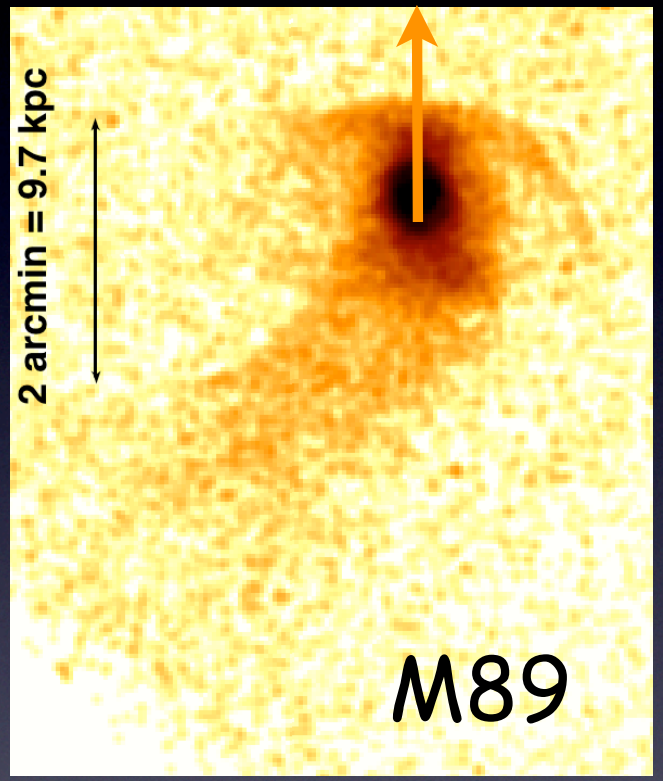
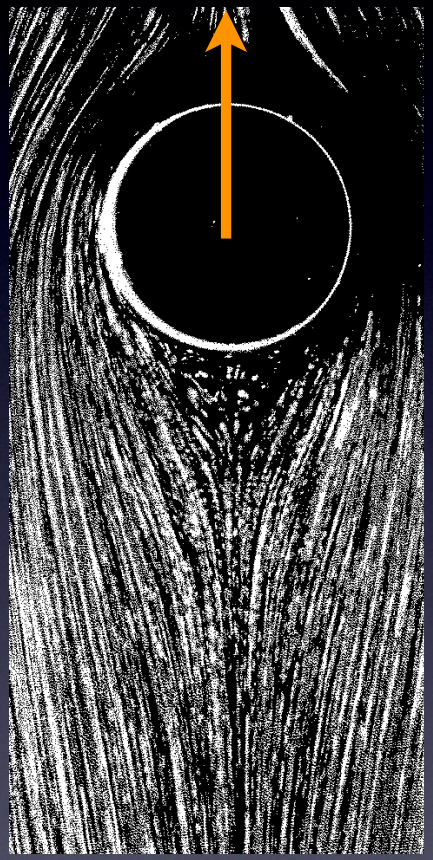
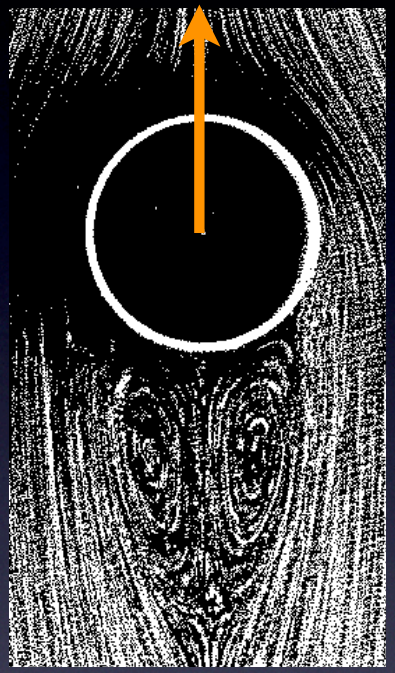
Shaken and stirred - but mixed? Viscous flow experiments in the ICM



Kraft et al., Roediger et al., in prep.



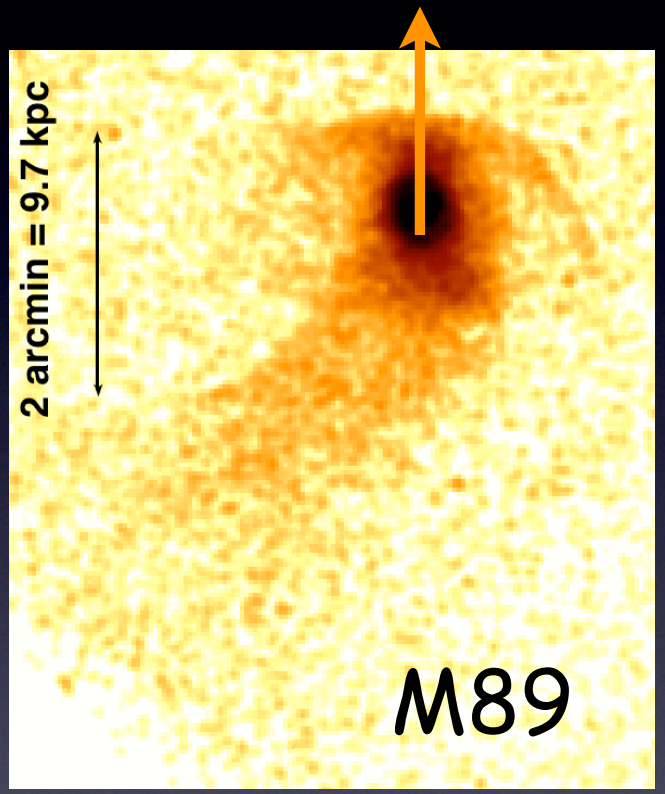


van Dyke - Album of Fluid Motion

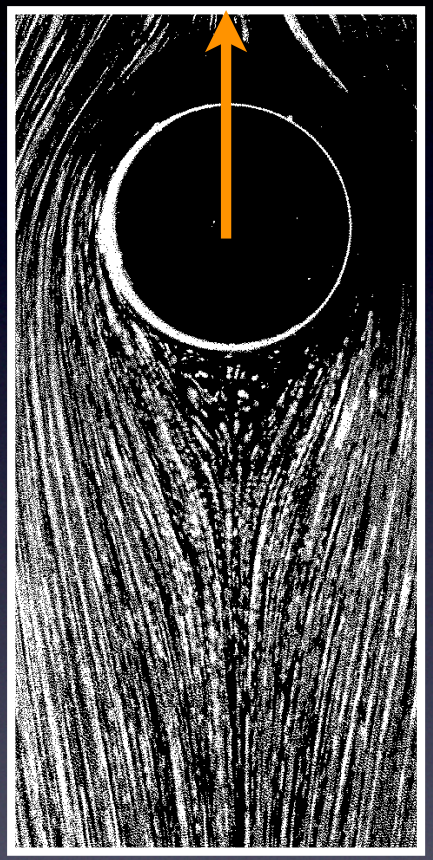
Elke Roediger (Hamburger Sternwarte), Ralph Kraft, Bill Forman, Paul Nulsen, Marie Machacek, Scott Randall, Christine Jones (CfA), Eugene Churazov (MPA)

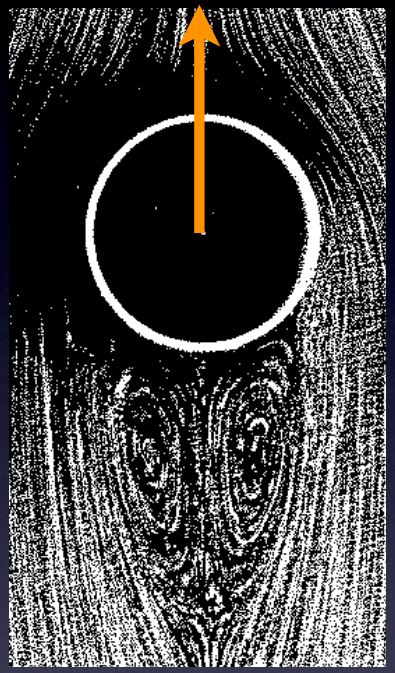
hamburger sternwarte

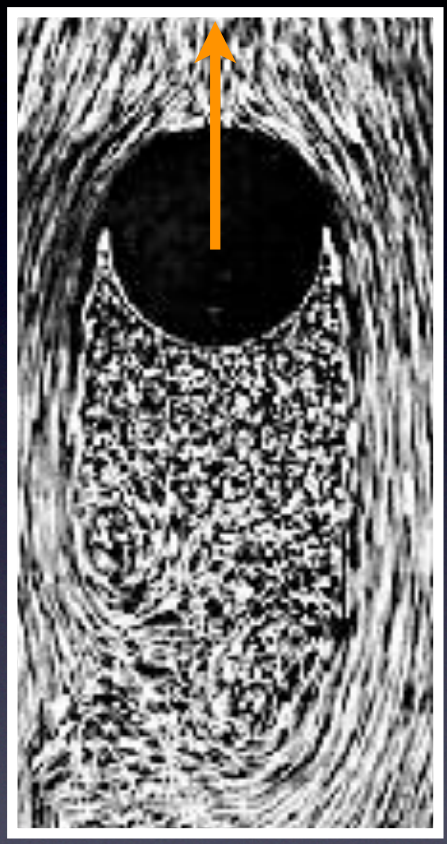
Gas-stripped elliptical galaxies



Kraft et al., Roediger et al., in prep.







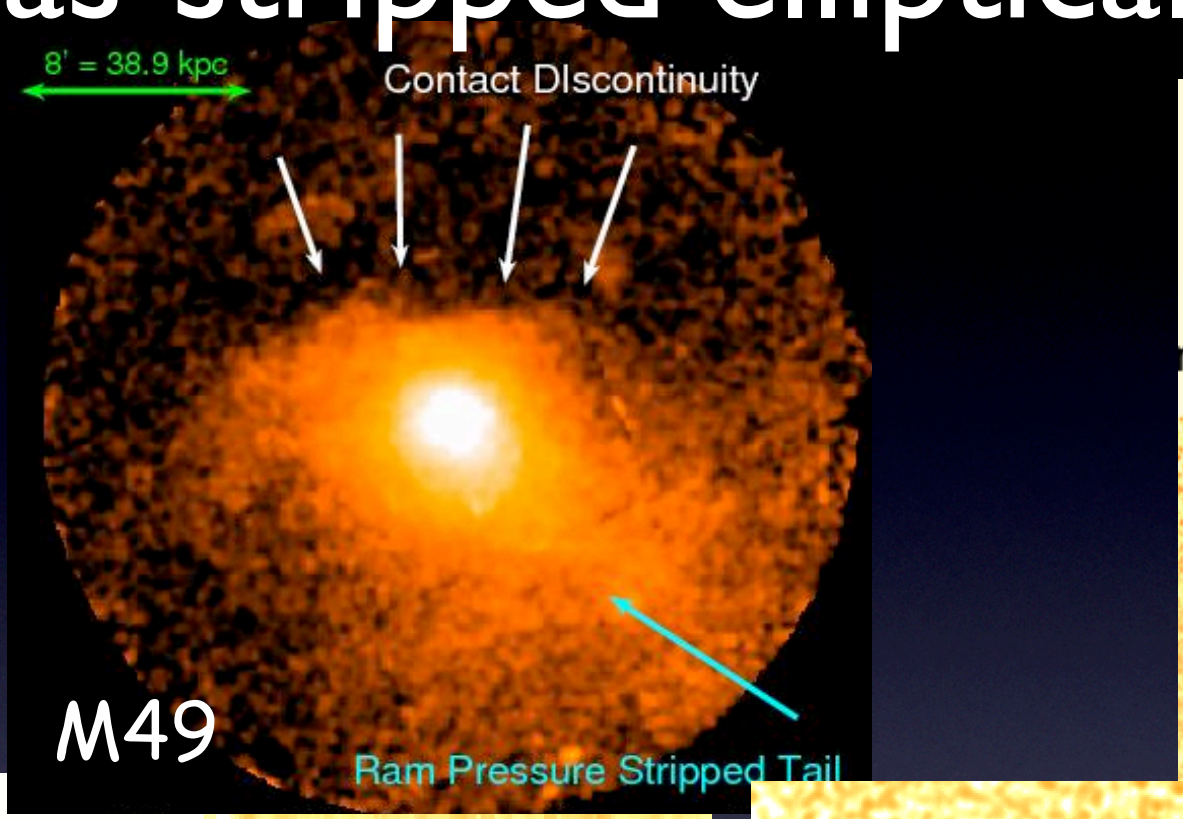
van Dyke - Album of Fluid Motion

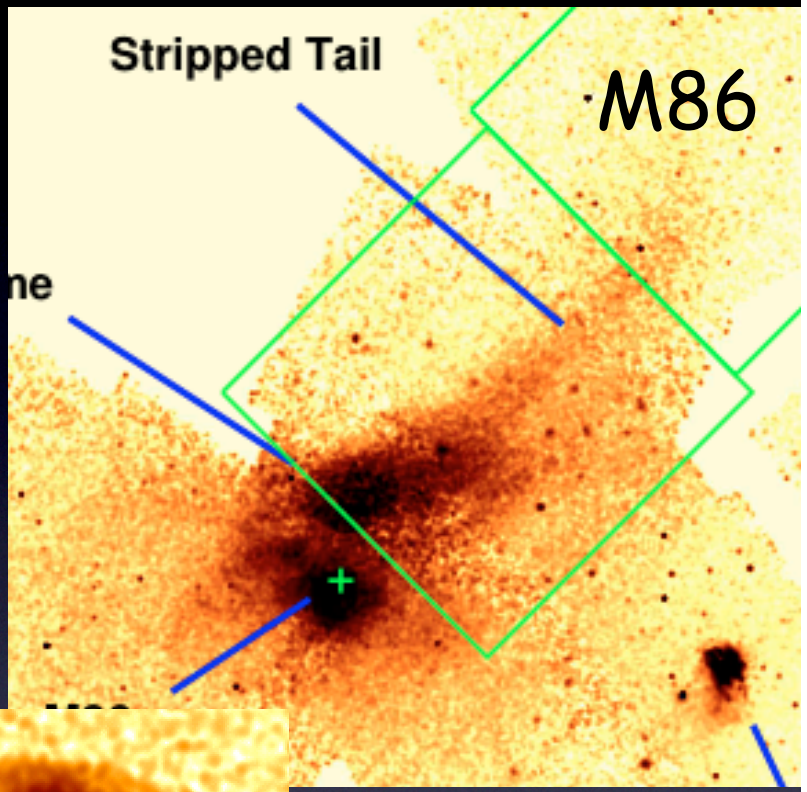
Re=1.5
high viscosity

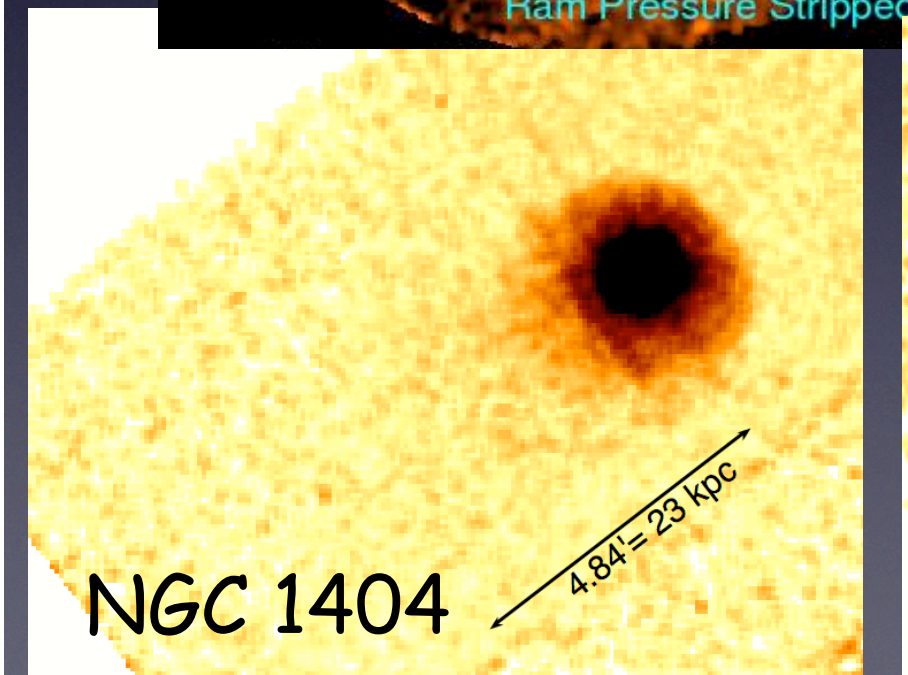
Re=26

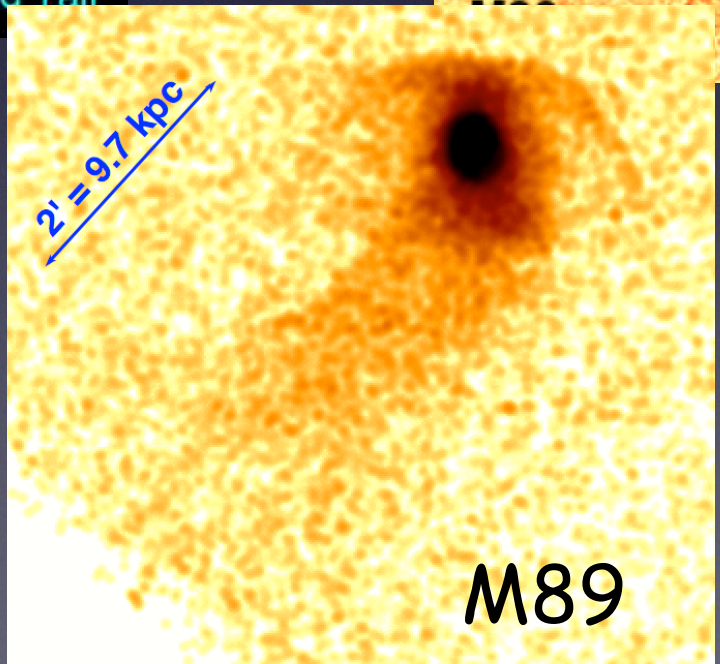
Re=2000
low viscosity

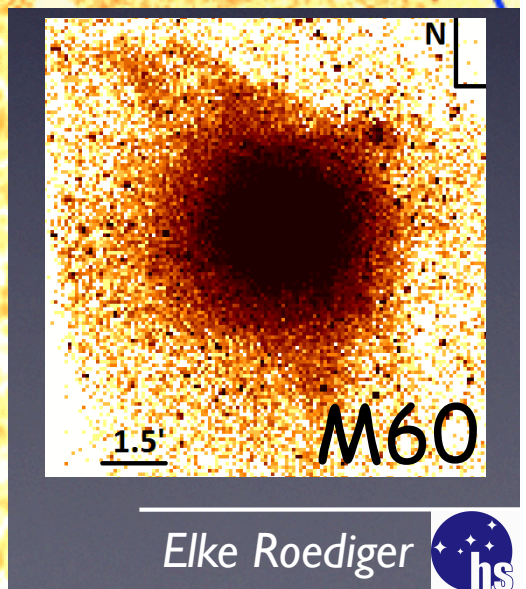
Gas-stripped elliptical galaxies





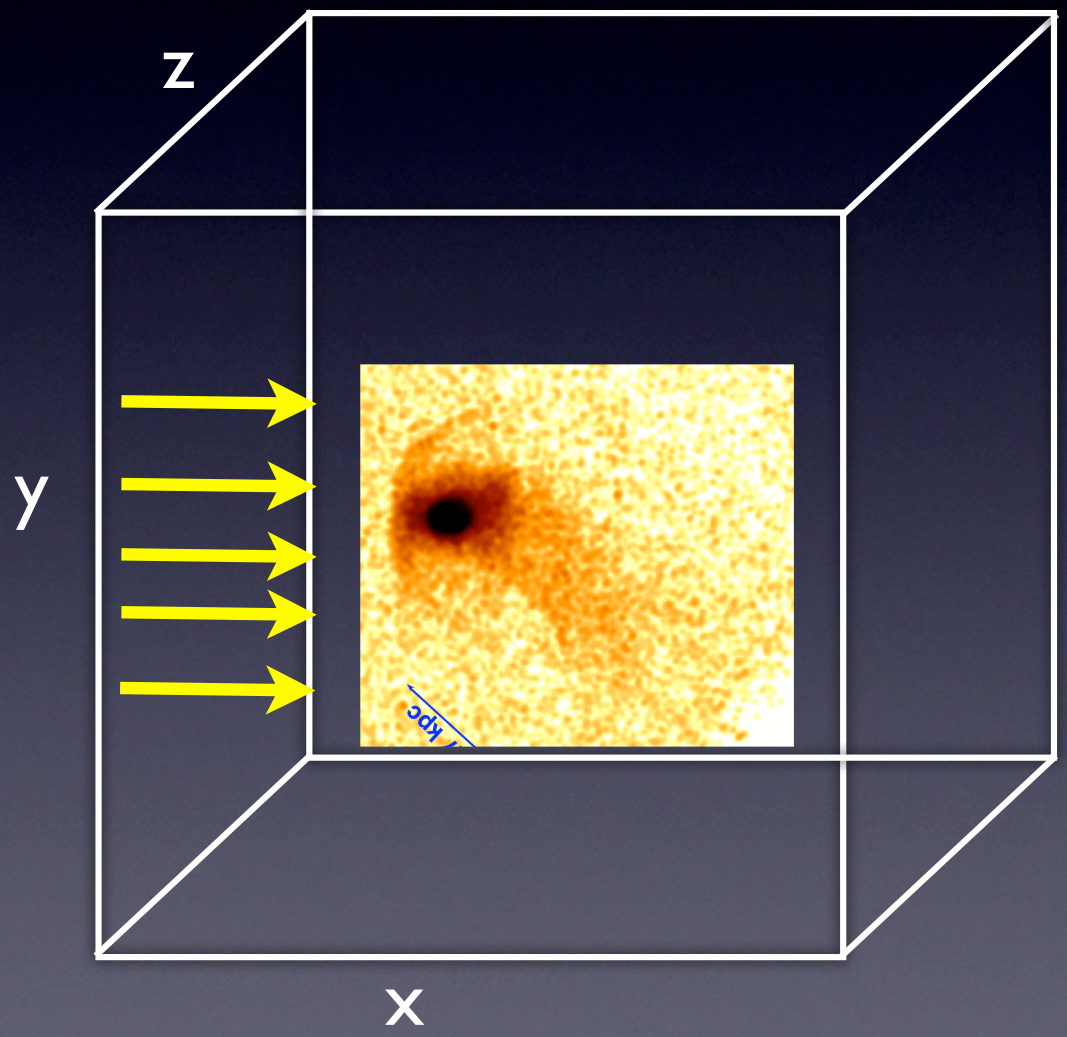






Elke Roediger

Simulating galaxy stripping

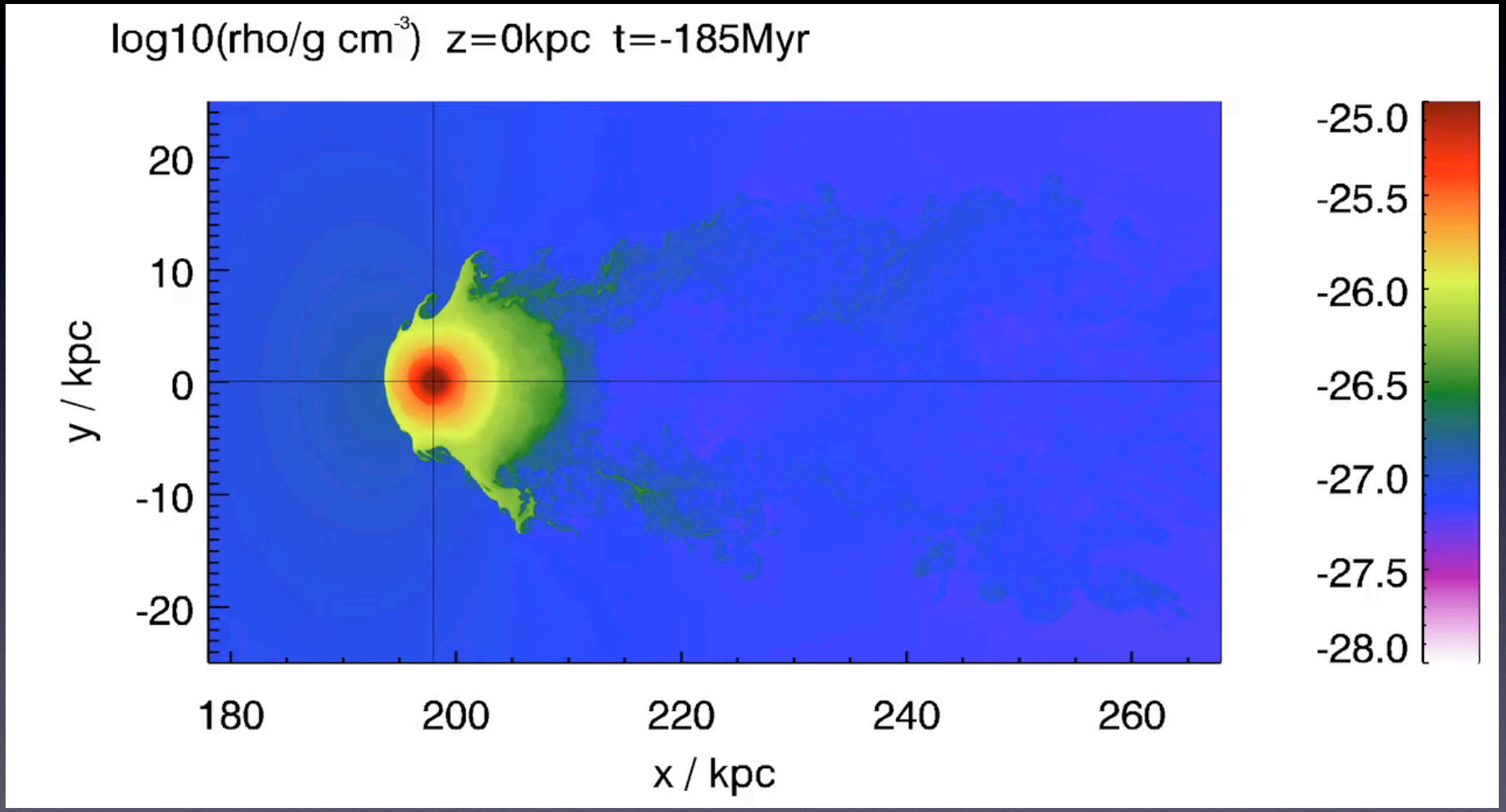


- FLASH code
- rest frame of galaxy
- galaxy potential tailored to M89
- ambient ICM head wind mimicks M89's infall into Virgo

Roediger et al.

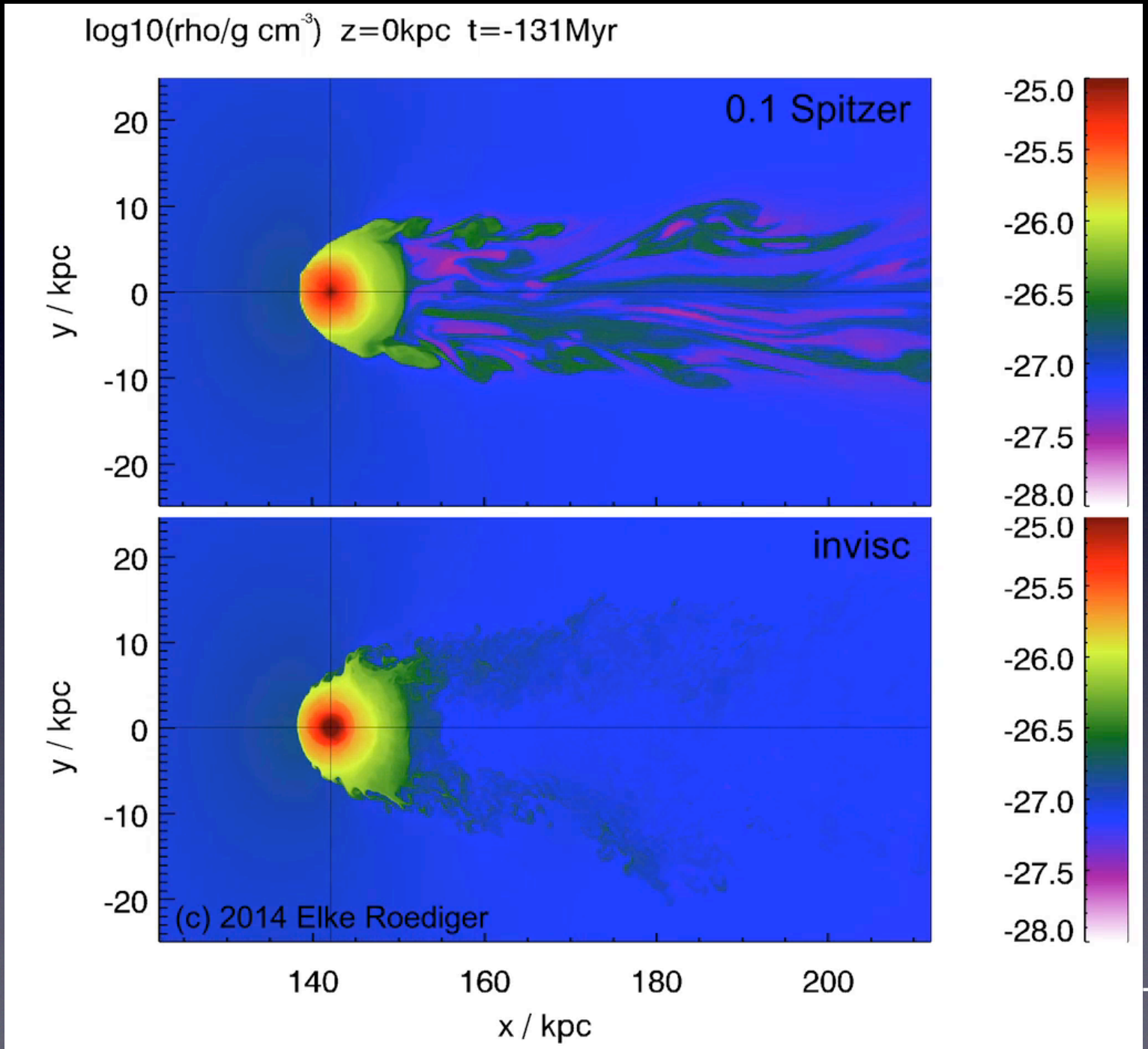
inviscid galaxy stripping

density slices

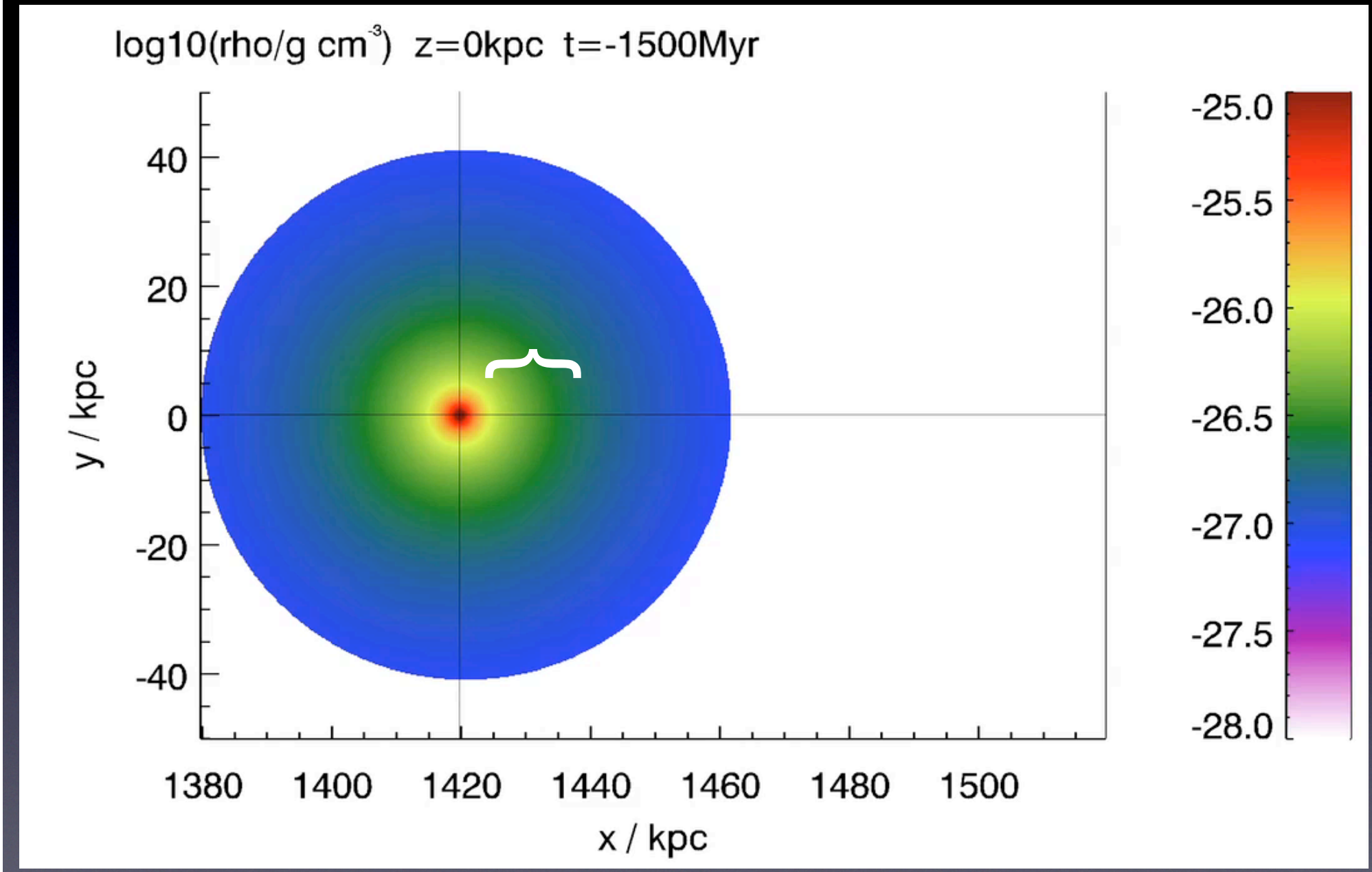


inviscid and viscous galaxy stripping

density slices

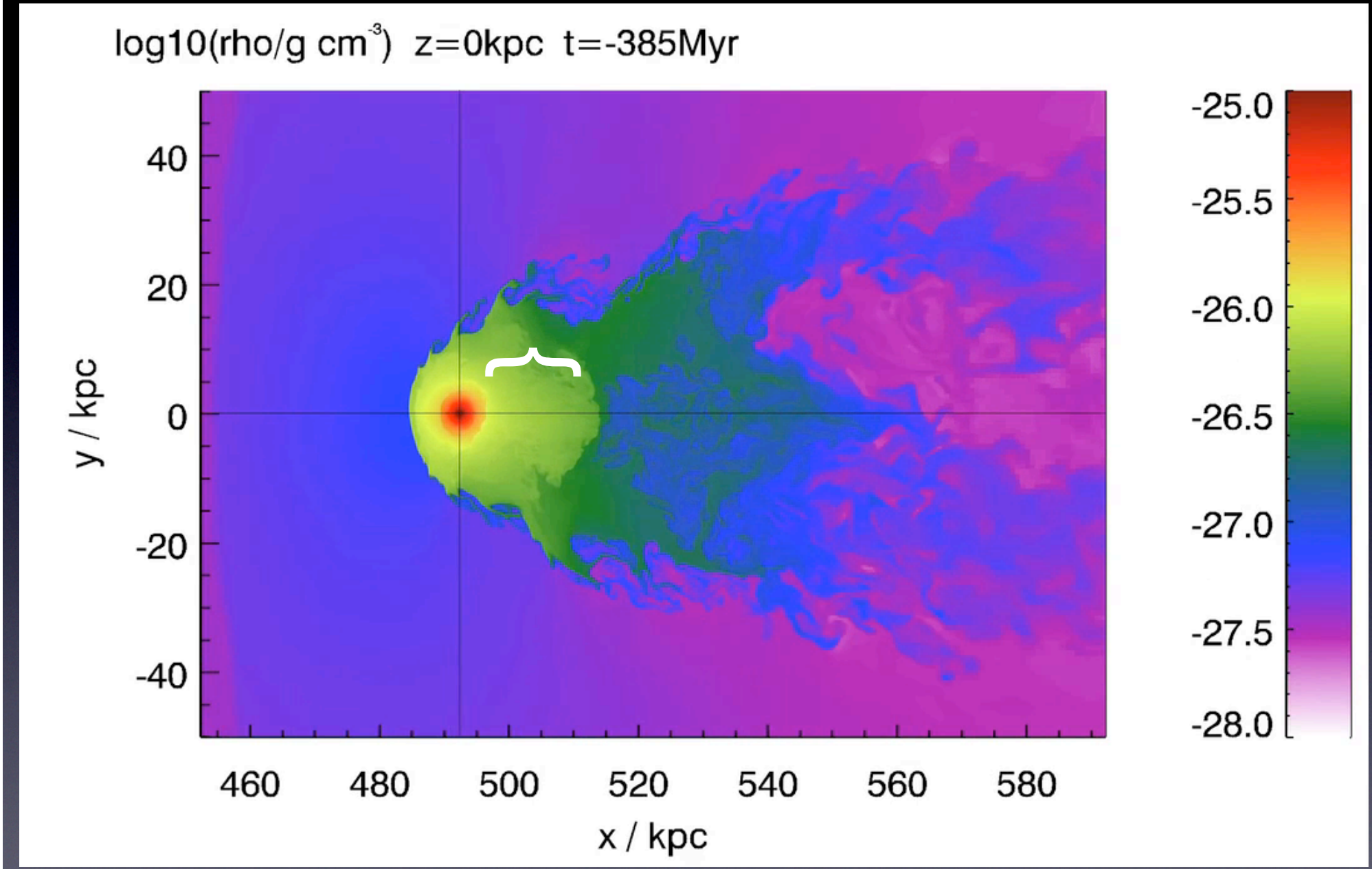


stripping of an extended atmosphere



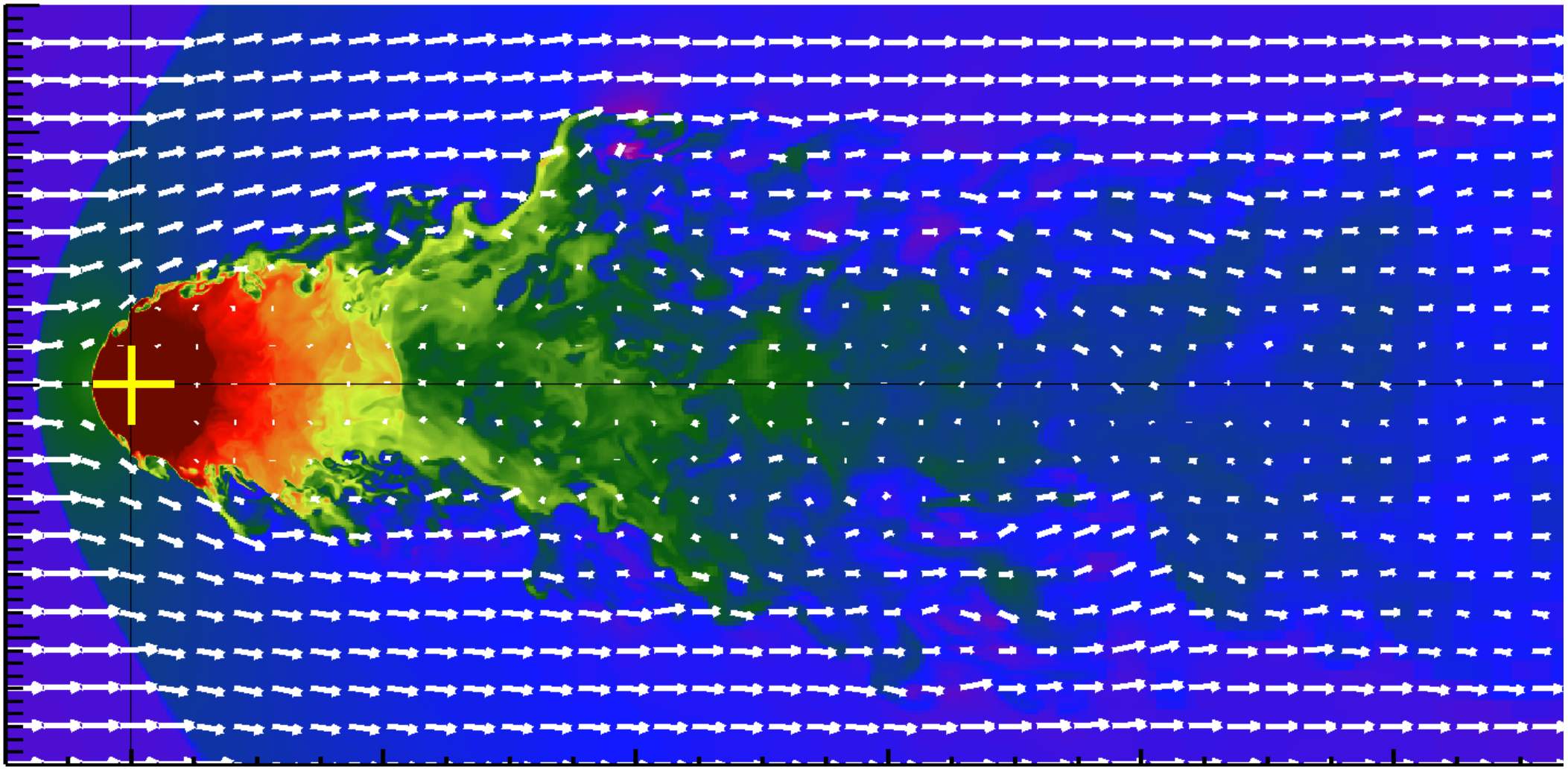
density slices

stripping of an extended atmosphere

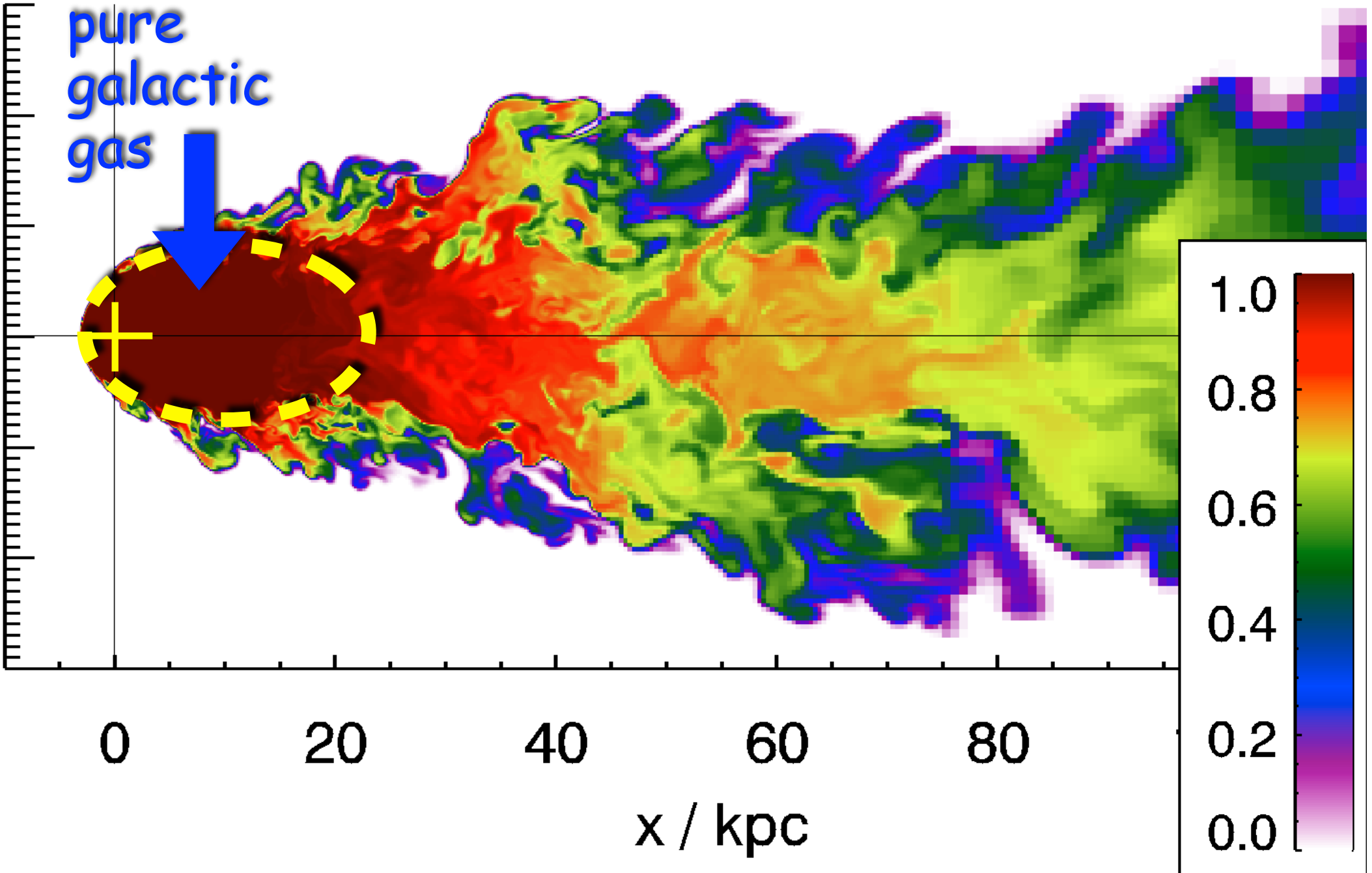


density slices

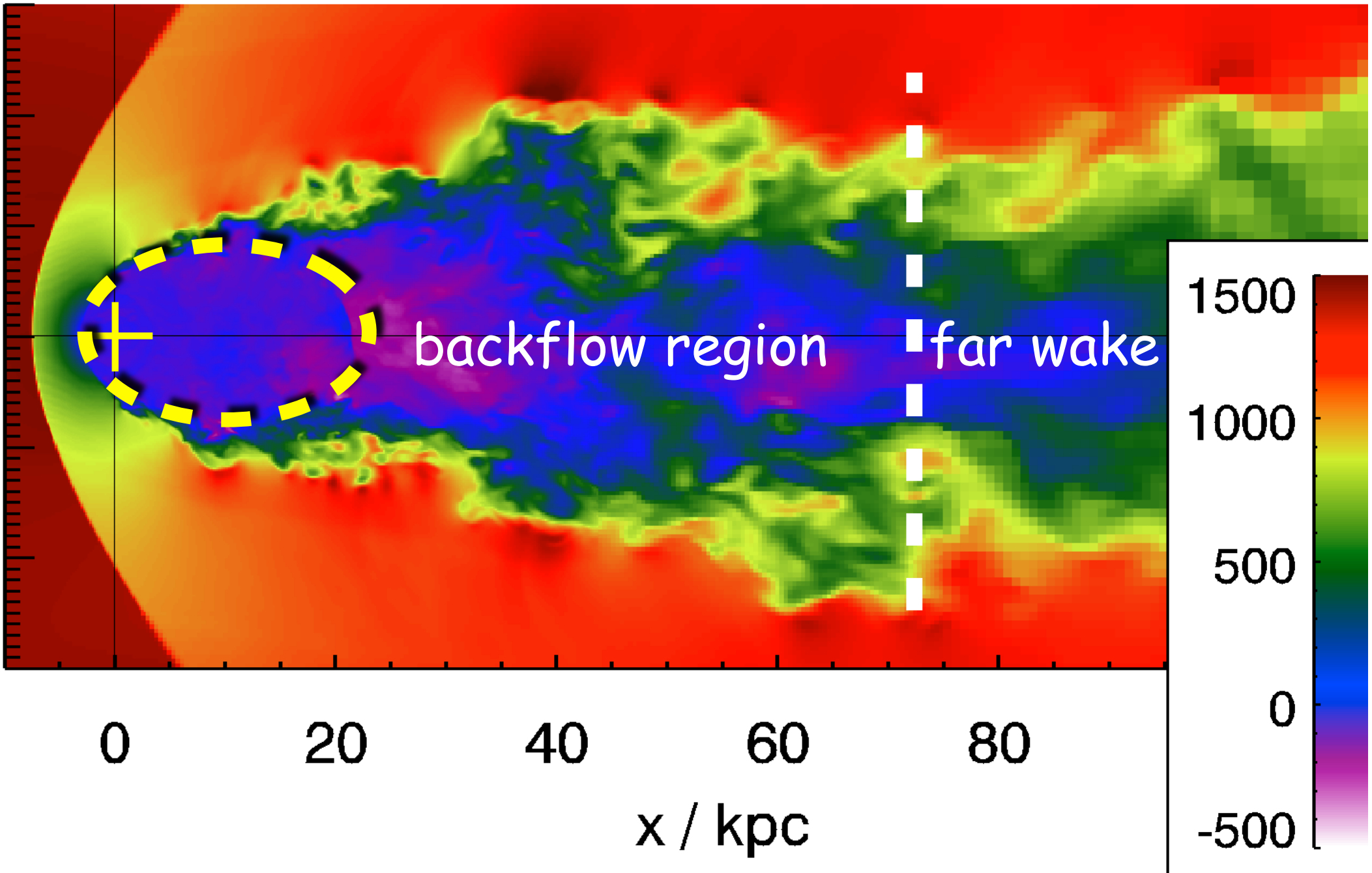
density

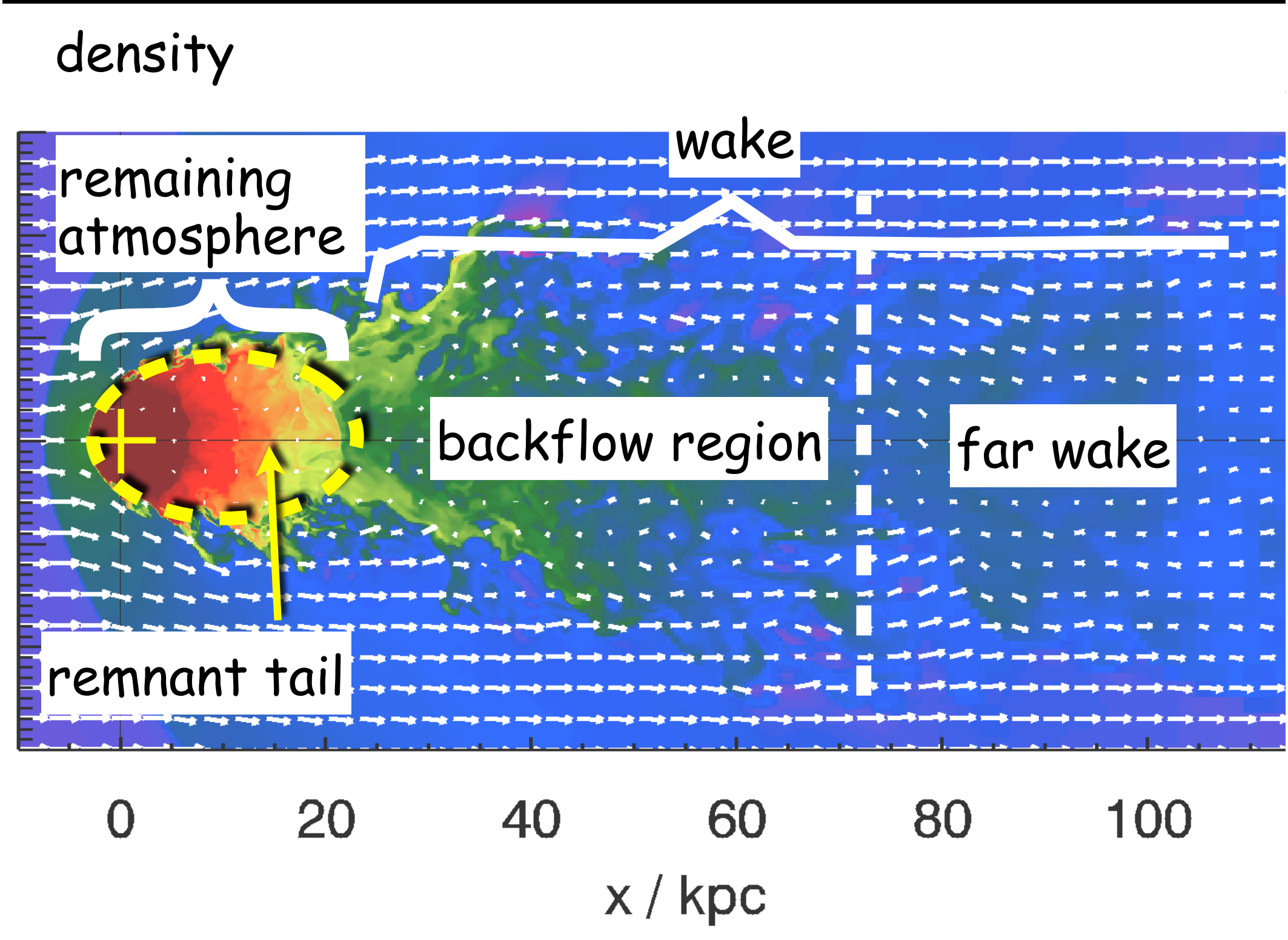


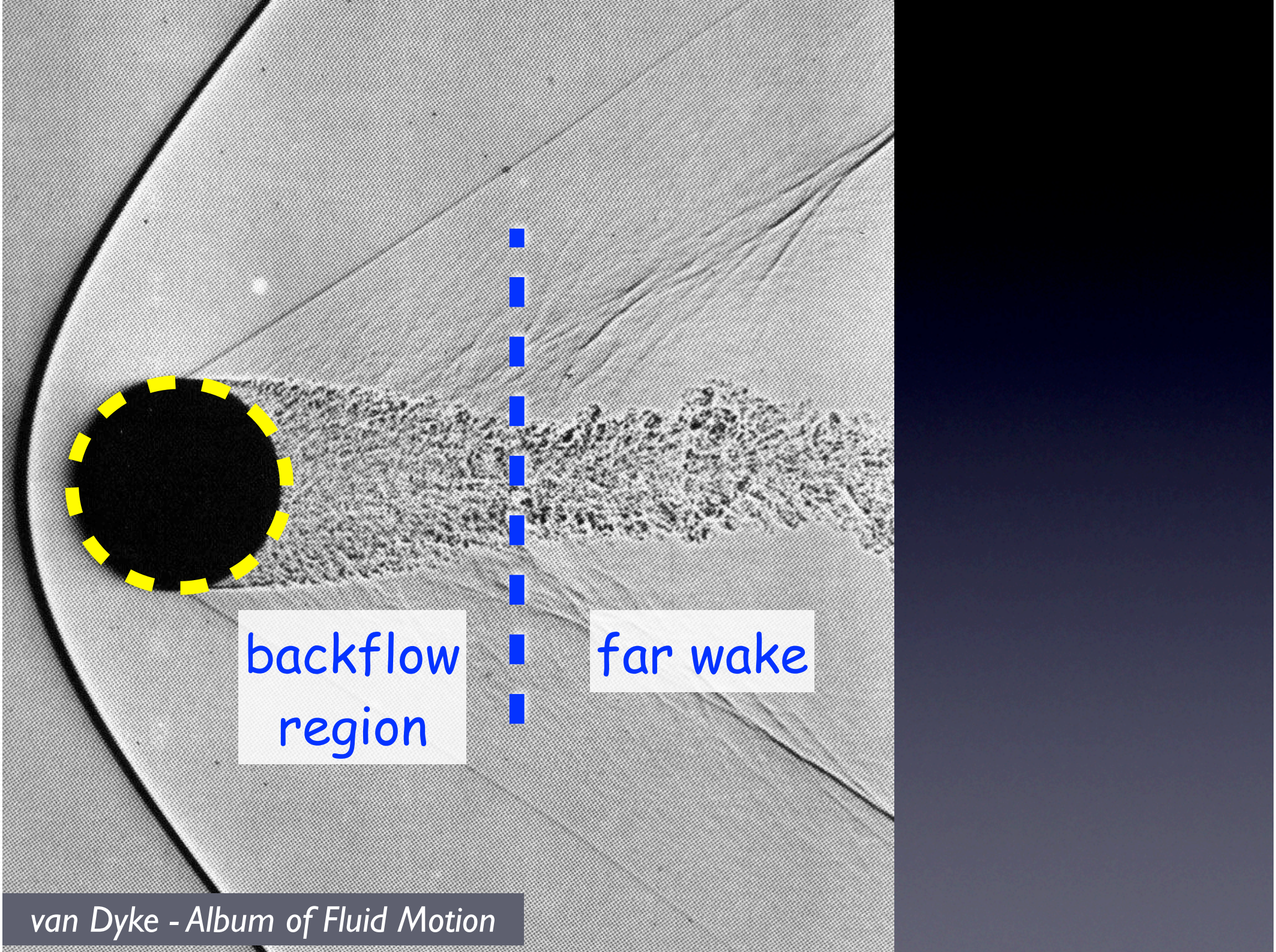
fraction of galactic gas



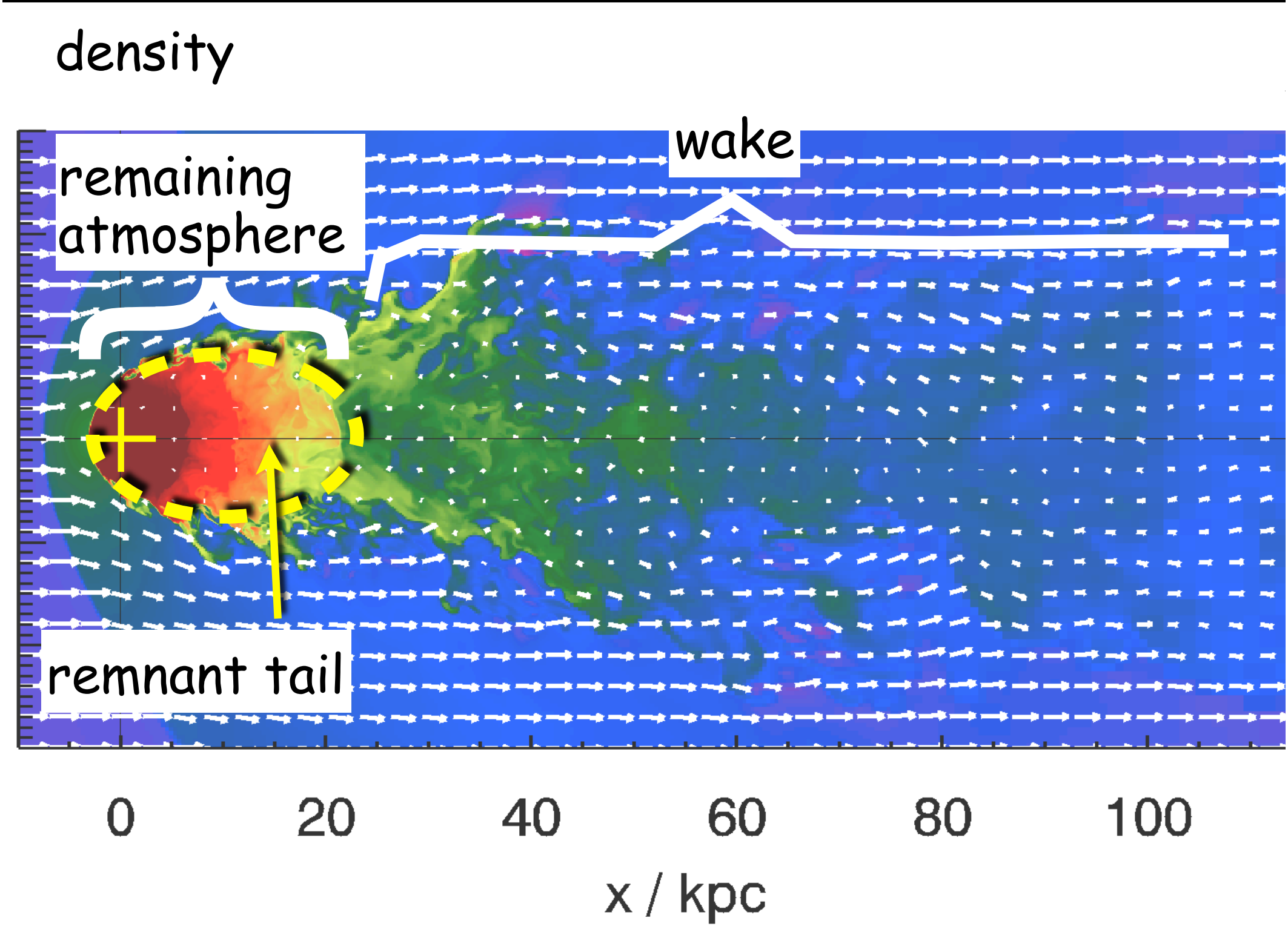
v_x in km/s



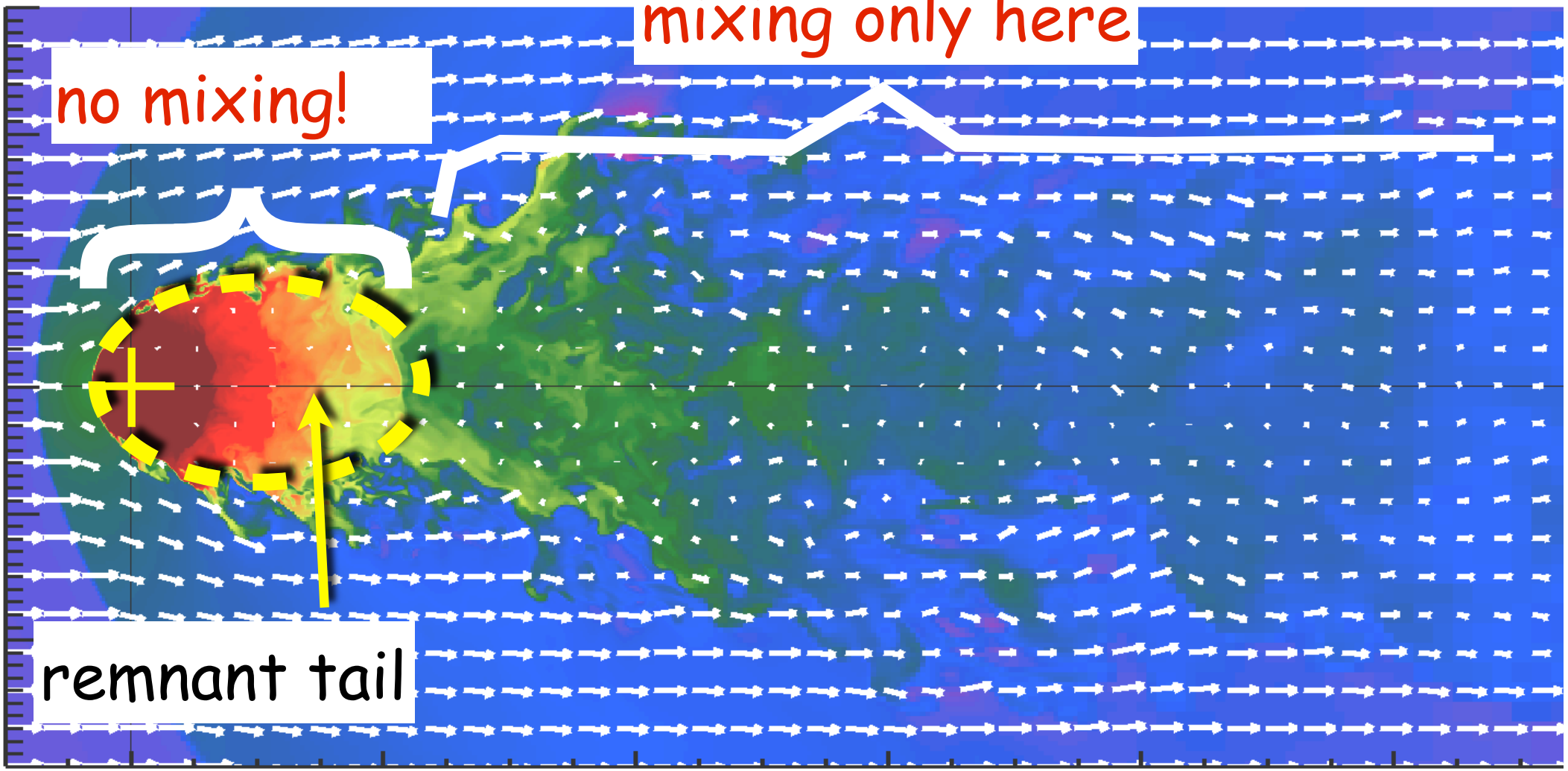

density
wake
remaining atmosphere
backflow region
far wake
remnant tail
0
20
40
60
80
100
x / kpc



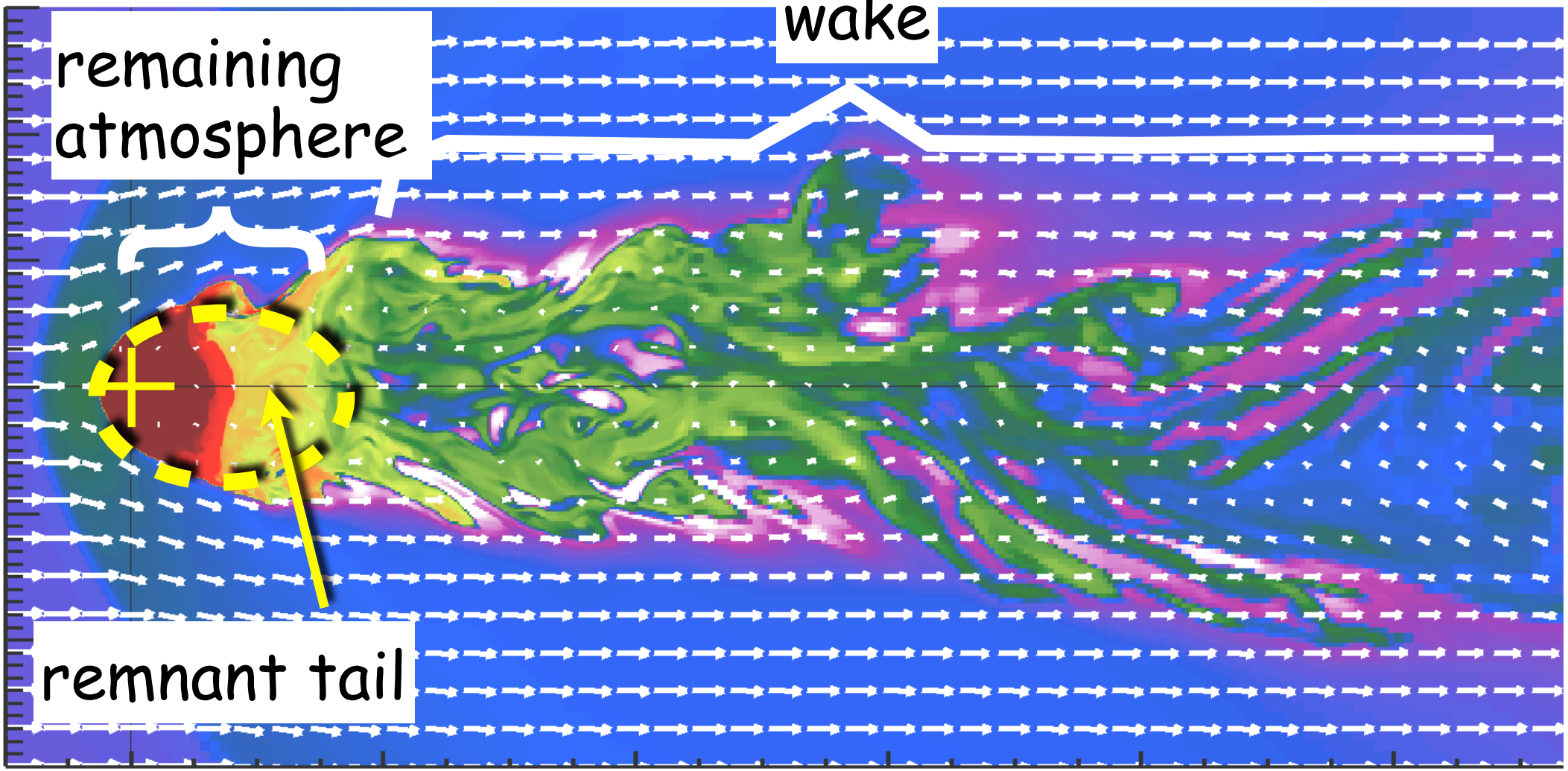
van Dyke - Album of Fluid Motion

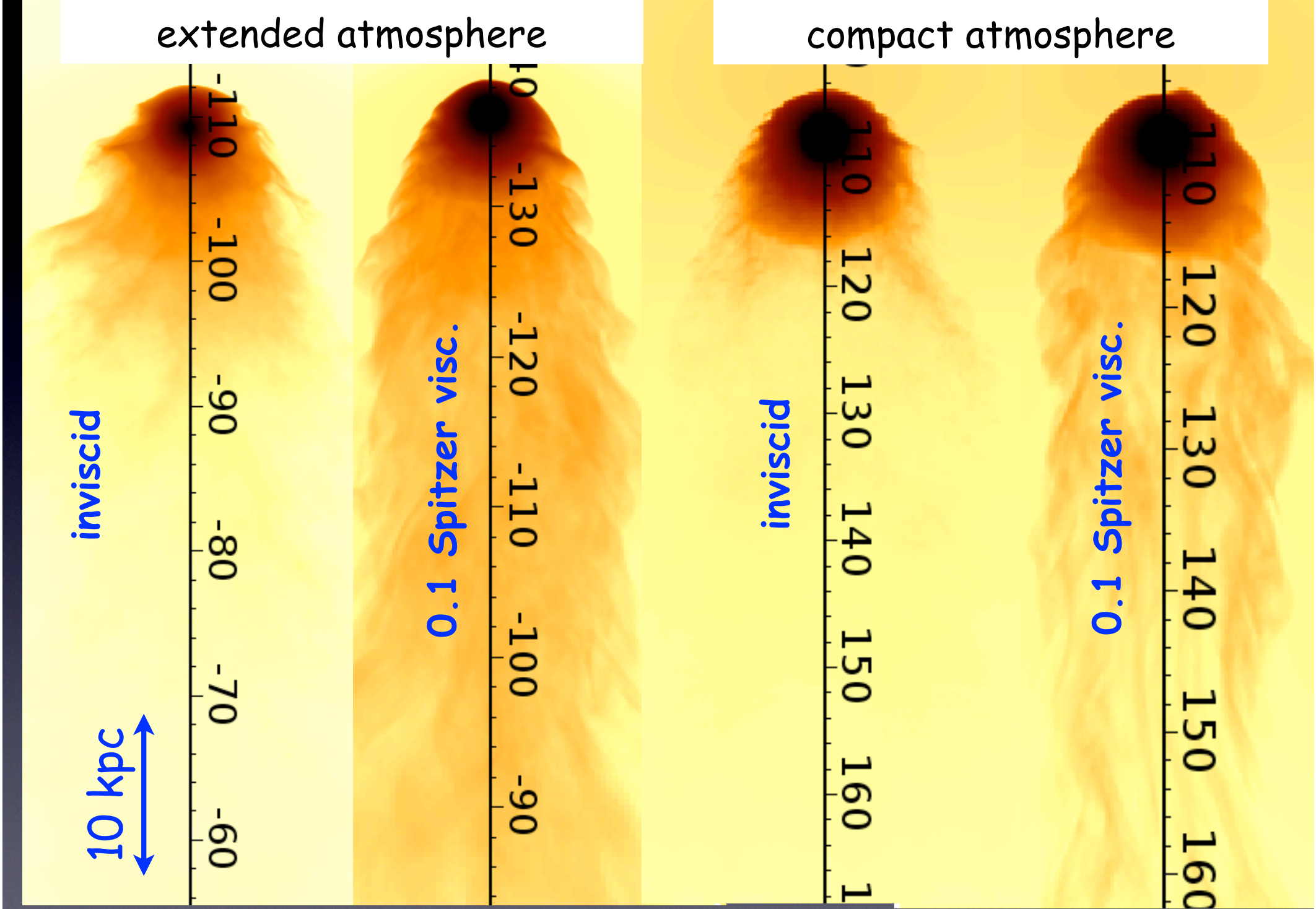

density
wake
remaining
atmosphere
remnant tail
0
20
40
60
80
100
x / kpc

density



density - 0.1 Spitzer viscosity





Mock X-ray (0.7-1.1keV)

extended atmosphere

compact atmosphere

inviscid

0.1 Spitzer visc.

inviscid

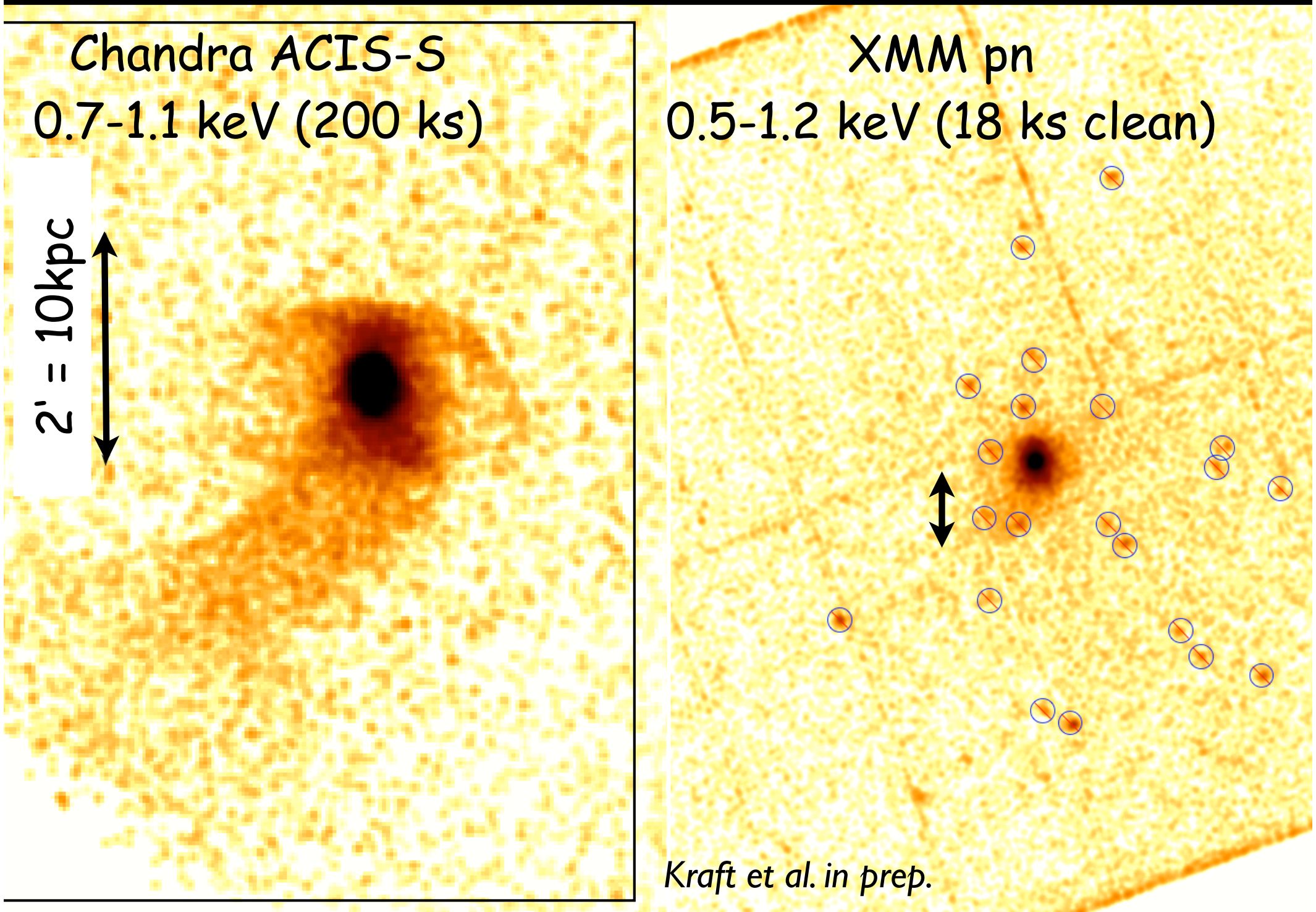
0.1 Spitzer visc.

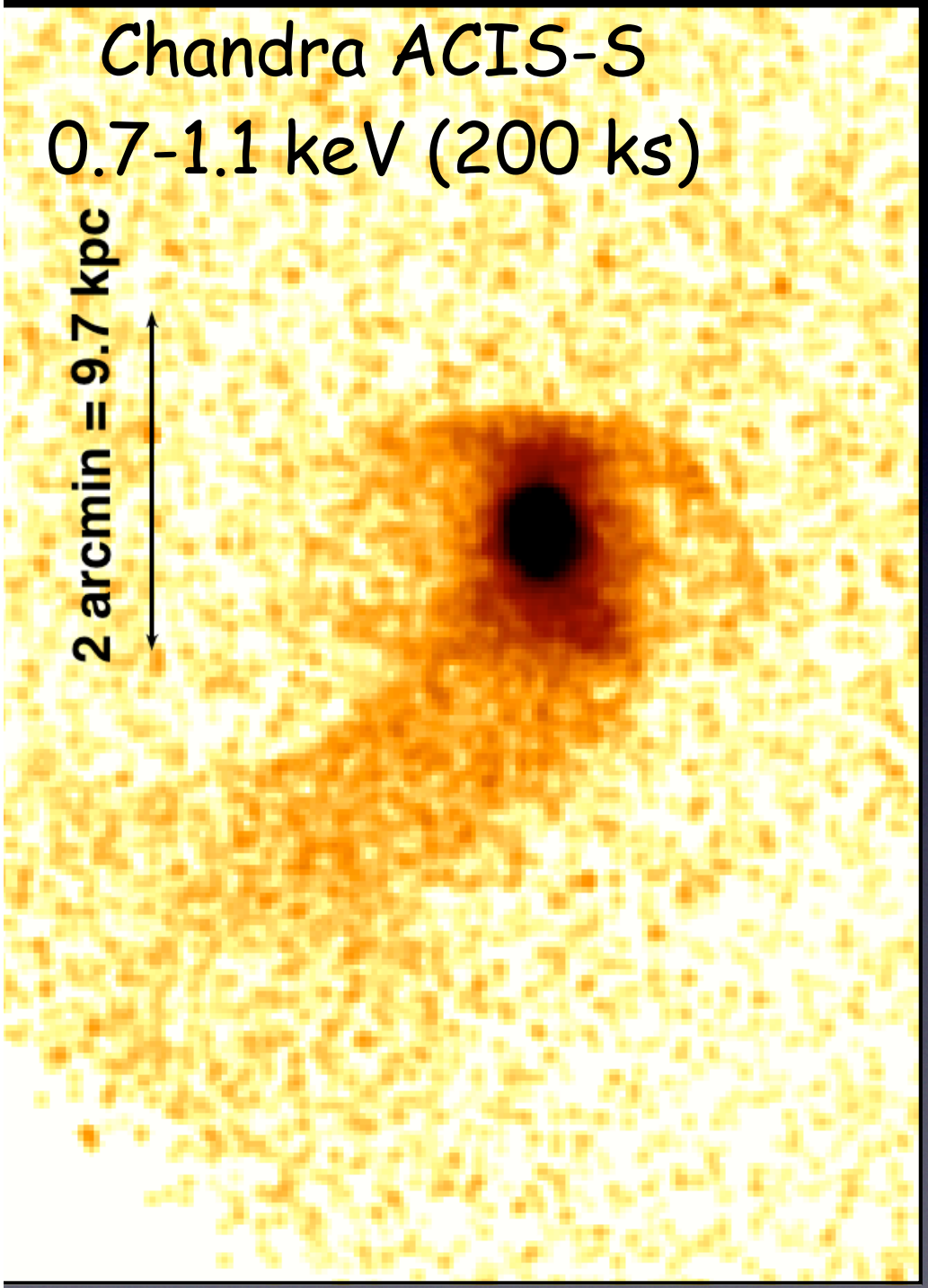
2 arcmin = 9.7 kpc

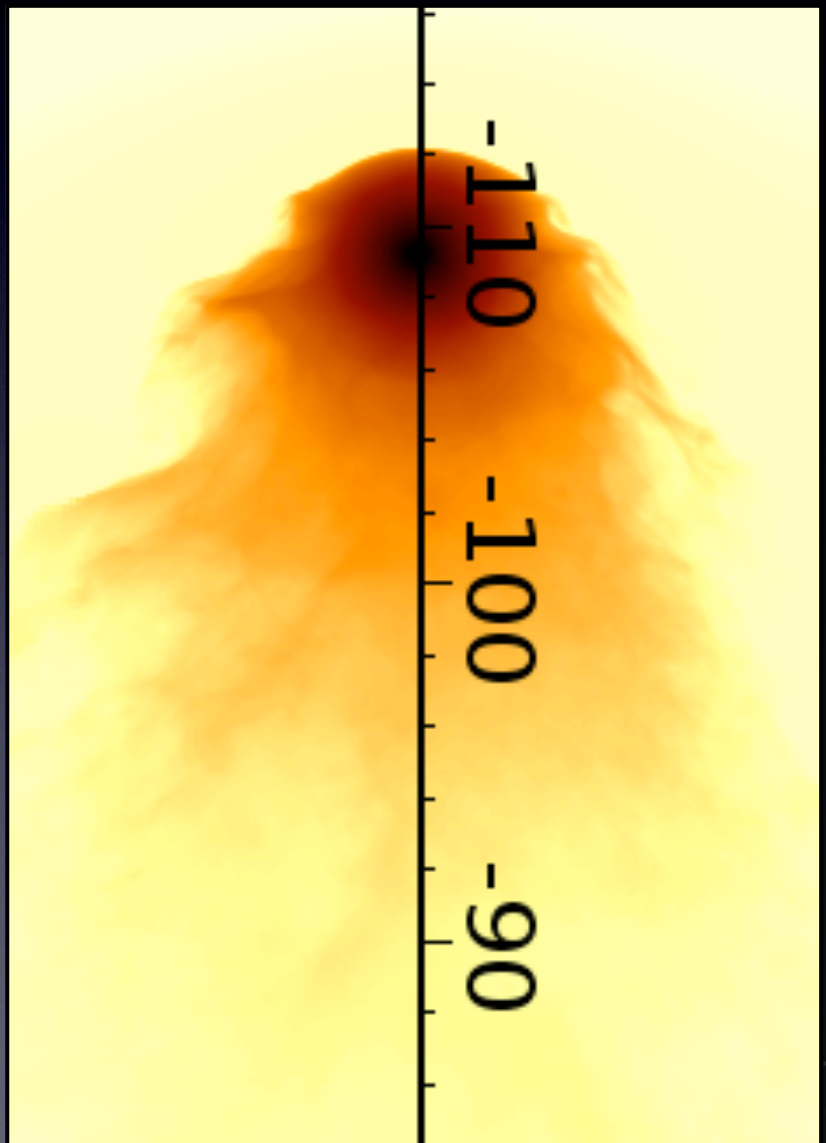
remnant tail

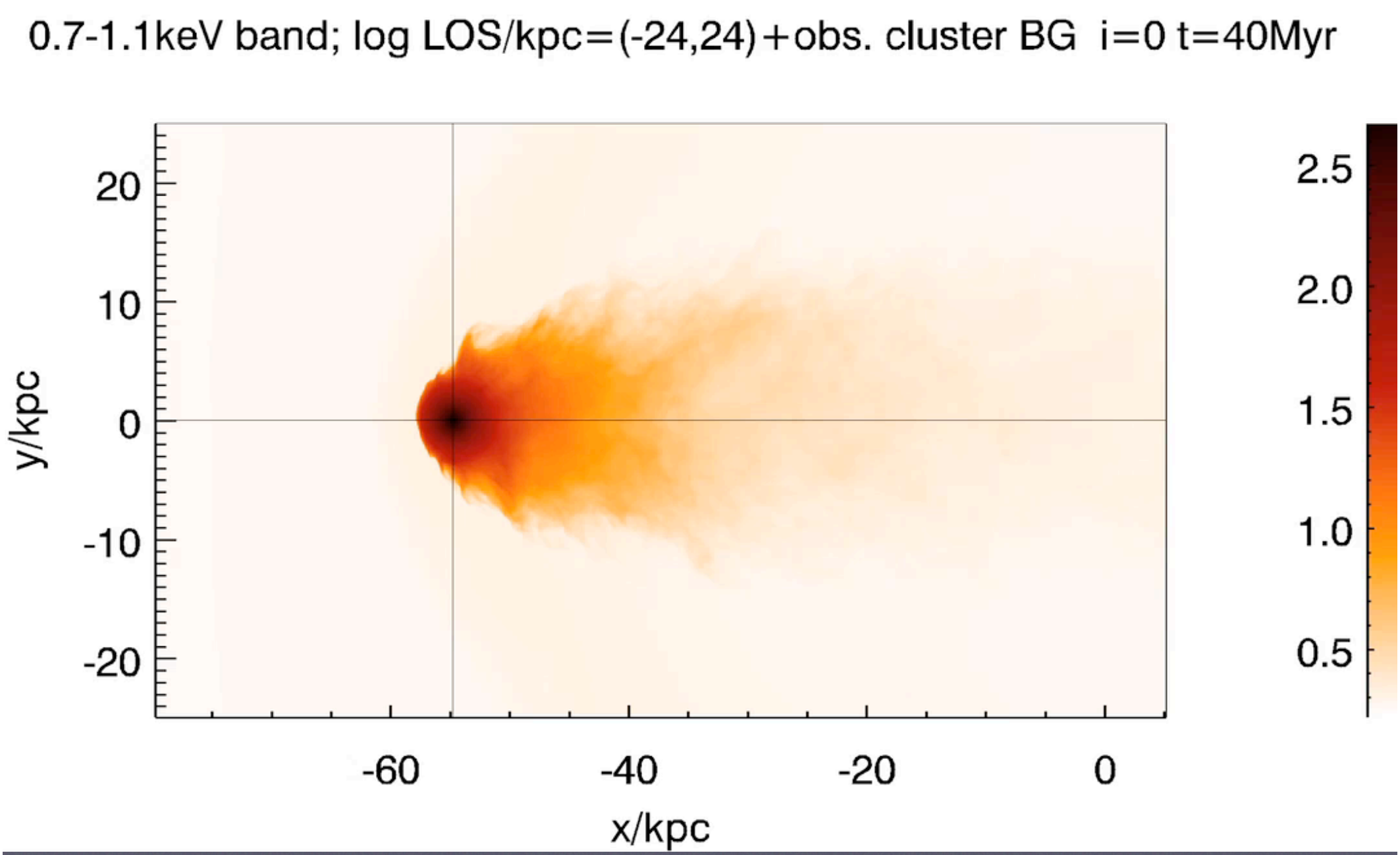
Mock X-ray (0.7-1.1keV)

Elke Roediger

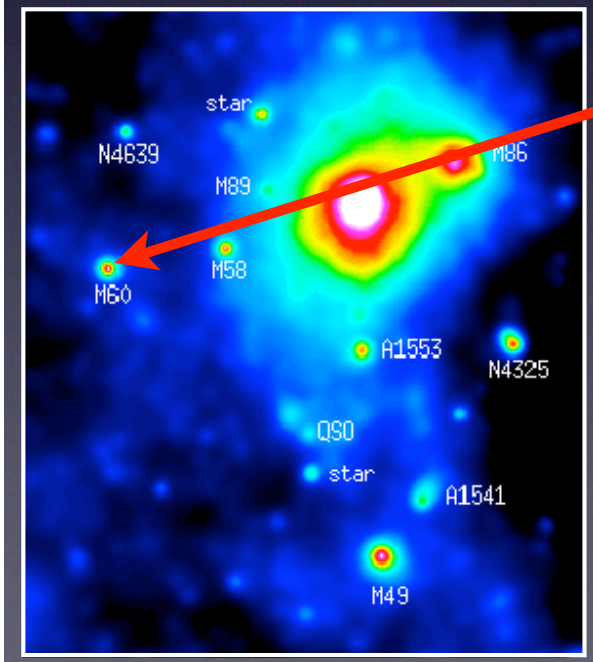

Chandra ACIS-S
0.7-1.1 keV (200 ks)
2' = 10kpc
XMM pn
0.5-1.2 keV (18 ks clean)
Kraft et al. in prep.

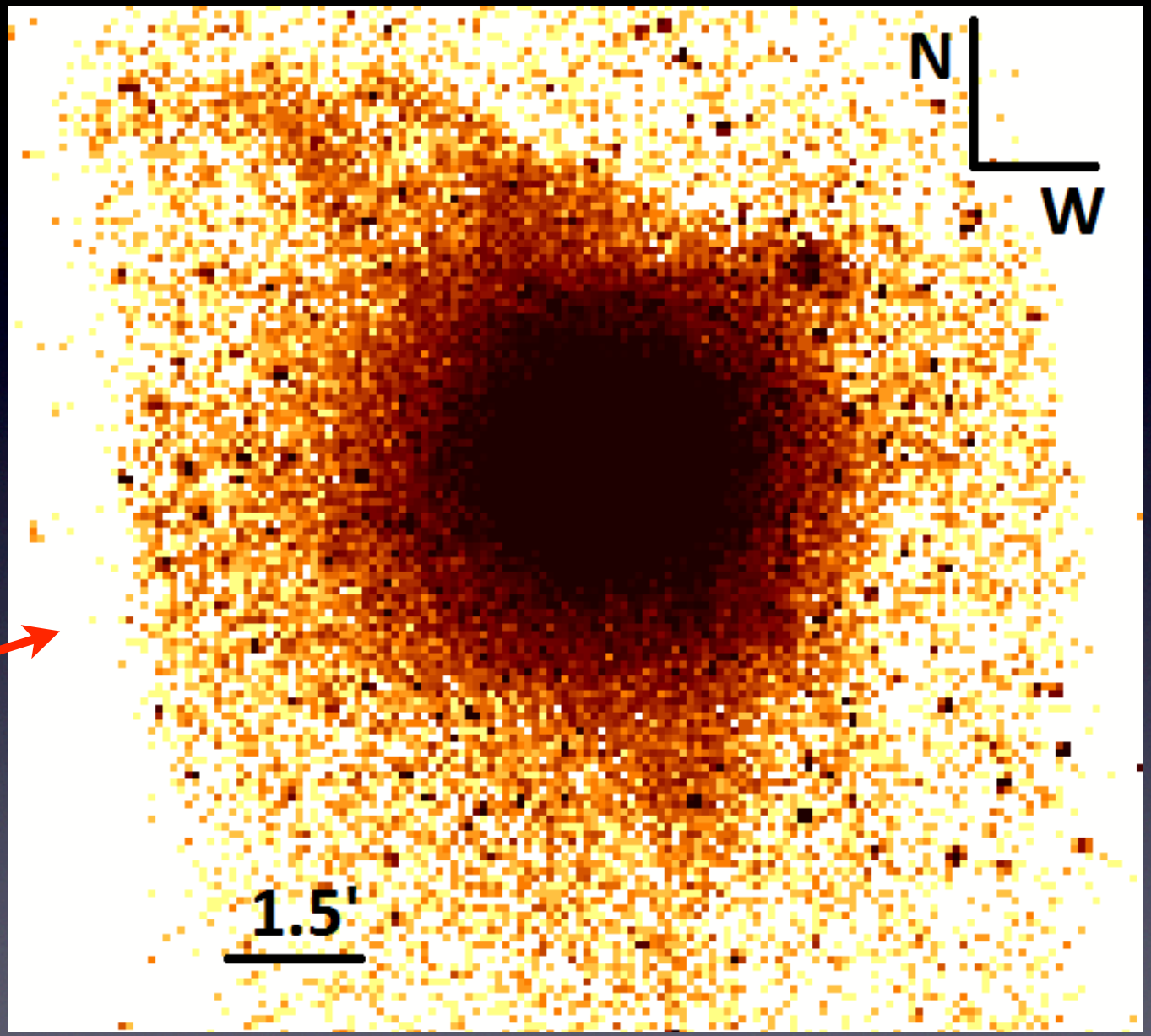

Chandra ACIS-S
0.7-1.1 keV (200 ks)
2 arcmin = 9.7 kpc


-110
-100
-90


0.7-1.1keV band; log LOS/kpc=(-24,24)+obs. cluster BG i=0 t=40Myr
20
10
0
-10
-20
y/kpc
-60
-40
-20
0
x/kpc
2.5
2.0
1.5
1.0
0.5

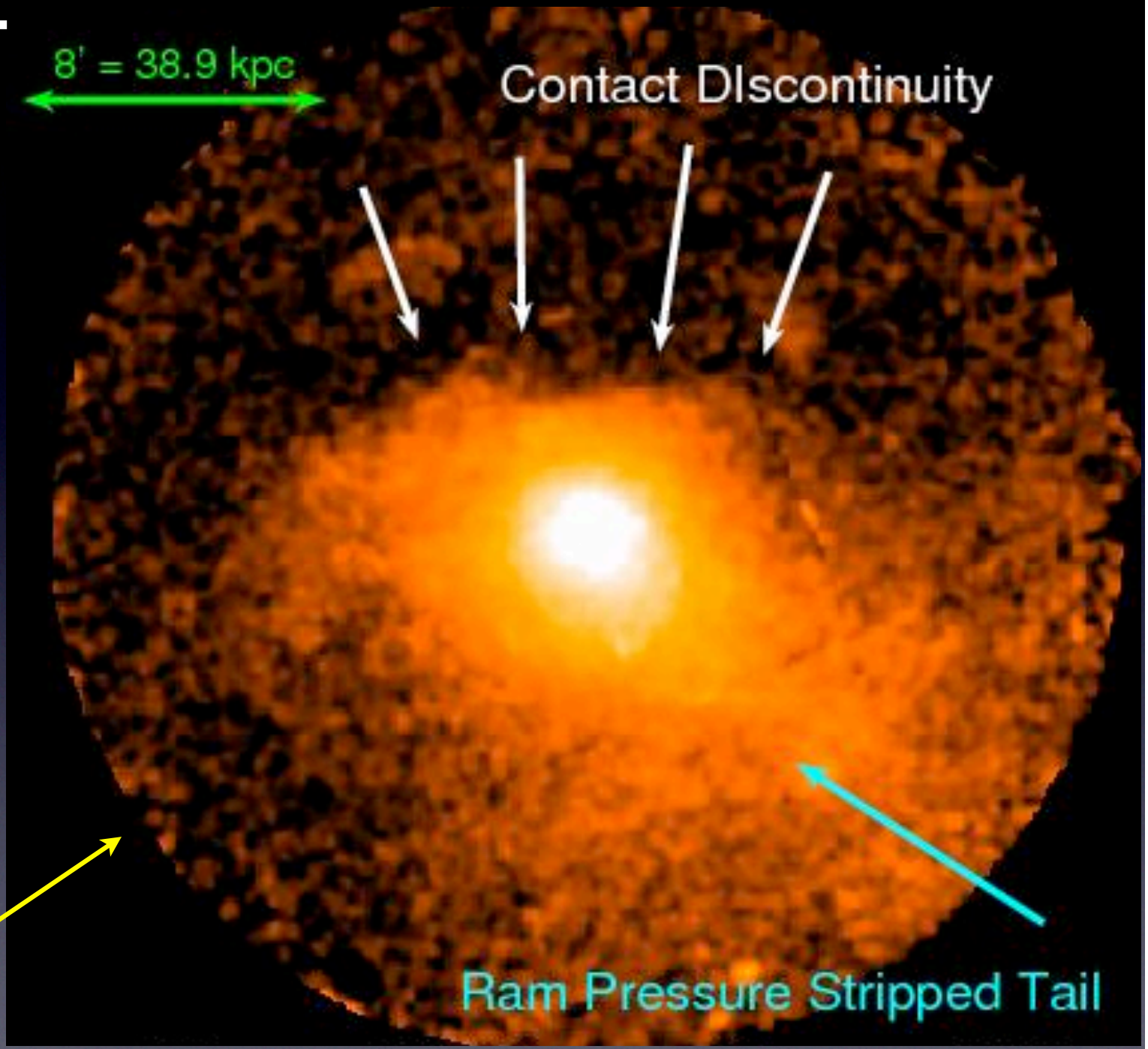
NGC 4649 (M60)

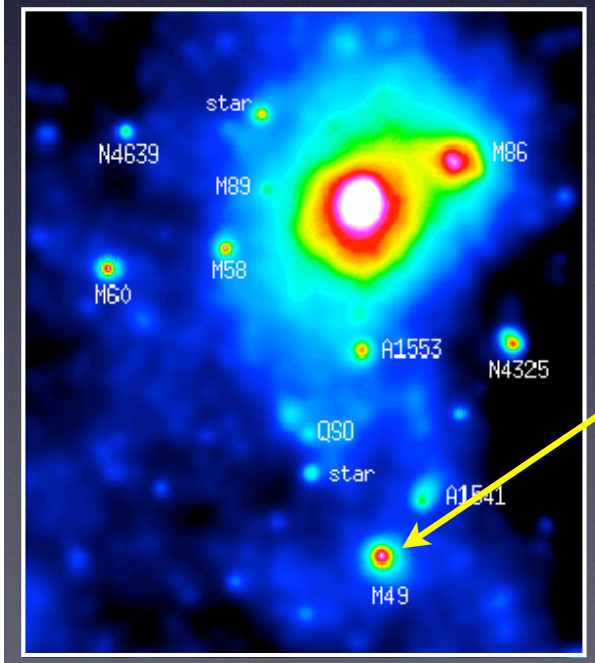




Chandra mosaic (Wood+ 2014, submitted)

NGC 4472 (M49)

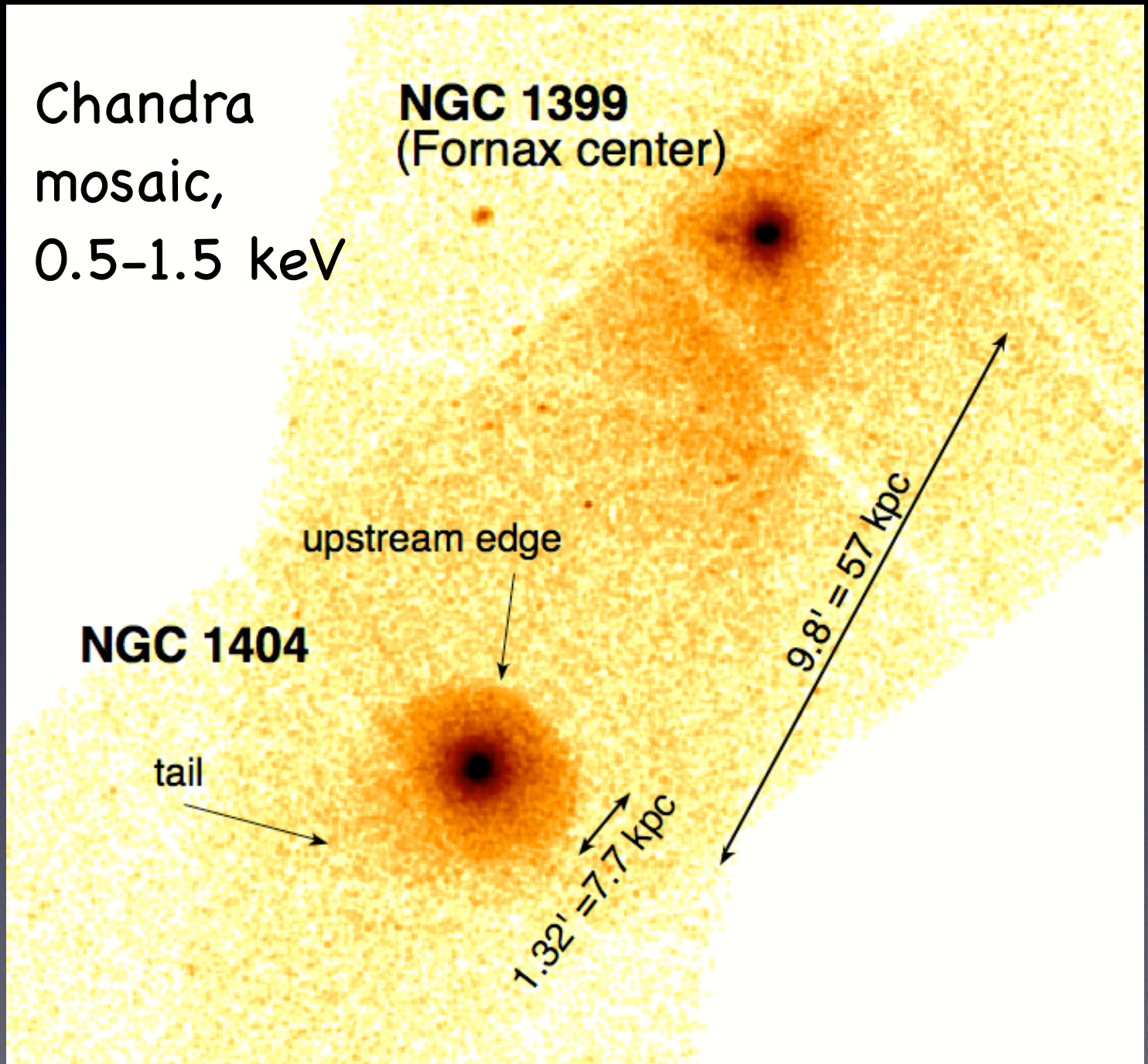




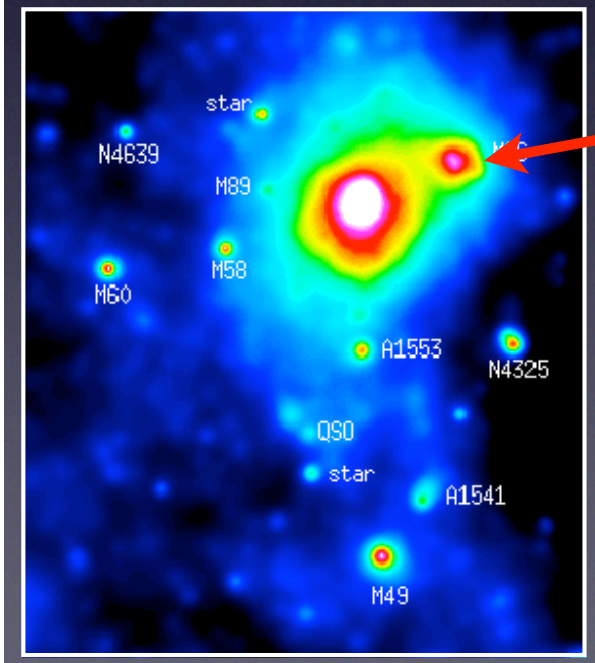
XMM-Newton image (0.5-2.0 keV) (Kraft+ 2011)

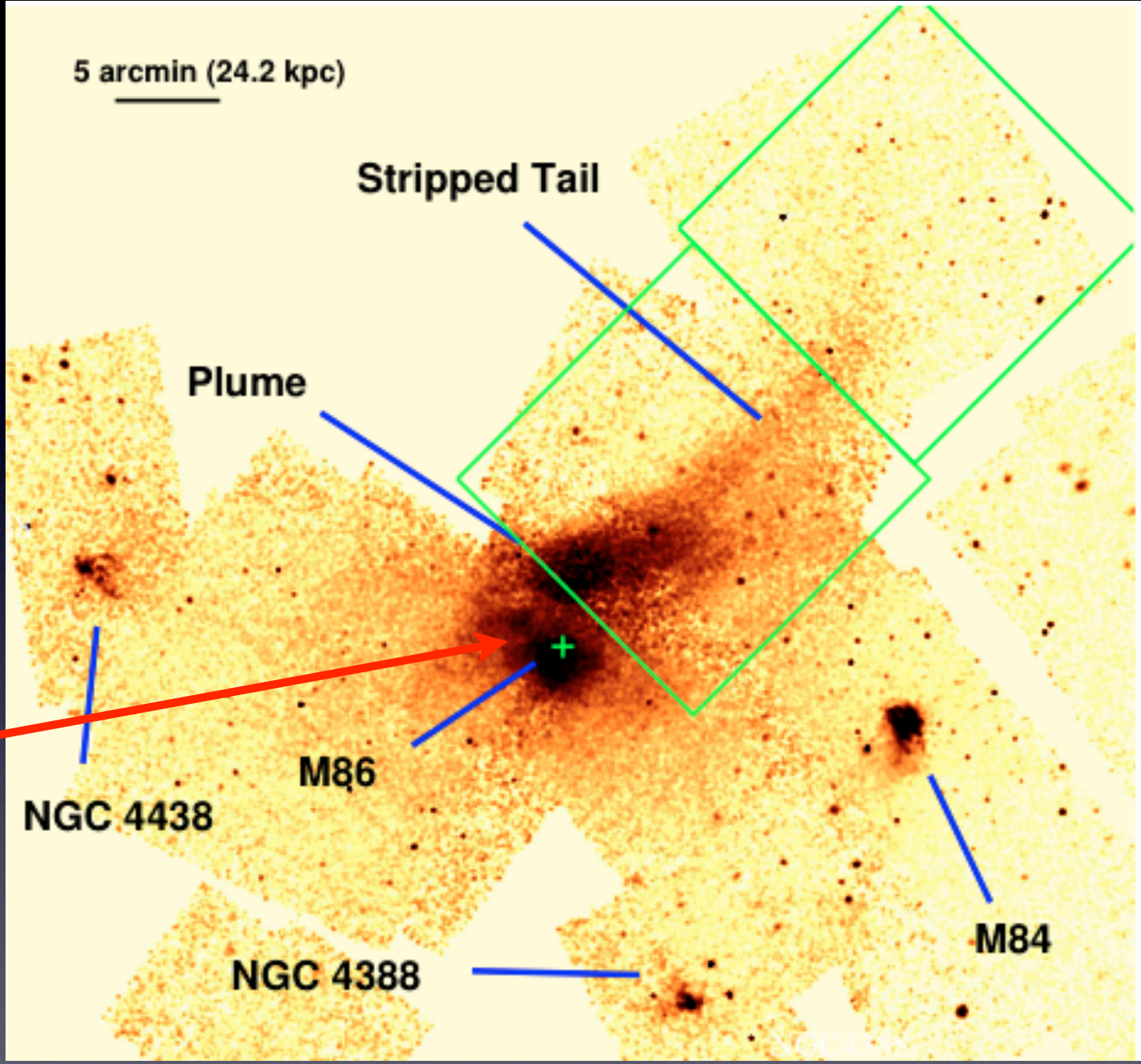
NGC 1404 in Fornax

Machacek+ 2005

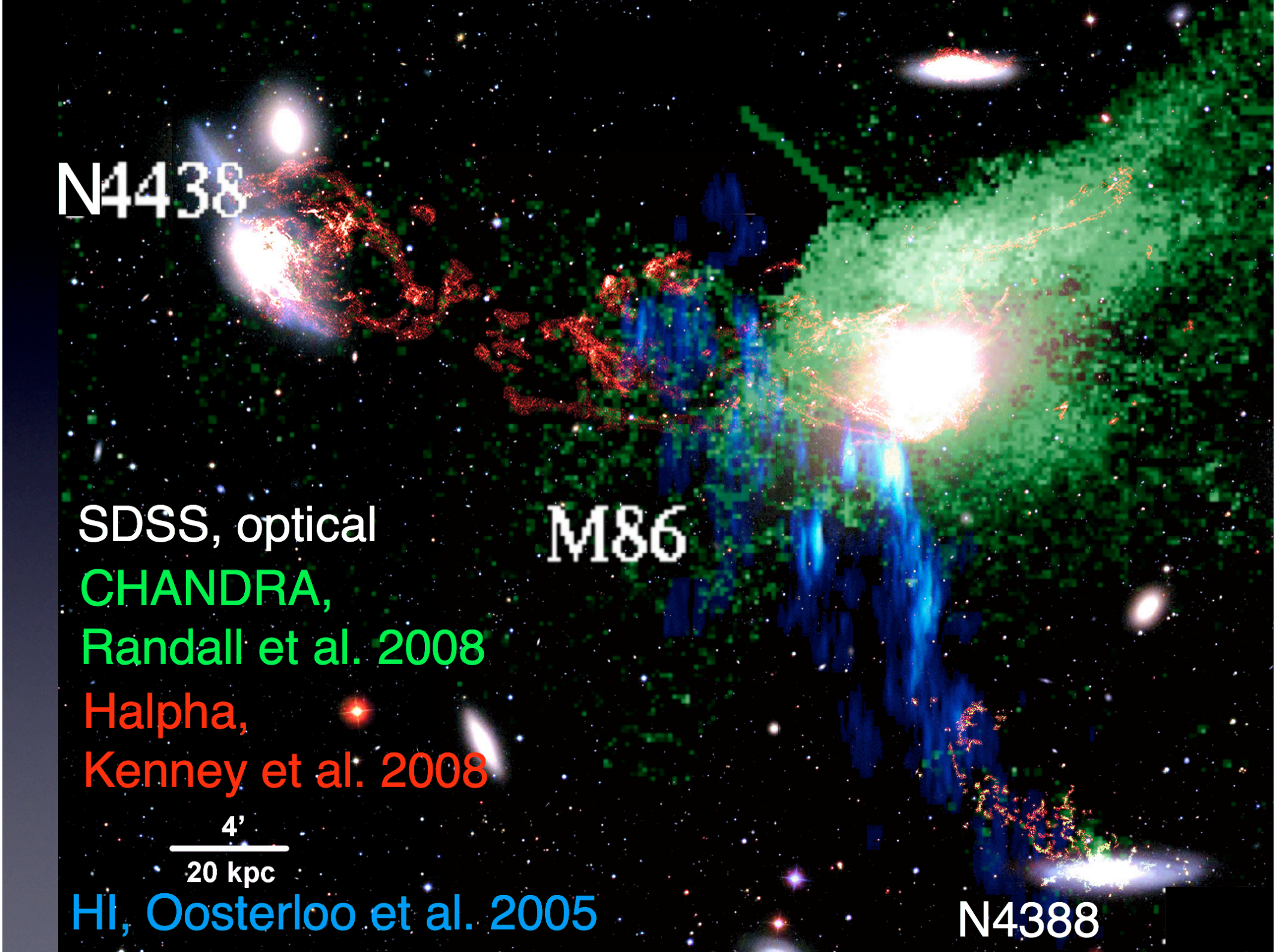


NGC 4406 (M86)





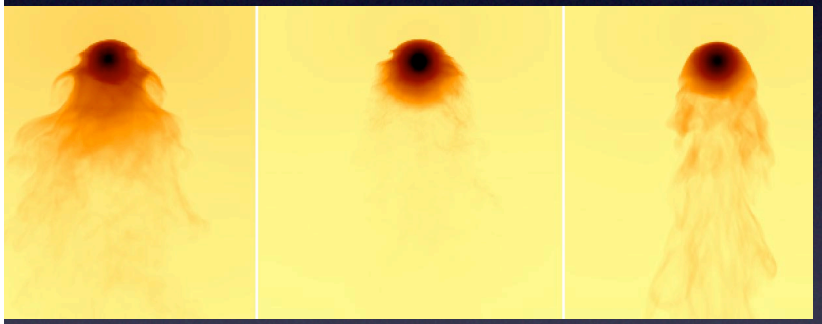
Chandra mosaic (Randall+ 2008)


N4438
M86
SDSS, optical
CHANDRA,
Randall et al. 2008
Halpha,
Kenney et al. 2008
4'
20 kpc
HI, Oosterloo et al. 2005
N4388

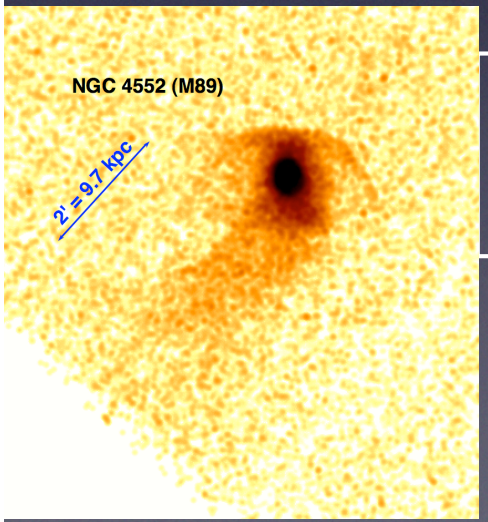
Summary

cluster dynamics establish opportunity for ICM mixing

ICM properties allow/ suppress/prevent it



observables for *correct dynamics*



first evidence against substantial isotropic viscosity in Virgo cluster

pilot studies done, more to come!