On X-ray Emission Process from the radio/optical Knots of Kiloparsec scale Jet of AGN

Knots getting naughtier!!

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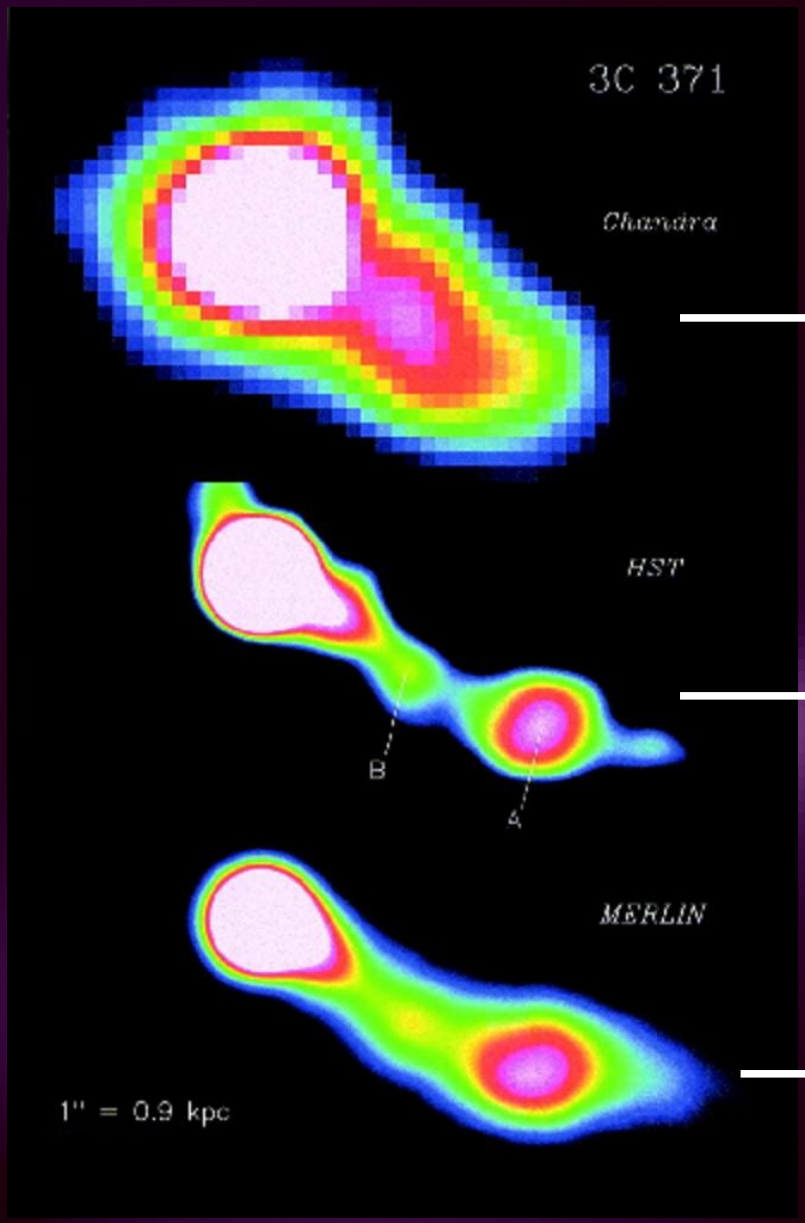
AGN Jet - Knots



3C 371

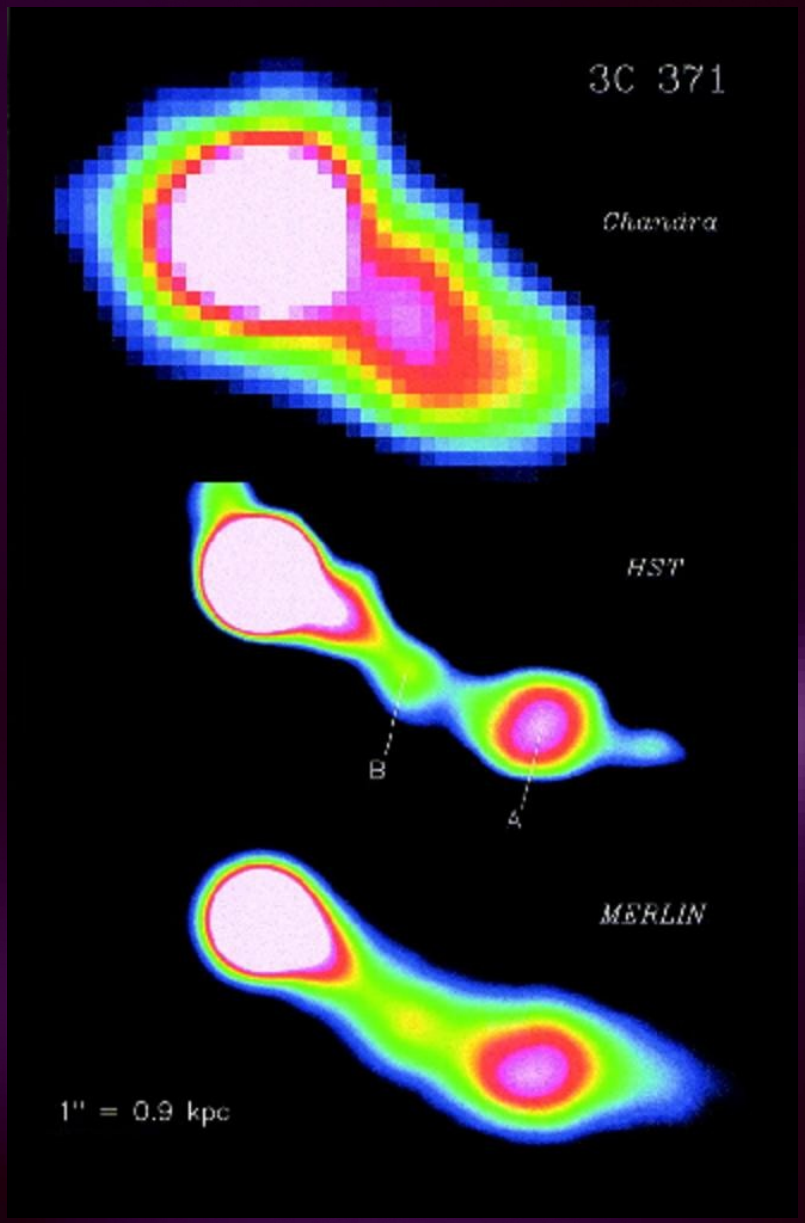
X-ray

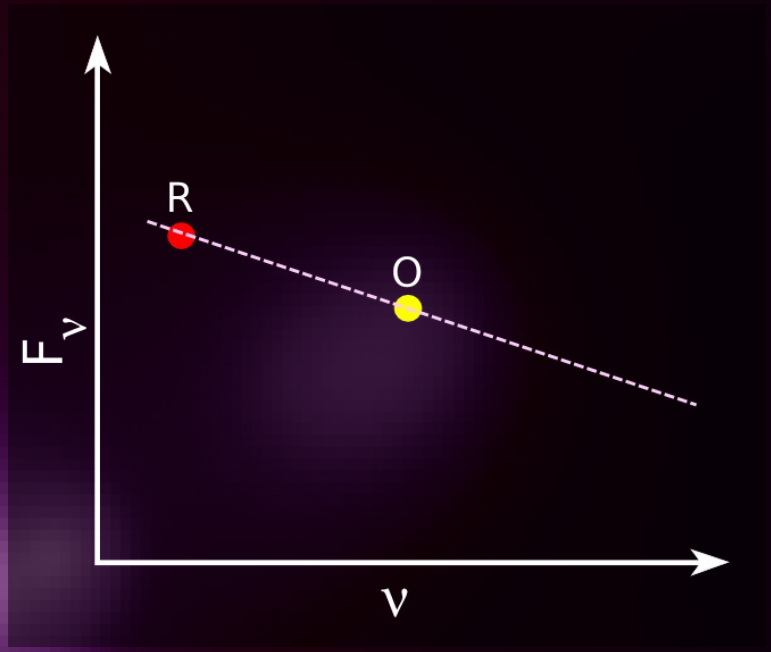
Optical

Radio

Pesce, J. E. et al., *APJ Letters* (2001), **556**, 79

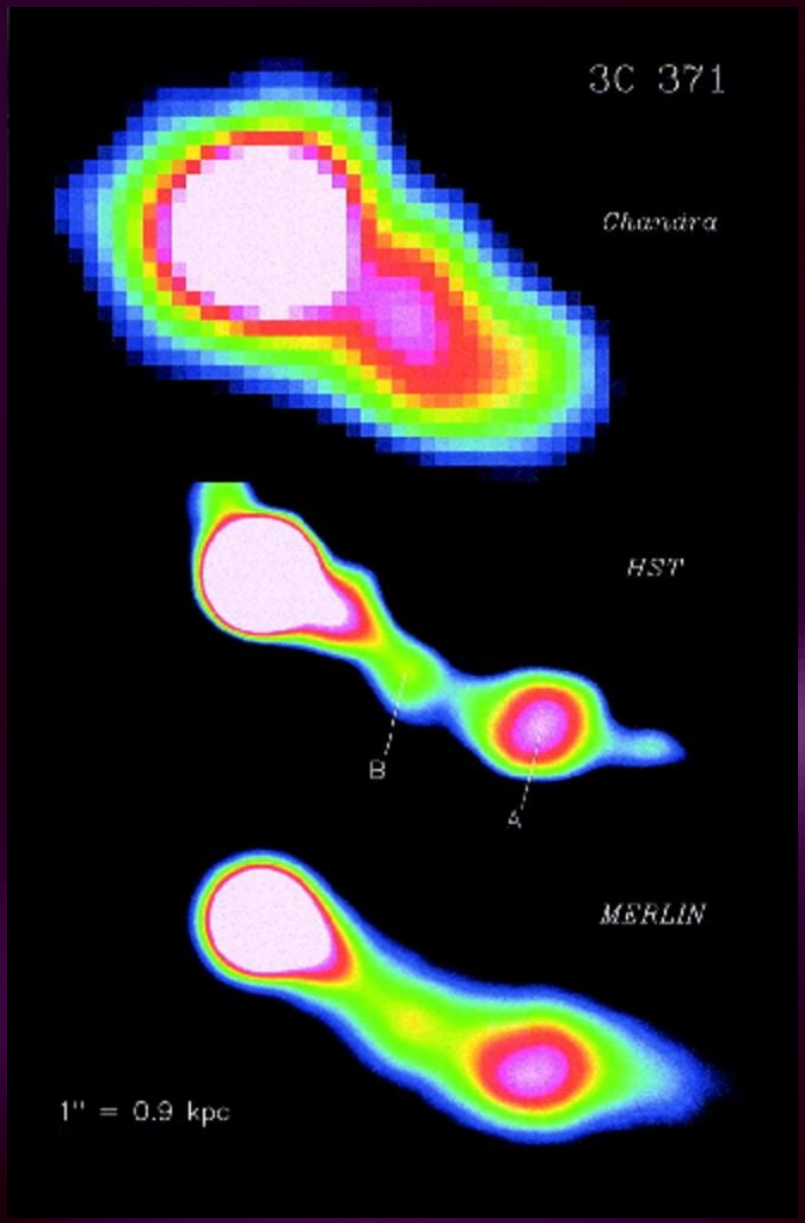
Knots - X-ray Emission Process



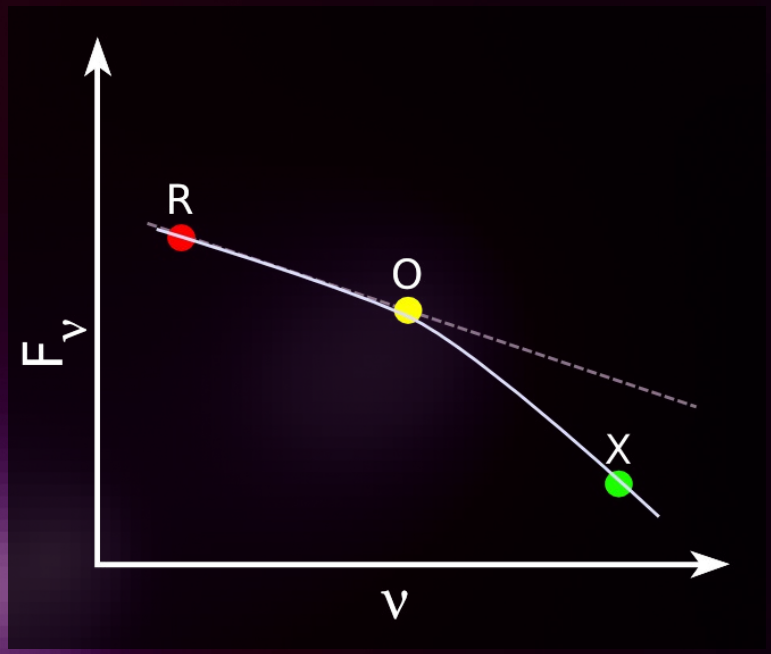


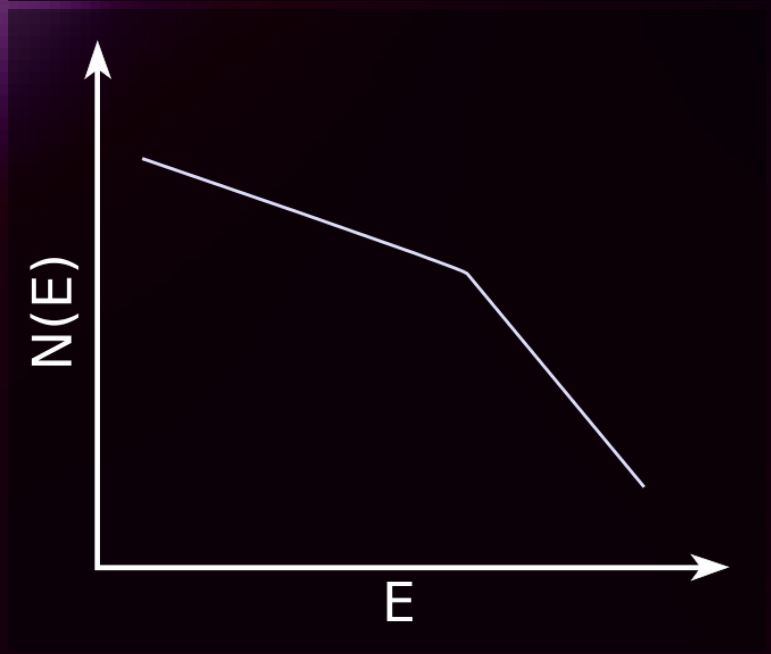
Sambruna, R. et al., *APJ* (2002), **571**, 206

Knots - X-ray Emission Process



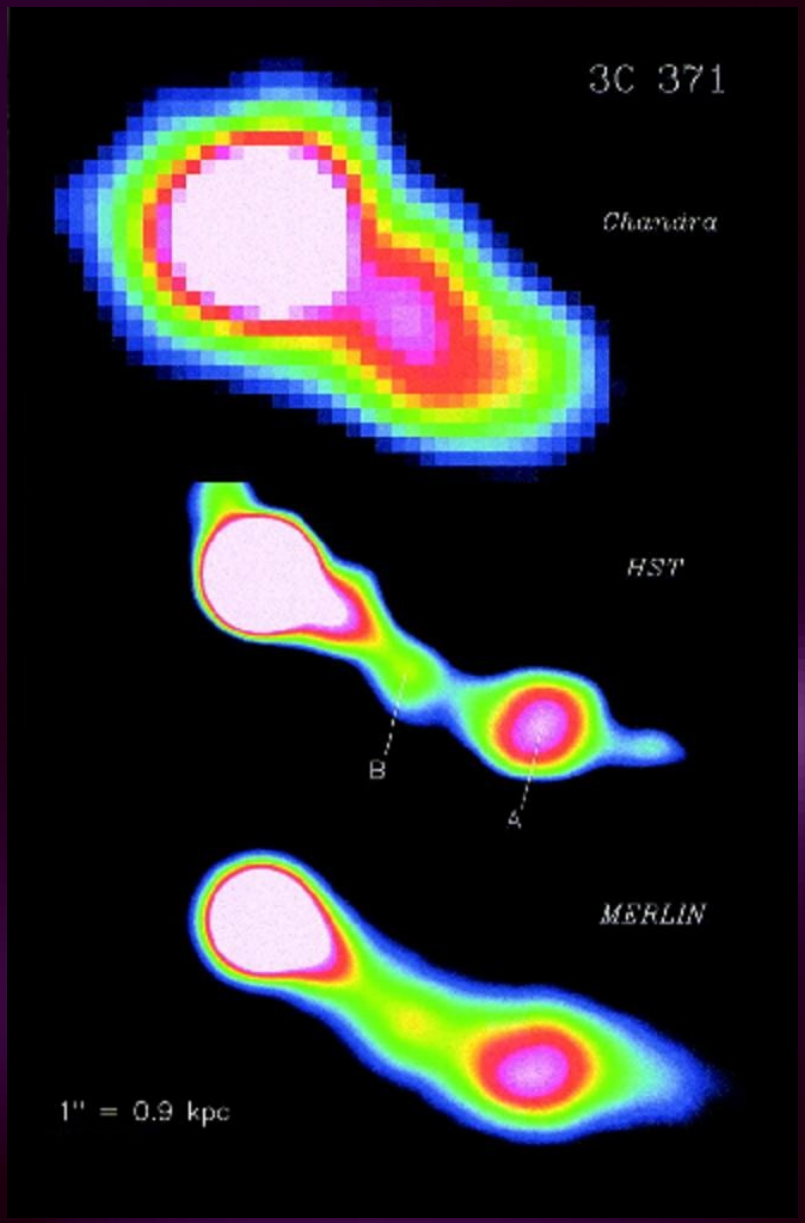
Single Emission Process

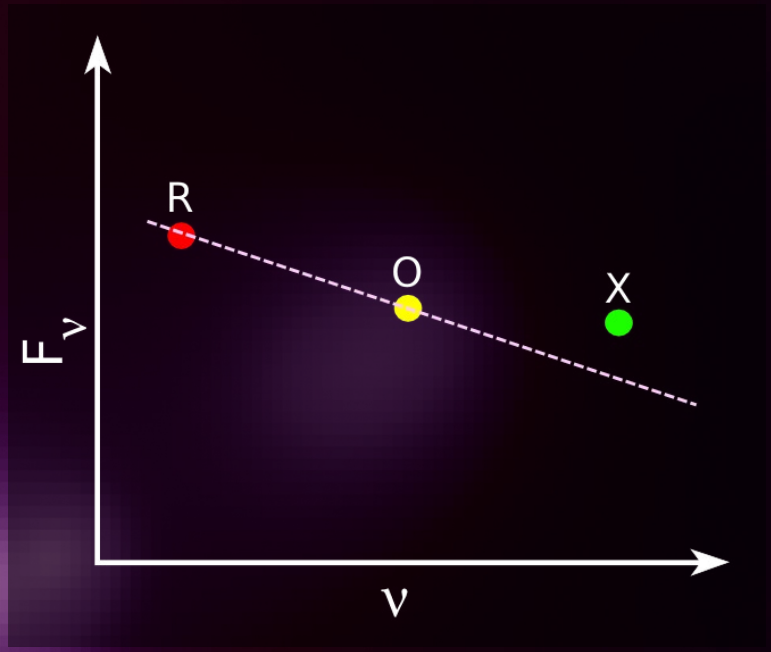


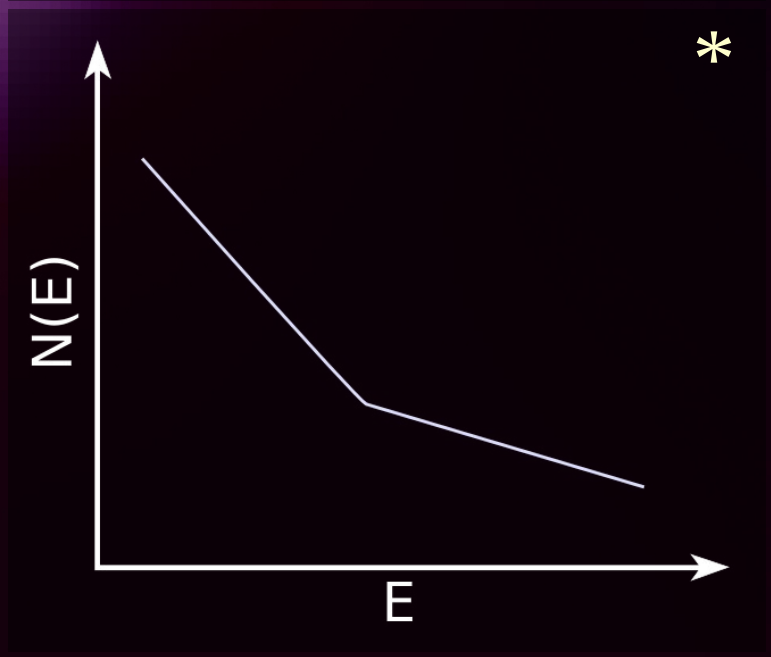


Sambruna, R. et al., *APJ* (2002), **571**, 206

Knots - X-ray Emission Process







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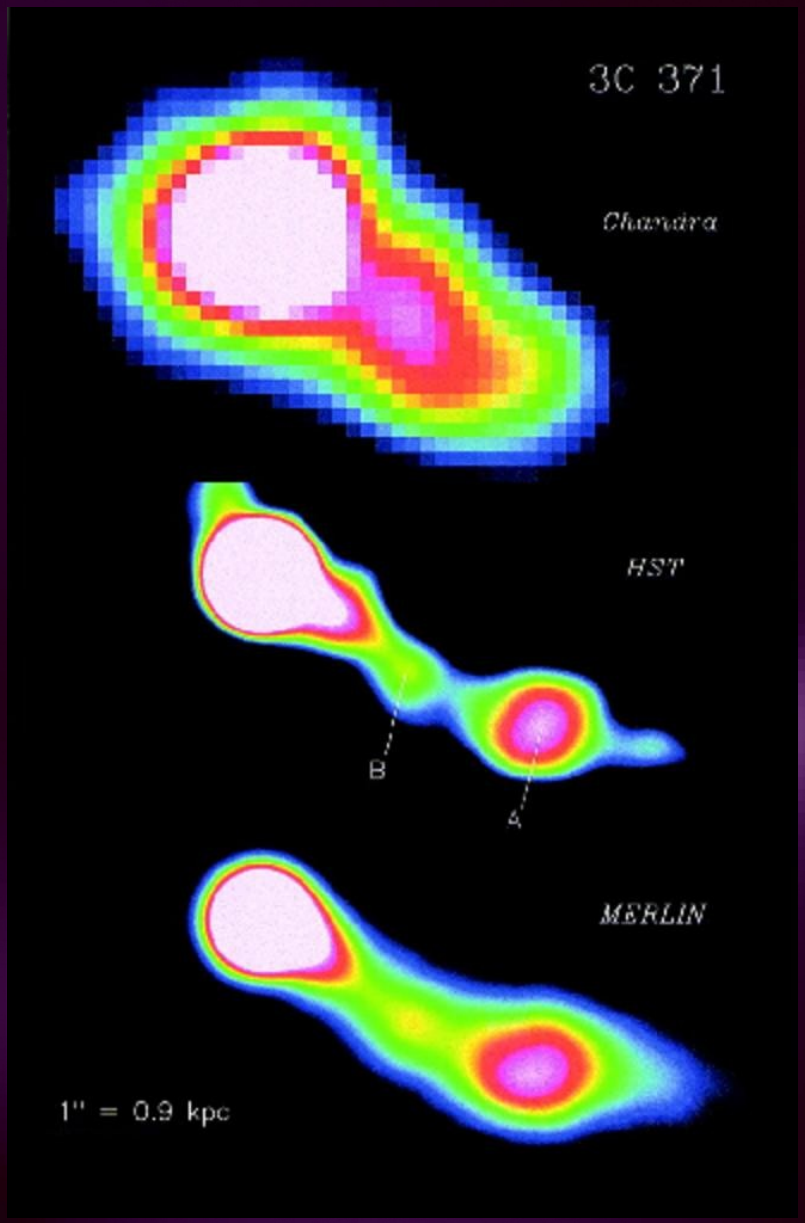
*Sahayanathan, S., *MNRAS Letters* (2008), **388**, 49

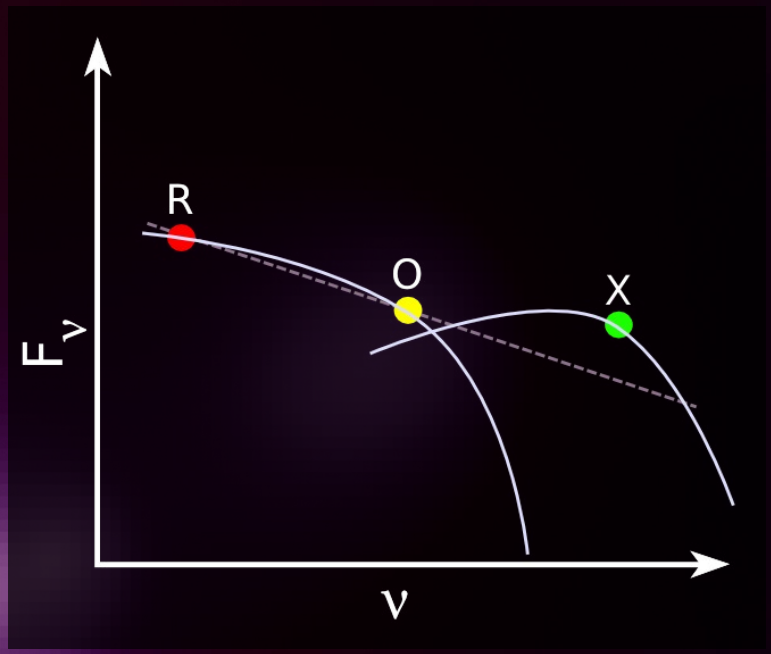
Knots - X-ray Emission Process



Different Emission Process (IC)

OR

Second Population

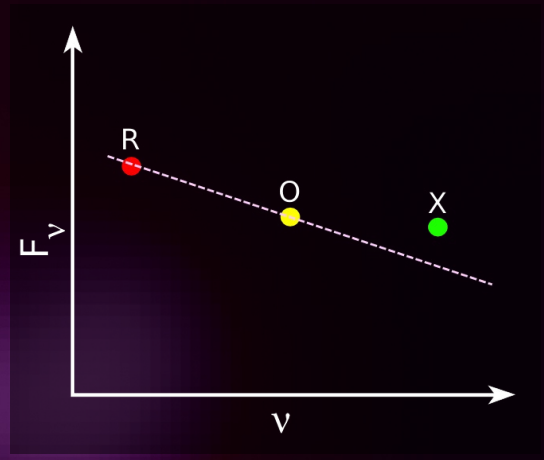


Sambruna, R. et al., *APJ* (2002), **571**, 206

X-ray Knots : IC Interpretation

Inverse Compton Process

- Possible target photons are:
  - Synchrotron photon (SSC)
  - CMB photons (IC/CMB)



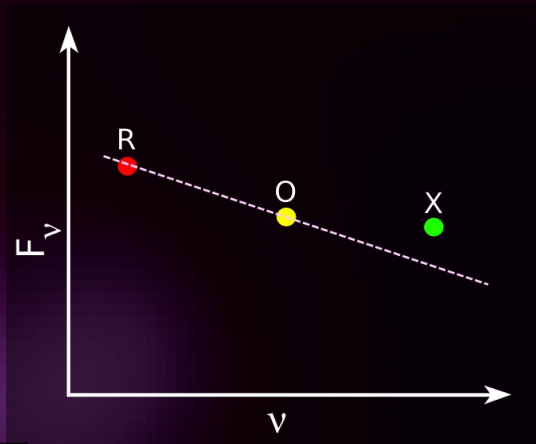
Tavecchio, F. et al., *APJ* (2000), **544**, 23

X-ray Knots : IC Interpretation

Inverse Compton Process

- Possible target photons are: { Synchrotron photon (SSC); CMB photons (IC/CMB)

$$N(\gamma)d\gamma = K\gamma^{-p}d\gamma$$



$$F_{syn}(\nu_s) \propto \delta^{(p+5)/2} B^{(p+1)/2} R^3 K \nu_s^{-(p-1)/2} \quad (1)$$

$$F_{ssc}(\nu_{ssc}) \propto \delta^{(p+5)/2} B^{(p+1)/2} R^4 K^2 \nu_{ssc}^{-(p-1)/2} \quad (2)$$

$$F_{ec}(\nu_{ec}) \propto u_{cmb} \nu_{cmb}^{(p-3)/2} \delta^{(p+3)} R^3 K \nu_{ec}^{-(p-1)/2} \quad (3)$$

R – Knot size

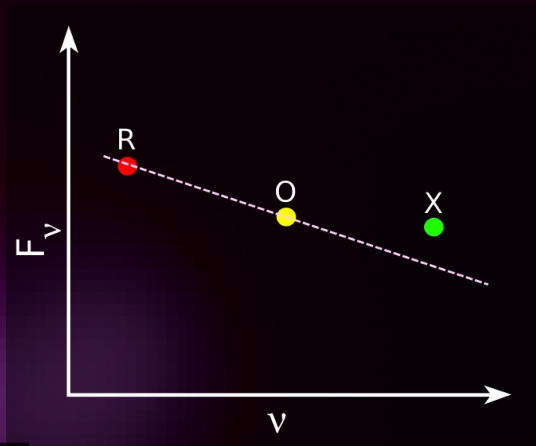
Sahayanathan, S., Godamba, S., *MNRAS* (2012), **419**, 1660 Tavecchio, F. et al., *ApJ* (1998), **509**, 608

X-ray Knots : IC Interpretation

Inverse Compton Process

- Possible target photons are: { Synchrotron photon (SSC); CMB photons (IC/CMB)

$$N(\gamma)d\gamma = K\gamma^{-p}d\gamma$$



$$F_{syn}(\nu_s) \propto \delta^{(p+5)/2} B^{(p+1)/2} R^3 K \nu_s^{-(p-1)/2} \quad (1)$$

$$F_{ssc}(\nu_{ssc}) \propto \delta^{(p+5)/2} B^{(p+1)/2} R^4 K^2 \nu_{ssc}^{-(p-1)/2} \quad (2)$$

$$F_{ec}(\nu_{ec}) \propto u_{cmb} \nu_{cmb}^{(p-3)/2} \delta^{(p+3)} R^3 K \nu_{ec}^{-(p-1)/2} \quad (3)$$

δ - B Relation

$(2) \div (1)^2$

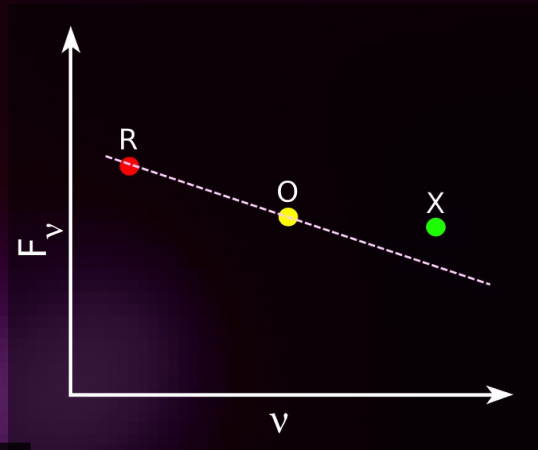
R – Knot size

X-ray Knots : IC Interpretation

Inverse Compton Process

- Possible target photons are: { Synchrotron photon (SSC); CMB photons (IC/CMB)

$$N(\gamma)d\gamma = K\gamma^{-p}d\gamma$$



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$$F_{ec}(\nu_{ec}) \propto u_{cmb} \nu_{cmb}^{(p-3)/2} \delta^{(p+3)} R^3 K \nu_{ec}^{-(p-1)/2} \quad (3)$$

δ - B Relation

(3) ÷ (1)

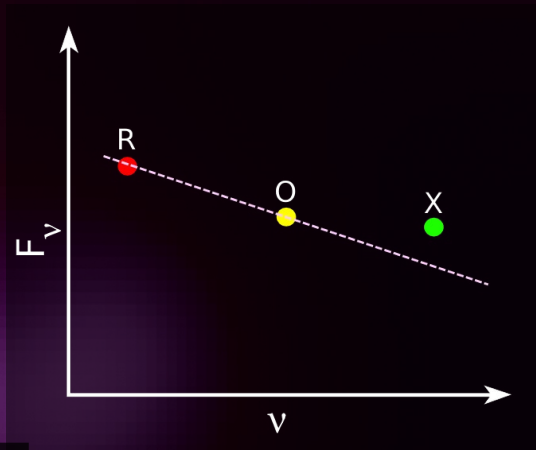
R – Knot size

X-ray Knots : IC Interpretation

Inverse Compton Process

- Possible target photons are: { Synchrotron photon (SSC); CMB photons (IC/CMB)

$$N(\gamma)d\gamma = K\gamma^{-p}d\gamma$$



$$mc^2 \int \gamma N(\gamma) d\gamma = B^2/8\pi \quad (0)$$

$$F_{syn}(\nu_s) \propto \delta^{(p+5)/2} B^{(p+1)/2} R^3 K \nu_s^{-(p-1)/2} \quad (1)$$

$$F_{ssc}(\nu_{ssc}) \propto \delta^{(p+5)/2} B^{(p+1)/2} R^4 K^2 \nu_{ssc}^{-(p-1)/2} \quad (2)$$

$$F_{ec}(\nu_{ec}) \propto u_{cmb} \nu_{cmb}^{(p-3)/2} \delta^{(p+3)} R^3 K \nu_{ec}^{-(p-1)/2} \quad (3)$$

δ - B Relation

Eliminate K using (0) and (1)

R – Knot size

X-ray Knots : IC Interpretation

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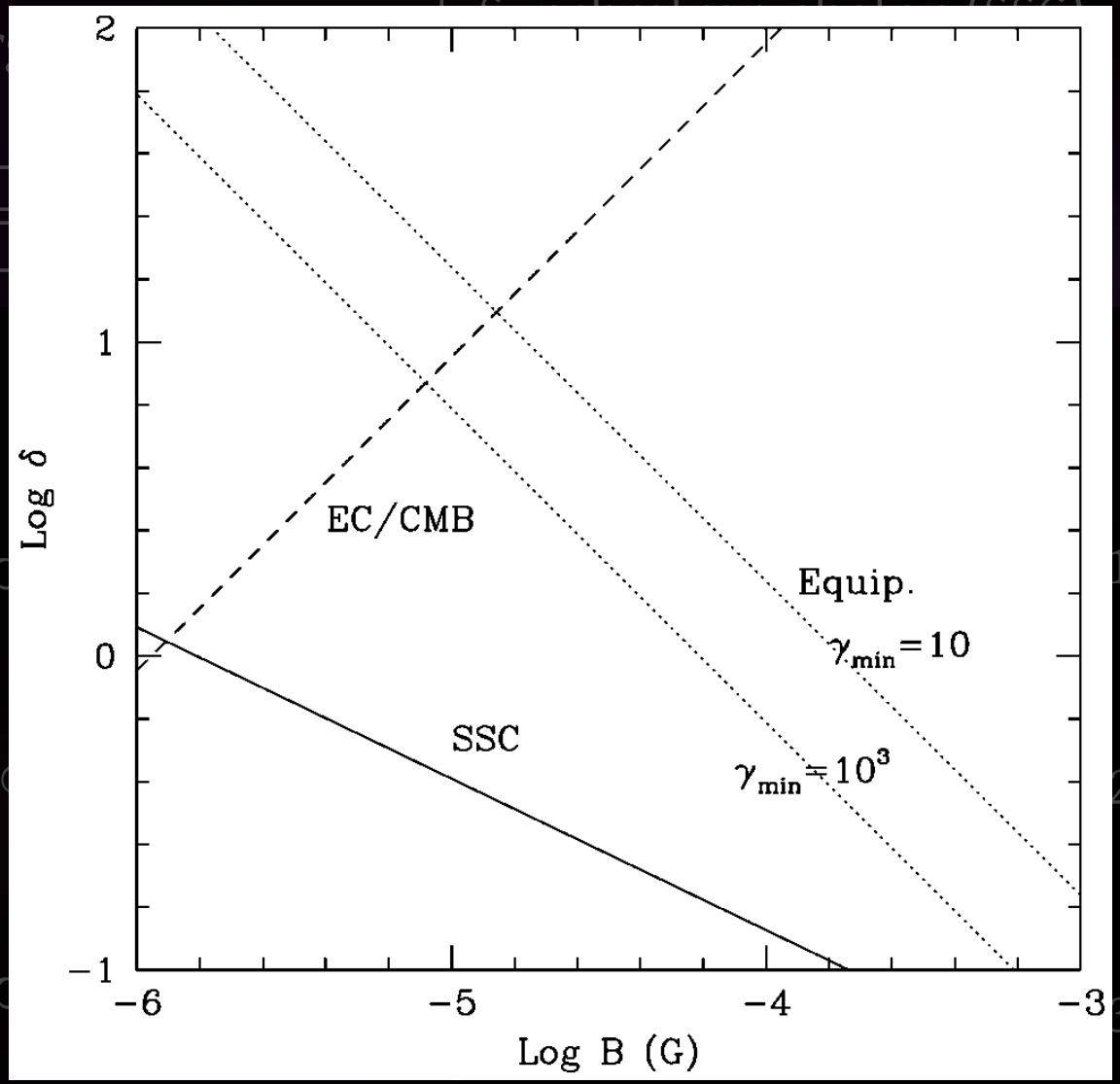
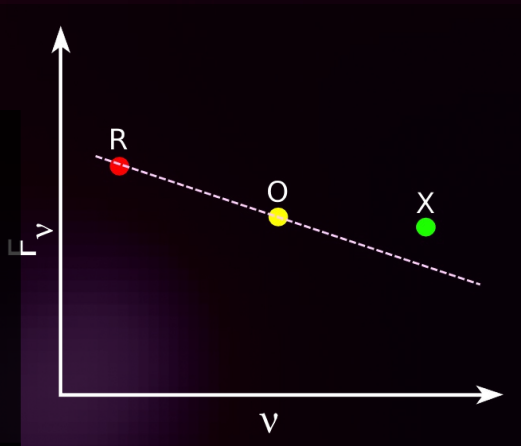
Inverse Compton Process





δ - B Relation

R – Knot size

Tavecchio, F. et al., *ApJ Letters* (2000), **544**, 23

X-ray Knots : IC Interpretation

IC/CMBR

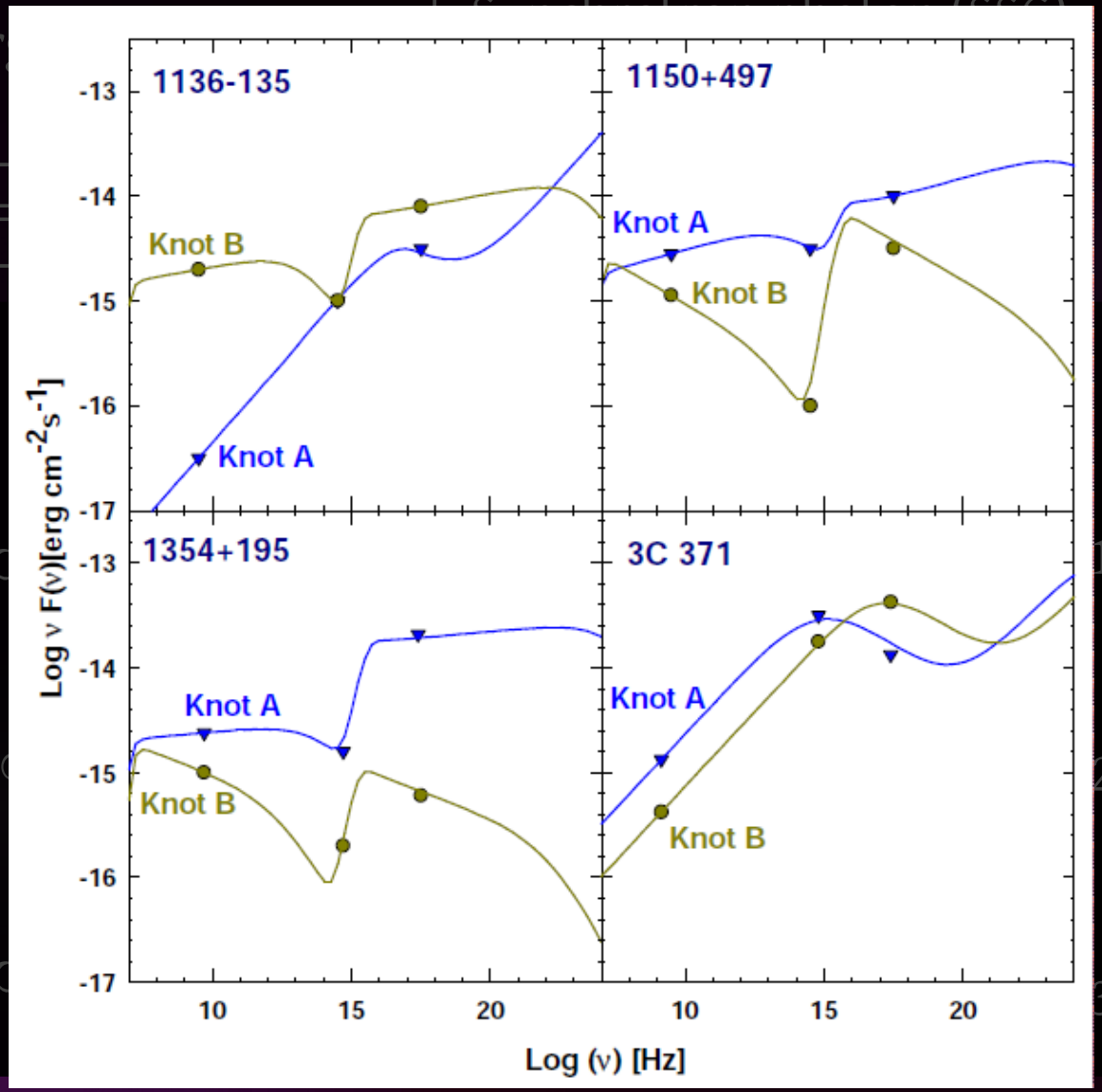
- Possible tar

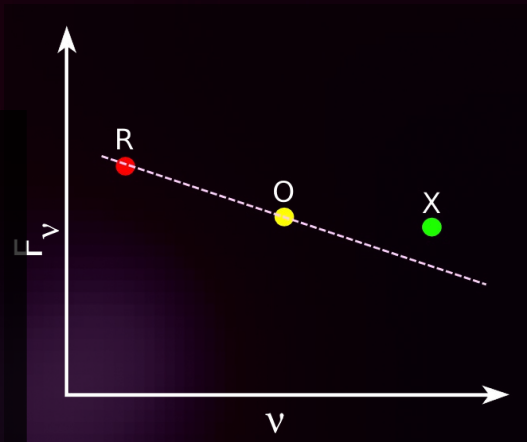
$$N(\gamma)d\gamma =$$

$$F_{syn}(\nu_s) \propto$$

$$F_{ssc}(\nu_{ssc}) \propto$$

$$F_{ec}(\nu_{ec}) \propto$$





Sahayanathan, S. et al., *ApJ Letters* (2003), **588**, 77

Sahayanathan, S., Ranjeev Misra, *ApJ* (2005), **628**, 611

Sambruna, R. et al., *ApJ* (2002), **571**, 206

Kharb, P. et al., *ApJ* (2012), **748**, 81

X-ray Knots : IC/CMBR Failure

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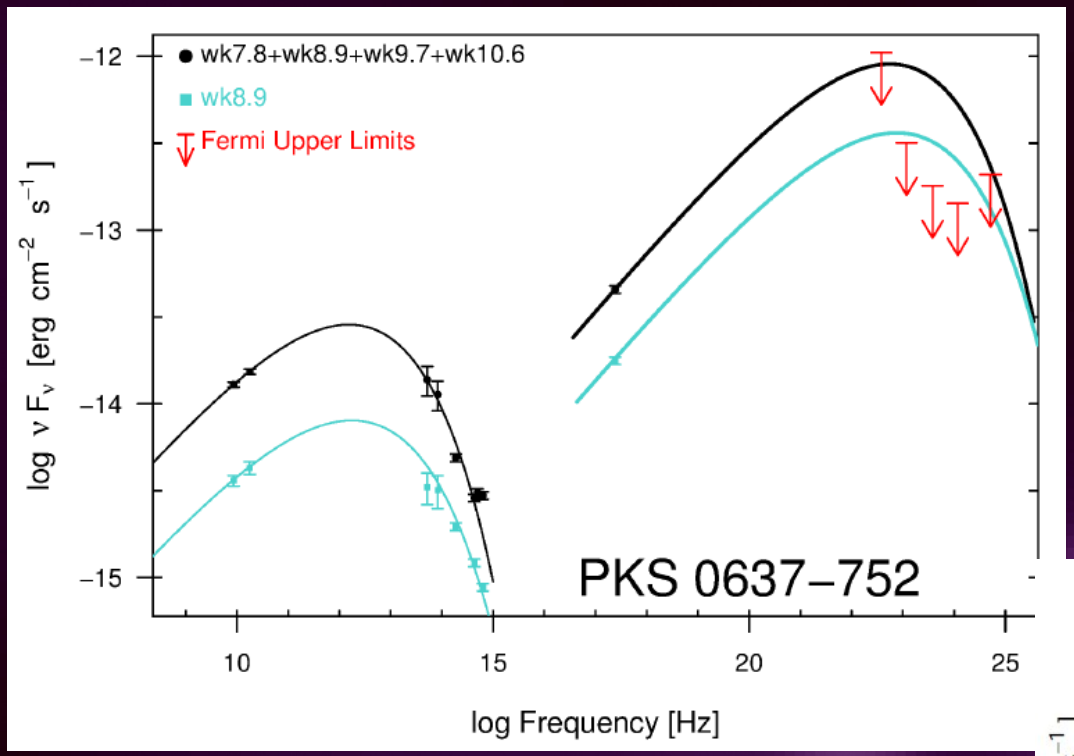

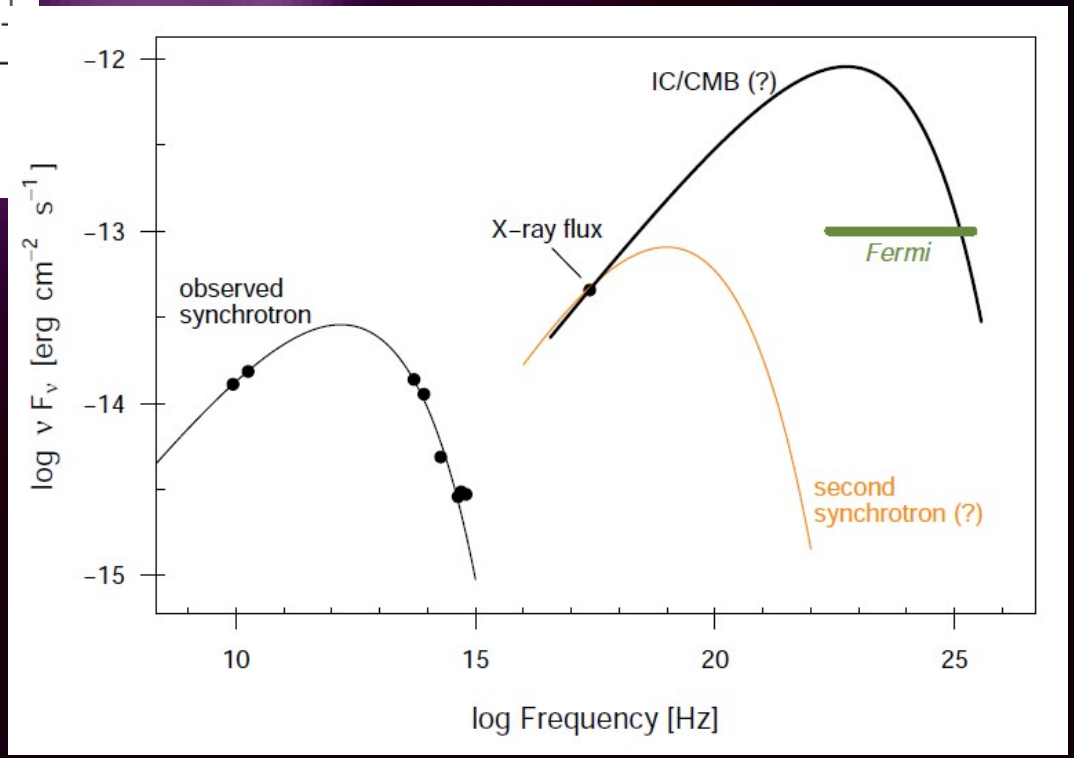

Meyer, E. et al., *ApJ* (2015), **805**, 154

Two-population Interpretation

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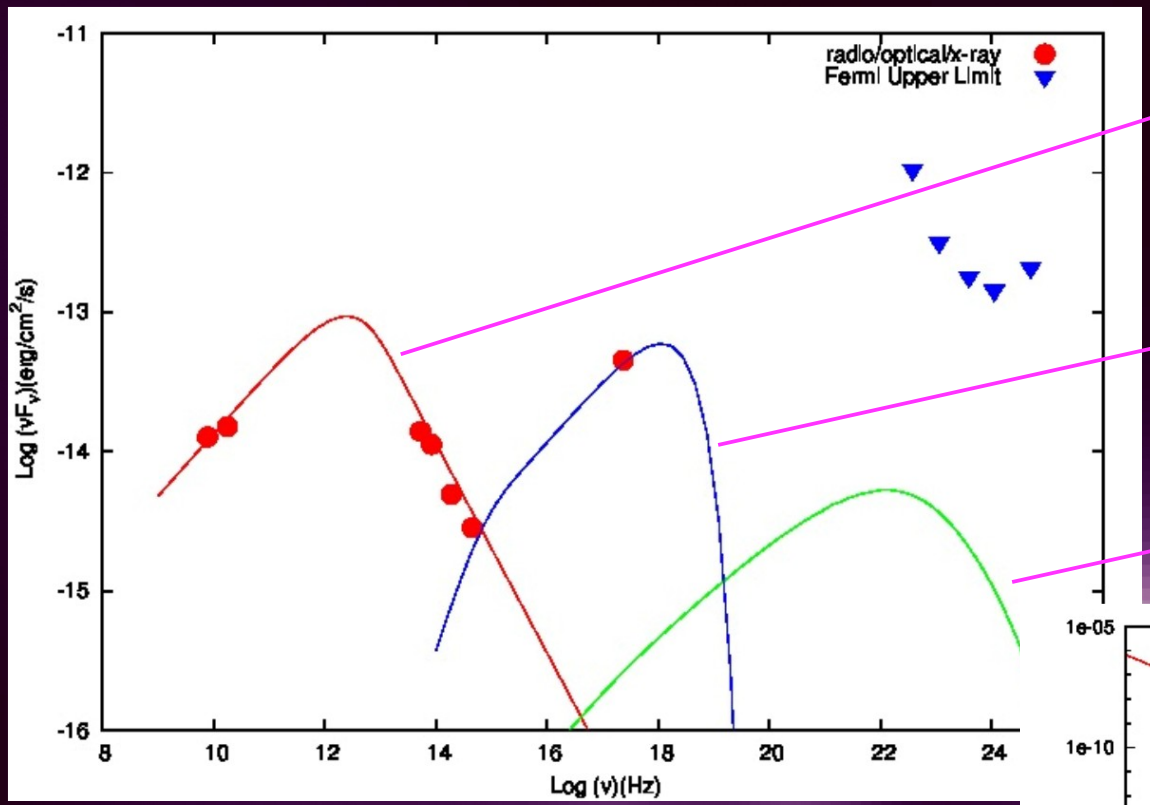
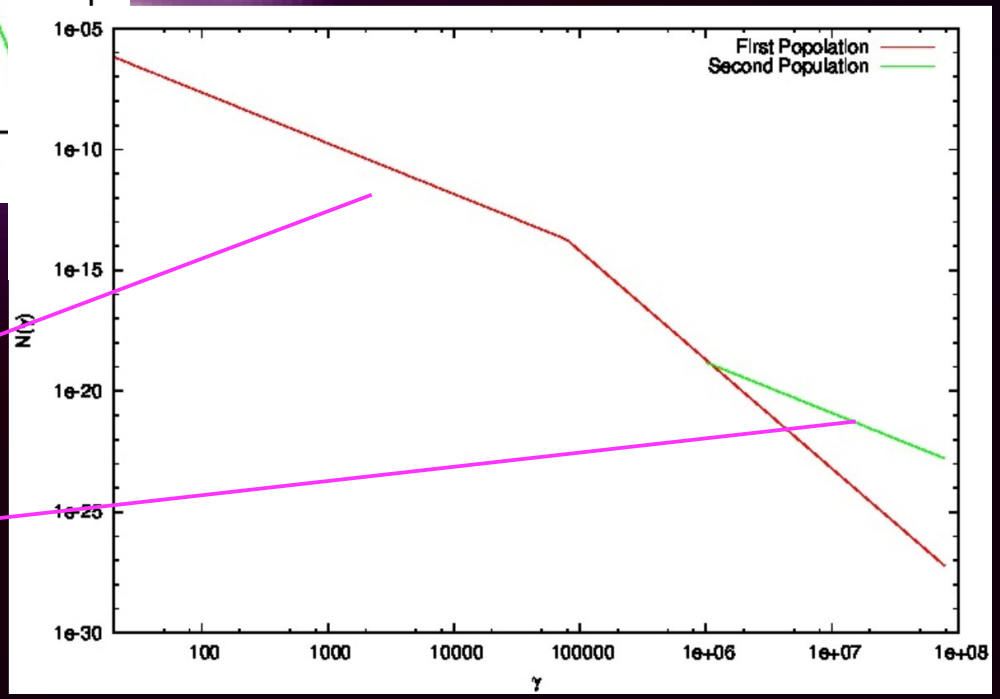


Synchrotron Emission from first population

Synchrotron Emission from second high energy population

SSC



First population

Second population

Two-population Interpretation

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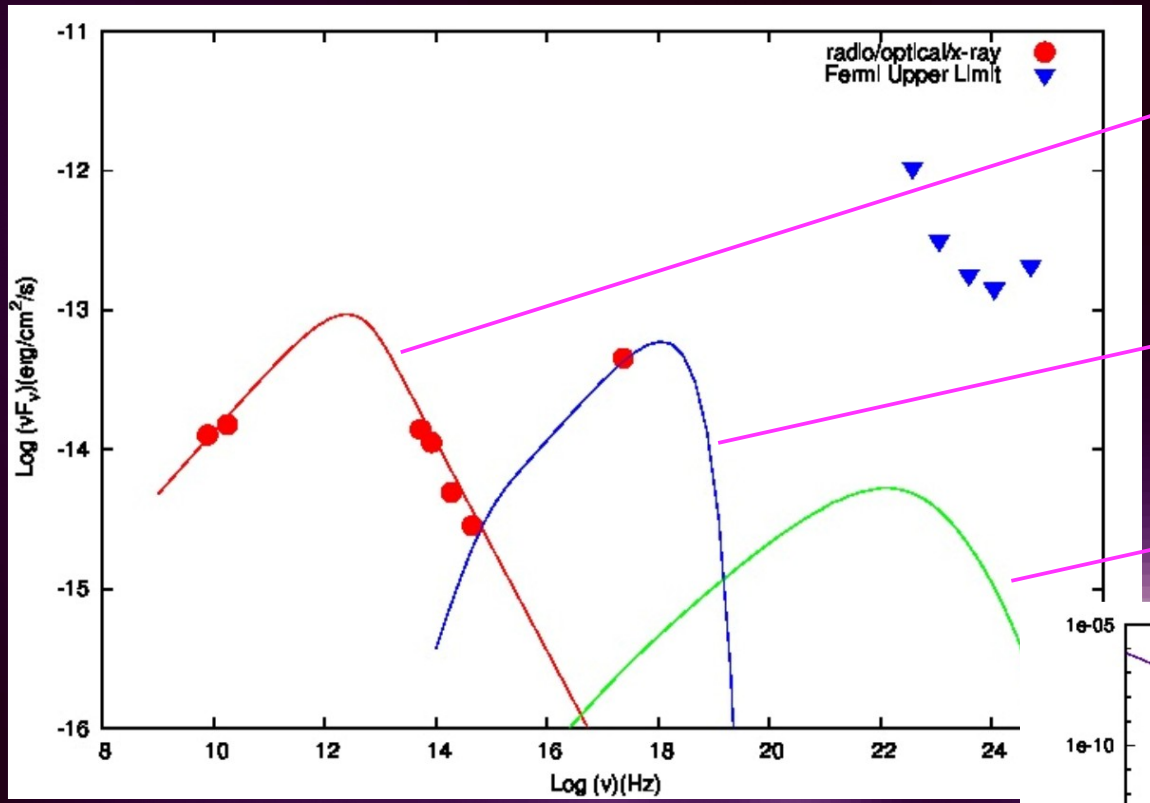
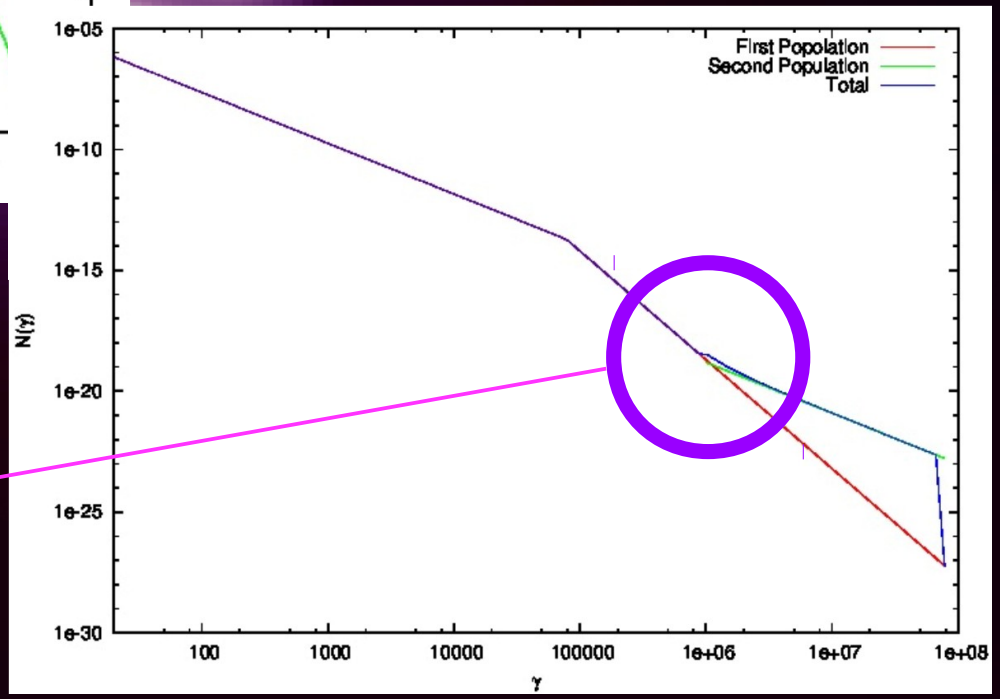


Synchrotron Emission from first population

Synchrotron Emission from second high energy population

SSC



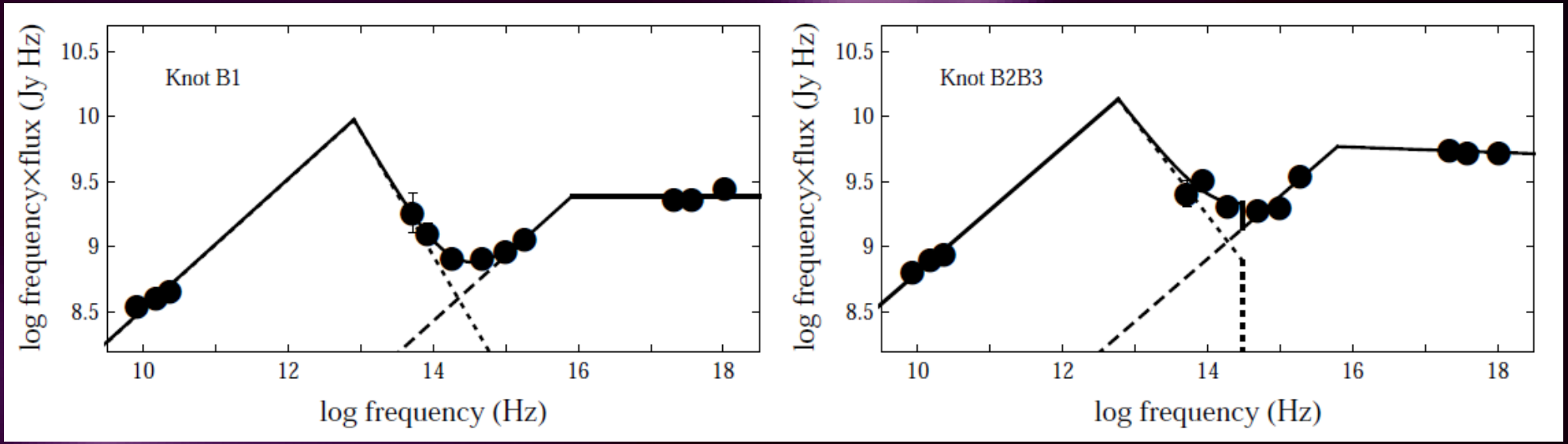
Concave Spectrum!!

(Unless regions are physically separated)

Two-population Interpretation

Shock Compression

- Downtream is compressed by shock
- Assymetric electron injection from the shock front
- Different electron population in downstream and upstream region

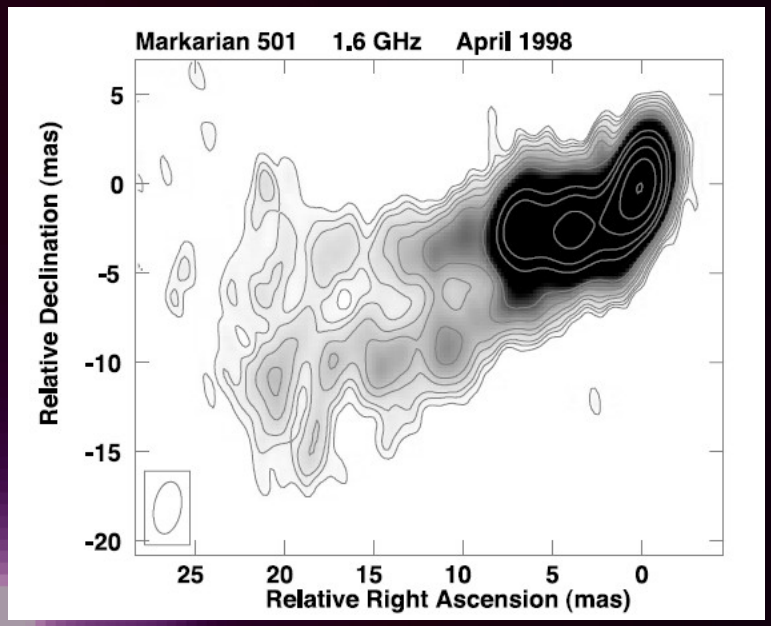


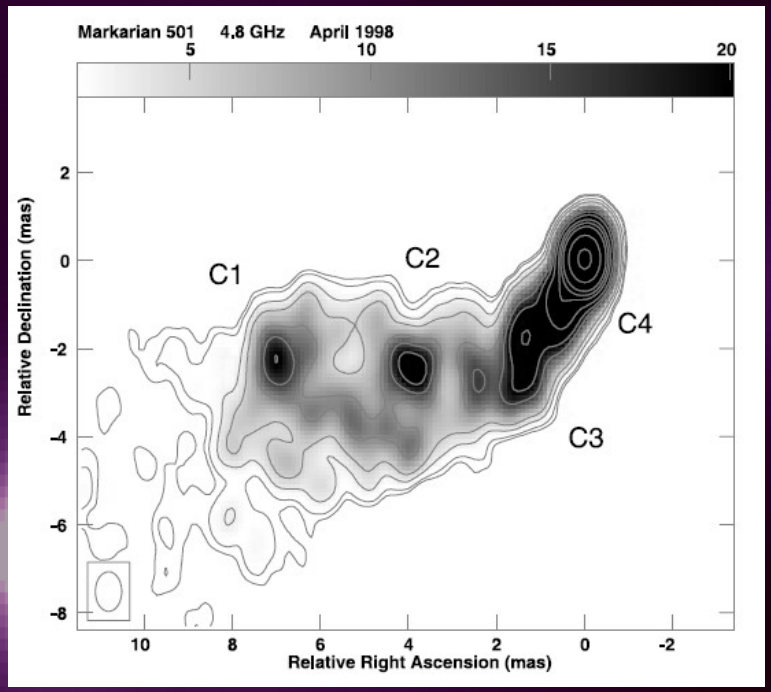
Liu, W. et al., *ApJ* (2015), **806**, 188

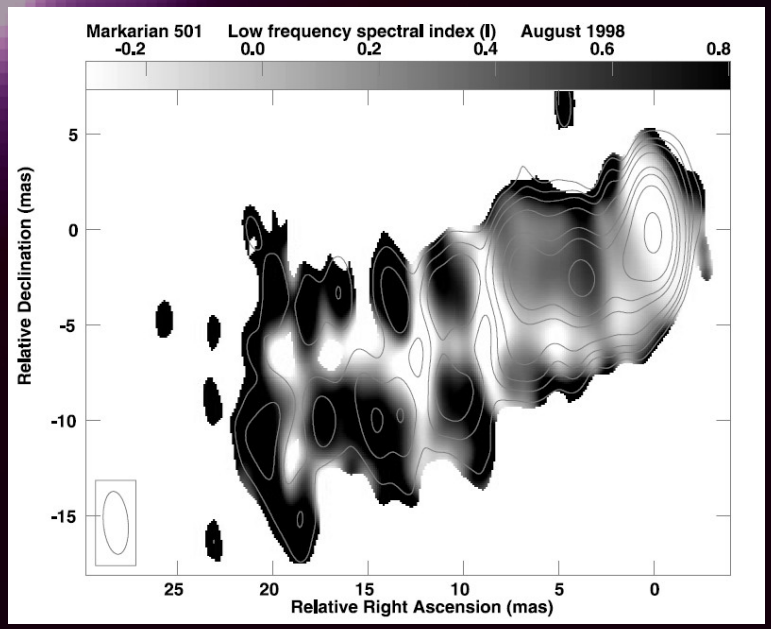
Two-population Interpretation

Shocked Jet with sheared boundary

- One accelerated at Sheared jet at boundaries*
- Another by a shock







Images from:
Giroletti, M., et al., *ApJ* (2004), **600**, 127

*Sahayanathan, S., *MNRAS Letters* (2009), **398**, 49

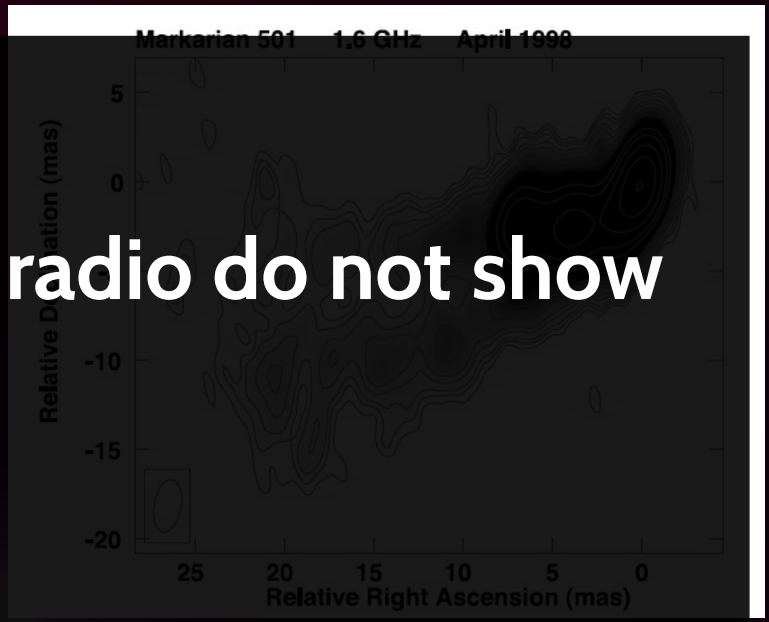
Sahayanathan, S., (2015) *under preparation*

Two-population Interpretation

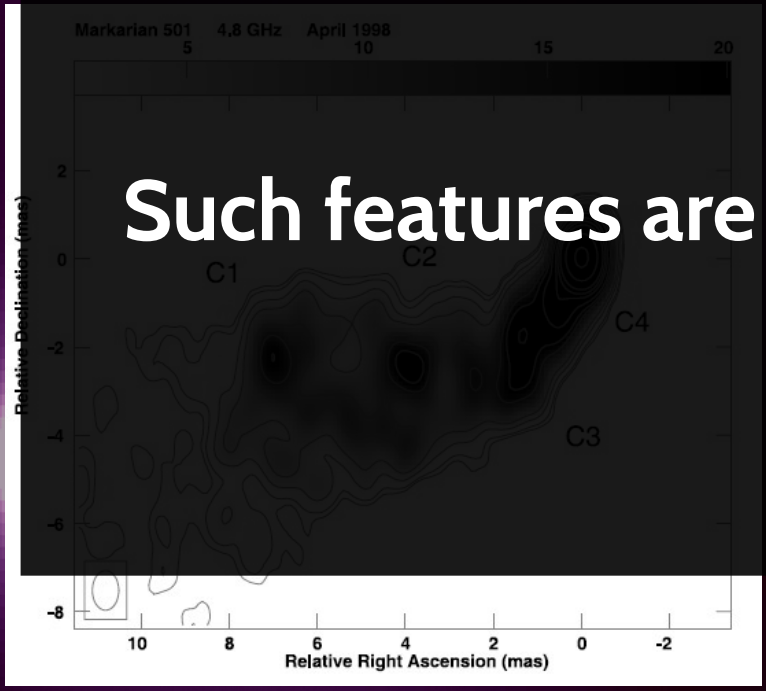
Shock with a sheared boundary

- One accelerated at Sheared jet at boundary*
- Another by a shock

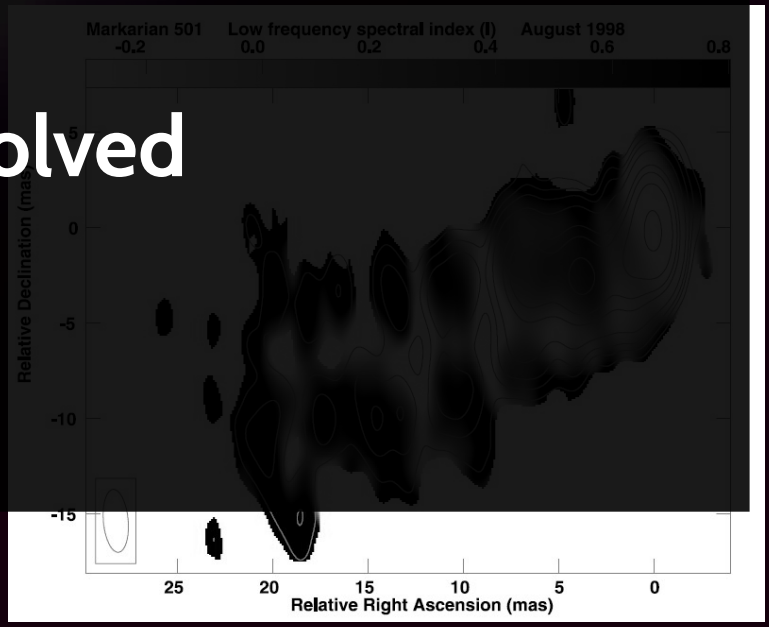
However X-ray knots in radio do not show such features



OR



Such features are unresolved



Single-population - EC Model

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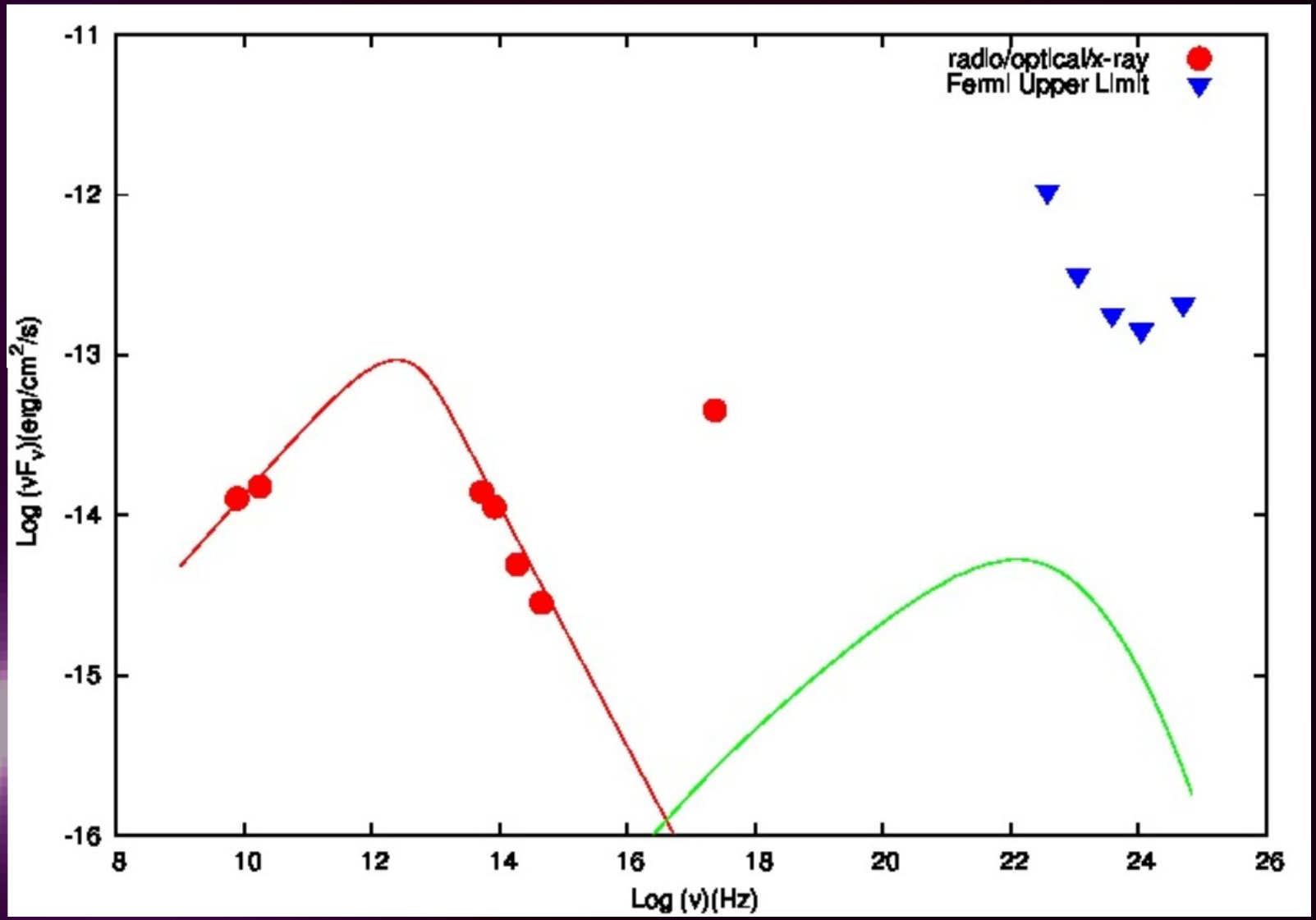

Sahayanathan, S., Ranjeev Misra, (2015) *under preparation*

Single-population - EC Model

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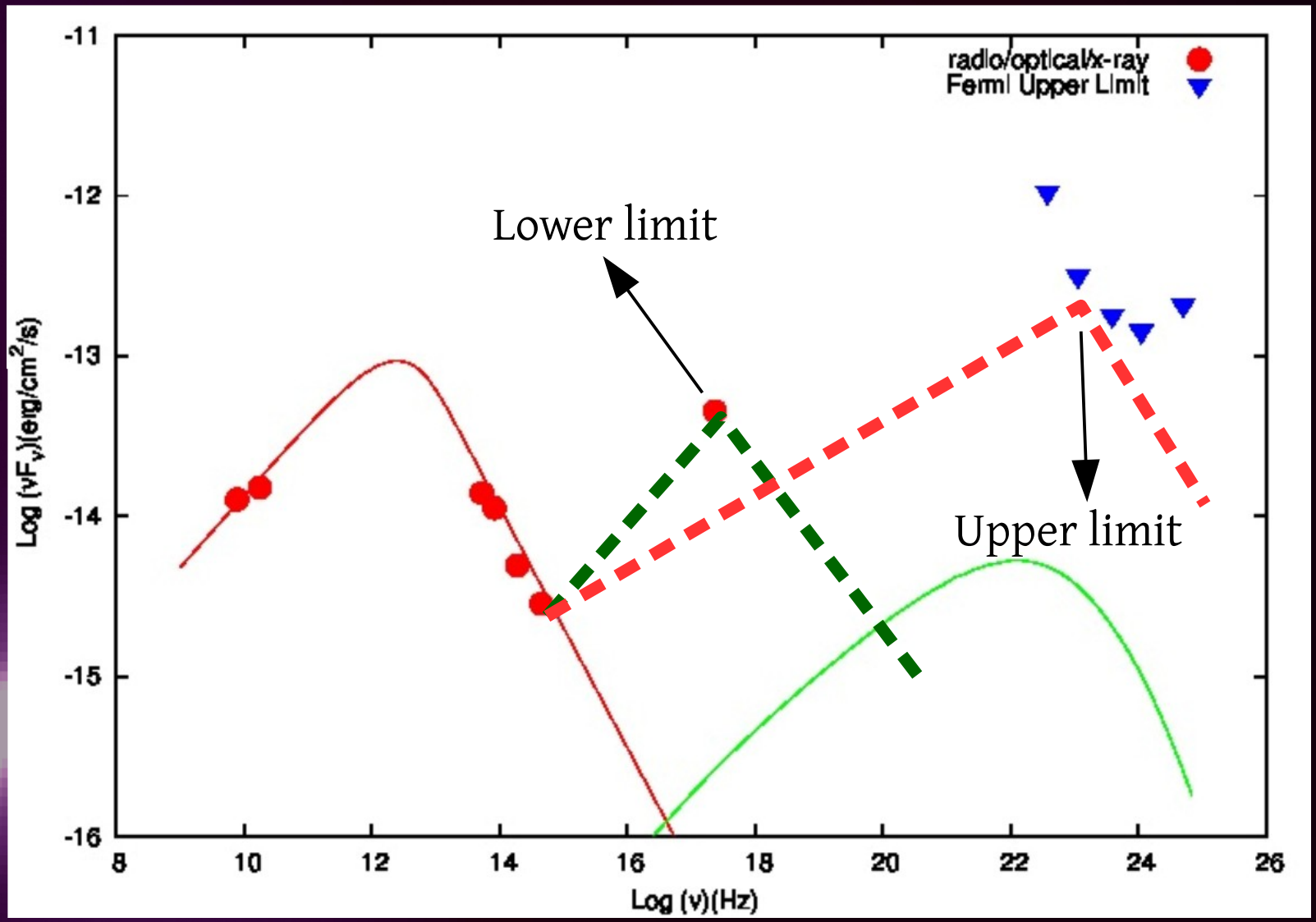
Allowed range of EC peak



Sahayanathan, S., Ranjeev Misra, (2015) *under preparation*

Single-population - EC Model

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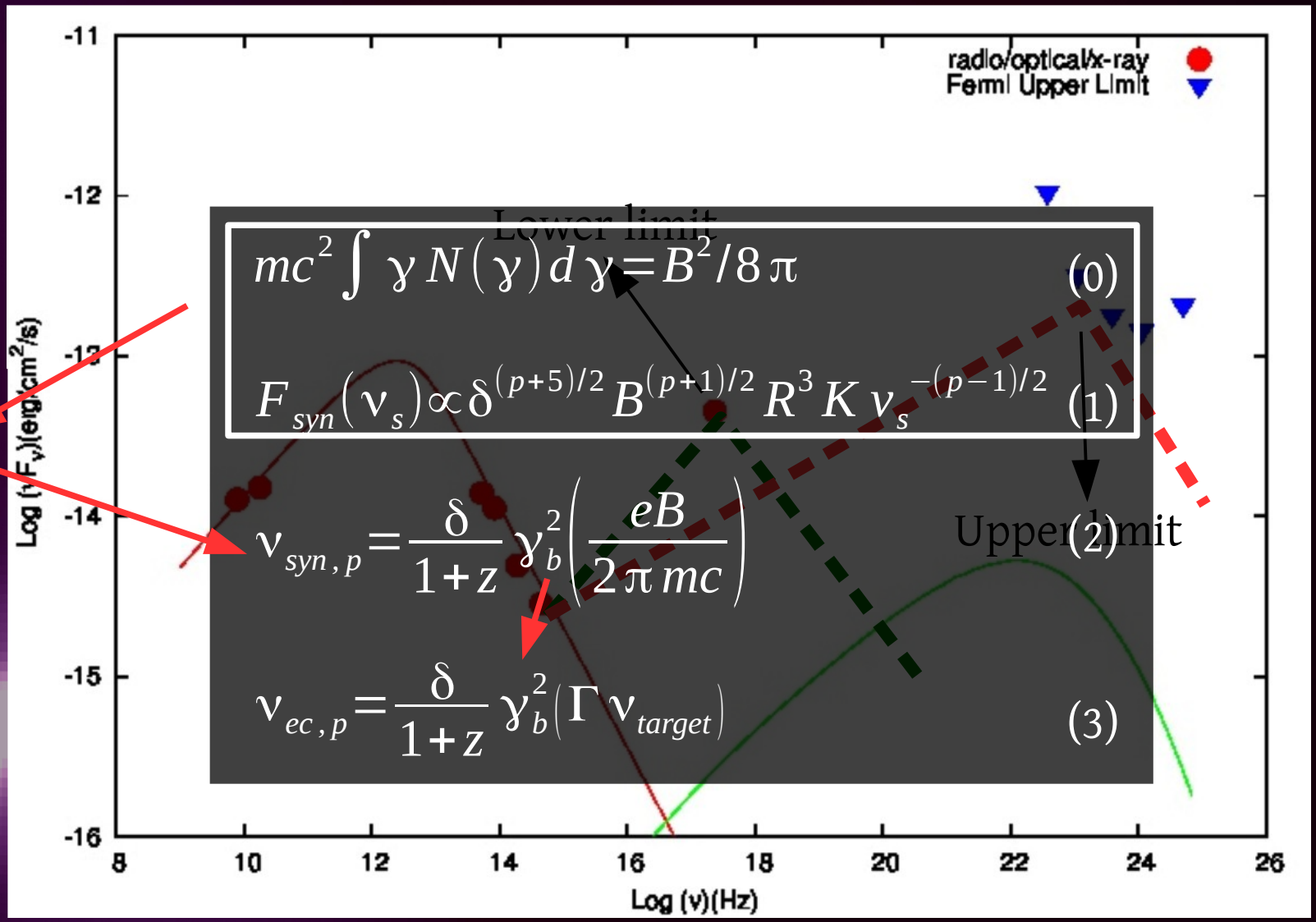
Allowed range of target photon frequency (Reverse Engineering)



$$mc^2 \int \gamma N(\gamma) d\gamma = B^2/8\pi \quad (0)$$

$$F_{syn}(\nu_s) \propto \delta^{(p+5)/2} B^{(p+1)/2} R^3 K \nu_s^{-(p-1)/2} \quad (1)$$

$$\nu_{syn,p} = \frac{\delta}{1+z} \gamma_b^2 \left(\frac{eB}{2\pi mc} \right) \quad (2)$$

$$\nu_{ec,p} = \frac{\delta}{1+z} \gamma_b^2 (\Gamma \nu_{target}) \quad (3)$$

δ - B

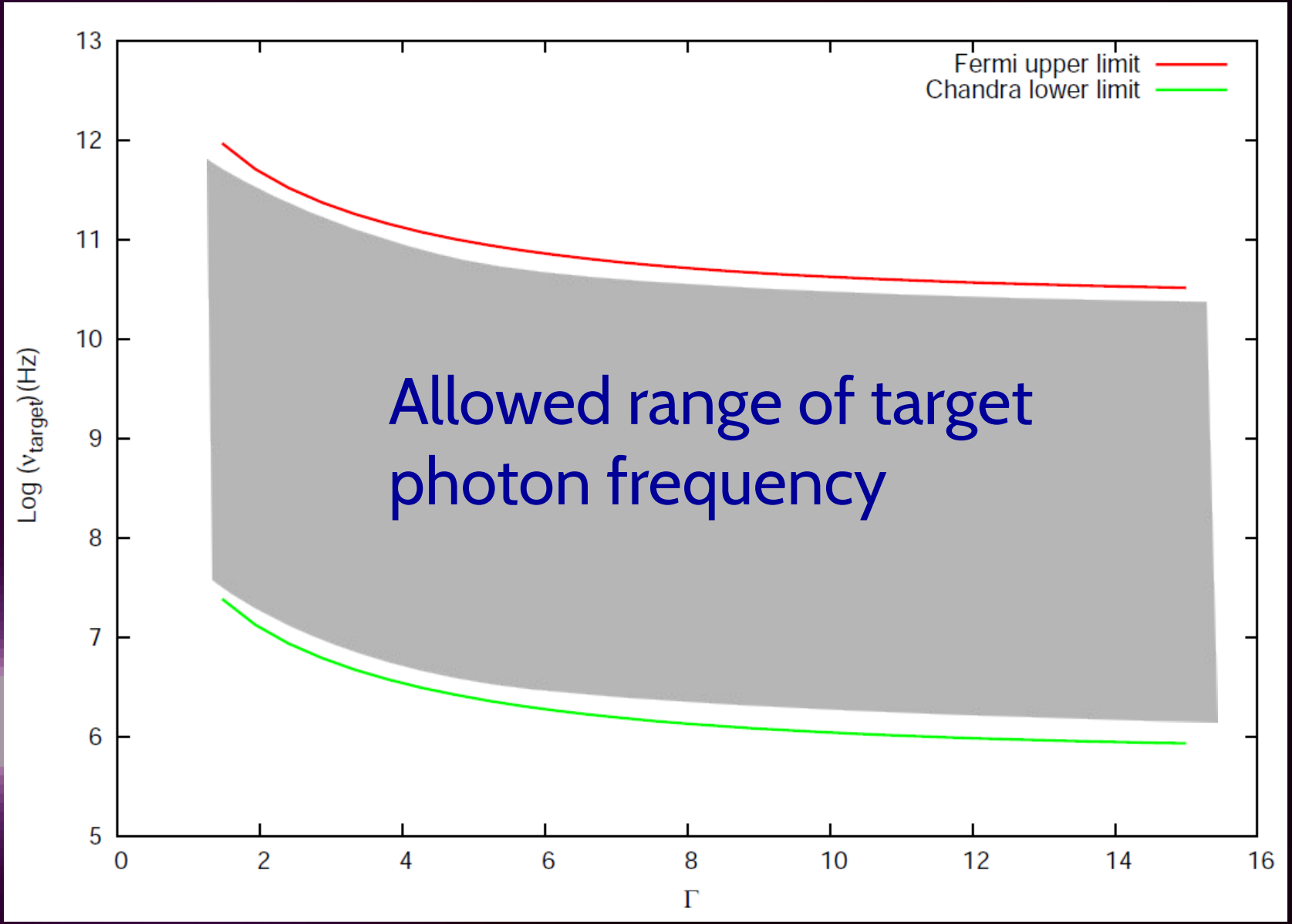
R – Knot size

Sahayanathan, S., Ranjeev Misra, (2015) *under preparation*

Single-population - EC Model

PKS 0637-752

Allowed range of target photon frequency (Reverse Engineering)



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Single-population - EC Model

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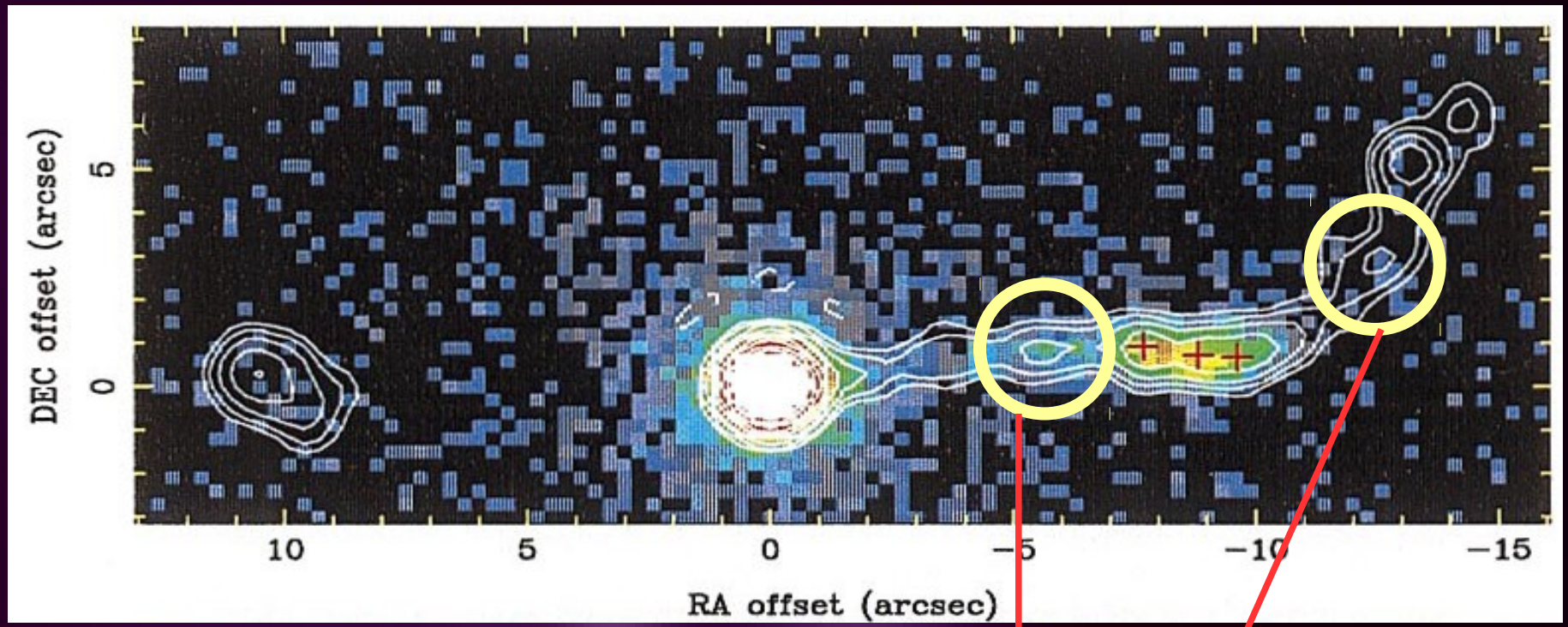

Radio Pockets

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Single-population - EC Model

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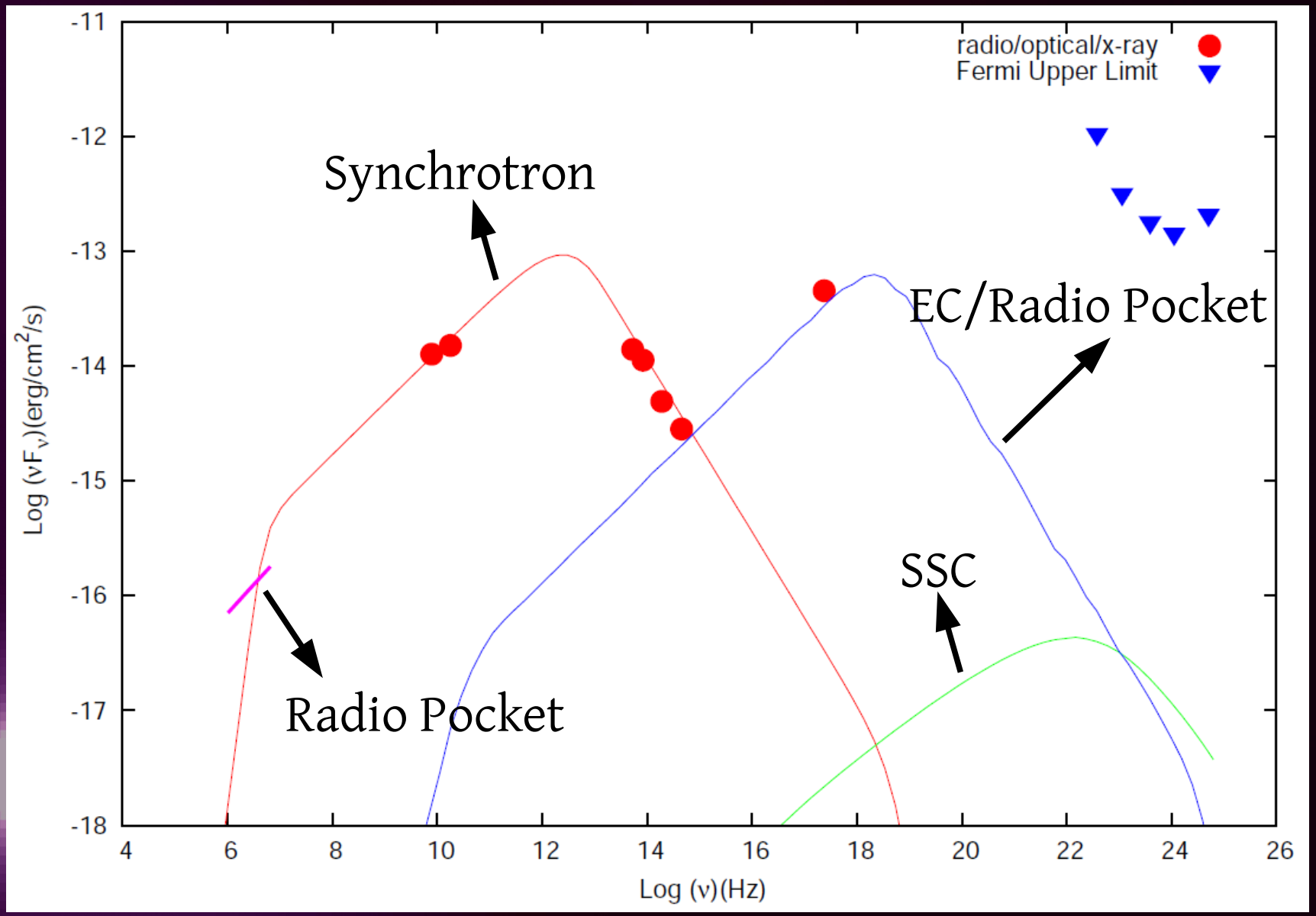

Sahayanathan, S., Ranjeev Misra, (2015) *under preparation*

Thank You!!


IF PEOPLE SAT OUTSIDE AND LOOKED AT THE STARS EACH NIGHT
I BET THEY WOULD LIVE A LOT DIFFERENTLY