


Circularly Polarized FRB: Bunching Curvature Radiation

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Boya Fellowship

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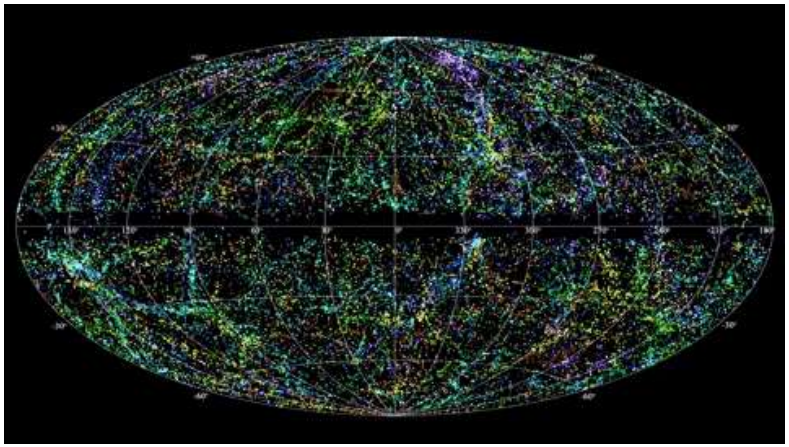
OUTLINES

- **Background**
- **Bunching CR**
- **Polarization Property**
- **Summary**

Fast Radio Burst

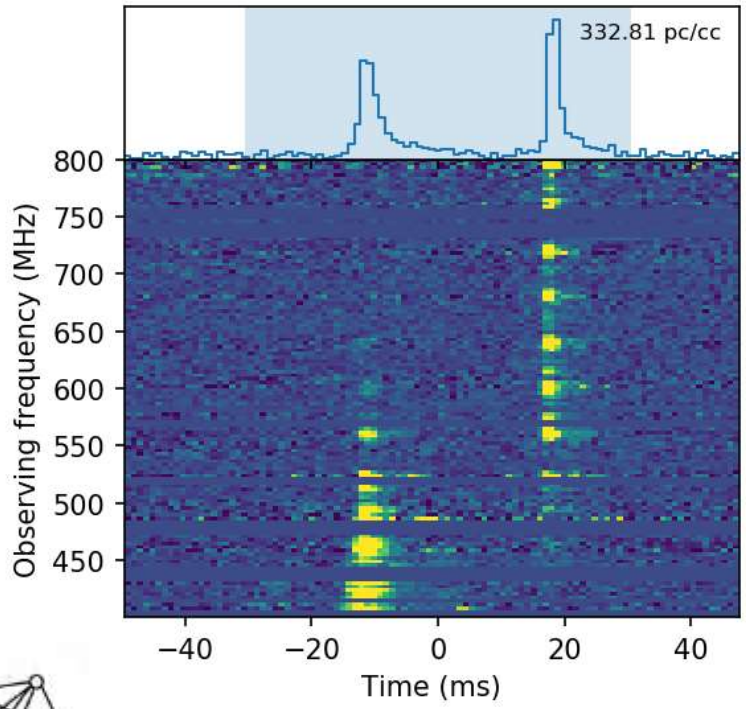
Hundreds of FRBs
Dozens of repeaters
One FRB-like burst from Galactic magnetar
More than 10 were localized precisely

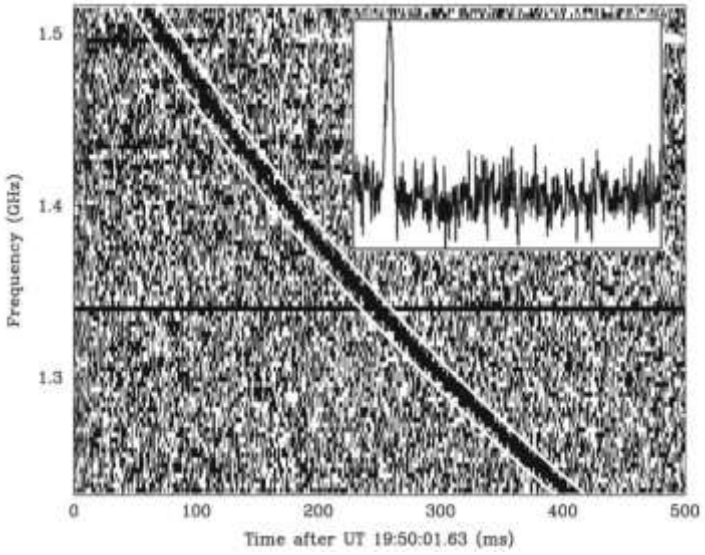


Large DM

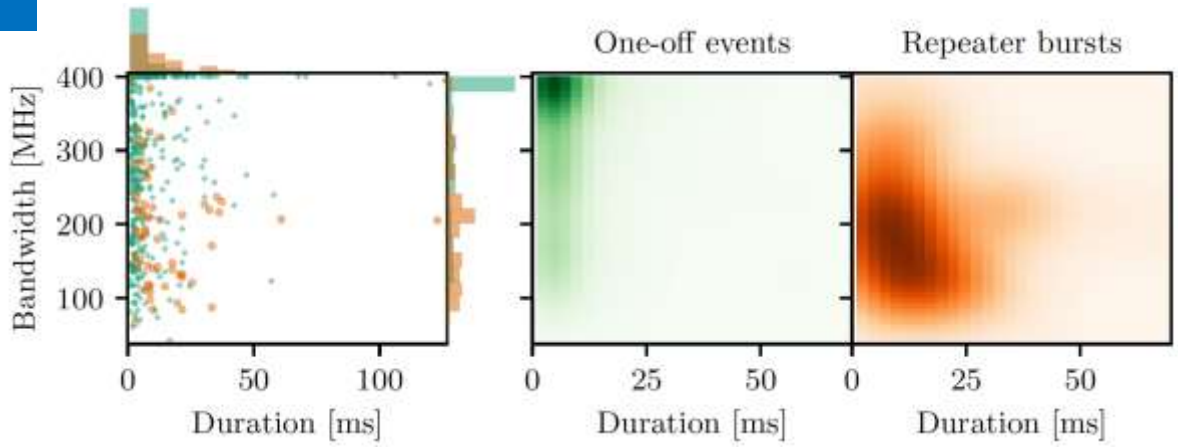
Spatial distribution

Cosmological origin



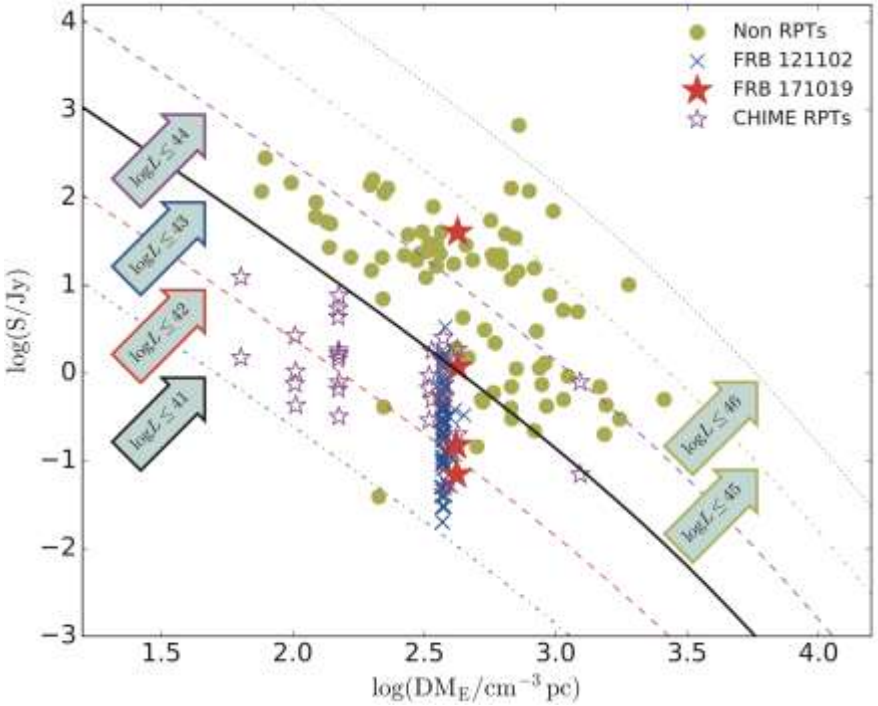


Repeating FRB



Repeaters favor narrowband and long duration

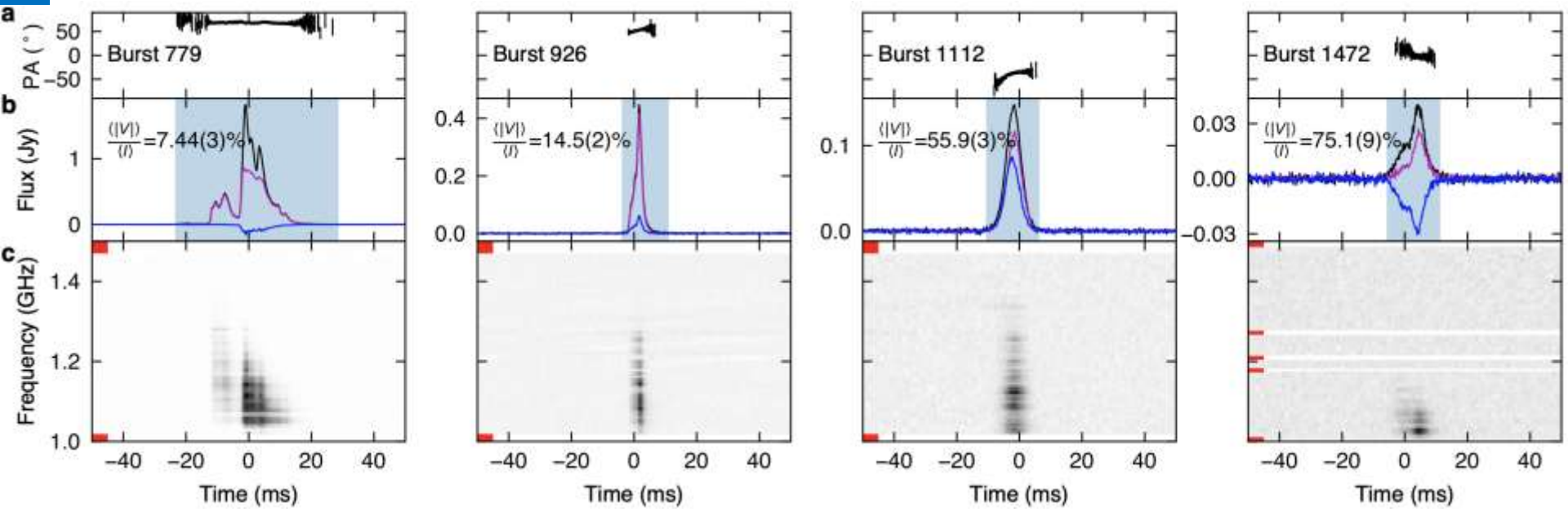
Pleunis et al. 2021



Open question: whether all can repeat?

Jiang et al. 2020

LP and CP



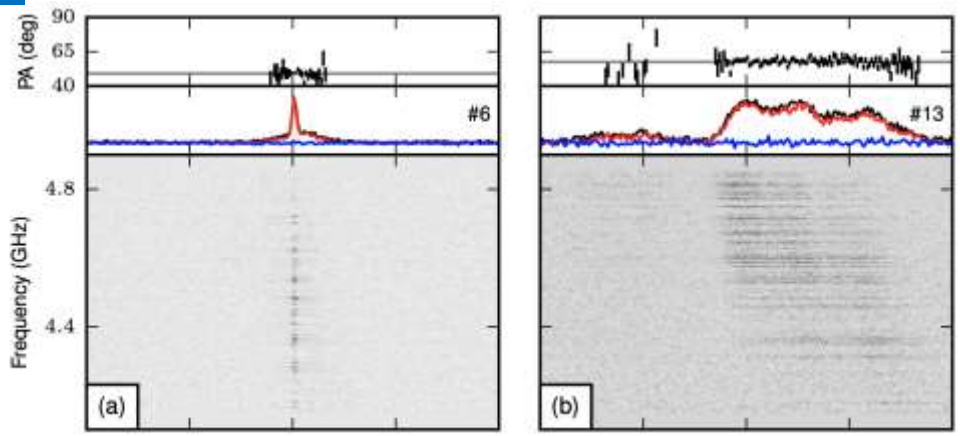
Xu et al. 2021

FRB Source	Band (GHz)	LP (%)	CP (%)	PA
20121102A	3–5	~ 100	0	Constant[a]
	1–1.5	< 20	< 15	-
20180301A	1-1.5	36–80	< 10	Either constant or varying
20180916B	0.3–1.7	≳ 80	≲ 15	Constant
	0.1–0.2	30–70	0	Constant
20190303A	0.4-0.8	≳ 20	-	Constant
20190417A	1–1.5	52–86	-	Constant
20190520B	2.8–8	15–80	< 15[b]	Constant
20190604A	0.4-0.8	~ 100	0	Constant
20201124A	0.7–1.5	0–100	0–75	Either constant or varying

Both highly linear and circular polarization fraction

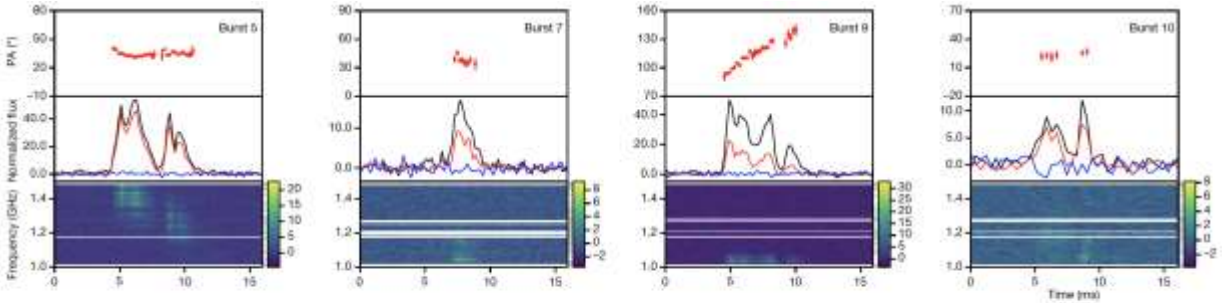
Most are highly linearly polarized

Polarization Angel



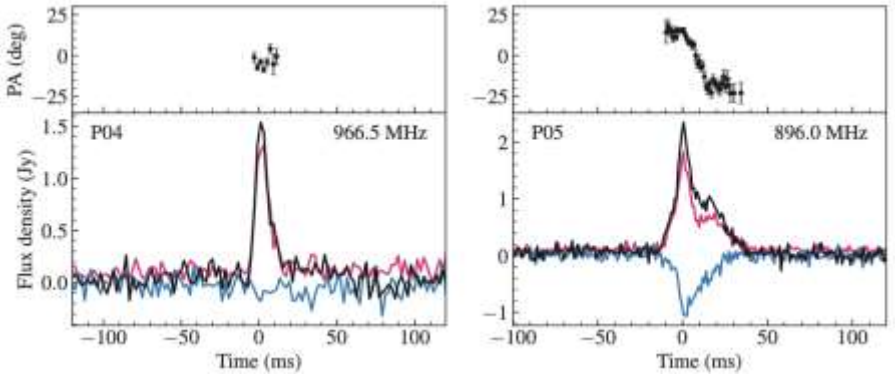
Both flat and variable PA envelope

FRB 121102



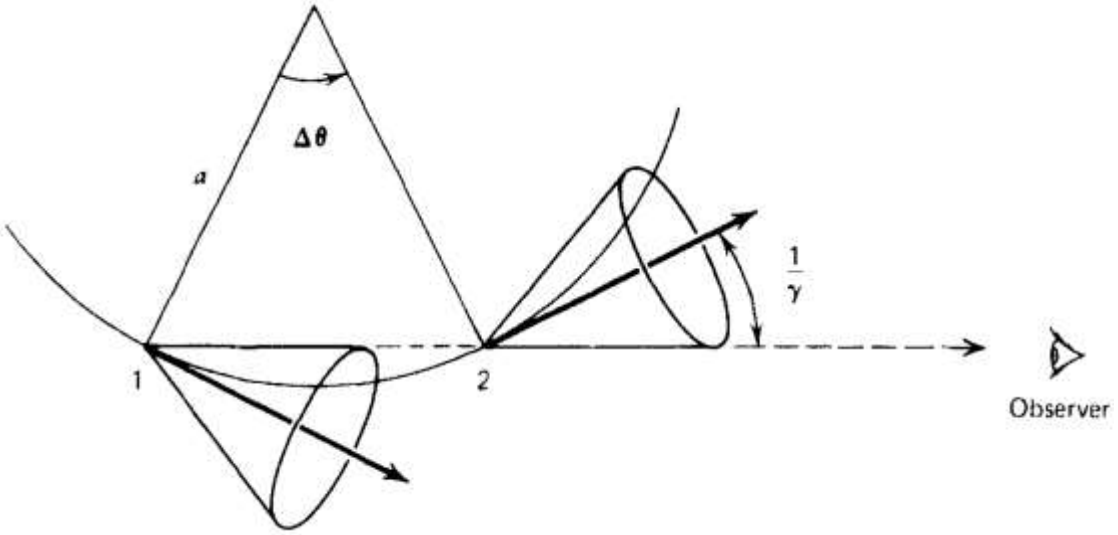
FRB 180301

FRB 20201124A

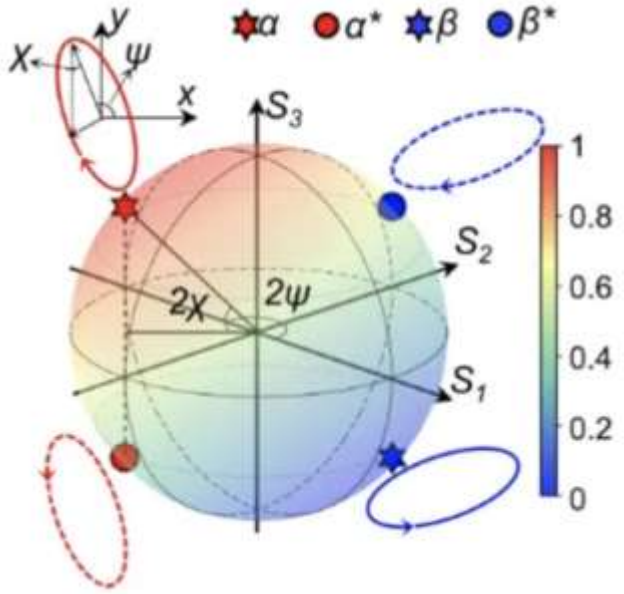


Michilli et al. 2018; Luo et al. 2020; Kumar et al. 2022

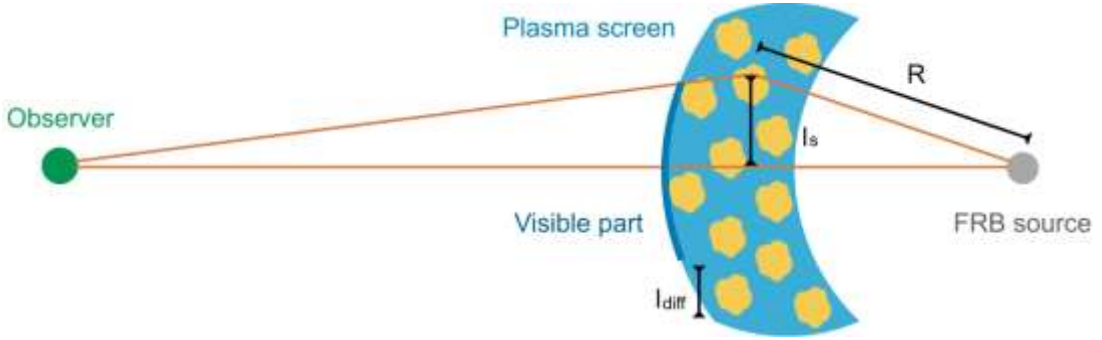
Intrinsic or Propagation?



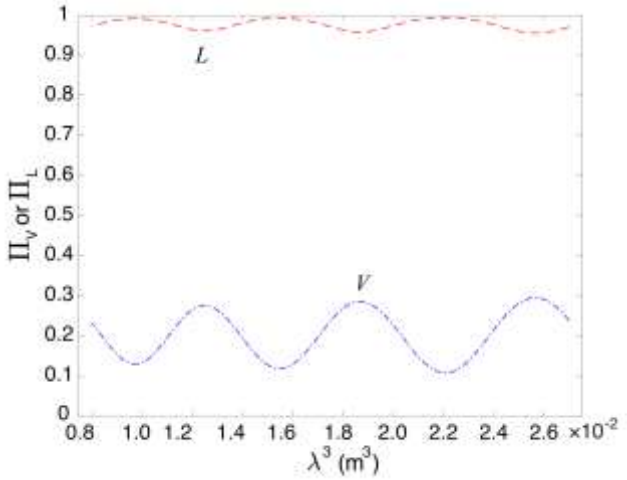
Intrinsic mechanism



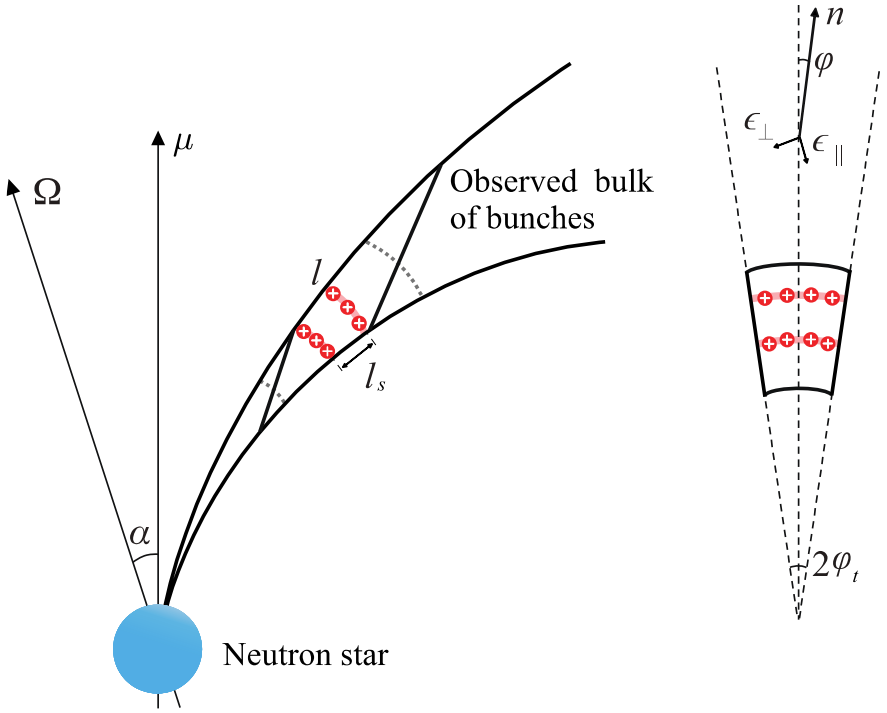
Radiative transferring



Multi-path effect



Curvature radiation from charges



The bulk size is much larger than half-wave length:

N electrons $\begin{cases} N_e \text{ in bunches (coherent)} \\ N_B \text{ bunches (adding incoherently)} \end{cases}$

$$\mathcal{L} \propto N_B N_e^2$$

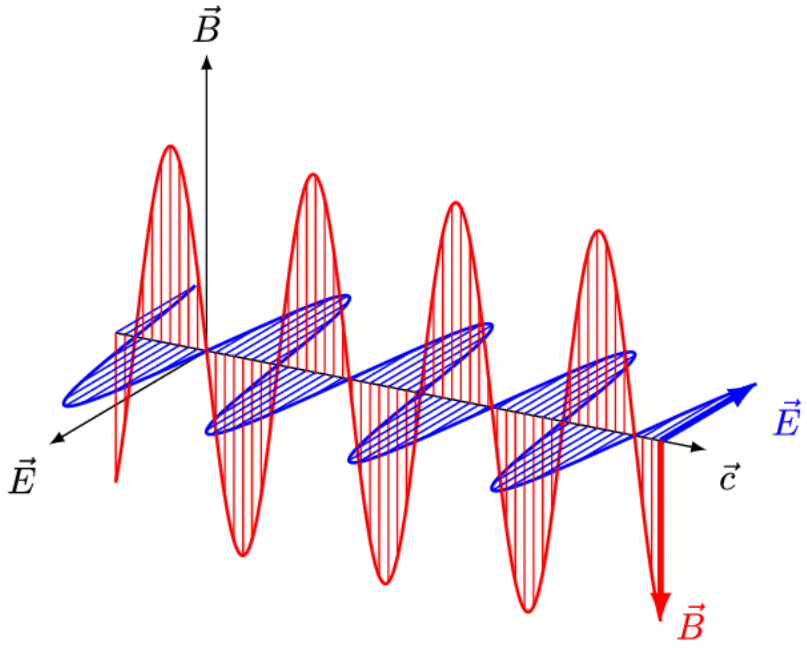
$$t_c \approx \frac{N\gamma m_e c^2}{\mathcal{L}} \approx 1.8\times10^{-12}\rho_7^2\gamma_2^{-3}N_{e,22}^{-1}\,\mathrm{s}$$

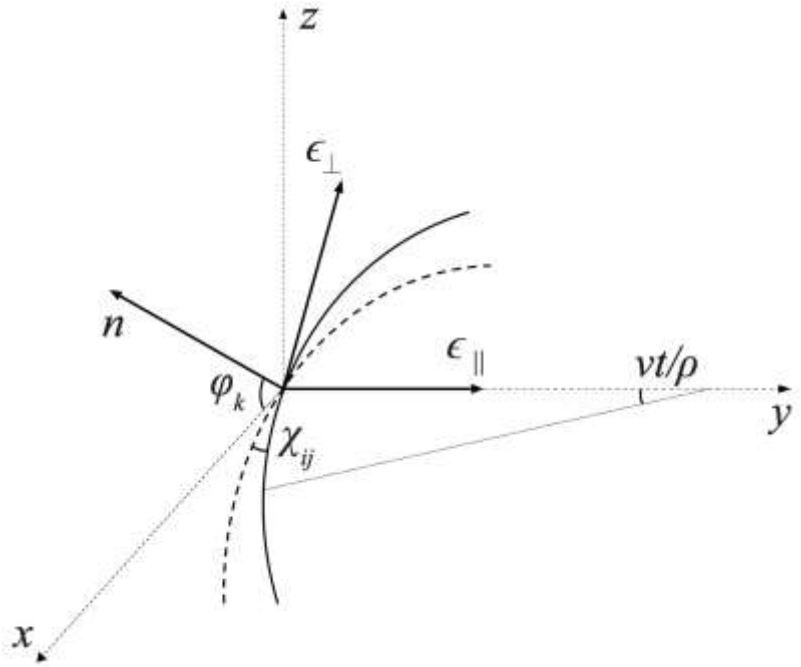
Cooling very fast

$$E_\parallel \simeq \frac{2\gamma^4 N_e e}{3\rho^2} \simeq 3.2\times10^6\gamma_2^4 N_{e,22}\rho_7^{-2}\,\mathrm{esu}.$$

Wang et al. 2022

Curvature radiation





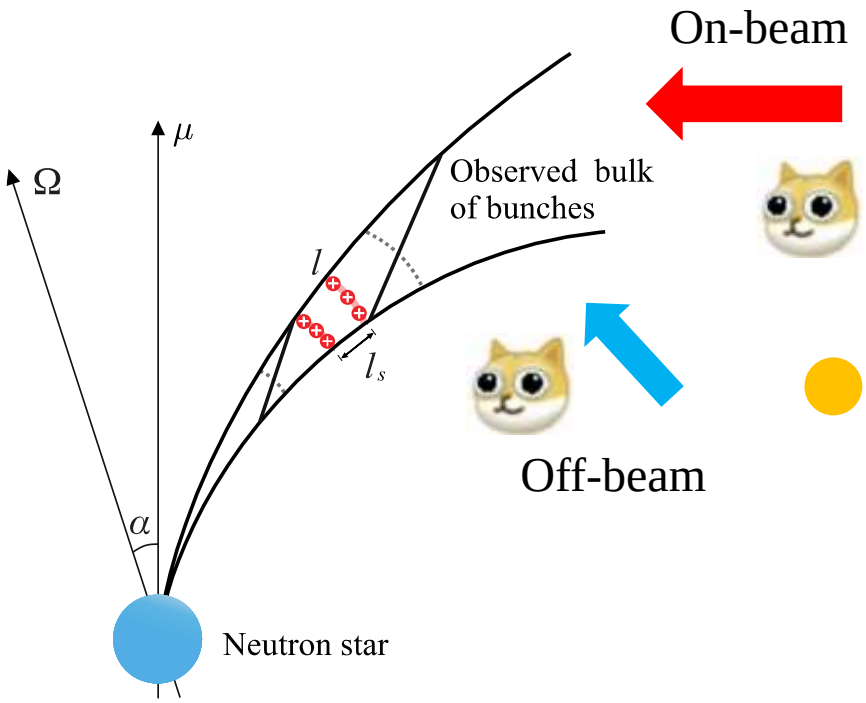
Several equations easy to get

$$A_{\parallel,i} \simeq \frac{2}{\sqrt{3}}\frac{\rho}{c}\frac{N_\theta}{\Delta\theta_s}\frac{N_\phi}{2\varphi_t}\int_{\chi_{d,i}}^{\chi_{u,i}} d\chi' \int_{\varphi_d}^{\varphi_u} \left[i\left(\frac{1}{\gamma^2}+\varphi'^2+\chi'^2\right) K_{\frac{2}{3}}(\xi) + \chi'\left(\frac{1}{\gamma^2}+\varphi'^2+\chi'^2\right)^{1/2} K_{\frac{1}{3}}(\xi)\right] \cos\varphi' d\varphi',$$

$$A_{\perp,i} \simeq \frac{2}{\sqrt{3}}\frac{\rho}{c}\frac{N_\theta}{\Delta\theta_s}\frac{N_\phi}{2\varphi_t}\int_{\chi_{d,i}}^{\chi_{u,i}} d\chi' \int_{\varphi_d}^{\varphi_u} \left(\frac{1}{\gamma^2}+\varphi'^2+\chi'^2\right)^{1/2} K_{\frac{1}{3}}(\xi)\varphi' \cos\varphi' d\varphi'.$$

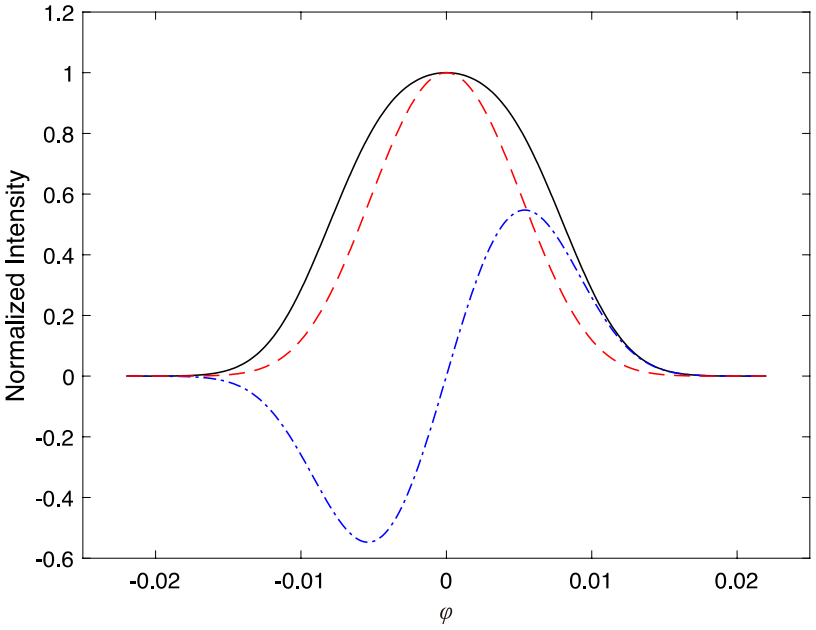
Wang et al. 2022

Curvature radiation



Linear polarization

Circular polarization



Beam center:
100% LP
Sign change of CP

Off-beam:
High CP fraction

Wang et al. 2022

The truly width

What is the duration of a transient?

I am staring at the lamp. Lights on for 10 minutes.

Duration is 10 min

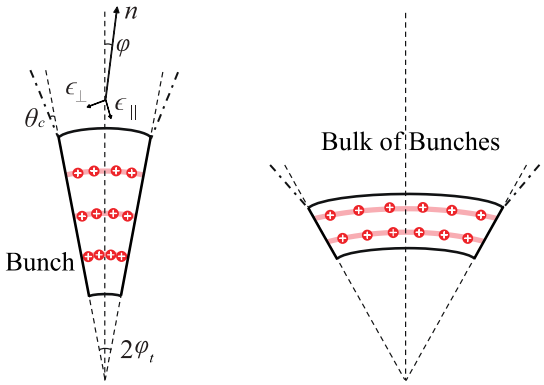
I just saw lights on for 5 minutes.

Duration is 5 min

$$w \simeq \frac{\min\left(t_{\rm int}\,,\,\theta_{\rm jet}\,/\Omega\right)}{1+z},$$

Intrinsic persistence?
Jet sweep LOS?

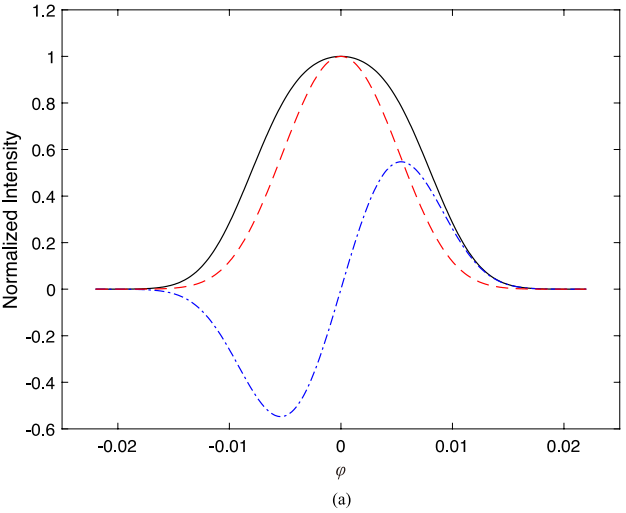
CR from bunches



Thick Bulk
(a)

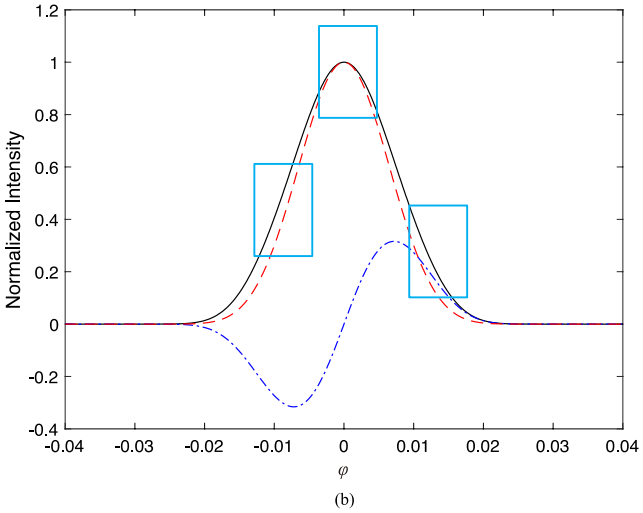
Thin Bulk
(b)

For thick bulk



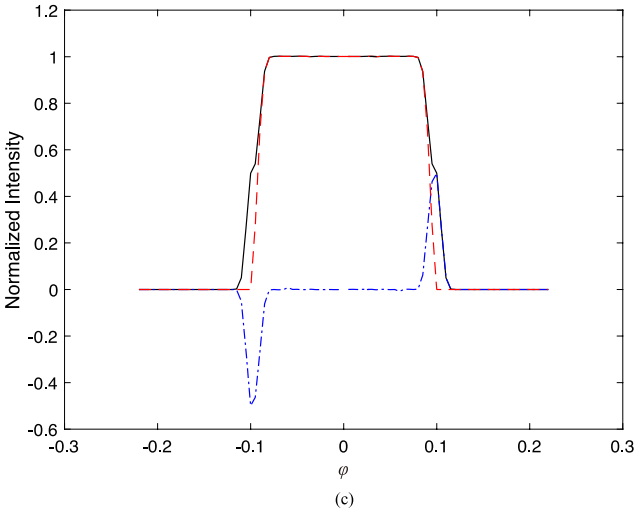
$\varphi_t = 0.1/\gamma$

<V/I> = 54%



$\varphi_t = 1/\gamma$

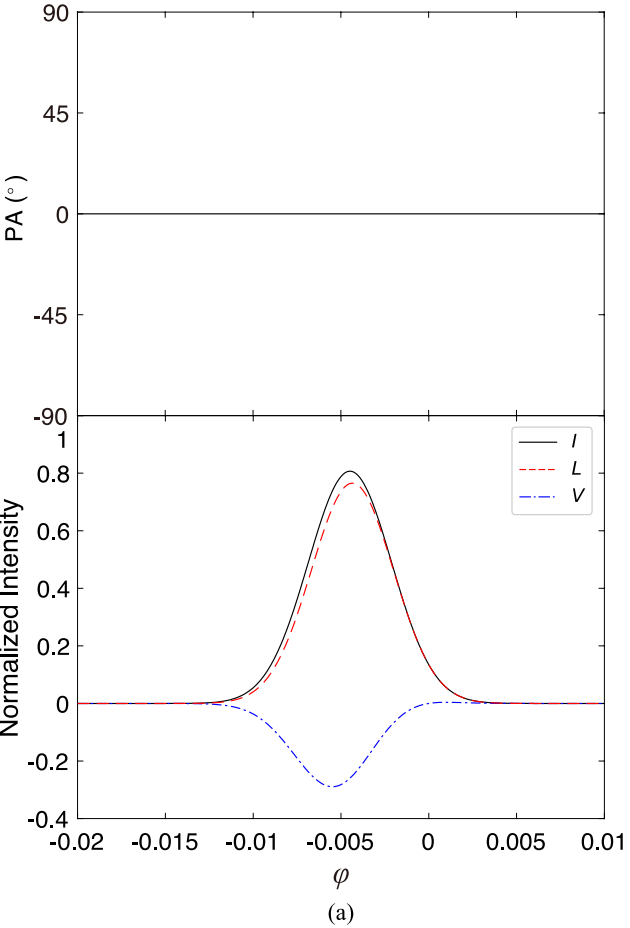
<V/I> = 38%



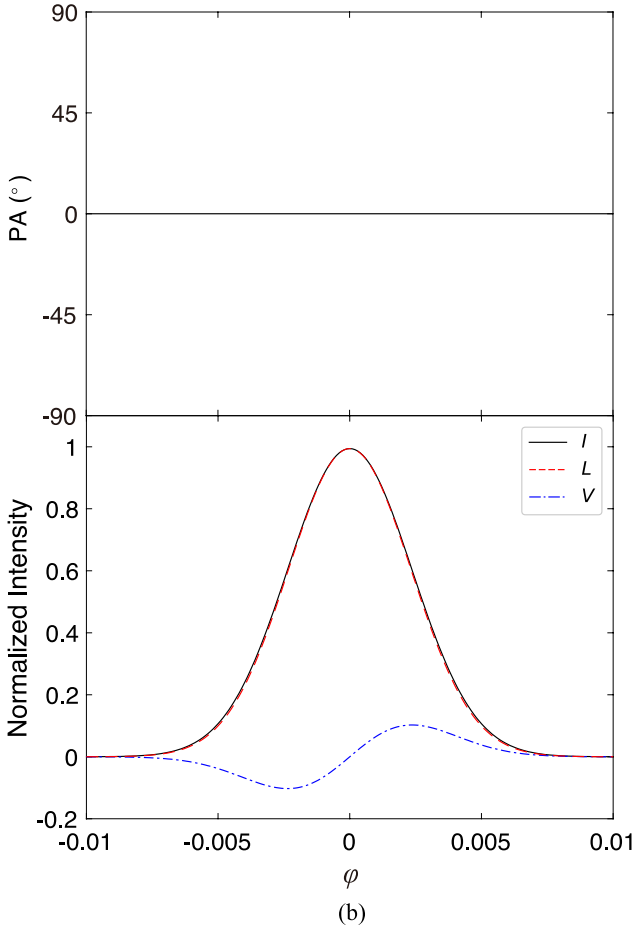
$\varphi_t = 10/\gamma$

<V/I> = 0%

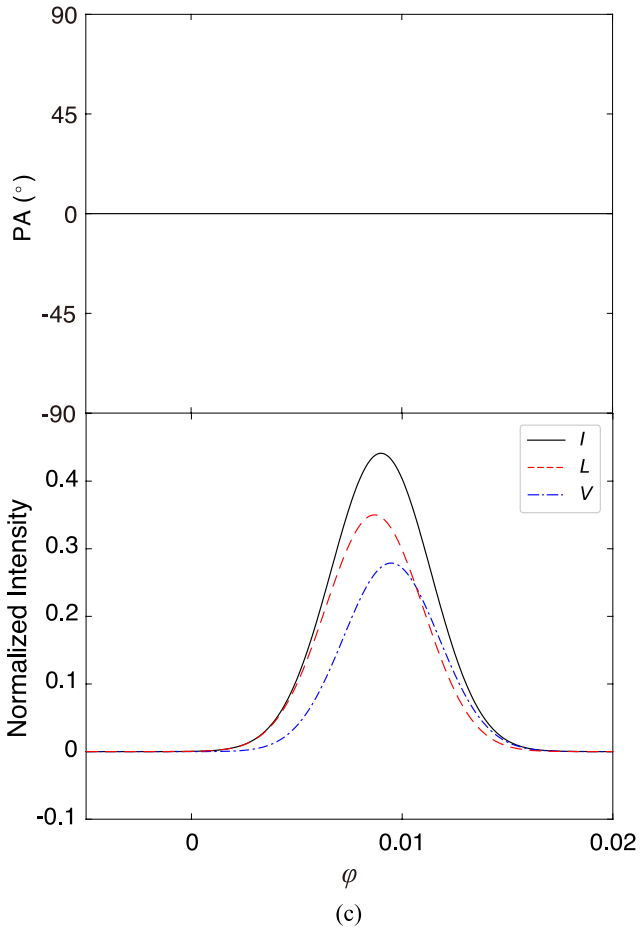
Observation window



(a)



(b)



(c)

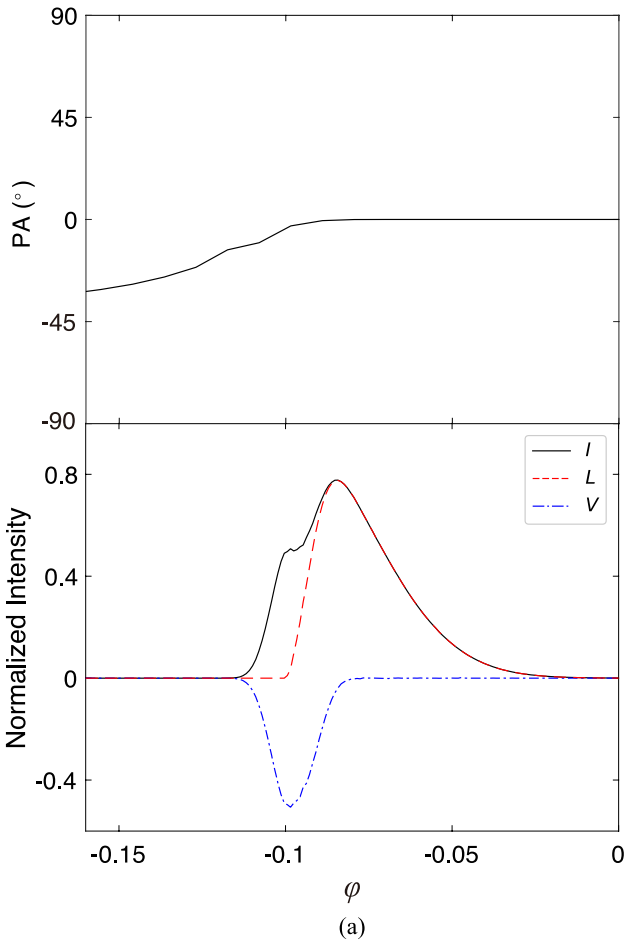
<V/I> = 32.2%

<V/I> = 13.5%

<V/I> = 60.2%

Thin bunch with $\varphi_t = 1/\gamma$

Observation window



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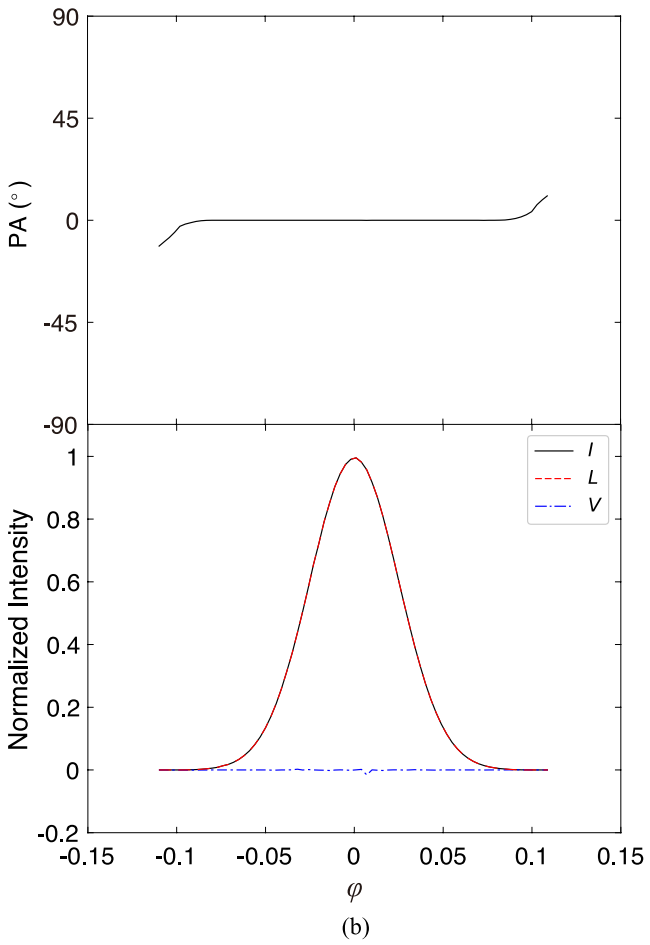
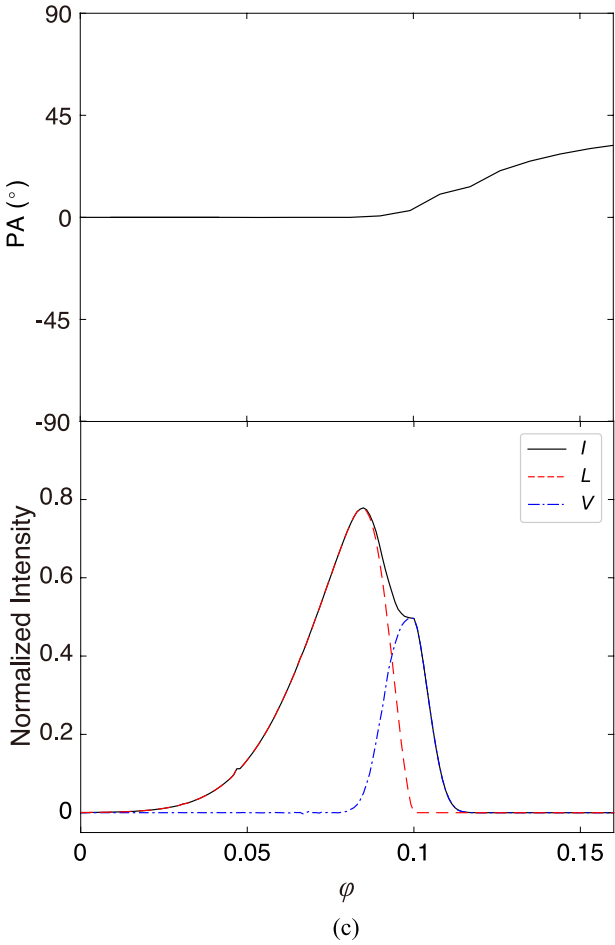


(b)



(c)

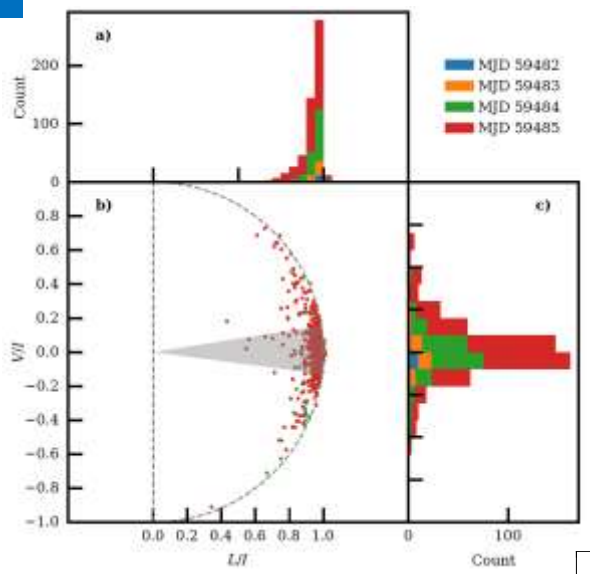
<V/I> = 25.4%

<V/I> = 0%

<V/I> = 25.4%

Thin bunch with $\varphi_t = 10/\gamma$

Observational Polarization



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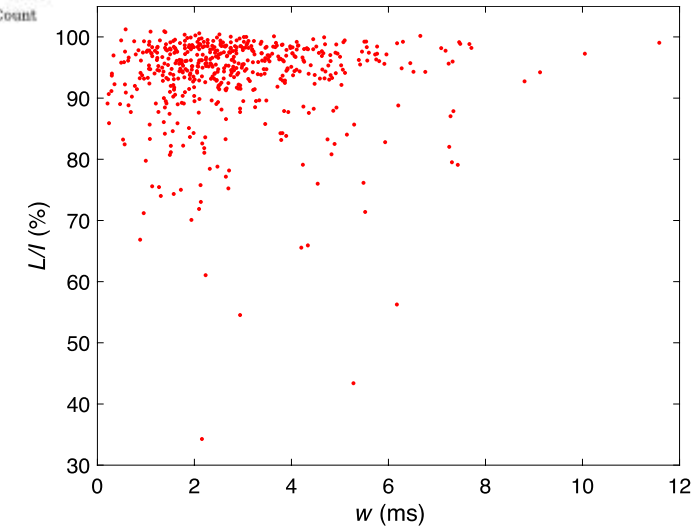
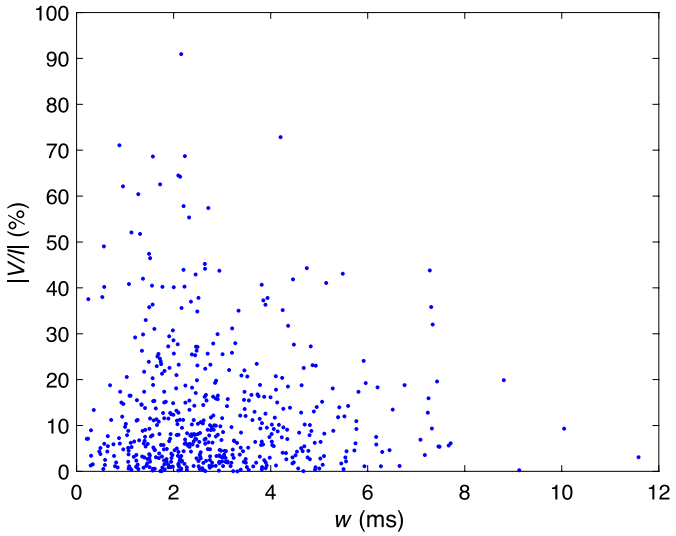
536 burst:

P/I > 90%: > 90%
V/I from 0 to 75%
Most have high LP

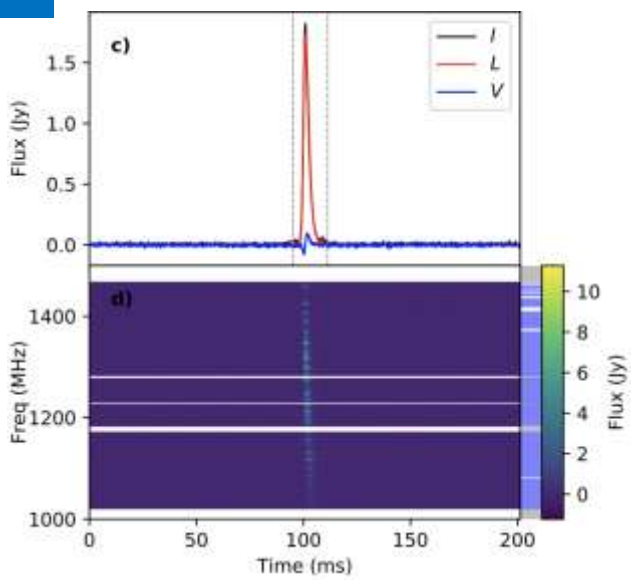


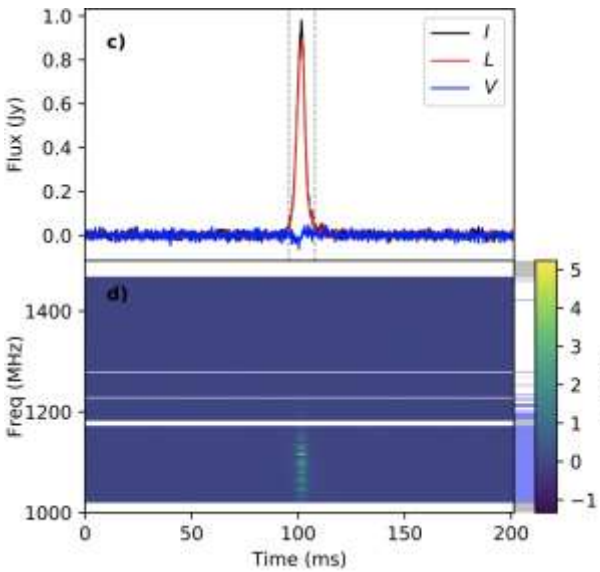


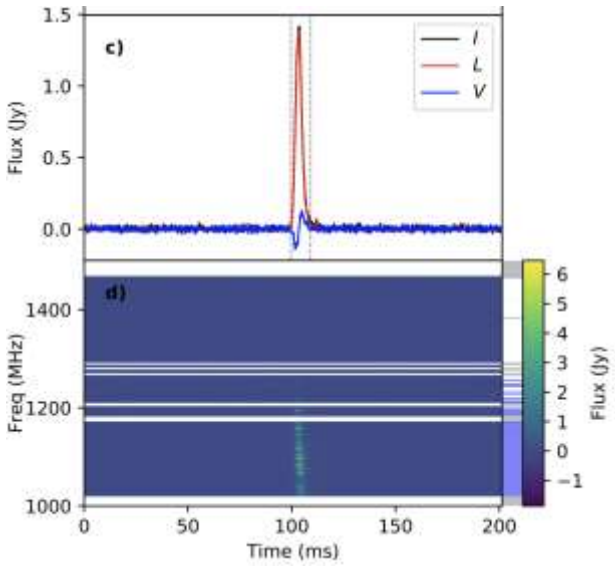
Thin bulk is most likely

Jiang et al. 2022

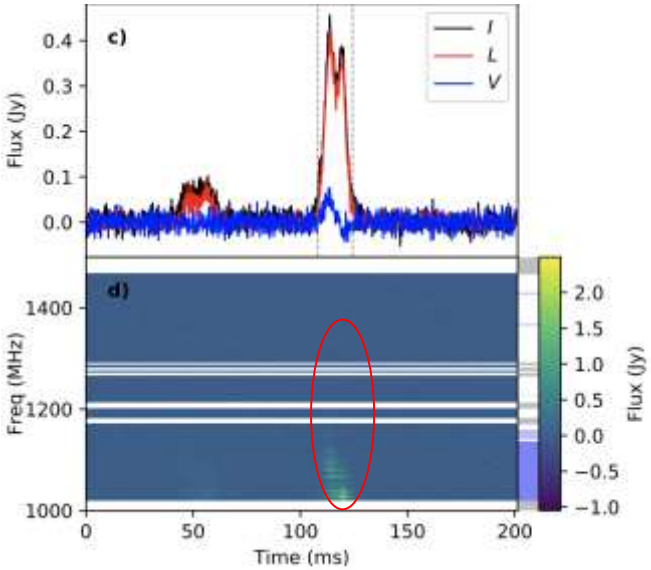
FRB 20201124A







3 among 536 bursts have sign change of CP!



Sub-pulse structure here
Not sign change within one pulse

Bunch length is not related to the opening angle

Jiang et al. 2022

Summary

Thanks !

- **Most** bunches seem to have opening angle, which is larger than 1/gamma. i.e., **thin bulk**.
- Rare chance for observing **sign change** of CP. Unless the central axis is located at the observation window.
- **High CP** is created within the **off-beam** case.
- Prediction: **No sign** change of CP could observe if <*V/I*> is larger than **60%.**
- **Propagation** effects may play a role: Stokes parameters **oscillate** with wavelength.