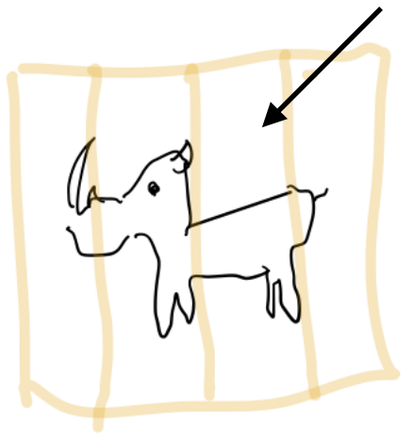
Plasma Lensing Birefringence: a Magnetic Zoo

Dongzi Li

2019. 3.19

Plasma Lensing Birefringence: a Magnetic Zoo



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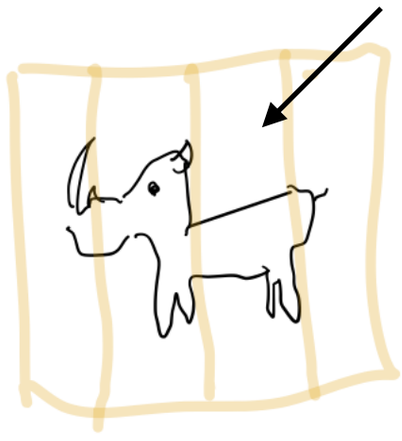
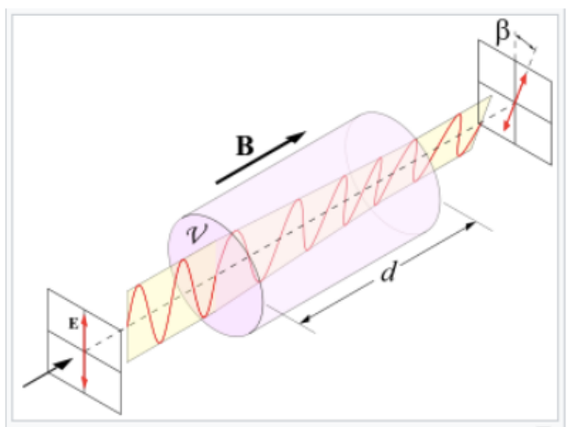


- **Faraday rotation: average B//**



Polarization rotation due to the Faraday effect

RM

- **plasma lensing: capture spatial structure of B//**

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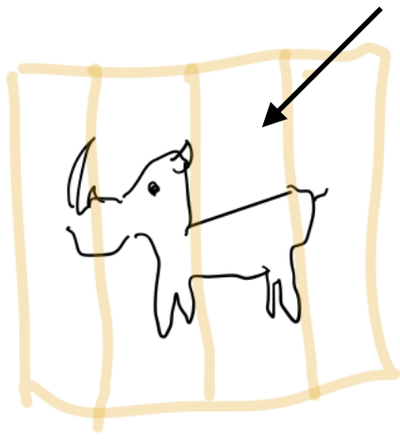

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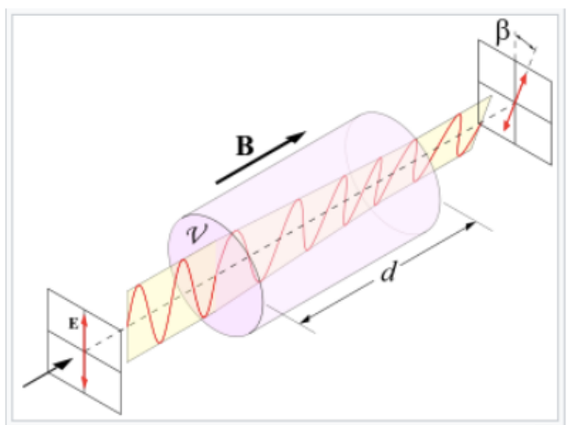

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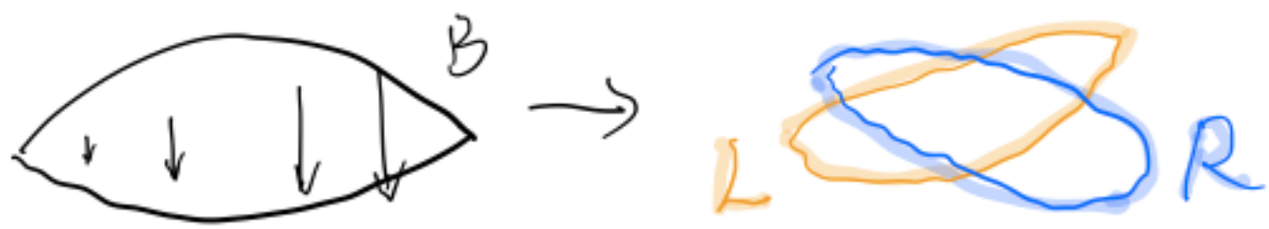

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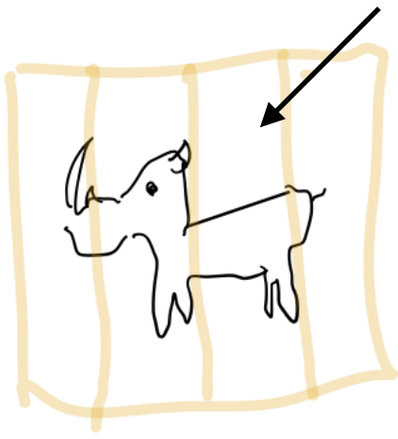

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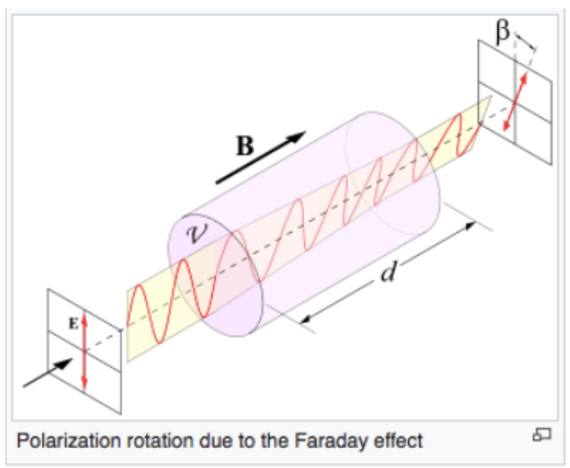

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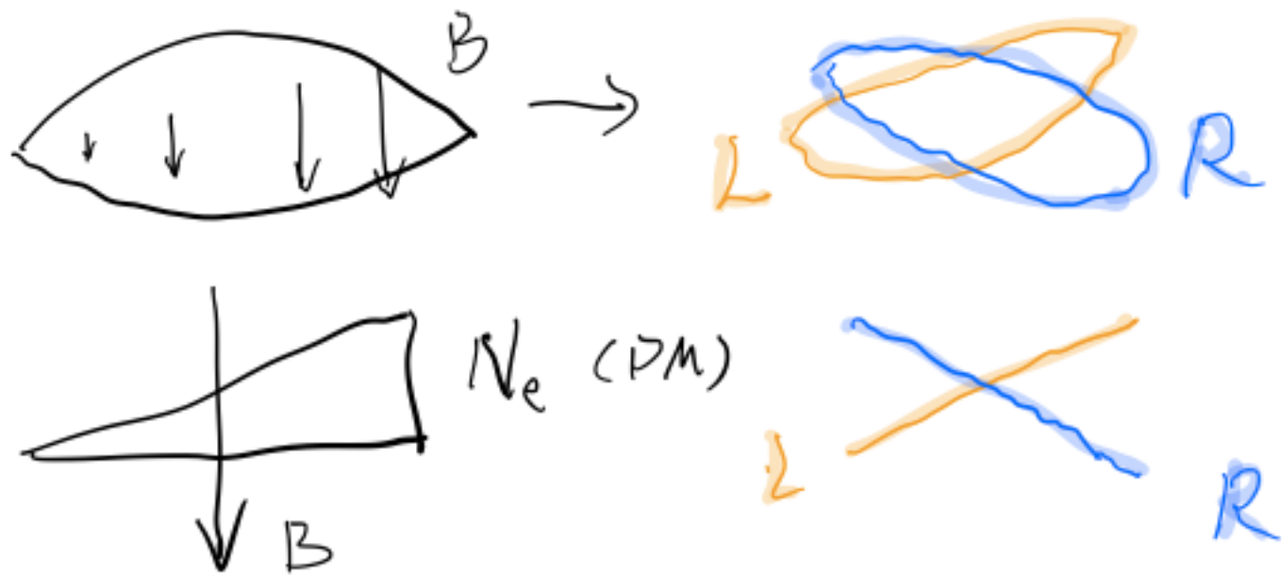

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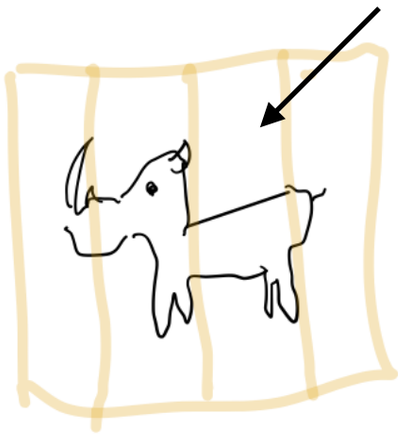

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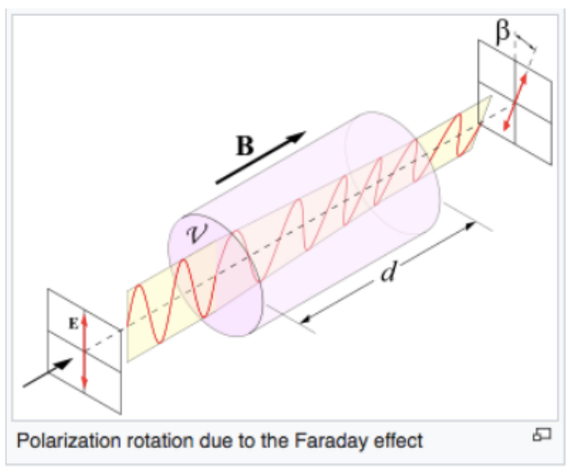

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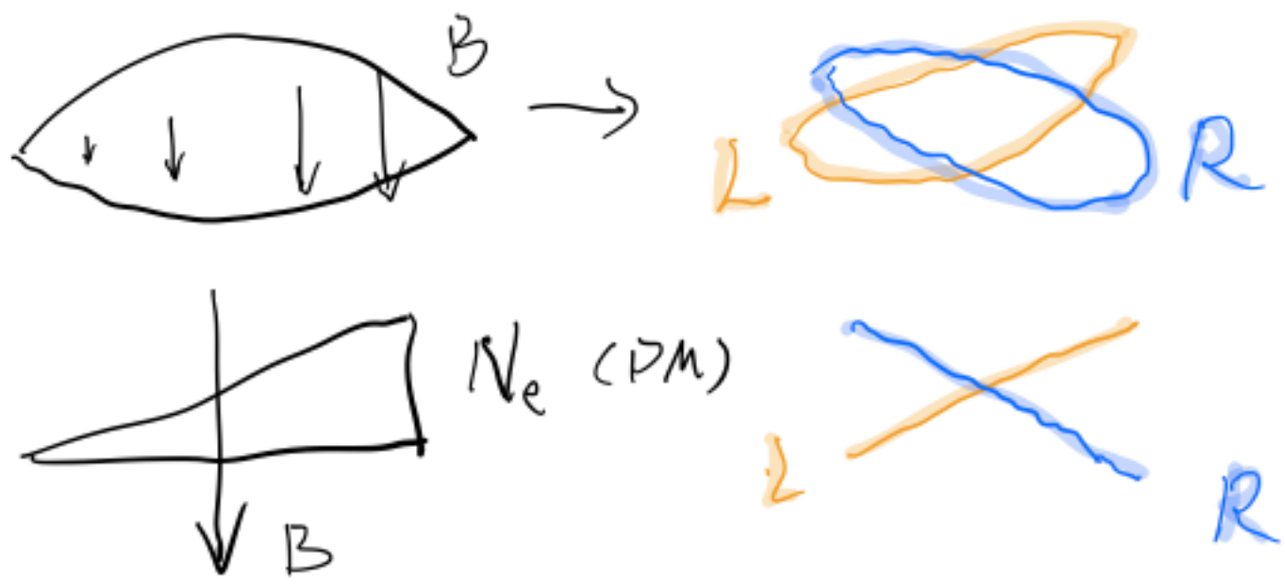


merits

probe magnetic environment *local* to the lens

eg.

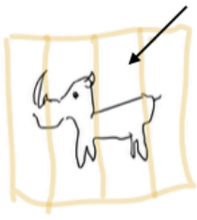
- nebulae magneto-environment: eg. Crab echoes

  (eg. Lyne et al 2001)

- FRBs: host galaxy B? (consider the extreme high RM in Michilli et al 2018)
- ISM: thin elongated lens —> magnetic structure?

  reconnection sheets (Pen & Levin 2014)? Helicity?

Plasma Lensing Birefringence:
a Magnetic Zoo



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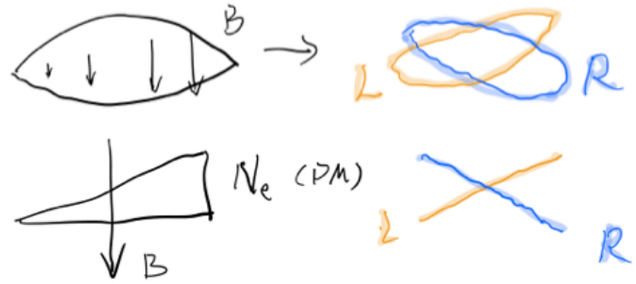

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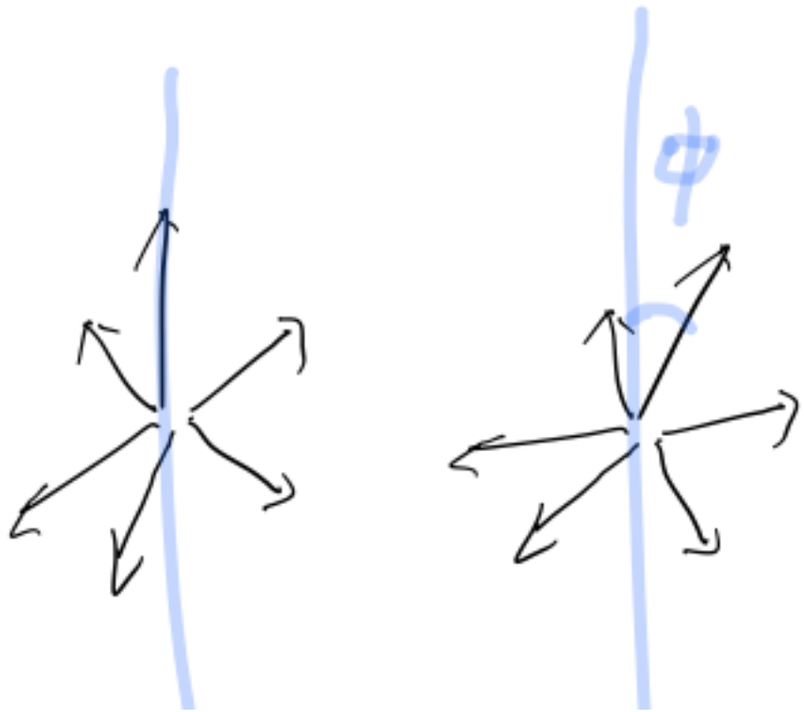
practical:

- no requirement for polarized sources



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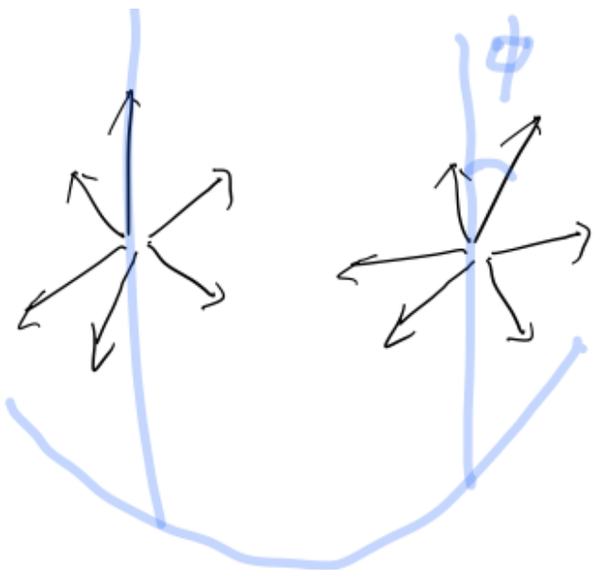

analogy to interferometry:
sensitive!

merits

probe magnetic environment
***local* to the lens**

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- nebulae magneto environment: eg. Crab echoes
- FRBs: host galaxy B?
- ISM: thin elongated lens —> magnetic structure?
  reconnection sheets? helicity?

practical:

- no requirement for polarized sources
- minimum observation time

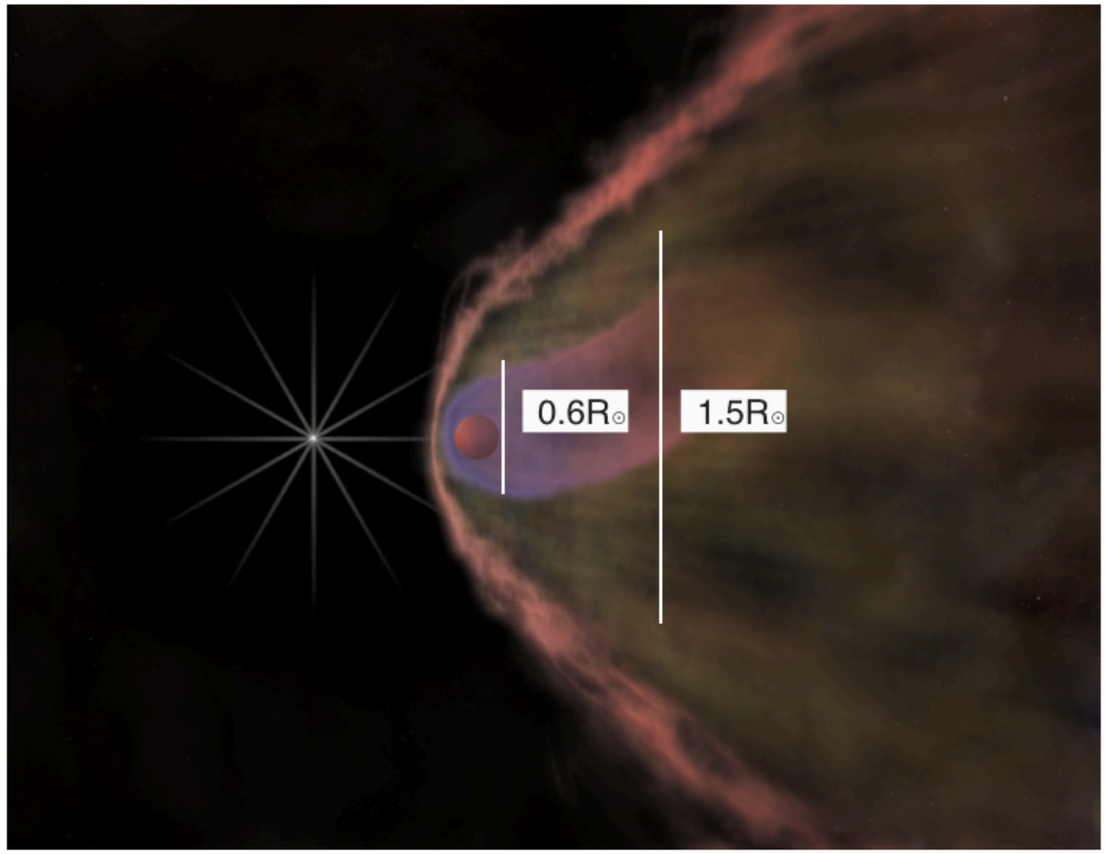
for example:

~20min, 48MHz bandwidth
Arecibo, ~300MHz
uncalibrated data

what can you do?

Li et al 2019 MNRAS 484.5723

Black widow pulsar B1957+20



Credit: NASA/CXC/M.Weiss.

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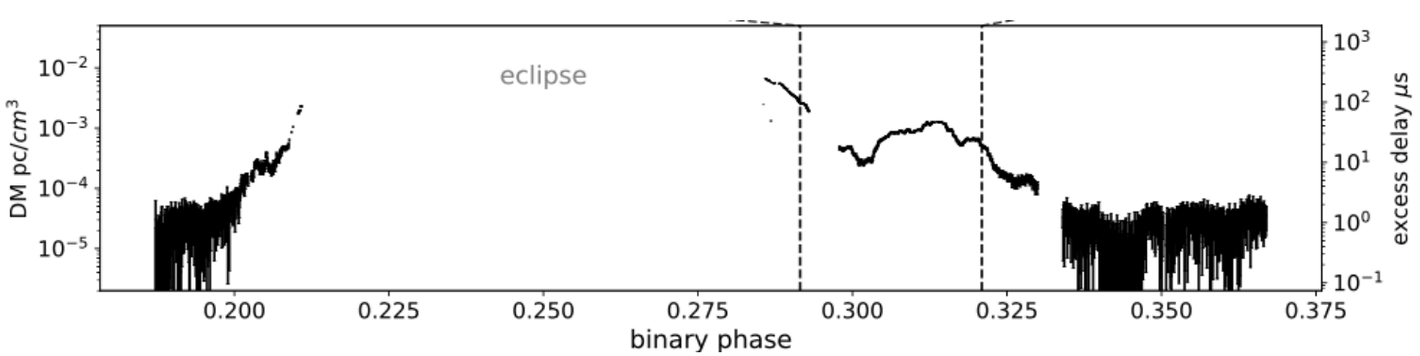
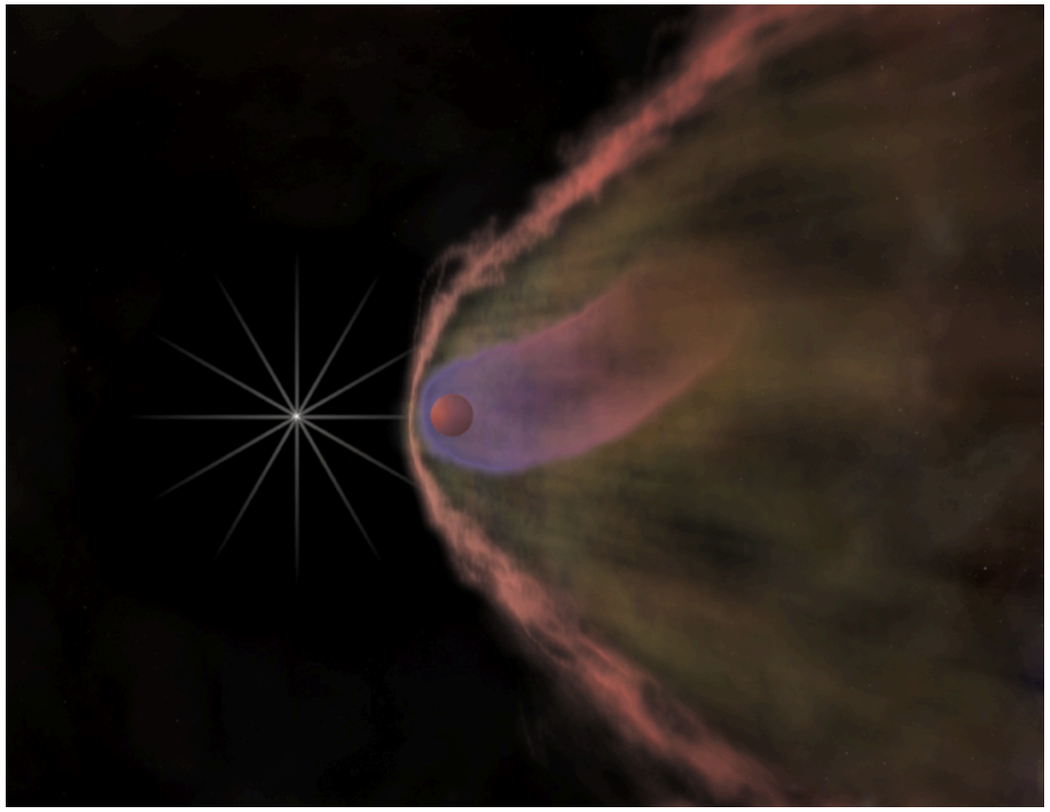
B>~20G to support the companion wind

also explain the extremely long eclipse with synchrotron-cyclotron absorption

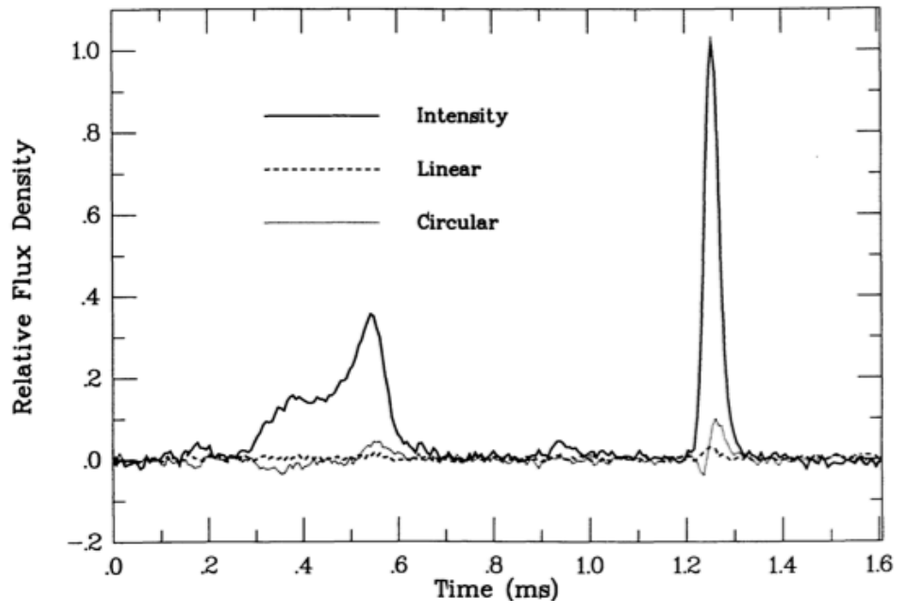


Thompson et al 1994

Black widow pulsar B1957+20



Credit: NASA/CXC/M.Weiss.



- low linear fraction

at egress B//<1.5G (90 Fruchter et al)

average 10-60 s
~1e4 km

reconnection loops with cp/2~250 km
average down B?
(94Thompson et al)

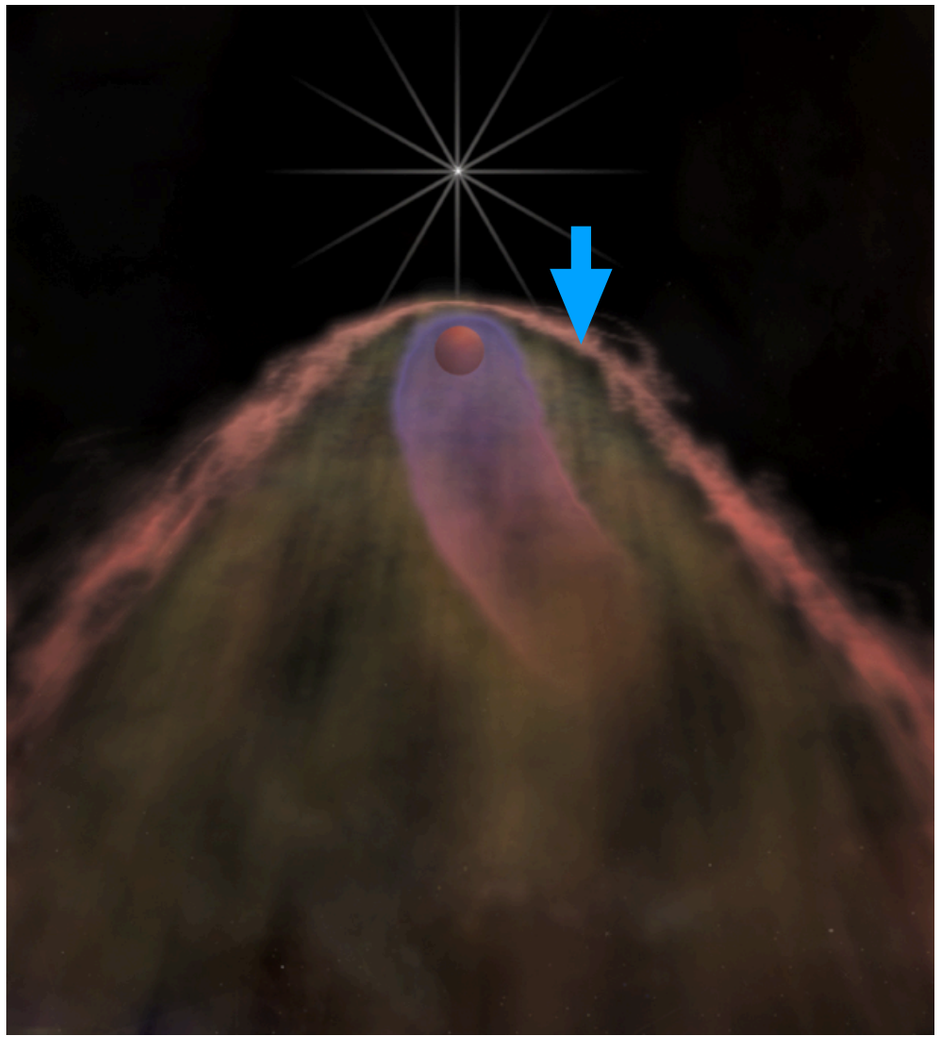
B>~20G to support the companion wind
and explain the long eclipse

- discovered ~1990s

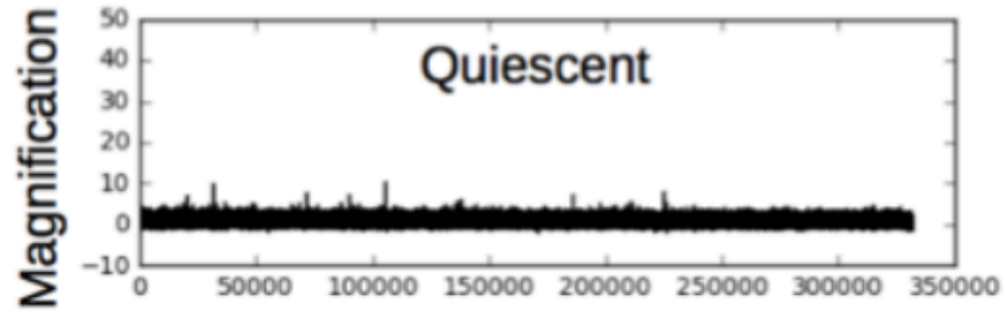
(90 Fruchter et al)
(94Thompson et al)

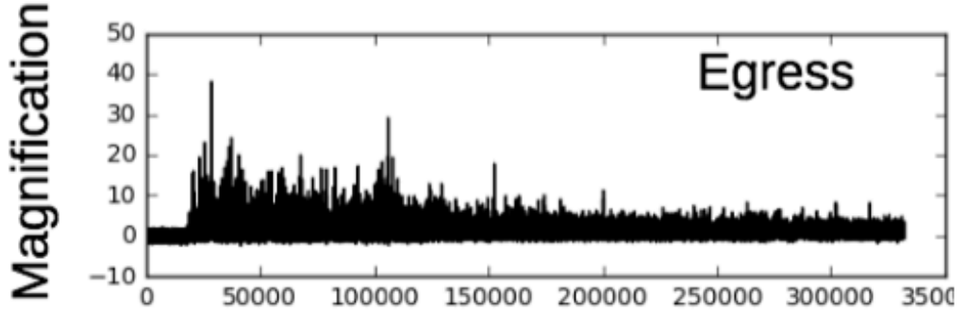
- It was already observed with Arecibo!

Black widow pulsar B1957+20



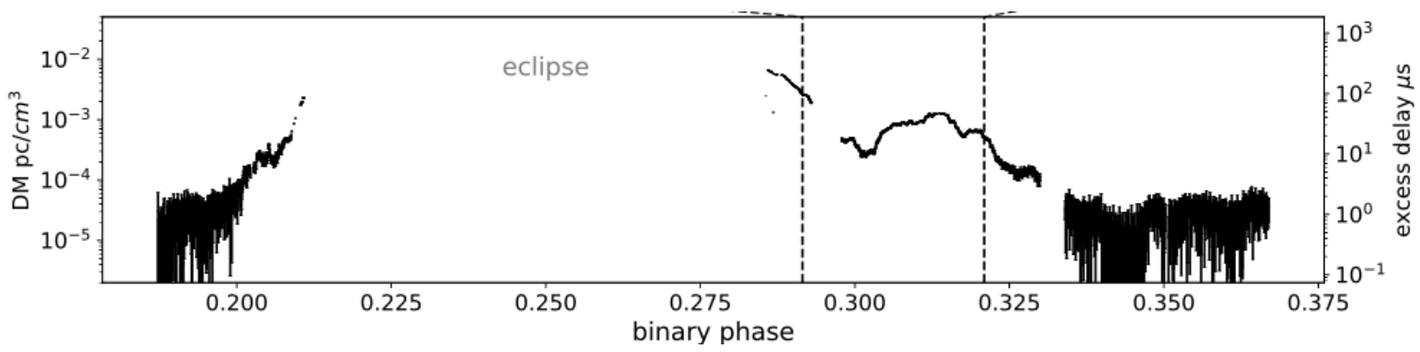
lensing events!

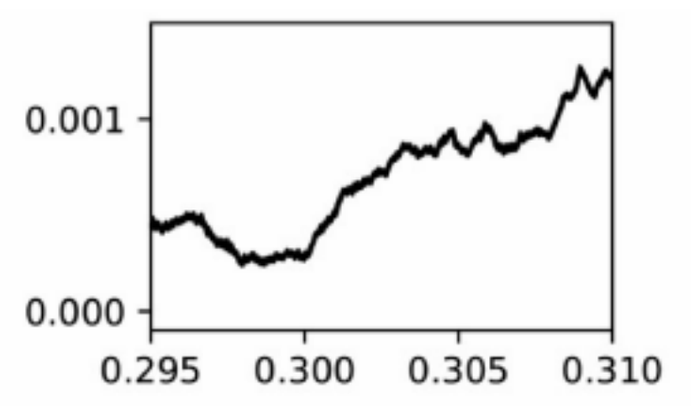




Discovery of highly magnified pulses
Arecibo at 312-360 MHz

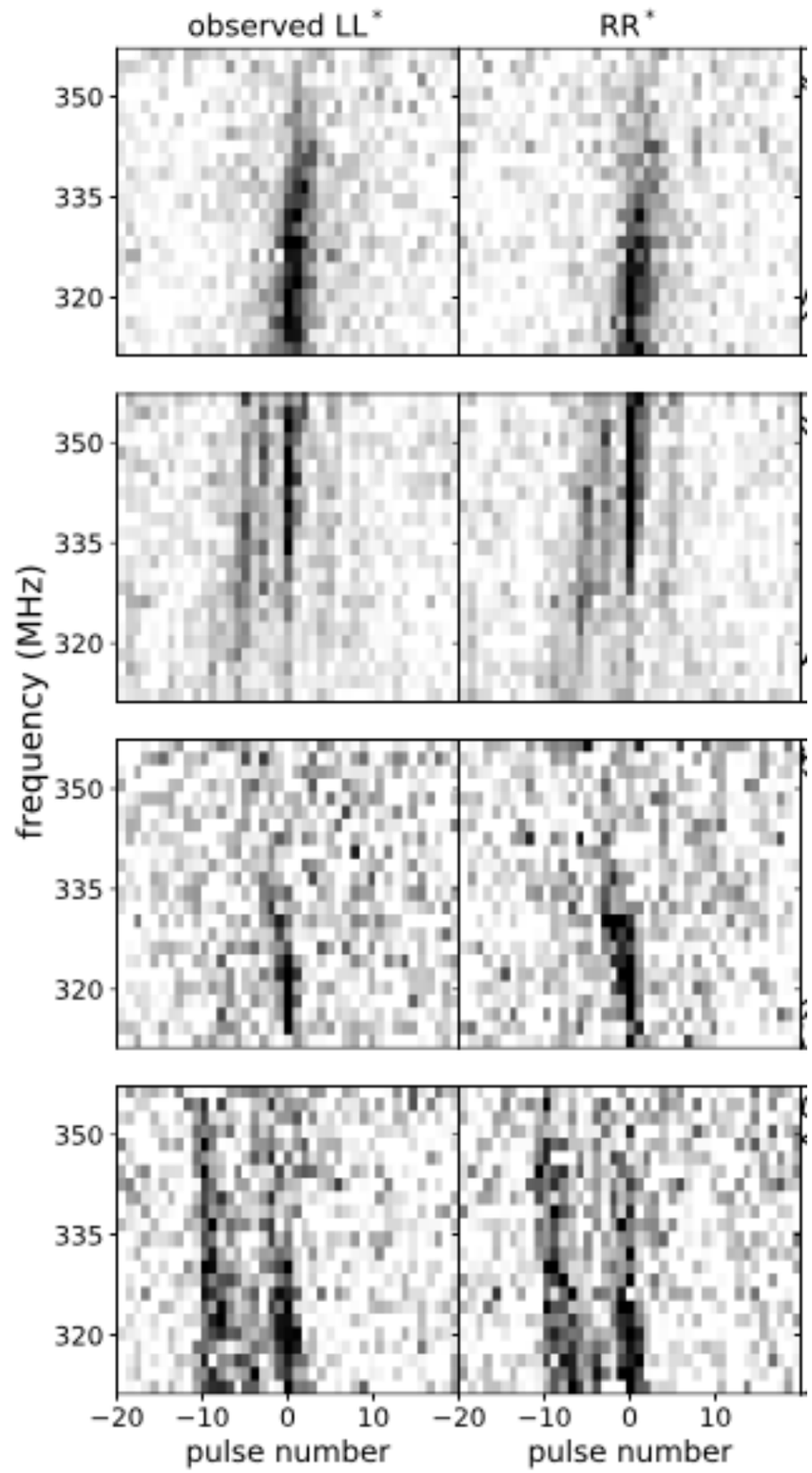
Main et al 2018 nature 557,522





- Look for plasma lensing birefringence!

look at the spectra of the magnified events!



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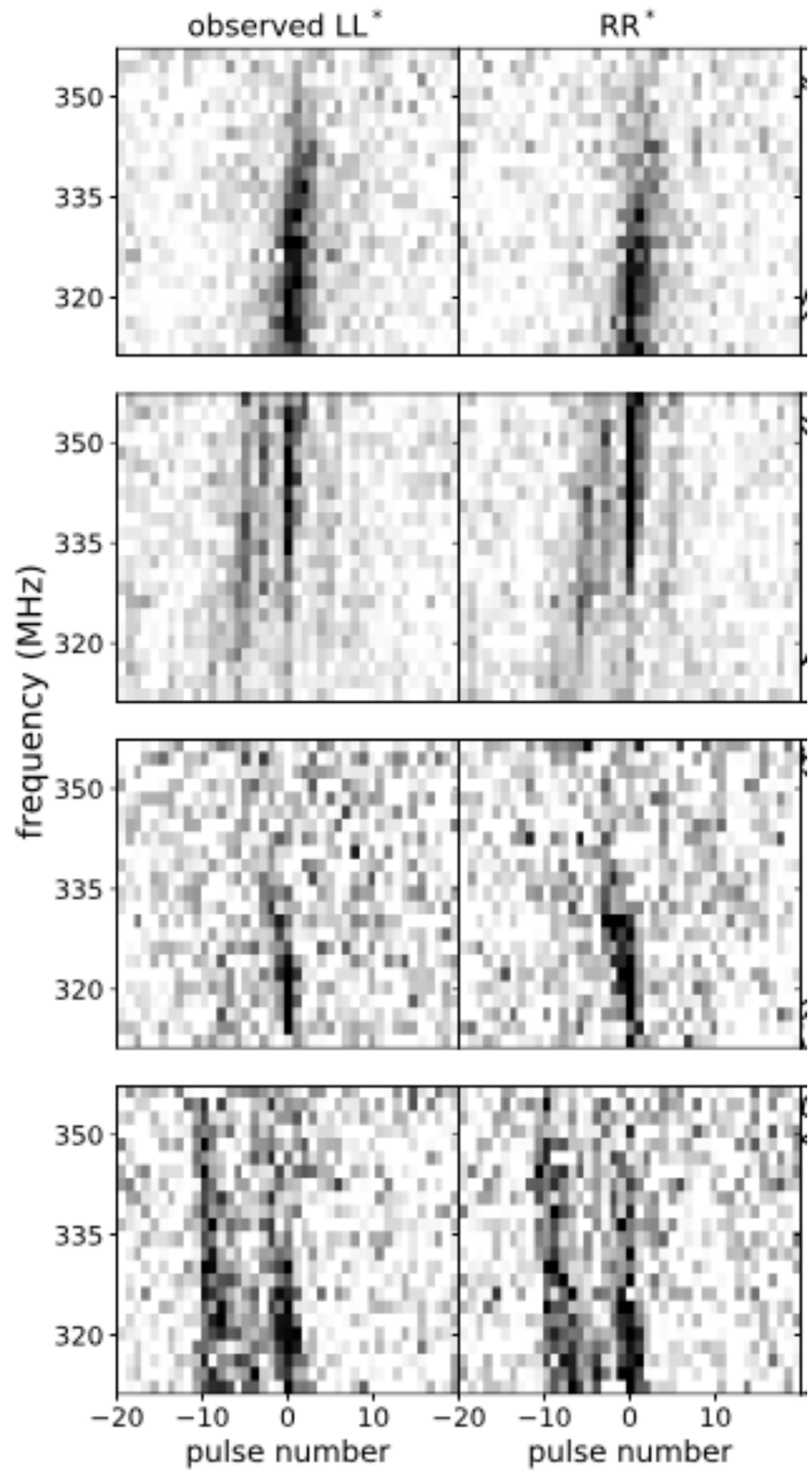
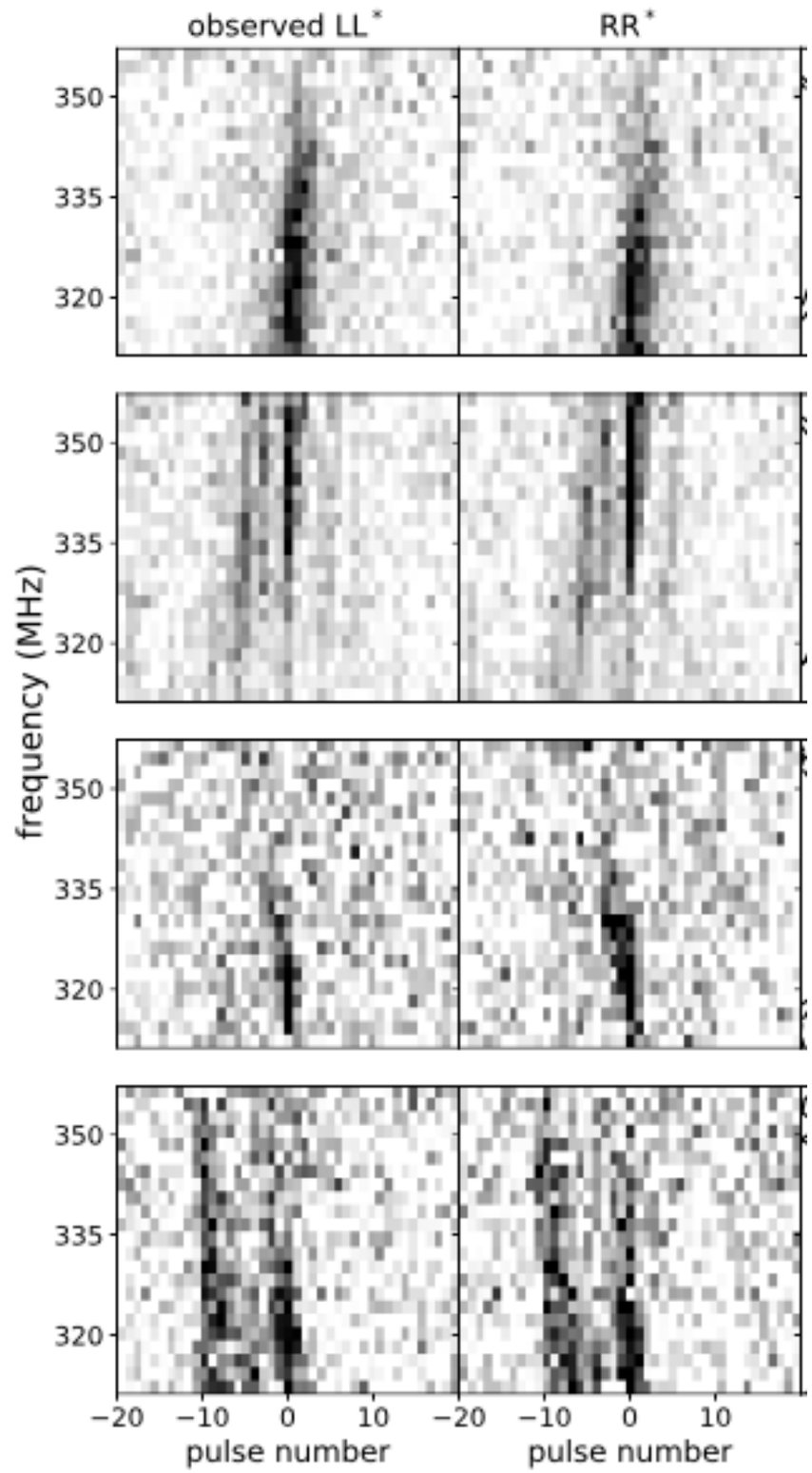


individual B//<3G, variance B//<10 mG

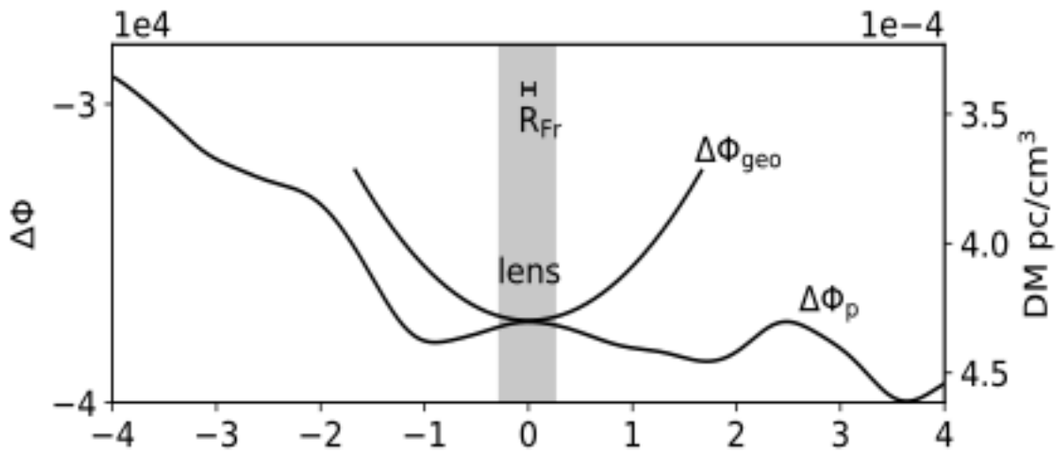
look at the spectra of the magnified events!

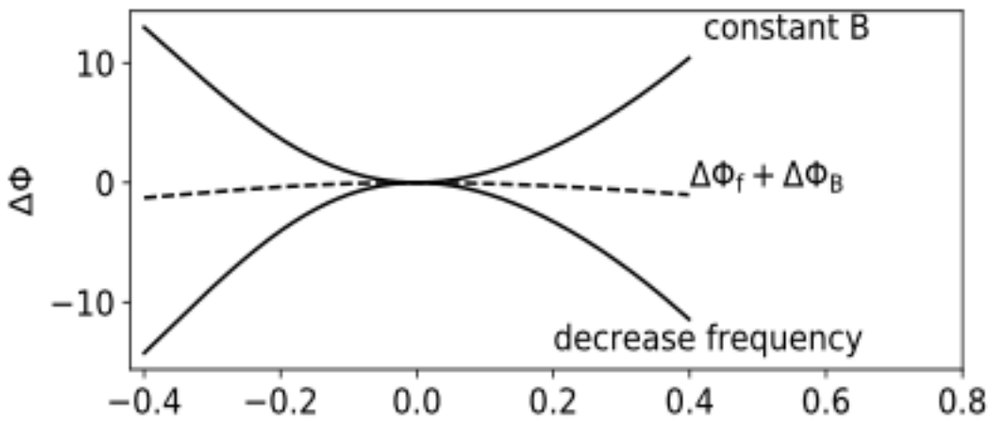


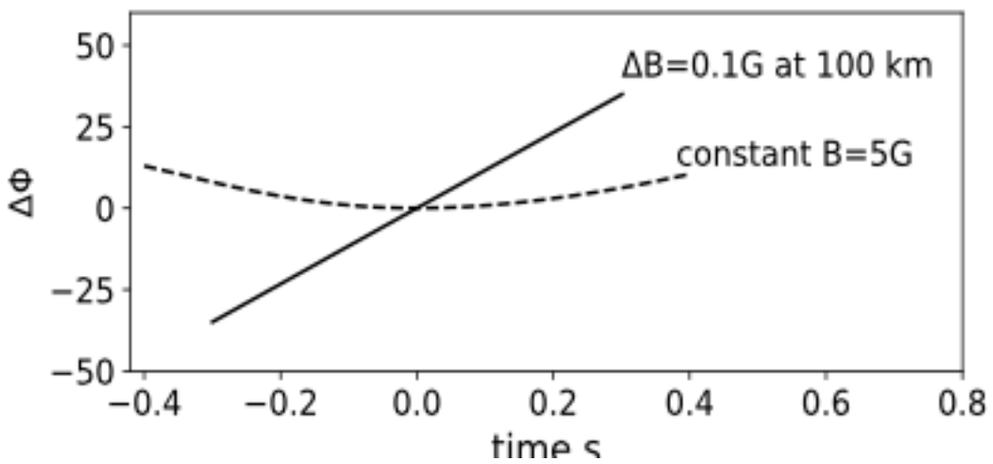
theoretical: 20 G

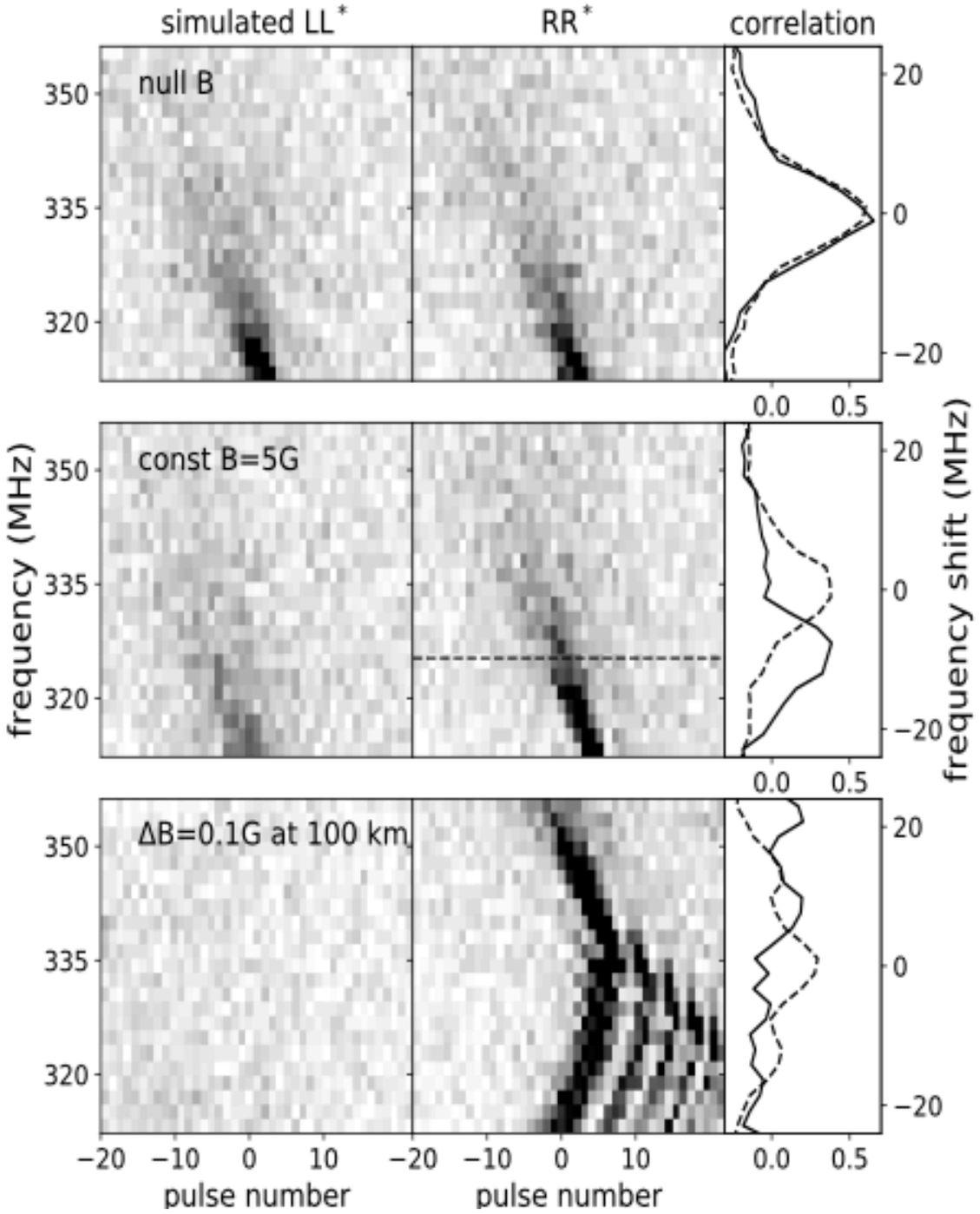
individual B//<3G, variance B//<10 mG

plasma lens in the presence of B//



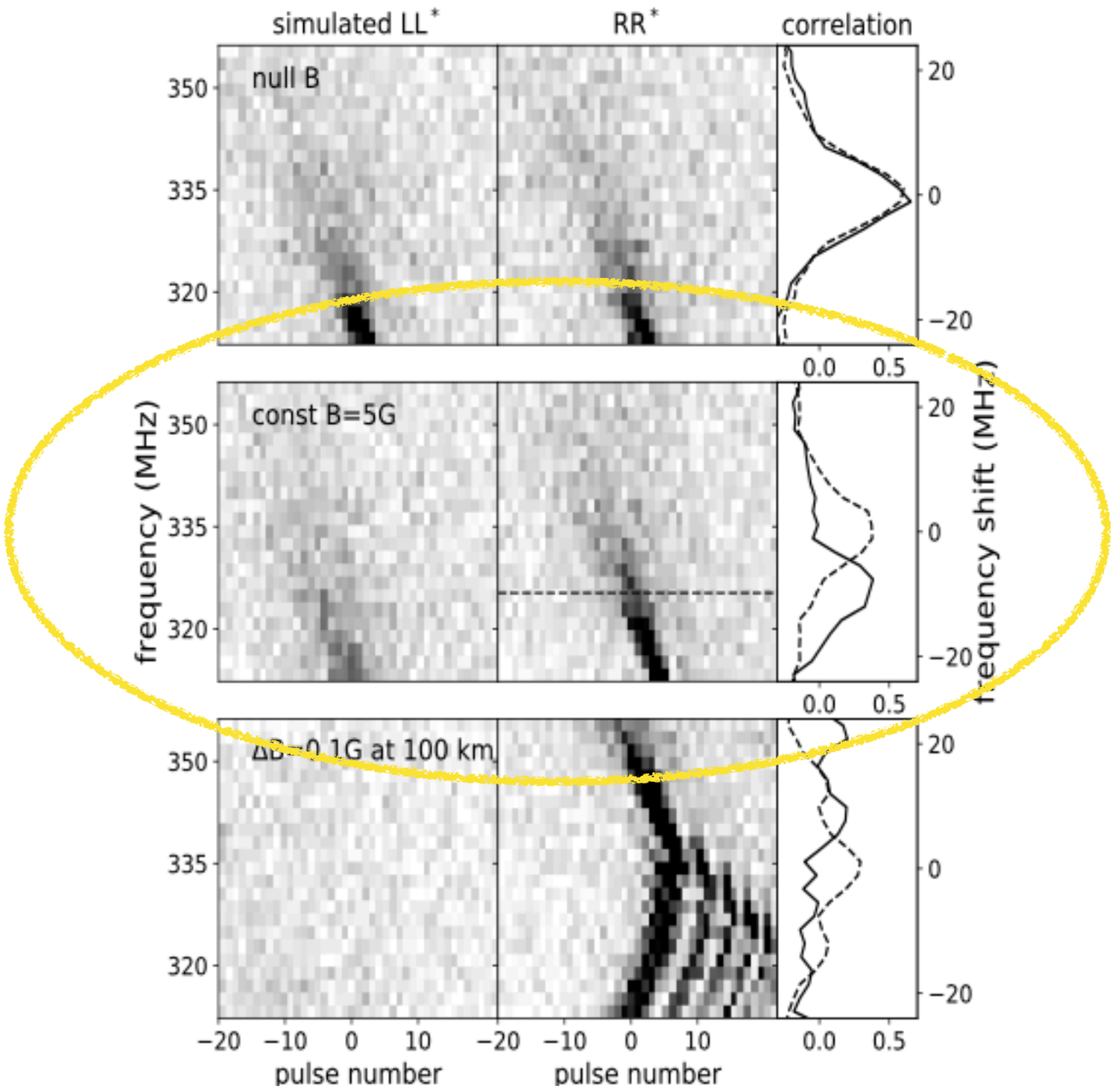






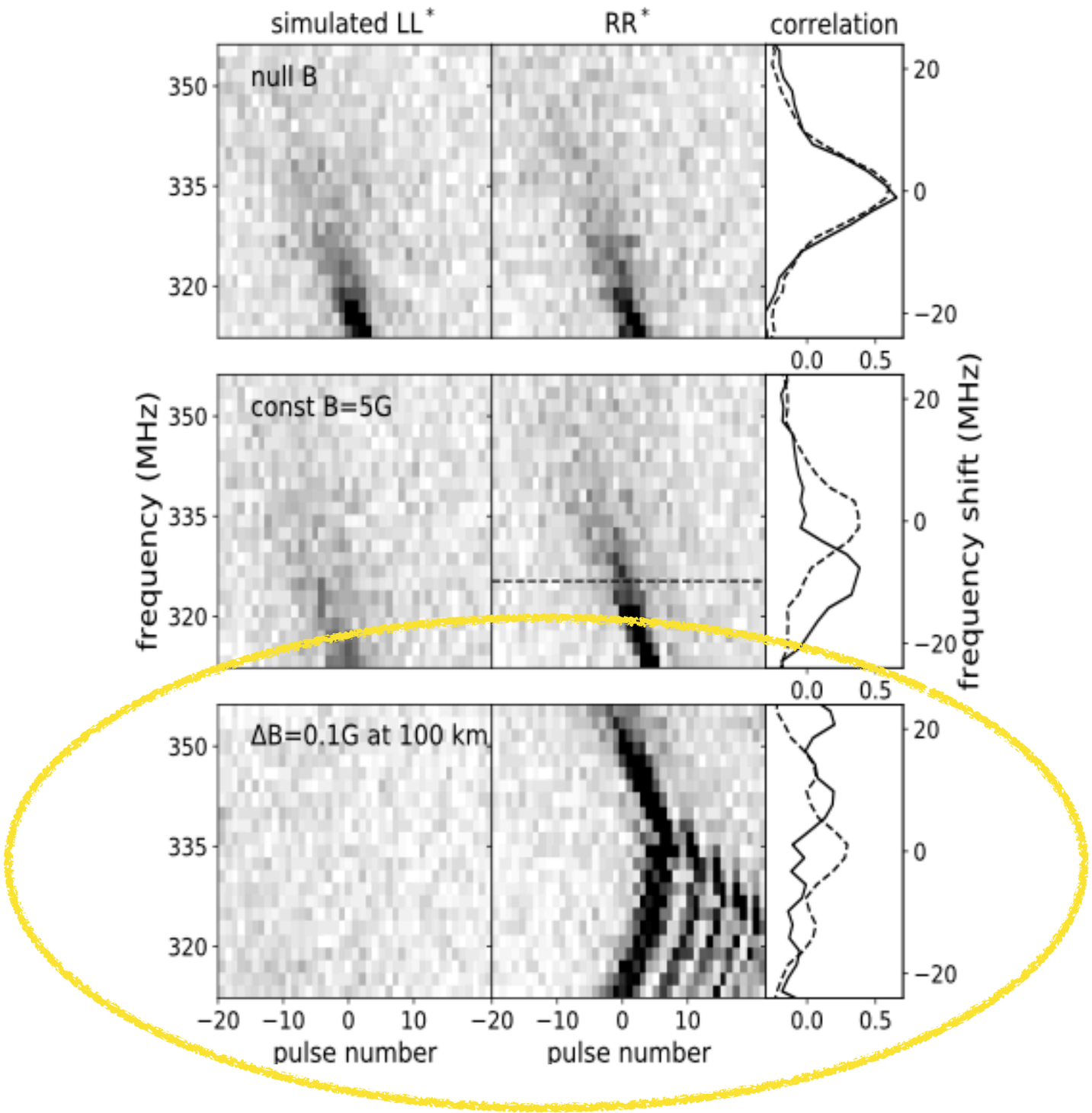
plasma lens in the presence of B//

offset by cyclotron frequency
f_c=2.8MHz/G * B



plasma lens in the presence of B//

cannot be magnified together



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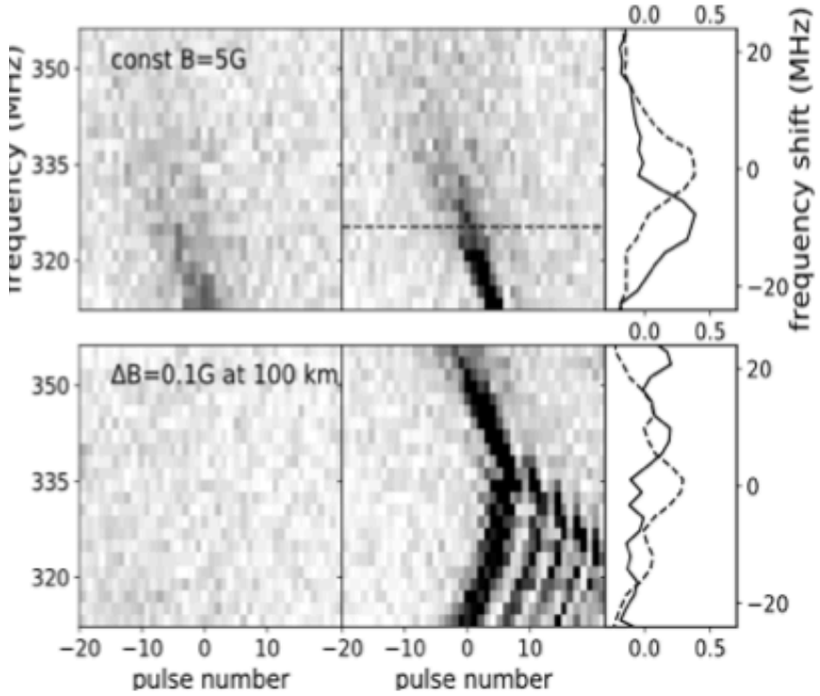
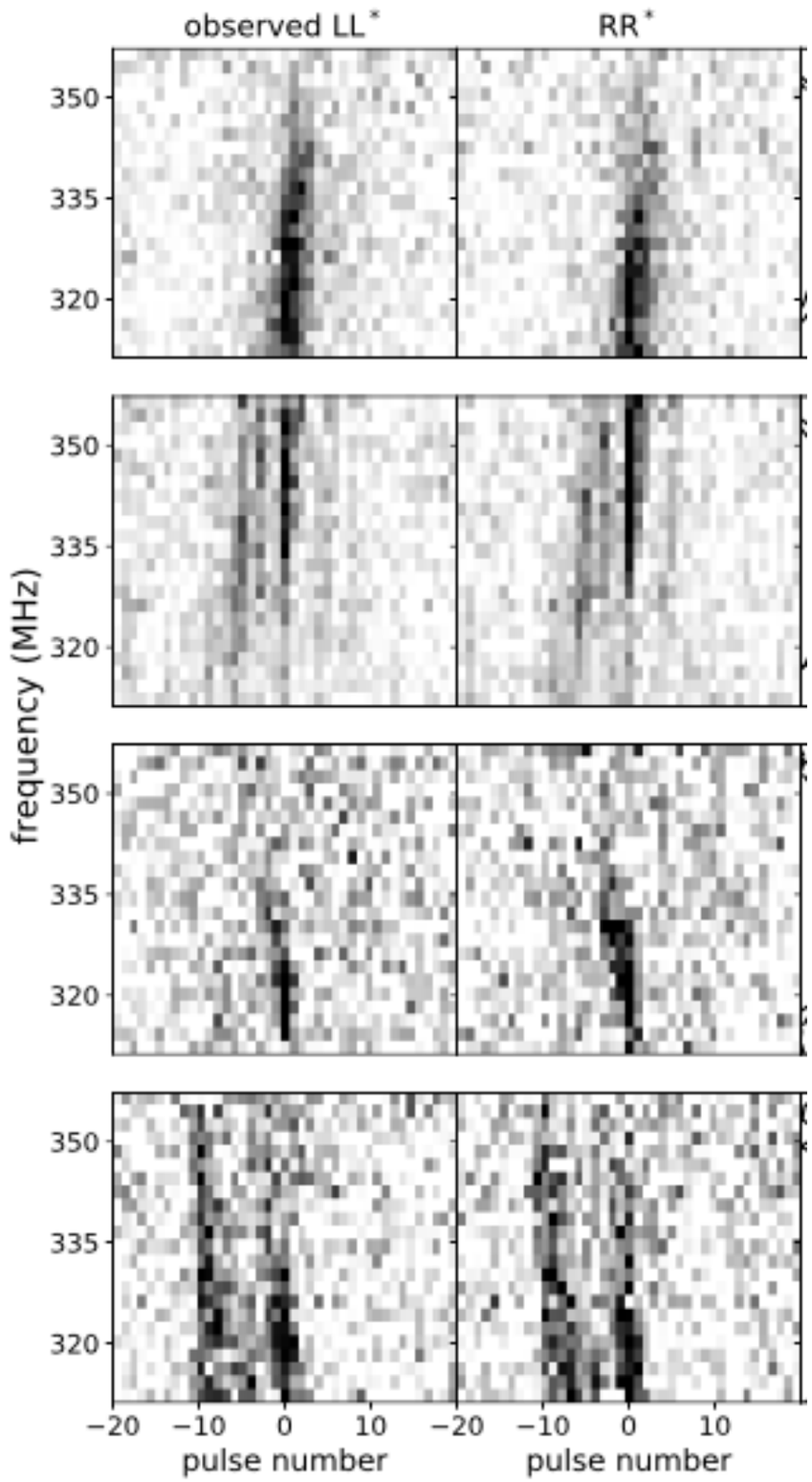


- spectra not shifted!
- LL,RR magnified together!

individual B//<3G, variance B//<10 mG



- Fast varying magnetic field: NO!!

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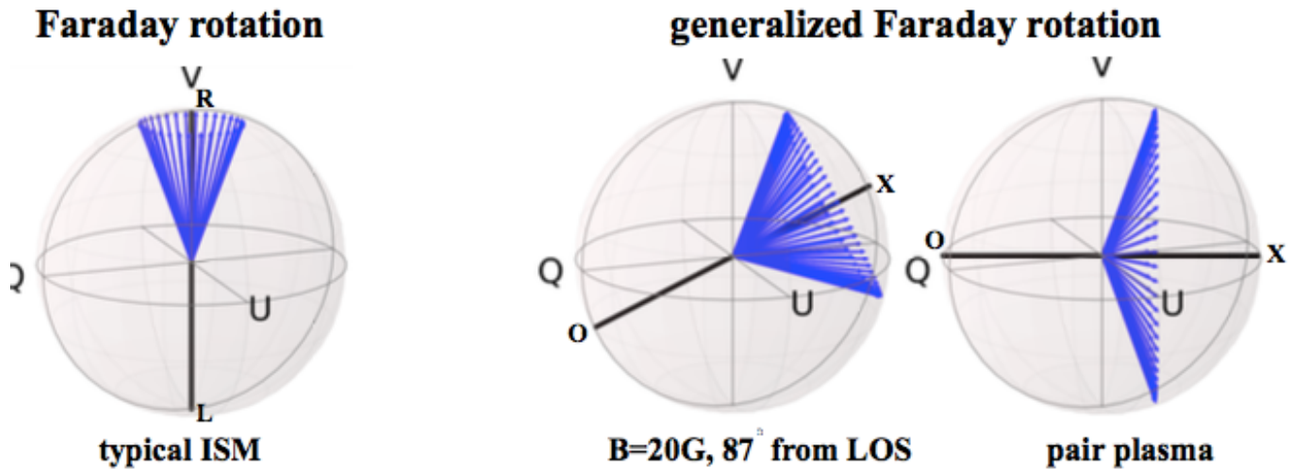
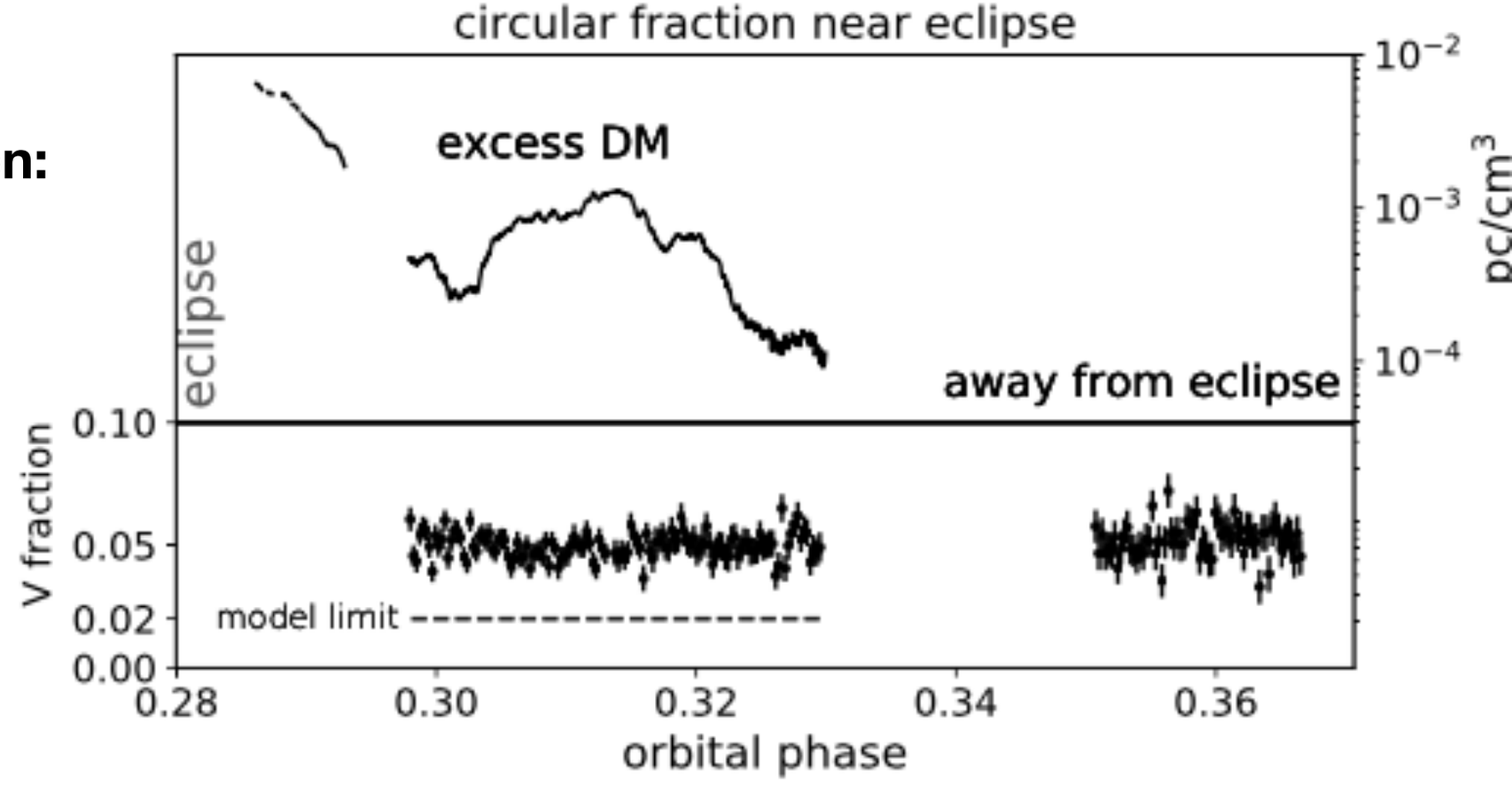
- Perpendicular magnetic field
- pair plasma



expect Faraday conversion: circular-linear rotation

circular fraction unchanged



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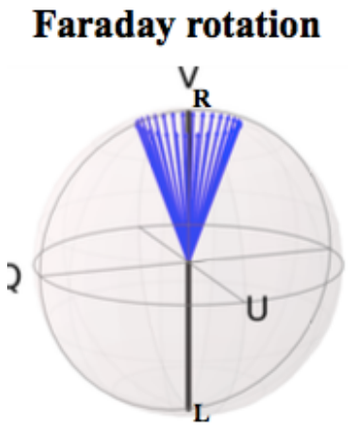

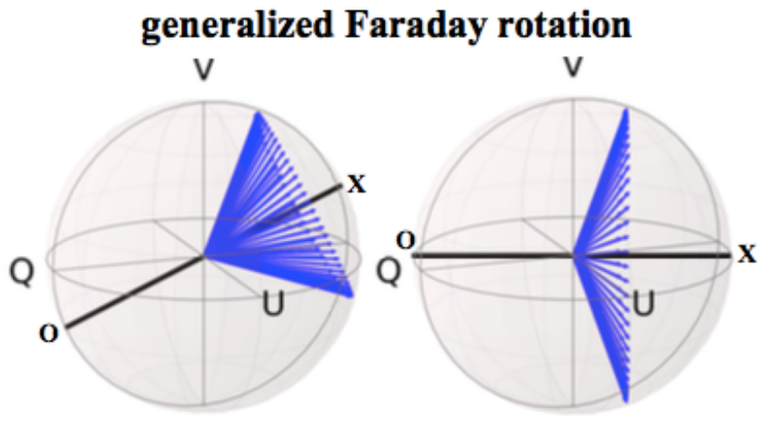

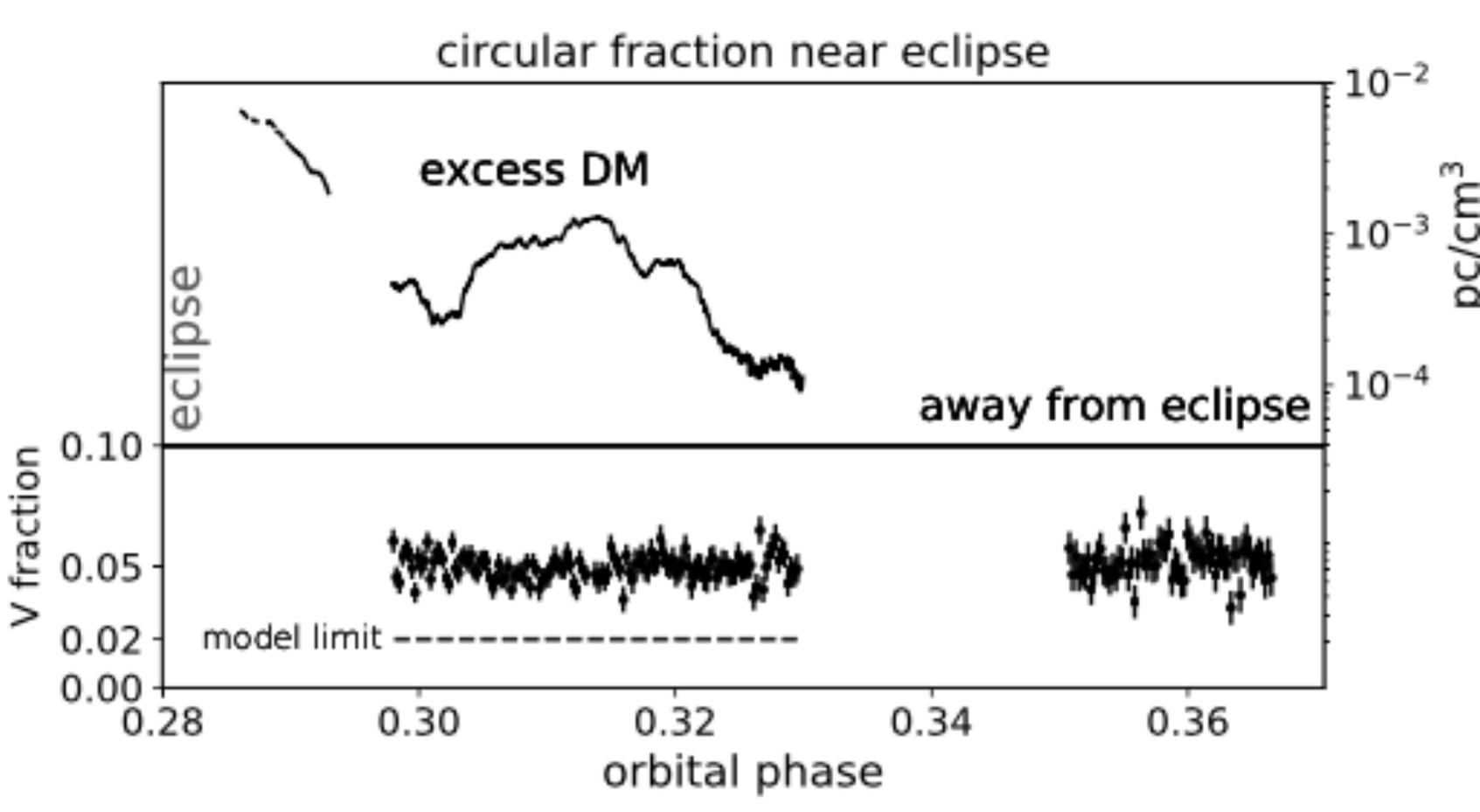

what can you do?

~20min, 48MHz bandwidth
Arecibo, ~300MHz

— same instrument as 30 years ago
Fruchter et al 1990

properties in the wind interface

- average B//<0.1G
- single pulse B//<3G
- variance B//<10mG
- not perpendicular
- not pair plasma

where is the 20G field?!

Li et al 2019 MNRAS 484.5723

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where is the 20G field?!

B may not explain everything, make the measurement!

Li et al 2019 MNRAS 484.5723

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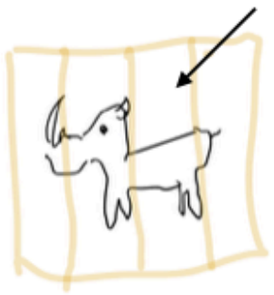

- **local properties of B field**
- **probe special magnetic structures**

no requirements for polarized sources,
no ionosphere influence

minimum observation time

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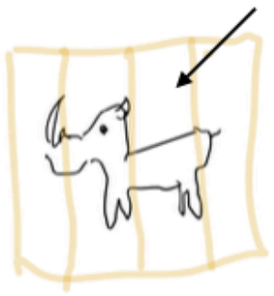

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Best observation data:

- sensitive instruments (can’t integrate)
- broad band (capture freq evolution)
- high time/frequency resolution

(ideally baseband data)

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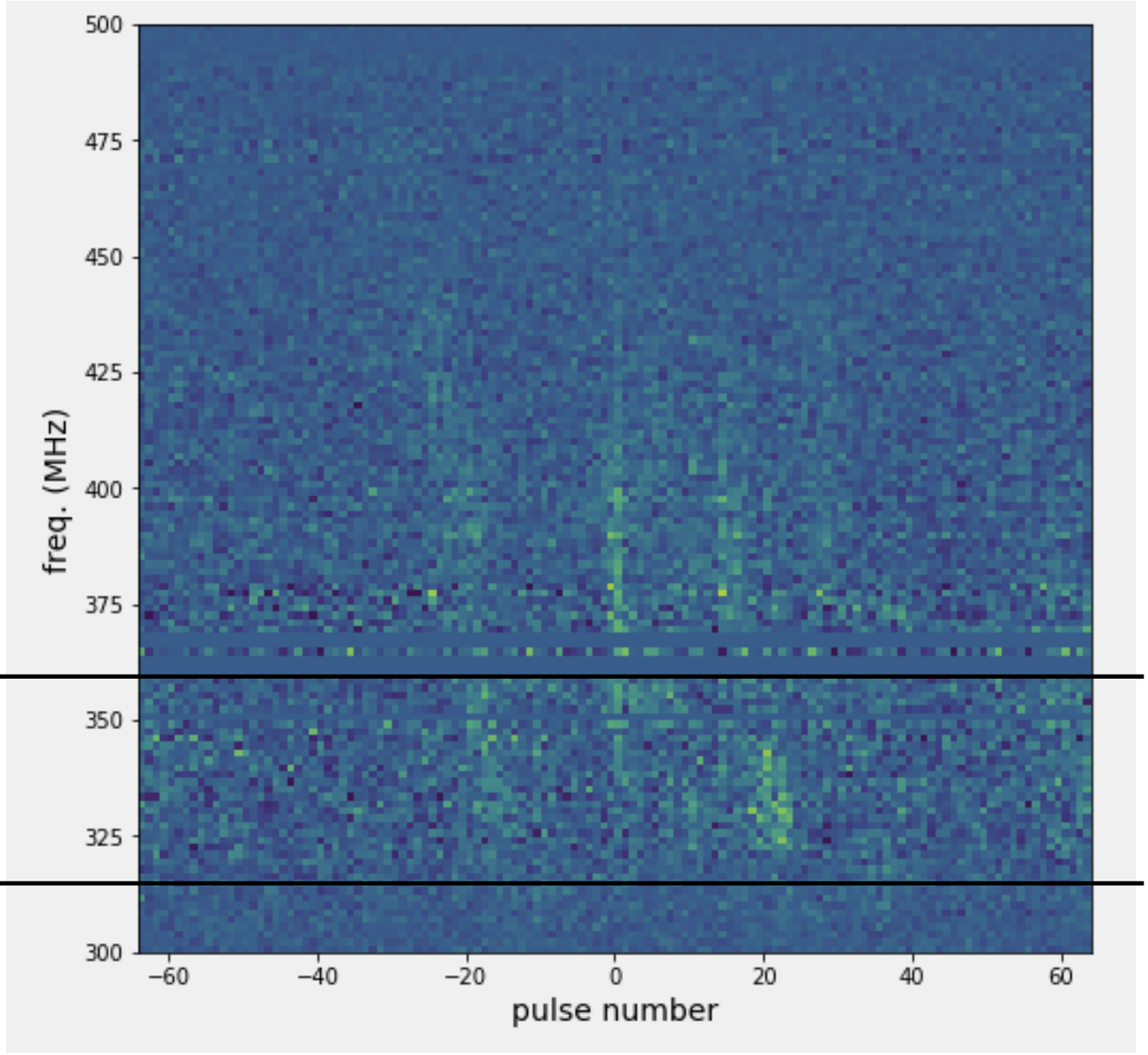
Arecibo P band

GMRT GWB



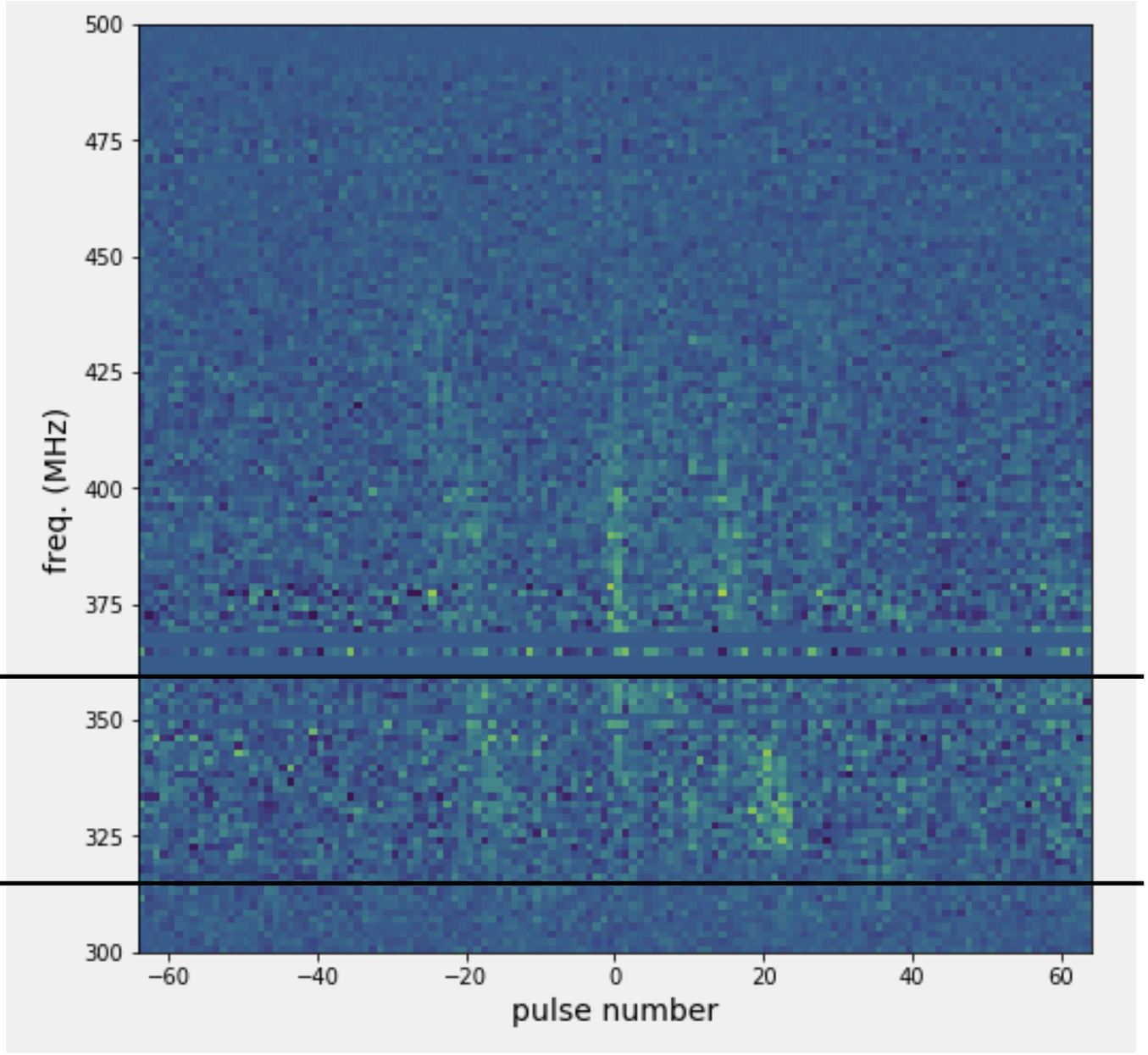
B1957 spectra, credit to Rob Main

Best observation data:

- sensitive instruments
- broad band
- high time/frequency resolution

baseband in great need!

GMRT GWB



Arecibo P band

B1957 spectra, credit to Rob Main

Thanks

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in collaboration with: Ue-Li Pen, Robert Main, Fangxi Lin, I-sheng Yang, Marten van Kerkwijk