# Modeling of Abrupt Changes in Pulsar Pulse Profile




**Rai Yuen**

Radio Astronomy, Xinjiang Astronomical Observatory

**Don Melrose**

SIfA, the University of Sydney

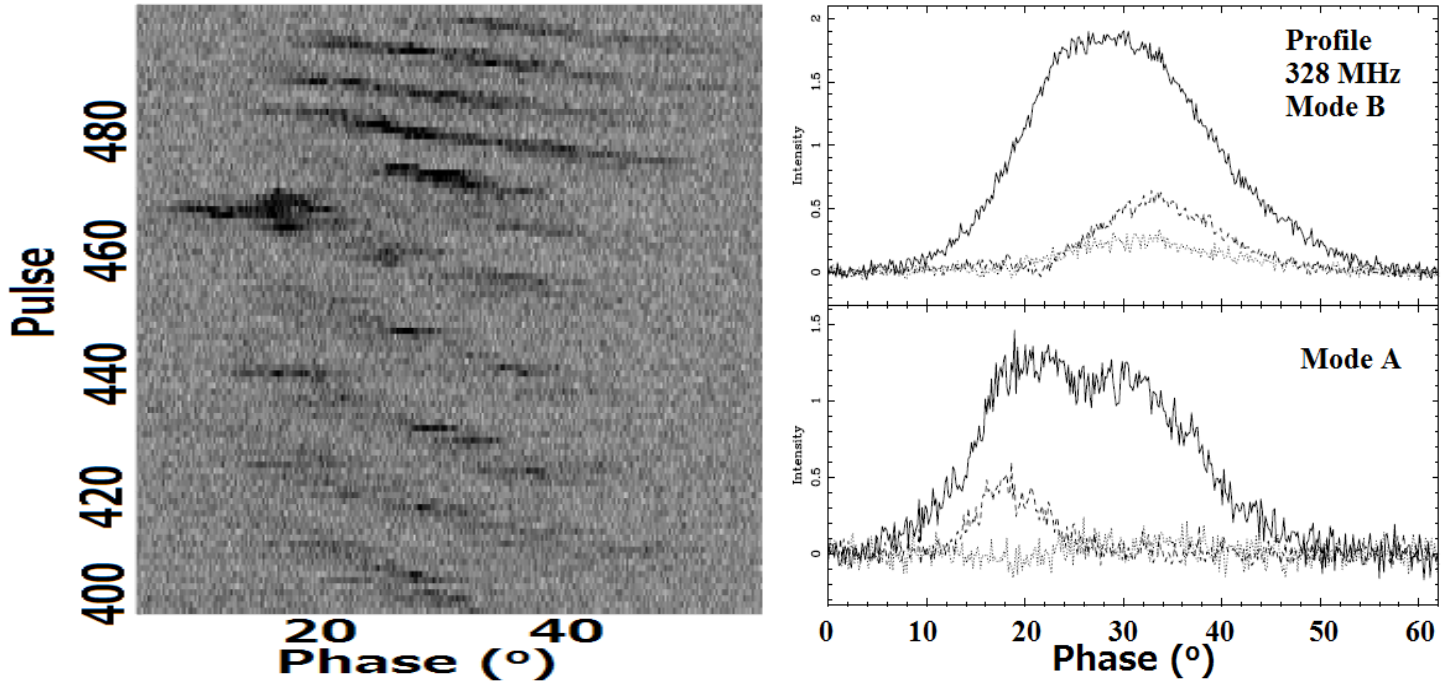

2017 Asia-Pacific Regional IAU Meeting, Taipei, Taiwan, 3–7 July 2017

# Outlines

- Phenomena showing changes of emission properties.
- Sketch a model for multiple-state magnetosphere.
- Illustrations for changes as result of switching between different magnetospheric states.

# What is changing?

- The phenomena:
  - ‘ON’ and ‘OFF’ emission (Kramer et al. 2006); correlation between pulse shape and the spin-down rate (Lyne et al 2010); nulling of 3 discrete timescales (Kerr et al. 2014)…
  - changes in emission mode → changes in subpulse drift rates → changes in profile properties (e.g., B0031-07, Smits et al. 2005)



# The need for more states

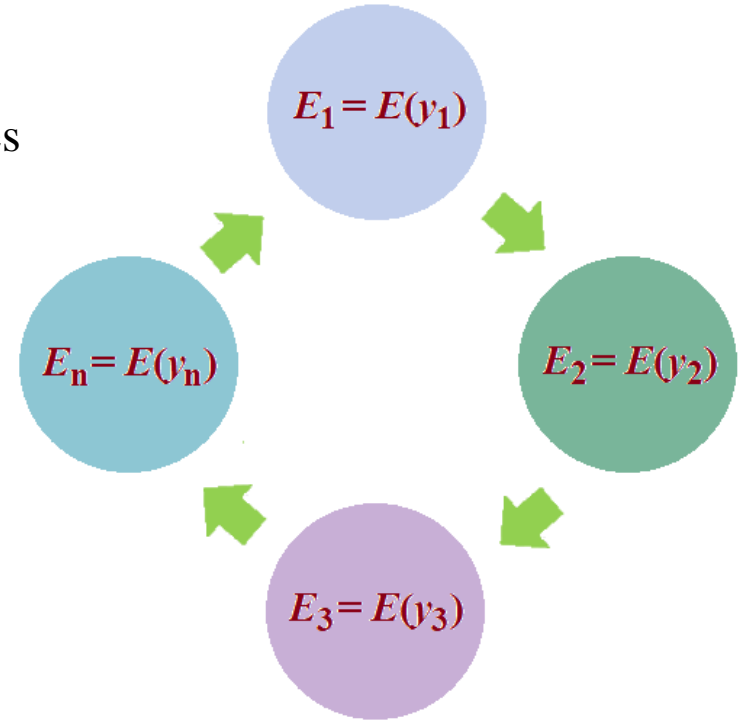
- Discrete variations in these emission properties imply:
  - multiple emission 'states' in the magnetospheres;
  - different pulsars have different sets of allowed states;
  - a pulsar behaves as if a 'normal' pulsar in each state.

- Let's give it more 'states':
  - multiple magnetospheric emission states ($y$) to switch into, and
  - each defined by unique $\boldsymbol{E} = \boldsymbol{E}(y)$;
  - switches between different states can occur **abruptly** or **steadily**.

# The need for more states

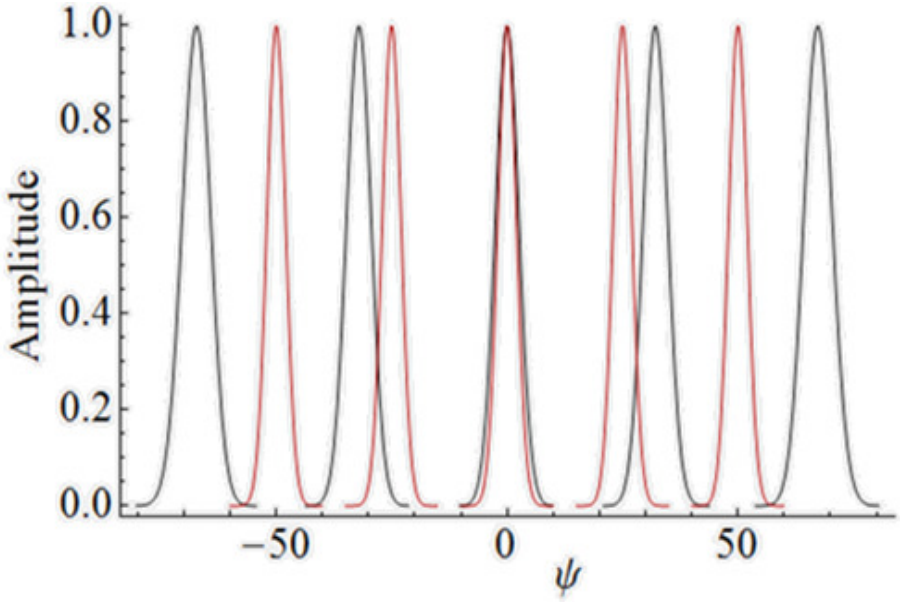
- Discrete variations in these emission properties imply:
  - multiple emission 'states' in the magnetospheres;
  - different pulsars have different sets of allowed states;
  - a pulsar behaves as if a 'normal' pulsar in each state.

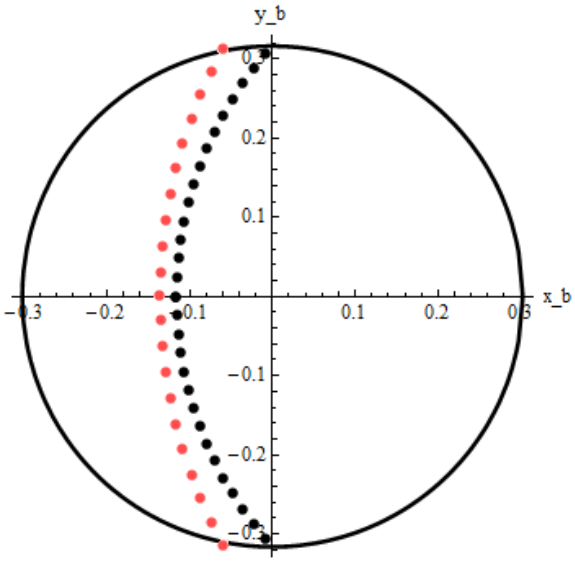
- Let's give it more 'states':
  - multiple magnetospheric emission states ($y$) to switch into, and
  - each defined by unique $\boldsymbol{E} = \boldsymbol{E}(y)$;
  - switches between different states can occur **abruptly** or **steadily**.



# Observing effects

- Apparent 'relative' subpulse drift: $\omega_{\mathrm{R}}(y) = m\omega_{\mathrm{dr}}(y) - \omega_{\mathrm{V}}$
- For $\omega_{\mathrm{V}} \neq 0$ or $\omega_{\mathrm{V}} = 0$ :
  - path through the polar region and duration of stay in the region are different.
  - profile displacement and broadening.



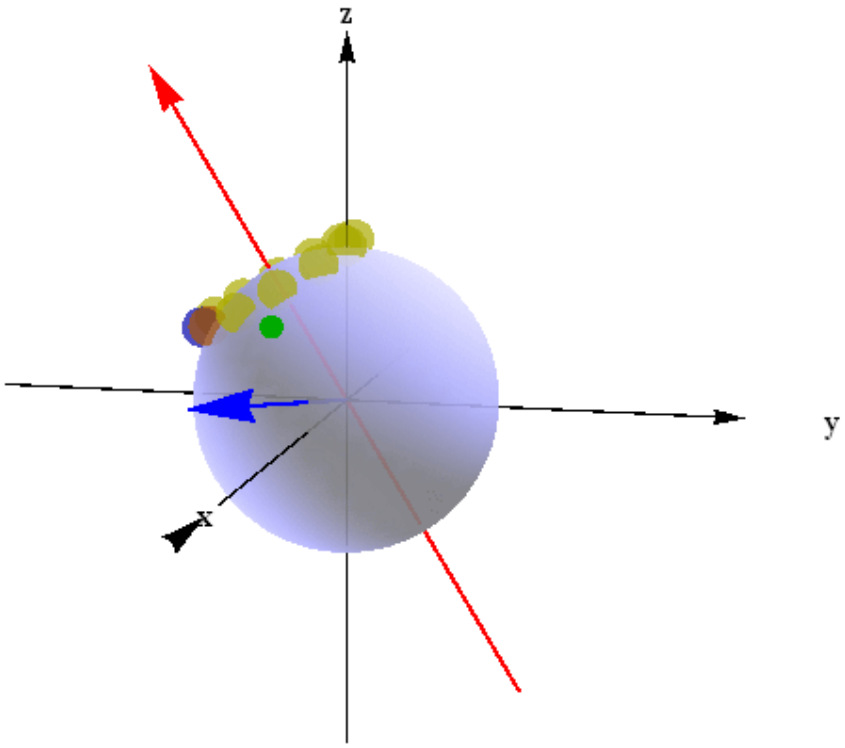



# Illustration: simple case

- A sudden switch in the magnetosphere, as reflected by a change in the subpulse drift rate, causes the profile characteristics to change.

| Emission spot | Peaks at $\psi = 0^o$ (blue) | |
|---|---|---|
| State | $\omega_V = 0$ | $\omega_V \neq 0$ |
| Pulse-width | $27^o$ | $35^o$ |
| Peak phase | $0^o$ | $0^o$ |

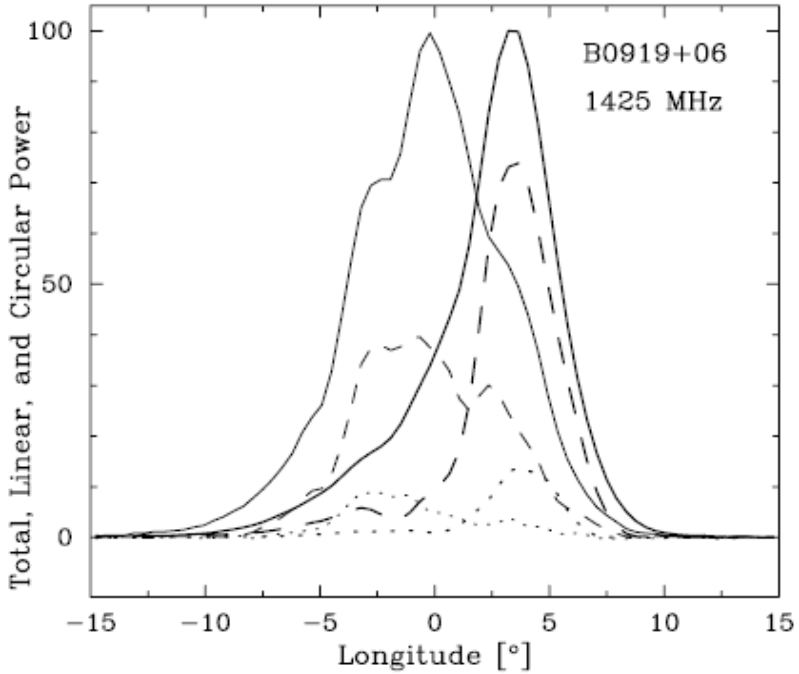
| Emission spot | Peaks at $\psi = -23^o$ (brown) | |
|---|---|---|
| State | drift $=0^o$ | drift $=50^o$ |
| Pulse-width | $35^o$ | $39^o$ |
| Peak phase | $-23^o$ | $-26^o$ |

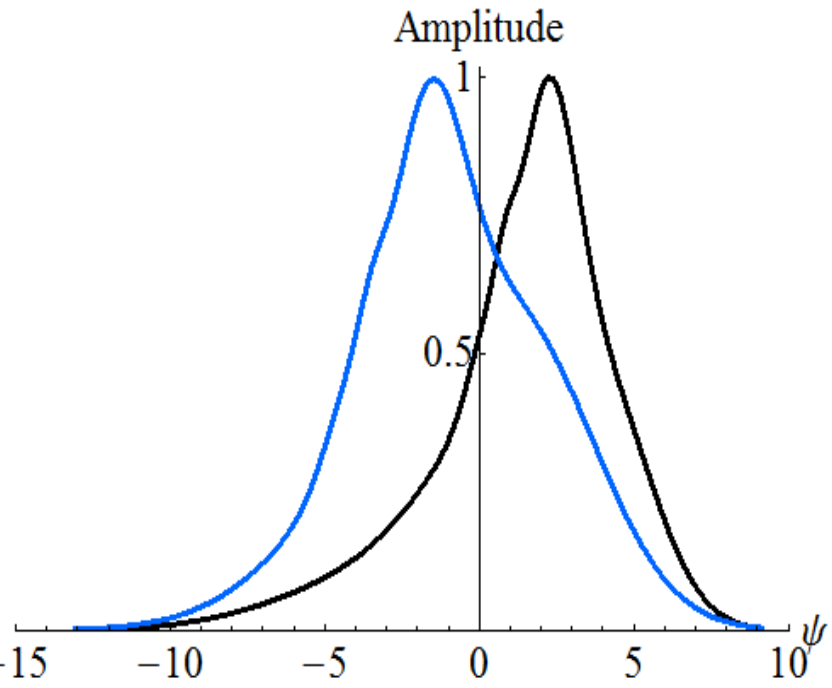


# Case study: B0919+06

- Switching in *y* from 0 to 0.42 results in (i) a shift in the profile peak by ~4°; and (ii) changes in the profile shape.
- Limitations of the model:
  - shifted profile shape indicate other mechanisms involved;
  - assume dipolar field structures.

(Rankin et al. 2006)



# Conclusions

*Things we don't understand… yet*

- **Cyclical switching:**
  - observations show recurring switching, or, in our language:

$$y_1 \rightarrow y_3 \rightarrow y_5 \rightarrow y_1 \ldots$$

  - can do it (simulationally), but don't know why it should (physically).
- **Pulsars that switch:**
  - traditional models make no distinction between pulsars with single and multiple states.
  - two groups of pulsars differ only in the switch rate: 'stable' corresponds to switching occurring too infrequently to have been observed.
- **Local vs global switching:**
  - implies whole magnetosphere switches simultaneously (through $E$).
  - e,g., synchronized changes in radio and γ–ray emission properties?

# Conclusions

*Things we don't understand… yet*

- **Cyclical switching:**
  - observations show recurring switching, or, in our language:

$$y_1 \rightarrow y_3 \rightarrow y_5 \rightarrow y_1 \ldots$$

  - can do it (simulationally), but don't know why it should (physically).
- **Pulsars that switch:**
  - traditional models make no distinction between pulsars with single and multiple states.
  - two groups of pulsars differ only in the switch rate: 'stable' corresponds to switching occurring too infrequently to have been observed.
- **Local vs global switching:**
  - implies whole magnetosphere switches simultaneously (through $E$).
  - e,g., synchronized changes in radio and γ–ray emission properties?

# Conclusions

*Things we don't understand… yet*

- **Cyclical switching:**
  - observations show recurring switching, or, in our language:

$$y_1 \rightarrow y_3 \rightarrow y_5 \rightarrow y_1 \ldots$$

  - can do it (simulationally), but don't know why it should (physically).
- **Pulsars that switch:**
  - traditional models make no distinction between pulsars with single and multiple states.
  - two groups of pulsars differ only in the switch rate: 'stable' corresponds to switching occurring too infrequently to have been observed.
- **Local vs global switching:**
  - implies whole magnetosphere switches simultaneously (through $\boldsymbol{E}$).
  - e,g., synchronized changes in radio and γ–ray emission properties?

# References


- Clemens & Rosen, 2004, *ApJ*, **609**, 340
- Demorest, et al., 2013 *ApJ* **762**, 94
- Goldreich & Julian, 1969 *ApJ* **157**, 869
- Kramer,  et al., 2006 *Science* **312**, 549
- Lyne, et al., 2010 *Science* **329**, 408
- Melrose & Yuen, 2014 *MNRAS* **437**, 262
- Rankin, et al., 2006 *MNRAS* **370**, 673
- Smits, et al., 2005, *A&A*, **440**, 683
- Yuen & Melrose, 2017, *MNRAS,* **469**, 2049

*Thank you.*