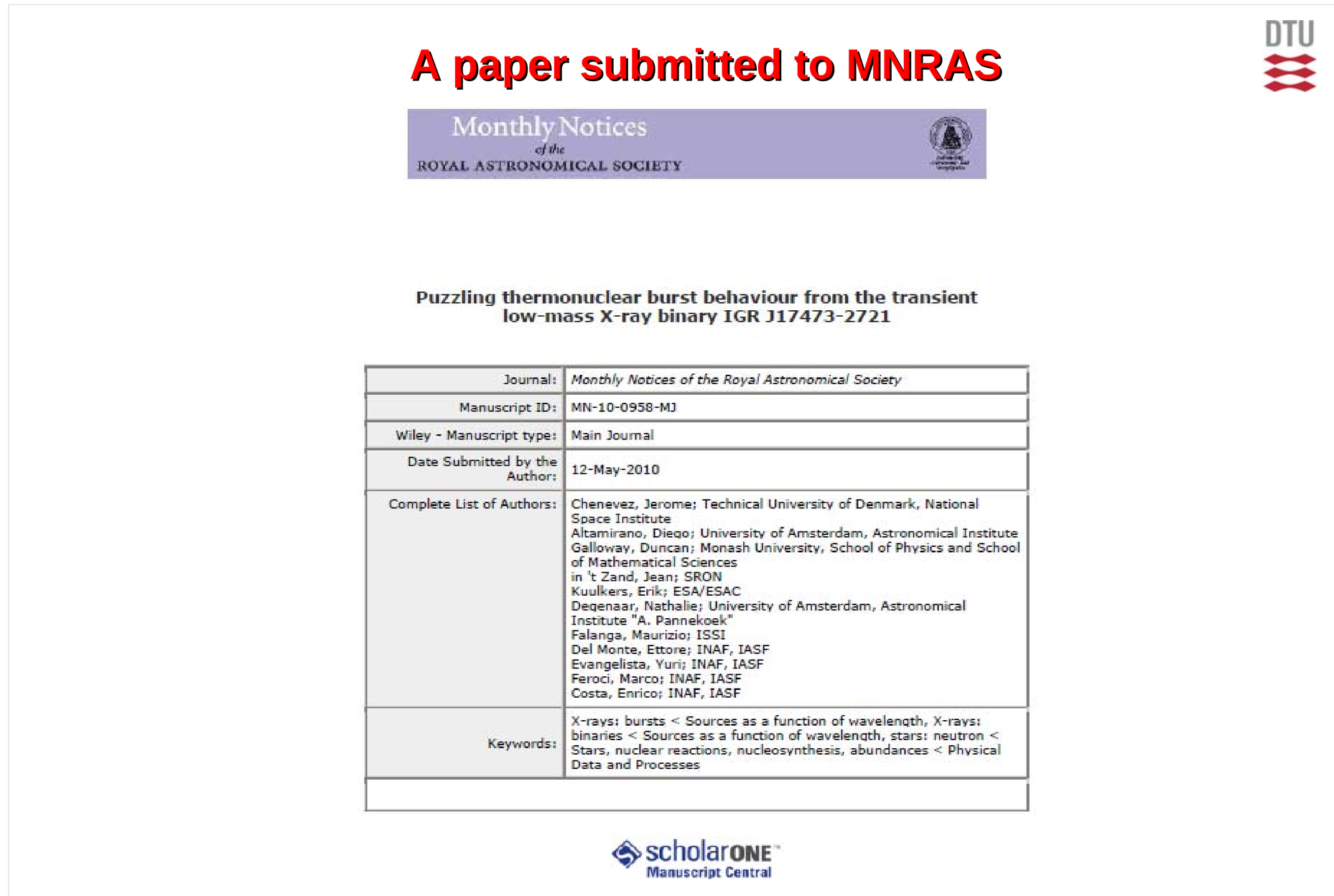
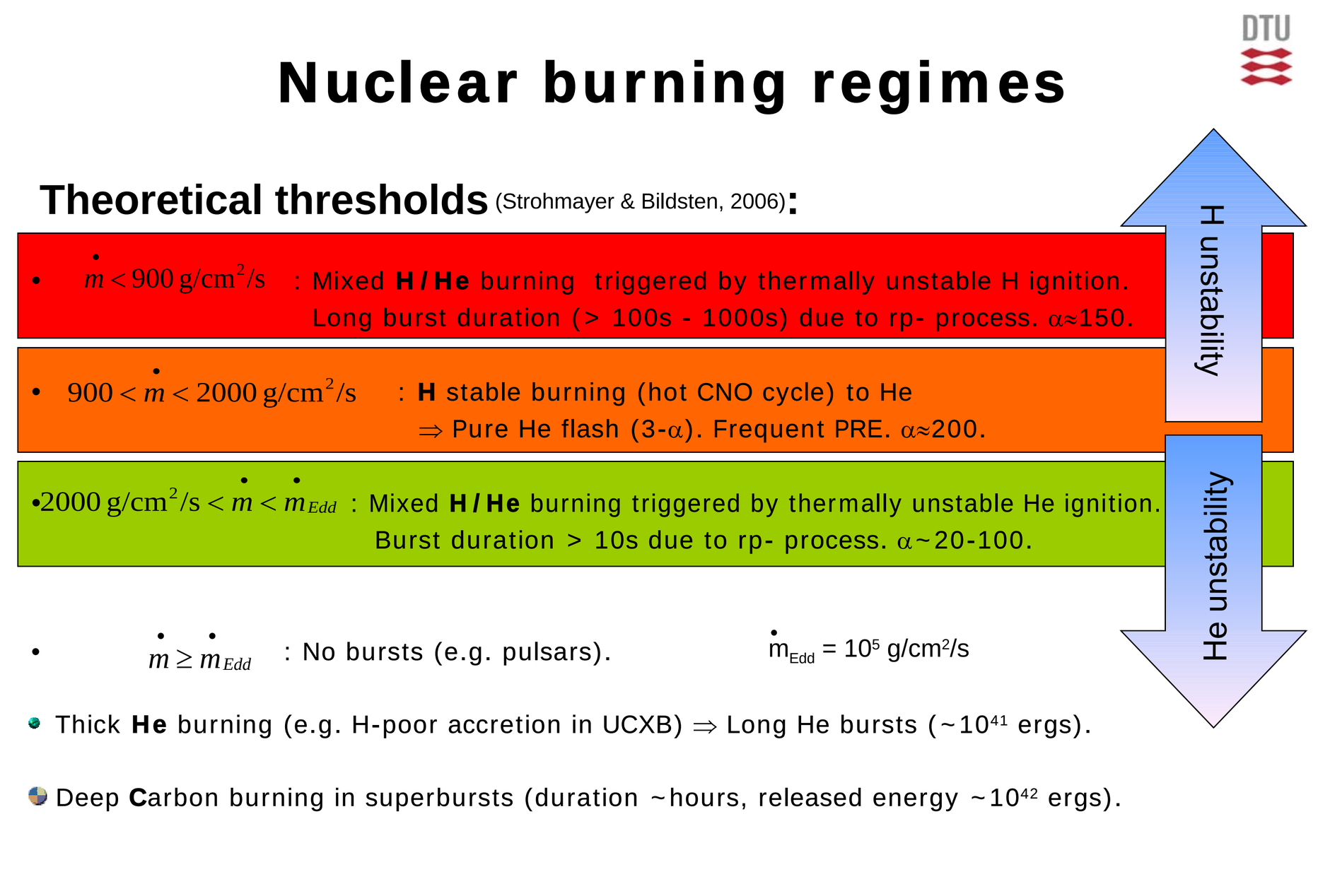
Abstract

We investigate the thermonuclear bursting behaviour of the X-ray transient source IGR J17473-2721, that in 2008 underwent a six month long outburst, starting (unusually) with an X-ray burst. We detected a total of 57 thermonuclear bursts throughout the outburst with *AGILE*, *Swift*, *RXTE*, and *INTEGRAL* satellites. The wide range of inferred accretion rates (between <1% and about 20% of the Eddington accretion rate dot-m$_{Edd}$) spanned during the outburst allows us to study changes in the nuclear burning processes and to identify up to seven different phases. The burst rate increased gradually with the accretion rate until it dropped (at a persistent flux corresponding to about 15% of dot-m$_{Edd}$) a few days before the outburst peak, after which bursts were not detected for a month. As the persistent emission subsequently decreased, the bursting activity resumed with a much lower rate than during the outburst rise. This hysteresis may arise from the thermal effect of the accretion on the surface nuclear burning processes, and the timescale is roughly consistent with that expected for the neutron star crust thermal response. On the other hand, an undetected "superburst", occurring within a data gap near the outburst peak, could have produced a similar quenching of burst activity.



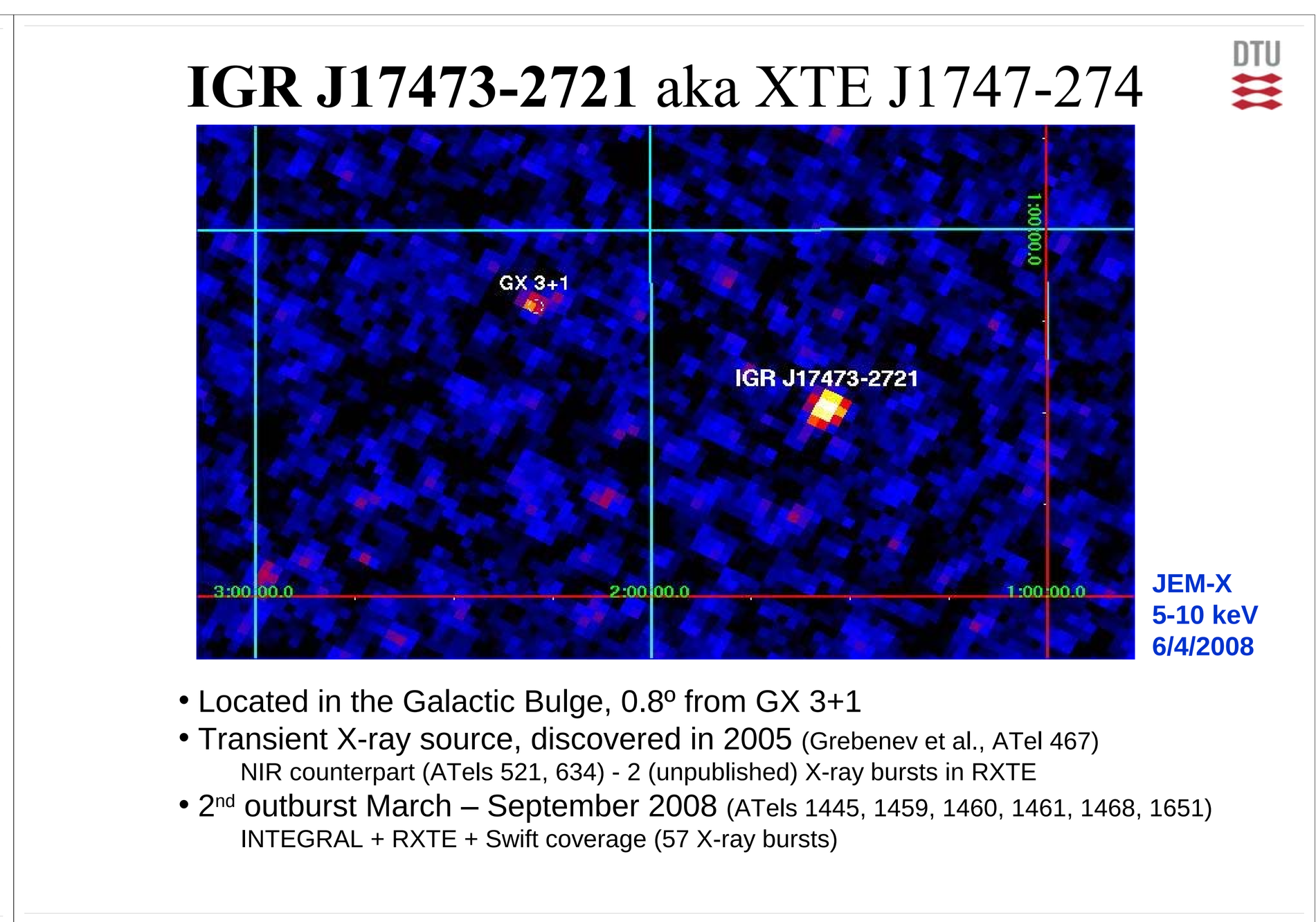
A multi-instrument survey of the X-ray burst activity from the X-ray transient source IGR J17473-2721 during its 6 month outburst in 2008.

Also to appear very soon on astro-ph!



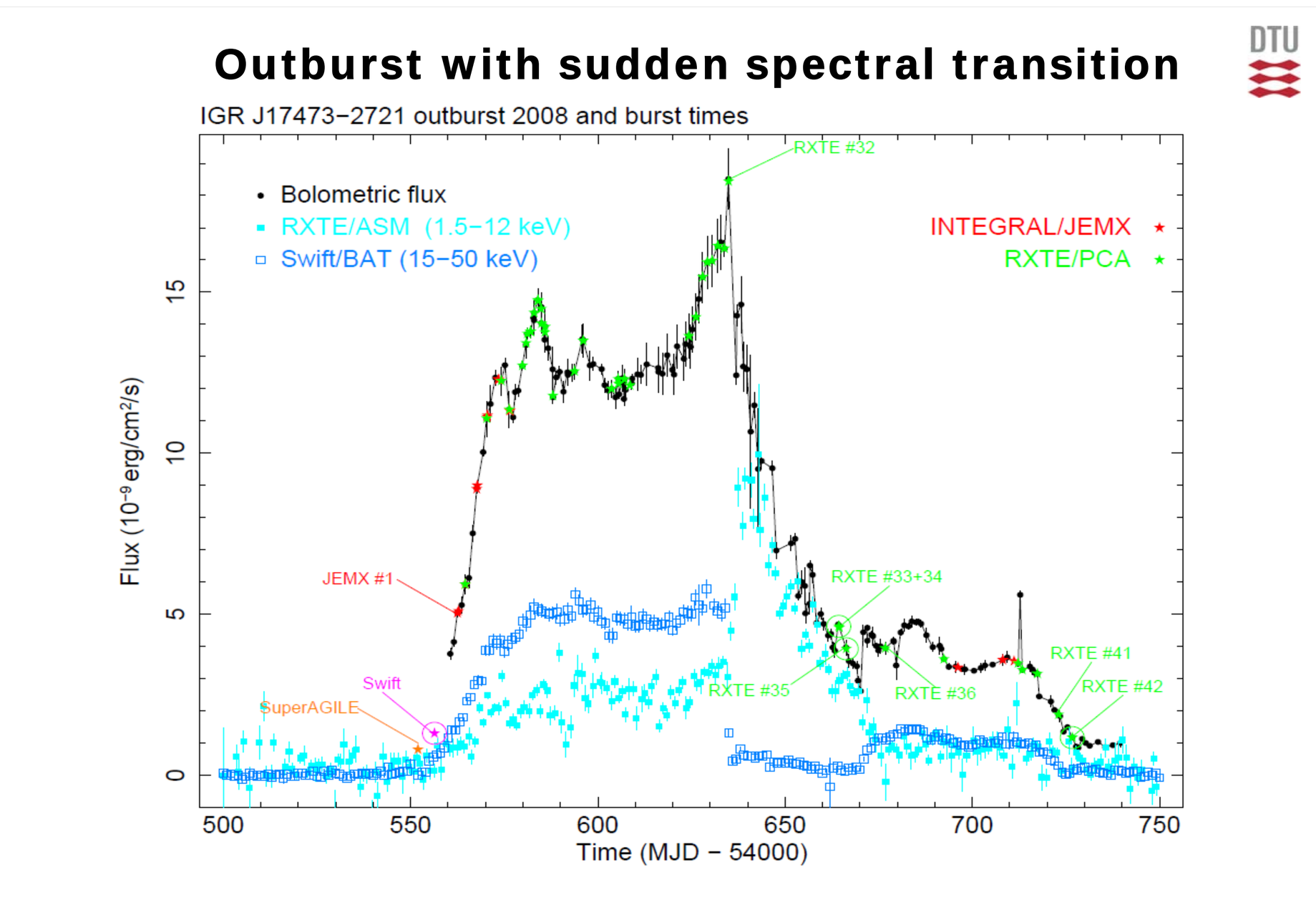
A theoretical reminder about type I X-ray burst thermonuclear burning regimes as a function of Hydrogen / Helium accretion rate onto the neutron star surface. He unstability and H stability increase with the local accretion rate until it reaches the Eddington limit.

Examples of other accretion/burning situations are also given: super-Eddington like in pulsars, low H-poor accretion rate like in UCXB, C burning in superbursts.



***INTEGRAL*/JEM-X mosaic image of the 2.5ºX1.5º field around IGR J17473-2721.**

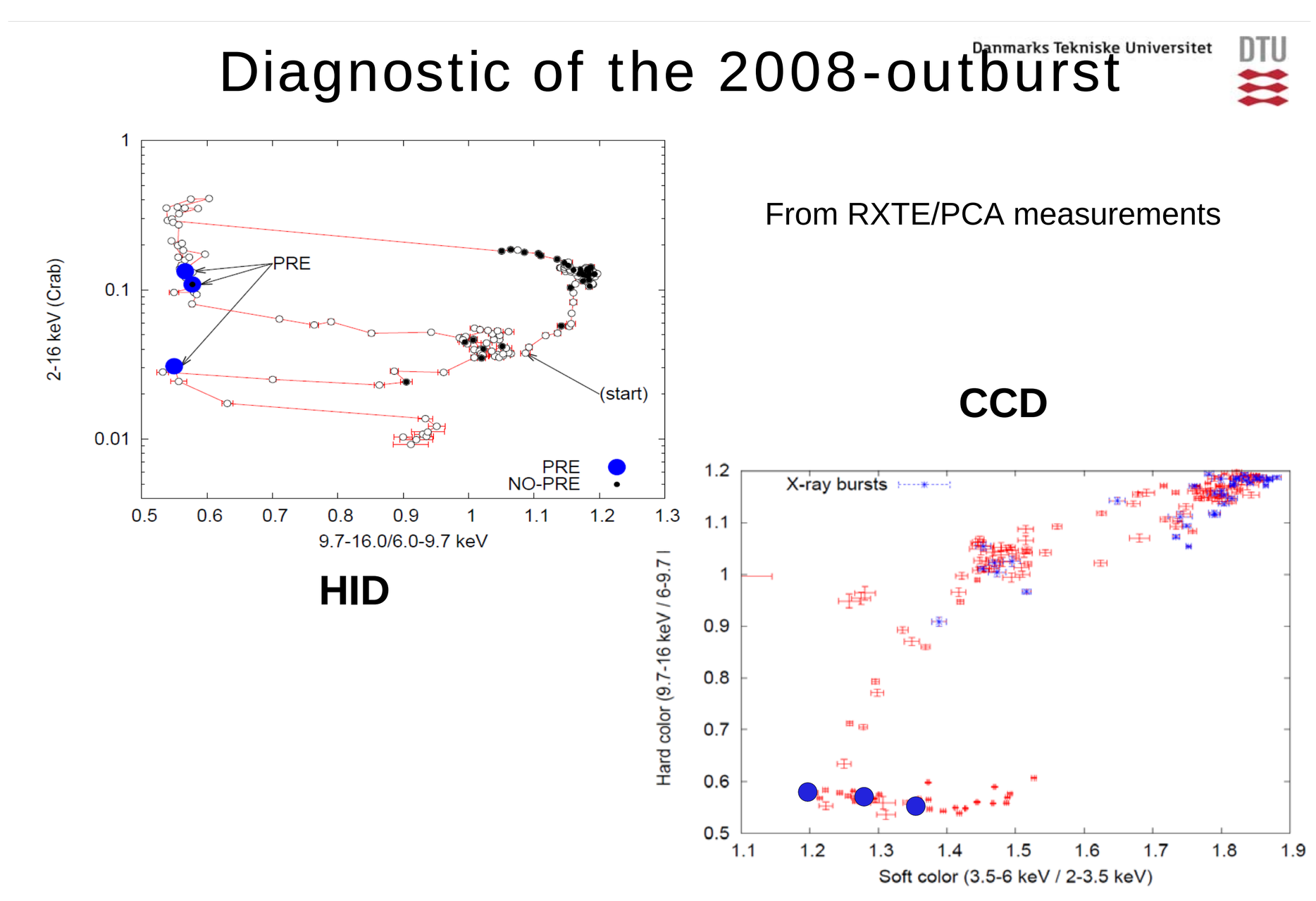
Though its closeness in the field of view, the source GX 3+1 does not contaminate the observations used in the present study.



Broad band X-ray light curves for IGR J17473-2721 during its outburst between 2008, February 4 and October 11, combining all available *RXTE* and *Swift*/BAT 1-day averaged data. The bolometric fluxes are derived from *RXTE*/ (PCA+HEXTE) fits and have been connected for clarity. Every PCA observation is represented by a black dot. The X-ray bursts observed by the different instruments are indicated by colored stars, with circles for the four Photospheric Radius Expansion (PRE) ones. Those indicated by names delineate the transition between different phases of burst behavior.

The bolometric flux is here a measure of the accretion rate.

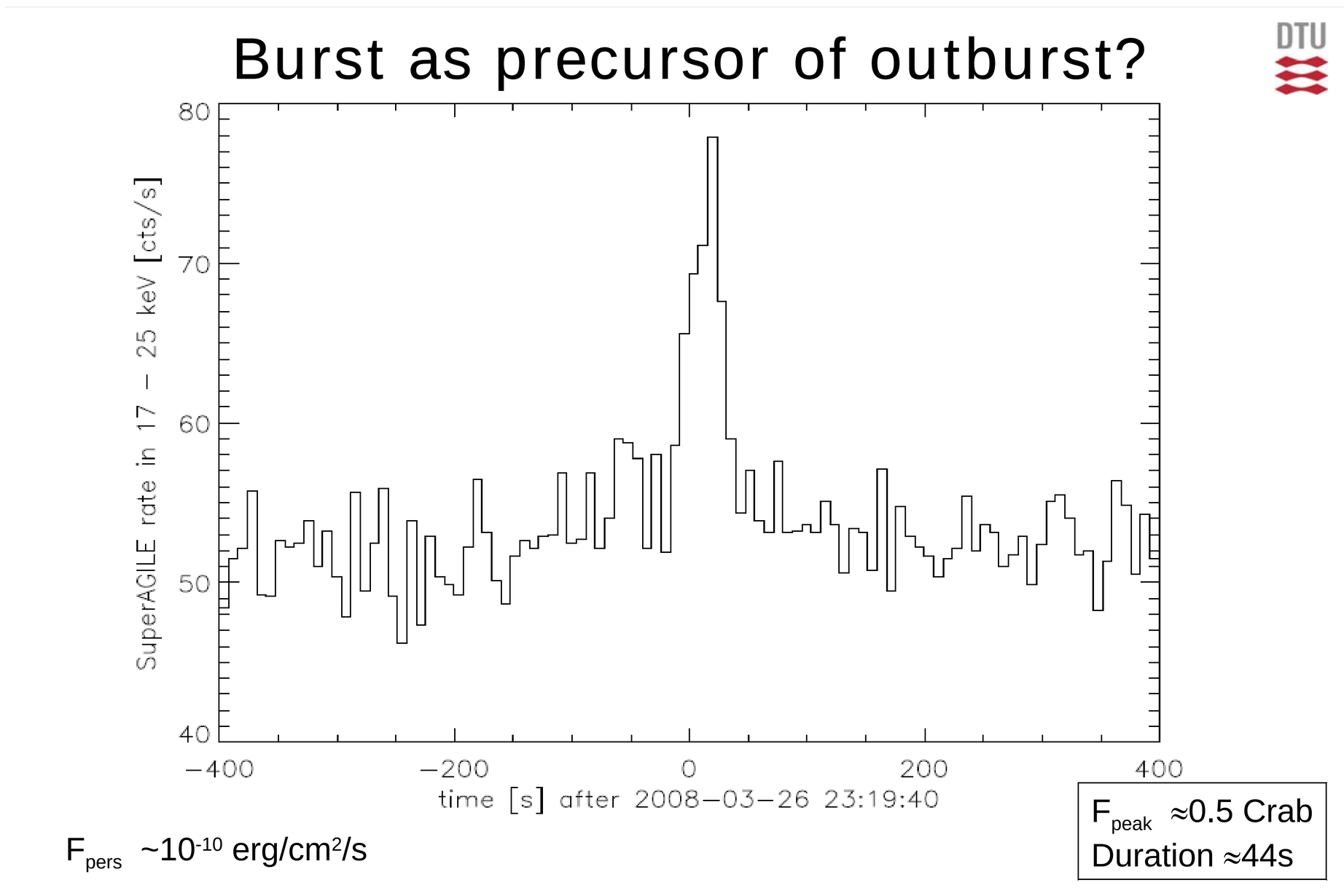
The sharp spectral transition at the maximum of the outburst bolometric emission is followed by an intermission of nuclear burst activity during one month.



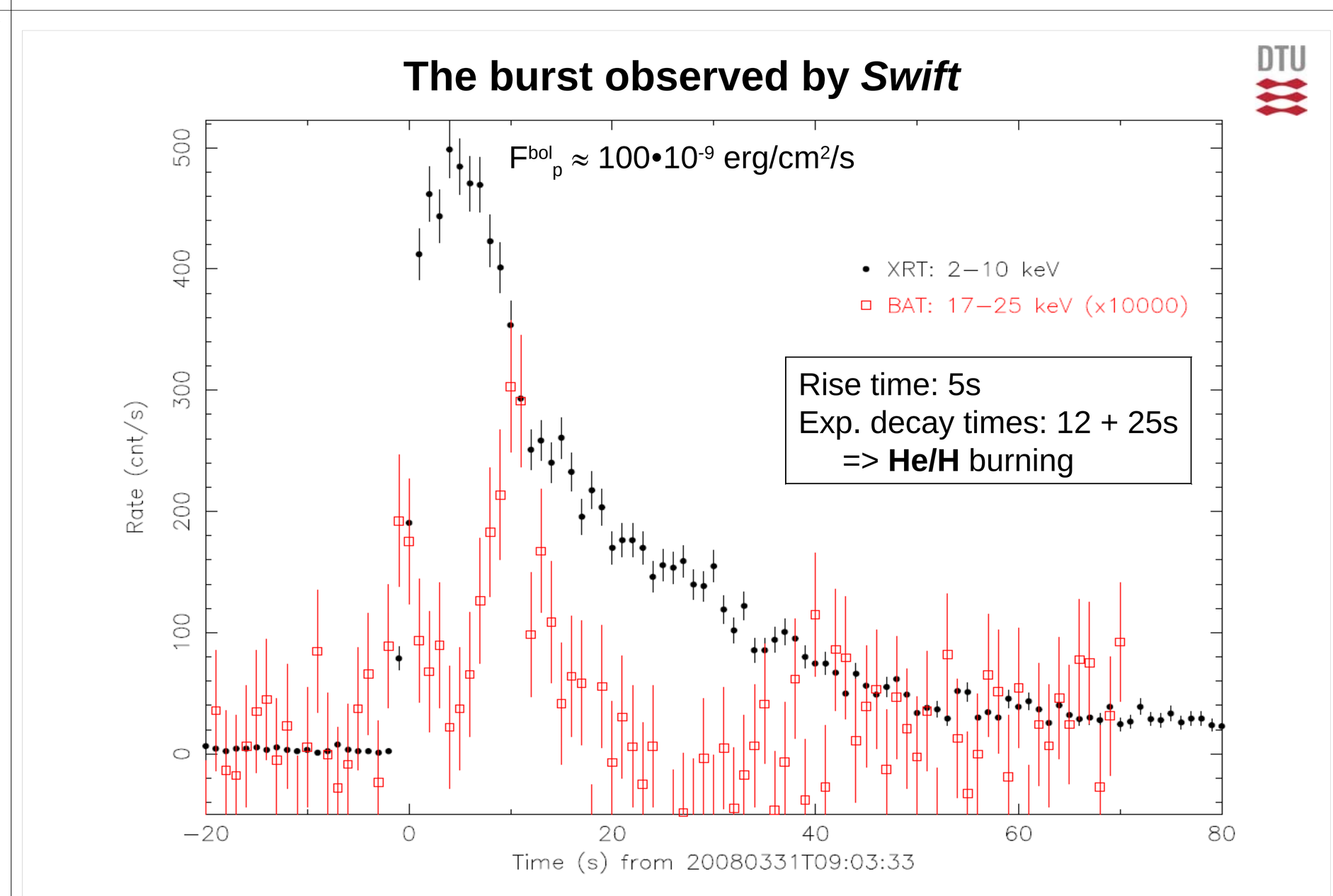
X-ray hardness-intensity diagram (HID) and color-color diagram (CCD) obtained from RXTE/PCA data for IGR J17473-2721 during its outburst in 2008. Intensity and colors are normalized to the Crab. The positions of the X-ray bursts observed by RXTE are shown through blue cruxes in the CCD and filled circles (blue for PRE bursts) in the HID; the arrow indicates measurements at MJD 54560.

A complete atoll-like cycle is described in the CCD. The PRE bursts all occur in the banana branch, during the low-soft state.

Two main spectral states are delineated: high-hard emission with frequent Hydrogen burning bursts before the peak of the outburst, and low-soft emission with sporadic Helium burning bursts after the peak.

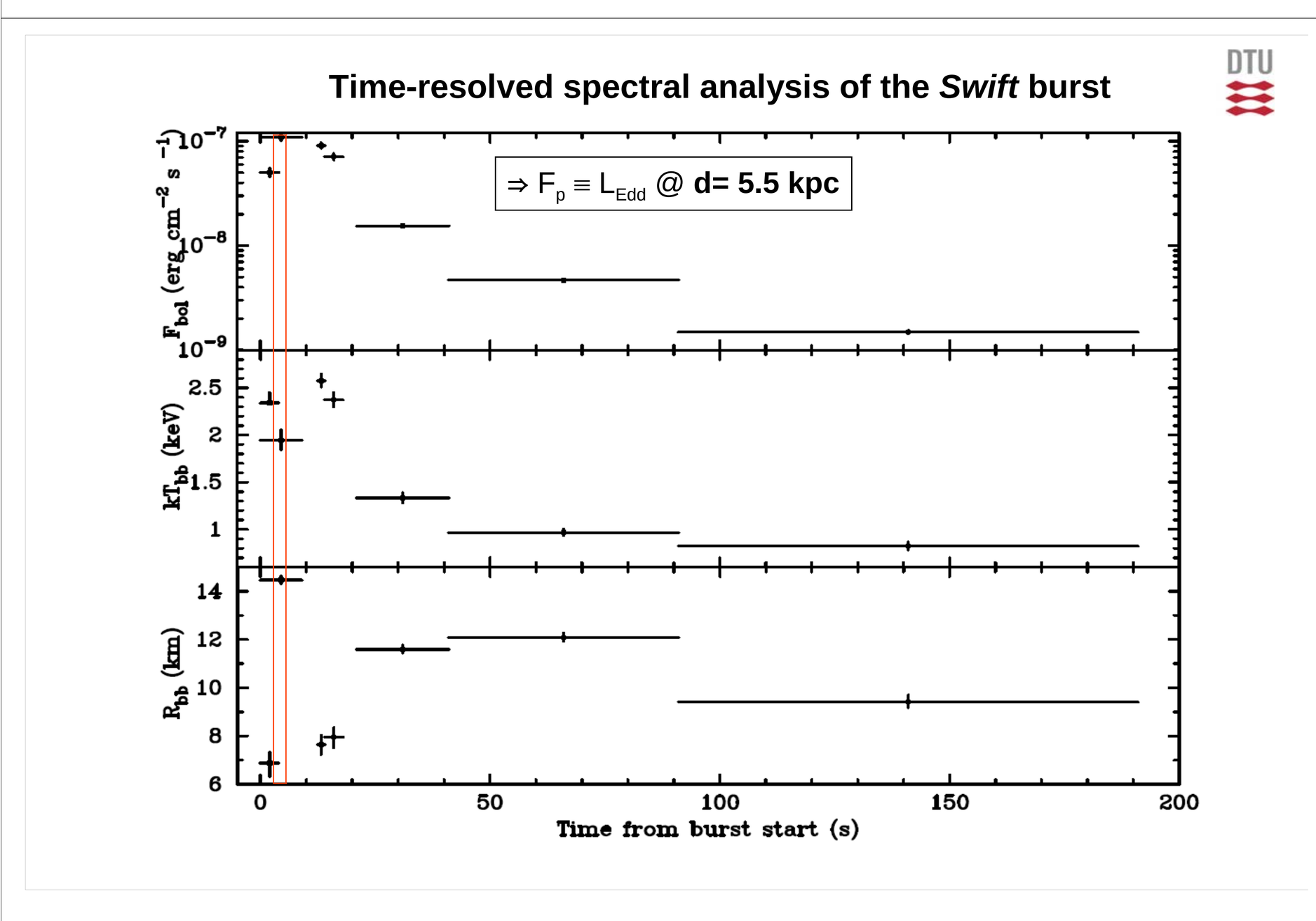


SuperAGILE (17-25 keV) 8-s bin light curve of the X-ray burst observed on 2008, March 26 (MJD 54551.972), just prior to the onset of the outburst (no measurable persistent emission) from IGR J17473-2721 .

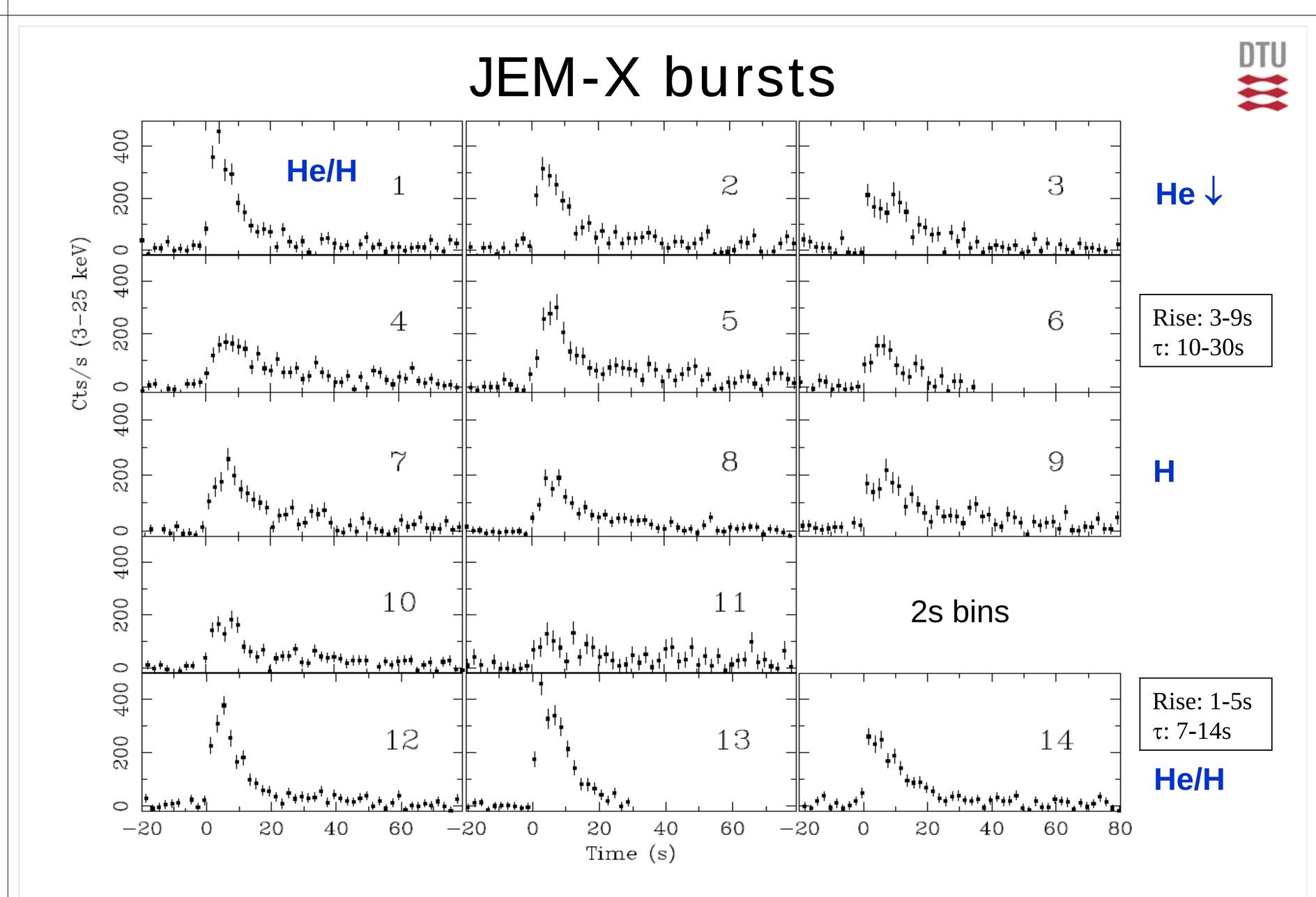


1-s bin light curves of the X-ray burst observed by *Swift* on 2008, March 31 (MJD 54556.377). The 2-10 keV exponential decay is dual: from 12s decay time in the first 14s to 25s decay time thereafter.

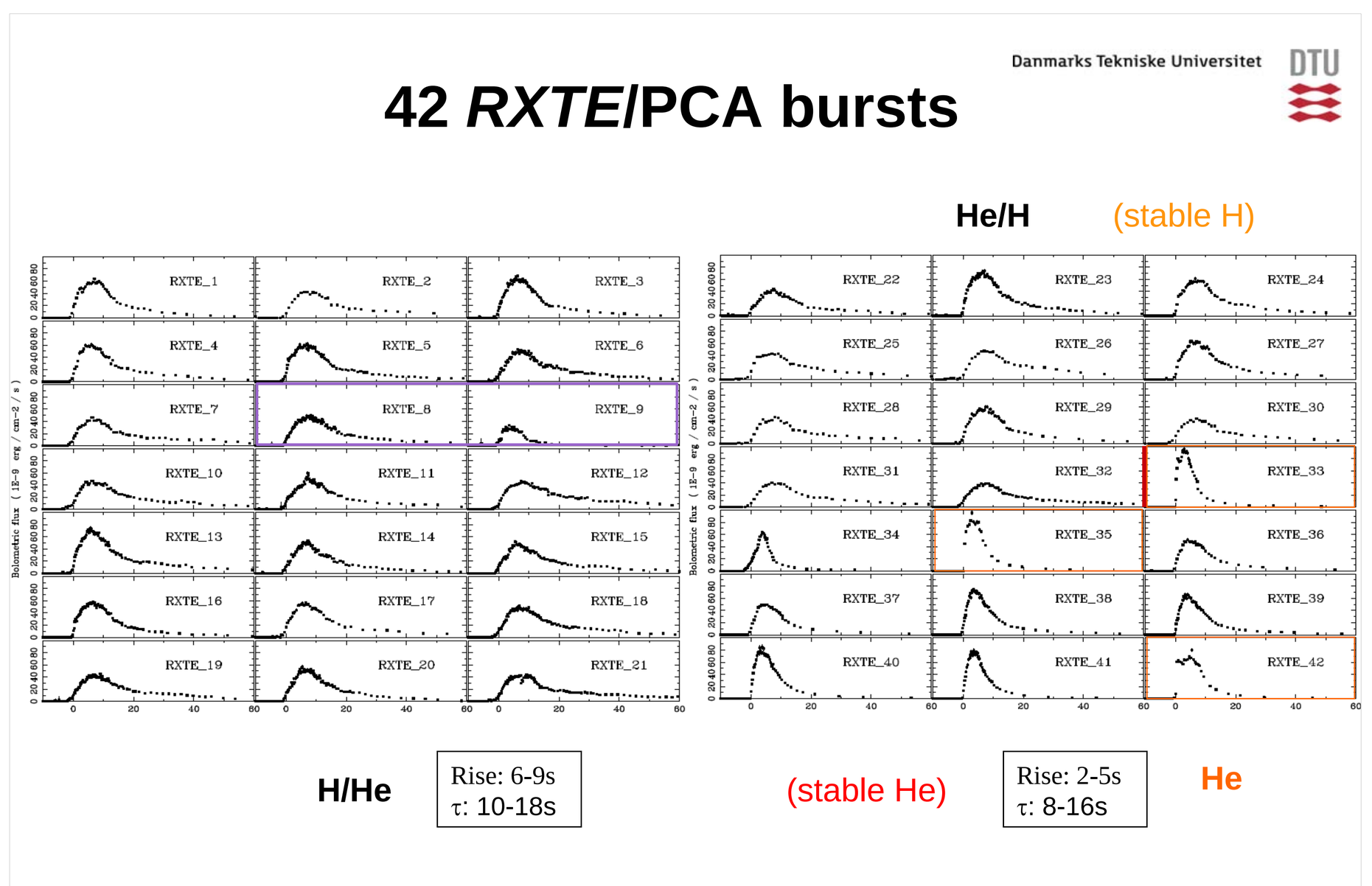
The BAT (17-25 keV) light curve makes possible to compare this burst with the SuperAGILE one. The double peak structure in high energy shows here evidence of a PRE event.



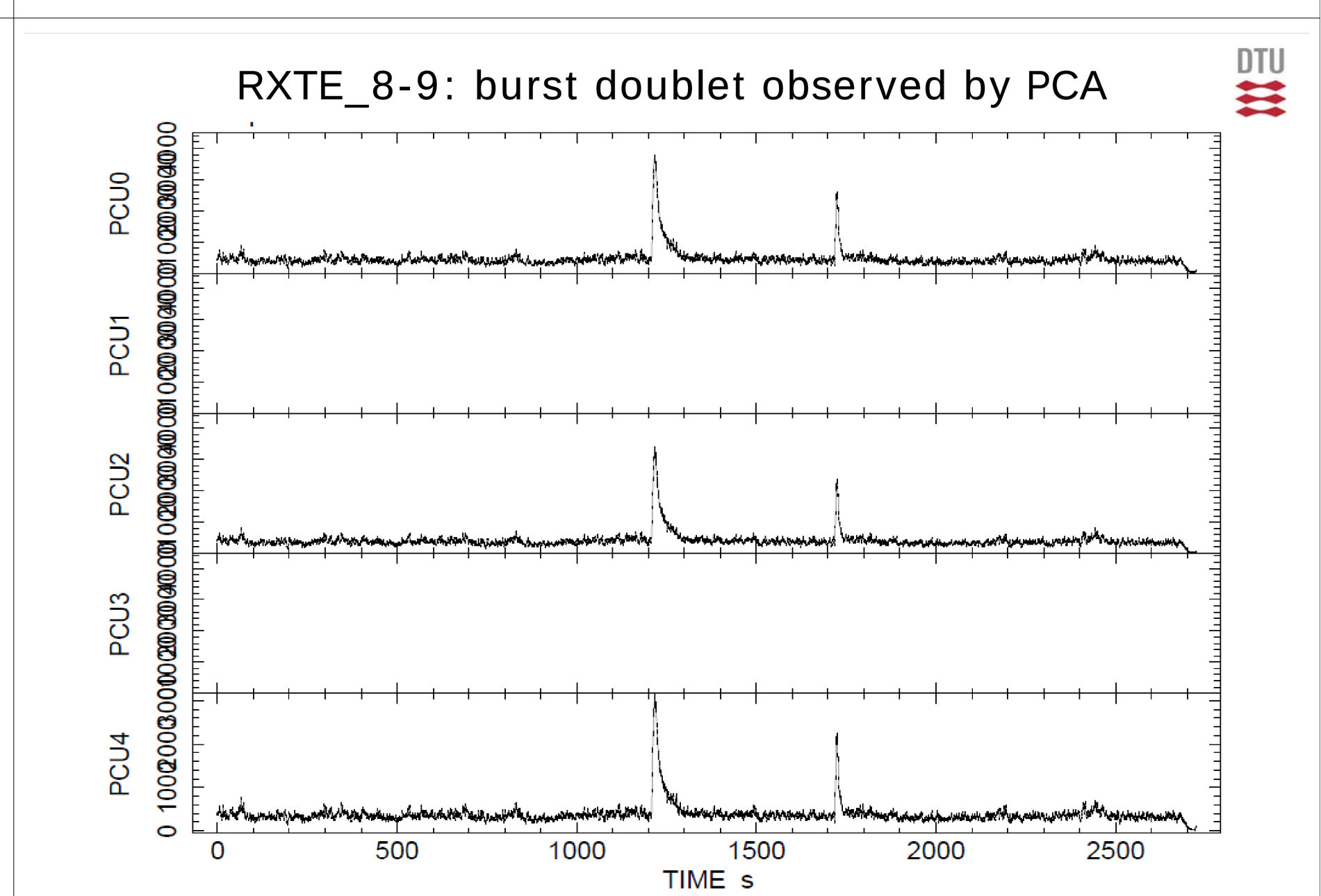
Time-resolved spectroscopy results of the X-ray burst observed by *Swift* on 2008, March 31.
The variations of the black-body radius indicate a PRE at the time delineated the by red band.
The radius is thus derived by the black-body fit normalisation for a distance of 5.5 kpc, obtained from the equivalence of the burst peak flux with the Eddington luminosity: L_{Edd} = 3.8 ×10^{38} erg/s.



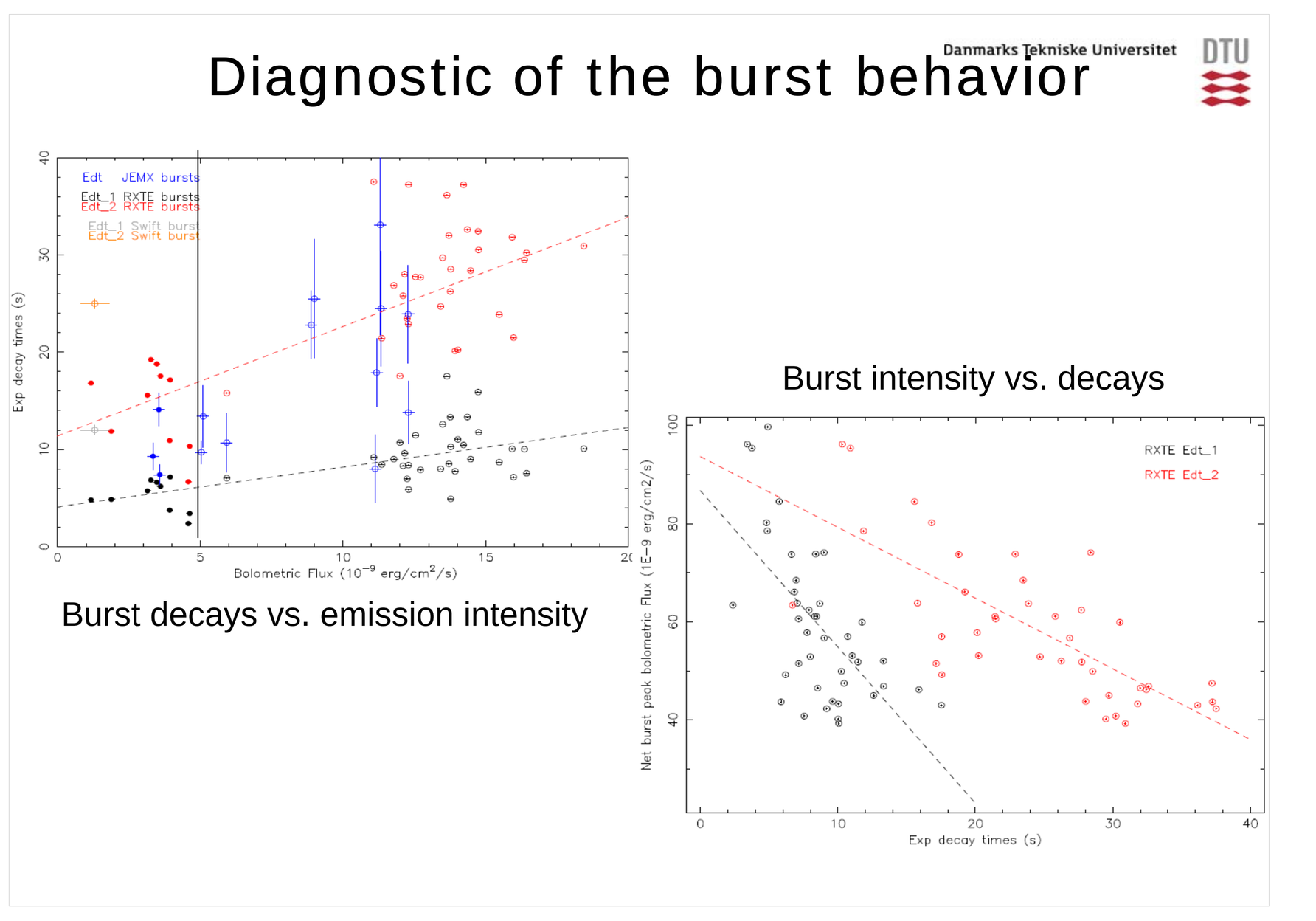
Chronologically ordered light curves of the X-ray bursts observed by *INTEGRAL*/JEM-X (3-25 keV) between MJD 54562 and 54576 (from 1 to 11) and between MJD 54696 and 54711 (12-14). The vertical scale and the 2-s binning are the same in every panel.
The main burning regime is mixed H/He, from H-poor bursts to H-rich bursts (1-11). The weaker and longer bursts from 1 to 11 indicate a decrease of the relative proportion of He in the bursting fuel with increasing bolometric flux.
Interpretation: He becomes more and more unstable and triggers unstable H burning faster as the accretion rate increases.



Chronologically ordered bolometric flux light curves of the X-ray bursts observed by *RXTE*/PCA. The mean recurrence time between bursts is ≈2 hours, but bursts 8 and 9 (magenta) are only separated by 10 minutes (see next panel).
Three pure He bursts, which have shorter rise and decay times than the average, are indicated in orange. Their peak fluxes are only a bit weaker than the peak of the *Swift* burst, and they are consistent with PRE bursts.



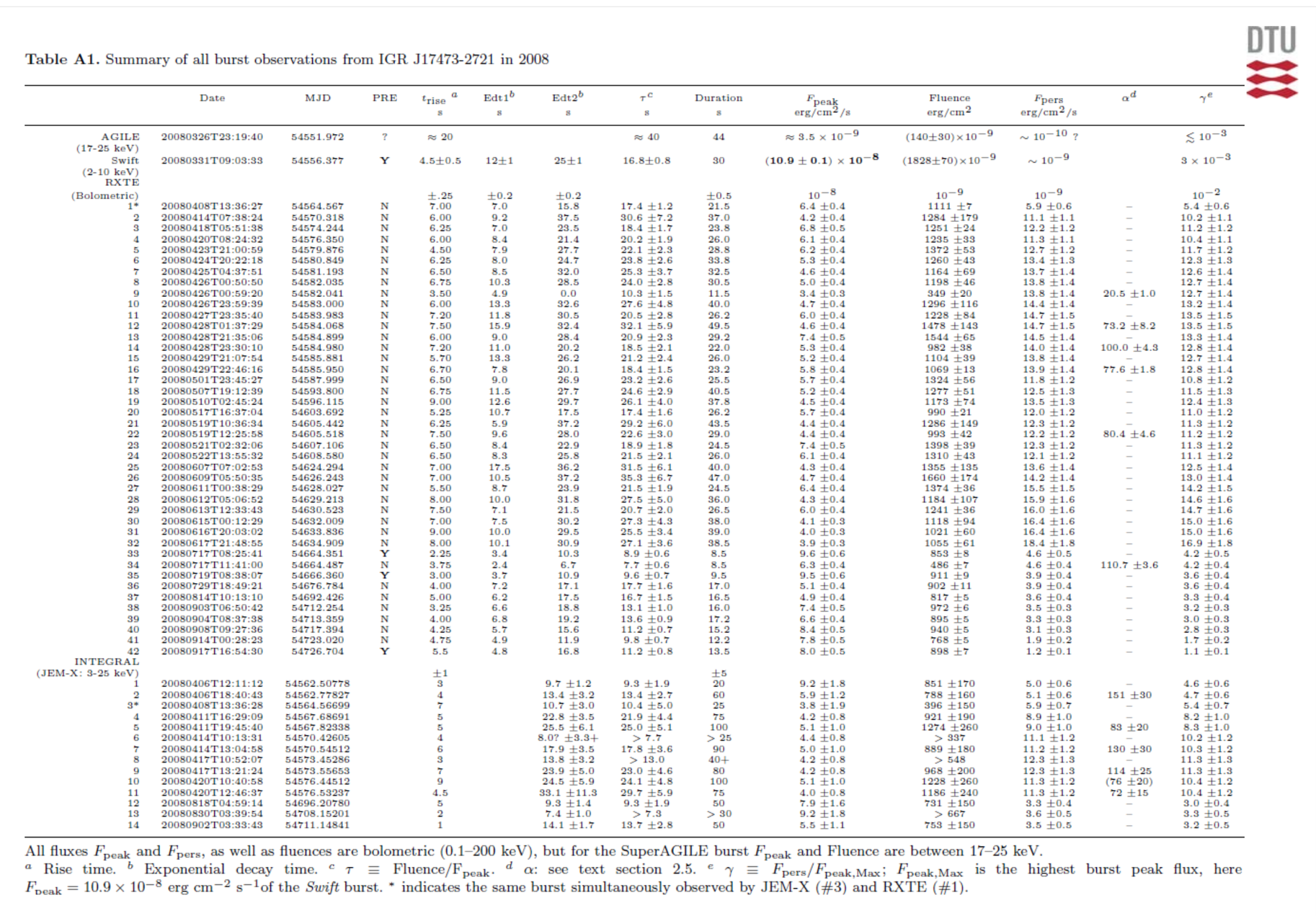
Such a double burst with only 10 minutes separation can be explained by the rotationally induced mixing of some unburnt H/He fuel in layers at different depths of the envelope of the neutron star (Keek et al., 2010).



Upper-left: Plot of the IGR J17473-2721 burst exponential decay times ("Edt") as a function of the persistent bolometric emission. Both *RXTE*/PCA (in black and red) and *Swift*/XRT burst (gray and orange) dual decays, as well as *INTEGRAL*/JEM-X decay times (in blue) are shown. Open and close circles represent bursts observed before and after the peak of the outburst, respectively. The dashed lines show the linear regression fits of the PCA decay times.

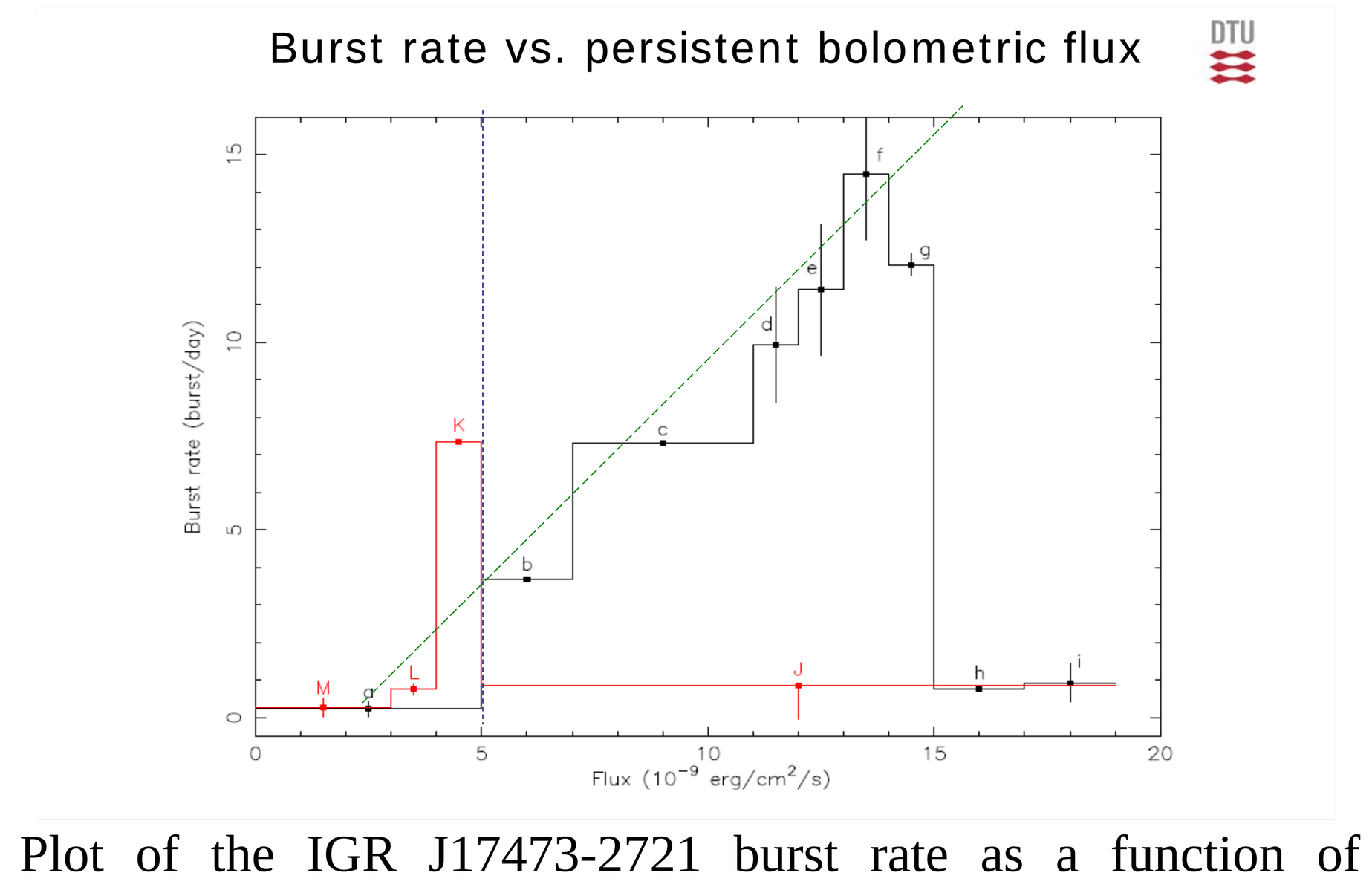
Lower-right: plot of the *RXTE* bursts peak fluxes as a function of the burst dual exponential times ("Edt"). The dashed lines show the linear regression fits.

Longer bursts occur at higher intensity, while the shortest all occur during the outburst decay (F_{bol} = 5 ×10^{-9} erg/s/cm^2). The shortests burst are also the most intense.



Observational parameters of the 57 detected X-ray bursts from IGR J17473-2721 in 2008.

Pairs of consecutive bursts are:
RXTE 8-9, 11-12, 13-14, 15-16, 21-22, 33-34, and INTEGRAL/JEM-X 1-2, 4-5, 6-7, 8-9, 10-11.
These make it possible to reliably measure of the α parameter and of the burst rate (see next panel).



Plot of the IGR J17473-2721 burst rate as a function of persistent bolometric flux derived from the waiting times between two observed consecutive bursts. Bins in black (lower case letters) and red (upper case letters) correspond to pre- and post-outburst peak, respectively. The letters indicate the number of bursts (*n*) and exposure times (*exp* in ks) per bin as follows: *n/exp*
a: 2/11.2, b: 3/39.8, c: 2/18.9, d: 8/50.6, e: 9/77.2, f: 8/44.1,
g: 6/24.9, h: 5/16.8, i: 1/3.4,
J: 0/60.2, K:2/72.8, L: 9/55.1, and M: 2/40.9.
The heights of the bins without error bars are given by one pair of bursts detected during an uninterrupted observation. The error bars are obtained either by the difference between the waiting times of two distinct pairs of bursts observed inside the same flux interval, or by the difference between the averaged time from burst to burst and the shortest time within two consecutive burst detections in separated observations.

SUMMARY

- Identification of IGR J17473-2721 as a transient NS –LMXB source
- Dramatic spectral transition simultaneous with burst intermission starting at outburst peak.
- Source distance ≈5.5 kpc derived from Eddington-limited PRE bursts
- 57 X-ray bursts ⇒ 7 phases of 4 different burning regimes identified:
  1. He-rich bursts at outburst onset (very low accretion rate)
  2. He-trig. H/He bursts in hard state (short recurrence times)
  3. He/H bursts with H (& He) stable burning at high accretion rate
  4. No burst activity at soft-high state (due to a **SUPERBURST**?)
  5. Pure He bursts (with PRE) at soft-low state: H stable burning
  6. Mixed He/H burning at hard-low state
  7. Last He burst at low accretion rate in soft state
- Rising bursting rate < 15% Eddington accretion rate and **hysteresis**

Conclusions:

Four burning regimes have been identified during the outburst of IGR J17473-2721 in 2008.

- Phases 1, 2, 3, and 6: mixed H/He (various H fractions)
- Phase 4: H and He stable burning (no bursts)
- Phase 5: Pure He flashes and stable H burning
- Phase 7: H-triggered He burst

Hysteresis of burst rate with accretion rate:
possibly due to the NS crust thermal response to accretion

1-month burst interruption after outburst peak:
possible burst quenching due to a missed superburst?