COMBINING INTERFEROMETRIC MEASUREMENTS WITH HYDRODYNAMIC SIMULATIONS TO UNDERSTAND THE COLLIDING WIND BINARY γ^2 VELORUM

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WINDS IN MASSIVE STARS

Radiation pressure on lines :

- v~ 2000 km s^{-1} $\longrightarrow$ highly supersonic
- $10^{-8} < \dot{M} < 10^{-4}\, M_{\odot}\, yr^{-1}$
- $3 \times 10^4 < T < 8 \times 10^4$

Crucial for stellar evolution and interstellar medium

Most (all ?) massive stars are in (close) binaries
-> wind interactions matter

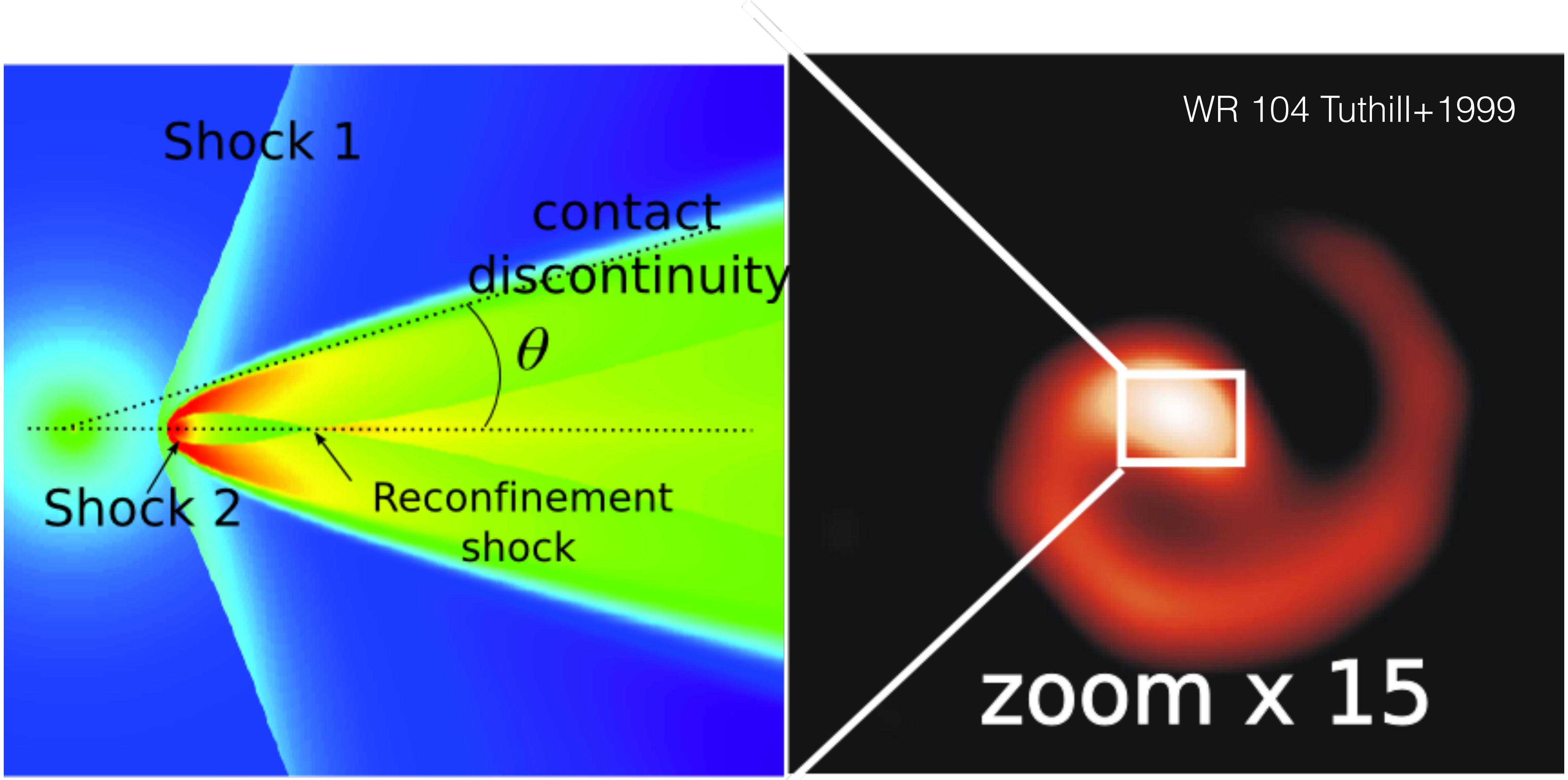
OBSERVING COLLIDING STELLAR WINDS

thermal X-ray emission
line variability (IR, UV, X-rays)
non-thermal radio emission
infrared emission if dust

} Wind structure at given distance

Explain structure : instabilities, radiative effects
Explain variability
Explain dust formation

HYDRODYNAMICS OF COLLIDING WIND BINARIES

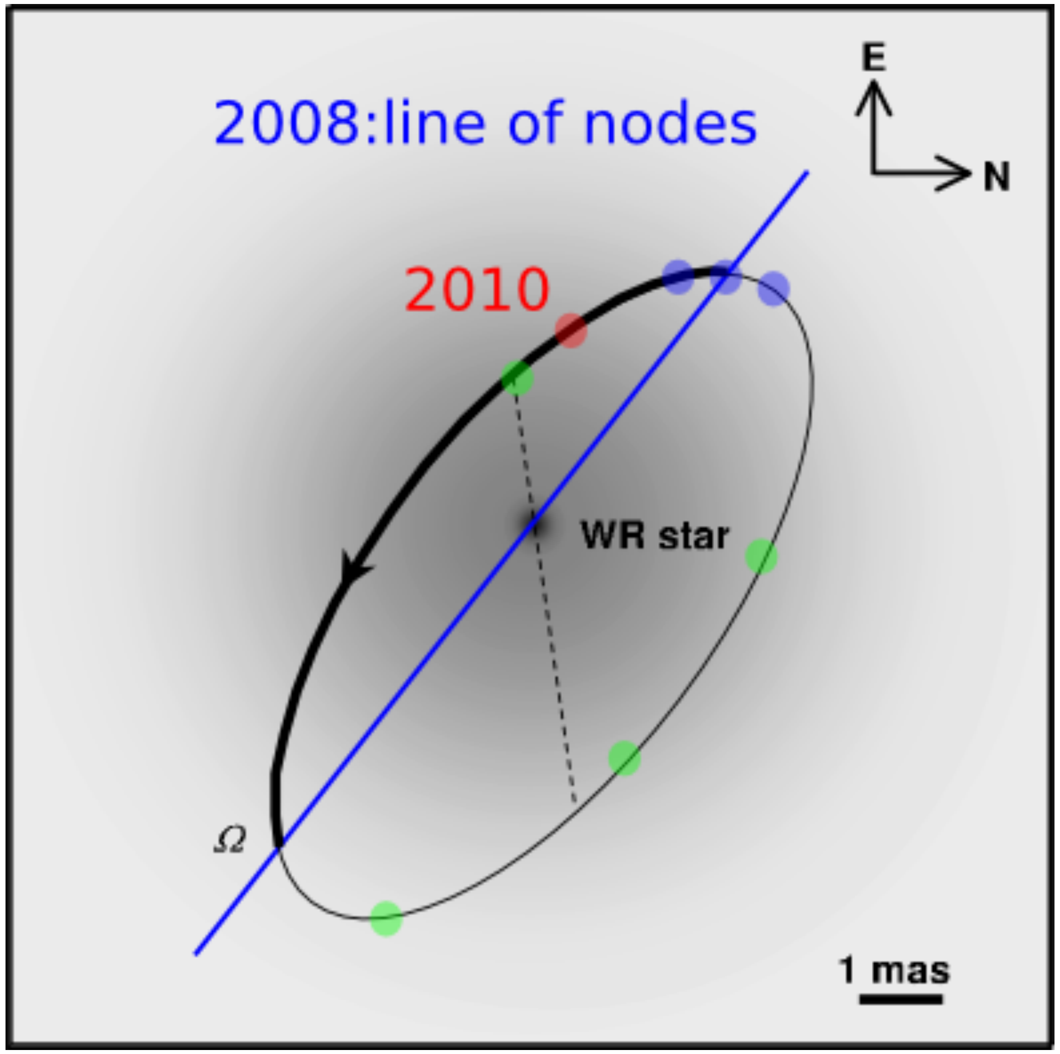


Structure set by $\eta = \frac{\dot{M}_1 v_1}{\dot{M}_2 v_2}$

γ² VELORUM

- closest WR +O5 binary
- P=78 d, e =.3, i=65°
- radio : $\dot{M}_{WR}$ 8 10^{-6} M_{sun} yr^{-1}
- IR : not dust production
- optical/UV: detection of wind collision region, probably with radiative braking (StLouis+1993; DeMarco+2002)

7 observations over 10 years,
2 high resolution phases

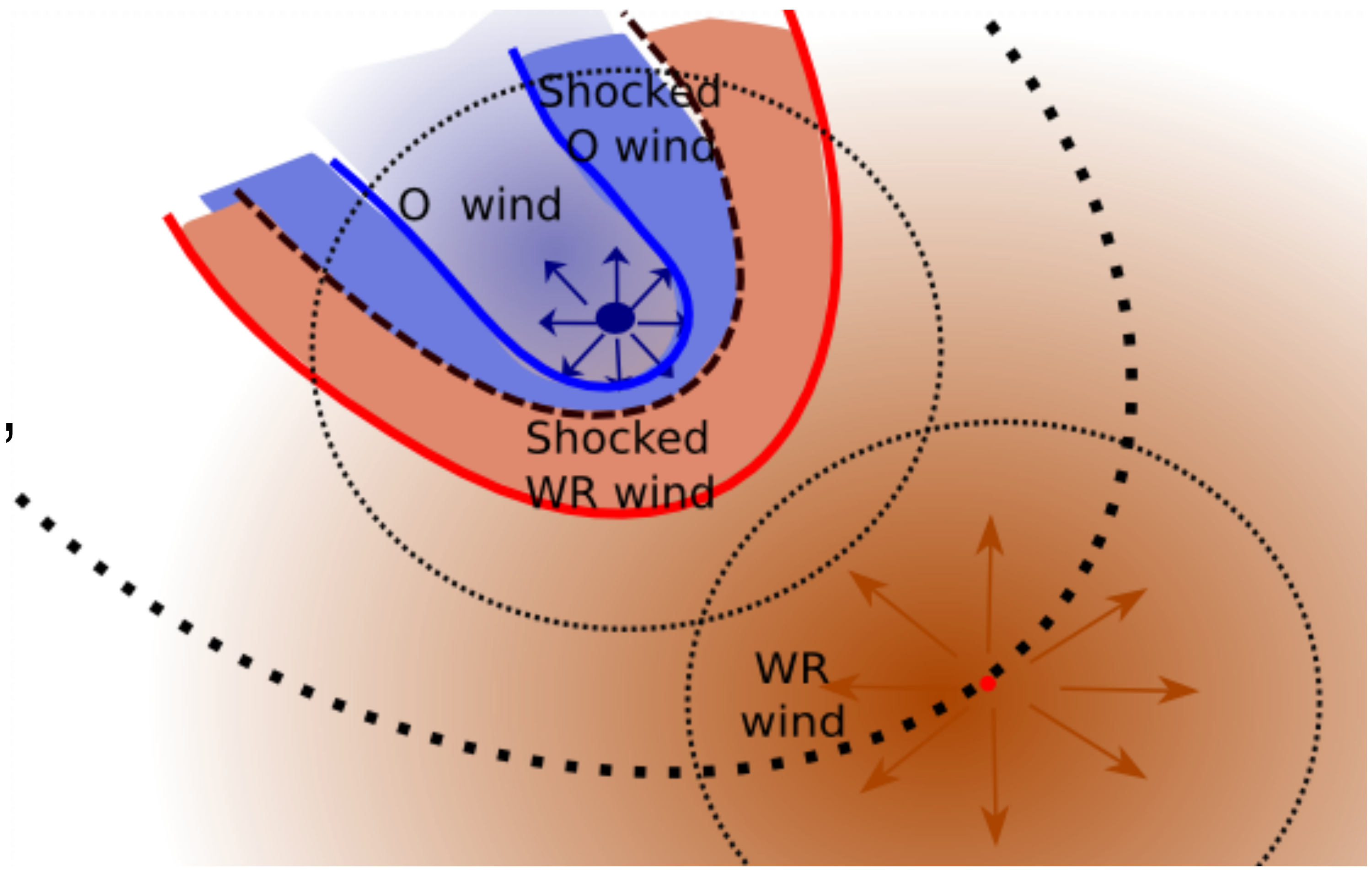


observed orbital phases (Lamberts+ to be subm.)

VLTI/AMBER OBSERVATIONS

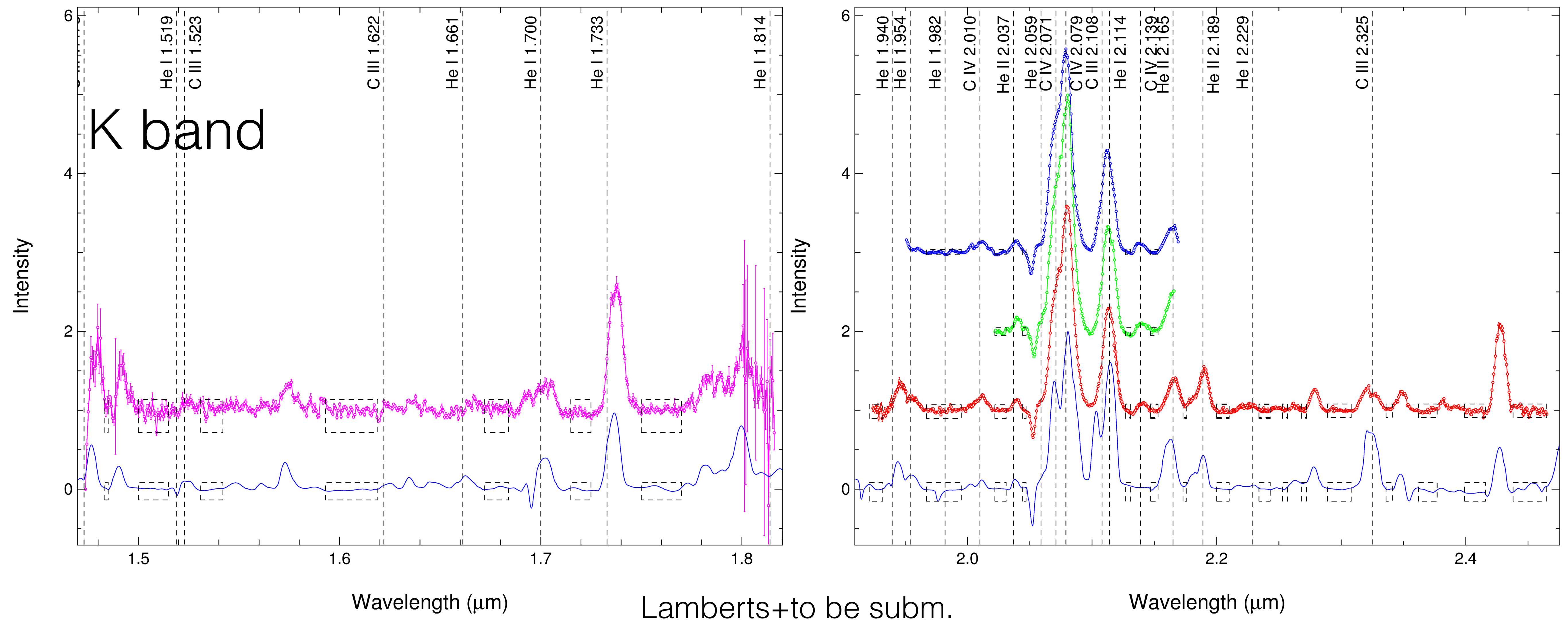
H, K bands,
$\Delta\lambda_{max}/\lambda = 12000$

low resolution full orbital coverage+high resolution, high SNR data



Provides spatial information: brightness ratio, angular sizes (continuum + lines), combined spectra

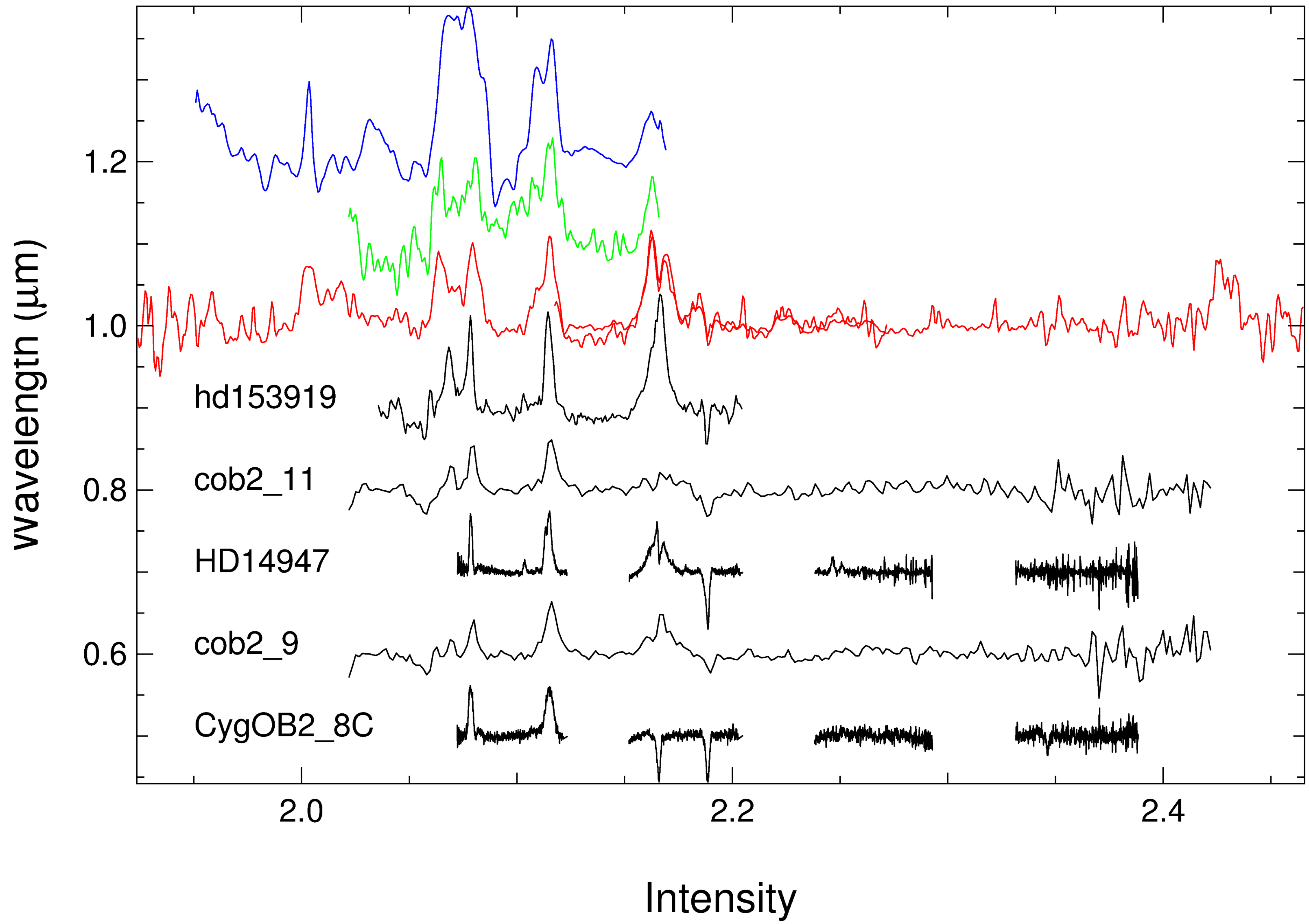
WR SPECTRUM



broad C IV and He II lines

Identification as WC8 with CMFGEN template

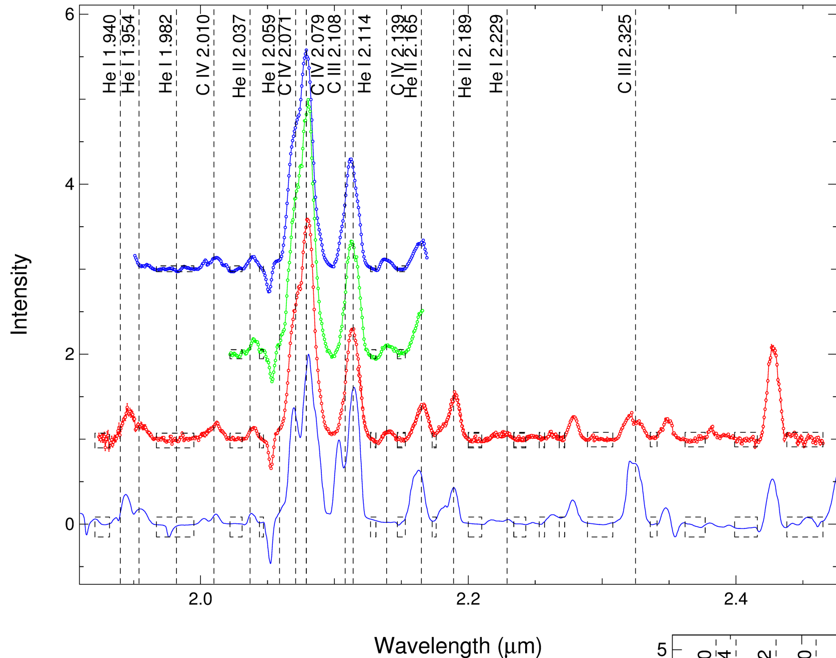
O STAR SPECTRUM



He, Ca, N,
H Brackett

Strong variability, similarities with X-ray binary -> presence of hot shocked material, identification as O5 If

IDENTIFYING THE WIND COLLISION REGION



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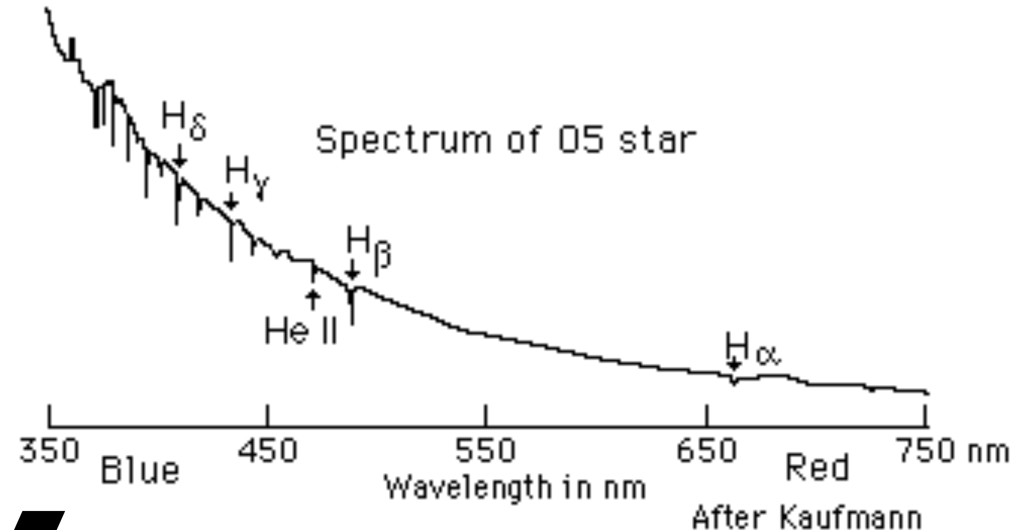

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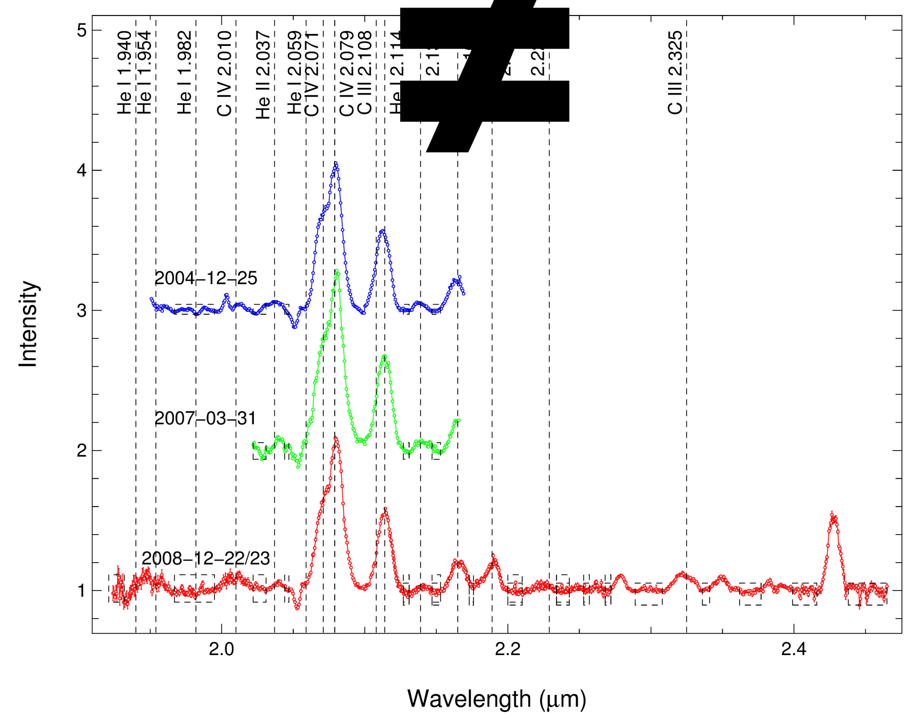
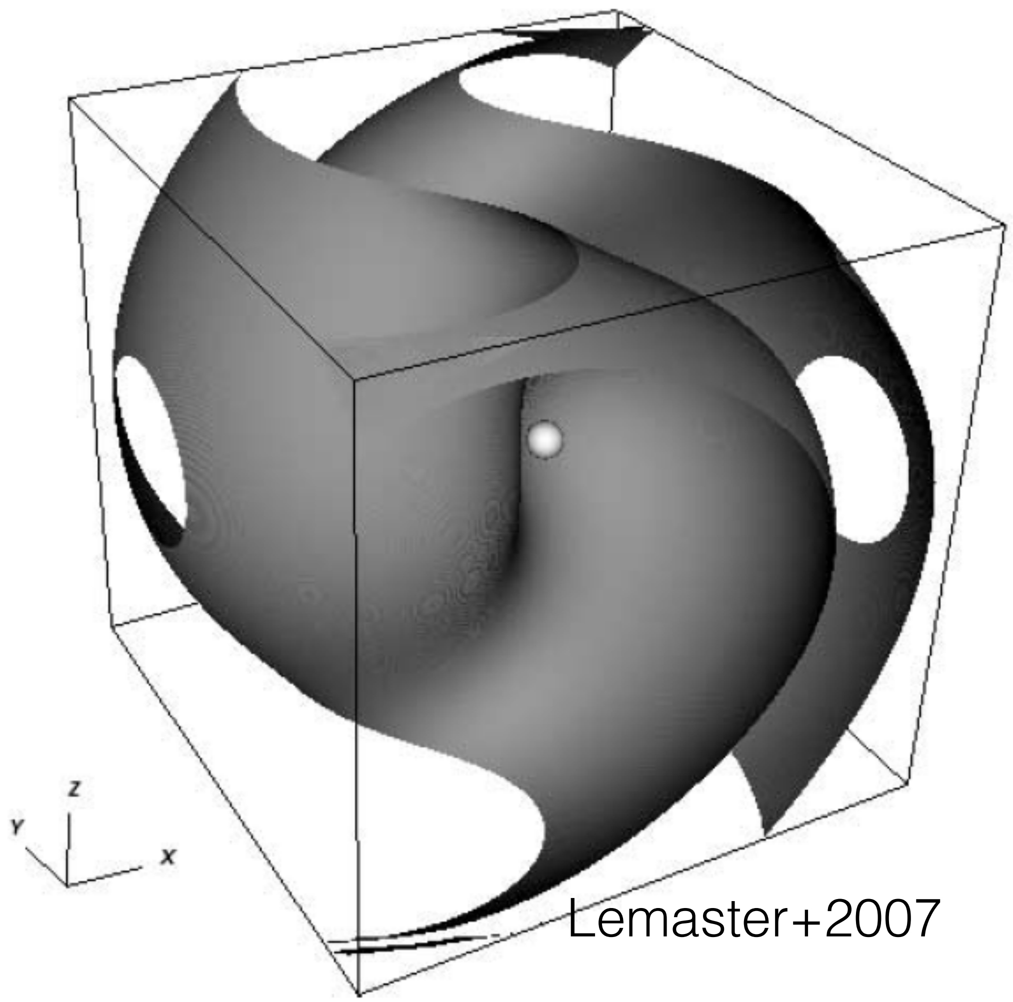


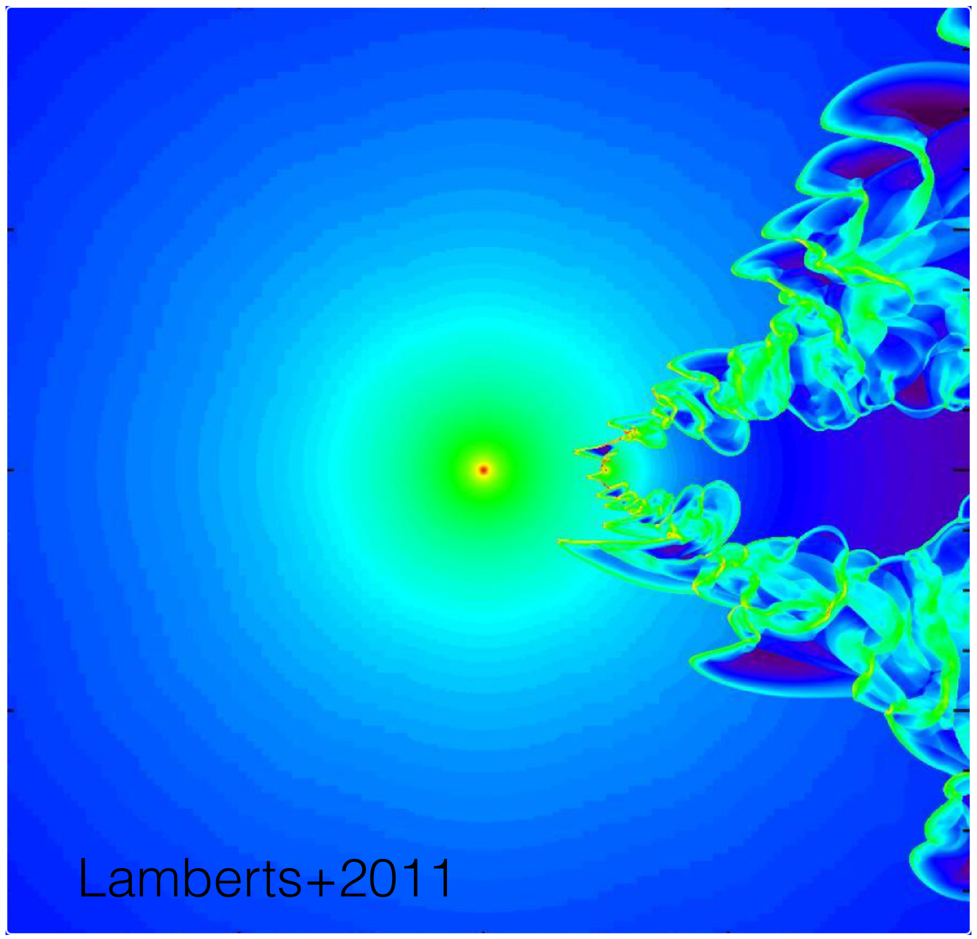
2 point sources model fails -> wind collision region? (Millour+2007)

Possibility to constrain if wind collision region well understood

POWER OF HYDRODYNAMIC SIMULATIONS



Lemaster+2007

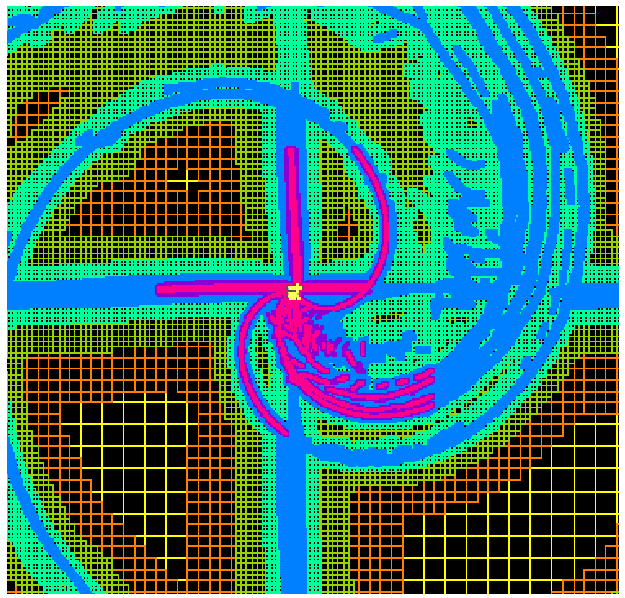


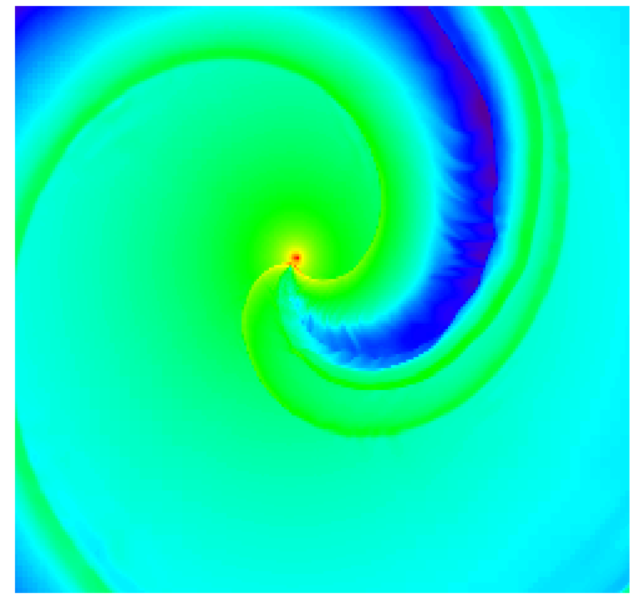
Lamberts+2011

Large scale 3D structure
Instabilities

SIMULATIONS WITH RAMSES

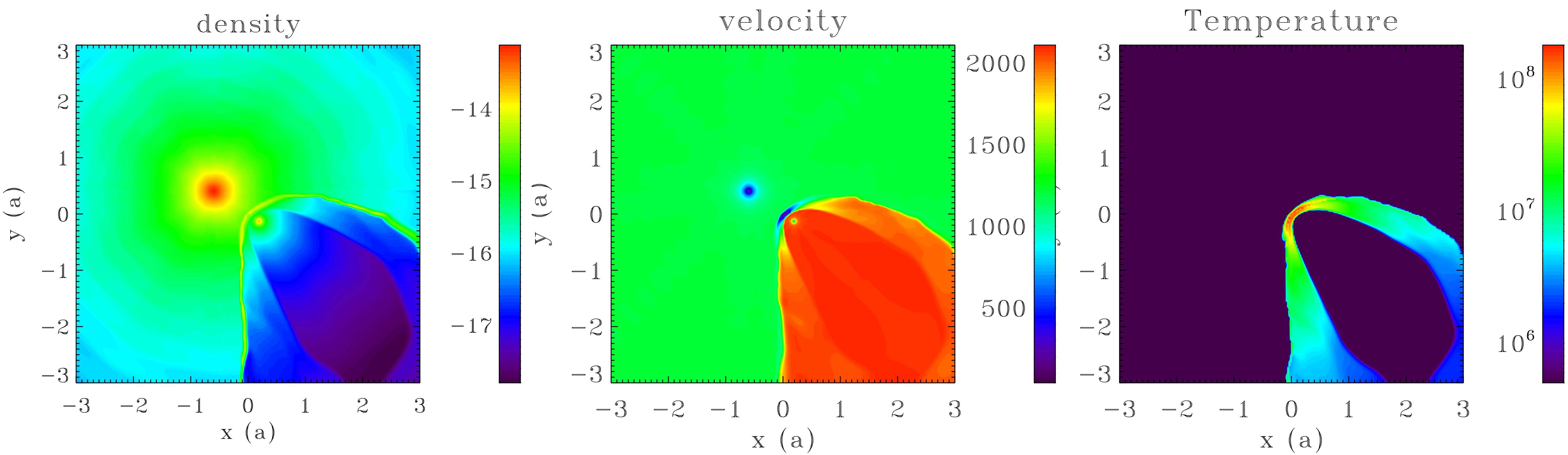
RAMSES (Teyssier+2002) solves hydro with adaptive mesh (AMR) -> great for discontinuities





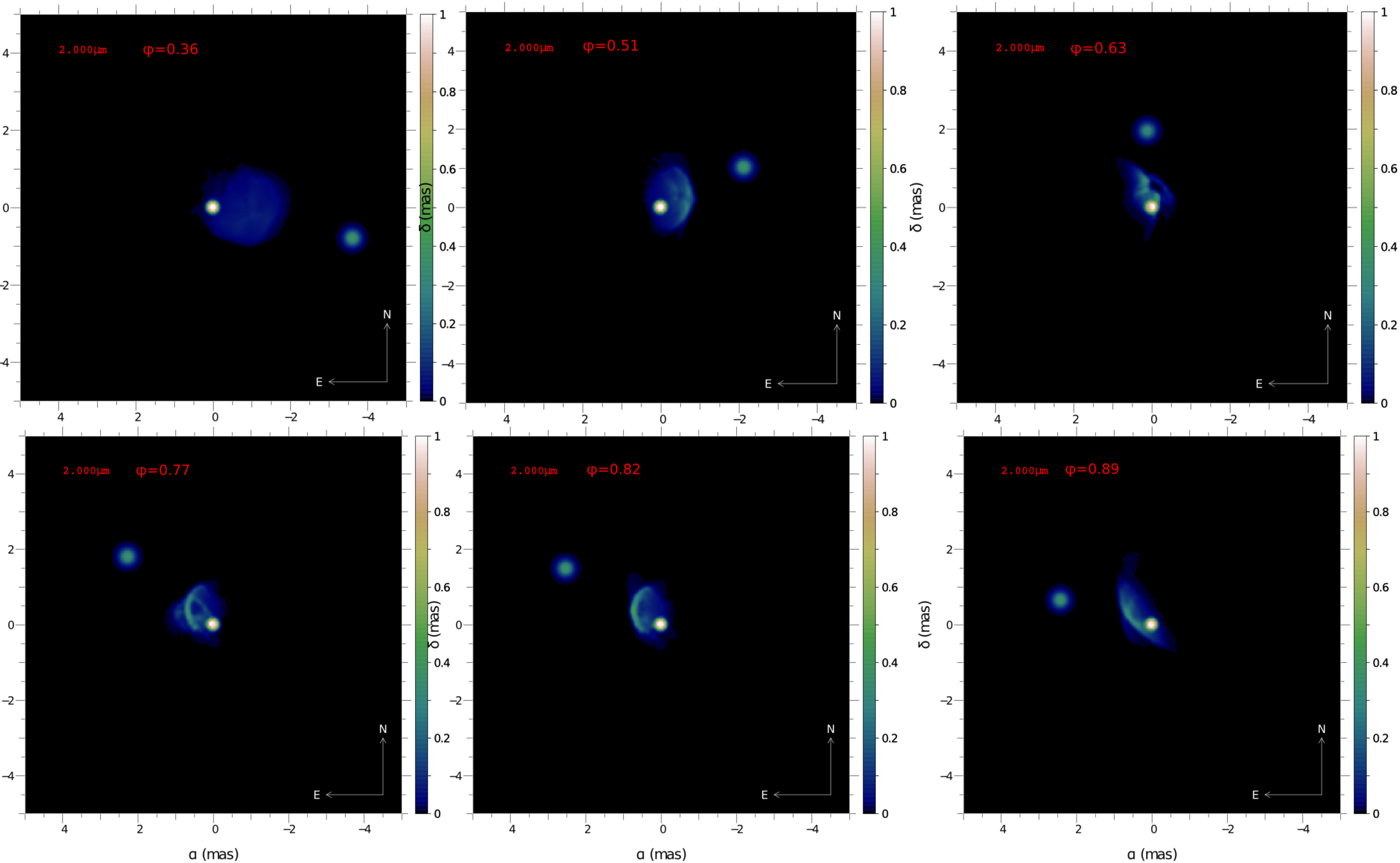
Simulation L_{box}=16 a , N=1024^3, radiative cooling and orbital motion

HYDRO STRUCTURE OF GAMMA VEL



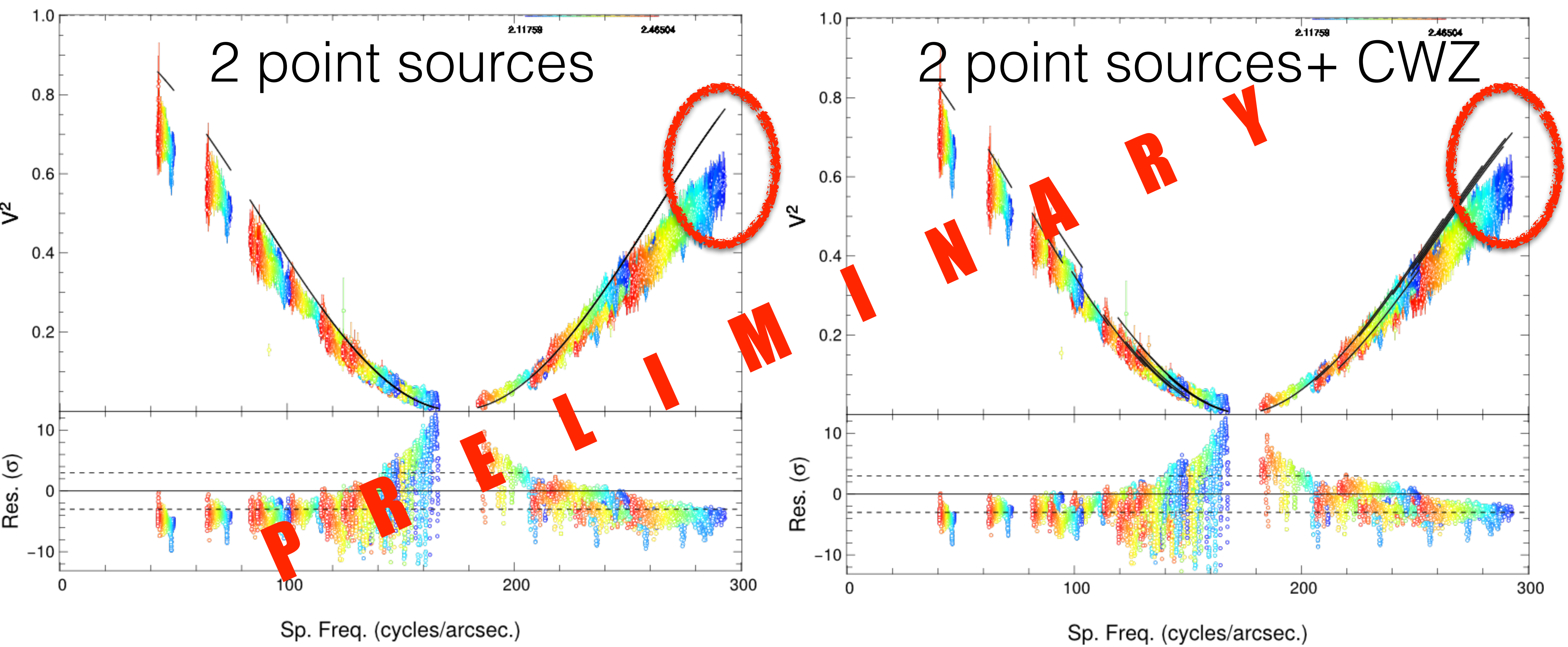
Limited development of instabilities
Cooling important in WR wind

CONTINUUM EMISSION



COMPARISON WITH OBSERVED VISIBILITY

Visibility -> spatial extension of system + flux ratios



Additional extended component necessary

CONCLUSIONS/PERSPECTIVES

γ^2 closest WR binary -> ideal target to study crucial phase of stellar evolution

Combining interferometry with hydrodynamic simulations confirms presence of wind collision region

Final step: better reproduce visibility curves, determine flux ratios of winds and radiative braking


THANK YOU!