# V1647 Ori: WHEN THE DISK IS UNSTABLE

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## PROTO-PLANETARY DISKS ARE OBSERVED TO BE UNSTABLE!

In models of planet formation usually the assumption is made that the proto-planetary disk is a "quiet" region that slowly evolves, via steady state, to form a planetary system and then dissipates. Observations are not in agreement with this picture. As an example we present here the case of the recent changes in the young star V1647 Orionis.

A new reflection nebula was discovered in early 2004 by an amateur astronomer (**McNeil's nebula**, 2004, IAU circ. 8214) in a previous dark region of the L1630 cloud in Orion. Subsequent studies showed it to be the consequence of an outburst that began in November 2003 and driven by the young eruptive star **V1647 Ori**. In the next few months the source rose in brightness of about 4 mag in I. Similar outburst from Young Stellar Objects (YSOs) are showed by **FU Orionis** objects. The physical reason of such violent event is that, due to a **disk instability**, the mass accretion rate onto the central star changes, within a period less than a month, from those commonly found around T Tauri stars (~ $10^{-7}$ $M_\odot$ $yr^{-1}$) into values of $10^{-3}$ – $10^{-4}$ $M_\odot$ $yr^{-1}$. The causes which lead to a FU Ori disk outburst are poorly understood. Possible mechanisms include thermal instabilities or interaction with companion stars. One of the main reason for the uncertainties in the theory is the paucity of observed FU Orionis. Due to the short time-scale of these phenomena compared to the disk lifetime, they are indeed **very rare events** (the last was in 1984). Our interest on this kind of variable YSOs is fed by the evidence that **chondritic material has formed when our own proto-solar nebula went through an episode of enhanced temperatures** (e.g. Bell et al. PPIV, p. 897), as experienced during a phase of increased accretion rate inside the proto-planetary disk.

Using **FORS2** at the VLT we have made a spectroscopic follow-up of V1647 Ori. The optical spectrum during the outburst is indeed very similar to that of a FUors, with **P-Cygni** profiles in the H Balmer emission lines and **FeII** lines in absorption. The total length of the outburst, 2 years, makes V1647 Ori a unique (somewhat intermediate) system among FUors and Exors (a different class of variable YSOs characterized by a smaller outburst length). Using **TIMMI2** at the ESO 3.6 m telescope we also followed the variation of the mid-IR emission.

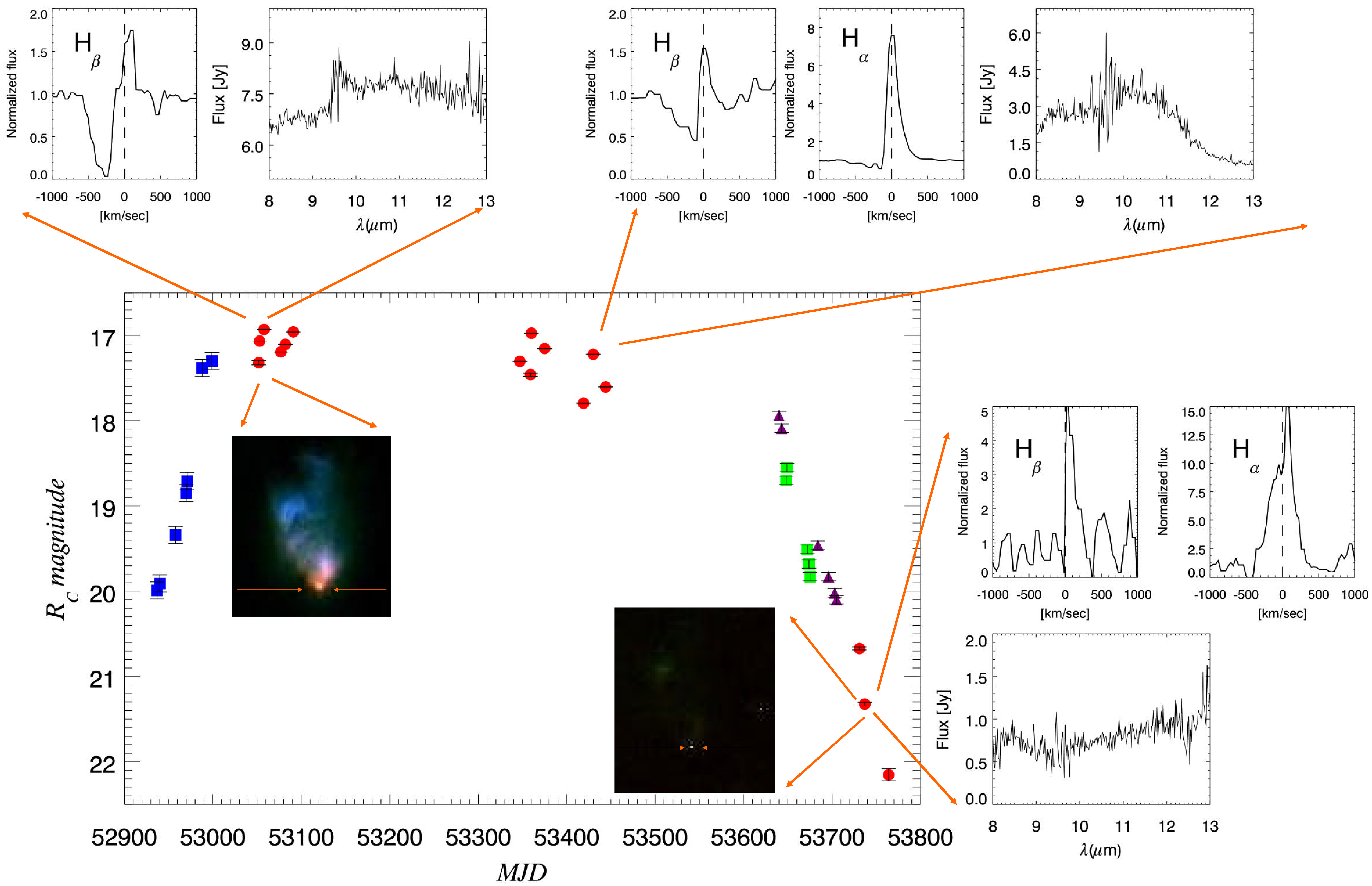


***Fig.1:*** *Light curve of V1647 Ori in the R band between November 2003 and January 2006 (red dots – FORS2 data; green squares – data from Kospal et al. 2005 IBVS 5661; violet triangles – data from Ojha et al. 2006 MNRAS, accepted; blue squares – data from Briceno et al. 2004 ApJ 606, 123). Over plotted are the BRz composite images of V1647 Ori and the McNeil's nebula, the line profiles of* $H_\alpha$ *and* $H_\beta$*, and the TIMMI2 spectra*

## IMPLICATIONS FOR PLANET FORMATION

Outburst statistics suggests that FU Orionis events are probably a normal part of the disk evolution. If we consider the outburst frequency, than all **young low-mass stars experience several FU Orionis outburst** during the early phase of stellar evolution (see e.g Hartmann "*Accretion processes in star formation*"). Converting the outburst frequency to the total mass accreted, we find that at least the 10% of the mass of a young low-mass star is accreted during the FU Orionis eruptions. This of course might also be true for the mass accreted into planets.

During the FU Ori phase **high temperatures (T ~ 10.000 K) are reached**. As was found for our own solar system, high temperatures might be important for the processing of solids in the disk. When the disk is "hot", **changes in the dust grain structure** might occur via the formations of crystals. Furthermore the ice mantel around silicates melts at these temperatures. Both these two processes favor the sticking of small particle and then the growth of dust grains.

Finally, we think that the FU Orionis phase might have important consequence for planet-formation scenarios (e.g. constraining the longevity and the stability of the disk).