NGC 7618 and UGC 12491: Gas-Dynamics in the Nearby Merger of Two Sub-groups

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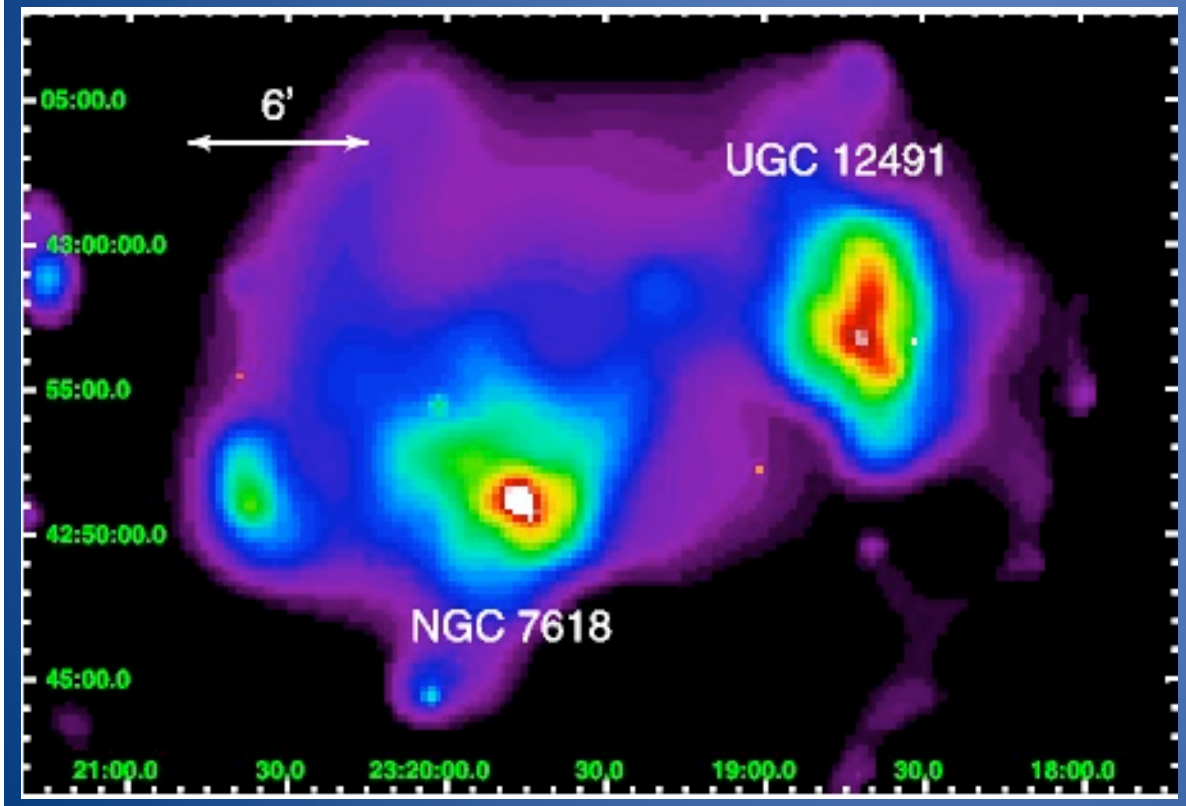
Basic Parameters

ASCA GIS (54 ks)



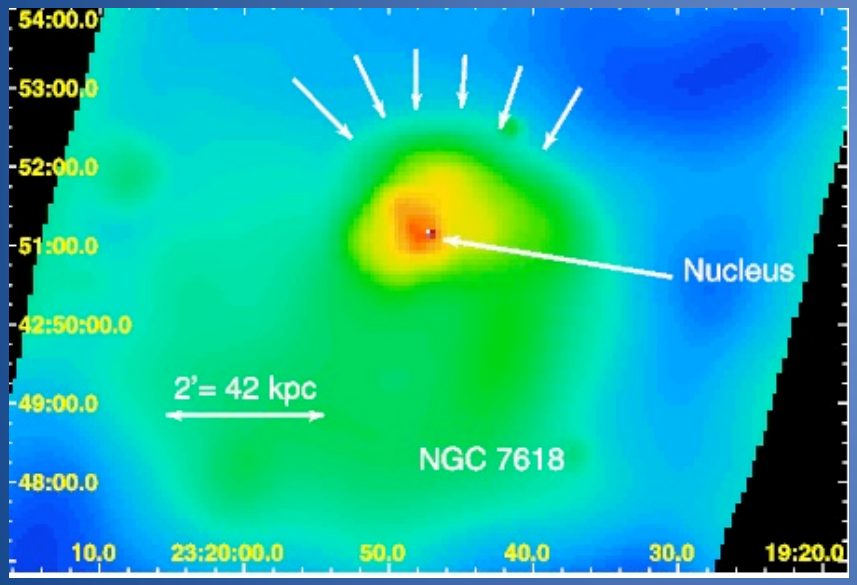
Nearby: 74 Mpc
1 arcsec = 347 pc
Δv_r ~ 17 km/s
⇒ in plane of sky
d ~ 290 kpc

Subgroups:
extended emission
> 150-200 kpc
10σ significance
L_X ~ 6 – 7 x 10^{42} ergs/s

Kraft et al. 2006

Goal: Constrain Kinematics and Identify Dominant Gas-Dynamical Processes

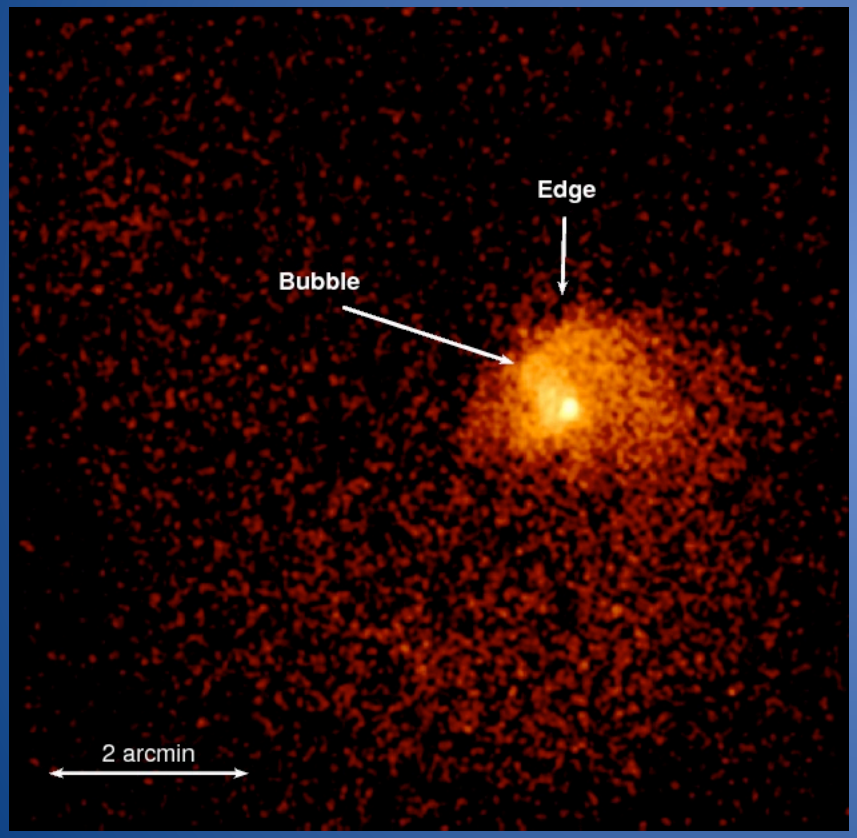
Chandra 0.5-2 keV , 8438 s



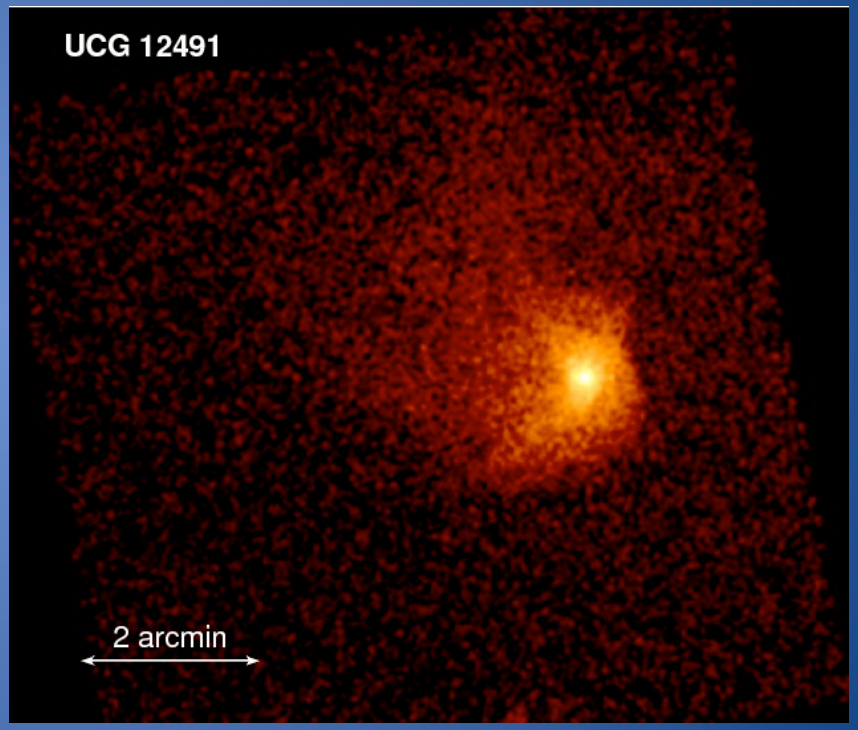
- Ram pressure stripping
- Tidal interactions from merger
- Non hydrostatic gas sloshing
- AGN-radio lobe-ICM interaction

Kraft et al. 2006

Chandra ACIS S3 0.5- 2 keV
1.5 arcsec Gaussian smoothed
NGC 7618 32 ks

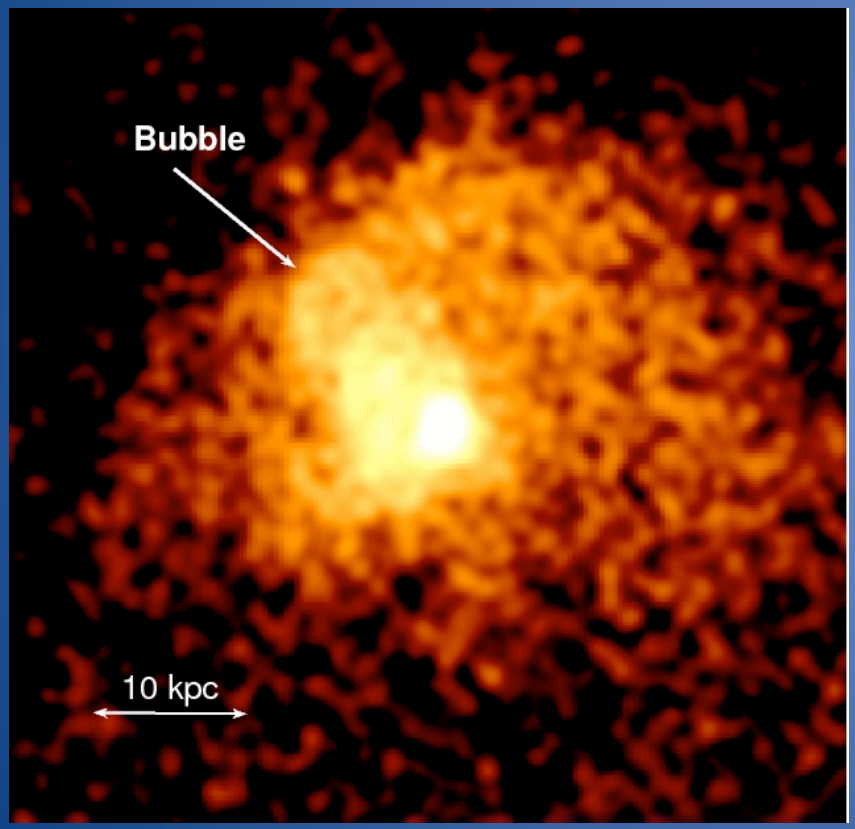


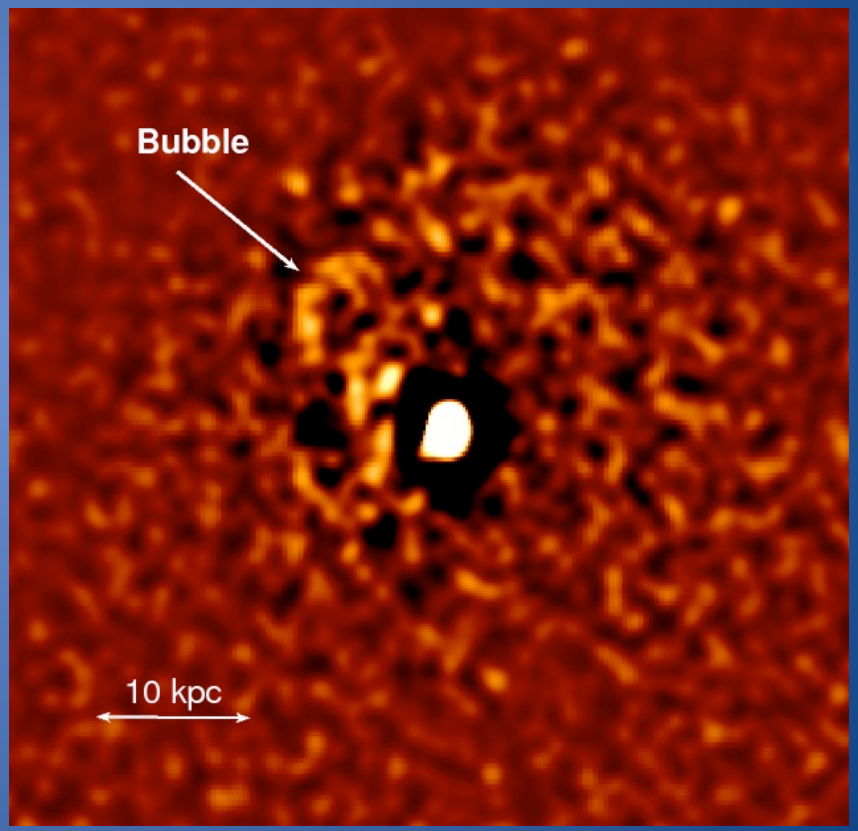
UGC 12491 31 ks



Machacek et al. in prep

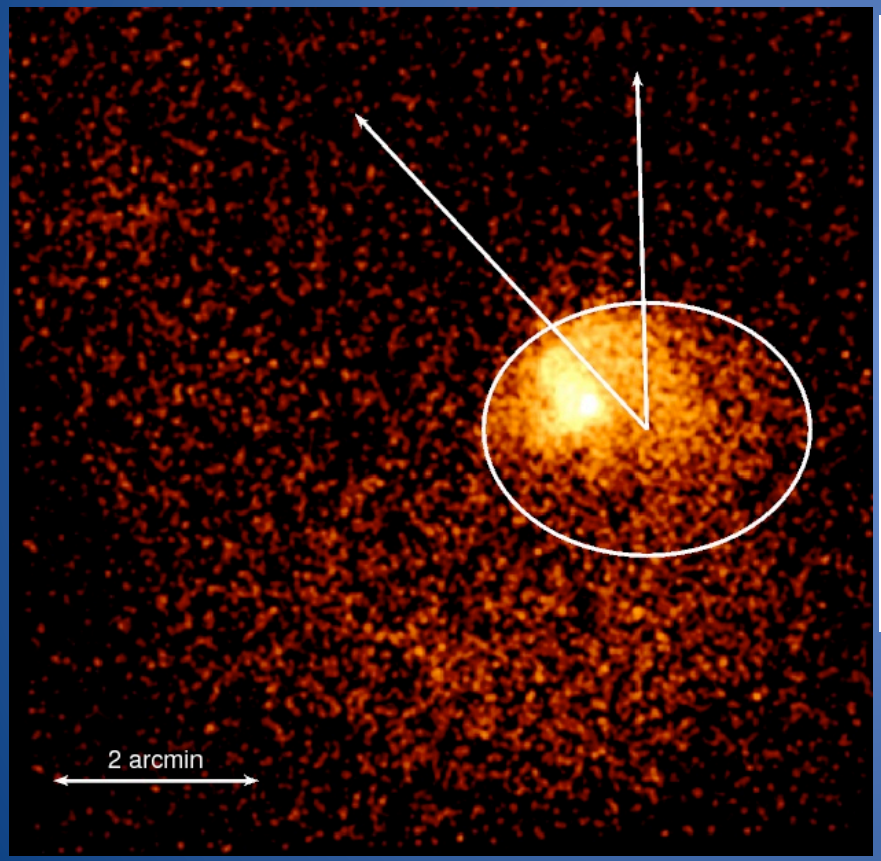
Complex Gas Dynamics
Turbulence, outflow, bubble?

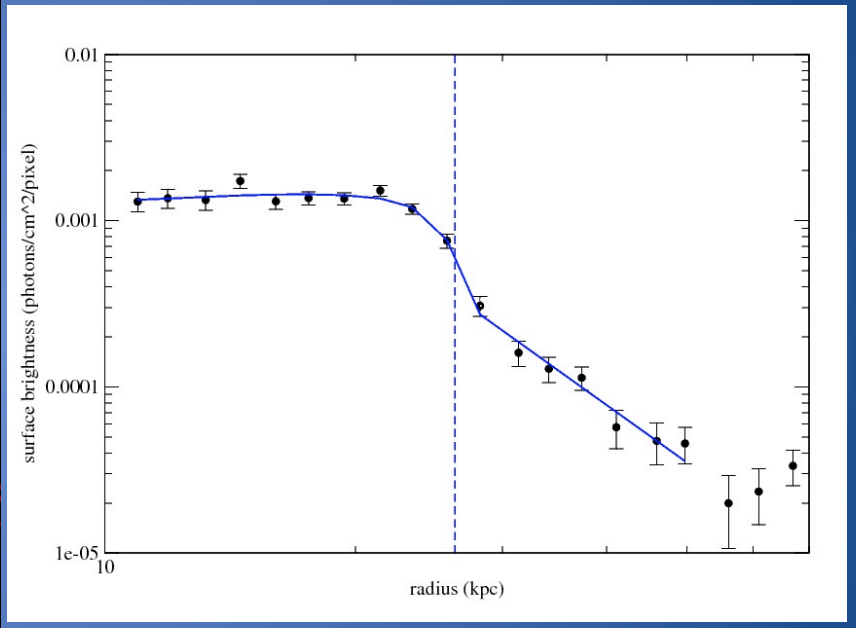




NGC 7618: Kinematic Constraints

Density Model $n \propto (r/r_{edge})^{-\alpha}$



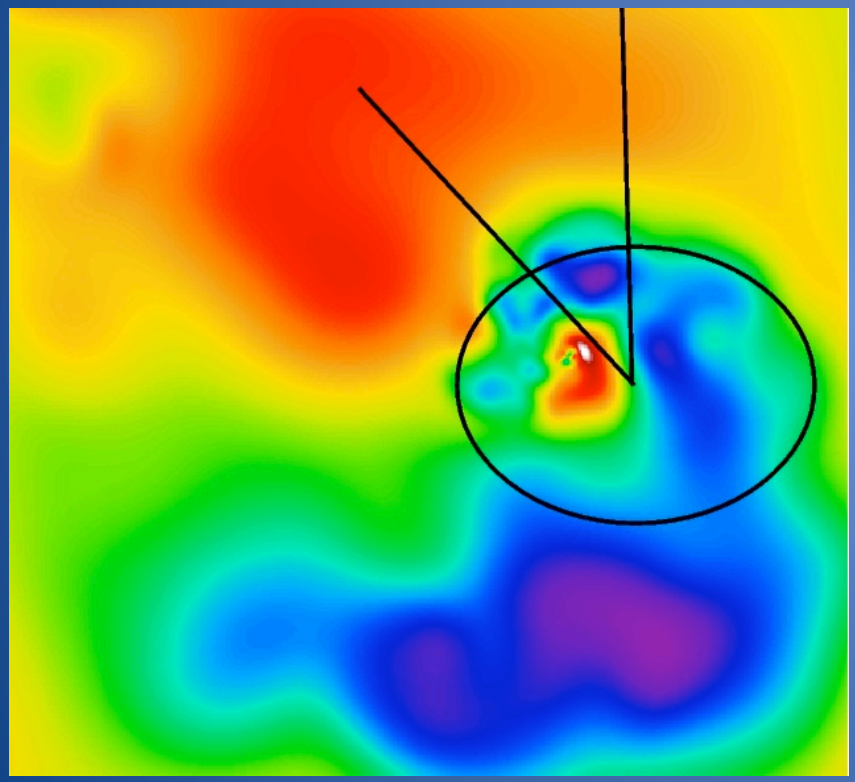


Off center ellipse

Edge at 26.3 kpc

Density $n_0/n_1 = 2.22$

NGC 7618: Temperature Structure



Cold front

T_0 = 0.75 ± 0.02 keV

North ICM

$T_1 = 1.4^{+0.3}_{-0.2}$ keV

$T_0/T_1 = 0.55$

Cool (0.75 ± 0.04 keV)
spiral-like tail

1 keV inner region

Cold Front (Edge) Analysis

Vikhlinin, Markevitch, Murray 2001, ApJ,551, 160

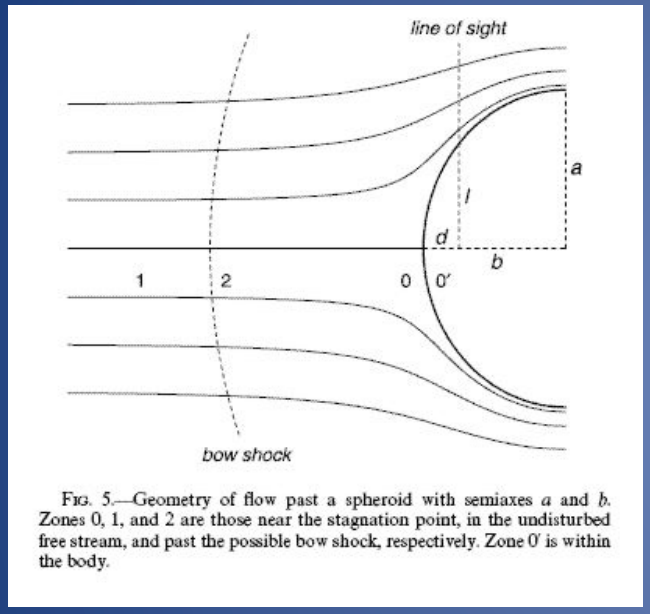


FIG. 5.—Geometry of flow past a spheroid with semiaxes *a* and *b*. Zones 0, 1, and 2 are those near the stagnation point, in the undisturbed free stream, and past the possible bow shock, respectively. Zone 0′ is within the body.

1 free stream IGM

0 stagnation point

0’ galaxy, inside edge

$p_0 = p_{0'}$

Landau & Lifshitz, 1959 ,
Fluid Mechanics,sec. 118

$$\frac{p_0}{p_1} = \left(1 + \frac{\gamma - 1}{2} M_1^2\right)^{\gamma/(\gamma-1)}, \quad M_1 \le 1, \tag{2}$$

$$\frac{p_0}{p_1} = \left(\frac{\gamma + 1}{2}\right)^{(\gamma+1)/(\gamma-1)} M_1^2 \left[\gamma - \frac{\gamma - 1}{2M_1^2}\right]^{-1/(\gamma-1)}, \quad M_1 > 1, \tag{3}$$

NGC 7618: Pressures & Velocities

Pressure ratio

$p_0/p_1 = 1.2\ ^{+0.3}_{-0.2}$

Mach = 0.49

v ~ 300 km/s

SLOSHING!

ICM response to gravitational perturbation or shock

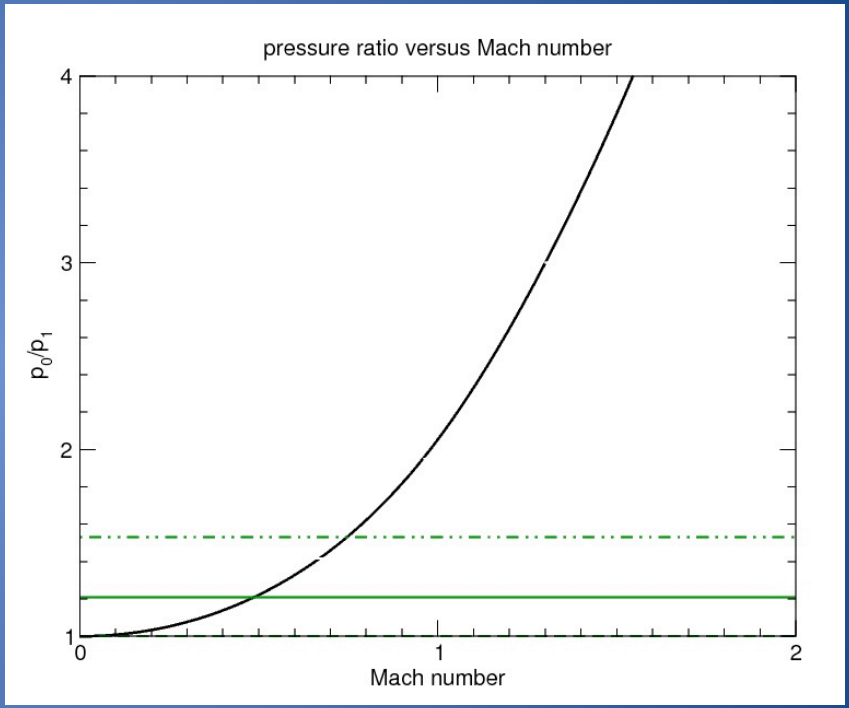
off centered cold front

spiral features in T map

modest pressure jump

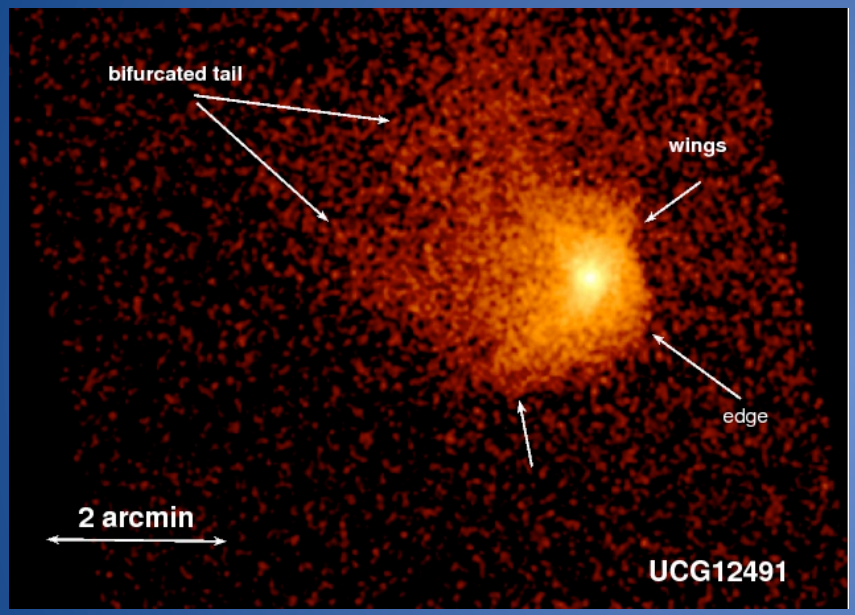
t ~ 10^9 yr

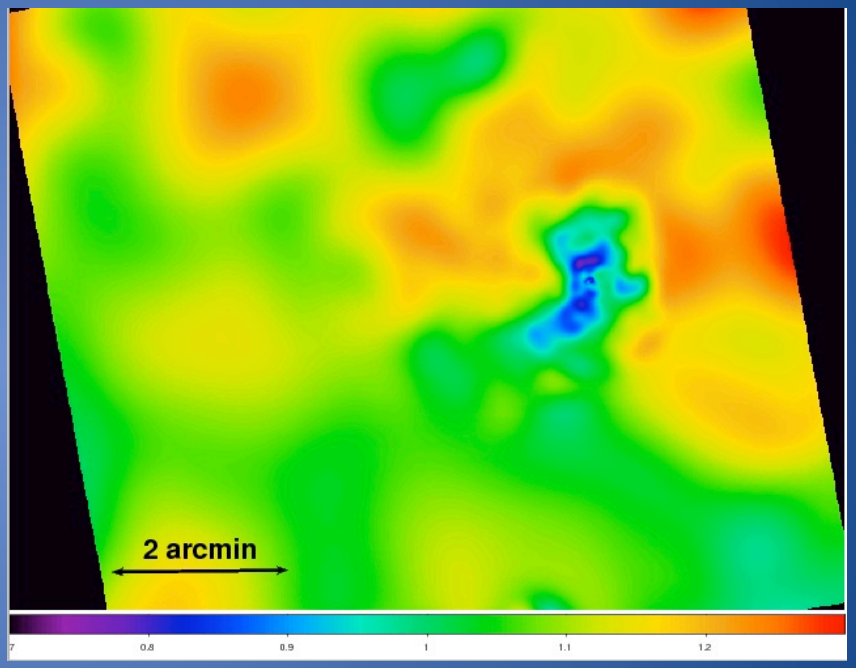
Ascasibar & Markevitch 2006



Is UGC 12491 the perpetrator?

UGC 12491: Stripping?



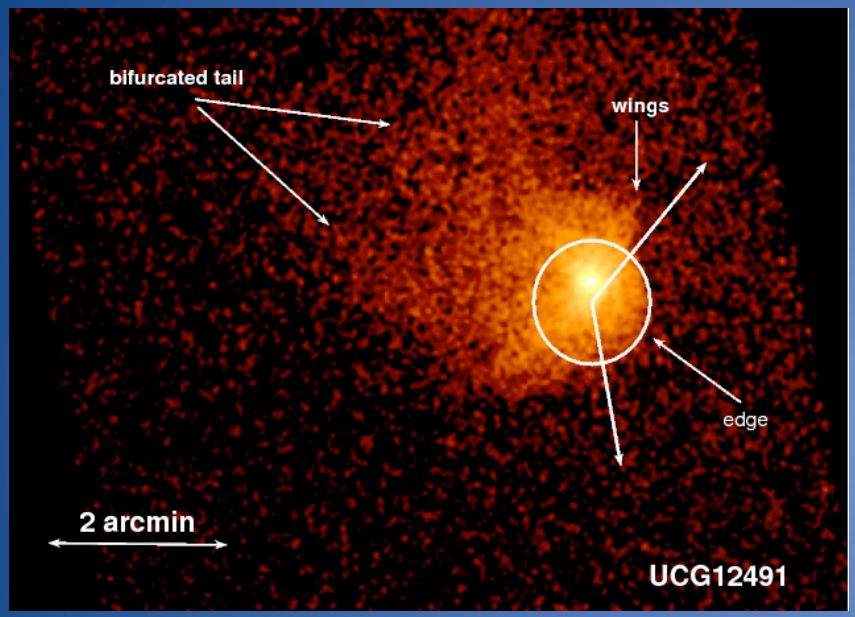


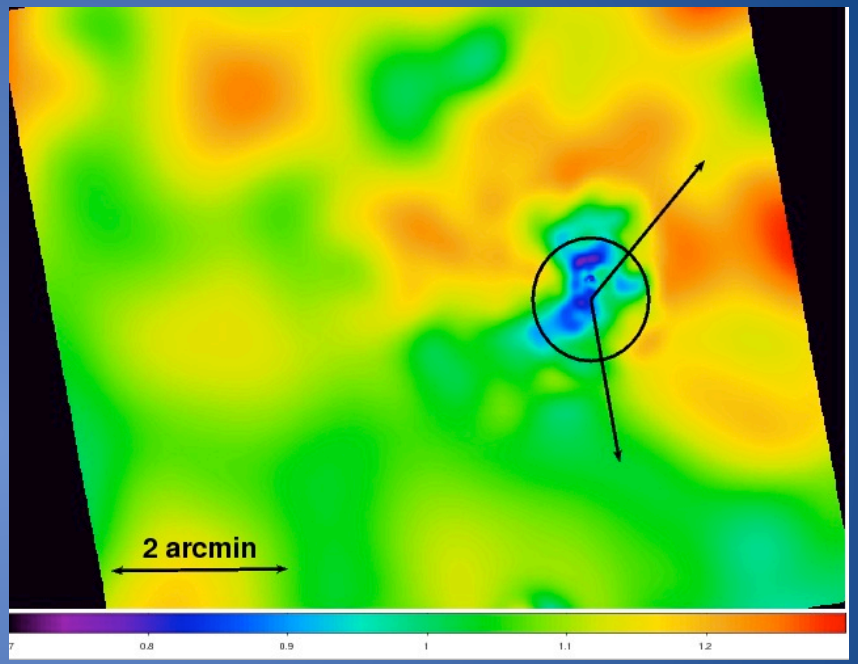
Bifurcated Tails common in Virgo galaxies undergoing stripping

Randall et al 2008

Sharp surface brightness discontinuity….cold front…

Cold Front Analysis





West IGM T_1 = 1.65 keV; Inside edge T_0 = 1.02 keV

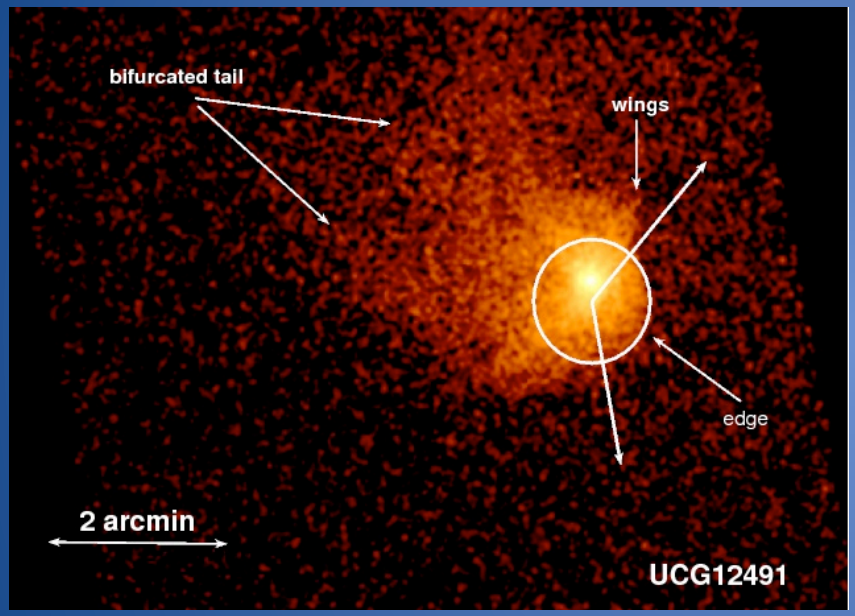
Sharpest surface brightness discontinuity along outer edge

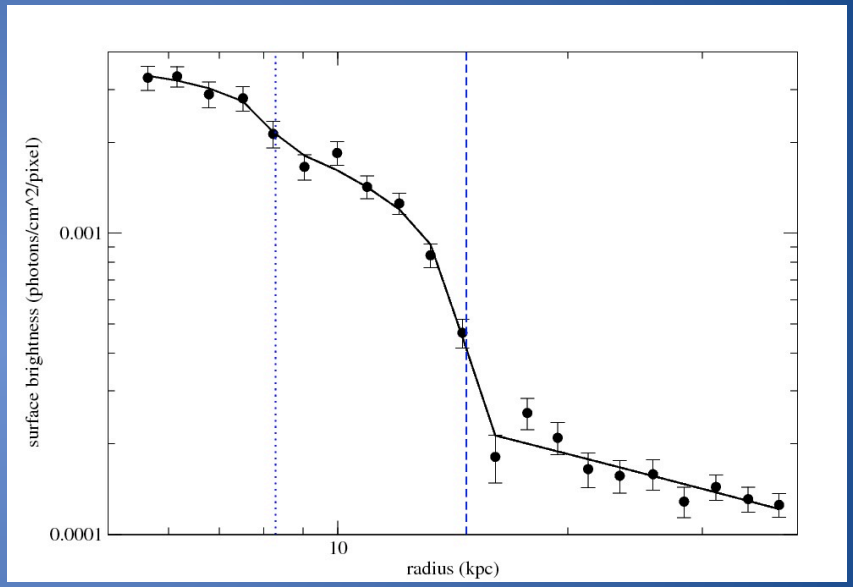
Coolest gas along the wings or inner edge…. T ~ 0.8 keV

Nuclear region ..intrinsic absorption (~ 10^{21} cm)

AGN Γ ~ 2.0, A ~ 1 (preliminary)

UGC 12491: Cold Front





Double edges?

Outer edge at 14. 7 kpc Outer density jump n_1/n_2 = 3.7

Inner edge at 8. 3 kpc Inner density jump n_0/n_1 = 1.4

UGC 12491: Velocity

Outer edge: Subgroup ?

Pressure ratio

$p_0/p_1 = 2.32$

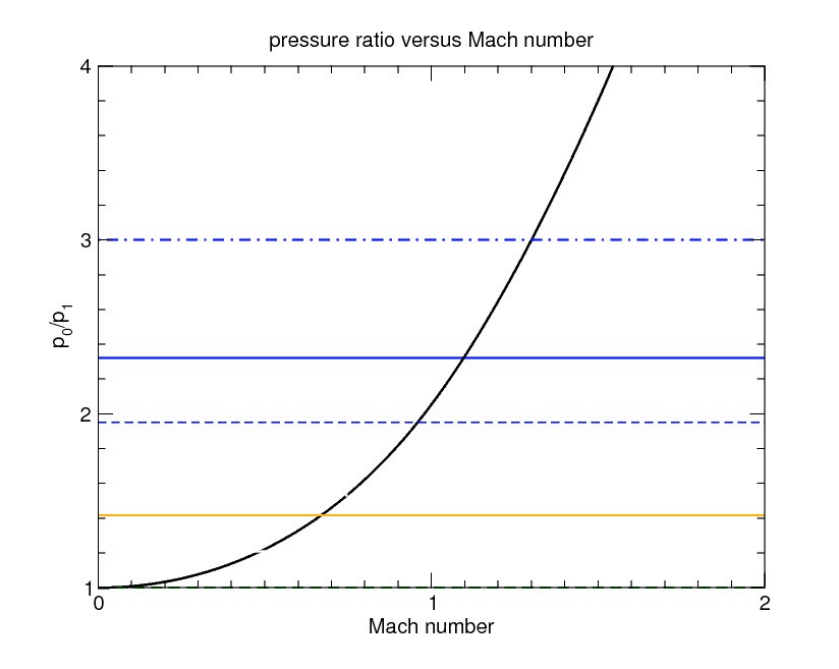
Mach $= 1.1^{+0.2}_{-0.15}$

$\Rightarrow$ v ~ 740 km/s

Mildly supersonic !

Merger Cold Front

- acted on by ram pressure
- usually transonic
- max near core crossing
- t ~ 10^8 yr



Inner Edge: Galaxy?

$p_0/p_1 = 1.42$

Mach =0.67 $\Rightarrow$ v = 350 km/s

X-ray Studies of Galaxy Subgroup Mergers
What are we learning?

Goal: Study the fundamental physics of structure evolution in cool group/cluster environment

- Constrain 3-D motion of galaxy subgroups
- Show gas stripping/sloshing in action

  identify gas motions in T structure of gas
- Identify matter/energy outflows into environment