Double notches: a zoom into the microphysics of coherent radio emission from pulsars

Great progress in understanding of the 'W'

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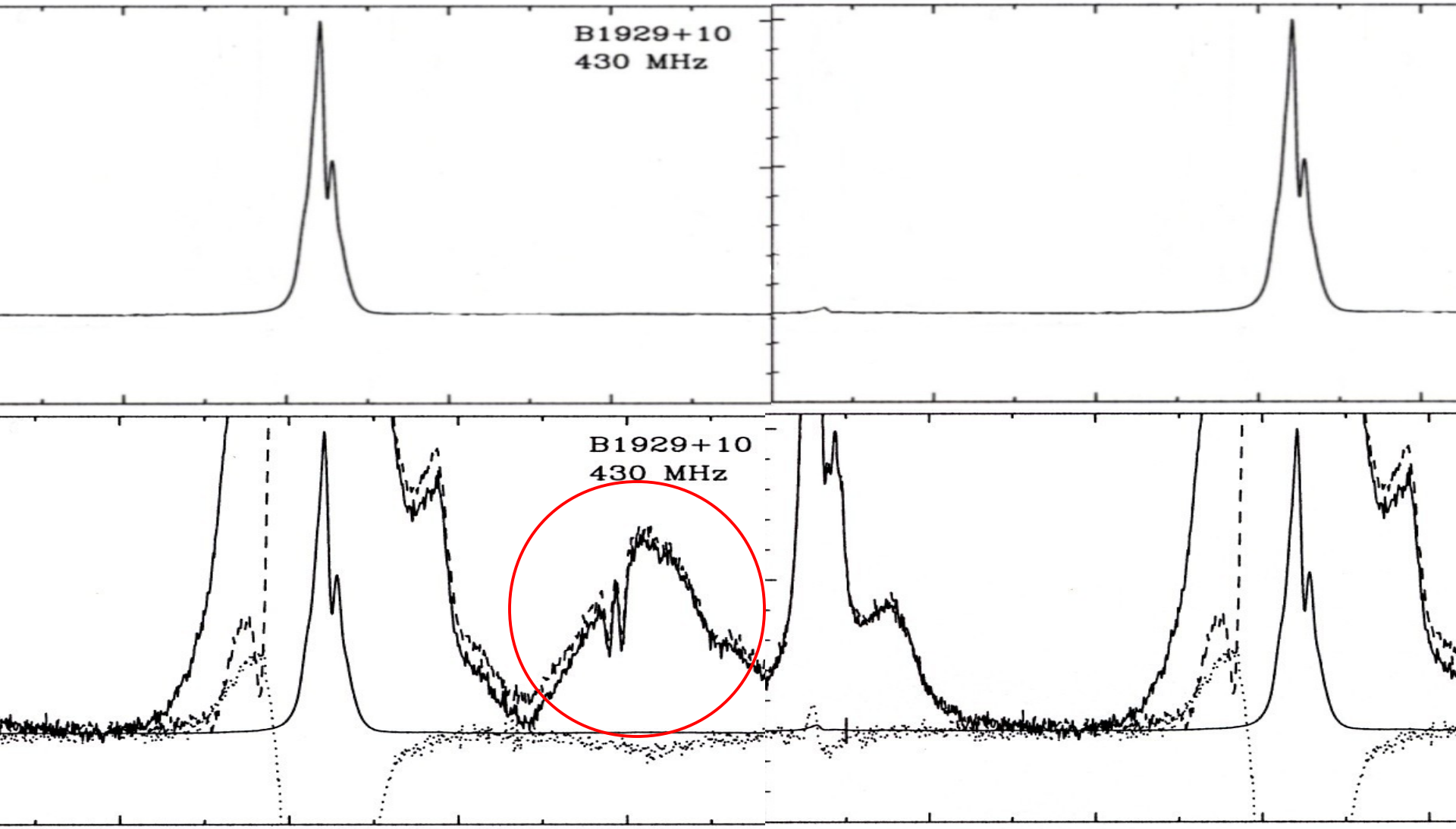
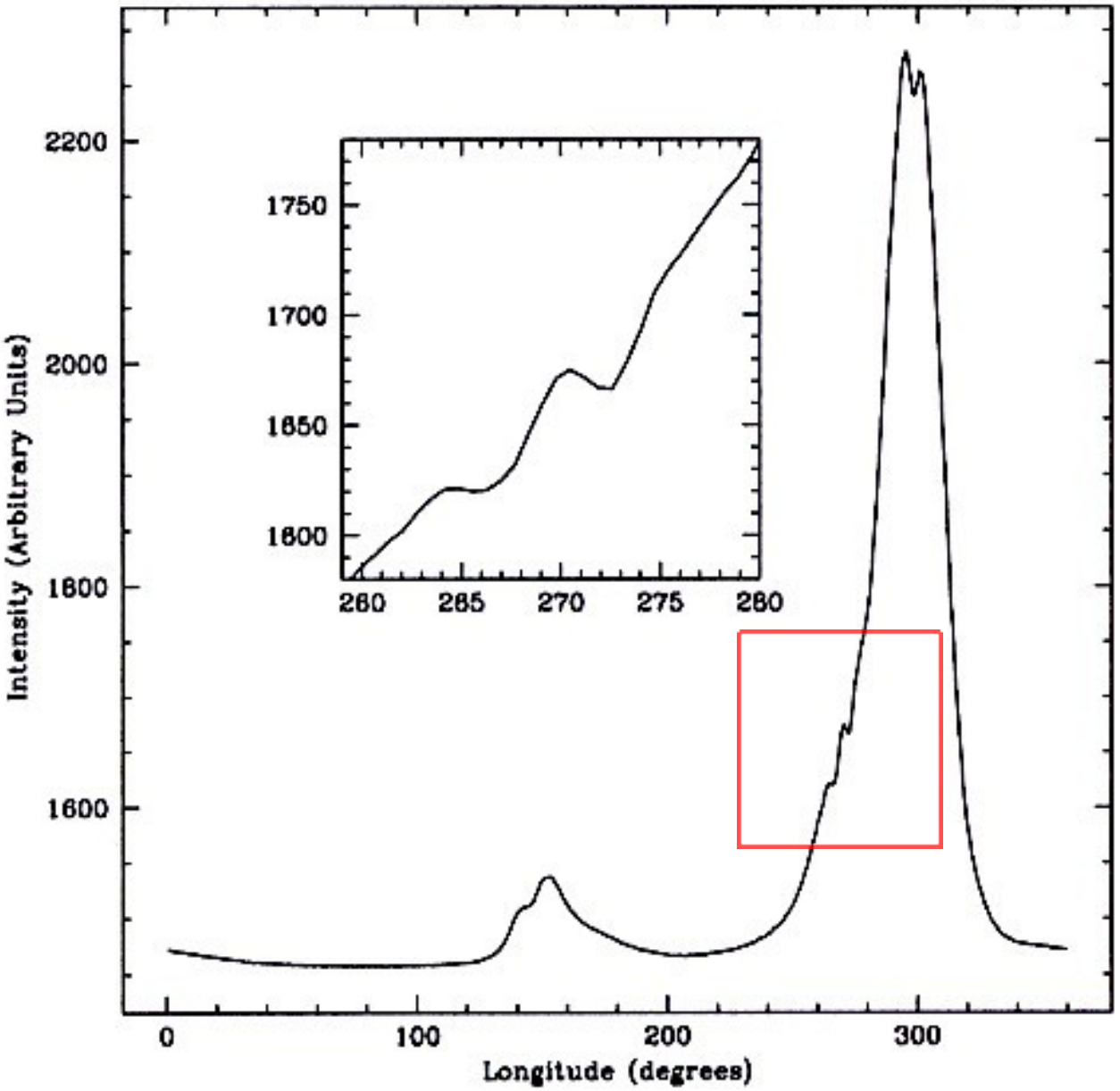
Double notches (dwuwcięcia, wuwcięcia)

Rankin & Rathnasree 1997; Navarro et al. 1997; McLaughlin & Rankin 2004



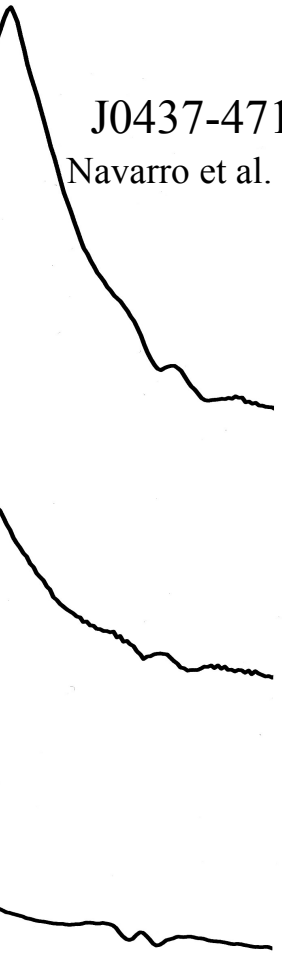
Detectable only in a handful of pulsars

B0950+08

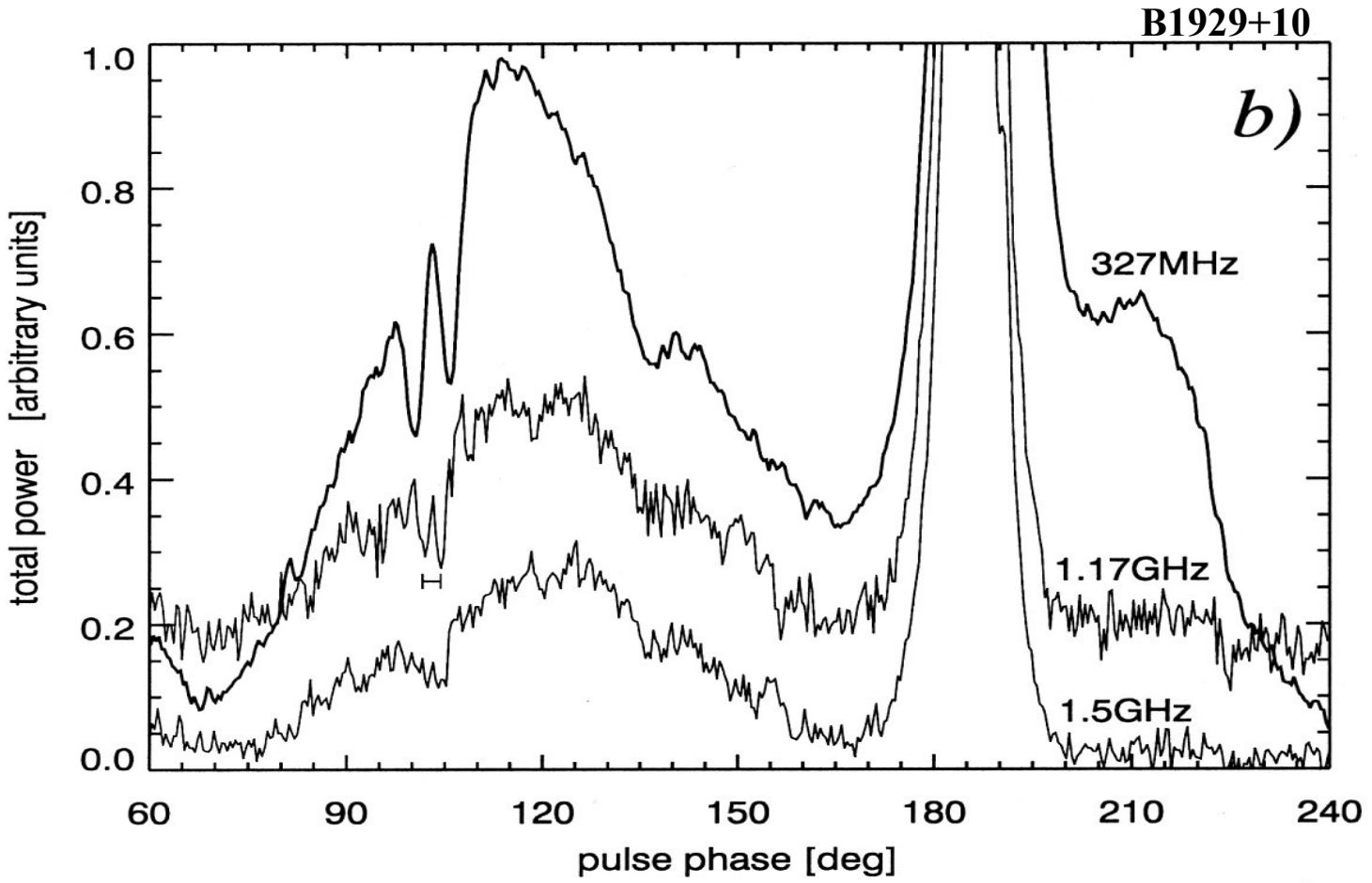

Intensity (Arbitrary Units)
2200
2000
1800
1600
0
100
200
300
Longitude (degrees)
1750
1700
1650
1600
260
265
270
275
280

SELECTED PROPERTIES

The notches approach each other at increasing frequency
Always keep the 'W' SHAPE with **W = Δ** and **depth of ~40%**
Only observed in highly polarised emission (Π~100%, 70%)



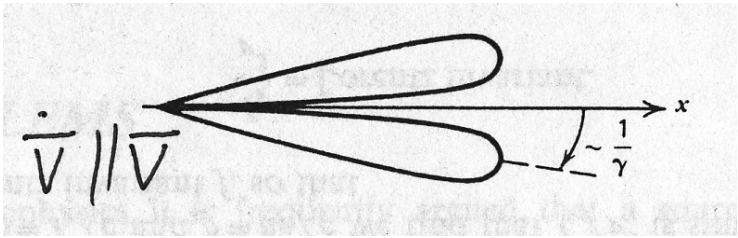
J0437-4715
Navarro et al. 1997



Dyks, Rudak & Rankin 2007

Microscopic physics is essential for double notches: they are **an imprint of elementary microbeam characteristic of a specific radiation process**

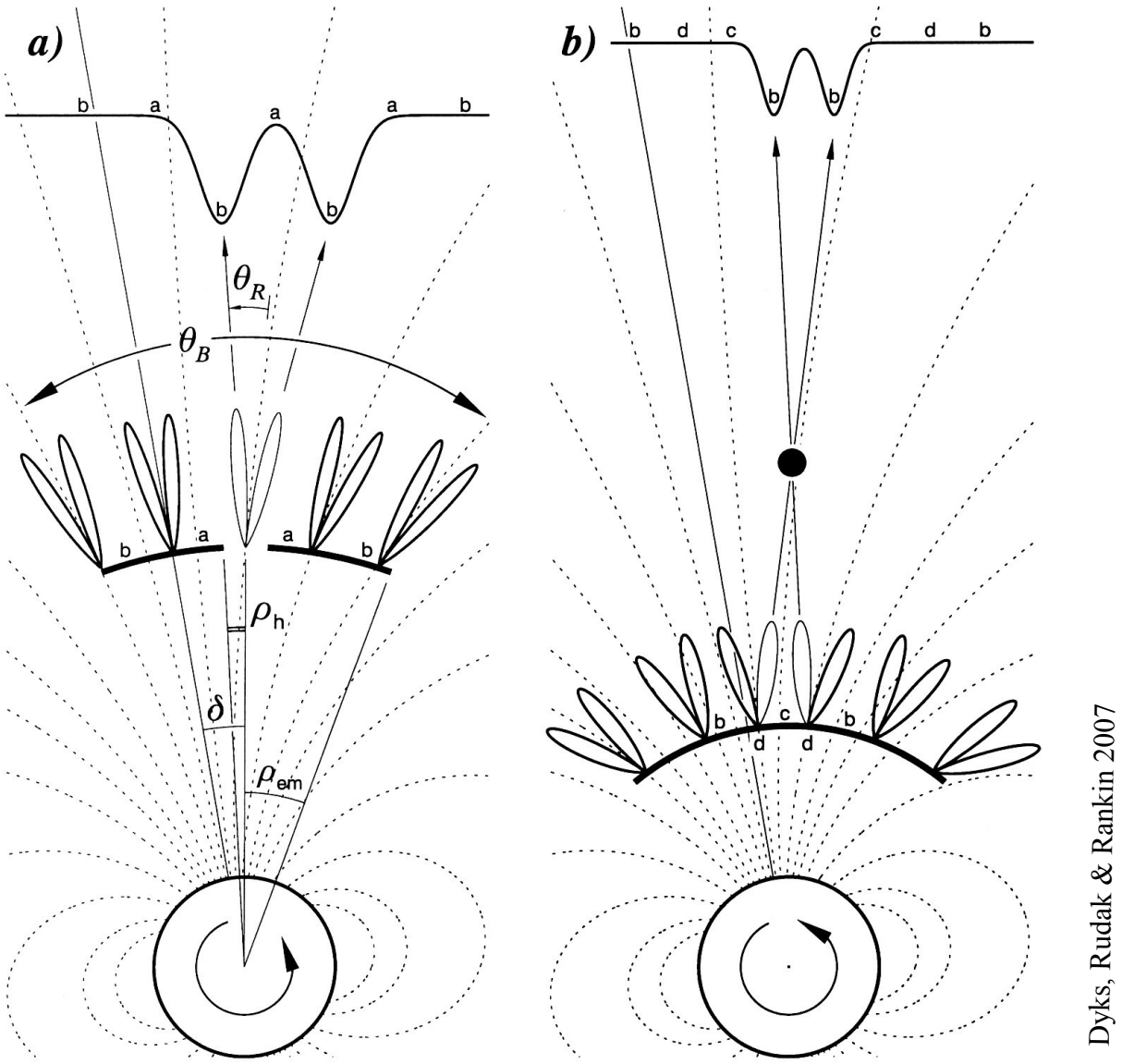
Initial (wrong!) idea: Acceleration parallel to velocity?



$\theta_R \simeq 0.447 \cdot \frac{1}{\gamma}$

e.g. Rybicki & Lightman 1975

General principle of the model (initial version):



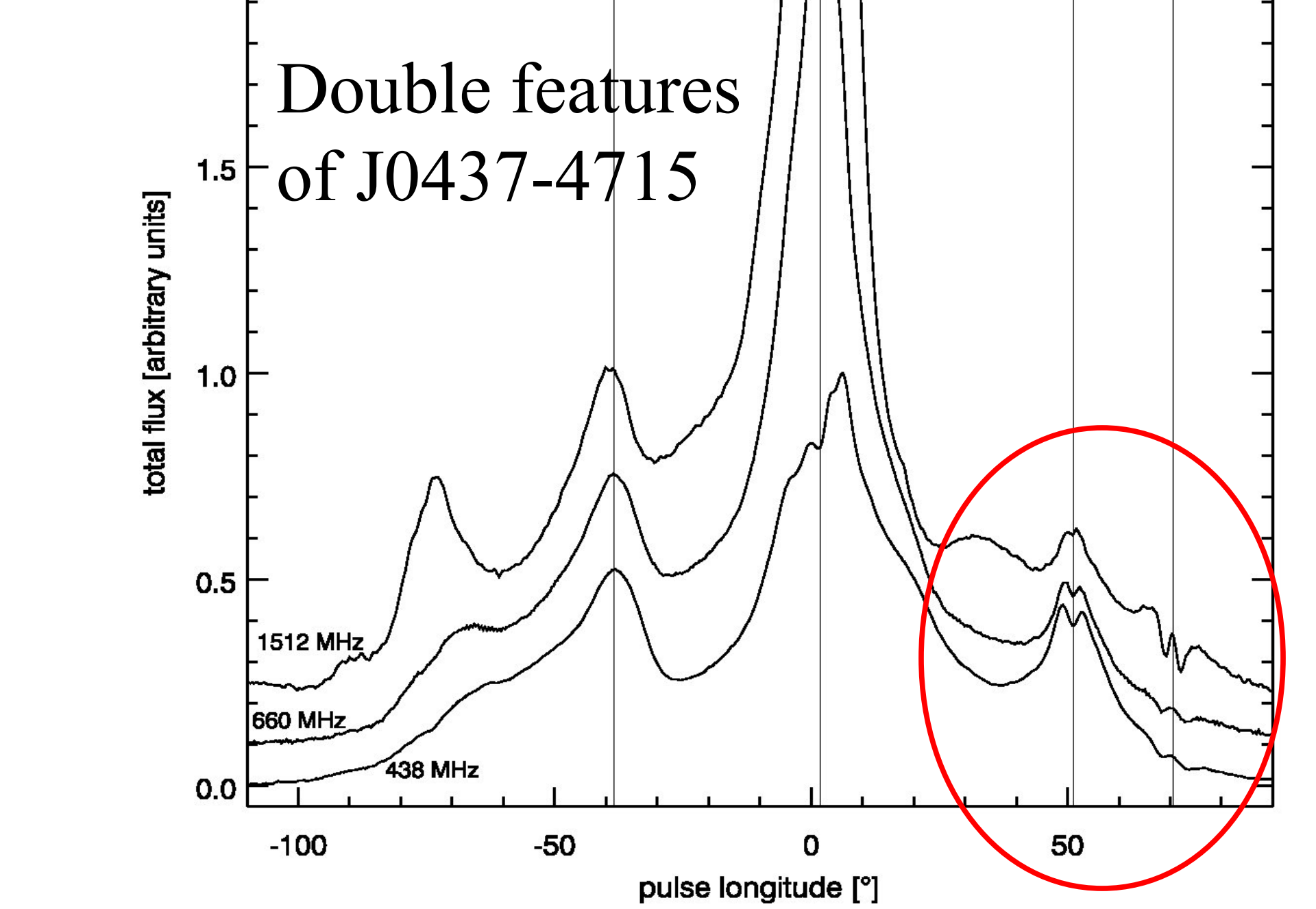
Dyks, Rudak & Rankin 2007

Powerful idea:

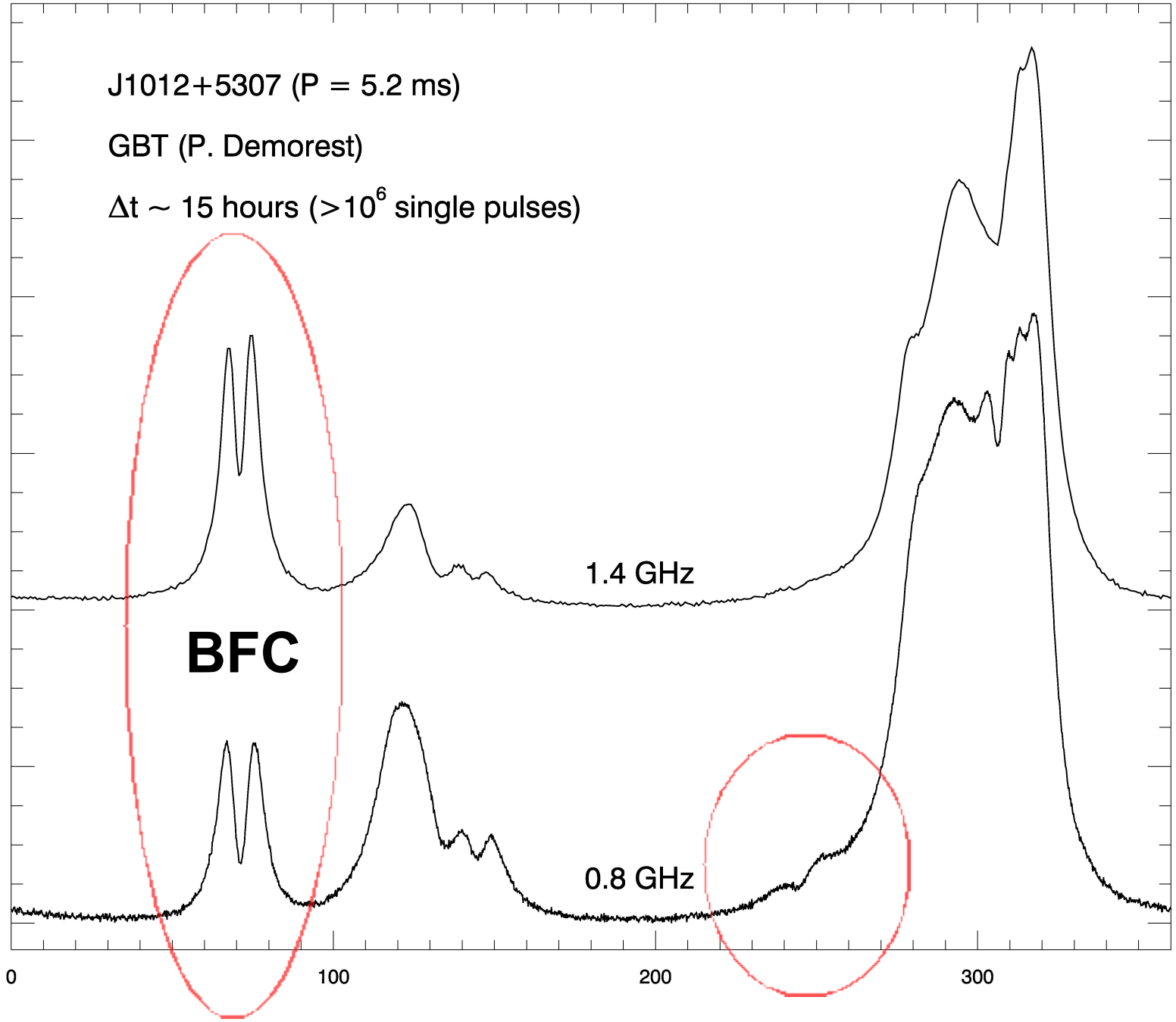
Explains **doubleness and symmetry**

The elementary microbeam becomes narrower at larger ν_{obs} for most emission mechanisms

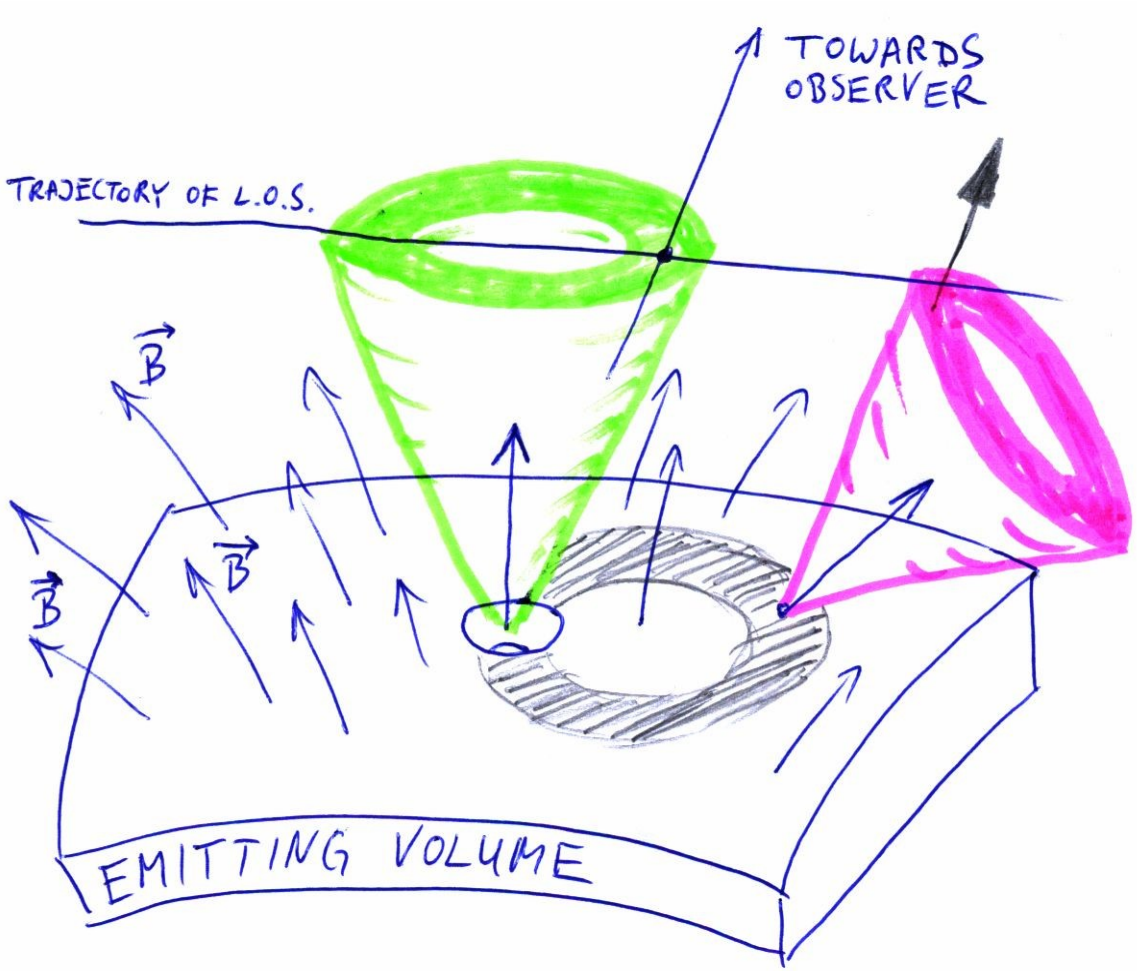
The microbeam is likely observable *in emission* (as a bifurcated emission component, or BFC)

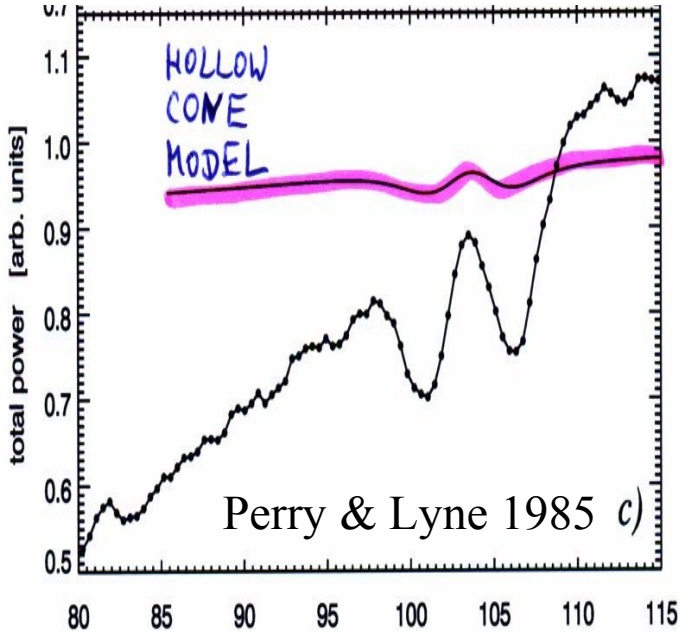


Navarro et al. 1997

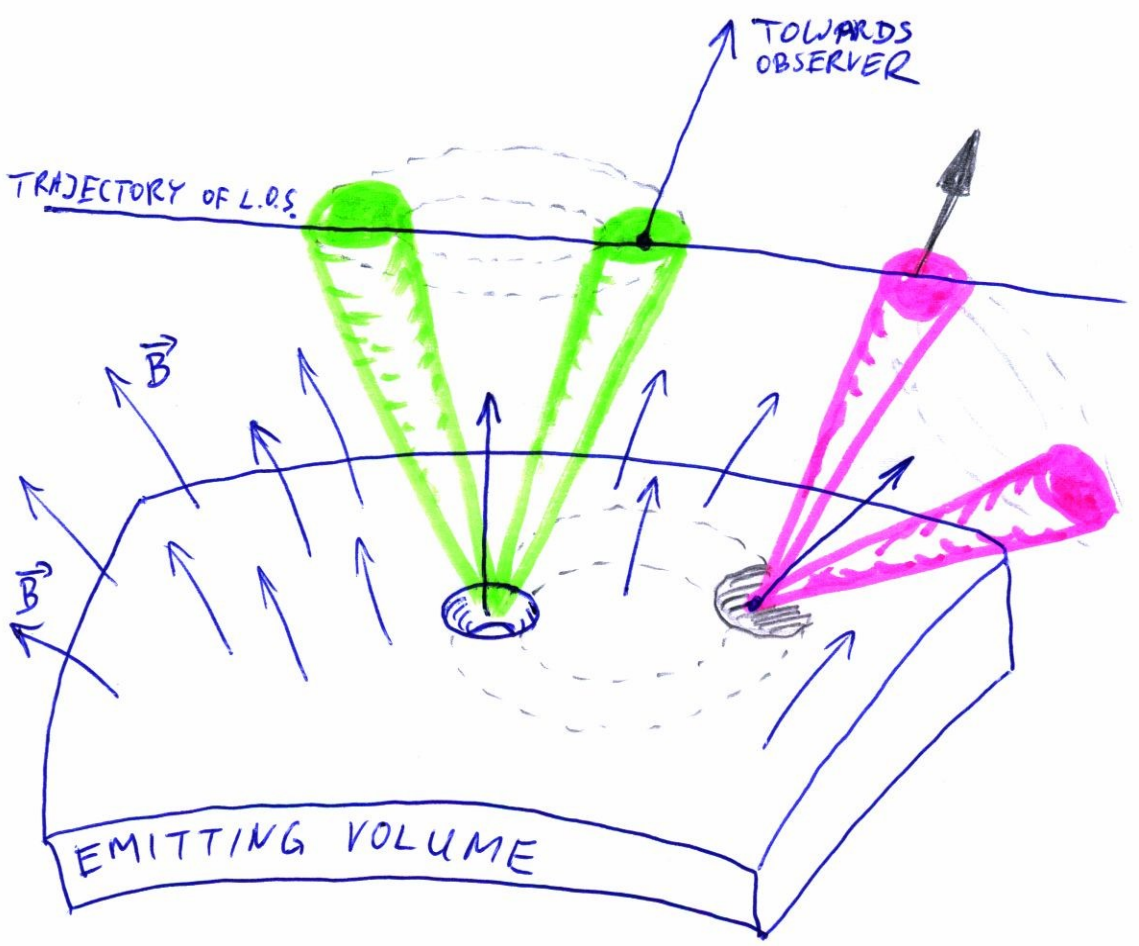

J1012+5307 (P = 5.2 ms)
GBT (P. Demorest)
Δt ~ 15 hours (>10^6 single pulses)
1.4 GHz
BFC
0.8 GHz
0
100
200
300

Hollow-cone beam does NOT work!
Spatial extent of the emitter makes the notches too shallow



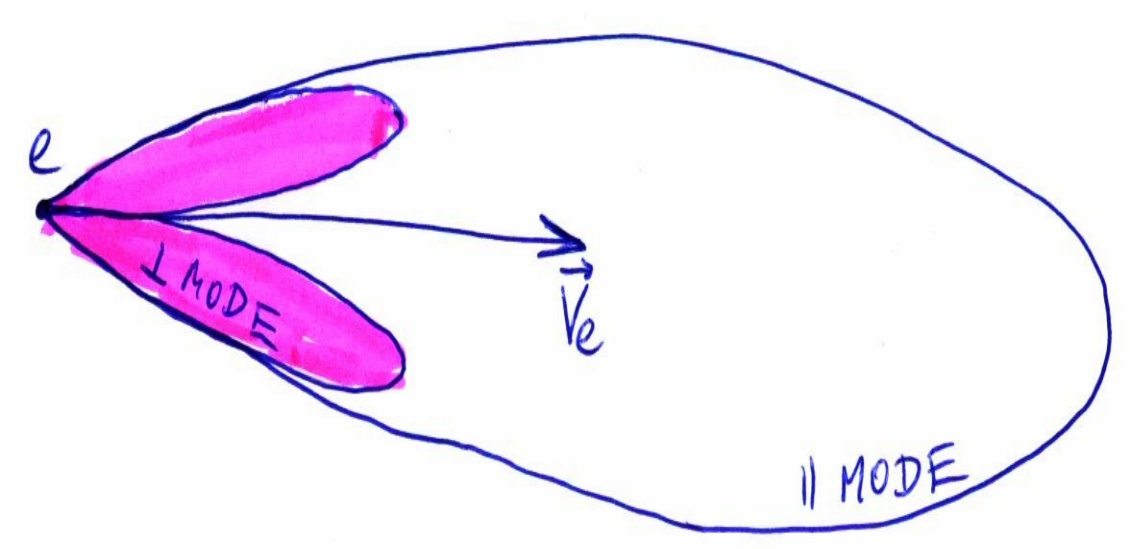


The beam that is needed:



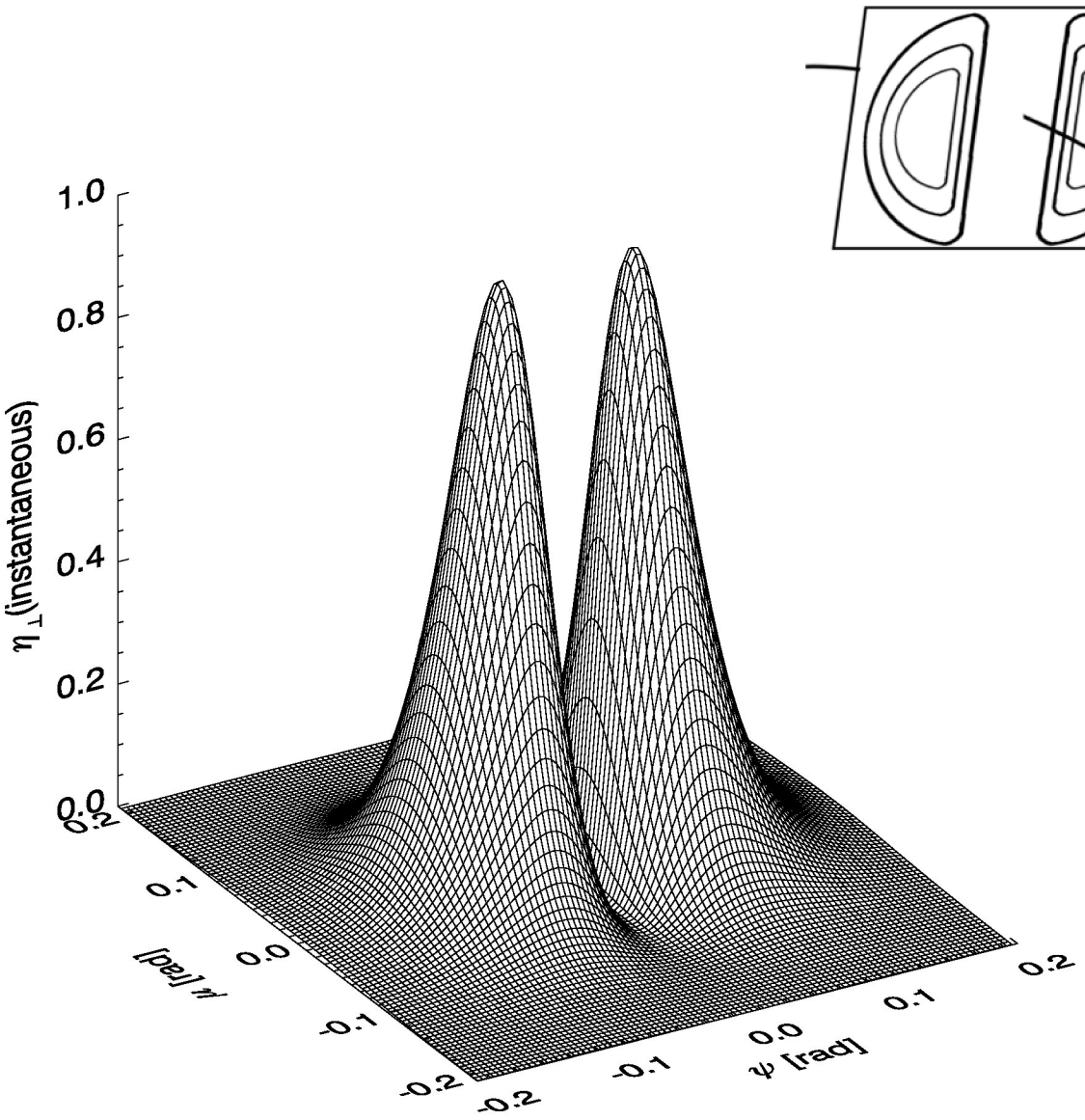
Dyks, Rudak & Rankin (2007)

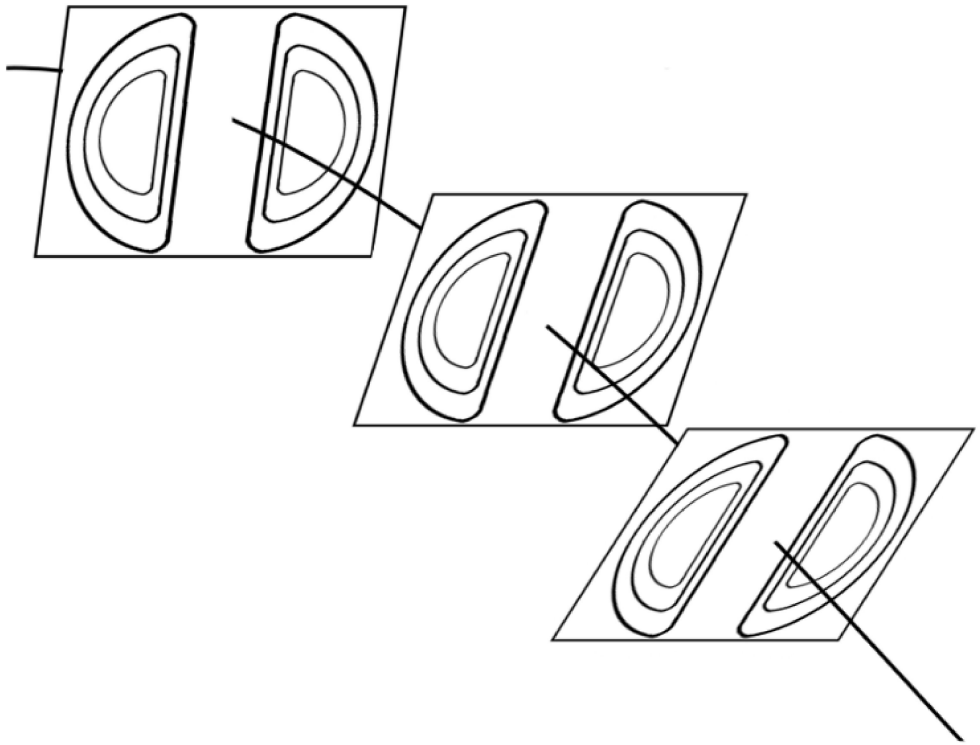
Curvature radiation in orthogonal polarisation state:



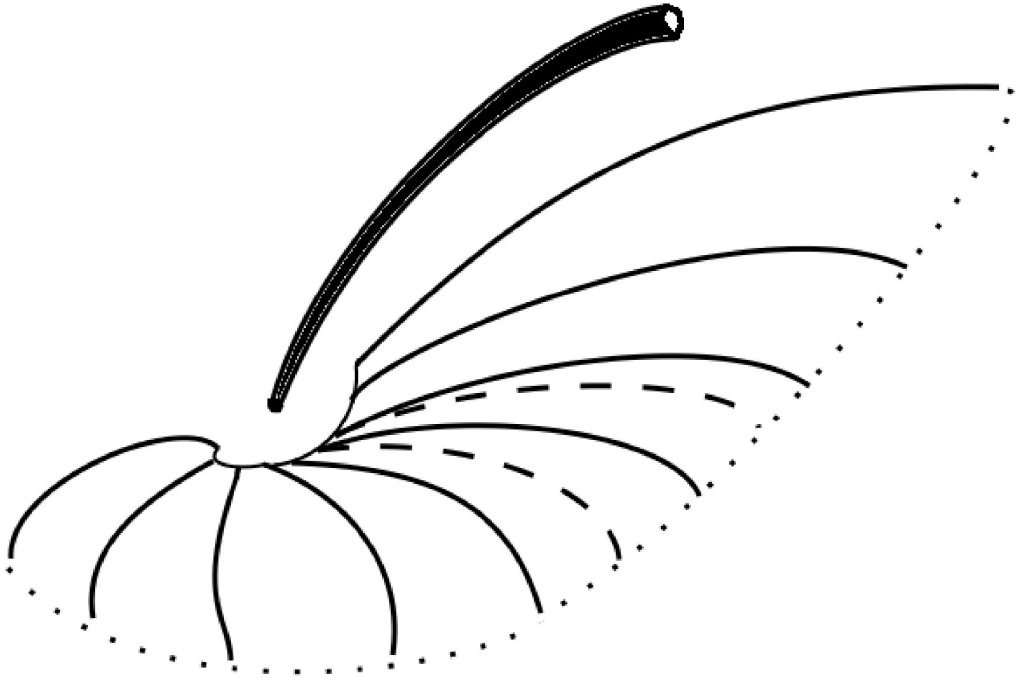
NOT axially symmetric!

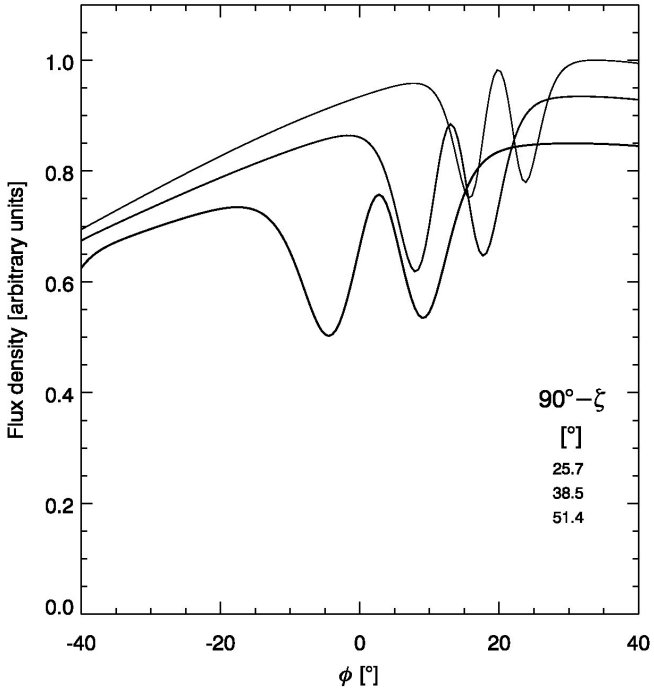
Split-fan shape of E-mode CR beam





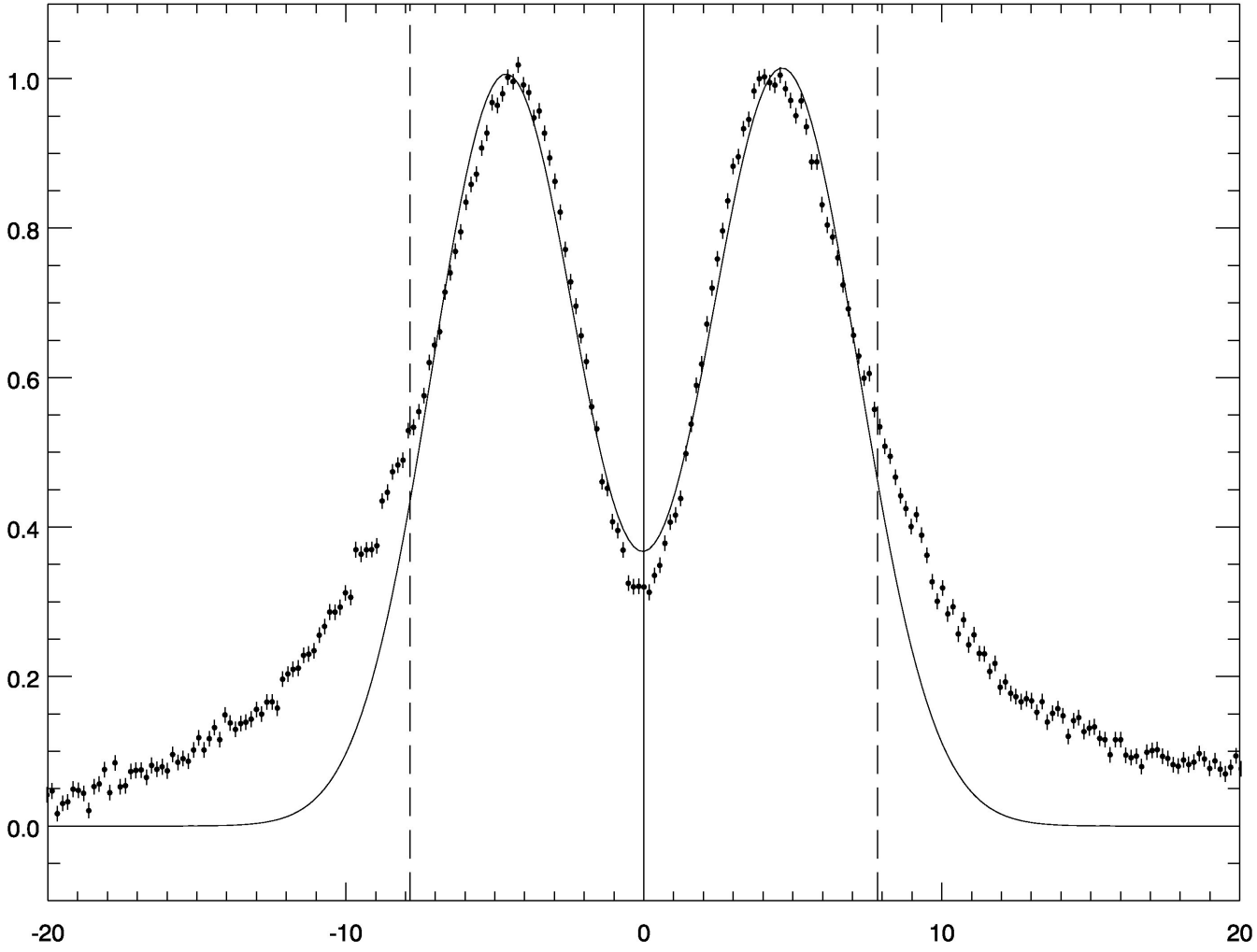
Reasonable eclipsers (opaque plasma streams) easily produce deep double notches





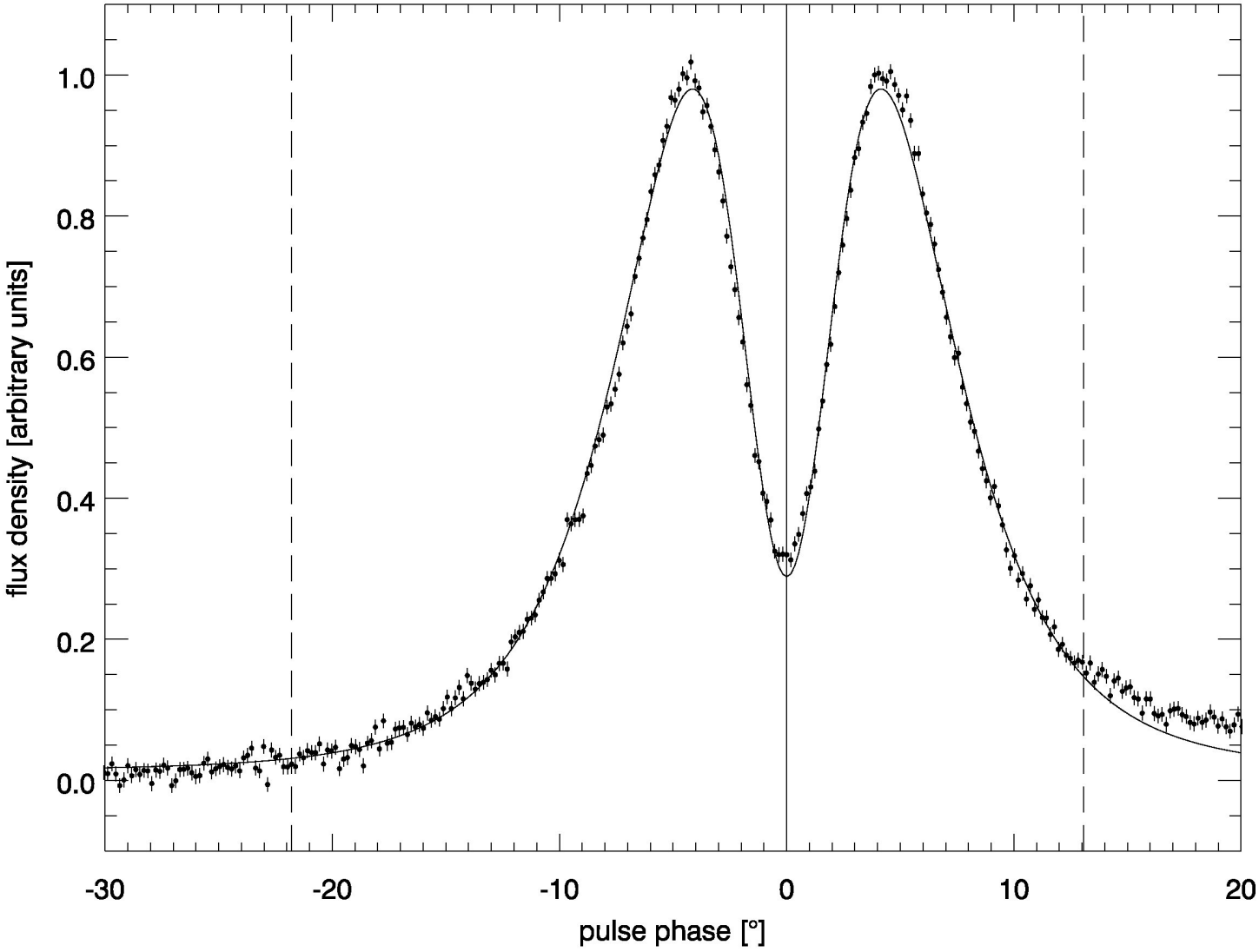
Dyks, Rudak & Demorest 2009

Traditional sum of gaussians does not work well…



The CR beam

(a single, physical curve has one order of magnitude better Chi^2)



⇒Collective plasma effects must amplify the non-coherent beam **isotropically** (kills several coherency models)

Width of BFC proportional to ν_{obs}^-1/3 (consistent with CR)

High polarisation degree consistent with unimodal emission

Conclusions

Notches and BFCs are **intrinsic to the emission mechanism**

Angular radiation patterns of classical electro-dynamics are directly observed in the sky

Many properties understood:
doubleness, symmetry, convergence rate, detailed shape of BFC, general eclipsing geometry,
large depth of notches (compact absorber not needed anymore).

The curvature radiation is the only natural emission mechanism consistent with the split-fan topology of the microbeam, and with the BFC's shape and convergence rate

Successful physical fits to a radio pulse component have been performed first time in history

=> important impact on the coherency models