

A Large Scale Jet in PKS 1127-145

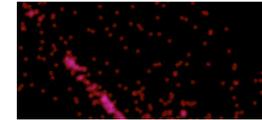
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Thomas Aldcroft & Jill Bechtold**

PKS 1127-145 Jet

- PKS1127-145 $z=1.18$ is a radio-loud Quasar
- AO1 Chandra Observation revealed a large scale jet $\sim 300(\sin\theta)^{-1}$ kpc
- $L_{\text{jet}}/L_{\text{core}} < 1 \%$
- $U_{\text{CMB}}(z) = U_0(1+z)^4$
 $z=1.18 \Rightarrow 9.75e-12 \text{ erg cm}^{-3}$

IMAGES BY DATE
IMAGES BY CATEGORY
SKY MAP
CONSTELLATIONS
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CHANDRA ZOOM-INS
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COSMIC DISTANCE

PKS 1127-145: Chandra Scores A Double Bonus With A Distant Quasar

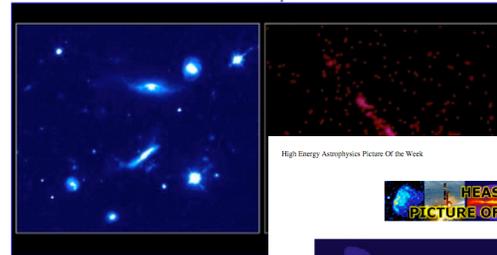


The X-ray image of the quasar PKS 1127-145, a highly luminous source of X-rays and visible light about 10 billion light years from Earth, shows an enormous X-ray jet that extends at least a million light years from the quasar. The jet is likely due to beam of electrons with protons.

Astronomy Picture of the Day

Discover the cosmos! Each day a different image or photograph of our fascinating universe is featured, along with a brief explanation written by a professional astronomer.

2002 February 8



PKS 1127-145: Credit: A. Siemiginowska (CU) & J. E. Grzimek (CU)

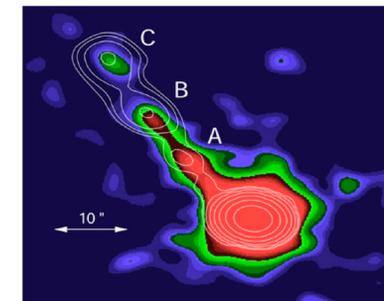
Explanation: The quasar known as PKS 1127-145 lies in the constellation of Hercules. The quasar itself is the brightest object in the Chandra image, a striking jet of X-rays extends from the quasar to dominate the X-ray view. Bright in both views, the quasar harbors a supermassive black hole which powers the jet. The jet is a beacon from the distant cosmos.

Tomorrow's picture

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A service of: LILA
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High Energy Astrophysics Picture Of the Week <http://heasarc.gsfc.nasa.gov/docs/ohj/chen/heapw/active/galax...>



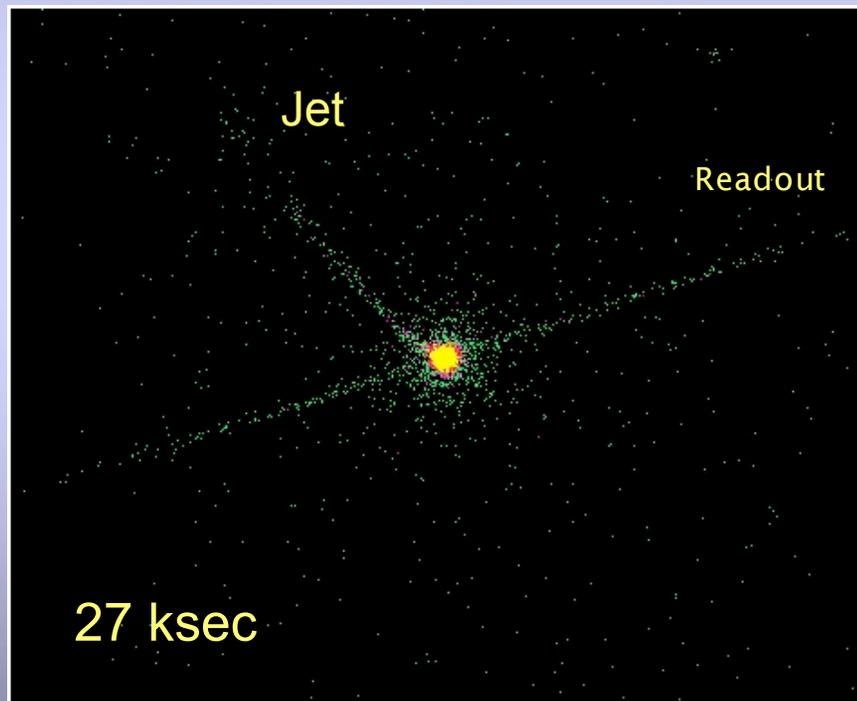
Credit: X-ray: NASA/CXC/A.Siemiginowska (CU) & J.E.Grzimek (U. Arizona); Radio: Siemiginowska et al. (VLA)

Ins and Outs of Black Holes

Somewhat inflow of material often produces large collimated outflows. This is exemplified in active galaxies, where large clouds of gas and, possibly stars and planets fall onto a black hole at the center of the galaxy, and producing an enormous jet of material which can be millions of light years long. Such jets are often called radio jets, since most were discovered using extremely high resolution observations with radio telescopes. The radio emission arises from relatively cool material inside the jet. Now high resolution X-ray images obtainable with the Chandra X-ray observatory show astronomers that radio jets are often X-ray bright, too. The image above shows a false-color X-ray image of the active galaxy

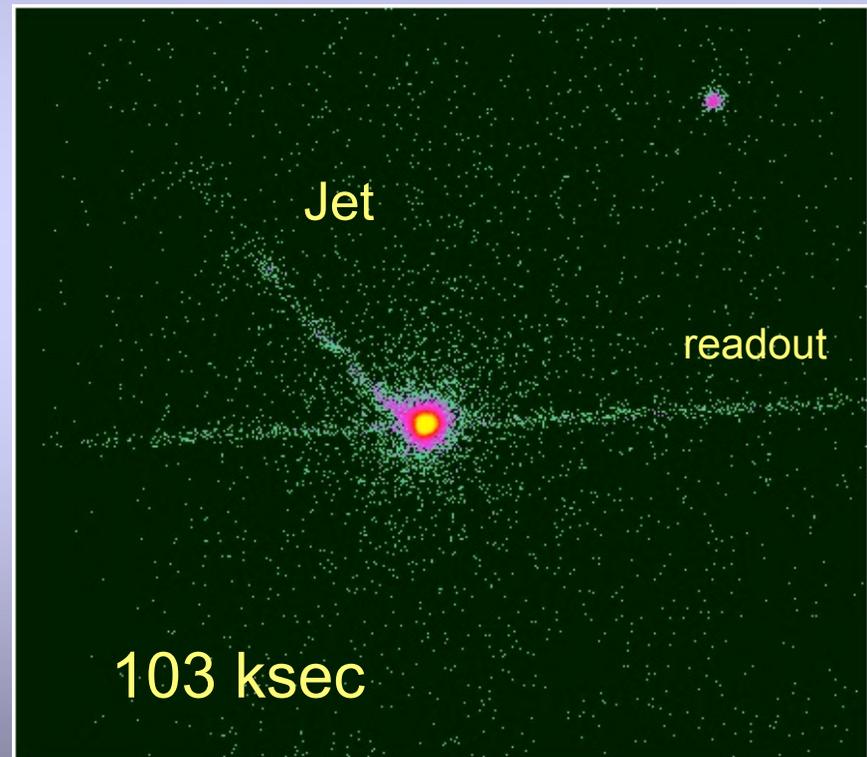
Chandra Observations of PKS 1127-145

AO1 May 2001

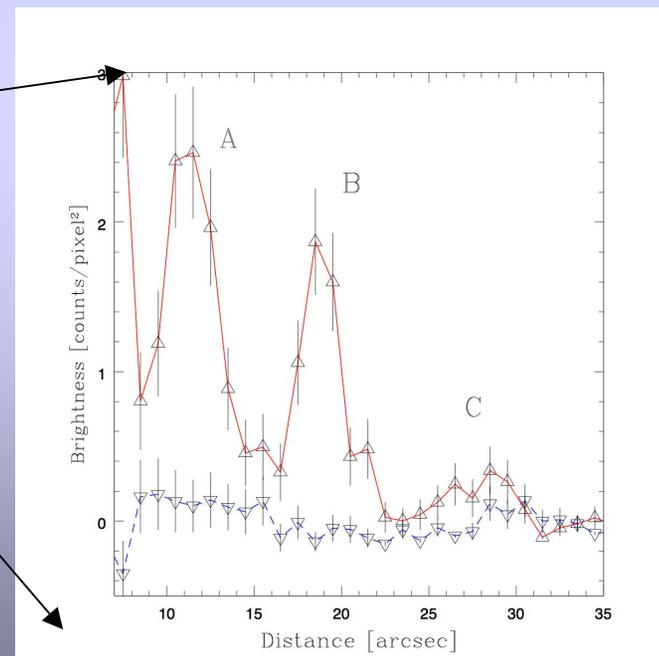
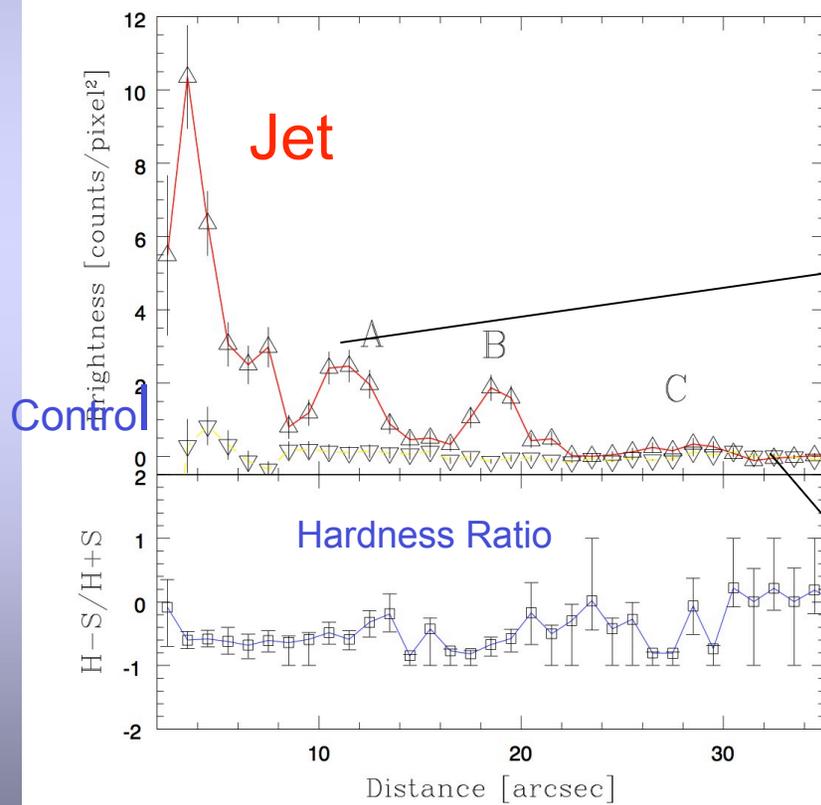
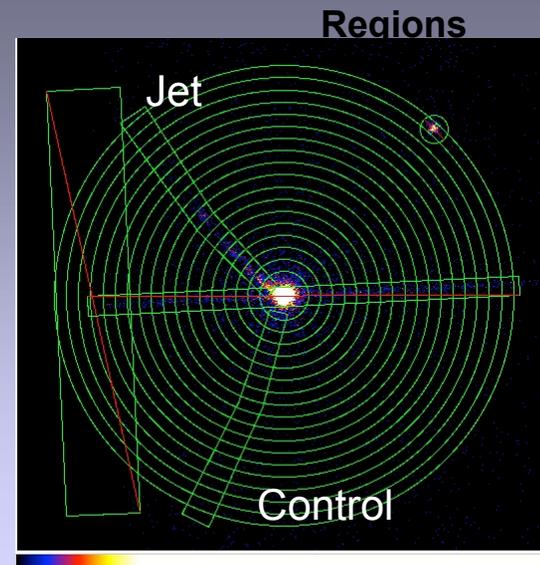


0.3-7 keV

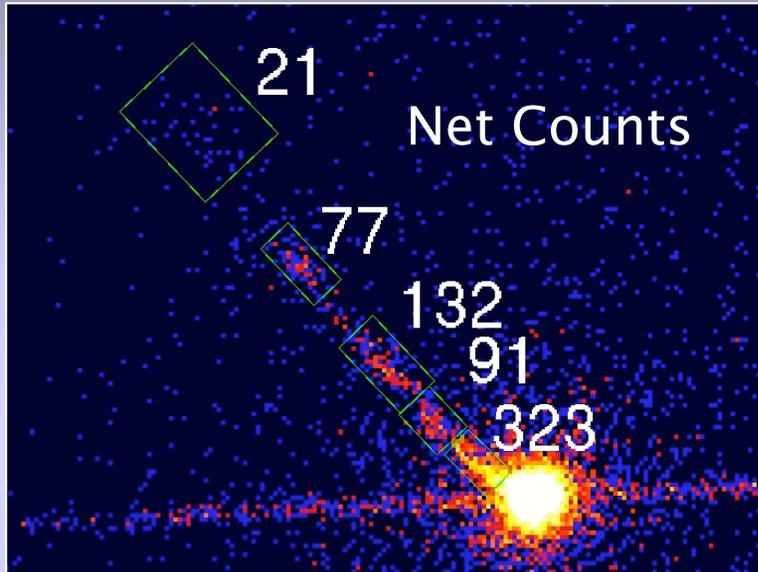
AO6 April 2005



X-ray Jet Profile



X-ray Jet Parameters

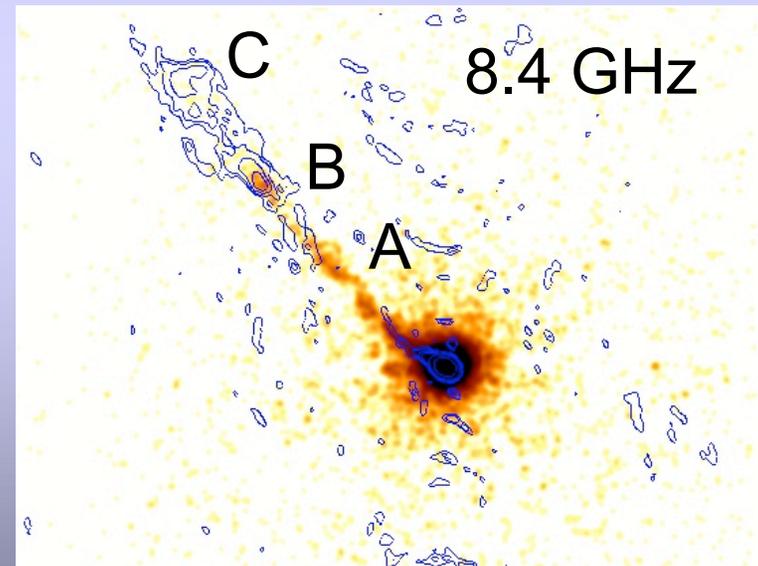
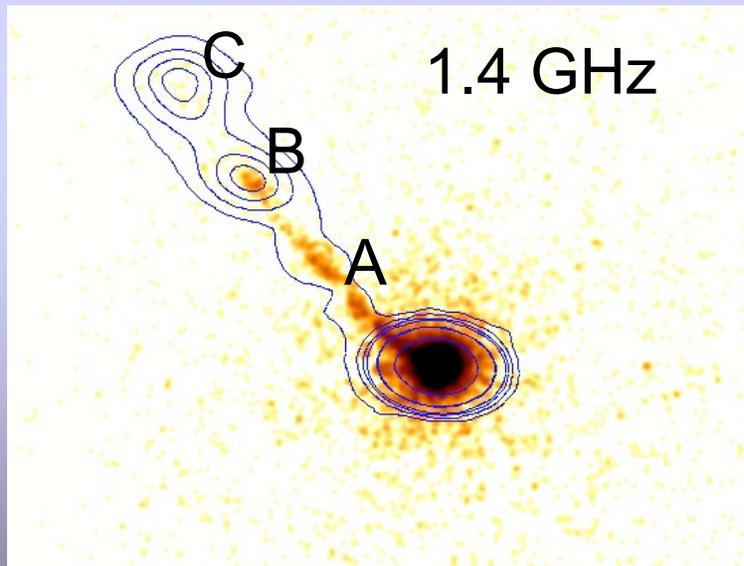


Fitting Power Law Model:

Box	Γ	
I	$1.67^{+/-0.11}$	Flat
o	$1.69^{+/- 0.19}$	
A	$1.66^{+/-0.15}$	
B	$2.0^{+/-0.2}$	Steep
C	$2.2^{+/-0.6}$	

Radio Jet

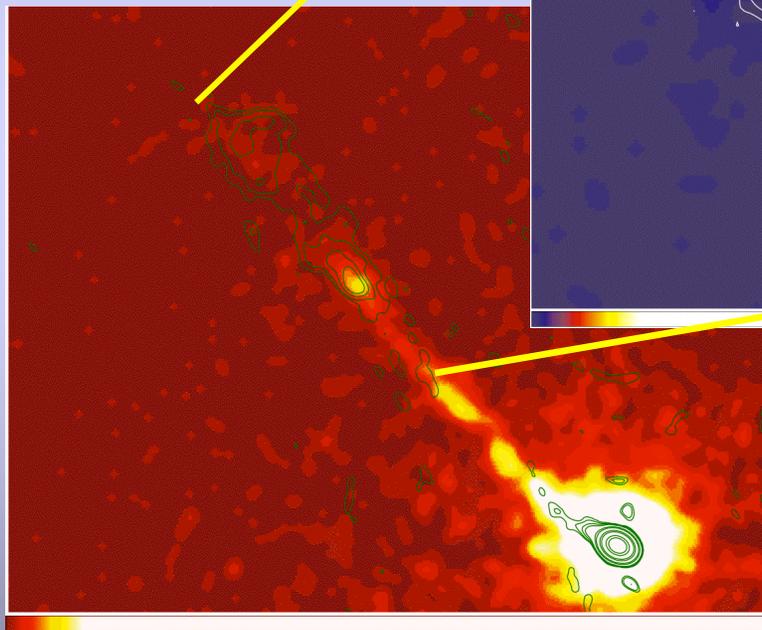
- * Very weak radio jet with the radio intensity increasing outwards.
- * Spectral index flattens at the outer knots ($\alpha_r \sim 0.8$)
- * Knot A < 2.5 mJy at 8.4 GHz ($\alpha_r > 1.5$)
- * ~10% polarization at knot C



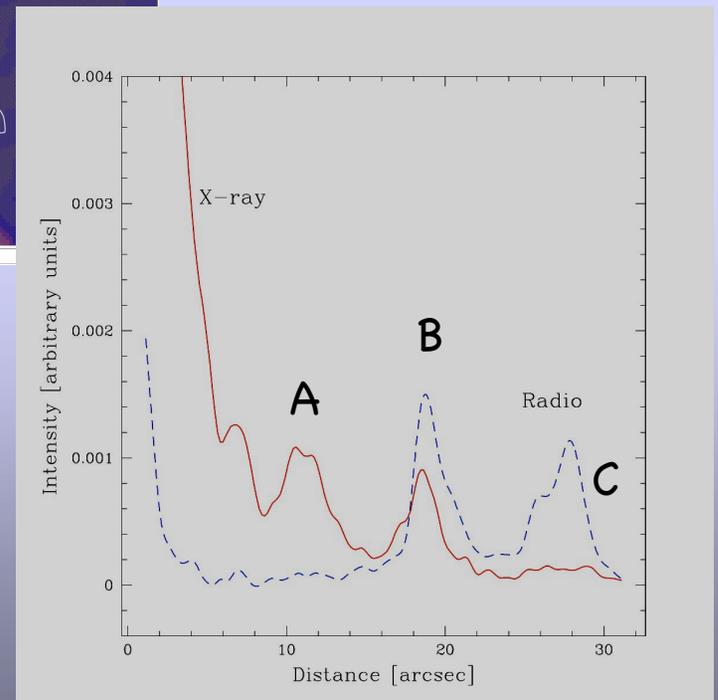
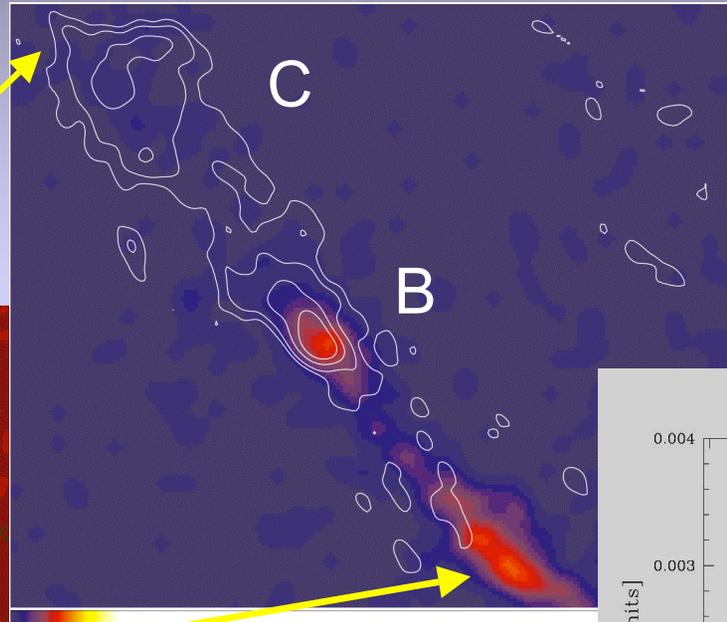
ACIS-S Images overlaid with Contours of radio emission

X-ray & Radio Emission

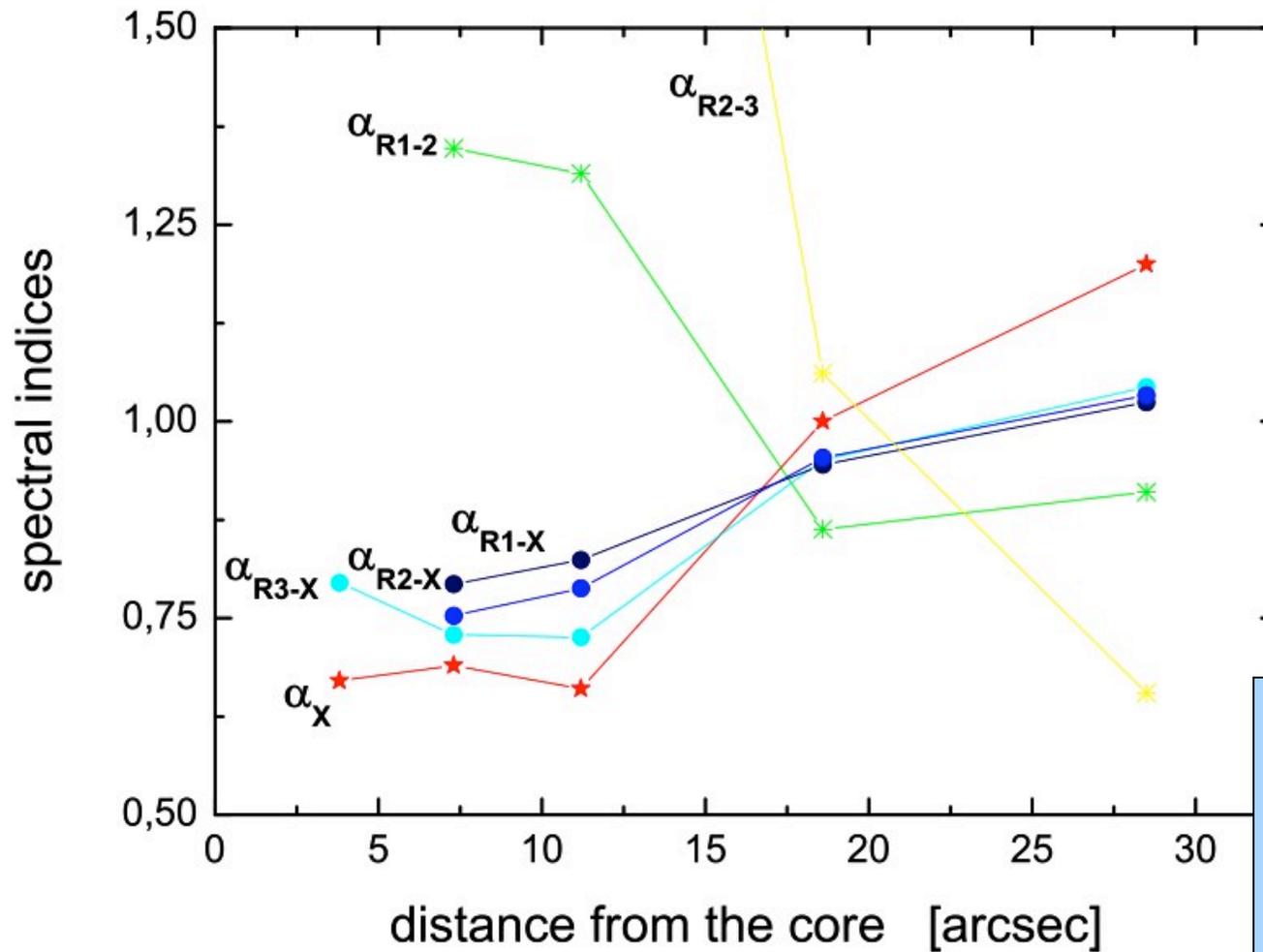
Knot B:
X-ray precedes
Radio by 0.2arcsec



8.4GHz Radio - contours

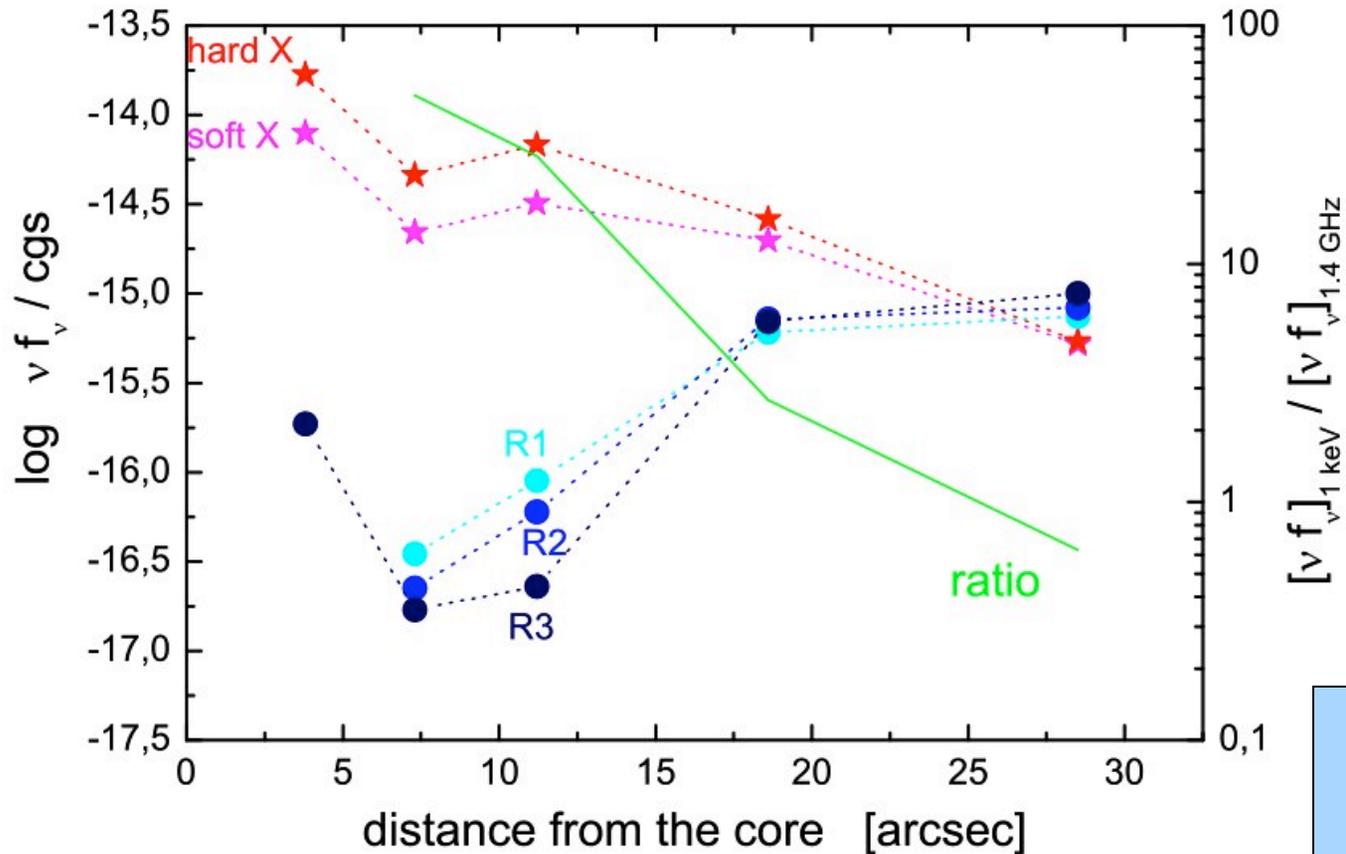


X-ray & Radio Emission: Spectral Index



R1 - 1.4GHz
R2 - 4.9GHz
R3 - 8.5GHz
X - 2keV

X-ray & Radio Emission: Flux

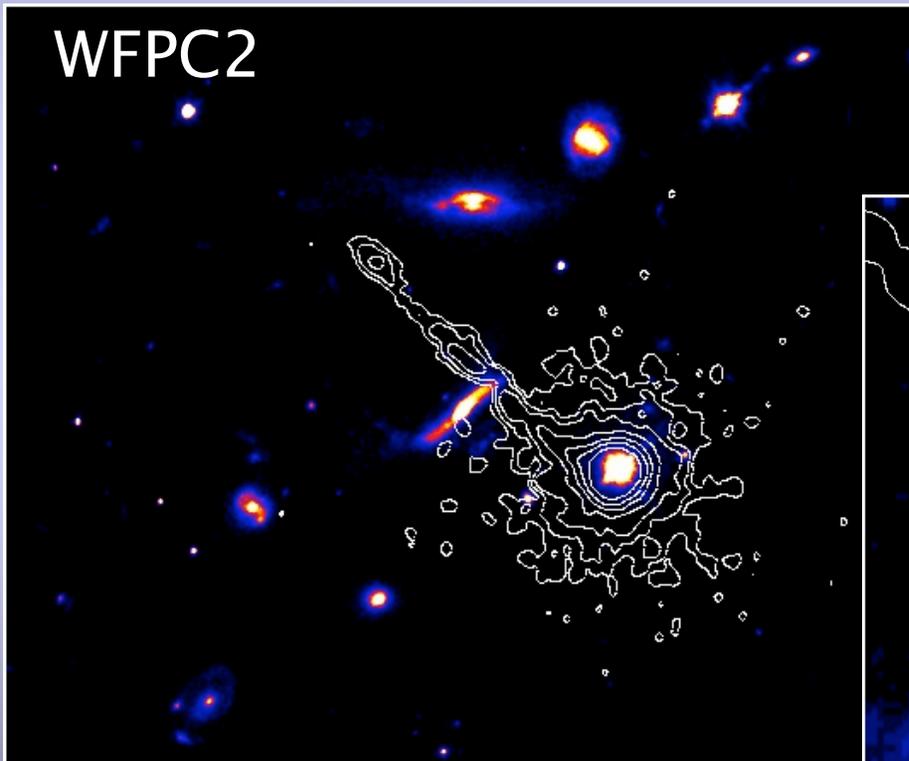


R1 - 1.4GHz
R2 - 4.9GHz
R3 - 8.5GHz
Soft - 0.3-2 keV
Hard - 2-7 keV

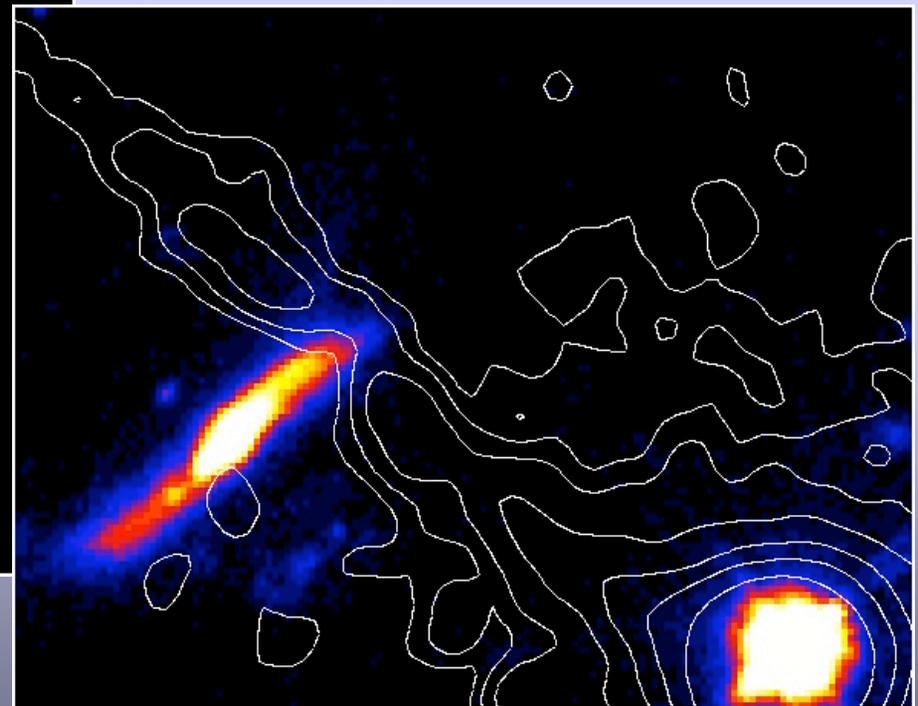
Optical/X-ray Images

Absorption of the X-ray Jet by
a large Spiral Galaxy at
 $z=0.312$?

⇒ NO! Bent internal to the Jet
⇒ Observed in Radio and X-ray!



Contours show ACIS-S data



Issues for Modeling the Jet X-ray Emission

- Decrease in X-ray Flux
- Increase in Radio Flux
- **Steepening** of X-ray continuum along the jet:
 - Inner Jet: $\alpha_x = 0.6$
 - Outer Jet: $\alpha_x > 1.0$
- **Flattening** of Radio Continuum along the jet:
 - Inner Jet: $\alpha_R > 1.5$
 - Outer Jet: $\alpha_R = 0.8-0.9$
- L_x/L_R ratio varies along the jet in a non-uniform way.

One-Zone Inverse Compton Model:

➤ IC/CMB Model:

- **Compton scattering of CMB photons on cold ($\gamma \sim 100$) electrons .**

At the equipartition condition high $\Gamma \geq 10$ (jet bulk Lorentz factors) are required at low redshifts. At $z=1.18$ for PKS1127-145 U_{CMB} is high, so $1 < \Gamma < 3$.

BUT

PKS 1127-145 Jet Morphology and Spectral properties give problems:

- **Knotty morphology**

=> long cooling times ($> 10^9 \text{yr}$ for $\gamma \sim 100$), so knots are hard to explain if the jet kinetic power has to be constant

- **Difference between X-ray and Radio Spectral Indices**

=> electron energy of X-ray emitting electrons lower than the radio electrons, so the X-ray spectra should follow radio spectra or be constant along the jet.

➤ **Adiabatic Expansion -> B-field conserved**

- Both IC/CMB X-ray emission and Synchrotron Radio emission should decrease
- But in PKS 1127-145 the luminosity ratio L_X/L_R varies along the jet!
- => No adiabatic expansion

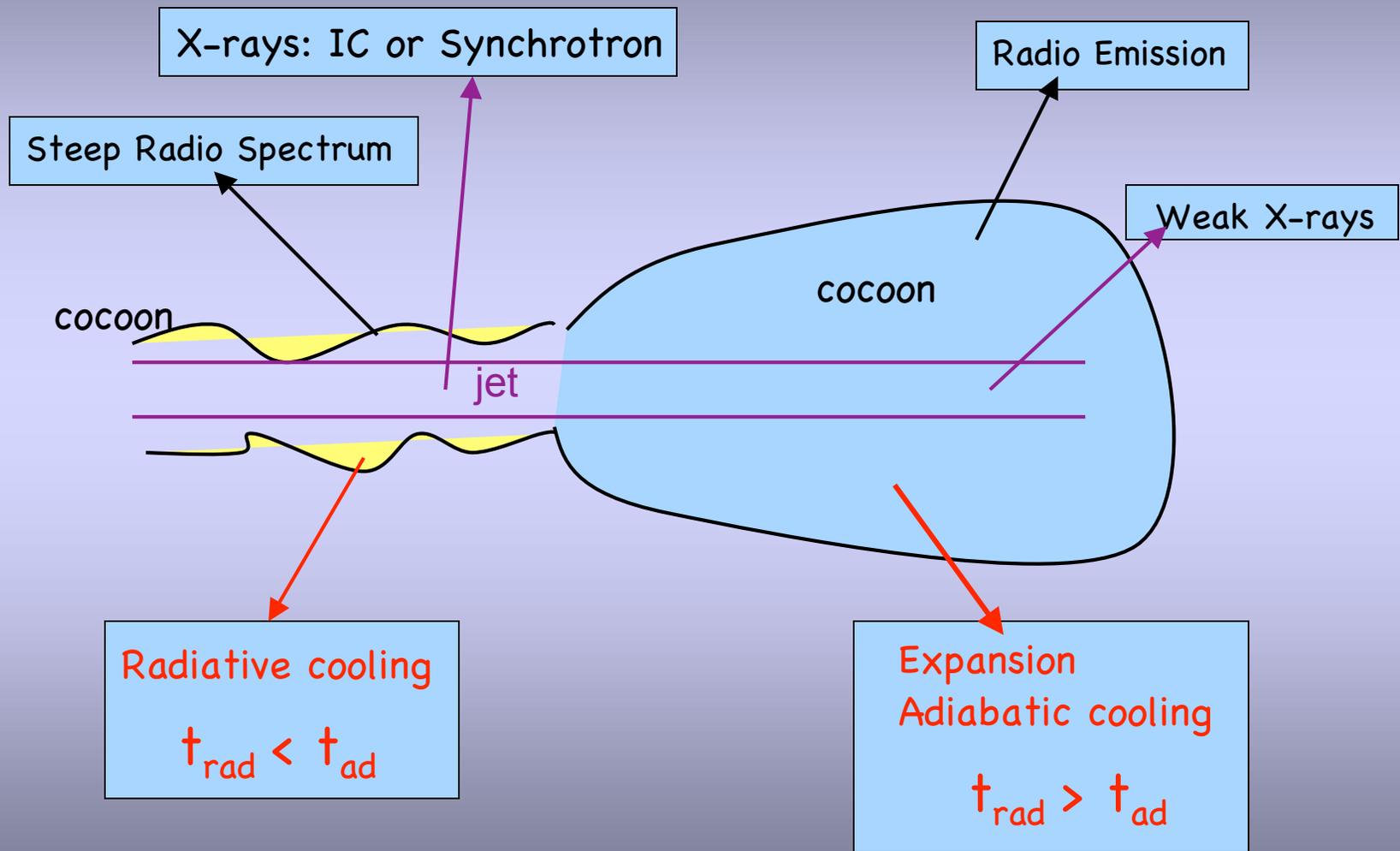
➤ **Amplification of B-field with no expansion:**

➤ **Radiative Cooling**

One-Zone Synchrotron Model

- Non homogenous models
 - => different electron populations
- Require **effective and continuous acceleration** to high energies ($E_e \sim 100$ TeV) along the entire jet.
- Acceleration process is not clear:
 - => turbulent acceleration?
 - => magnetic reconnection?
 - ⇒ multiple shocks?
- No adiabatic expansion (as seen for the IC/CMB model)
- Requires **very high amplifications** of the B field!
 - X-ray/Radio ($0 \rightarrow r$) => $\delta^{5/2} B^{1/2}$
 - => $B_r/B_0 > 100$

Two-Component Model: Jet+Cocoon

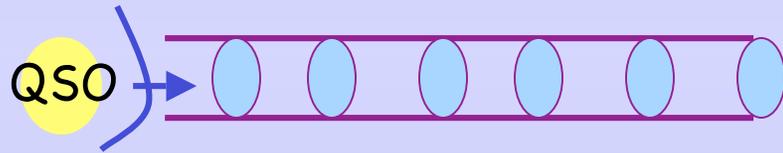


Modulated Jet Activity

QSO Intermittent Activity

=> Modulated Jet Ejections

=> Different spectral and spatial evolution of
Radio and X-ray Emission



Jet duration Time linked to the QSO activity timescale to

Create a jet => 10^5 years for PKS1127-145

Total Power in one episode: $2.5e58$ erg

$L_{\text{Edd}} = 9e46$ erg/sec => $\dot{M}_{\text{Edd}} \sim 1.5 M_{\text{sun}}/\text{yr}$

Summary

- Chandra Deep Image of the PKS 1127-145 Jet provides data for detailed analysis of the knots: **Inner jet regions** show **flatter** X-ray spectra than the **outermost regions** of the Jet.
- Jet **Radio emission is very weak** and the jet becomes weaker (non-detectable at 8.4GHz) at the strong X-ray emission of knot A.
 - => **X-rays are more efficient for jets studies**
- The **offsets** between X-ray and radio brightness, which were detected in the AO1 data are not present.
- **Constraints on the jet X-ray emission models**: one zone model cannot explain the morphology and spectral properties of the jet in PKS1127-145.
- **Two-zone** models are promising, although the constraints on model parameters are not easily obtained from the current observations.