M31*, The Nearest Extra-Galactic SMBH X-ray (and Radio Properties) +BH-XRT

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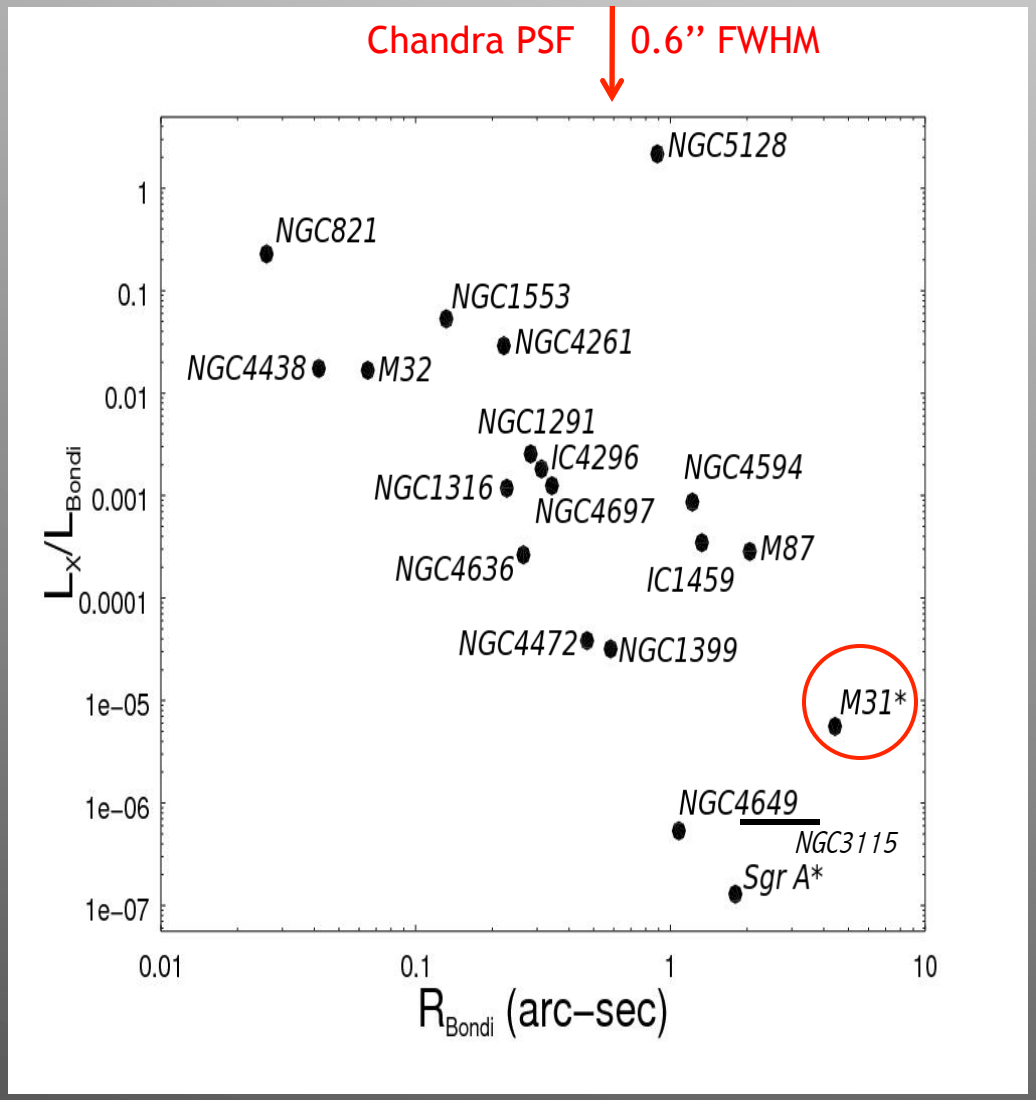
Fig courstesy: M. Gilfanov, Z. Li

How do Quiescent BH Accrete?



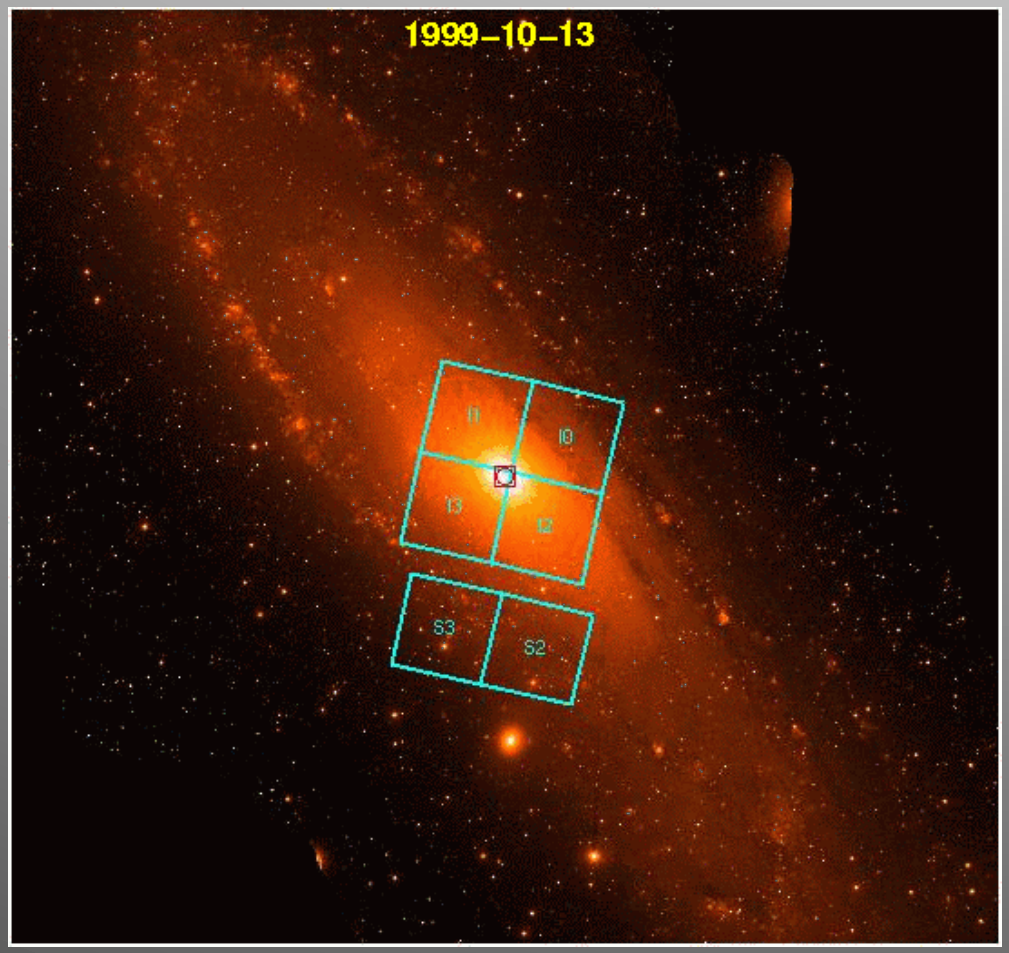
- BH spend the majority of their time at low accretion rates.
- RIAF forms, but what fraction gets blown out?
- Indirect: Spectra, CV/NS comparisons
- Resolve the flow!
- M31* best target. Sgr A*, NGC3115, M87 next (jet).

Why is M31* excellent?

Angular Bondi Radius ~ (M/kT)/D

	M	kT (keV)	D (kpc)	R(B)	Comment
M31*	1.4e8	0.3	780	5.2”	XRBs all resolved, accurate subtraction possible
Sgr A*	4e6	1.3	8	1.8”	0.3 keV absorbed
M87	6.4e9	0.8	17,000	1.7”	Bright Jet!
NGC3115	1-2e9	0.3-0.6	9,700	2”-4”	XRBs unresolved but subtracted w/ average 2-6keV spectrum

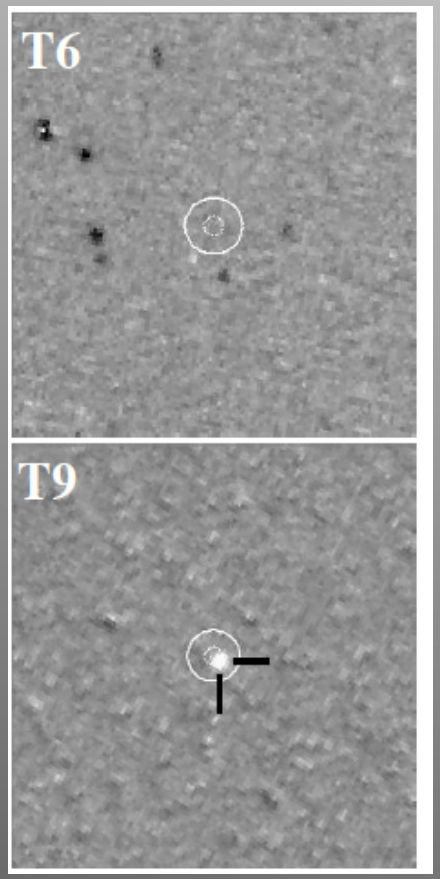
Our Chandra Monitoring Campaign +Intensive CXO/VLA/HST AO13

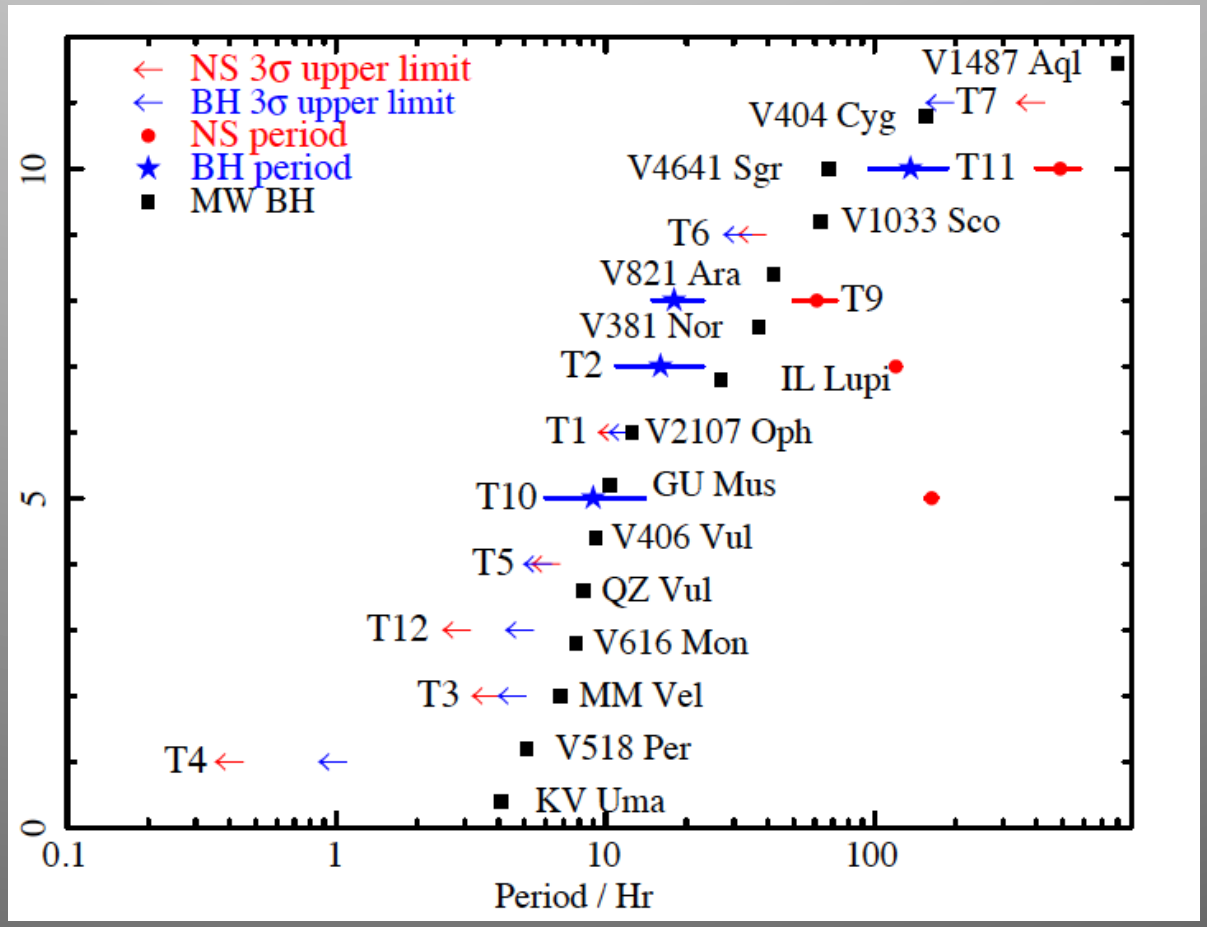


- ACIS+HRC concentrated in bulge
- AO1 through 13, total is >1Ms. Nucleus w/ ACIS-I only ~300ks. 5ks snapshots
- 50/50 GO/GTO – multi-year program not possible w/o GTO time!
- AO13(this week!): burn in nucleus with 400ks ACIS-S

Orbital Period Distribution for XRNe

Barnard, Garcia etal 2012





Shorter than in MW (P=8%): evidence for capture (triple) formation, re: Voss & Gilfanov 2007

A Decade Long Light-Curve

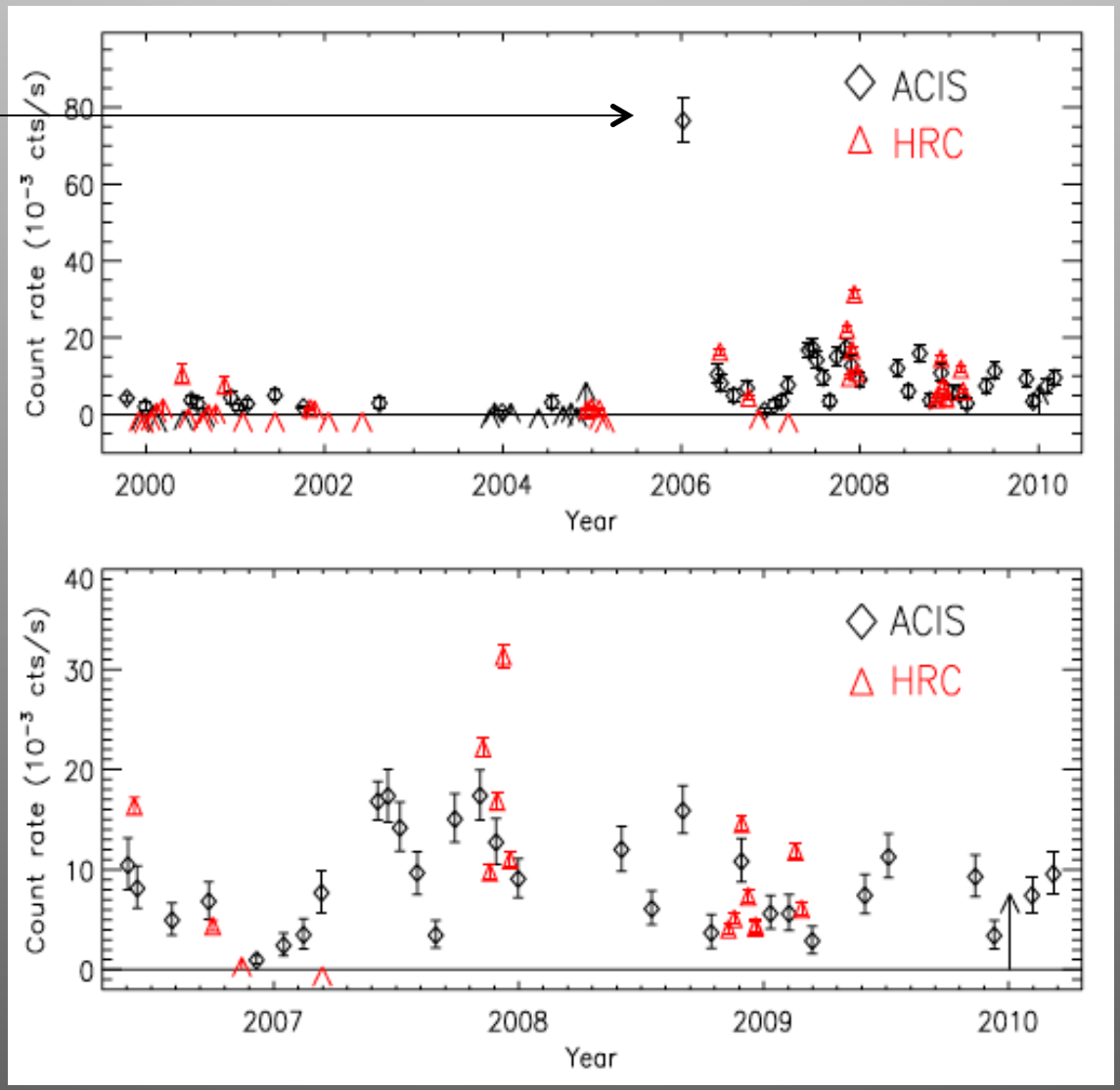
(Li, Garcia, et al 2011)

- Imaging
  - Chandra HRC, slightly better PSF
  - 40 obs, 1999 – 2010, 571ks
- Spectra
  - Chandra ACIS, allows spectral determination
  - 58 obs 1999-2010, 305ks
- HST/ACS
  - Register to Local Group Survey (stars, 0.03’’)
  - Resister X-ray to LGS Globulars (~0.1-0.2’’)
  - HST – Chandra ~0.2’’
- VLA – Radio Spectrum

The Murmur from the Hidden Monster

4x10^{37}ergs/sec

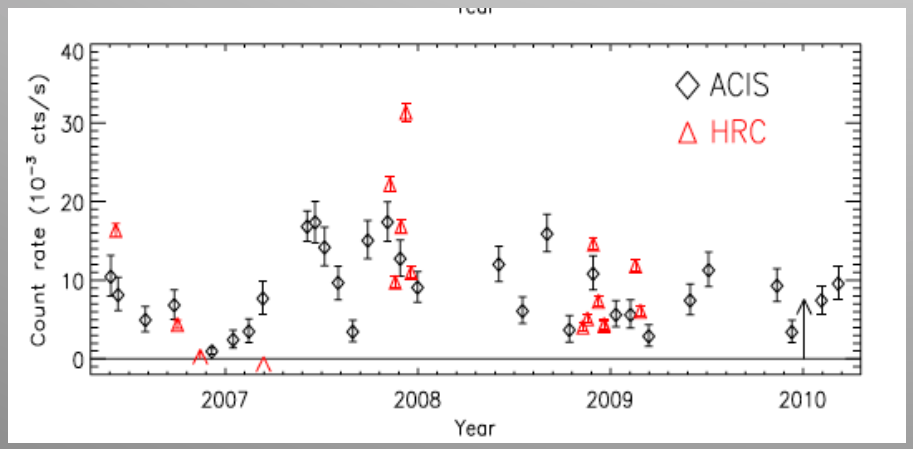
<~10^{36} ergs/sec



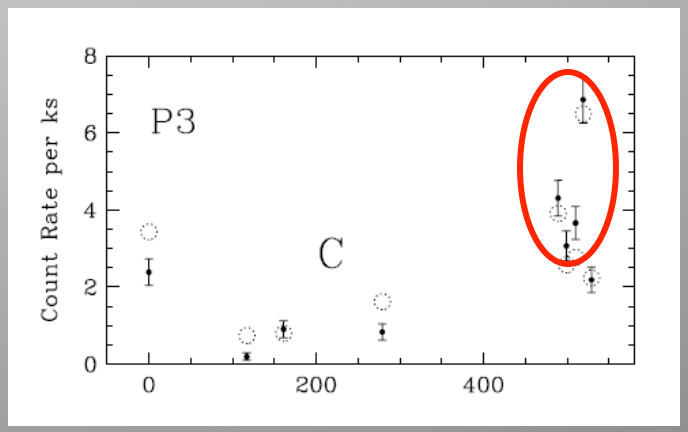
~5x10^{36} ergs/ec

X-ray flares in M31*

Post 2006



Dec 2007



Jan 2006 flare 100x
Since then 10x to
100x common

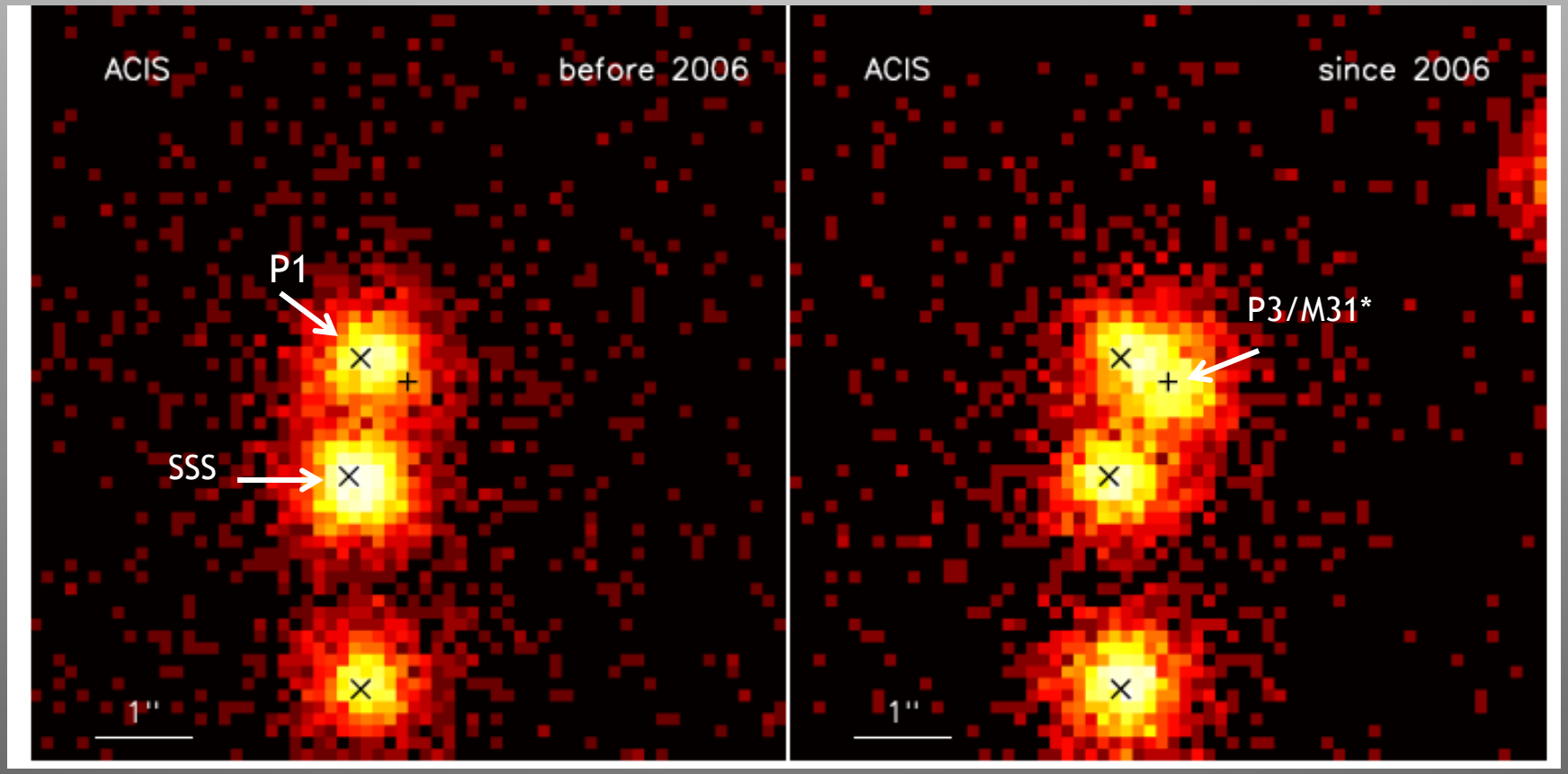
X3 in 10 days
Search for
Shorter variation
Null (4000s)

10 days ~orbital timescale
at 100 Schwarzschild (Martin's father) radii
Srg A* flares x10-100 on timescale of hours
(Baganoff et al. 2001, Marrone et al. 2008)

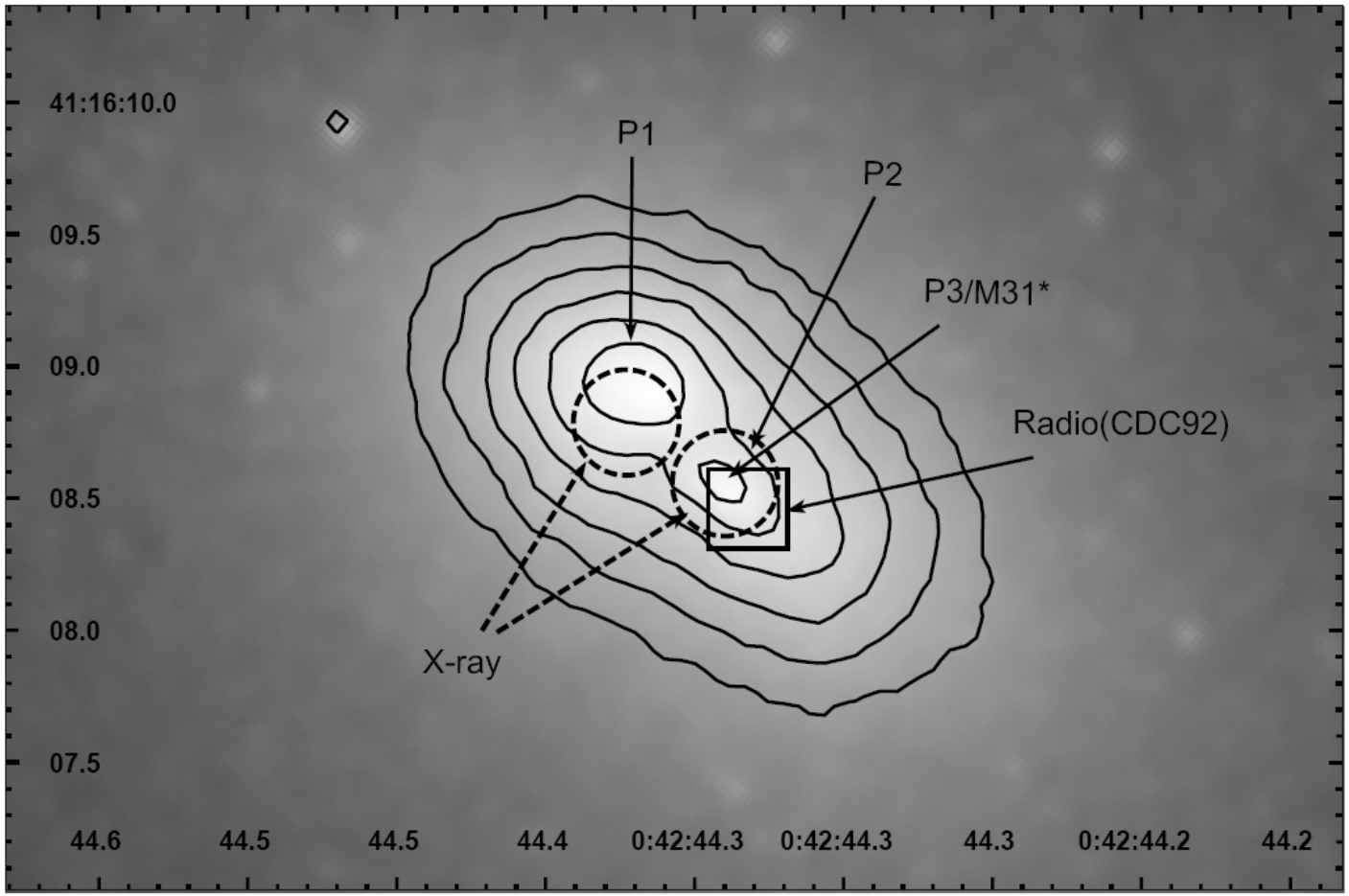
Scaling to mass of M31* (x35) – M31* flares would be few days long

⇒ M31* variation may be similar to Sgr A* flares (IR, sub-mm also?)
⇒ Are flares in q-SMBH common at lowest luminosities?

The Murmur from the Hidden Monster

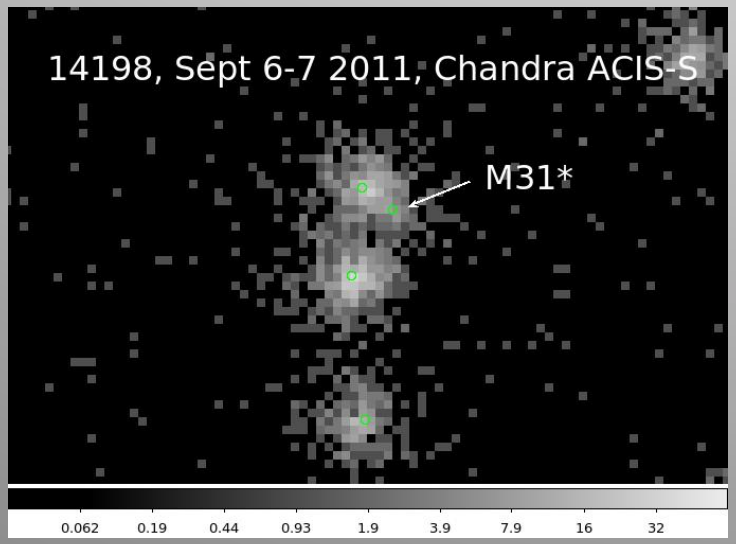


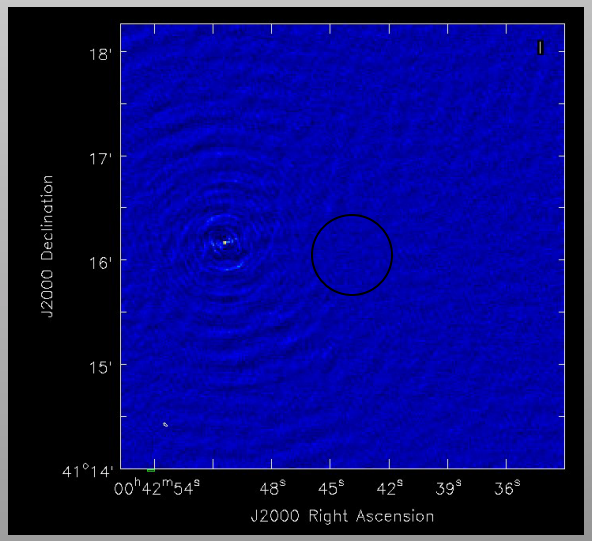
Positional Co-Incidence Only



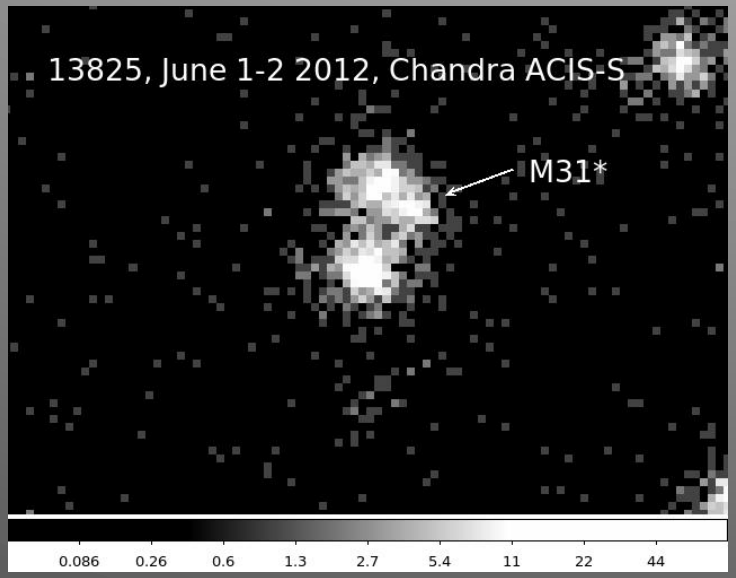
M31* or XRB? Radio / X-ray Correlation would help!
But pre/post 2006 variability unusual for XRB

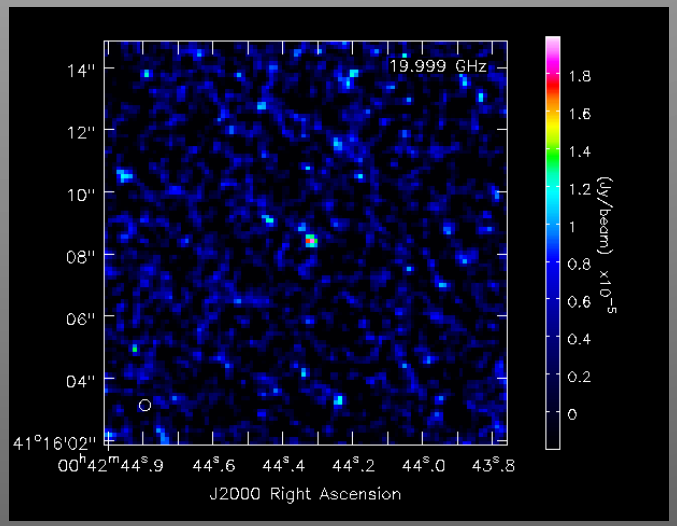
Most Recent Data – X-ray/Radio correlation?





EVLA, Sept 2011, <10 uJy (50+ typical)

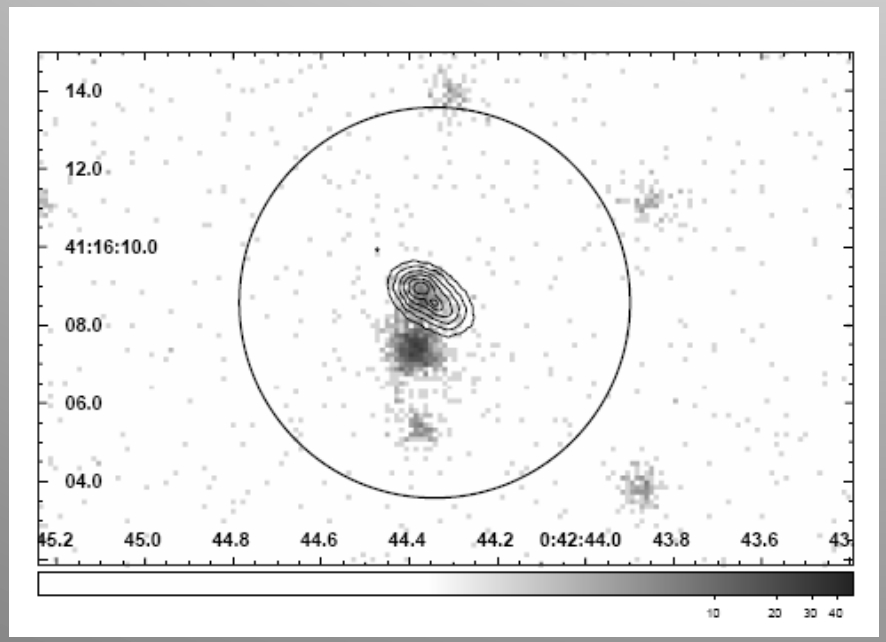


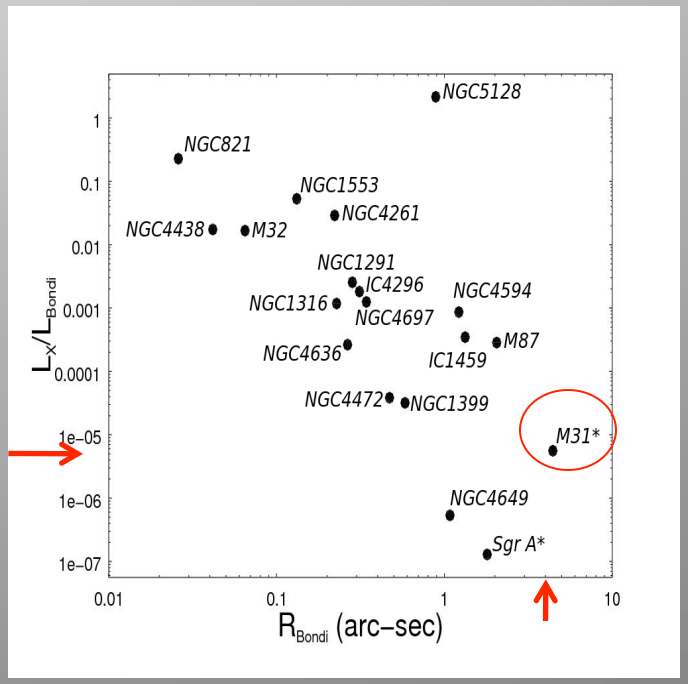


EVLA, June 2012 ~20 uJy

M Garcia, The Great Andromeda Galaxy, Princeton 2012

Bondi Rates



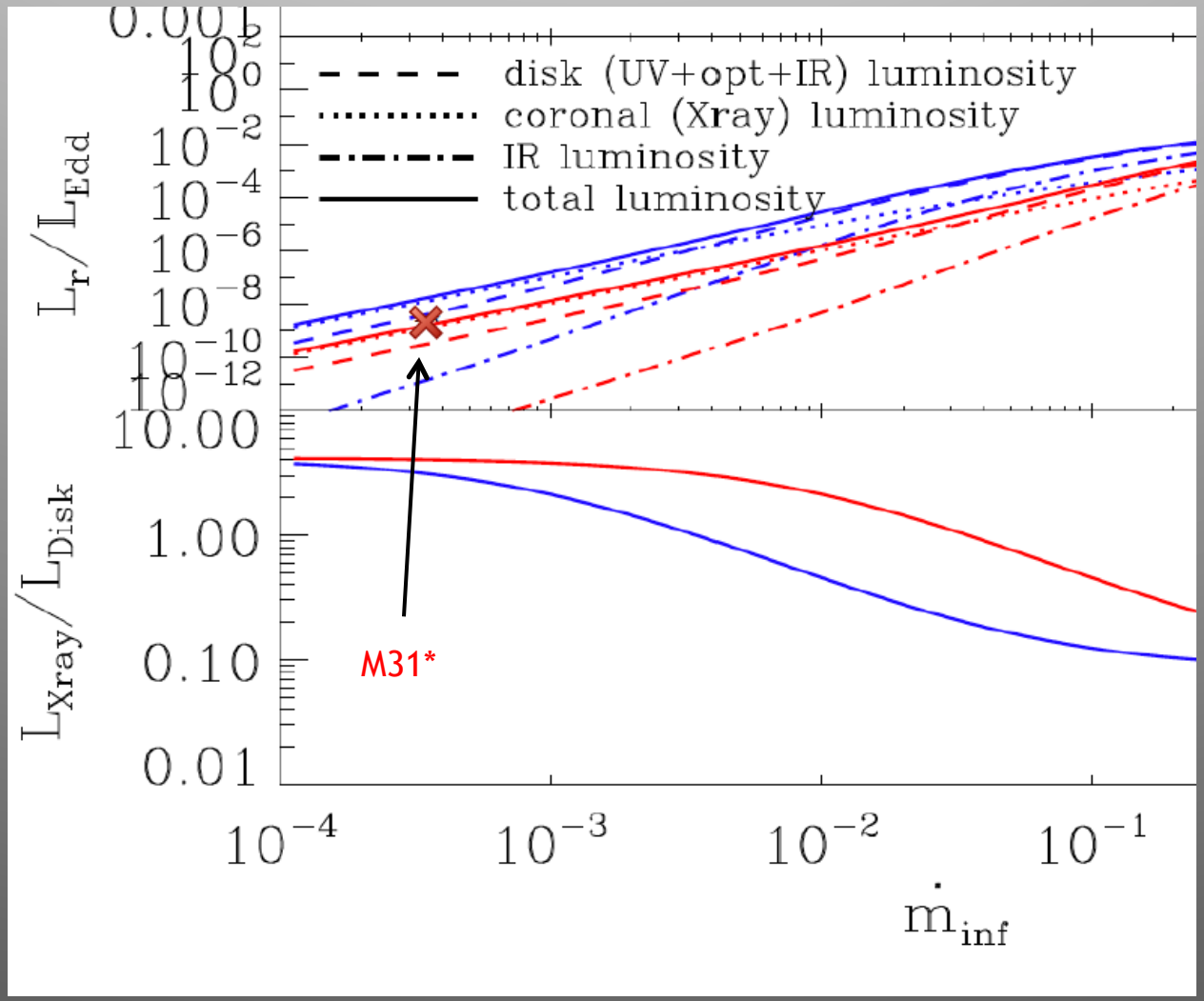


Density within <5” ~ 0.1 cm^{-3} (X-ray emission measure)

R(B) = 2GM(BH)/cs^2, cs ~$(T)^{1/2}$T=0.34 +/- 0.05 keV
R(B) = 5.2”, 18.7pc

Mdot(B) ~ p / cs^3=7 x 10^{-5} Msun/year
L(B) = 4 x 10^{41} erg/sec
Lx/L(B) ~ 5 x 10^{-6}

From Princeton to Aspen and Back Again: RRIOS, Rotating Radiating In/Out Solutions

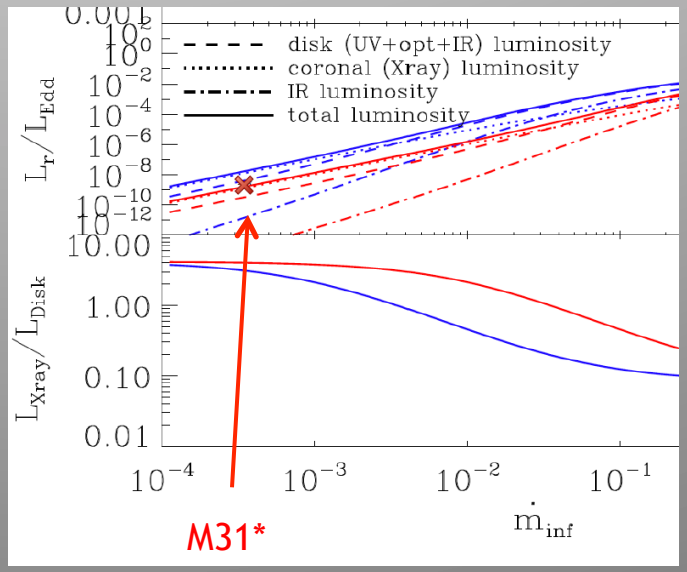


Choi and Ostriker 2012

From Princeton to Aspen and Back Again: RRIOS, Rotating Radiating In/Out Solutions

Lauer etal 2012

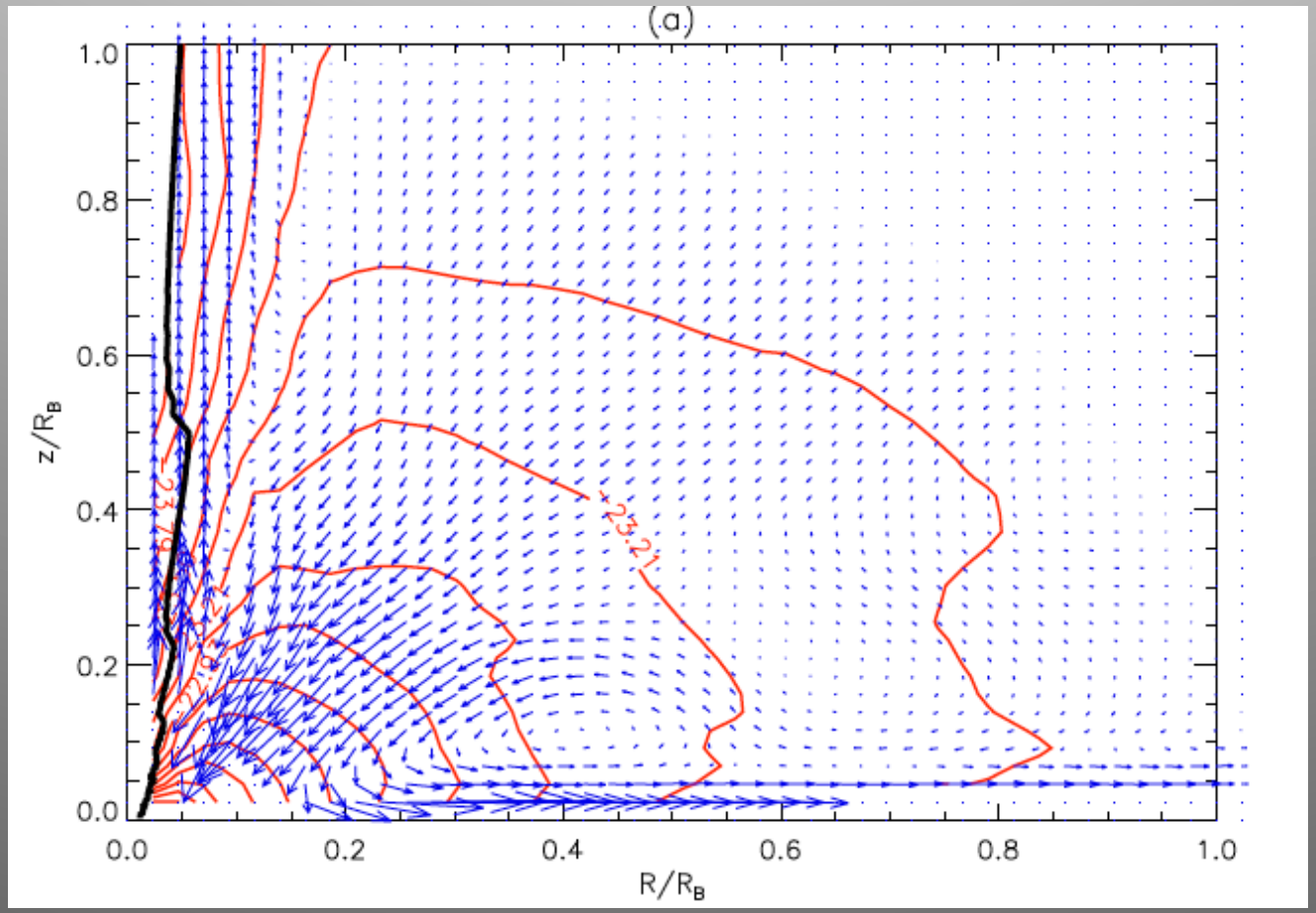
M31* Slightly Resolved in UV



Choi and Ostriker 2012

Prediction: Opt+UV ~ 1/5 X-ray. Data: ☑

From Princeton to Aspen and Back Again: RRIOS, Rotating Radiating In/Out Solutions



Li, Ostriker, Sunyaev 2012

Red lines = Constant density
Blue arrows= Flow

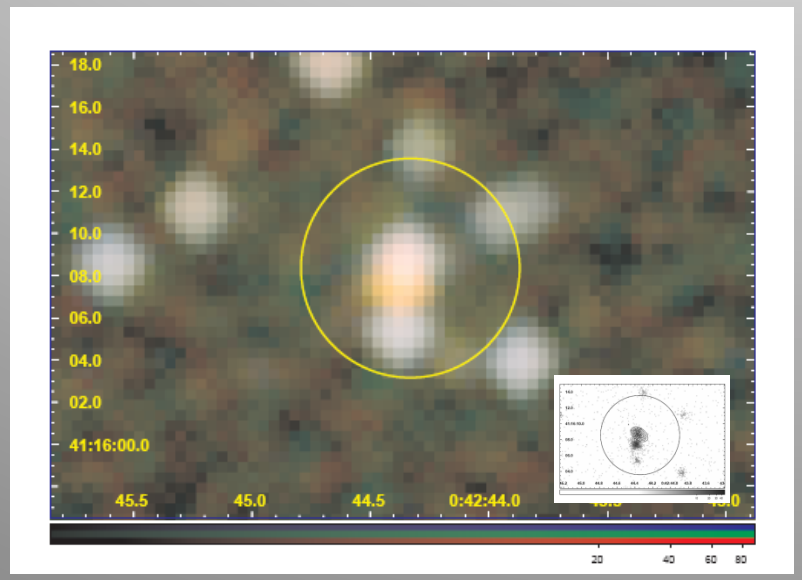
Bremss dominates

Resolve structure in NGC3115, M31*, accretion flows?

Bondi flows: Structure?

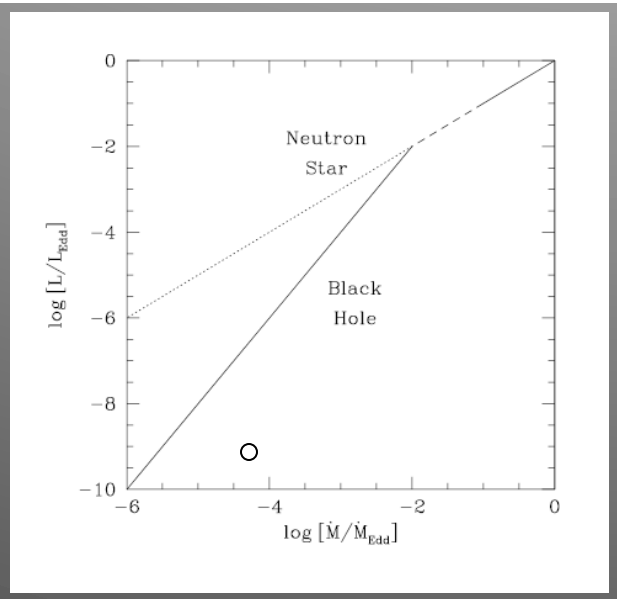
	M	M_B/M_{Edd}	L/L_{Edd}	R(B)	Comment
M31* Point / resolved	1.4e8	$5x10^{-5}$	10^{-9}	5.2”	Variable Point(?) source, diffuse just below detection?
Sgr A* diffuse	4e6	$1x10^{-5}$	$5x10^{-12}$ 100x in flares	1.8”	Slightly resolved at ~R_B
NGC3115 diffuse	2e9	$4x10^{-4}$	$<2e^{-10}$ p $1.5x10^{-10}$ d	4”	Resolved at ~R_B

WOULD we see extended Structure?



'color' X-ray image
150ks sum
SMOOTHED

No hint of excess
At R(B)
NO extended emission
<6e35 (100 cts)

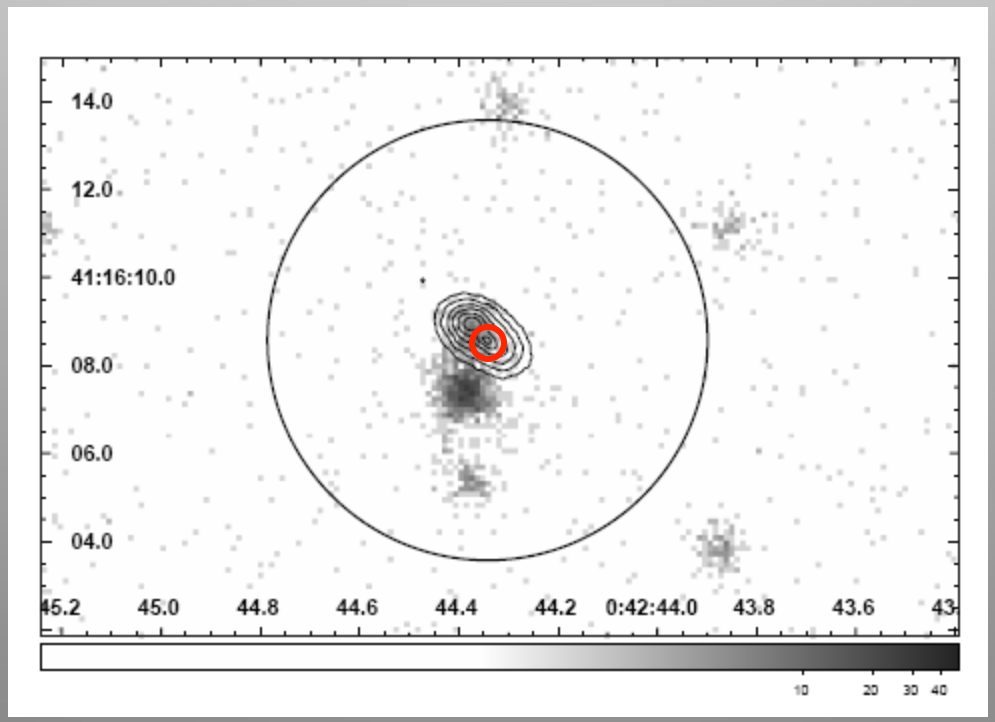


Narayan and McClintock 2008 New Astr Rev

Assume M31* and Sgr A* accreting at same Fractional Eddington rate, then Lx scales With Mass.

Scale by 35 to Sgr A* extended structure,
⇒Predicts ~4e35 for M31* (close to CURRENT limit)
⇒Large uncertainty due to high absorption

X-ray and Radio Spectrum



Longest single ACIS-S Observation (50ks, 2001 – so faint!)
70 counts at M31*, X-ray energy slope = 0.9 +/- 0.2
Bremms would also fit

Radio SPECTRAL data non-simultaneous, different VLA arrays,
but taking average: Radio energy slope = 0.8 (same as X-ray!)

X-ray far above extrapolation of Radio slope,
Similar slopes – X-ray point source SSC (jet?)

Stellar Wind Feedback (SN heating)

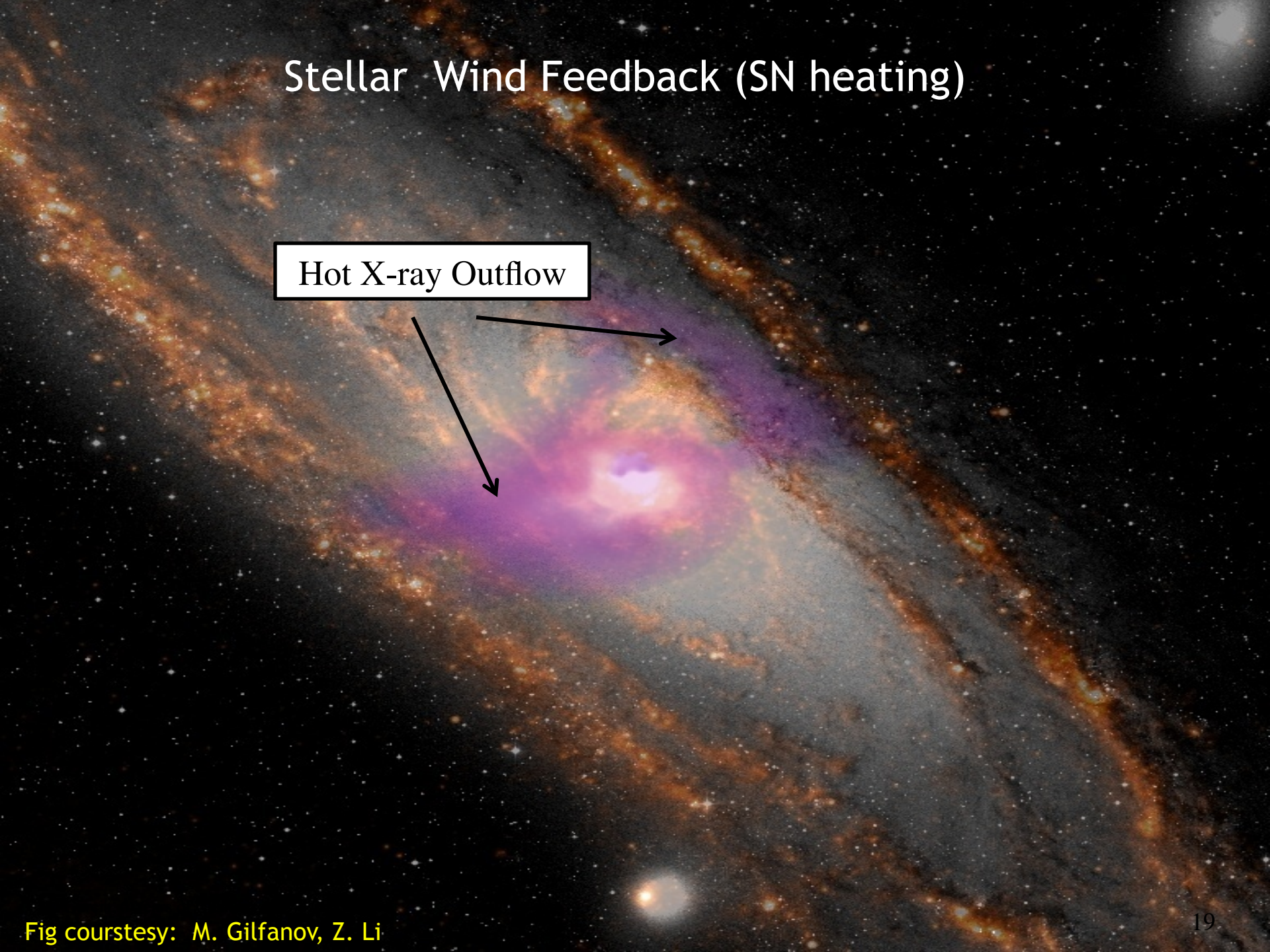
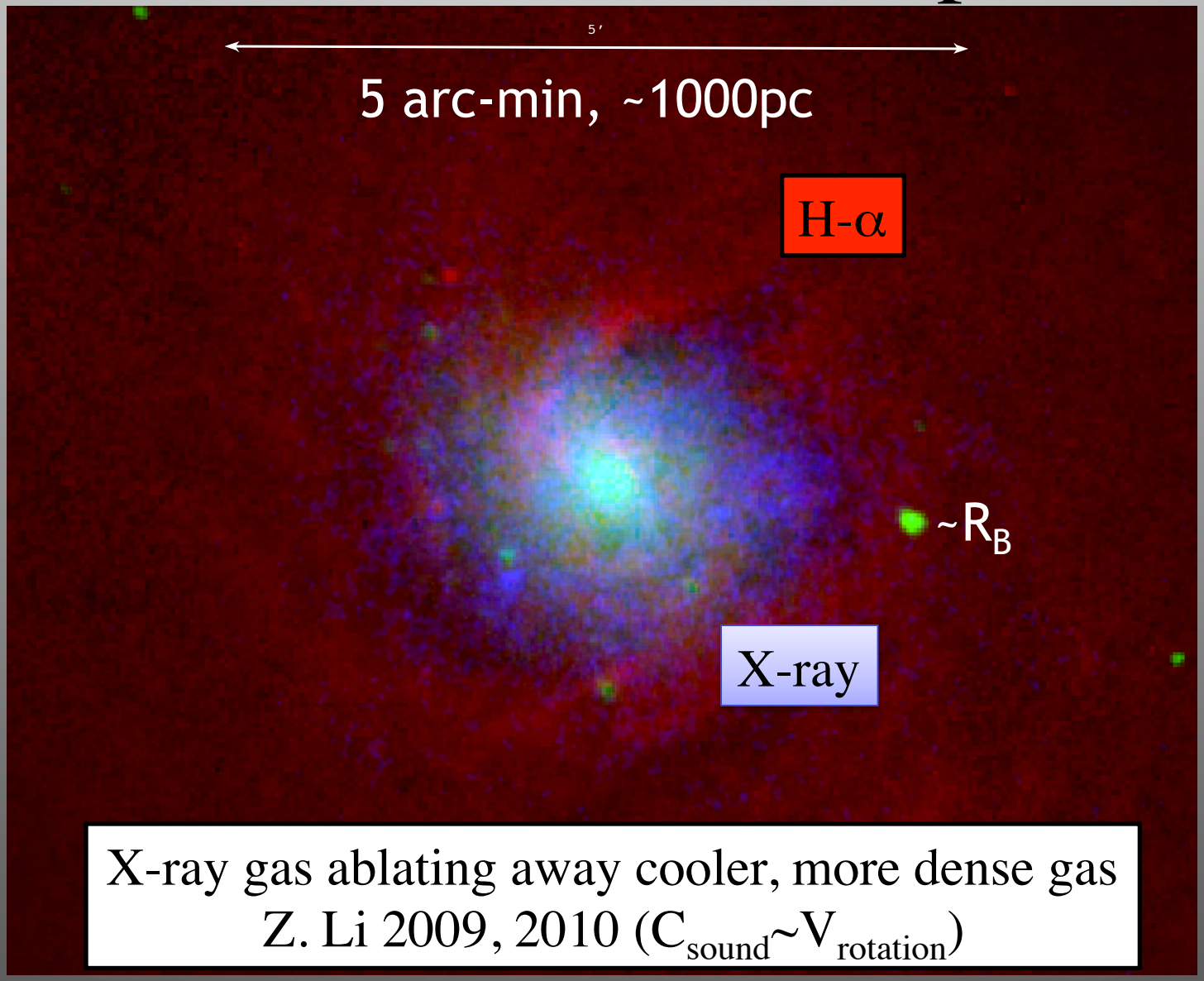


Fig courstesy: M. Gilfanov, Z. Li

Feedback: Nuclear Spiral



X-ray gas ablating away cooler, more dense gas
Z. Li 2009, 2010 (C_{sound}~$V_{rotation}$)