# A model of the emission from LS 5039 based on relativistic hydrodynamics

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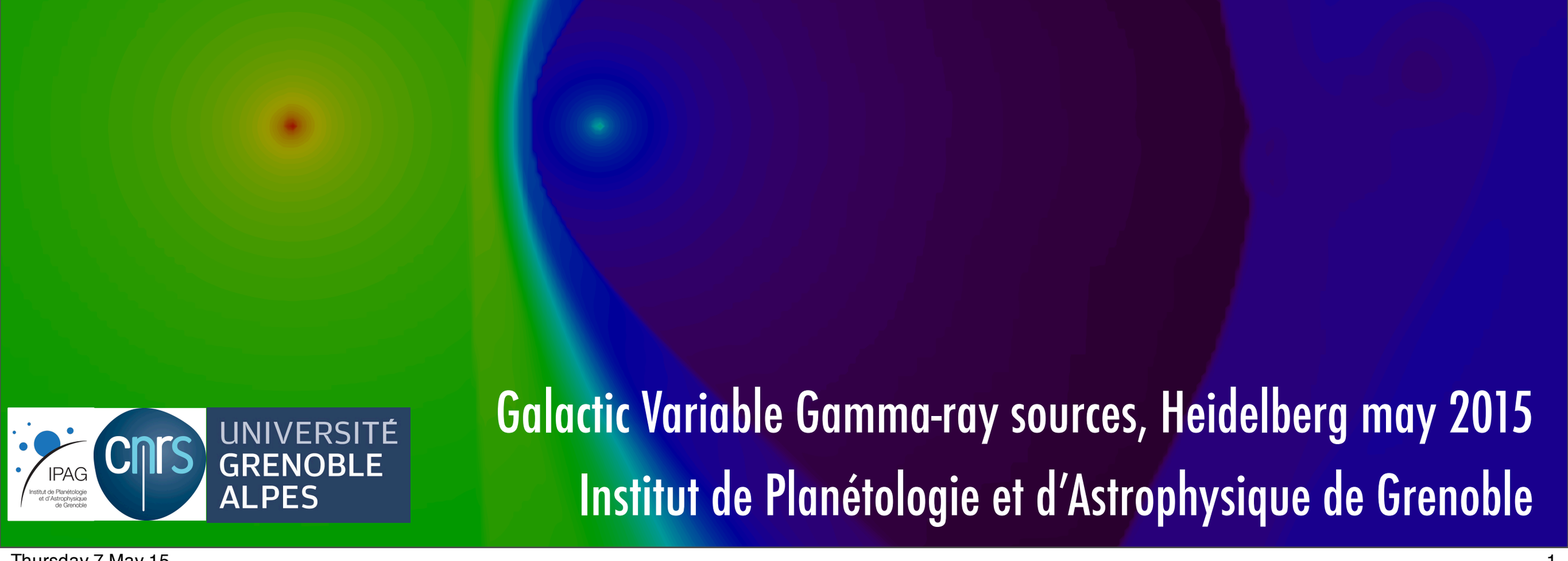
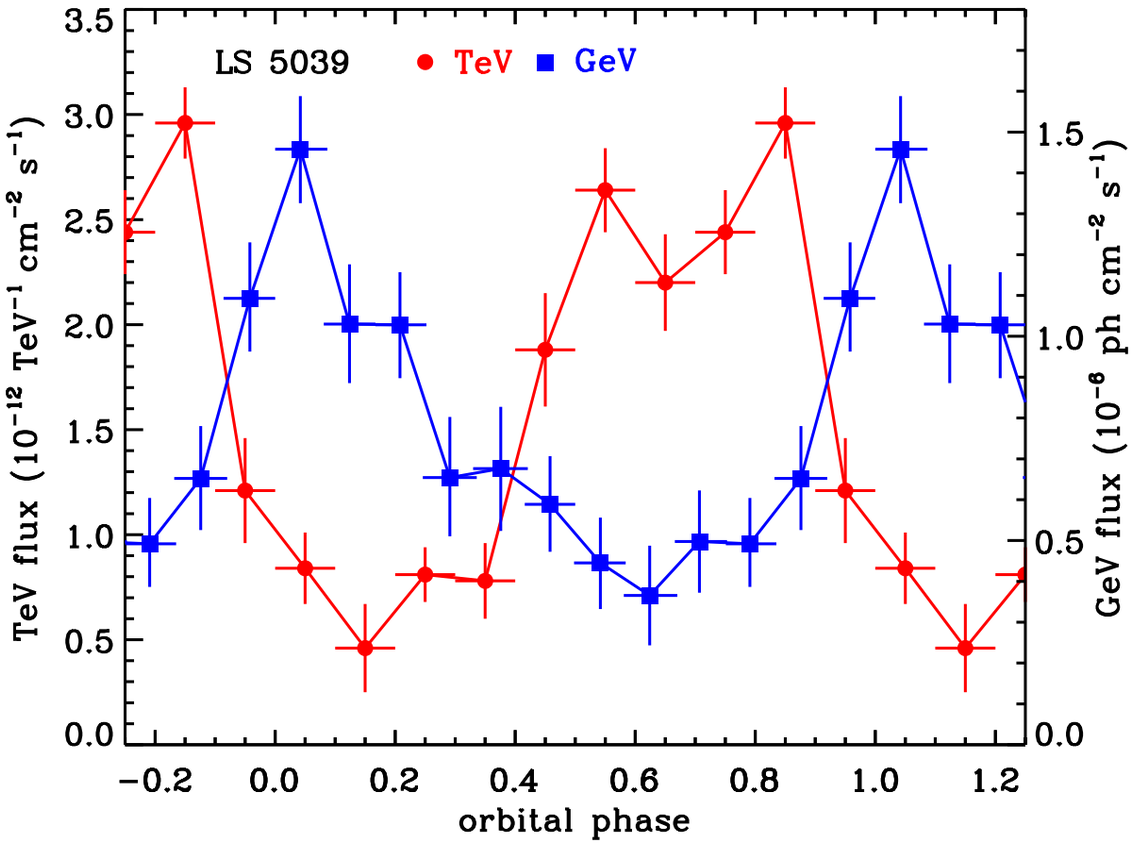
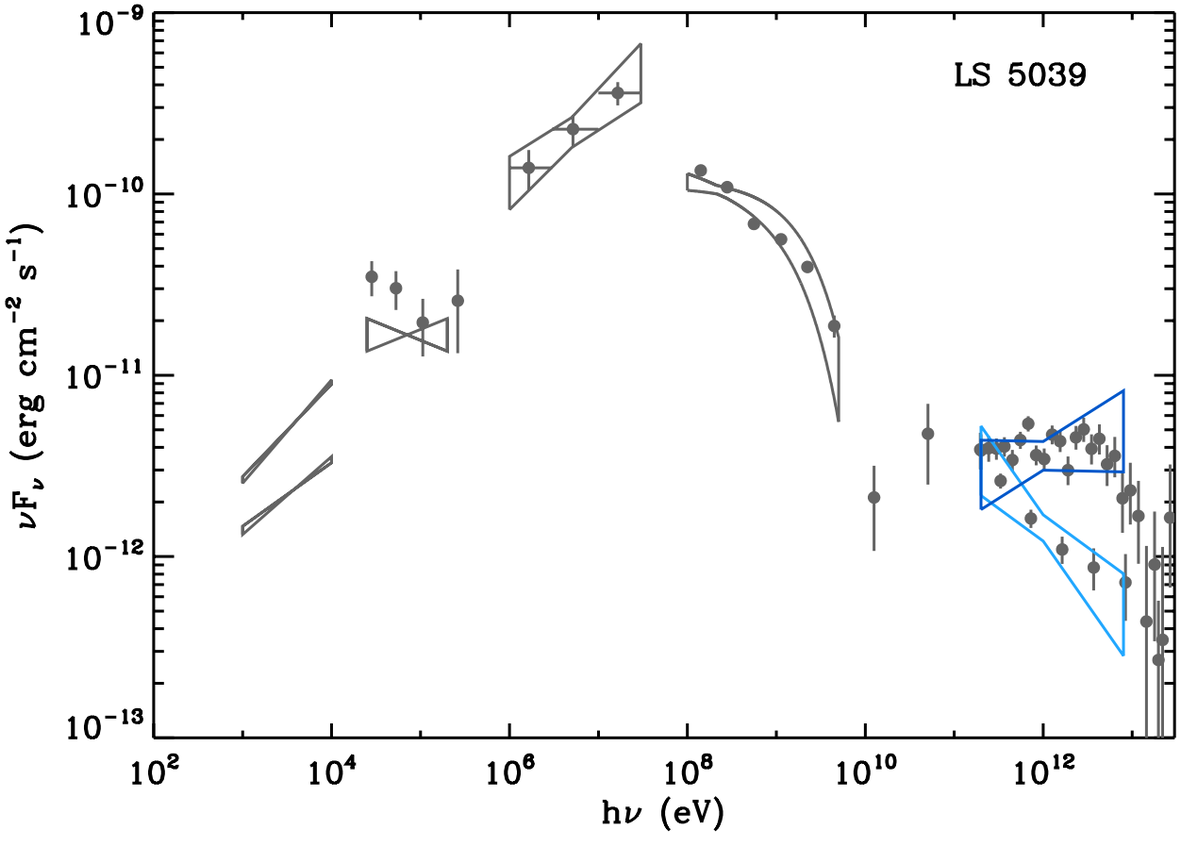


Galactic Variable Gamma-ray sources, Heidelberg may 2015
Institut de Planétologie et d'Astrophysique de Grenoble

# Well-established observations & ingredients




Orbital modulations and spectra well-known in LS 5039

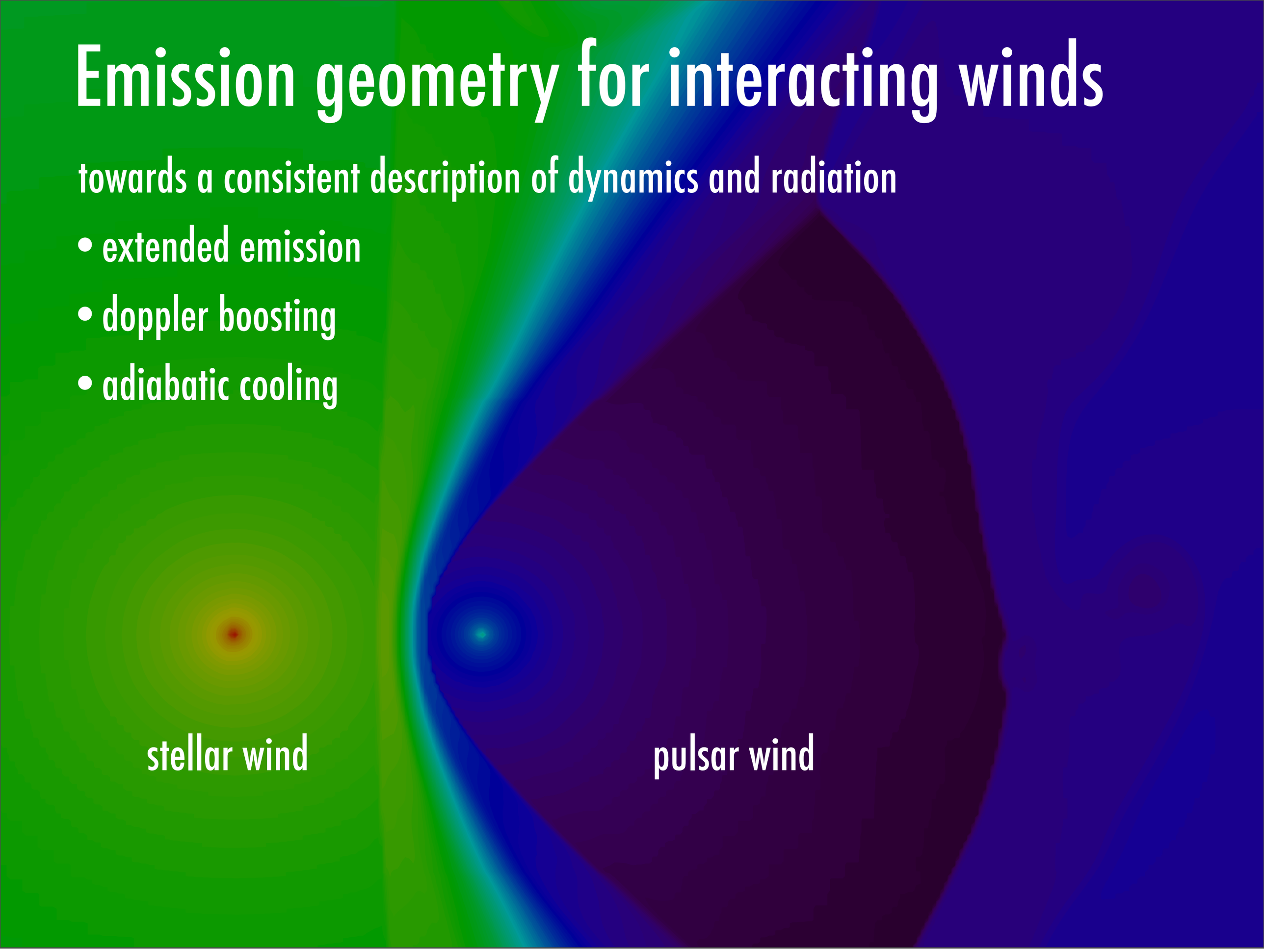
Generic ingredients: electrons + sync + IC + $\gamma\gamma$ + relativity

What is the recipe and what can it tell us about pulsar winds ?

# Emission geometry for interacting winds

towards a consistent description of dynamics and radiation

- extended emission
- doppler boosting
- adiabatic cooling



# The RHD simulation

- RAMSES relativistic hydrodynamics (Godunov+AMR+relativistic EoS)

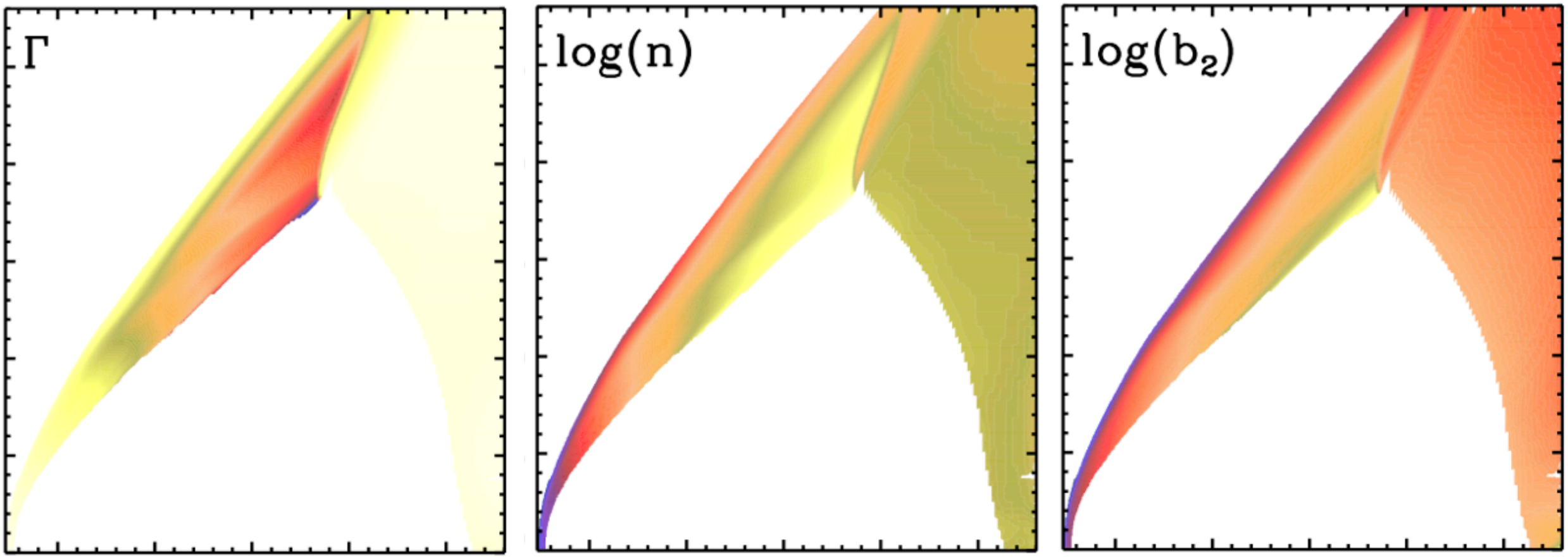
  ⇒ low pulsar magnetisation σ, no radiation feedback

$$\eta = 0.1 \left( \frac{\dot{E}}{8 \times 10^{35}\,\mathrm{erg\,s^{-1}}} \right) \left( \frac{2 \times 10^{-8}\,\mathrm{M_\odot\,yr^{-1}}}{\dot{M}} \right)$$

$$v_w = 2000\,\mathrm{km\,s^{-1}} \quad \Gamma_p = 7$$

- one 3D simulation rescaled with orbital separation (no orbital motion)
- HLL solver (numerical diffusion quenches Kelvin-Helmholtz)

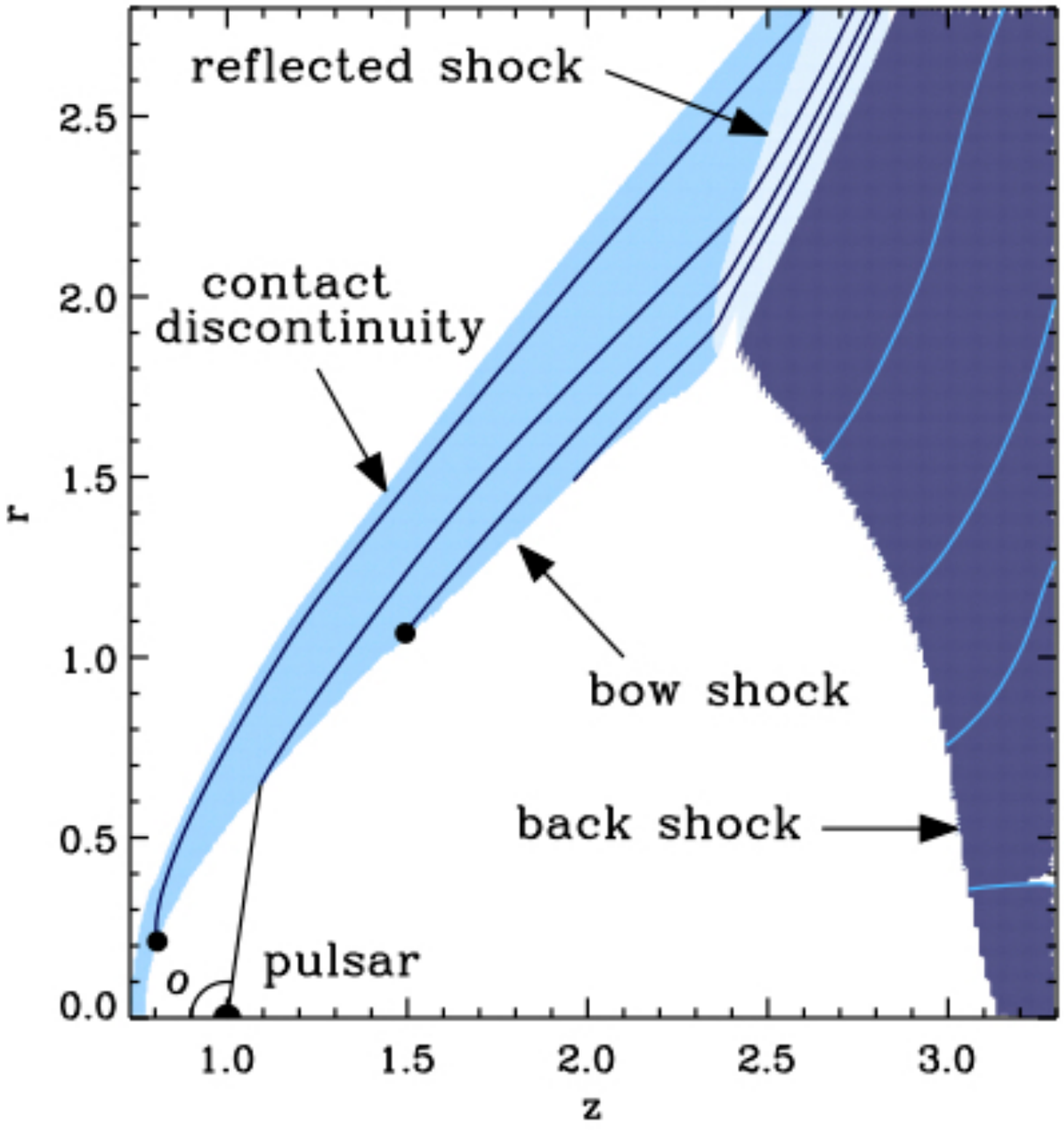
# Conditions in the shocked pulsar wind




$B \sim 1/d_p$ at (perpendicular) shock

induction equation in shocked region $\Rightarrow B \sim \Gamma n r$

# Particle evolution in a post-processing step




in units of orbital separation

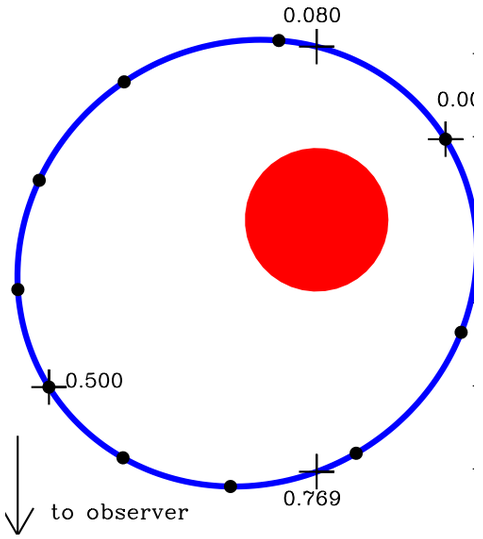
radiative & adiabatic cooling along streamlines with power law injection along shock:

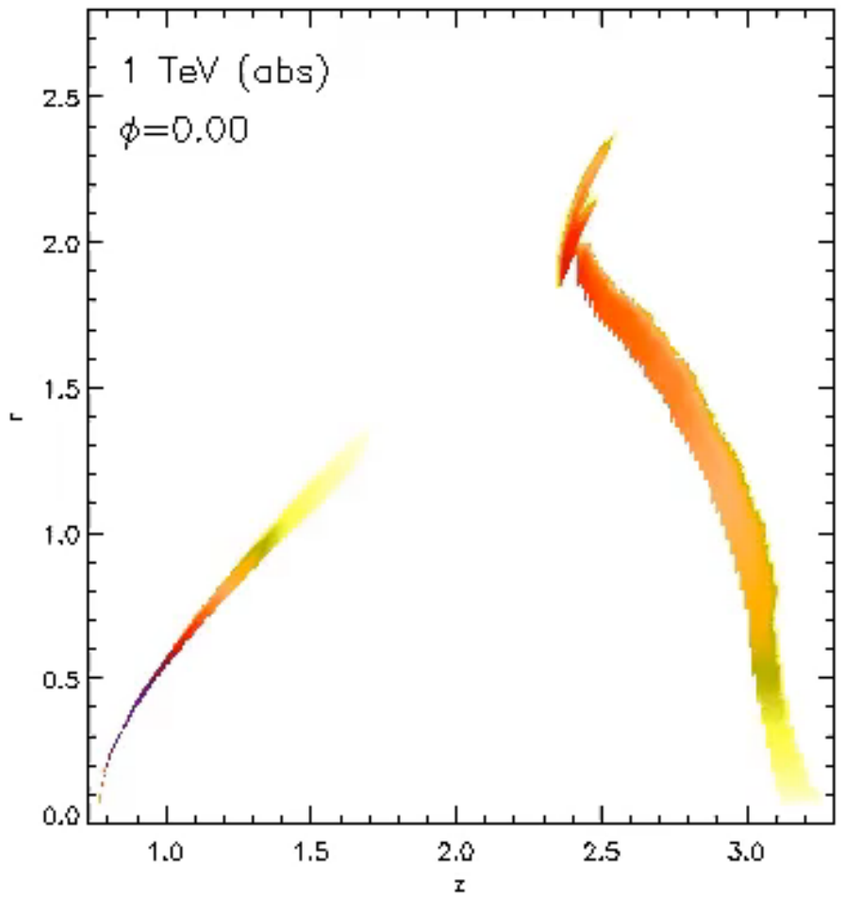
- normalised to local density
- $E_{max}$ given by $\tau_{acc}=\tau_{rad}$
- $E_{min}$ derived from local pressure
- same slope everywhere

G. Dubus, Heidelberg May 2015

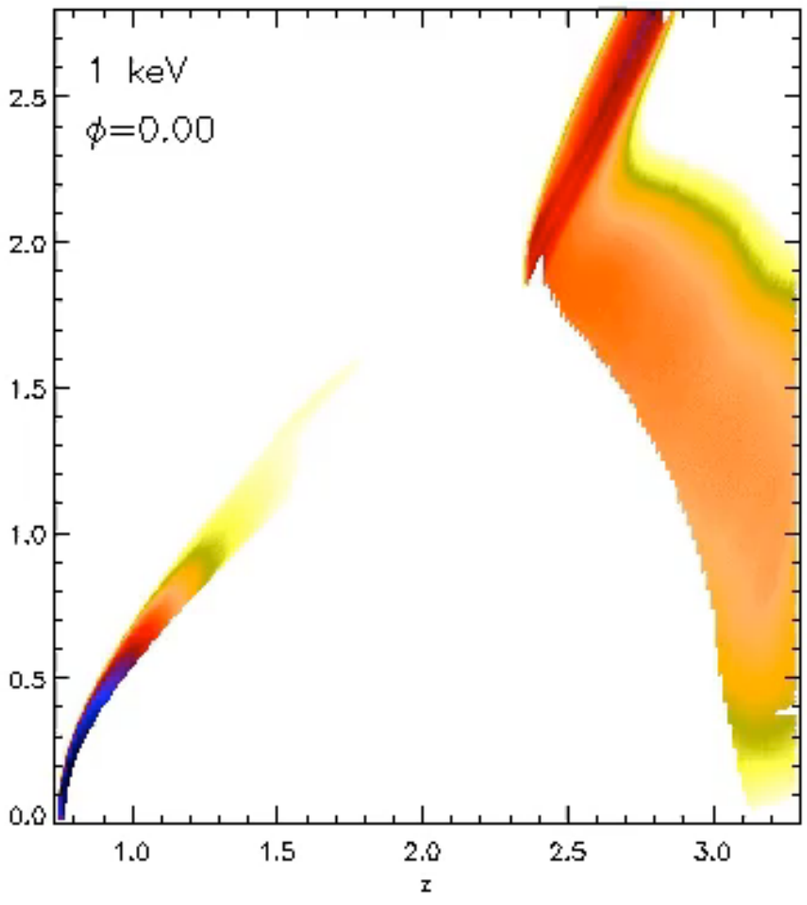
# Emission from the particles

- 3D calculation including relativistic effects, synchrotron, anisotropic IC scattering & pair production on stellar photons.
- phase-dependent spectra & orbital modulation




in units of orbital separation




in units of orbital separation

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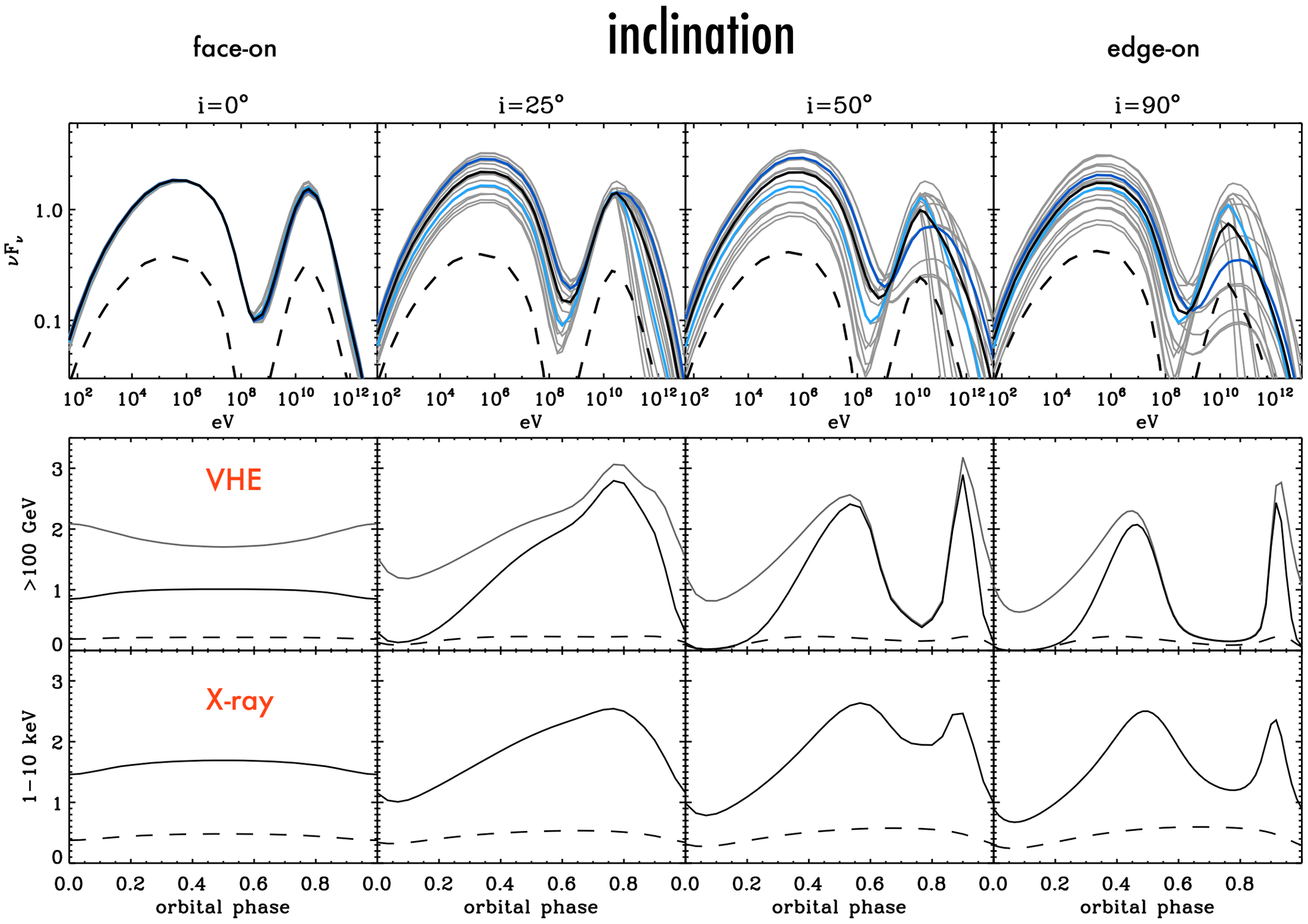
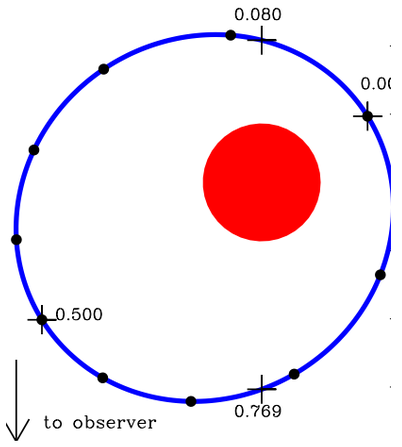
# Doppler boosting shapes the modulation




infc

supc

avg

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# Influence of other parameters

infc
supc

## magnetic field

σ

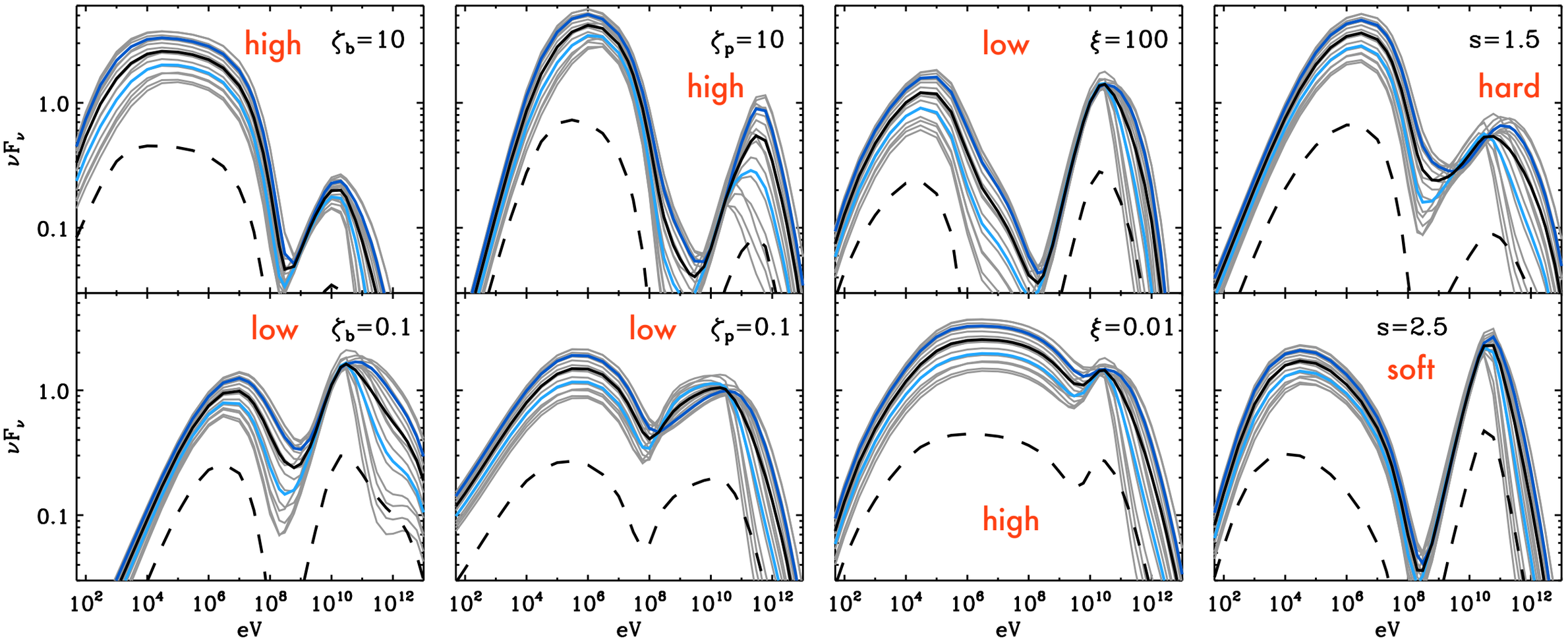
## $E_{min}$

pulsar power

## $E_{max}$

acceleration efficiency

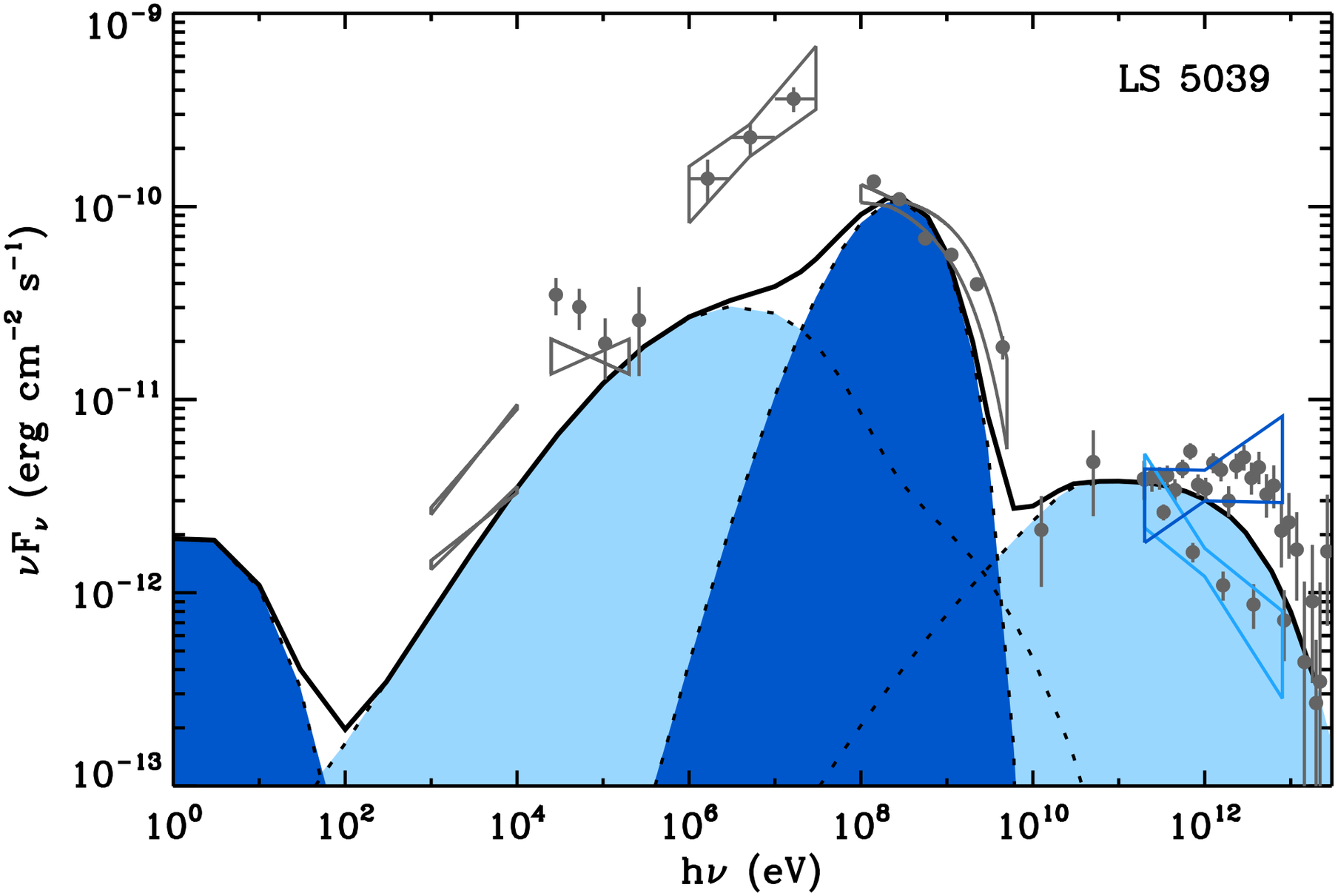
## slope




Tough to reproduce hard VHE spectrum + level of X-ray emission in LS 5039

# Two-component model of LS 5039

Power-law with hard slope $E^{-1.5}$ + Maxwellian with $\Gamma \approx 5000$

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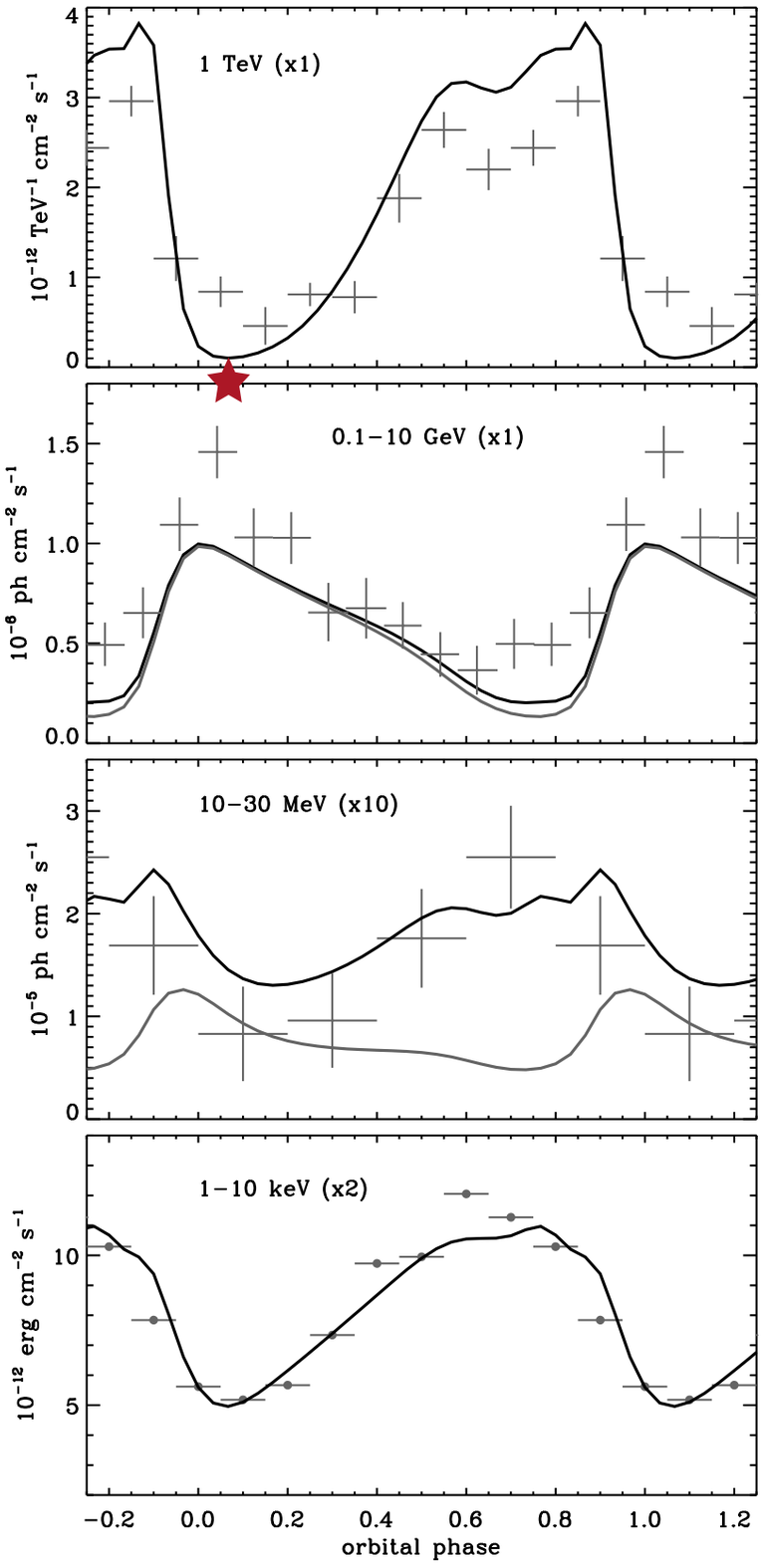
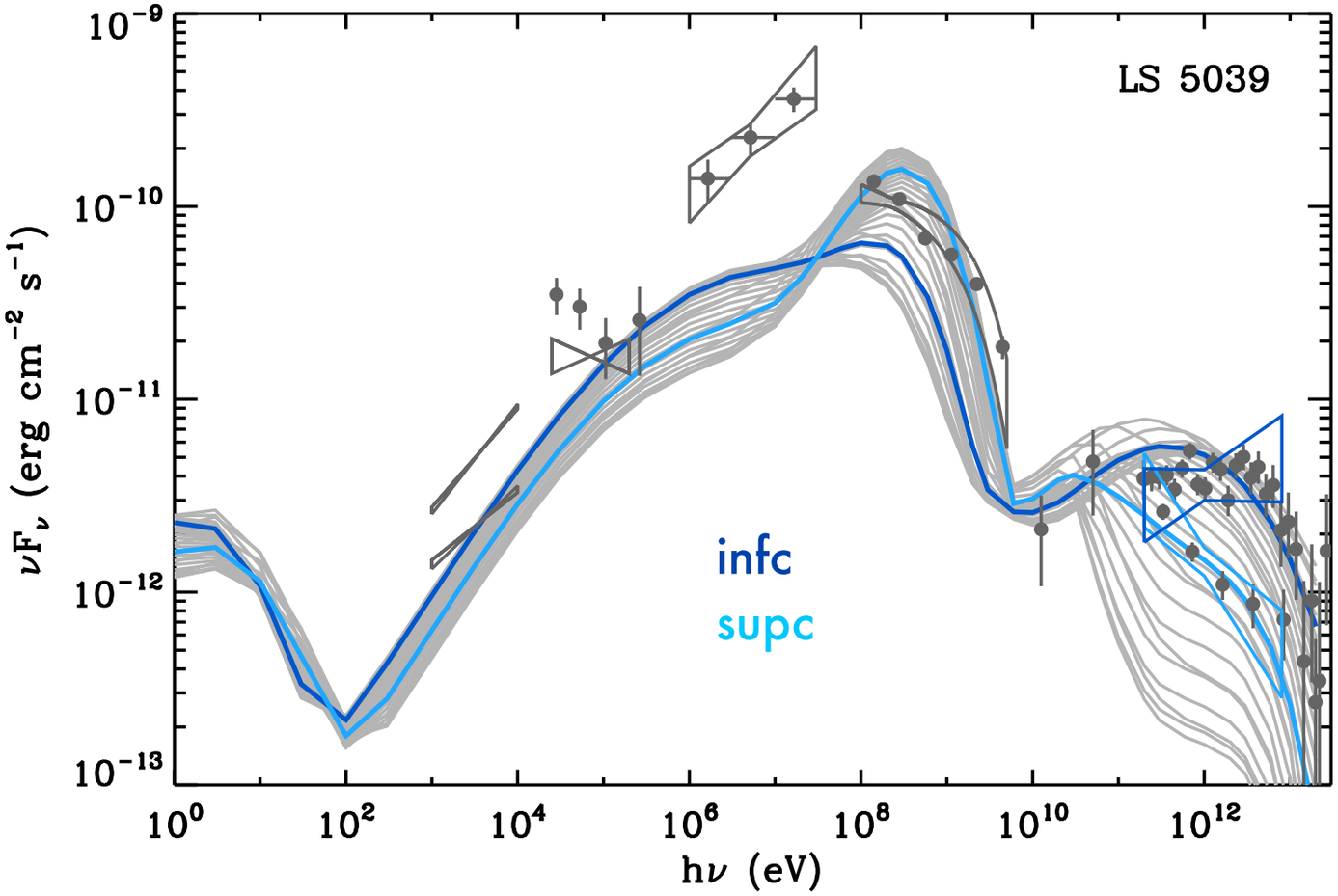
# Orbital variability in reasonable agreement




- modulation set by Doppler boost ⇒ $i \approx 35^0$

(for $\eta$=0.1)

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# A RHD-based model of LS 5039's emission

- power-law is radiatively efficient, adiabatic cooling negligible
- 88% of the energy in radiatively-inefficient Maxwellian
- total $E_p \approx 10^{35}$ erg $s^{-1}$, lower than expected (low stellar wind mass loss?)

- pulsar wind magnetisation $\sigma \approx 1$
- points to shock driven reconnection in equatorial plane (e.g. Sironi & Spitkovsky 2011)

- wish list: RMHD, location-dependent acceleration, orbital motion

Dubus, Lamberts, Fromang et al. 2015 (arXiv:1505.01026)