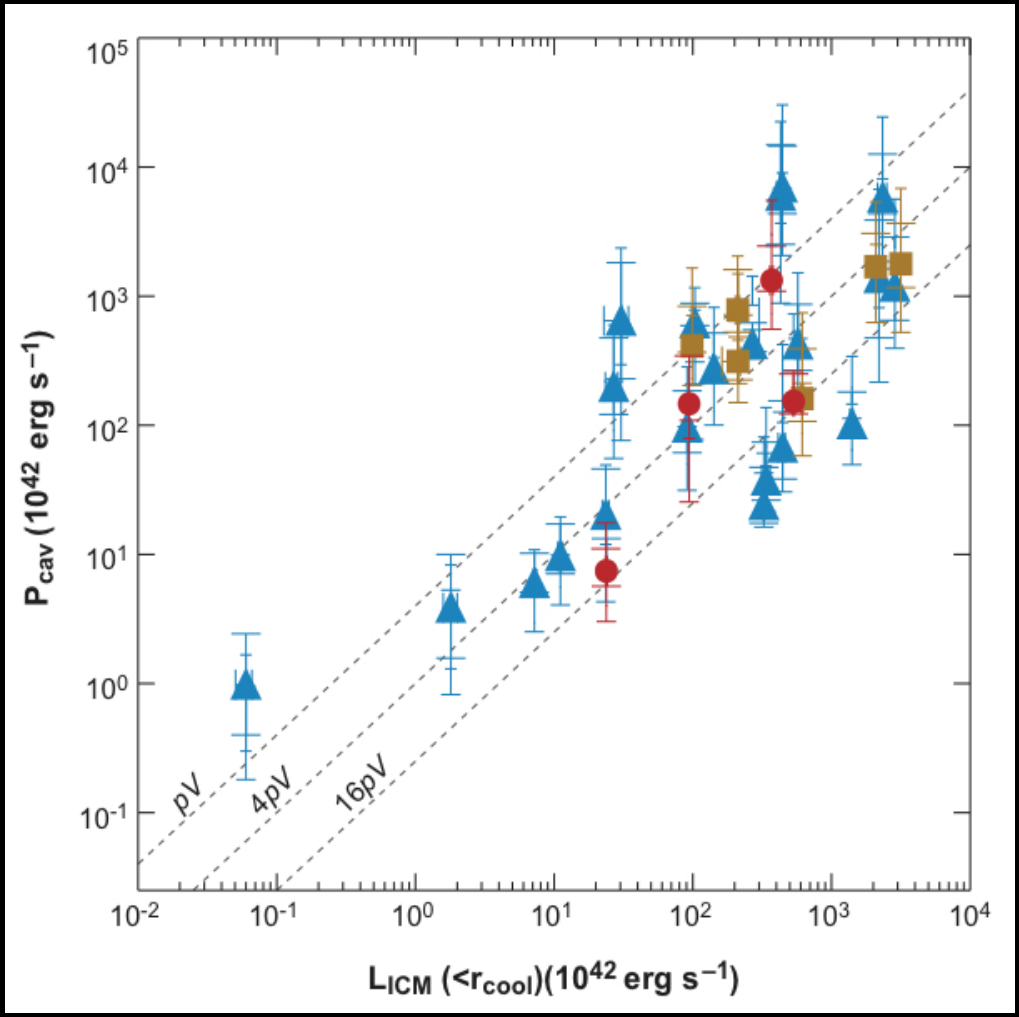
Hubble (optical) +

Chandra (X-ray) +

VLA (radio)

McNamara et al. (2005)

AGN feedback may offset cooling



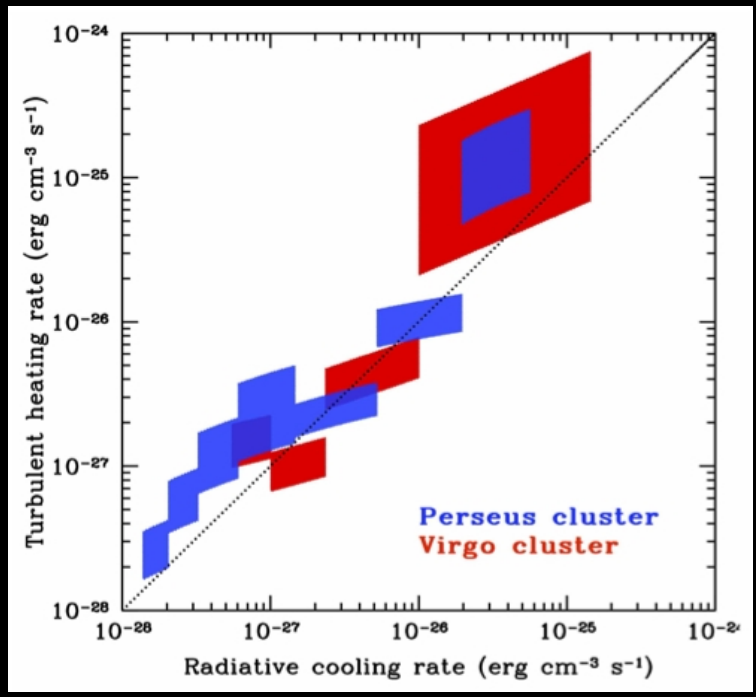
Rafferty+06: Cavity power VS ICM clusters

Energy needed to create a cavity = internal (thermal) energy + work to inflate

$$H = E + pV$$

Dissipation of Turbulence

Heating VS Cooling - Zhuravleva+14



How to measure turbulence?

1. **Line widths**
   Upper limits in most cases
   (instrumental limits – statistics)

   Sanders+13
   Pinto+15

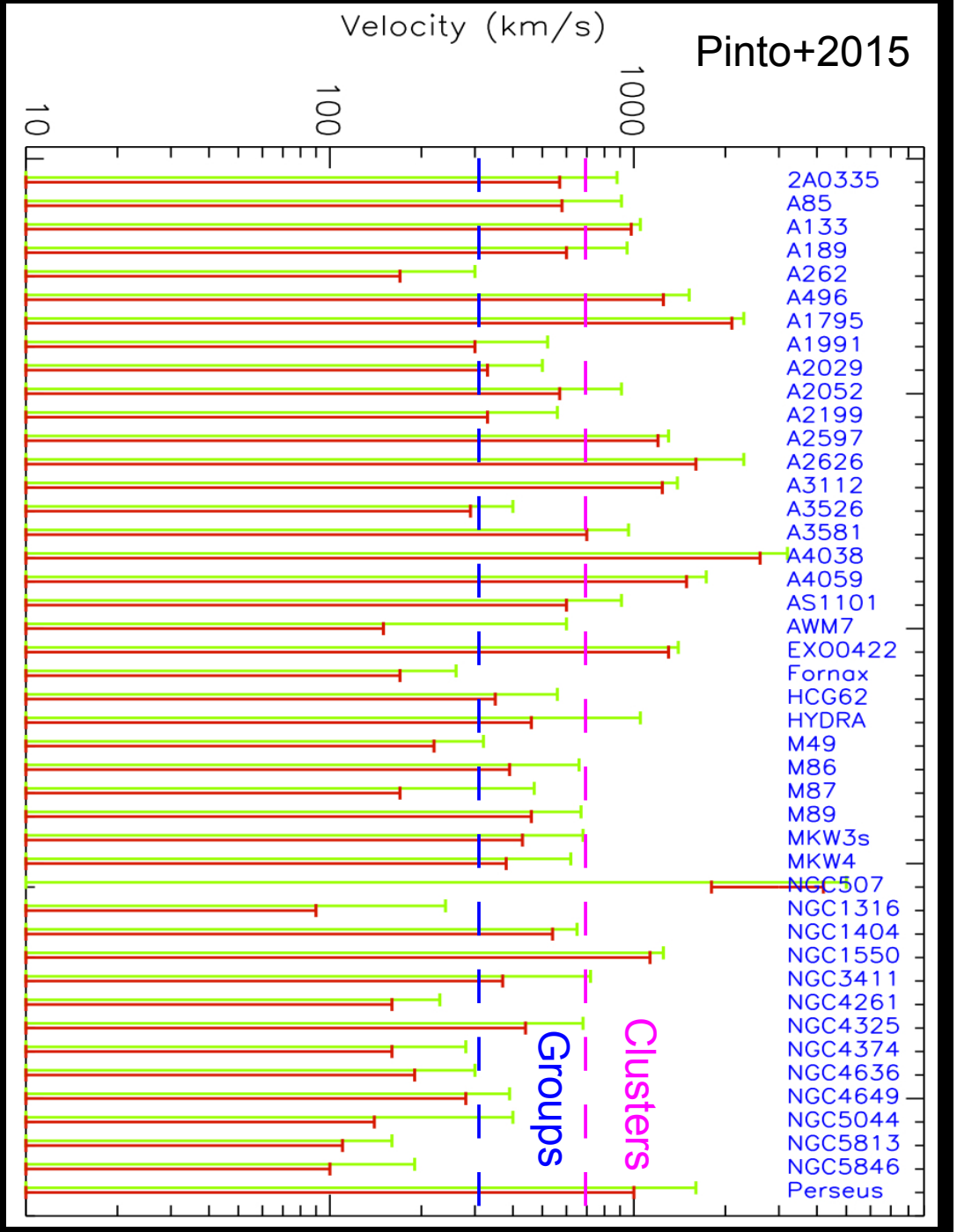
2. **Resonant scattering**
   Accurate lower limits
   (atomic data – high Mach numbers issues)

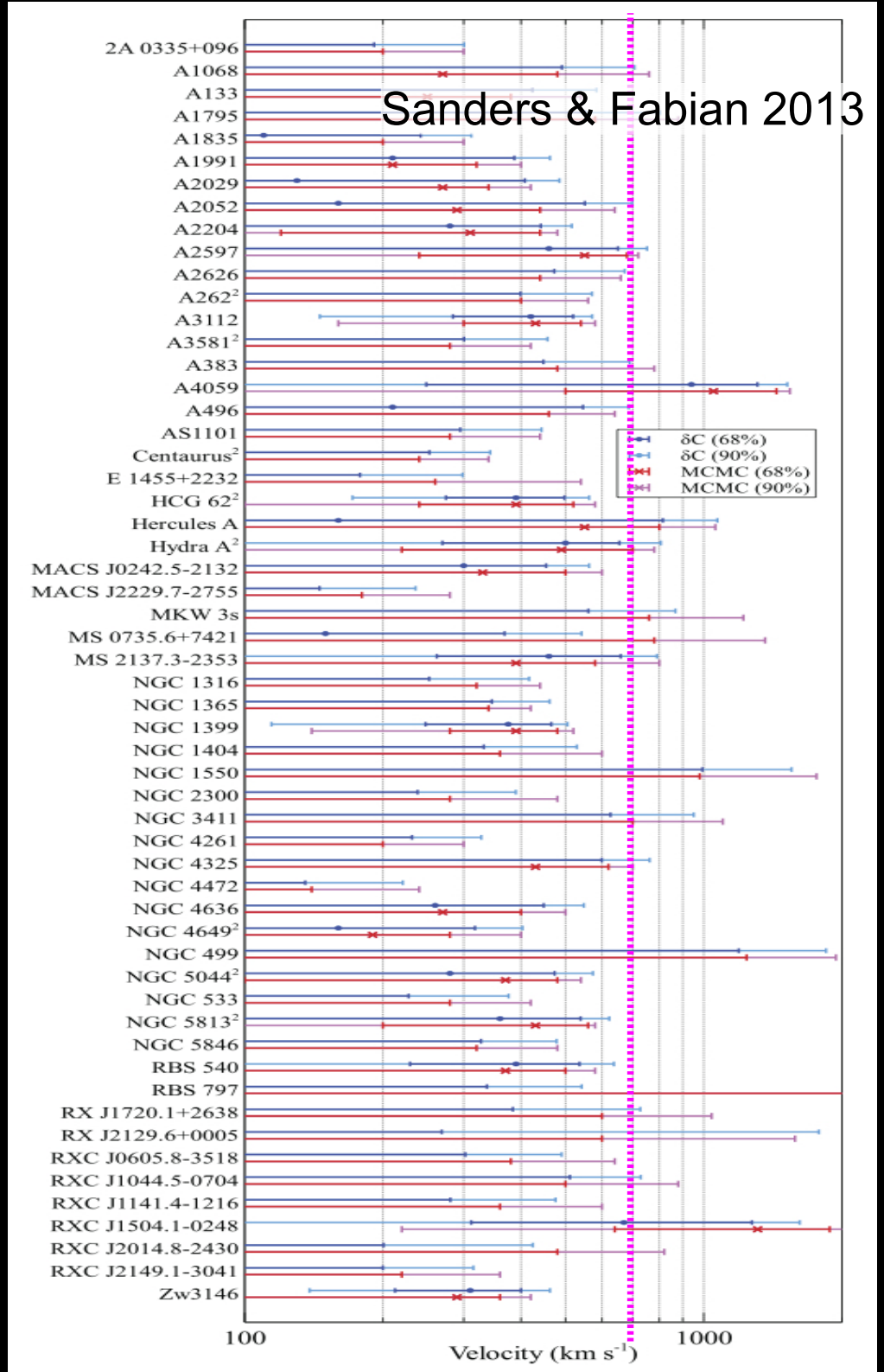
   Sanders+08
   Werner+09
   de Plaa+12

3. **Surface brightness fluctuations**
   (Substructures, theoretical models, stat.)

   Sanders+12
   Zhuravleva+14
   Walker+15

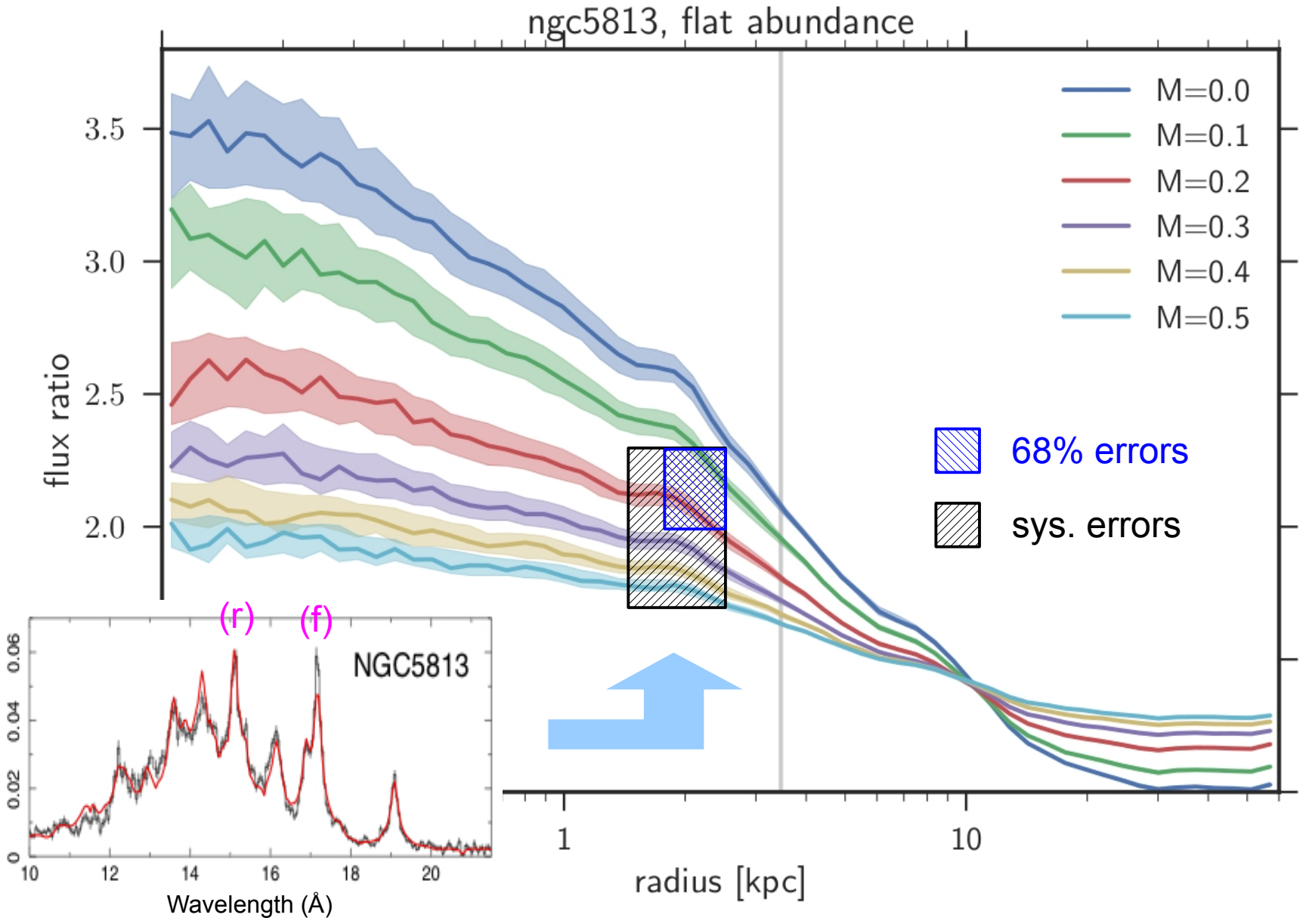
Line widths


Velocity (km/s)
10
100
1000
Pinto+2015
2A0335
A85
A133
A189
A262
A496
A1795
A1991
A2029
A2052
A2199
A2597
A2626
A3112
A3526
A3581
A4038
A4059
AS1101
AWM7
EXO0422
Fornax
HCG62
HYDRA
M49
M86
M87
M89
MKW3s
MKW4
NGC507
NGC1316
NGC1404
NGC1550
NGC3411
NGC4261
NGC4325
NGC4374
NGC4636
NGC4649
NGC5044
NGC5813
NGC5846
Perseus
Groups
Clusters

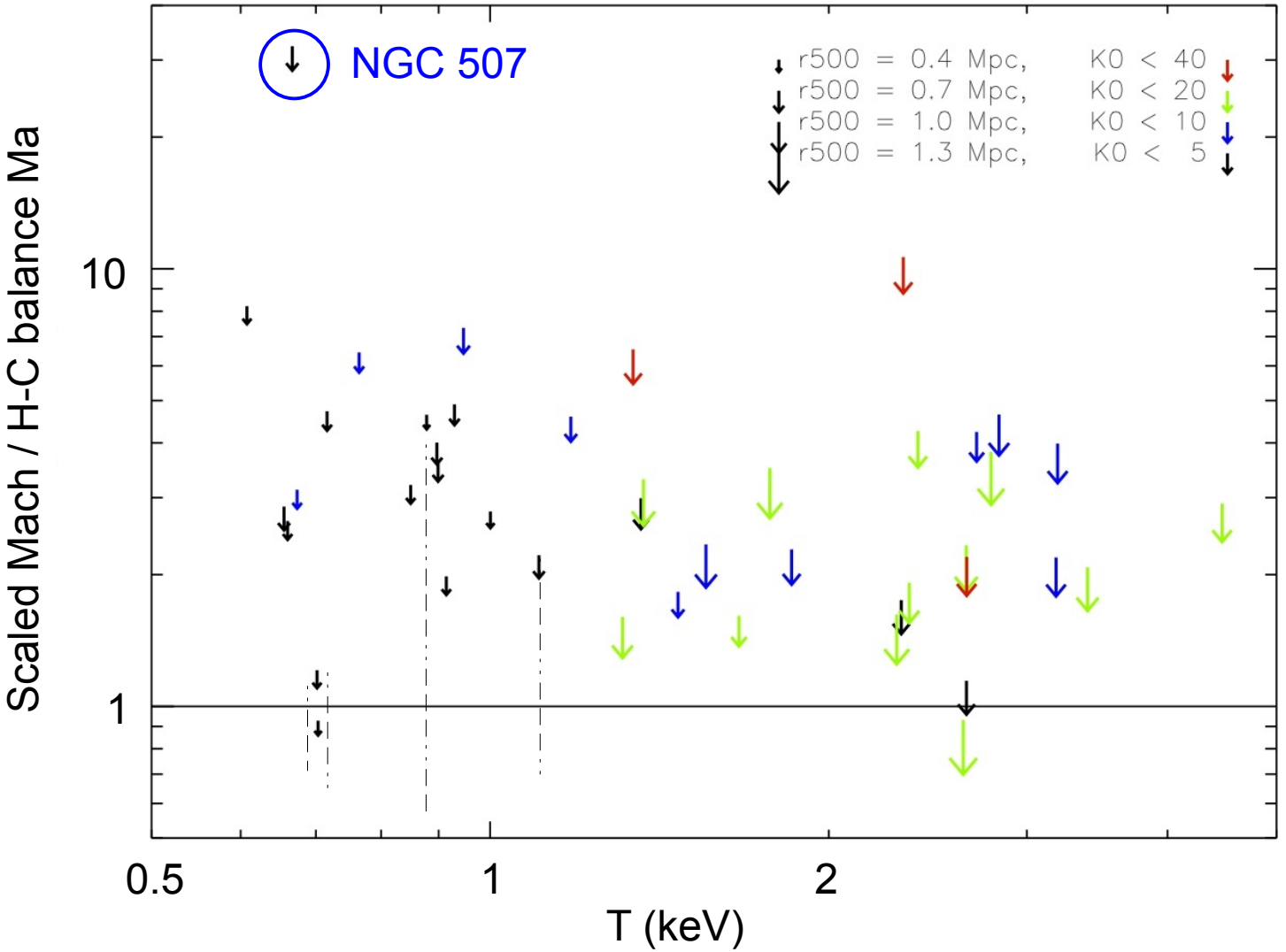

Sanders & Fabian 2013
2A 0335+096
A1068
A133
A1795
A1835
A1991
A2029
A2052
A2204
A2597
A2626
A262[2]
A3112
A3581[2]
A383
A4059
A496
AS1101
Centaurus[2]
E 1455+2232
HCG 62[2]
Hercules A
Hydra A[2]
MACS J0242.5-2132
MACS J2229.7-2755
MKW 3s
MS 0735.6+7421
MS 2137.3-2353
NGC 1316
NGC 1365
NGC 1399
NGC 1404
NGC 1550
NGC 2300
NGC 3411
NGC 4261
NGC 4325
NGC 4472
NGC 4636
NGC 4649[2]
NGC 499
NGC 5044[2]
NGC 533
NGC 5813[2]
NGC 5846
RBS 540
RBS 797
RX J1720.1+2638
RX J2129.6+0005
RXC J0605.8-3518
RXC J1044.5-0704
RXC J1141.4-1216
RXC J1504.1-0248
RXC J2014.8-2430
RXC J2149.1-3041
Zw3146
δC (68%)
δC (90%)
MCMC (68%)
MCMC (90%)
100
1000
Velocity (km s^{-1})

Resonant scattering

Fe XVII (f/r) simulations by Anna Ogorzalek & Irina Zhuravleva



Upper limits / Mach numbers required to balance cooling



Pinto+2015

Future

ASTRO-H / SXS

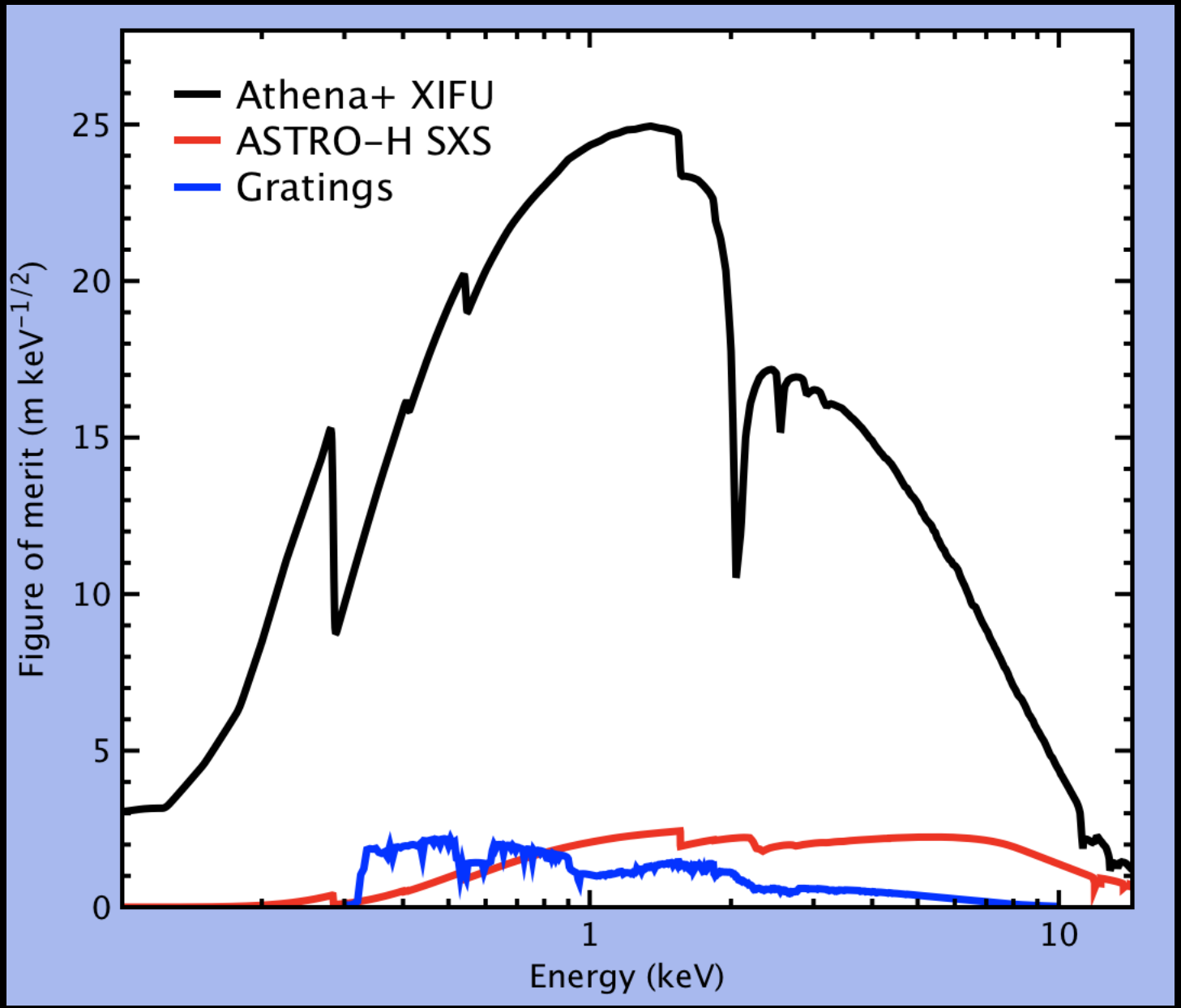
Spatially-resolved (~1', ~5eV)
direct velocity measurements

ATHENA / X-IFU

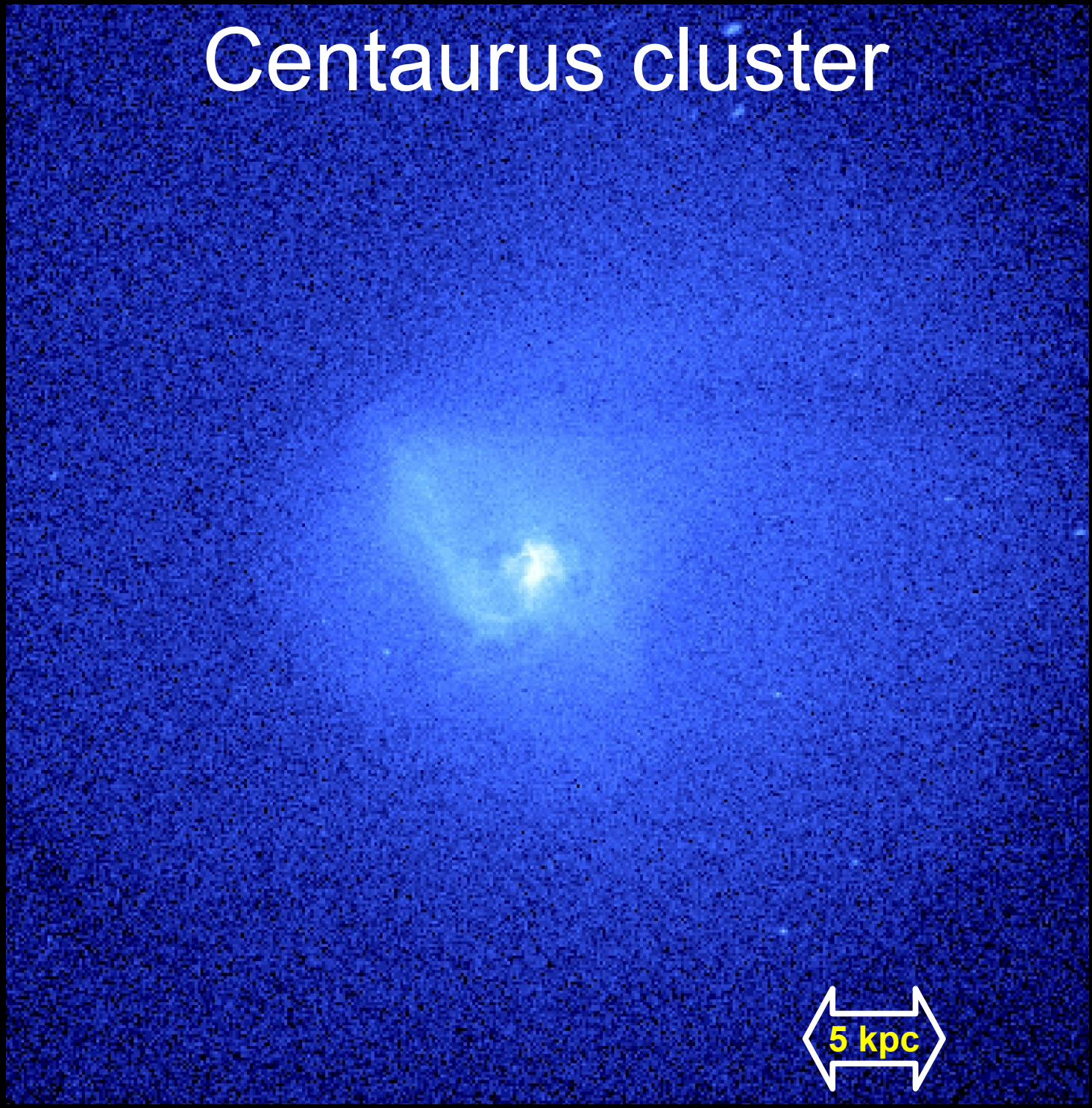
Spatially-resolved (~5", ~2.5eV)
direct velocity measurements

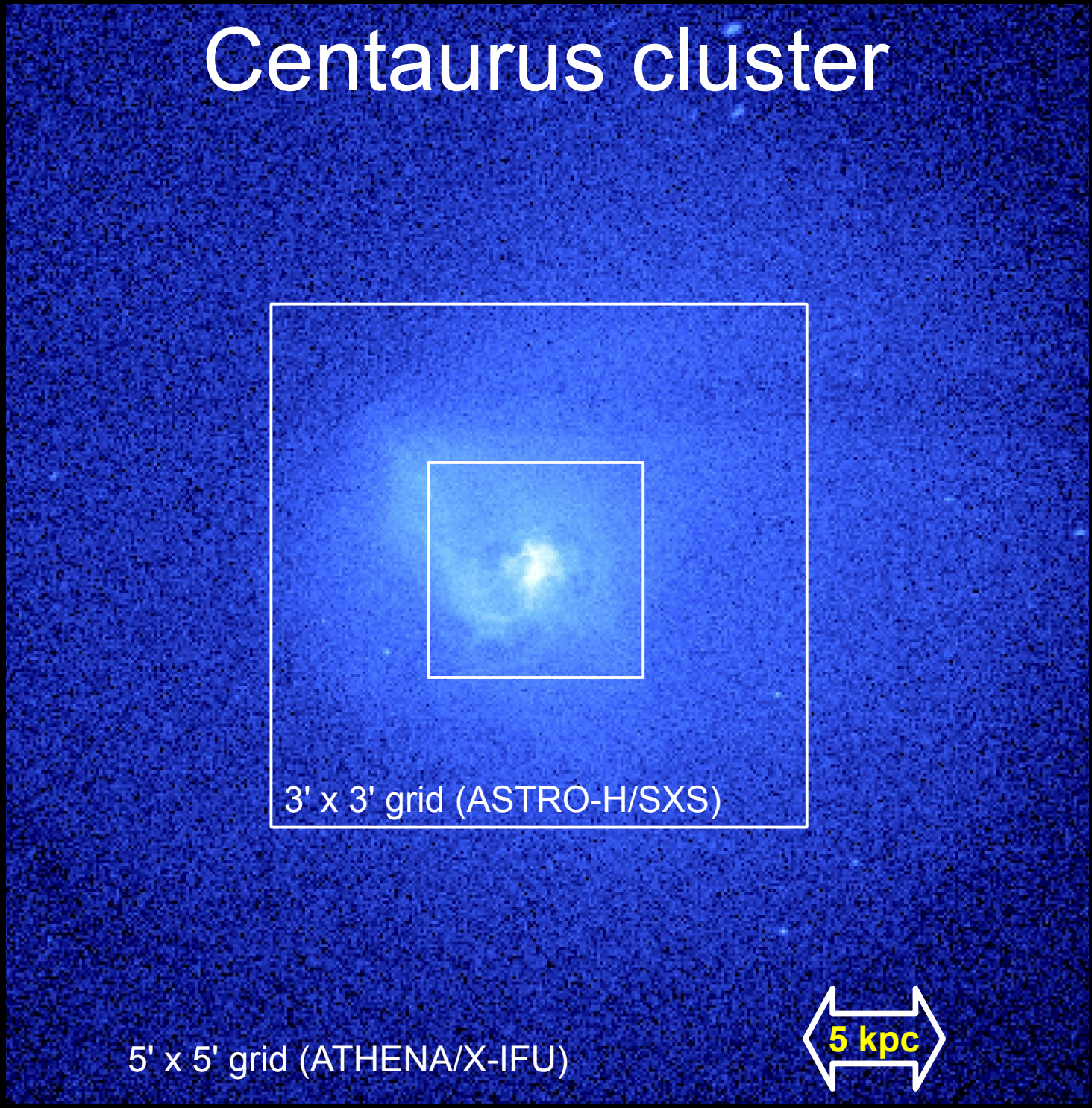
ATHENA (2028+)

high spatial resolution & high spectral resolution

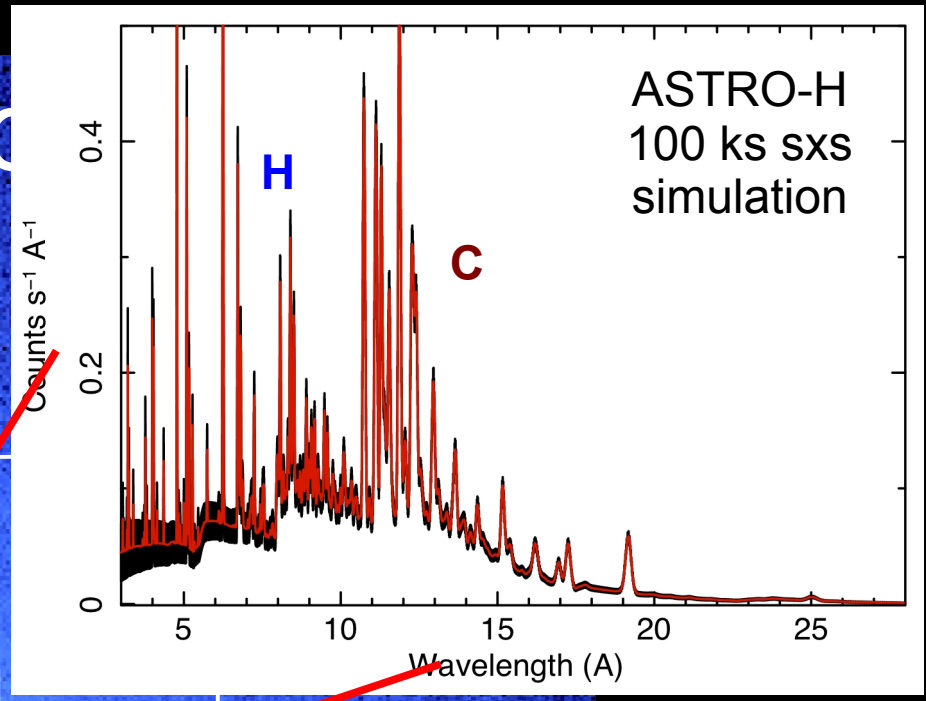


Centaurus cluster




Centaurus cluster
3' x 3' grid (ASTRO-H/SXS)
5' x 5' grid (ATHENA/X-IFU)
5 kpc

Centaurus c

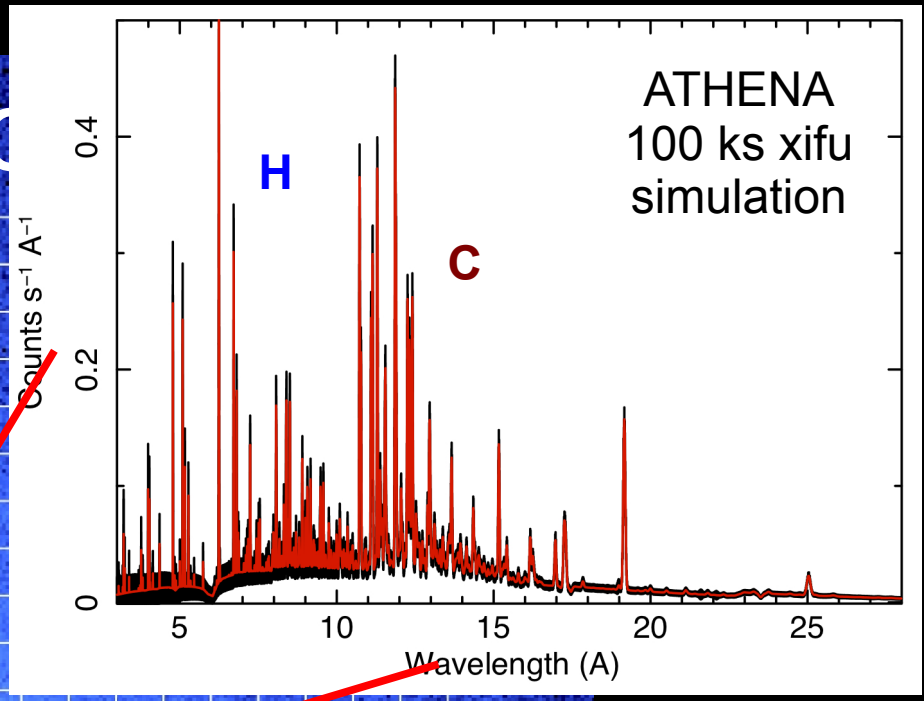


3' x 3' grid (ASTRO-H/SXS)

5' x 5' grid (ATHENA/X-IFU)

5 kpc

Centaurus c

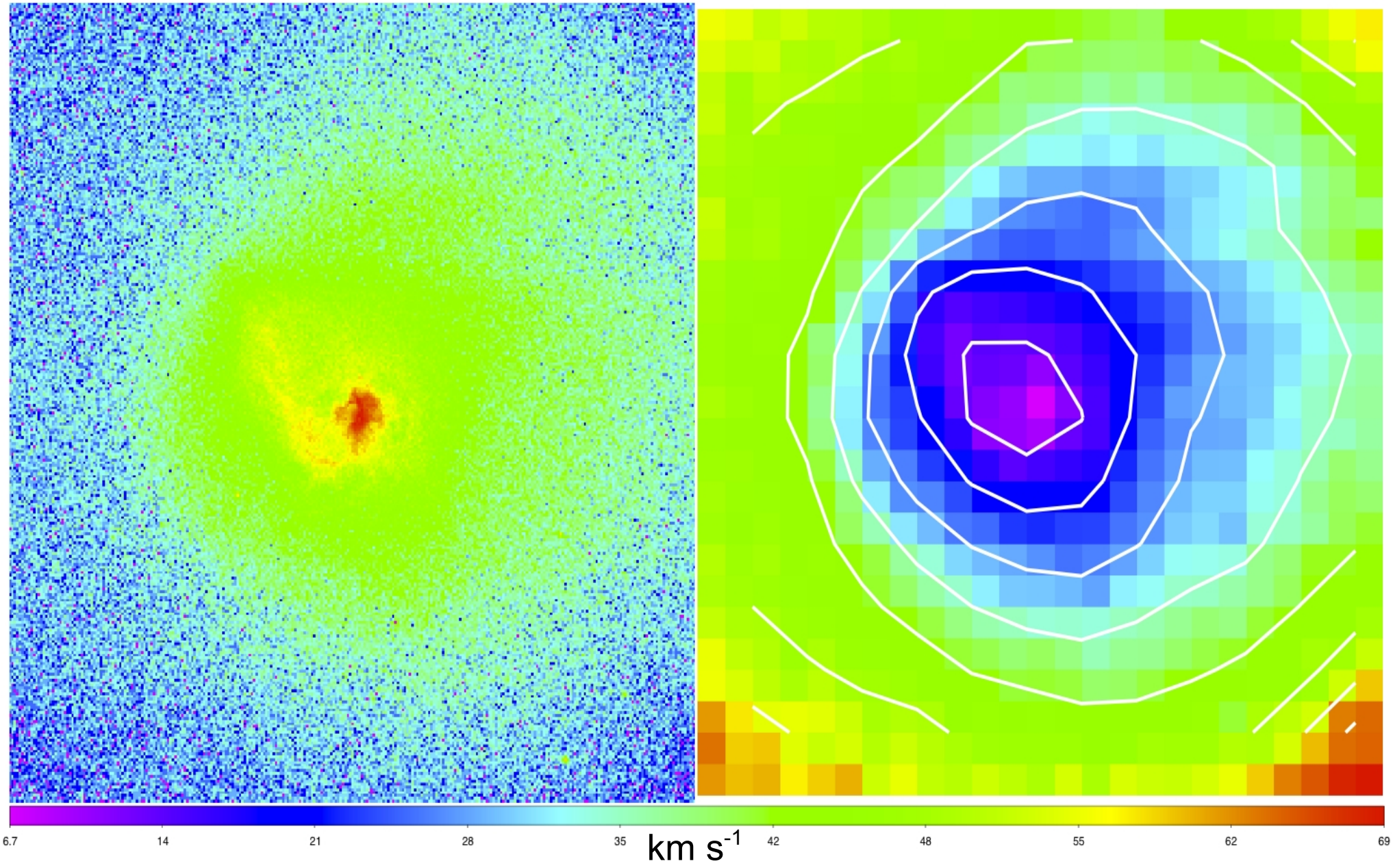


5' x 5' grid

5 kpc

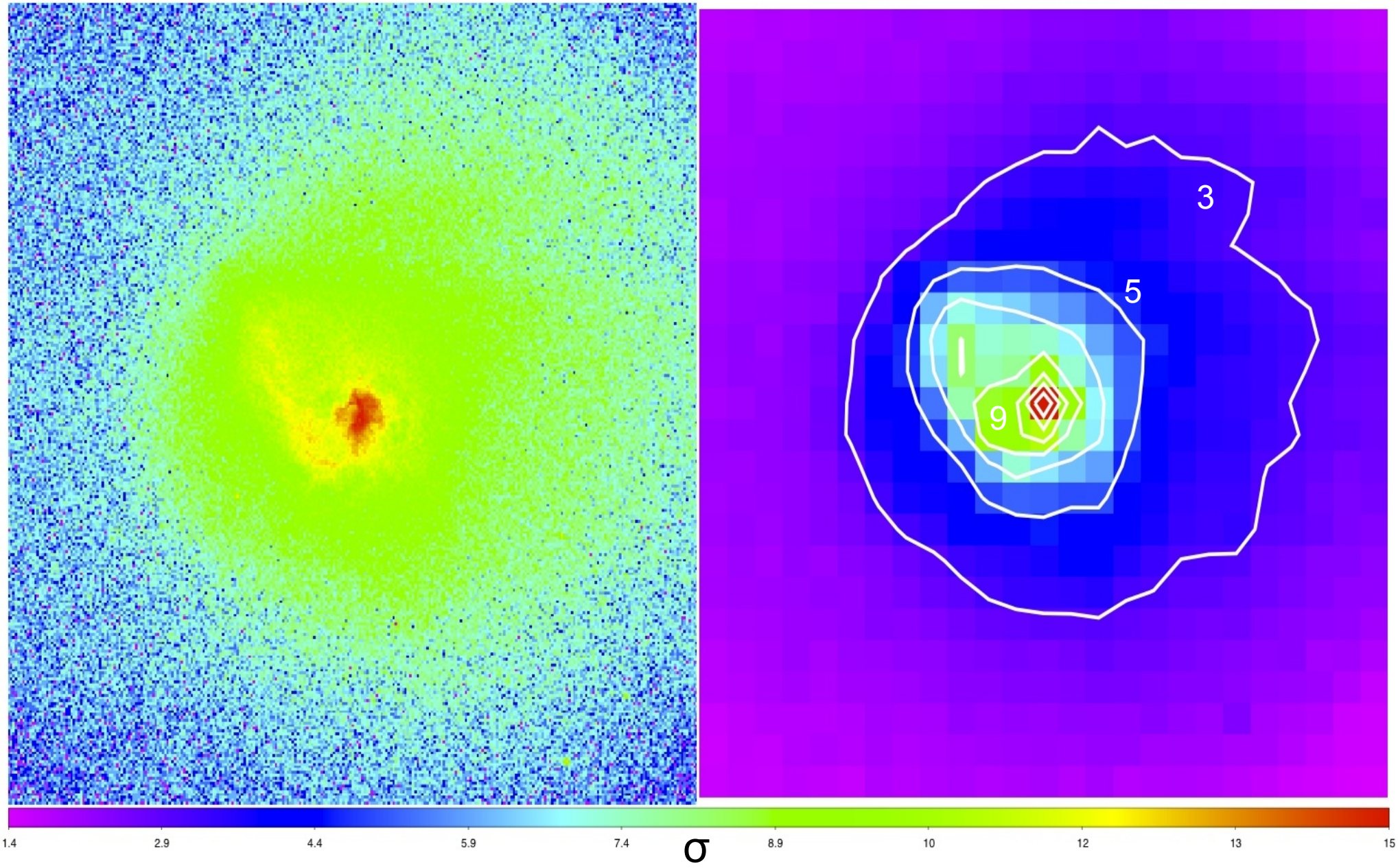
Centaurus cluster (100 ks XIFU)

Stat. uncertainty on velocity widts

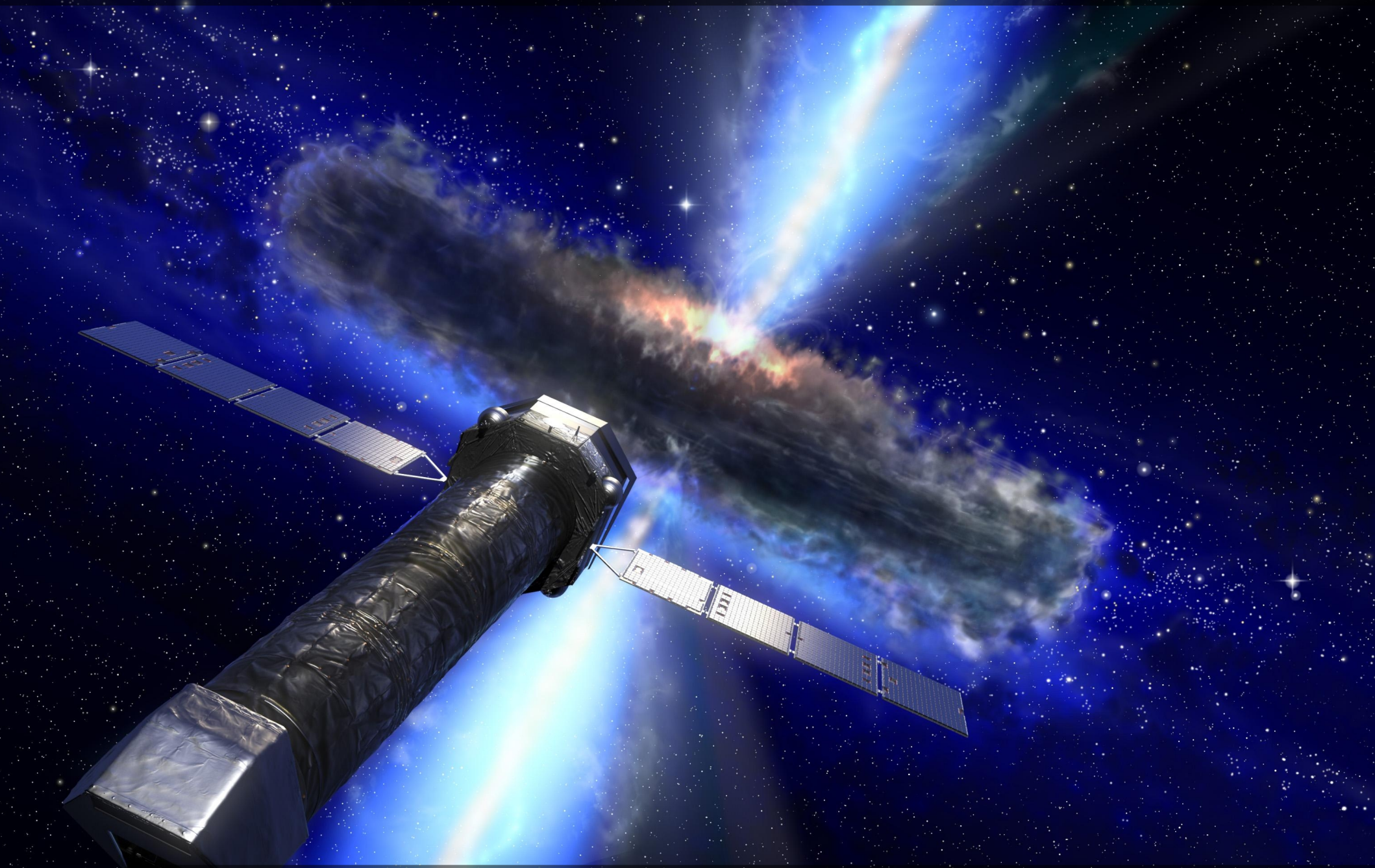


Centaurus cluster (100 ks XIFU)

Velocity broadening detection



ATHENA is really THE New Frontier of X-ray Astronomy



...and it's such a pleasure to be part of it, thanks!