Timing analysis of the heartbeat of the black hole binary GRS 1915+105

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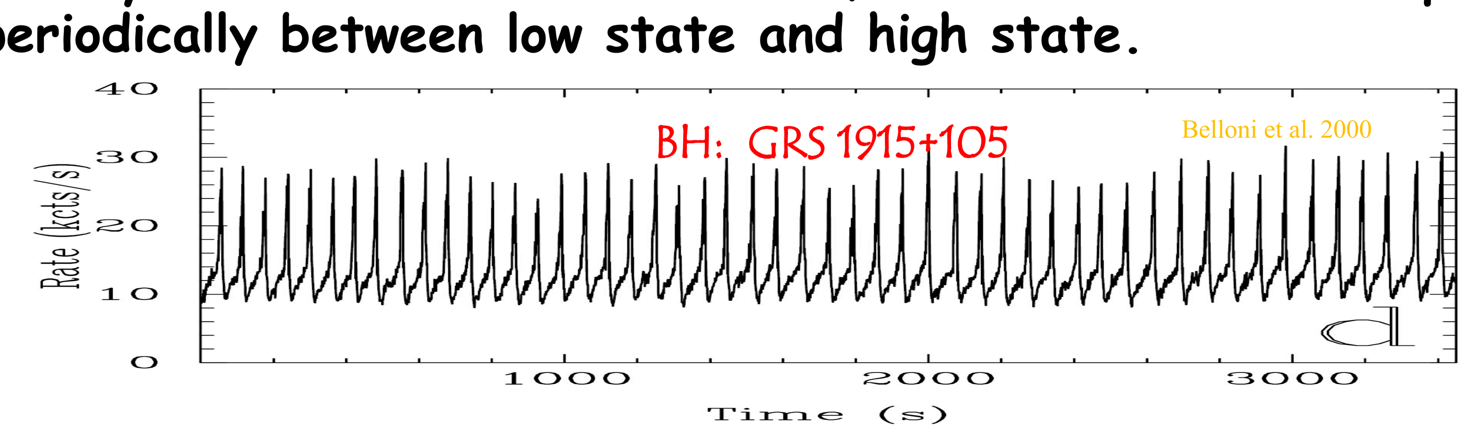
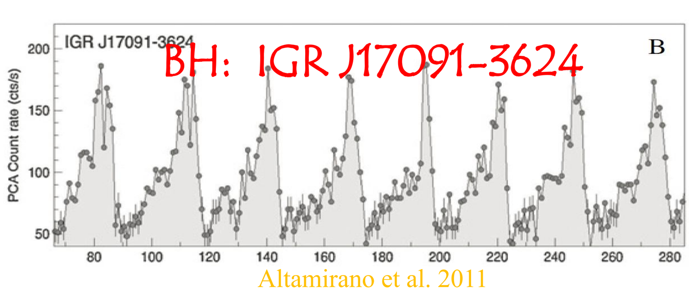
Abstract

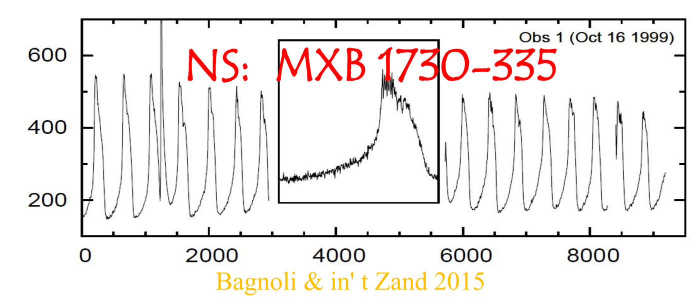
We present a comprehensive timing analysis of two RXTE observations of the microquasar GRS 1915+105 during the heartbeat state. The phase-frequencypower map of the double-peaked class shows that when the quasi-periodic oscillation disappears in the rise phase of the pulse its sub-harmonic is still present with a hard phase lag. In the slow rise phase, the energy-frequency-power map shows that most of the aperiodic variability is produced in the corona, and may also induce the aperiodic variability observed at low energies from an accretion disk, which is further supported by the soft phase lag especially in the intermediate frequency range (with a time delay up to 20 ms). In the rise phase of the pulse, the low-frequency aperiodic variability is enhanced significantly and there is a prominent hard lag (with a time delay up to 50 ms) indicating that the variability is induced by extension of the disk toward small radii as implied by the increase in flux and propagates into corona. These timing results are generally consistent with the spectral results presented by Neilsen et al. (2011, 2012) which indicated that the slow rise phase corresponds to a local Eddington limit and the rise phase of the pulse corresponds to a radiation pressure instability in the disk.

Introduction

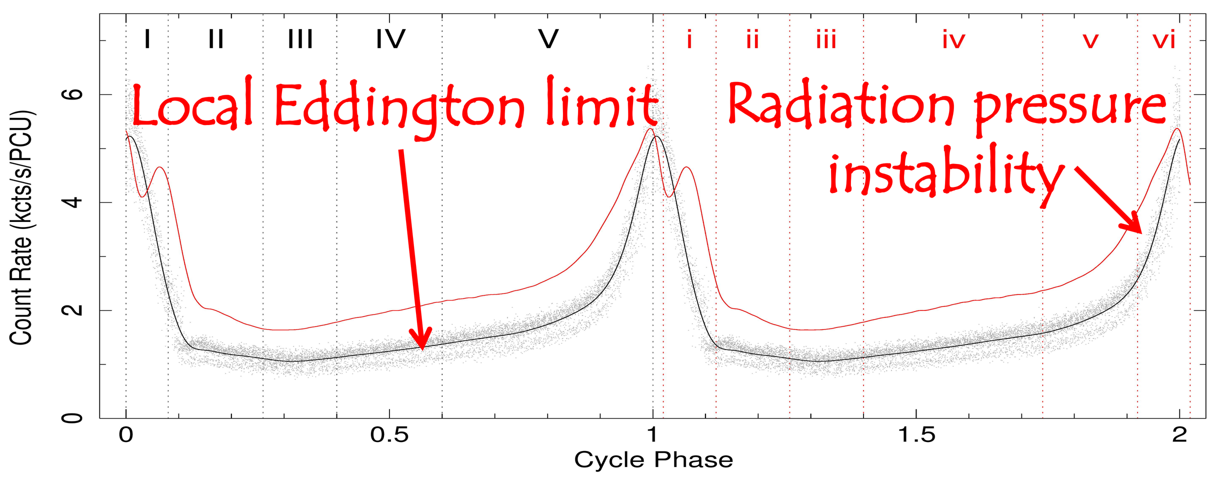
Heartbeat state (ρ class) is peculiar and only found in three X-ray binaries. In this state, source oscillates quasi-periodically between low state and high state.







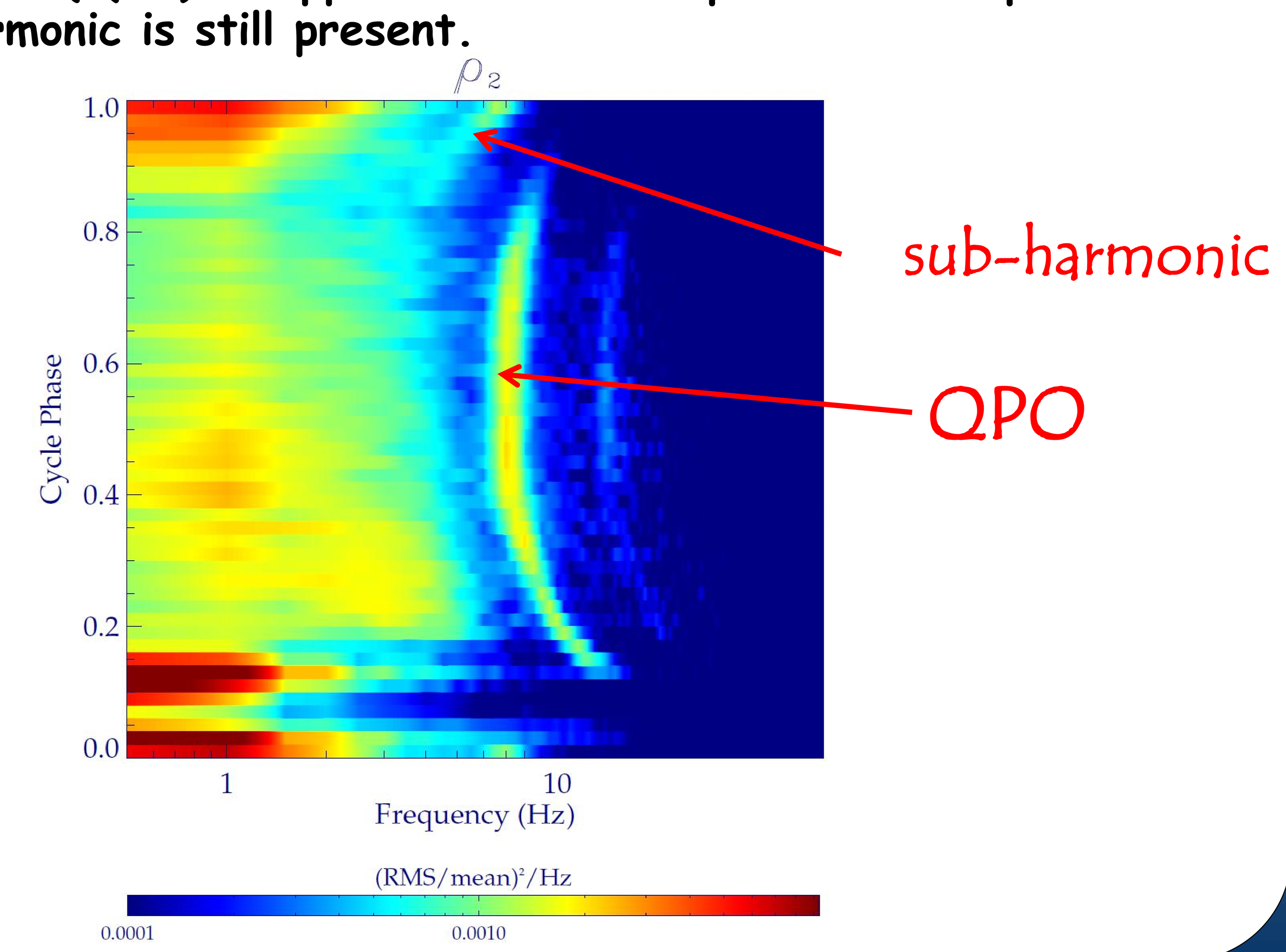
Phase-resolved analysis of ρ class is suitable for studying the origin of X-ray variability and the accretion physics of ρ class.



Phase-folded light curves of the single-peaked heartbeat (ρ_1 class; black) and double-peaked heartbeat (ρ_1 class; red) of GRS 1915+105.

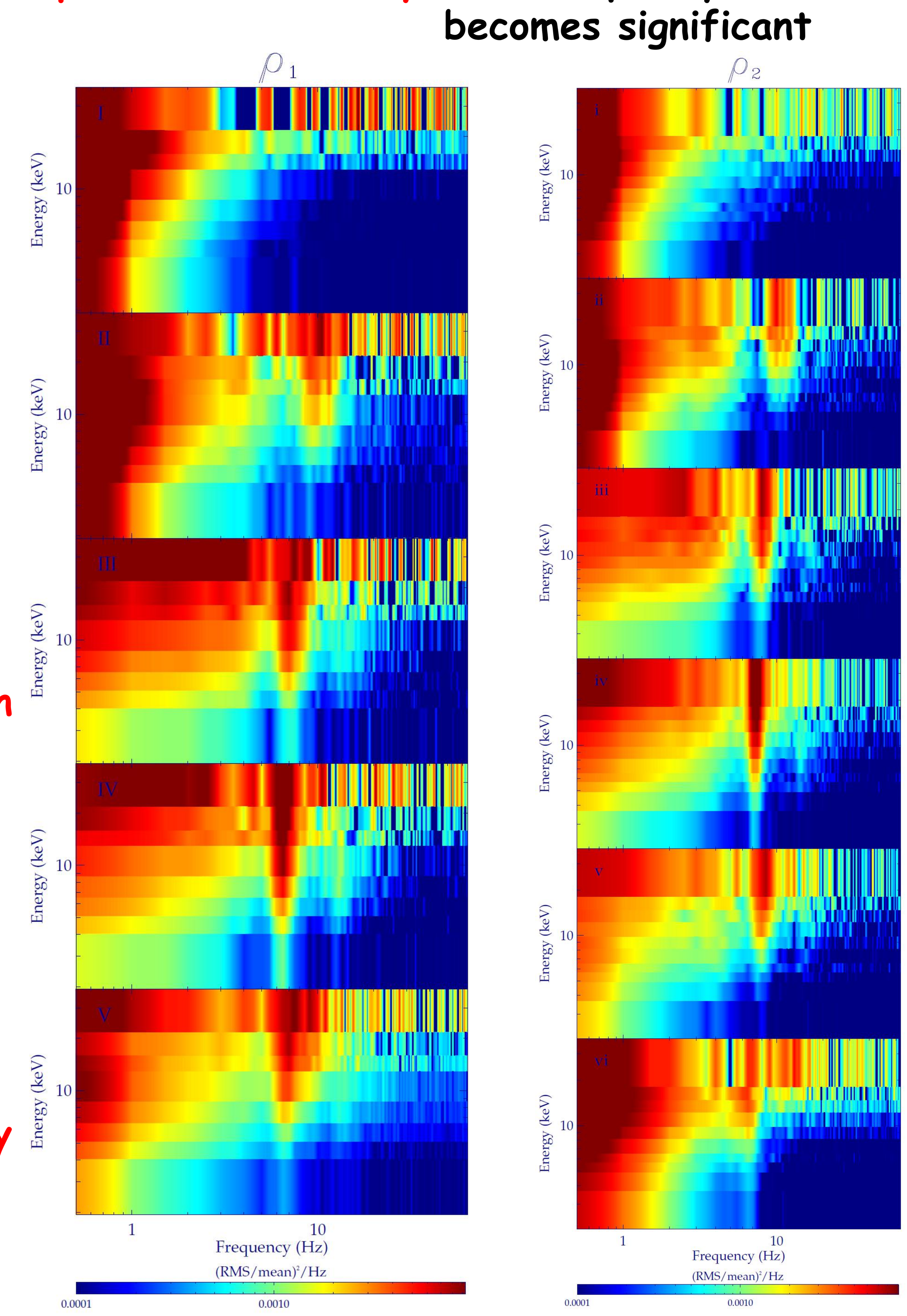
Results

Phase-frequency-power map shows the evolution of X-ray variability, and indicates that the when the quasi-periodic oscillation (QPO) disappears in the rise phase of the pulse its sub-harmonic is still present.



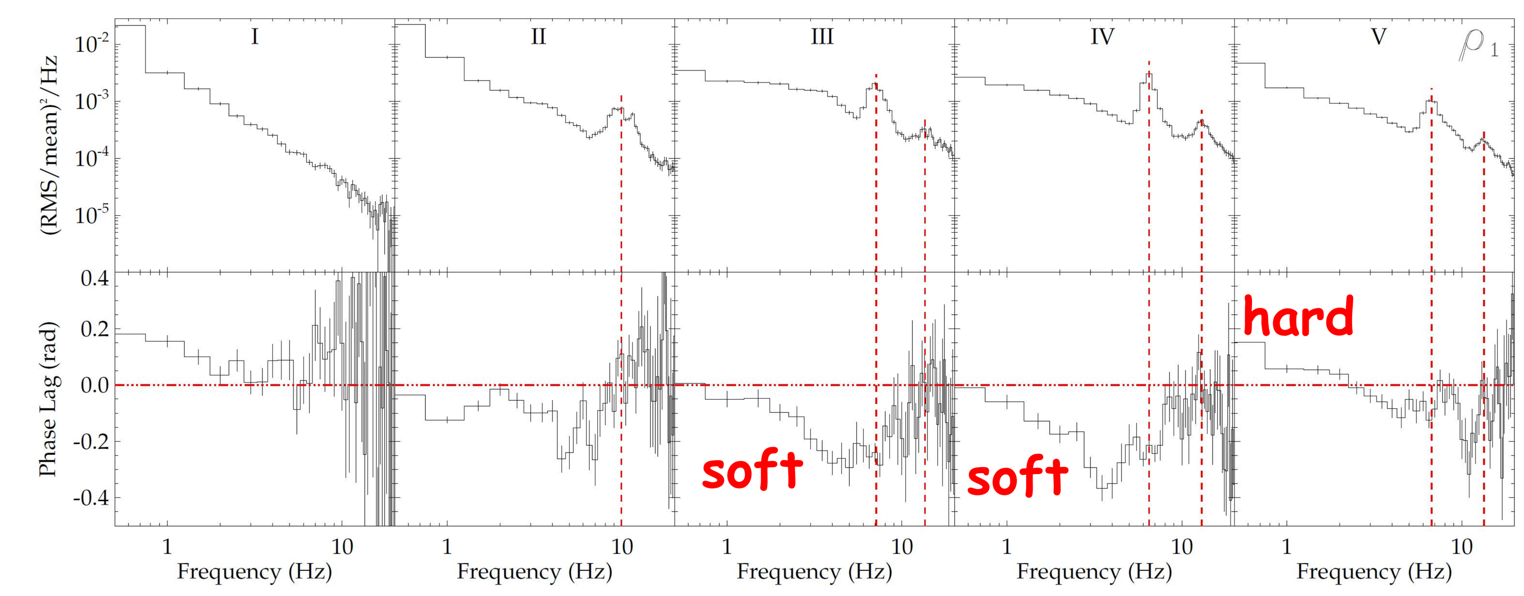
Local Eddington limit: corona variability dominates

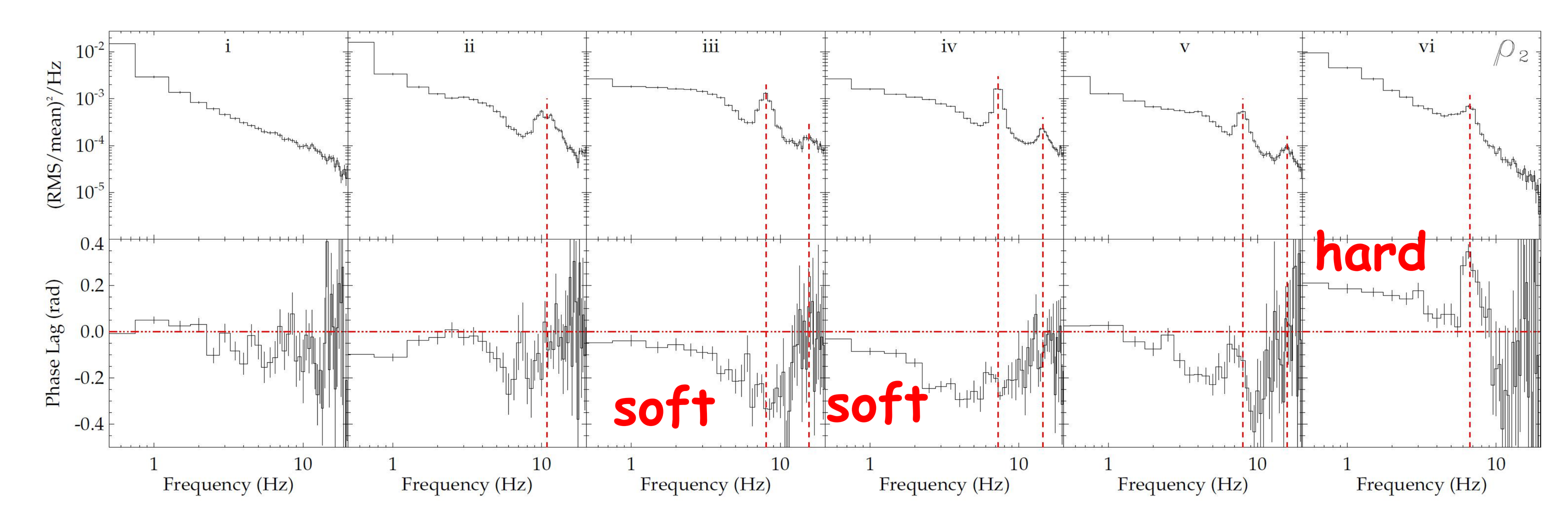
Radiation pressure instability: low-frequency disk variability becomes significant



Local Eddington limit: soft lag

Radiation pressure instability: hard lag





Conclusions

We obtained a **spectral-timing unified picture**:

When the disk is in a **local Eddington limit**, inside of the critical radius part of the mass is expelled by radiation pressure, and the periodic variability from the corona is initiative and drives the aperiodic variability from the disk;

When there is a **radiation pressure instability** in the disk, the low-frequency aperiodic variability at smaller radii of the disk is initiative and drives the low-frequency aperiodic variability from the corona.