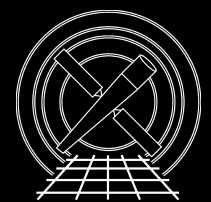
A Chandra X-ray image of a galaxy, likely a spiral galaxy, showing a bright central region and a long, narrow, and slightly curved jet of high-energy radiation extending from the center towards the right side of the frame. The jet is composed of many small, bright spots, suggesting discrete emission regions. The background is dark, with several other bright, point-like sources of X-ray emission scattered throughout.

Chandra Insights into the Impact of Evolving Radio Jets on the ISM from pc to kpc



Chandra X-ray Center

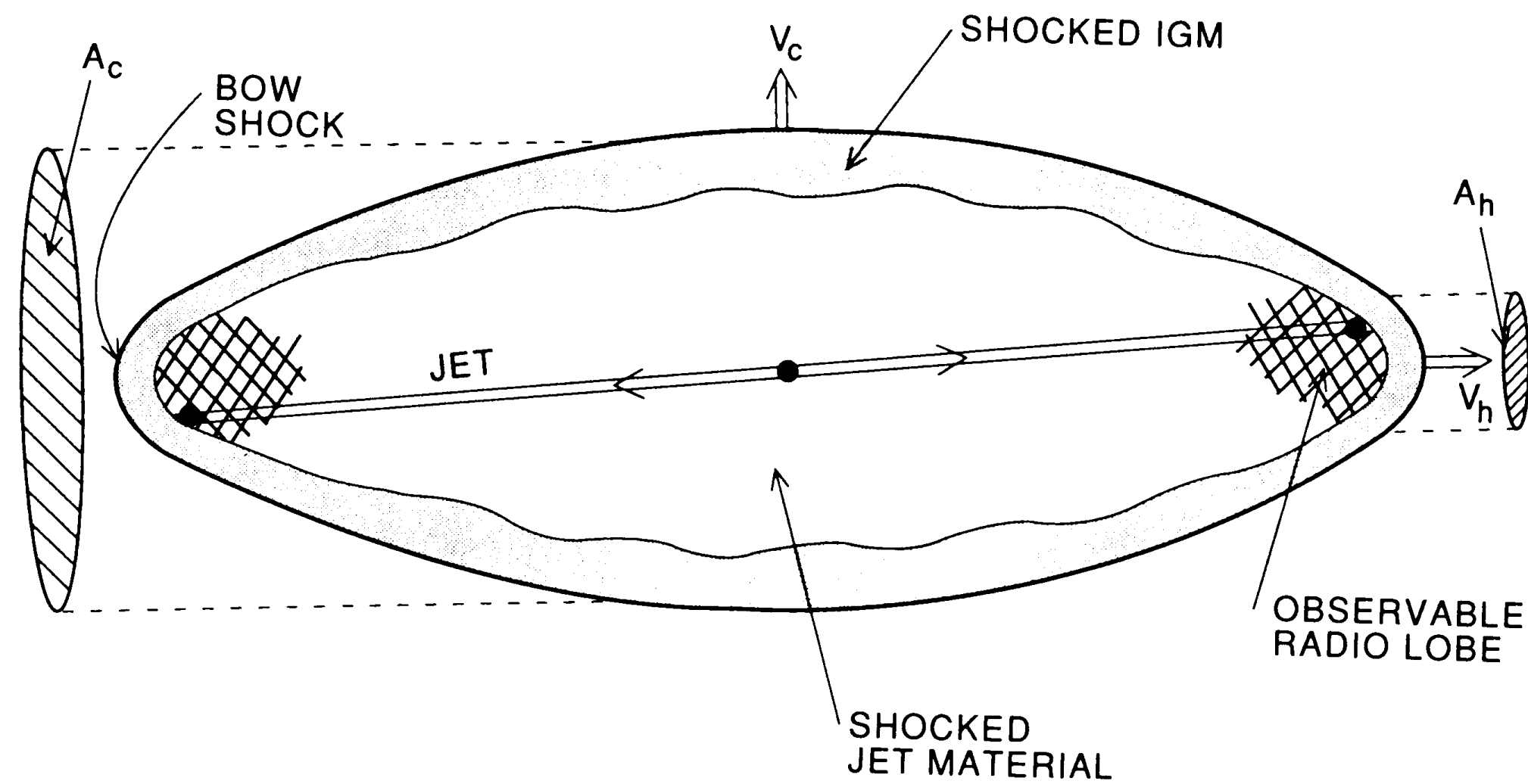
Images courtesy of NASA/Chandra/HST unless otherwise noted

Aneta Siemiginowska

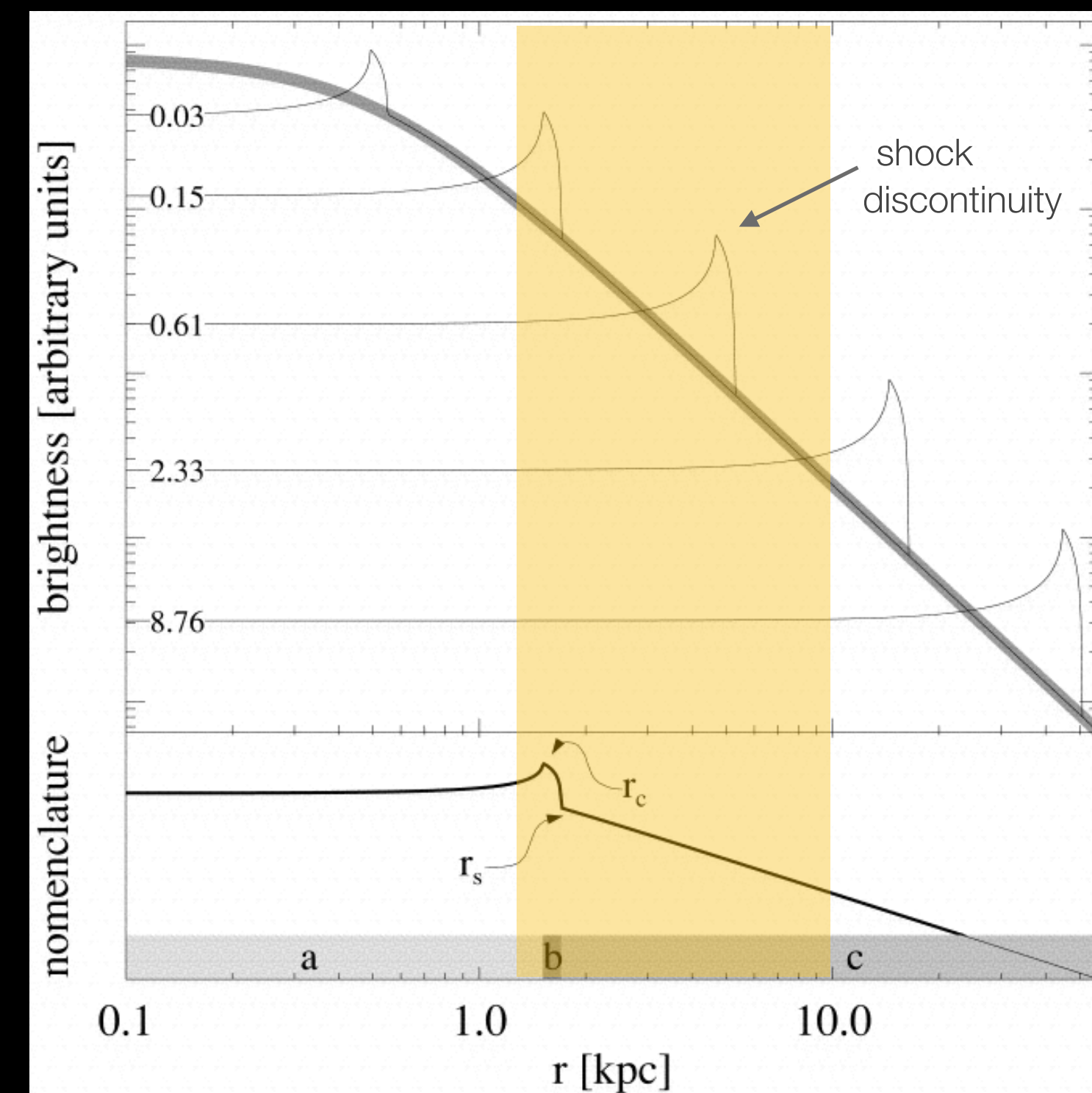
CENTER FOR **ASTROPHYSICS**
HARVARD & SMITHSONIAN

Evolution of a Radio Source

BEGELMAN AND CIOFFI (1989)

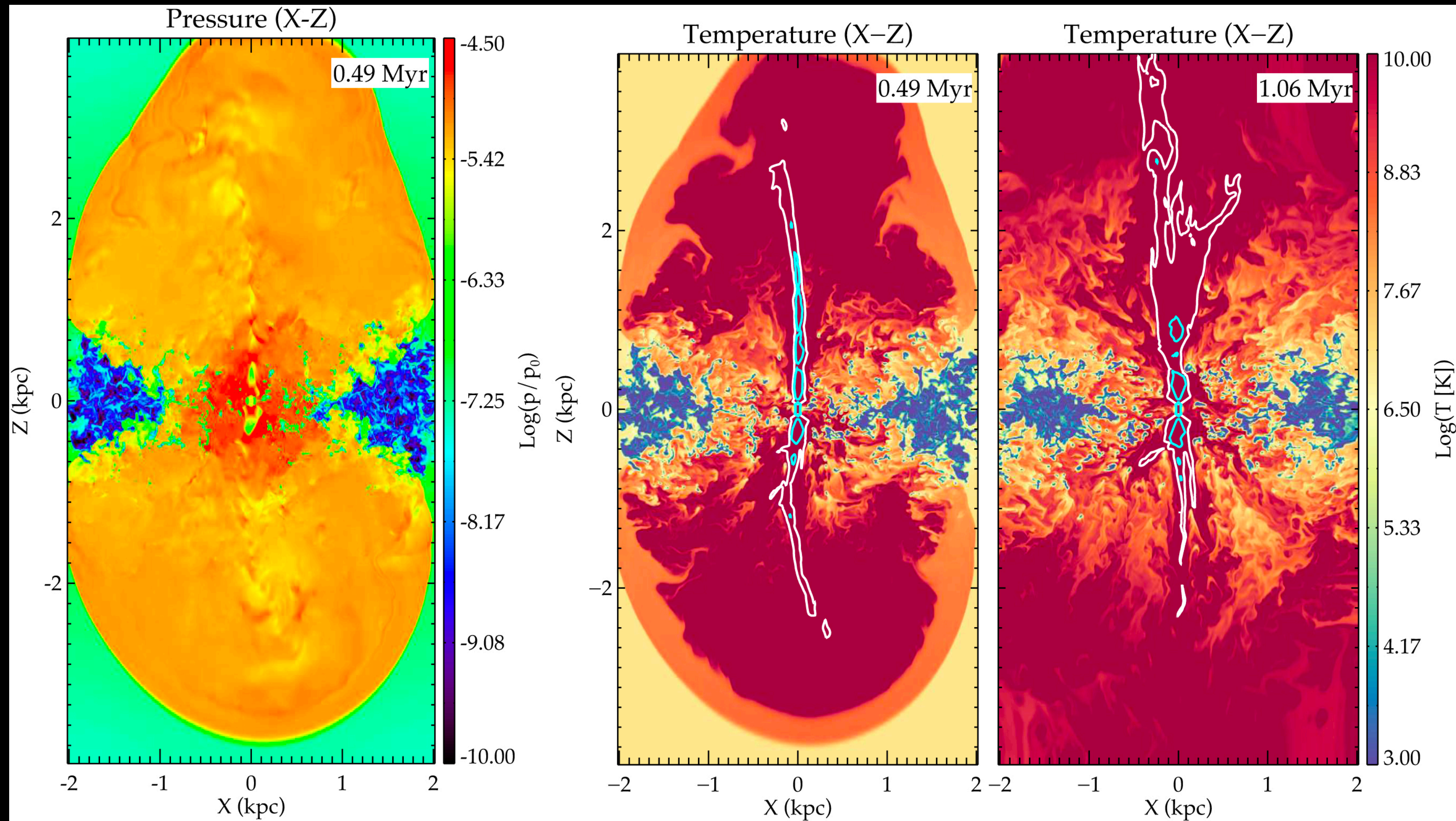


Host Galaxy



Heinz et al 1998

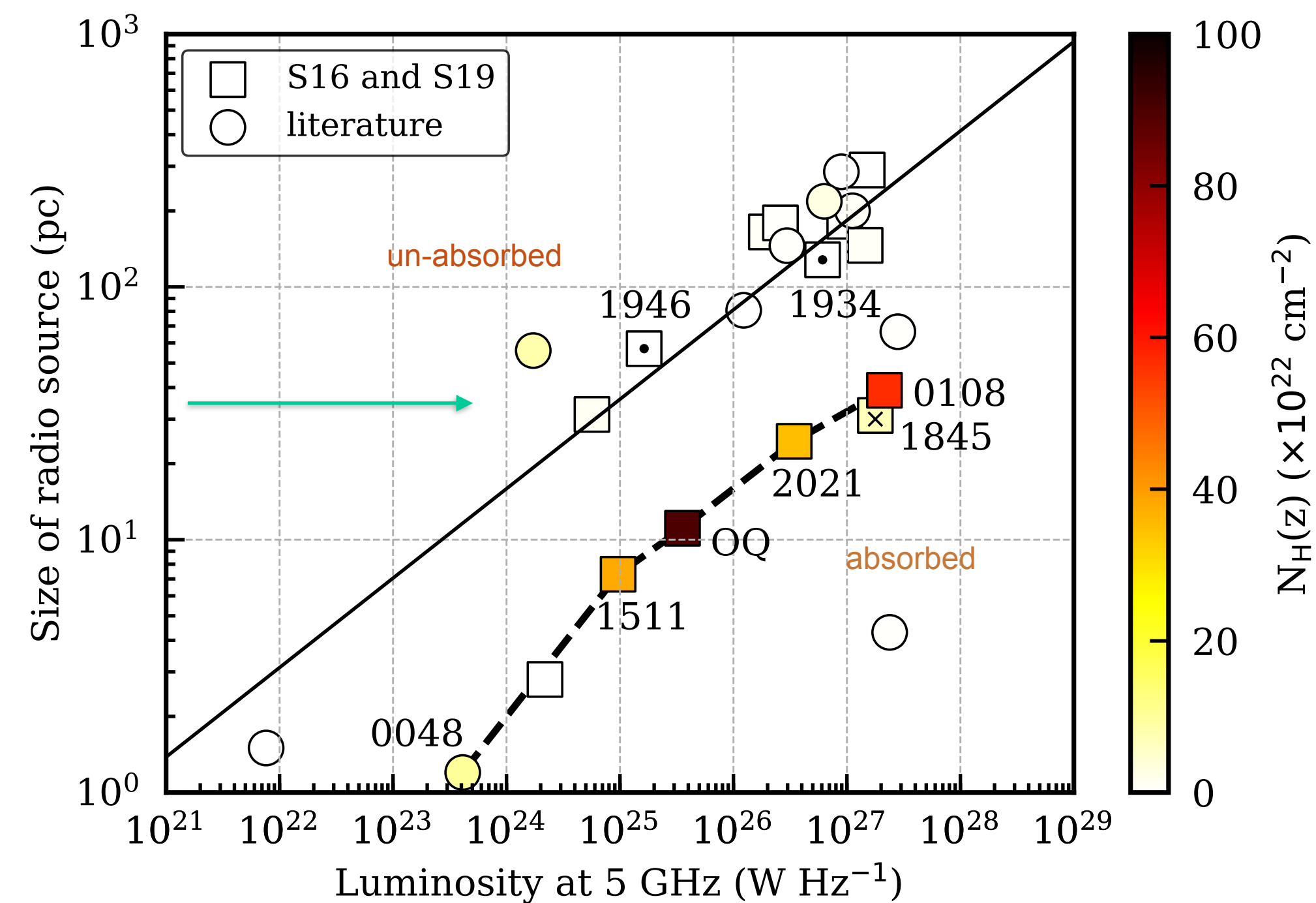
Jet-ISM interactions / Simulations



Young Radio Sources

Limiting size of the absorbing medium

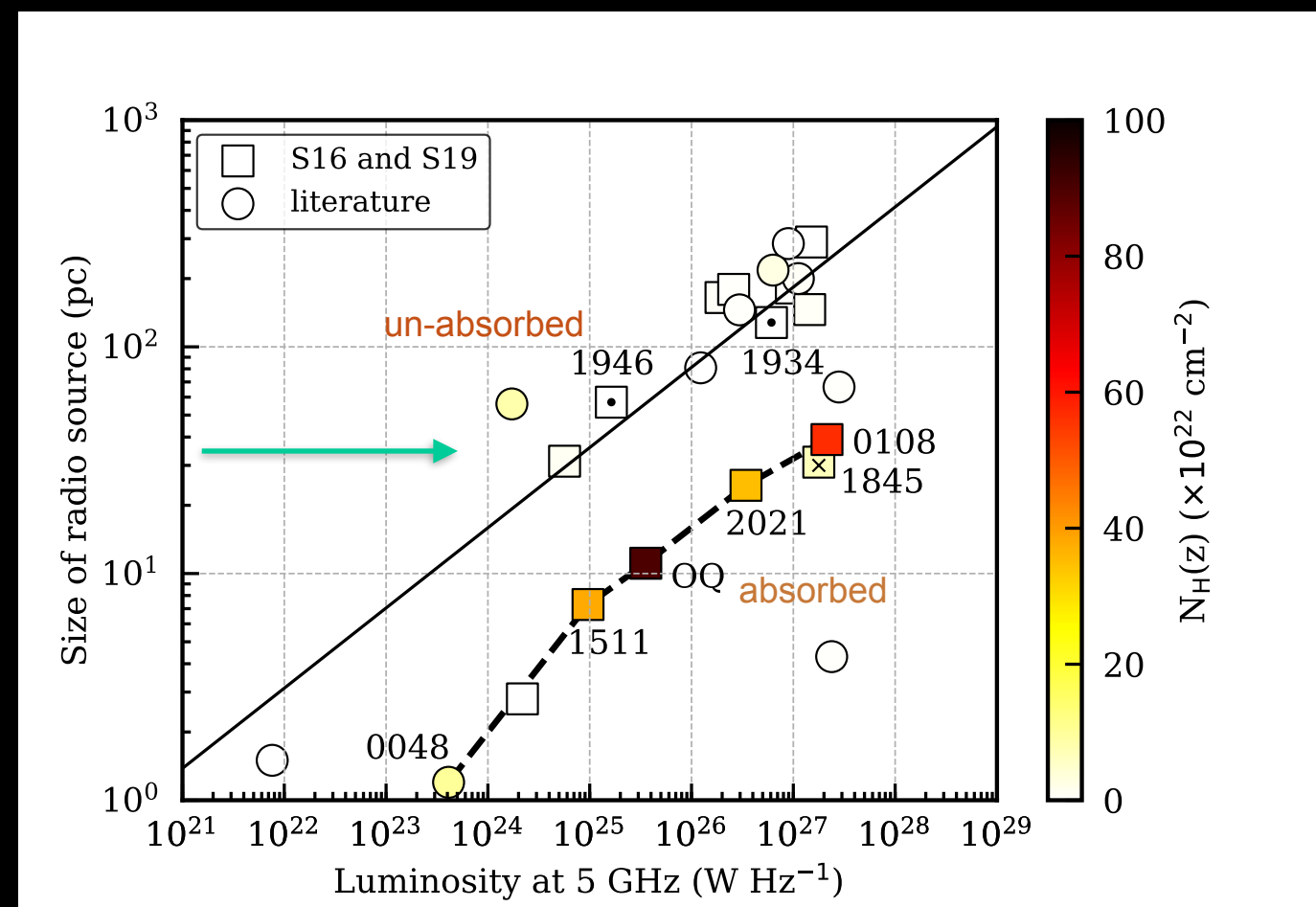
Compact Radio Size < ~500 pc
Unresolved in X-rays



Siemiginowska et al 2016
Sobolewska et al 2019

Young Radio Sources

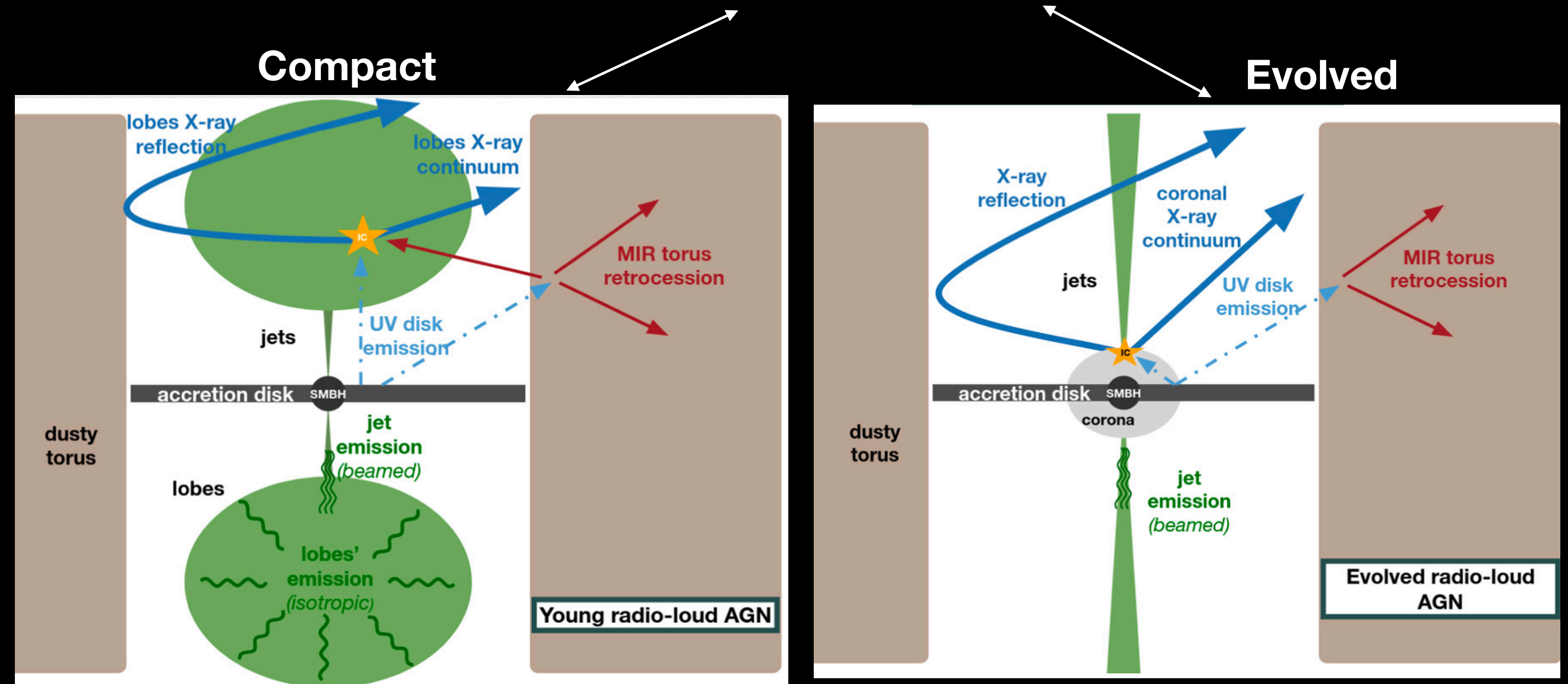
Compact and **unresolved** in X-rays
Limiting size of the absorbing medium



Siemiginowska et al 2016
 Sobolewska et al 2019

Nuclear Region

Jets impact the cloudy and dusty medium
 Differences in the X-ray radiation process

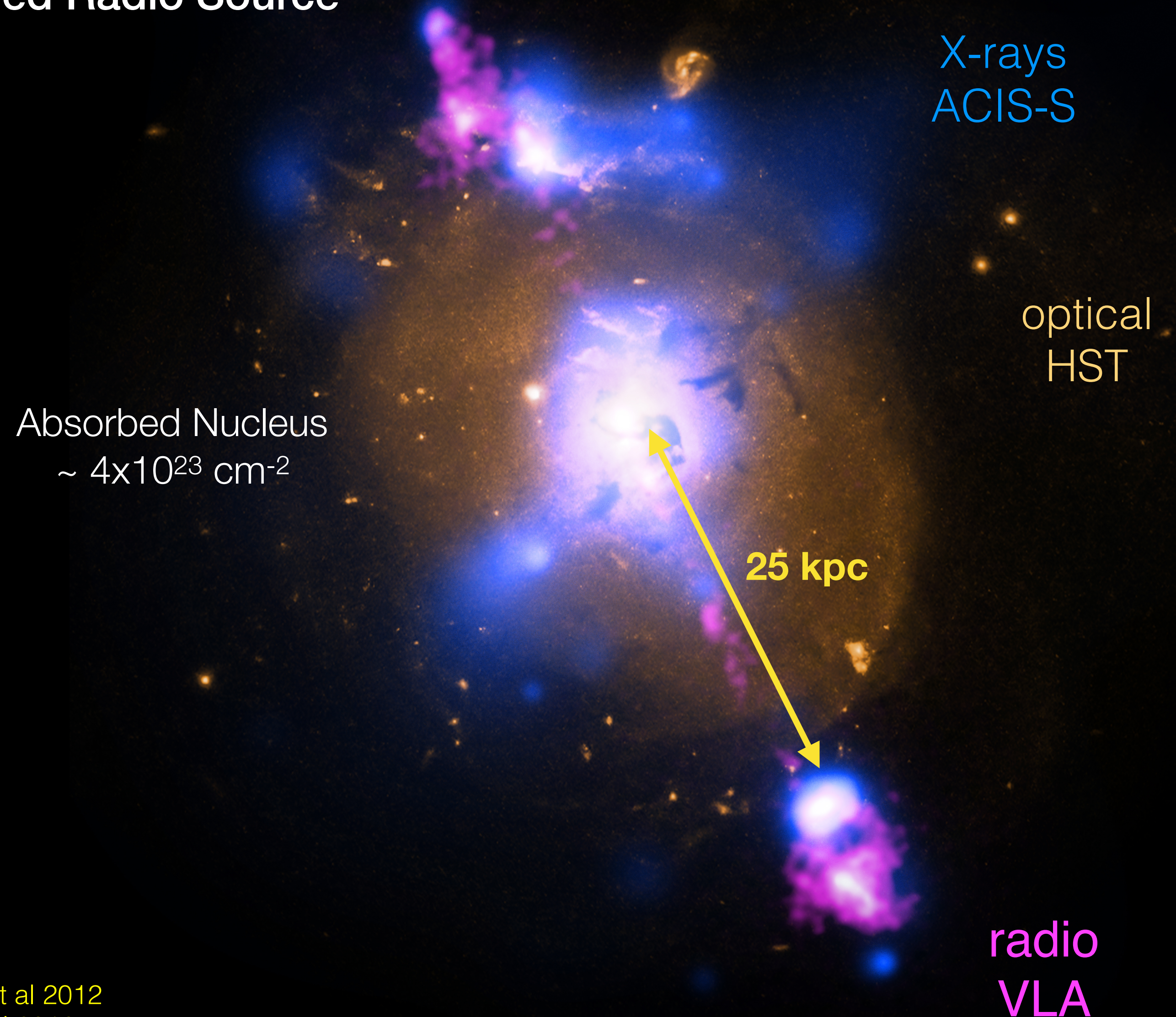


Krol et al 2024

also poster 01-06

Radio Galaxy 4C 29.30 ($z=0.0647$)

Evolved Radio Source



X-rays
ACIS-S

optical
HST

AGN L_x (2-10 keV) = $5 \times 10^{43} \text{ erg/s}$
Temp (ISM) = 0.5 keV

Radio:

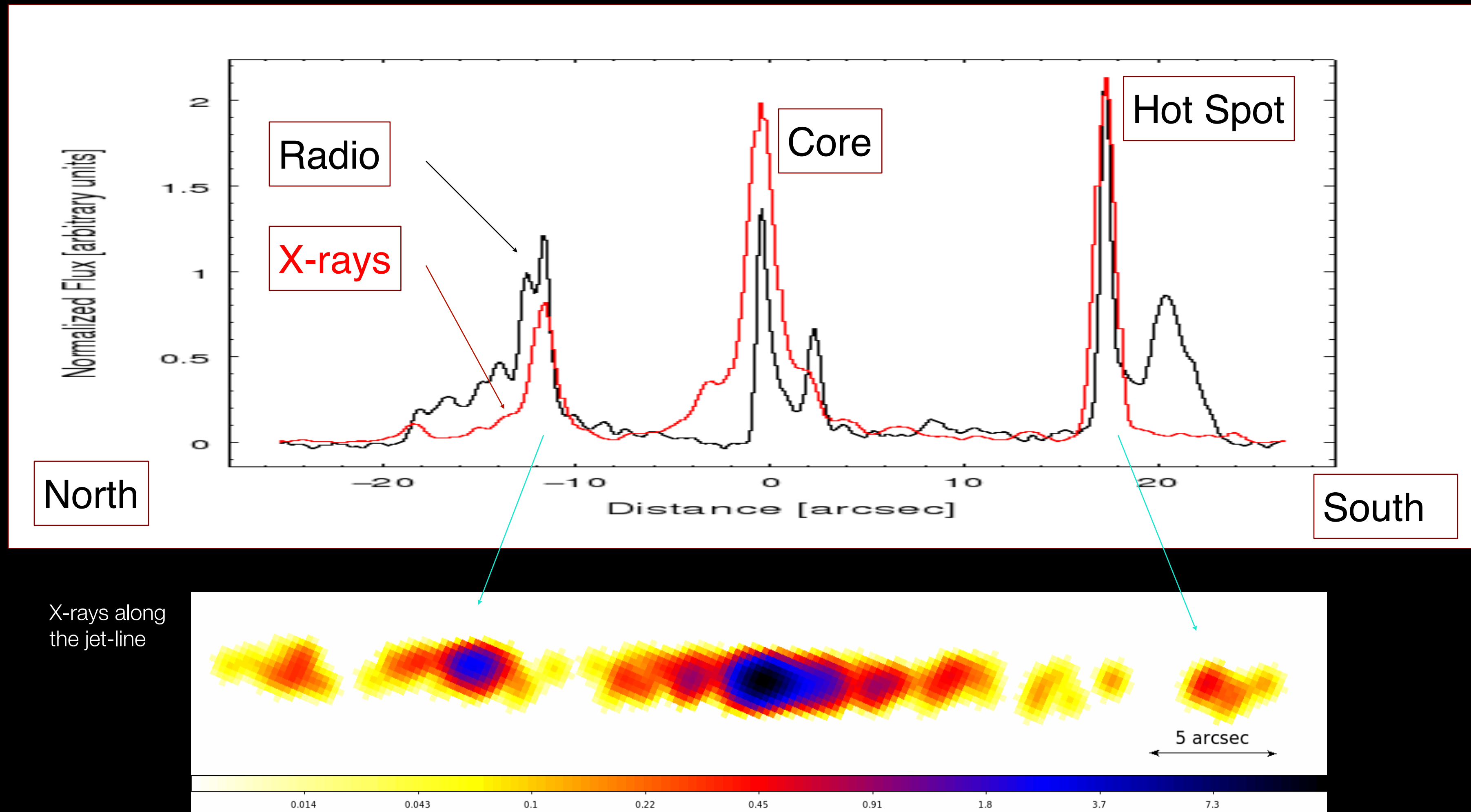
Jet, knots, hotspots, lobes

X-rays:

AGN nucleus, jet, knots, hot spots
diffuse structures

radio
VLA

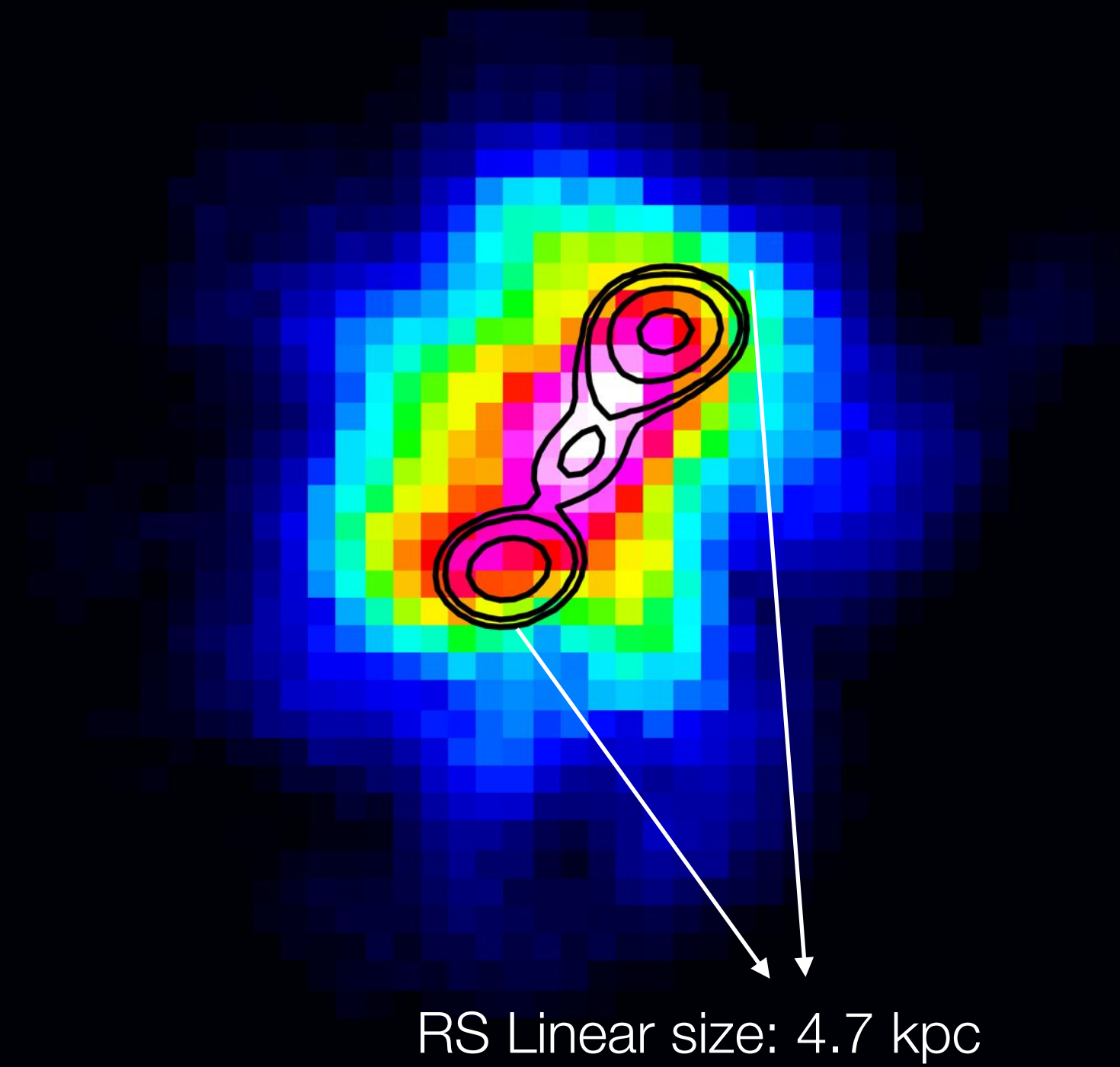
Tracing Jet-ISM Interactions



Type 2 Quasar PKS 0023-26 $z=0.322$

Jet Interactions with the ISM of the host galaxy

Chandra
ALMA 1.7mm

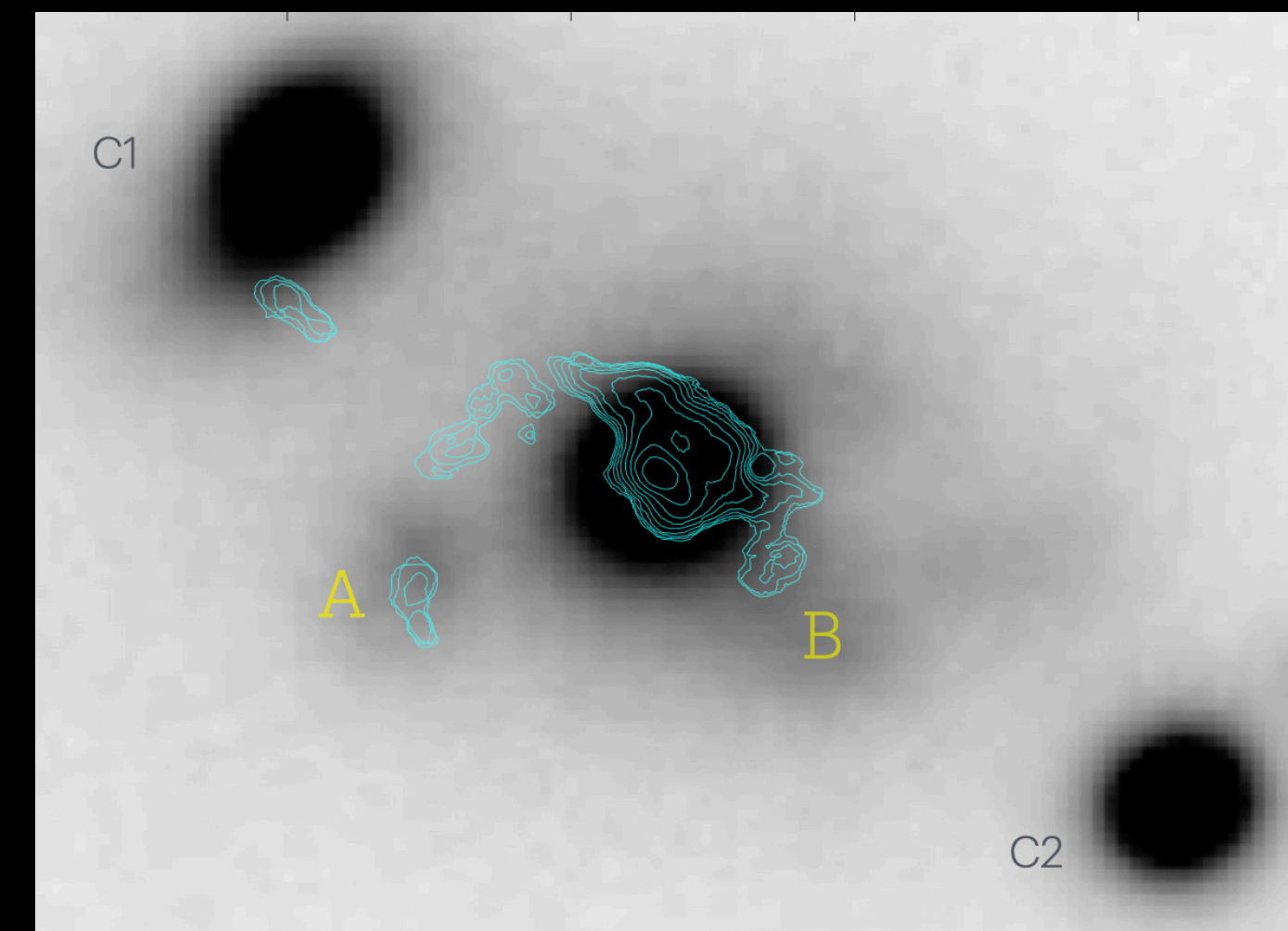


Jet Power $\sim$ a few 10^{46} erg/s

L_R (5GHz) = 1.3×10^{44} erg/s

L_{Bol} = $(2.5 - 4) \times 10^{45}$ erg/s

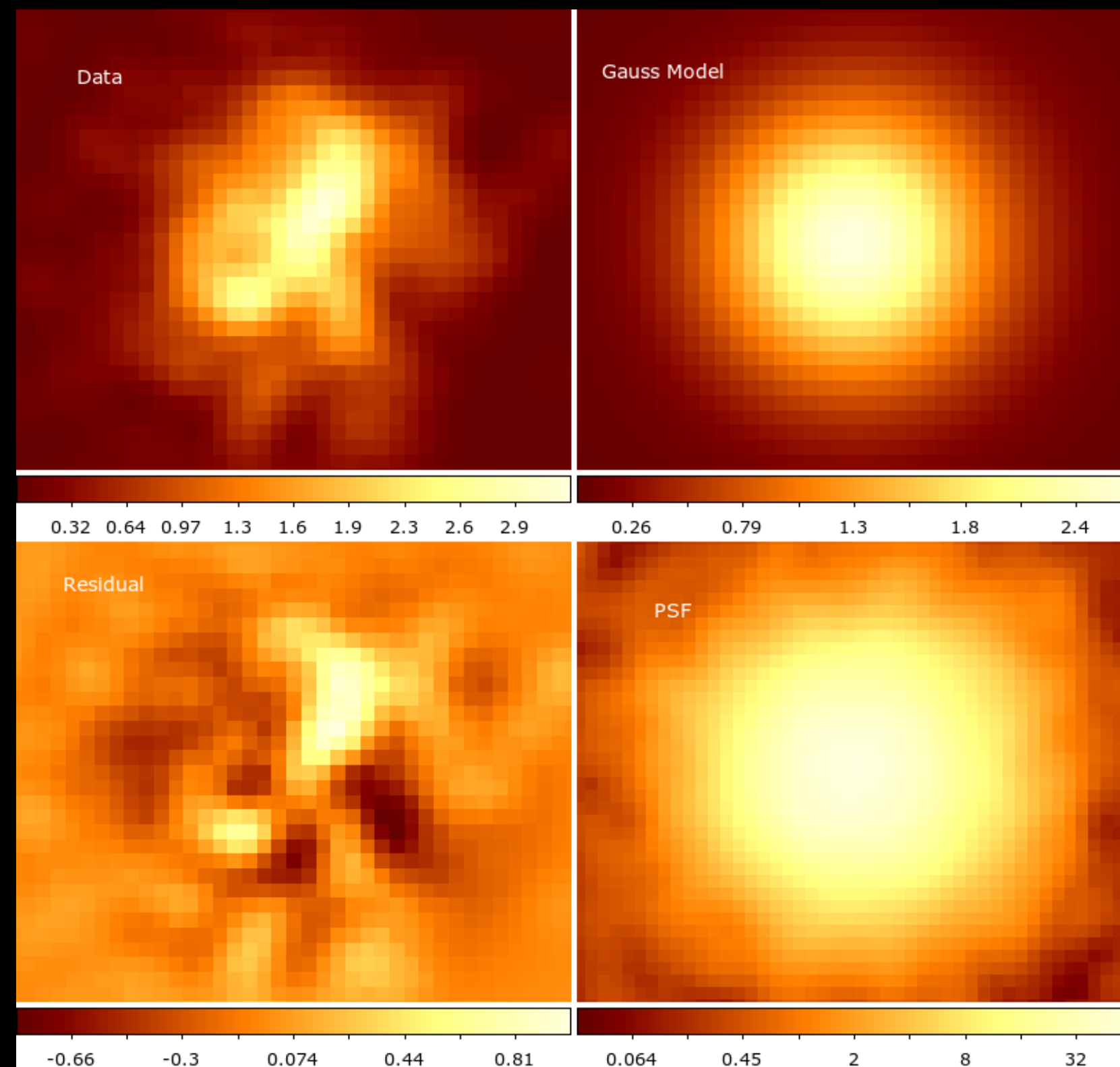
Optical Image with CO density contours



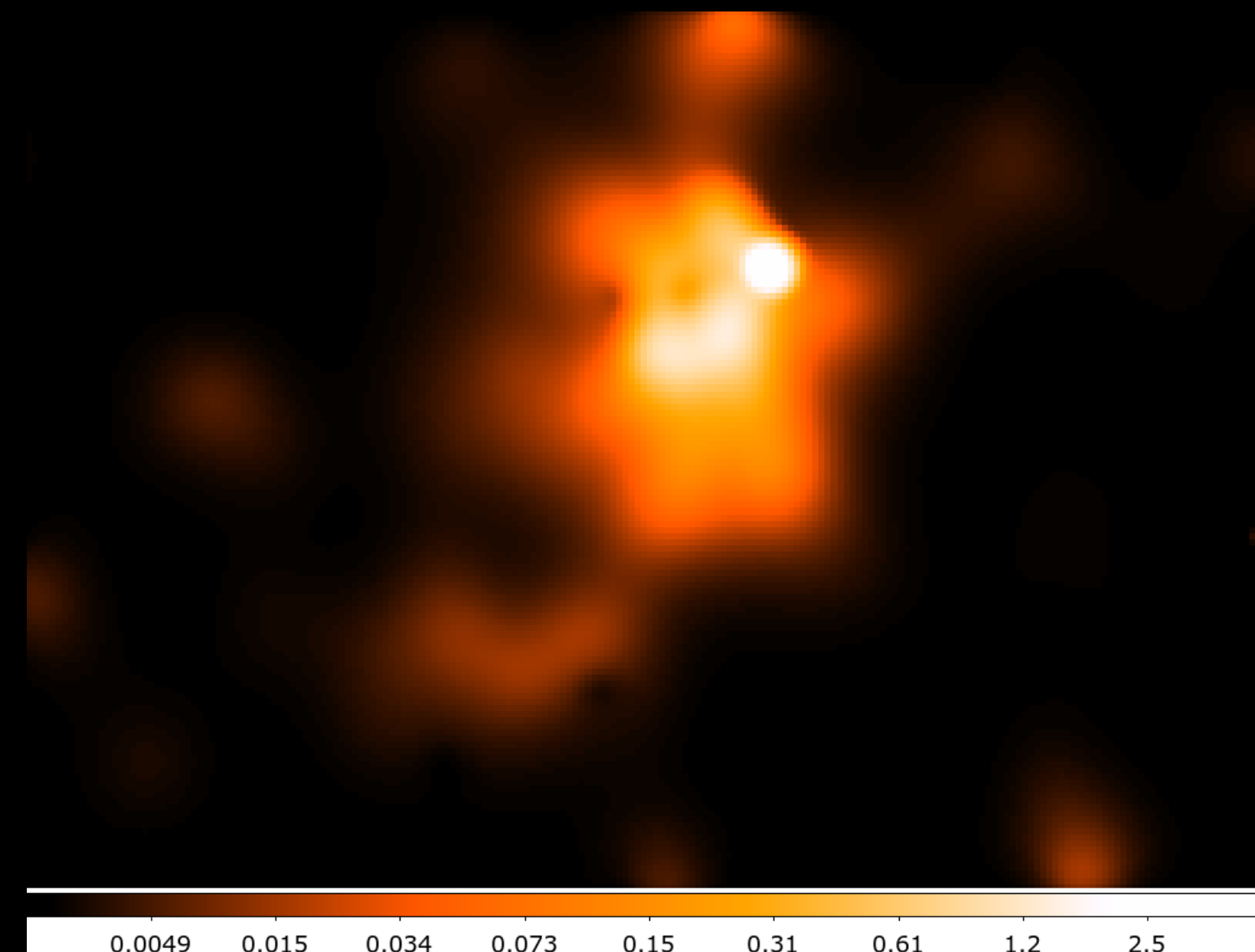
Type 2 Quasar PKS 0023-26 $z=0.322$

Chandra X-ray Image Analysis

Sherpa 2D model



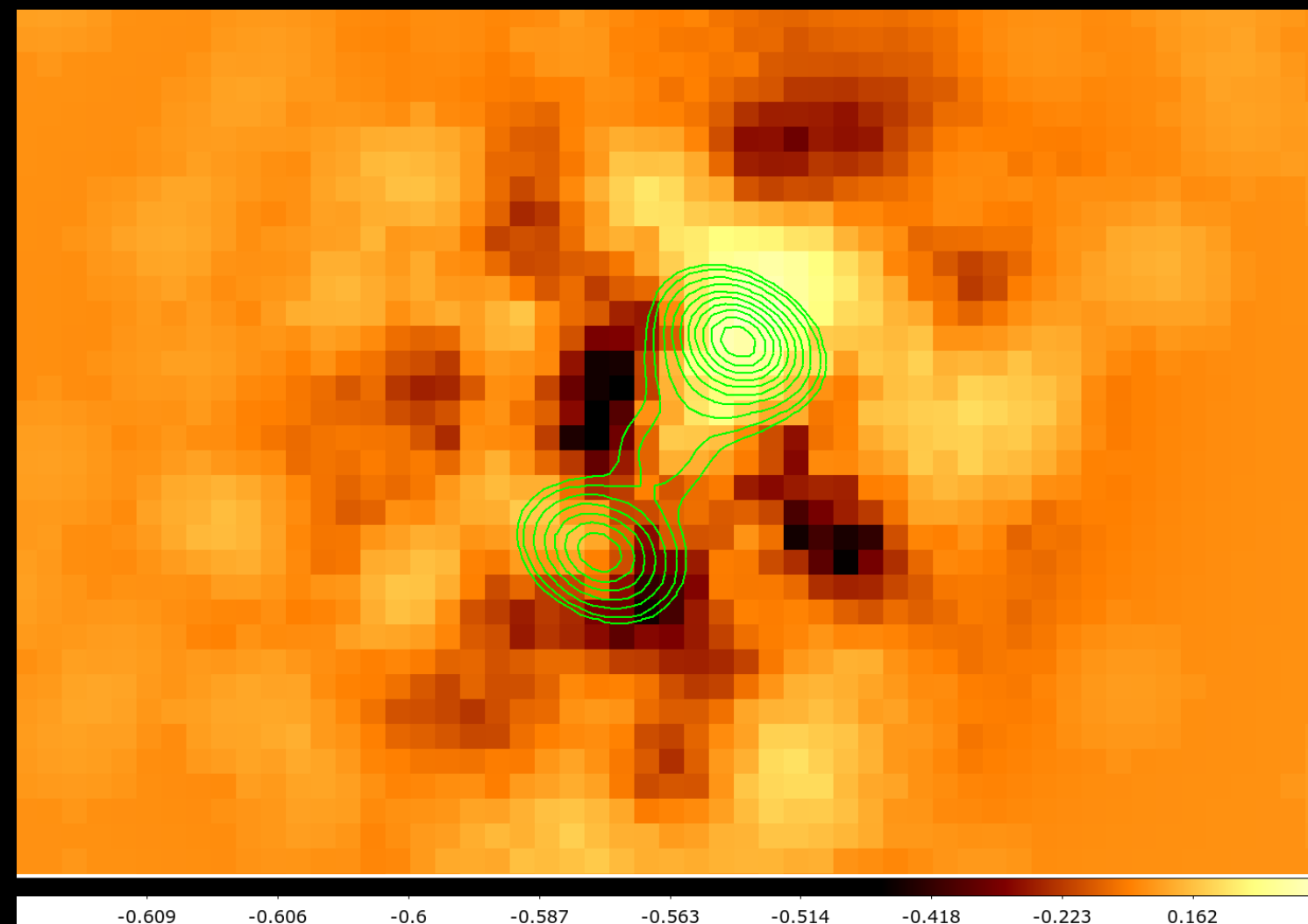
Jolideco - deconvolution



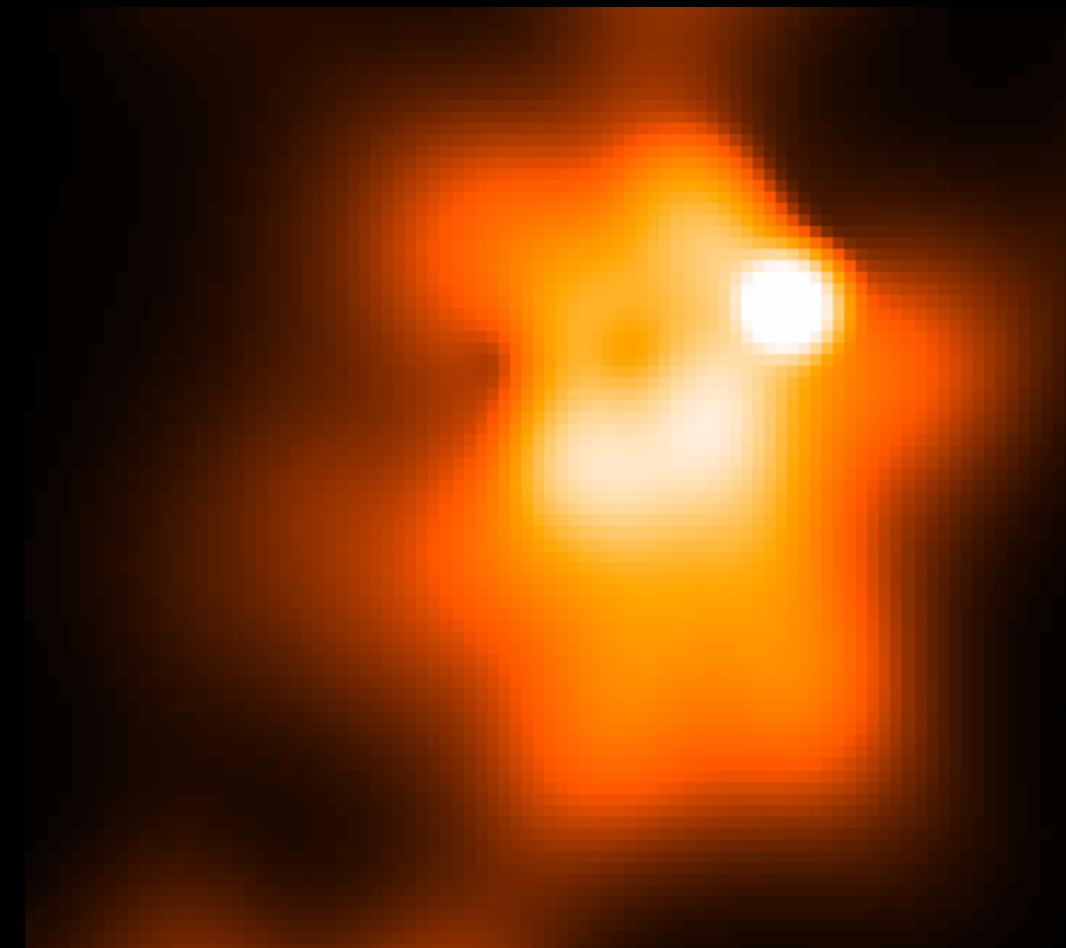
Type 2 Quasar PKS 0023-26 $z=0.322$

Chandra X-ray Image Analysis

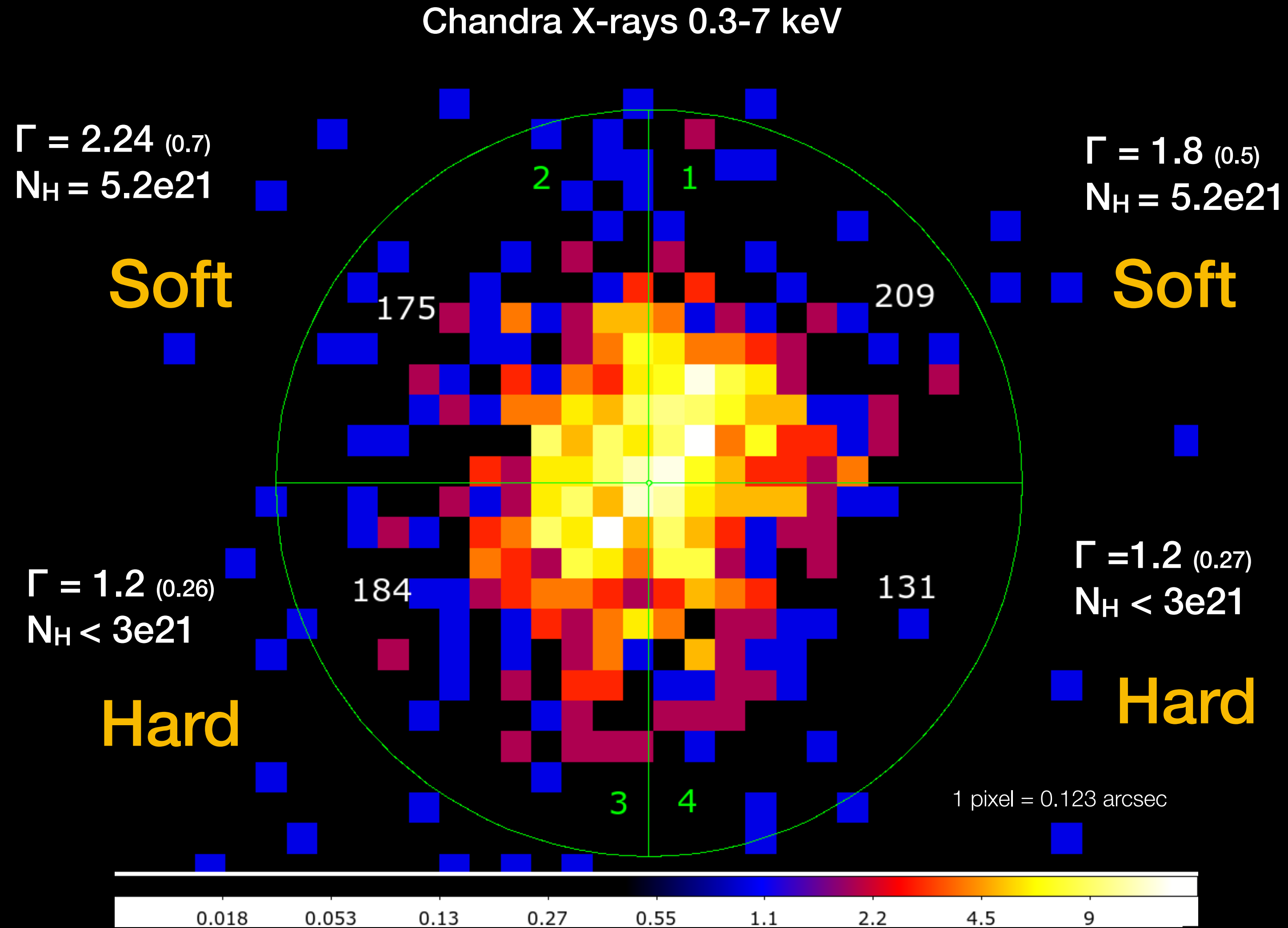
Sherpa 2D model - Residuals



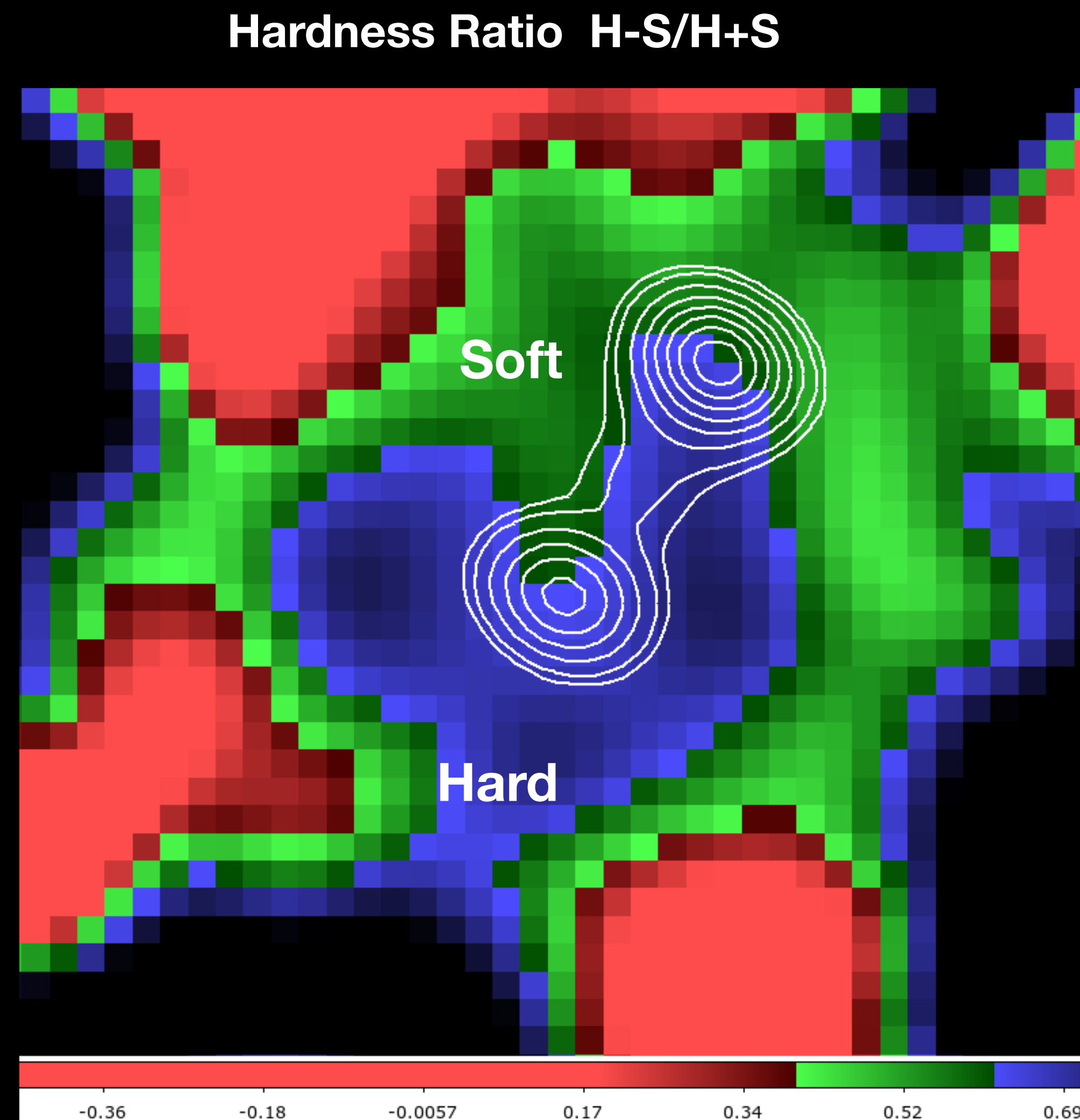
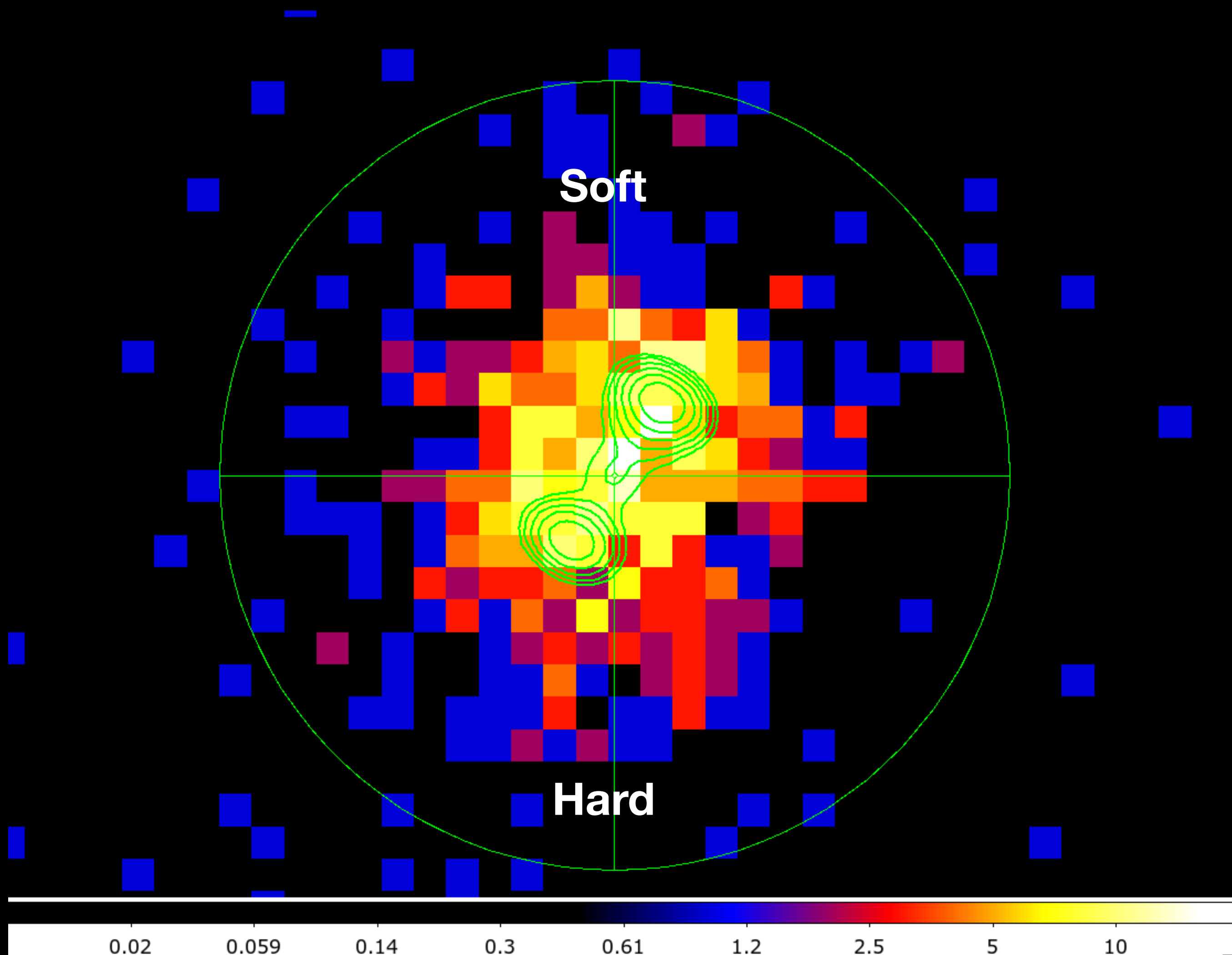
Jolideco - deconvolution



Type 2 Quasar PKS 0023-26 $z=0.322$

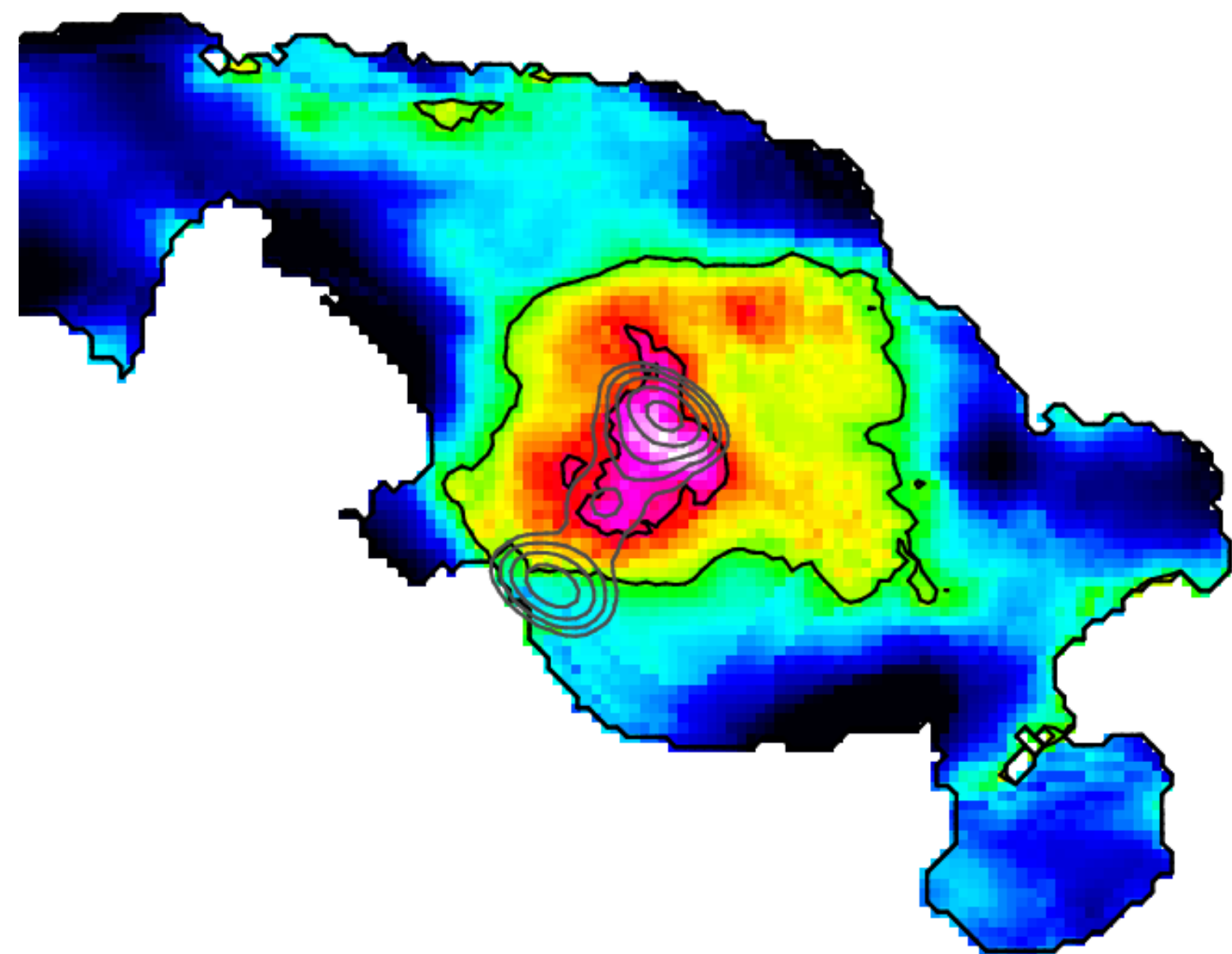


Type 2 Quasar PKS 0023-26 $z=0.322$



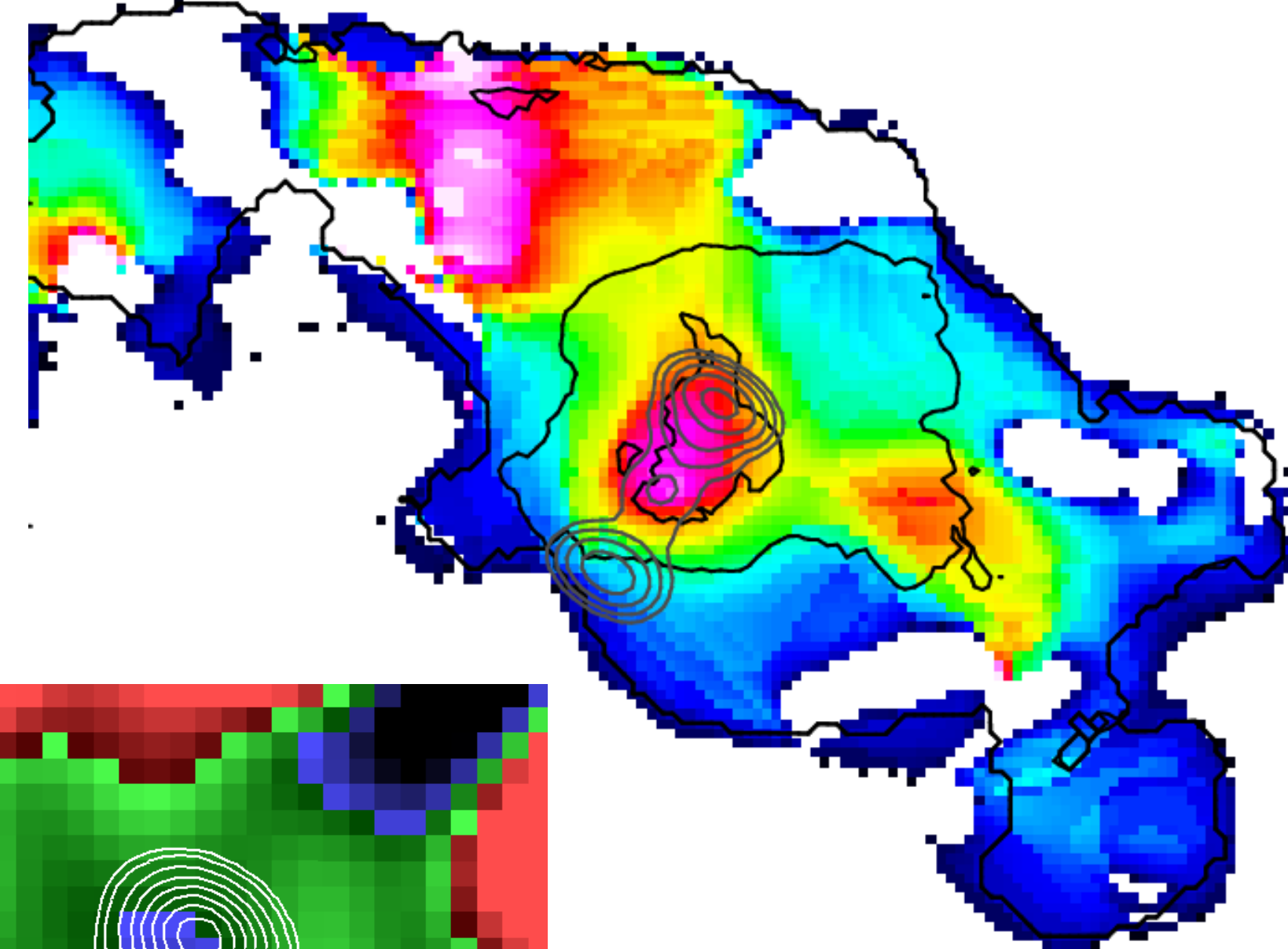
Type 2 Quasar PKS 0023-26 $z=0.322$

Brightness temperature
ratio of CO(3-2)/CO(2-1)

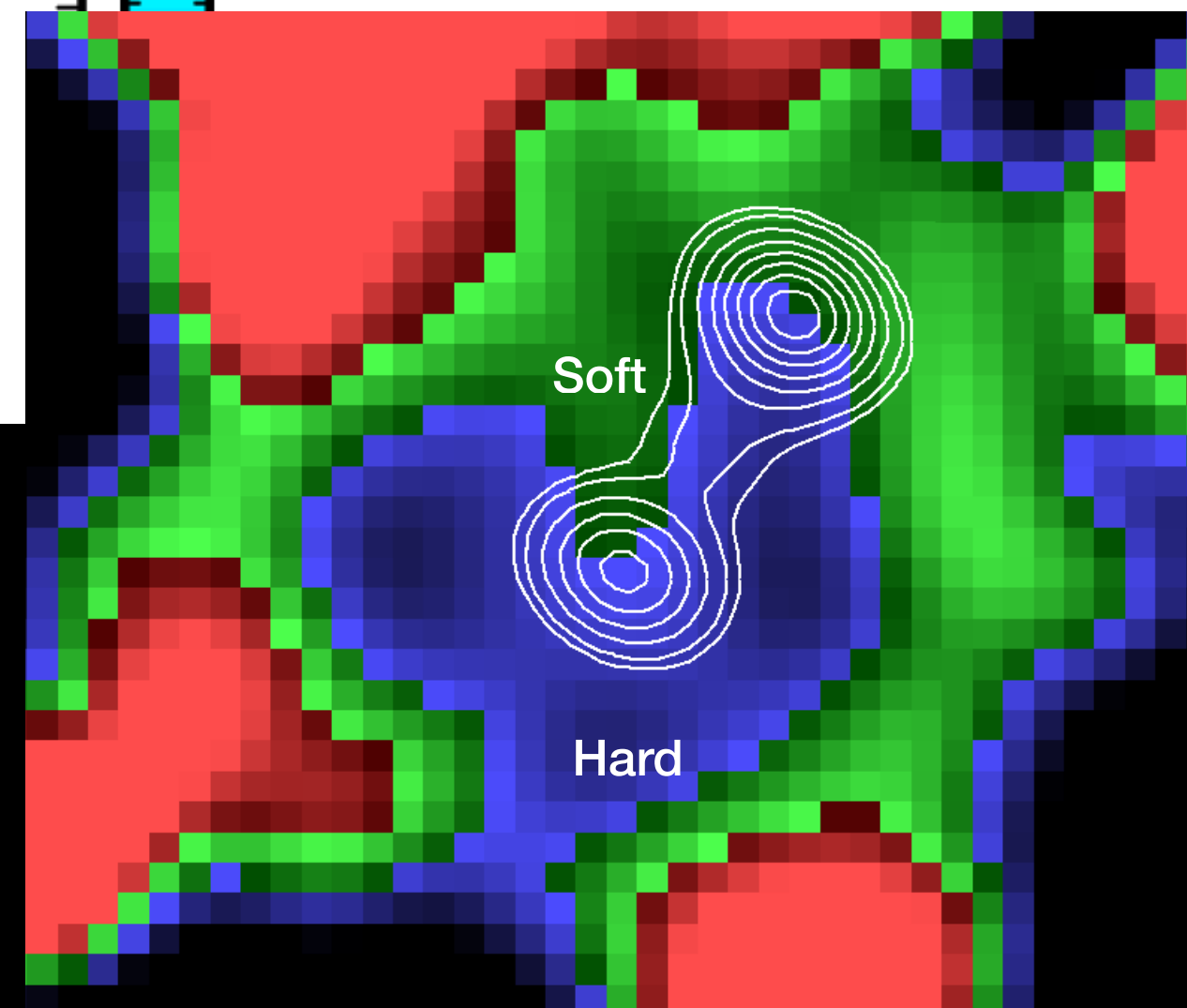


1.0
0.8
0.6
 $(3-2)/(2-1)$

Velocity dispersion of CO(3-2)



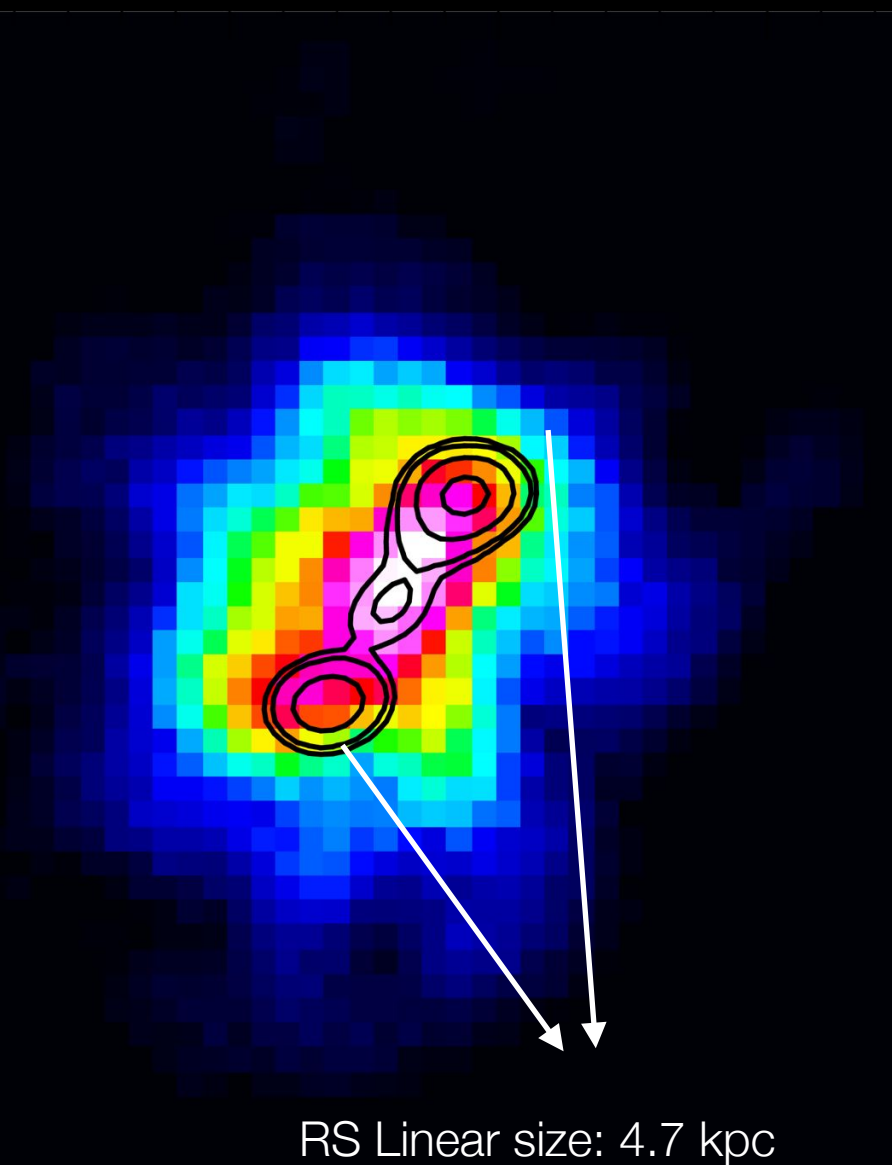
80
60
40
20



Soft

Hard

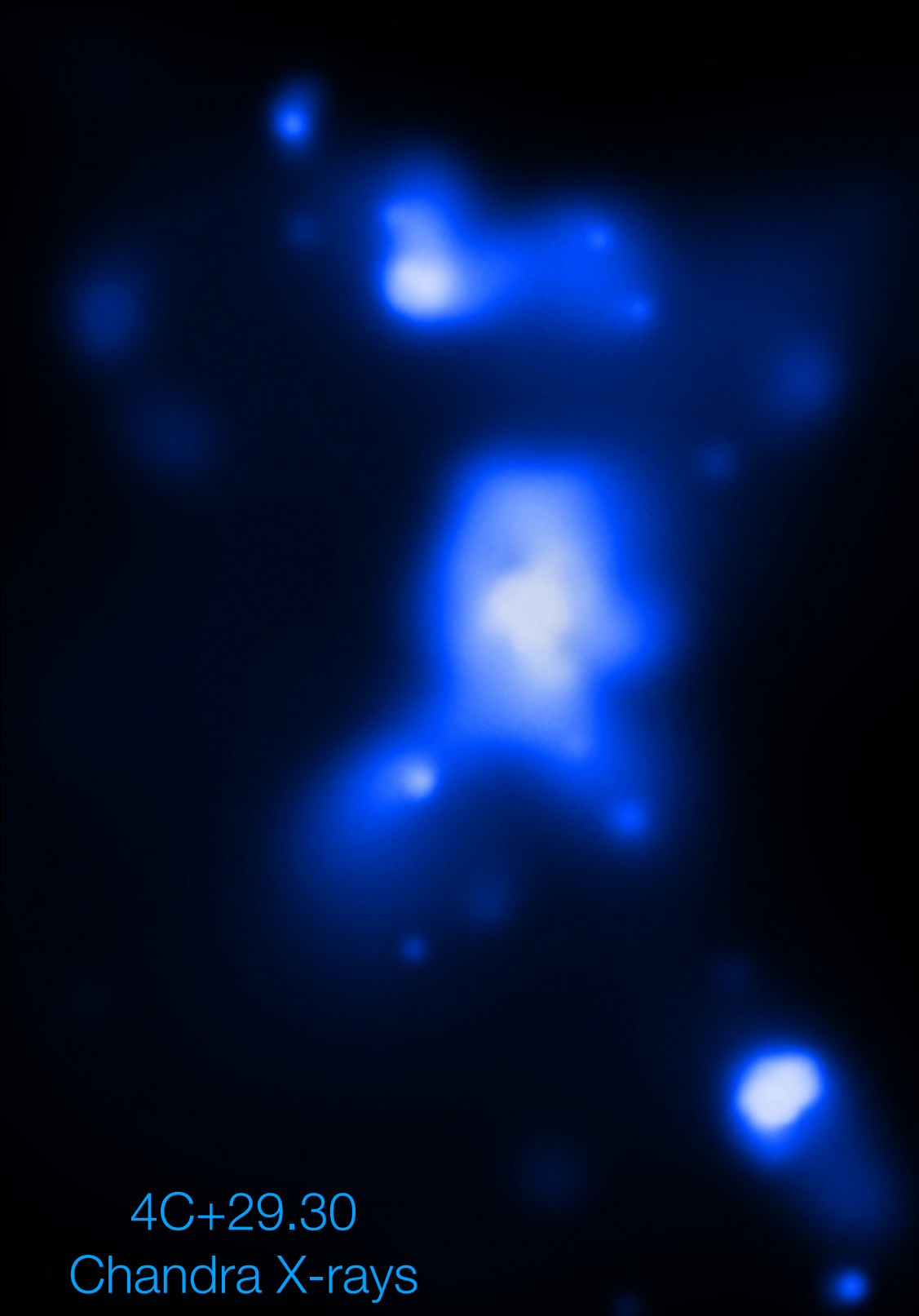
Jet-ISM Interactions in PKS0023-36



- Jet Power $\sim$ a few 10^{46} erg/s
- X-ray luminosity of the thermal gas: $L_{X(0.5-2 \text{ keV})} \sim 10^{43}$ erg/s
- X-ray elongation in the same direction as radio emission
- highest velocity of molecular gas in the core region
- high velocity dispersion and distribution of the gas wrapping around the radio lobes on kpc-scales
- CO transitions indicate high excitation temperatures of molecular gas (or optically thin conditions)
- jet compresses and heats up the gas

Summary

- High angular resolution of Chandra gives unprecedented views on the evolving jets impact on the ISM
- Different X-ray radiation process in young radio sources
- Tracing jet interactions and impact on ISM
- Important data for understanding feedback process
- Studies require deep high resolution X-ray observations and need for future X-ray missions

A Chandra X-ray image of the radio galaxy 4C+29.30. The image shows a bright central source with several distinct, elongated jet structures extending outwards. The jets appear as bright, diffuse regions with some internal structure, set against a dark background. The overall shape is somewhat irregular, with the jets extending in different directions.

4C+29.30
Chandra X-rays

**Thank you to everyone involved in different aspects of
the Chandra projects over the past 25**

X-rays/Radio:

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Dominika Krol (CfA)
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Doug Burke (CXC)
Lukasz Stawarz (UJ)

ALMA:

Raffaella Morganti (Astron)
Tom Oosterloo (Astron)
Clive Tadhunter (Sheffield)

Thank you Chandra!