OAO/MITSuME photometry of dwarf novae: I SU UMa

今田　明
（OAO）

Discovery of superhumps during a normal outburst of SU Ursae Majoris

Akira Imada[1], Hideyuki Izumiura[1], Daisuke Kuroda[1], Kenshi Yanagisawa[1],
Nobuyuki Kawai[2], Toshihiro Omodaka[3], and Ryo Miyanoshita[3]
[1]*Okayama Astrophysical Observatory, National Astronomical Observatory of Japan, Asakuchi, Okayama 719-0232*
[2]*Department of Physics, Tokyo Institute of Technology, Ookayama 2-12-1, Meguro-ku, Tokyo 152-8551*
[3]*Faculty of Science, Kagoshima University, 1-21-30 Korimoto, Kagoshima, Kagoshima 890-0065*

(Received ; accepted)

Abstract

We report on time-resolved photometry during a 2012 January normal outburst of SU UMa. The light curve shows hump-like modulations with a period of 0.07903(11) d, which coincides with the known superhump period of SU UMa during superoutbursts. We interpret this as superhump, based on the observed periodicity, profiles of the averaged light curve, and the $g' - I_c$ variation during the normal outburst. This is the first case that superhumps are detected during an isolated normal outburst of SU UMa-type dwarf novae. The present result strongly suggests that the radius of the accretion disk already reaches the 3:1 resonance even in the midst of the supercycle.

Key words: accretion, accretion disks — stars: dwarf novae — stars: individual (SU Ursae Majoris) — stars: novae, cataclysmic variables — stars: oscillations

1. Introduction

SU UMa-type dwarf novae, a subclass of dwarf novae, exhibit two types of outbursts: normal outburst and superoutburst (for a review, see Warner 1995; Osaki 1996). During superoutburst, hump-like modulations called superhumps are visible. Basically, the light source of superhumps is understood as phase-dependent tidal dissipation in an eccentric accretion disk (Whitehurst 1988; Hirose, Osaki 1990). The general consensus is that an eccentricity of the accretion disk is excited by a 3:1 orbital resonance (Osaki 1989). According to the original thermal-tidal instability model (TTI model, Osaki 1989), the radius of the accretion disk monotonically increases with each normal outburst. When the disk finally reaches the 3:1 resonance radius, the accretion disk is tidally deformed and triggers a superoutburst. The TTI model reproduces well basic behavior of SU UMa-type dwarf novae. However, a reform of the TTI model may be required, particularly in systems with unusual recurrence times of superoutbursts (Hellier 2001; Patterson et al. 2002; Osaki, Meyer 2003).

Over the past few years, research activity concerning SU UMa-type dwarf novae has been significantly improved. One of the most important research is that unprecedented photometric surveys during superoutbursts have been carried out by T. Kato and his colleagues (Kato et al. 2009; Kato et al. 2010; Kato et al. 2012). They collected all of available data and analyzed the light curves during superoutbursts, from which they have established the basic picture of the superhump period changes (see figure 3 of

allows us to investigate detailed light curves that cannot be achieved under ground-based observations (Still et al. 2010; Cannizzo et al. 2010; Wood et al. 2011; Kato et al. 2012; Cannizzo et al. 2012). Although these surveys improve our understanding of SU UMa-type dwarf novae, the diversity of the observations claims further modification of the TTI model.

In order to decipher and understand the observed diversity of SU UMa-type dwarf novae, we started a new approach: simultaneous multicolor photometry of dwarf novae not only during outburst but also during quiescence. As a first step, we performed multicolor photometry of SU UMa itself from 2011 December to 2012 February. SU UMa is a prototype of SU UMa-type dwarf novae ranging V=11.3-15.7 (Ritter, Kolb 2008) and its orbital period is determined to be $P_{\rm orb}$=0.07635 d (Thorstensen et al. 1986). However, anomalous behavior with short and long time scales were reported in the previous studies (Rosenzweig et al. 2000; Kato 2002). In this letter, we report on detection of superhumps during a 2012 January normal outburst. This is the first recorded superhumps that emerged in the middle of a supercycle. Results of the whole observations will be discussed in a forthcoming paper.

2. Observation and Result

Time-resolved CCD photometry were performed from 2011 December 1 to 2012 February 20 at Okayama Astrophysical Observatory using the 50-cm MITSuME

OAO/MITSuME photometry of dwarf novae: I SU UMa

Akira Imada[1], Hideyuki Izumiura[1], Daisuke Kuroda[1], Kenshi Yanagisawa[1],
Toshihiro Omodaka[2], Ryo Miyanoshita[2], Nobuyuki Kawai, and Daisaku Nogami[4]
[1]*Okayama Astrophysical Observatory, National Astronomical Observatory of Japan, Asakuchi, Okayama 719-0232*
[2]*Faculty of Science, Kagoshima University, 1-21-30 Korimoto, Kagoshima, Kagoshima 890-0065*
[3]*Department of Physics, Tokyo Institute of Technology, Ookayama 2-12-1, Meguro-ku, Tokyo 152-8551*
[4]*Kwasan Observatory, Kyoto University, Yamashina-ku, Kyoto 607-8471*
imada@oao.nao.ac.jp

(Received ; accepted)

Abstract

We report on multicolor photometry of SU Ursa Majoris during 2011 December - 2012 February. Our photometry revealed that quiescence is divided into two types based on the magnitude of R_c band. Quiescent light curves showed complicated profiles with various amplitudes. Although a weak signal of the orbital period was detected in the quiescent light curves, the main light source is not originated from the hot spot, but from the accretion disk itself. During a declining stage of a normal outburst, we detected a hint of superhumps. If this is cofirmed as the superhumps, this is the first case that superhumps are observed during an isolated normal outburst. The color-color diagram revealed two possible cycles and quiescence is further divided into three types based on color indice. We newly discovered that $g' - R_c$ becomes redder a few days prior to an outburst. Although the driving mechanism is unclear, one possibility might be that the inner portion of the accretion disk is filled and obscures the central white dwarf.

Key words: accretion, accretion disks — stars: dwarf novae — stars: individual (SU Ursa Majoris) — stars: novae, cataclysmic variables — stars: oscillations

1. Introduction

Cataclysmic variables are semi-detached interacting binaries that consist of a white-dwarf primary and a late-type secondary. The secondary star filles its Roche lobe, transferring mass into the primary Roche lobe via the inner Lagrangian point (L1), by which the accretion disk is formed around the primary (for a review, see Warner 1995). Dwarf novae constiitue a subclass of cataclysmic variables, classified into three subclasses according to their activities (for a review, see Osaki 1996; Kato et al. 2004; Osaki 2005). SU UMa-type dwarf novae are a subclass of dwarf novae. They show two types of outbursts: normal outburst which lasts for a few days and superoutburst which lasts for more than 10 days. During the superoutburst, tooth-like modulations termed superhumps are visible. The mean period of the superhump are a few percent longer than that of the orbital period, which are believed to be caused by phase-dependent tidal dissipation of the eccentrically-deformed precessing accretion disk (Whitehurst 1988; Hirose, Osaki 1990).

It is widely accepted that the mean superhump period varies as the superoutburst proceeds. This indicates that the structure of the accretion disk varies, or the eccentric mode propagates across the disk, or both. Recently,

sic picture of the superhump period change. The basic profile of $O-C$ diagram consists of three stages: stage A when the mean superhump period is constant, stage B when the mean superhump period increases as the superoutburst proceeds, and stage C when the mean superhump period keeps constant but the period slightly shorter than that of stage A. The vast majority of SU UMa-type dwarf novae follows the basic picture of $O-C$ diagram. However, there exists several exception. For instance, some objects do not show stage A. Such systems include xxx, xxx, xxx, and xxx. Other exception to be noted is that the mean superhump period decreases during stage B. Such systems tend to have longer superhump period, but the physical mechanism of this trend is unknown. In order to understand the diversity of the superhump period changes, time-resolved photometry not only during superoutburst but also during quiescence are imperative.

Another noticable topic is that unprecedentedly precise light curves have been provided by *Kepler* (Borucki et al. 2010; Haas et al. 2010). The obtained light curves include some SU UMa-type dwarf novae such as V344 Lyr and V1504 Cyg (see also table 1 of Still et al. 2010). ? reconstruct the thermal-tidal instability model using Kepler data of V344 Lyr. More recently, various authors analyzed

特に重要な成果

- Normal outburst時にsuperhumpを検出

→　TTI modelのreformを要請

(PASJ letter submitted)

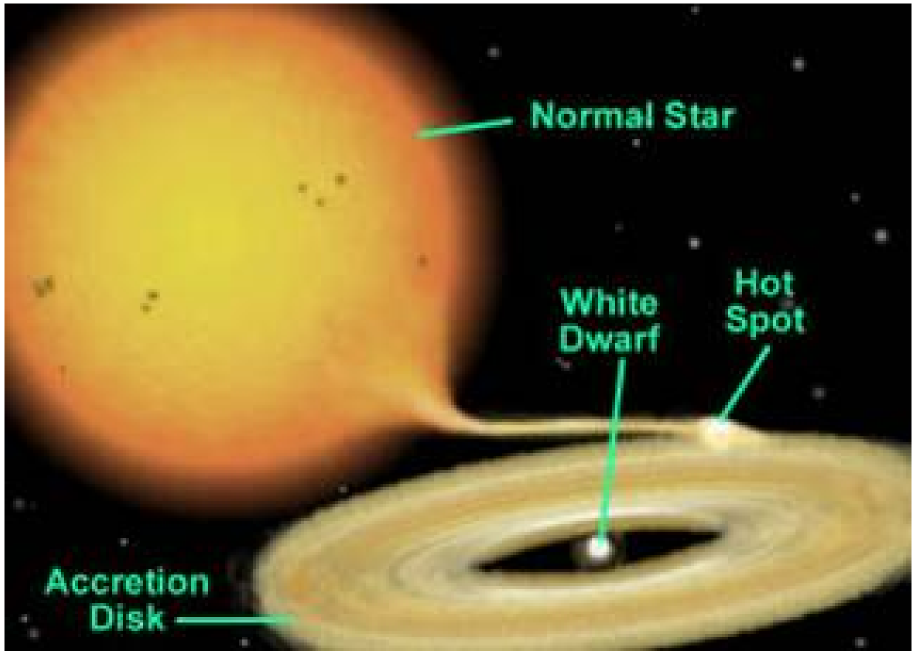
- 色変化にoutburstの「予兆」を発見

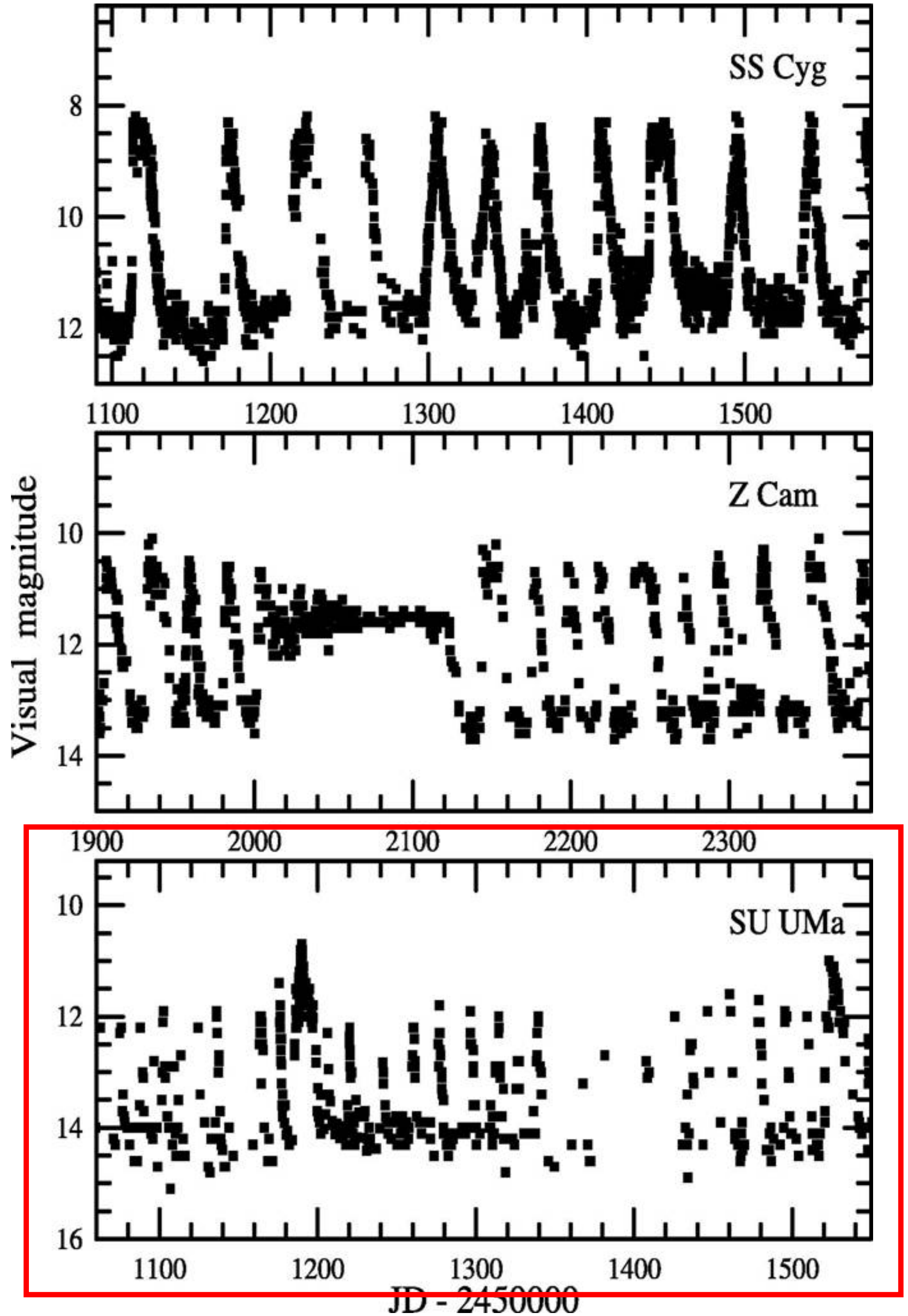
→　disk instability modelのreformを要請

(PASJ in preparation)

矮新星

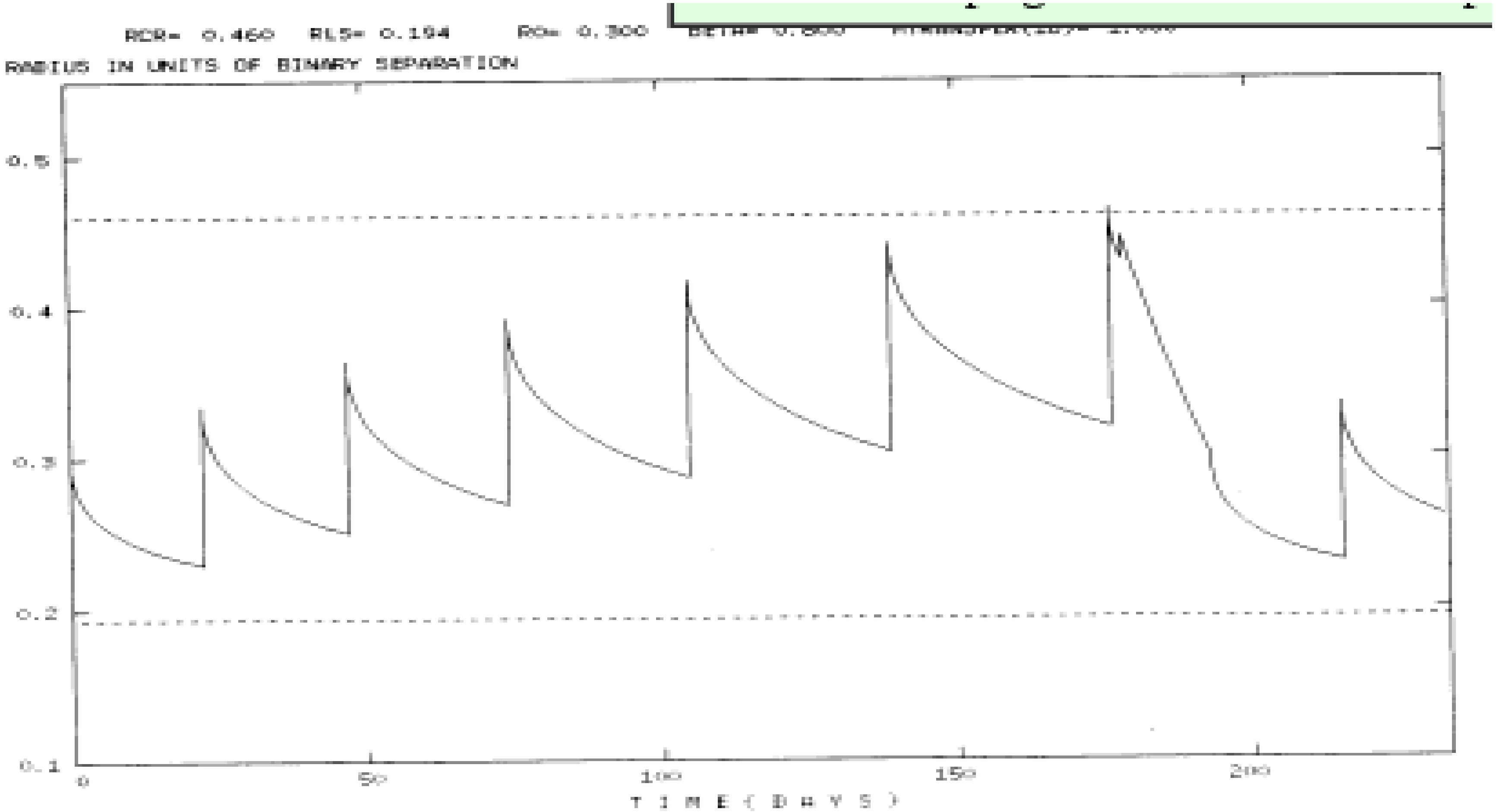
- 軌道周期およそ1～9時間の近接連星系。
- 時々outburstを起こす。
- 光度曲線の違いから3種類に分類。





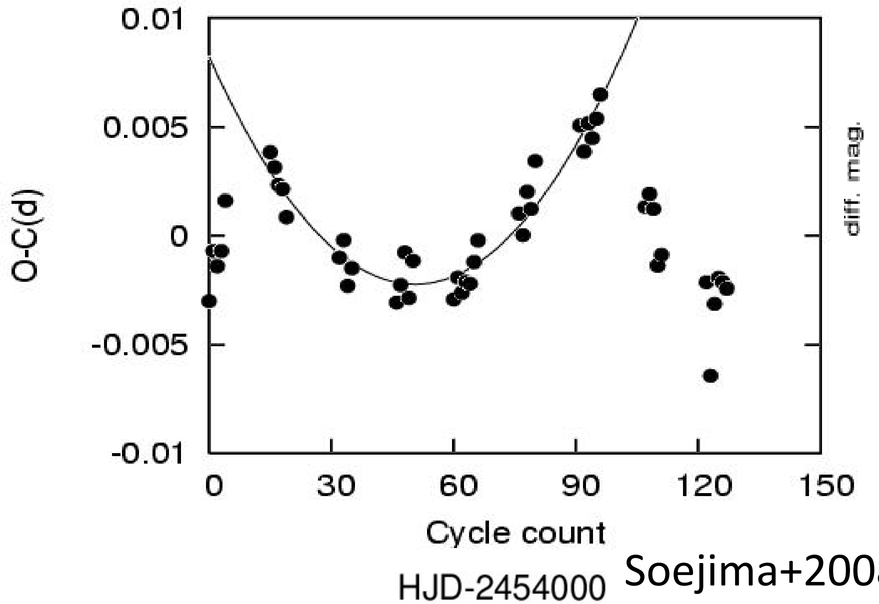
Kato+ (2004)

TTI model

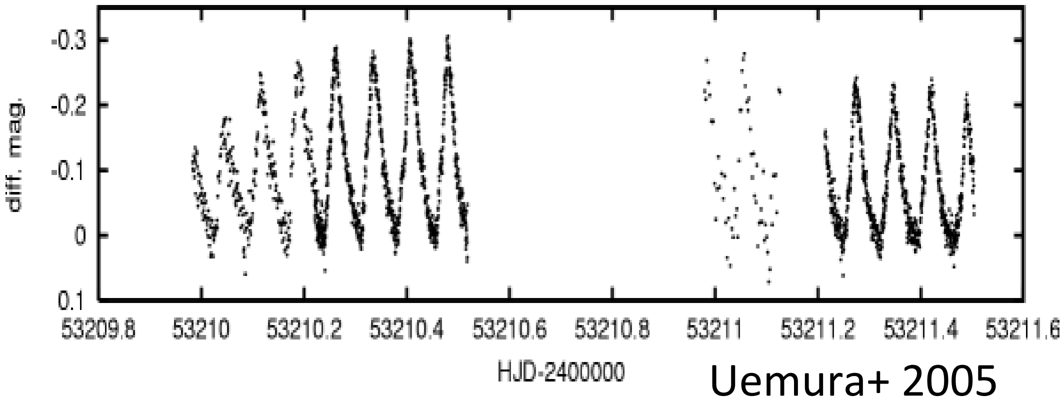


- Superoutburst は共鳴半径に到達してから。

Superhump period change



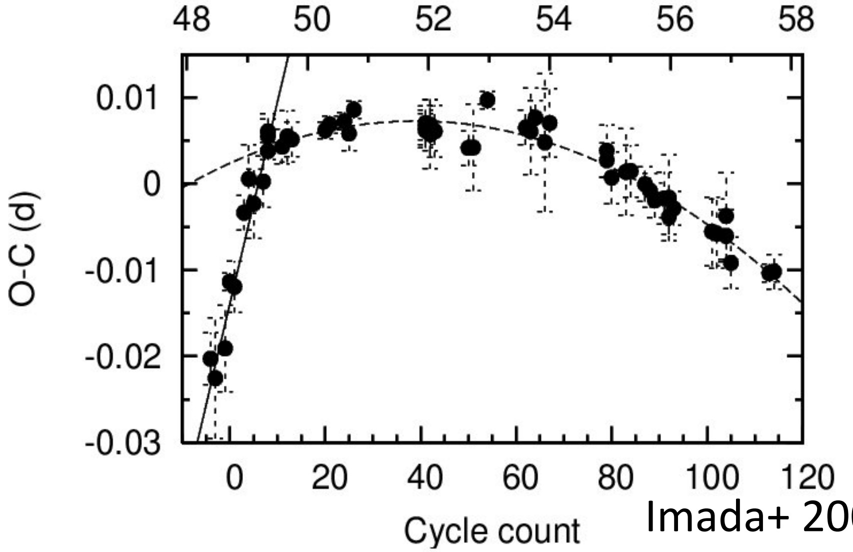
Soejima+2008



Uemura+ 2005

- O-C図は天体ごとに個性があり、その全ての挙動を説明することは不可能。

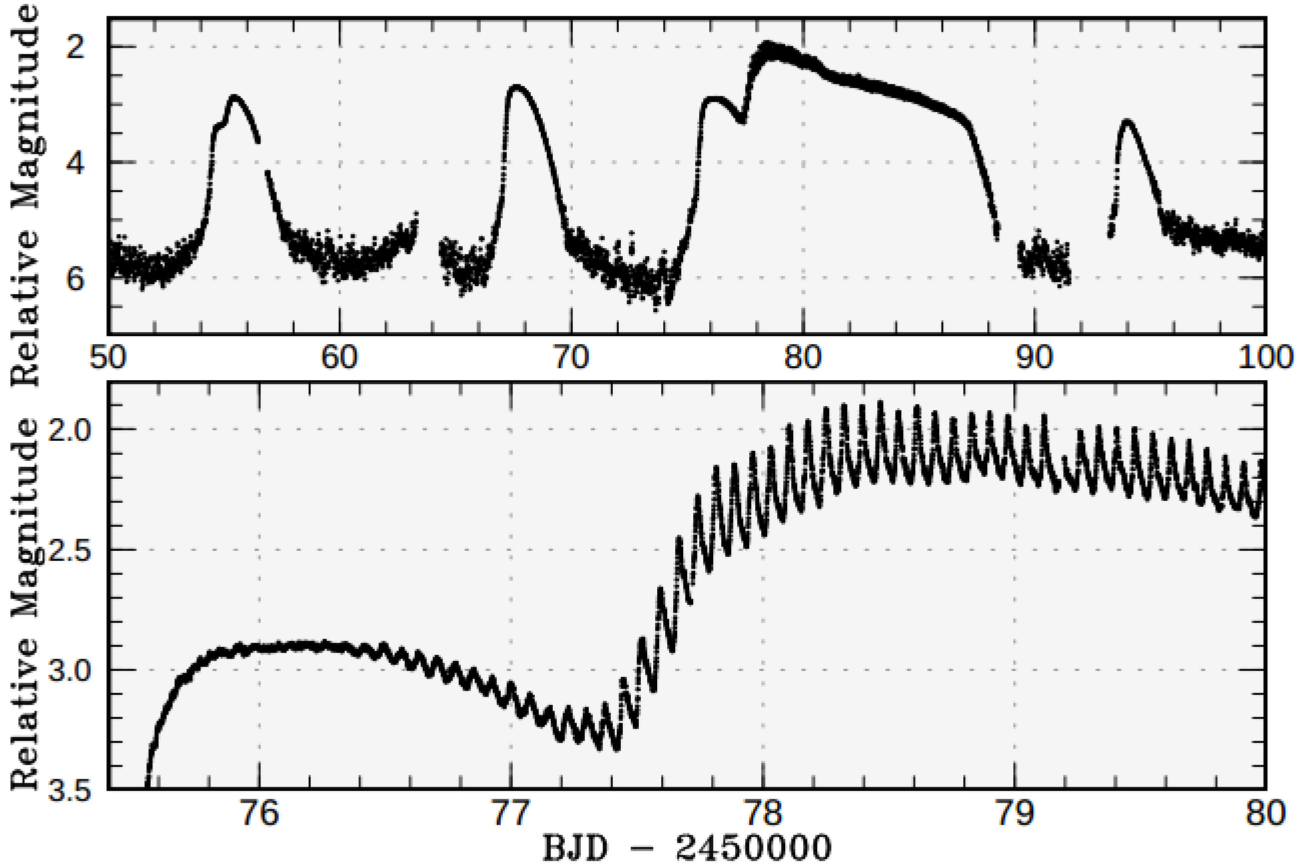
更なる理解のためには静穏時の光度曲線について知る必要があるのでは？



Imada+ 2008

Kepler light curve of dwarf novae

- もはや地上では太刀打ち不能（笑）



Kato et al. (2011)

そもそも何故MITSuMEで観測を始めたか？

- Superoutburst時のsuperhump周期変化の統計的な解析が進み、基本的な描像が確立してきた(Kato et al.)。

- Keplerによる連続測光観測で過去に例を見ない詳細なデータが取得されるようになった。

●「色」という独自性を活かして新たな視点から研究する必要性
●Superhump周期変化の多様性を理解するためには増光時の観測のみならず、静穏時の観測をする必要あり。

目の前にMITSuMEがあるではないか（笑）！

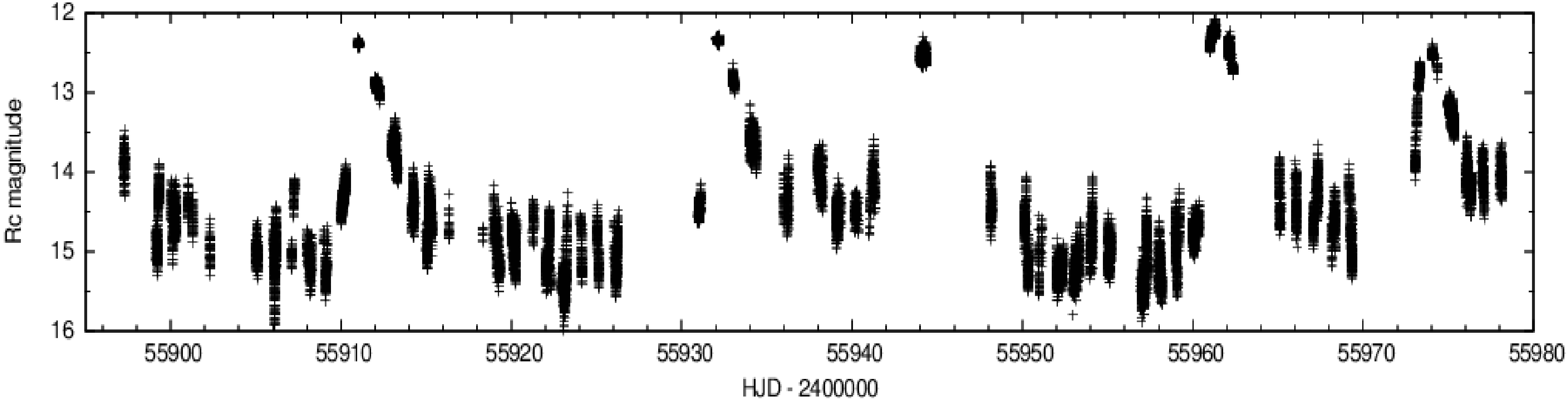
OAO/MITSuME observations of SU UMa

- というわけで手始めにSU UMaを観測
- 2011年12月1日～2012年2月20日まで
- 合計夜数60夜、データ点20000×3

- 極小期でも15等くらいのため、50cmの口径なら静穏時の光度曲線がhigh S/Nで取得可能！

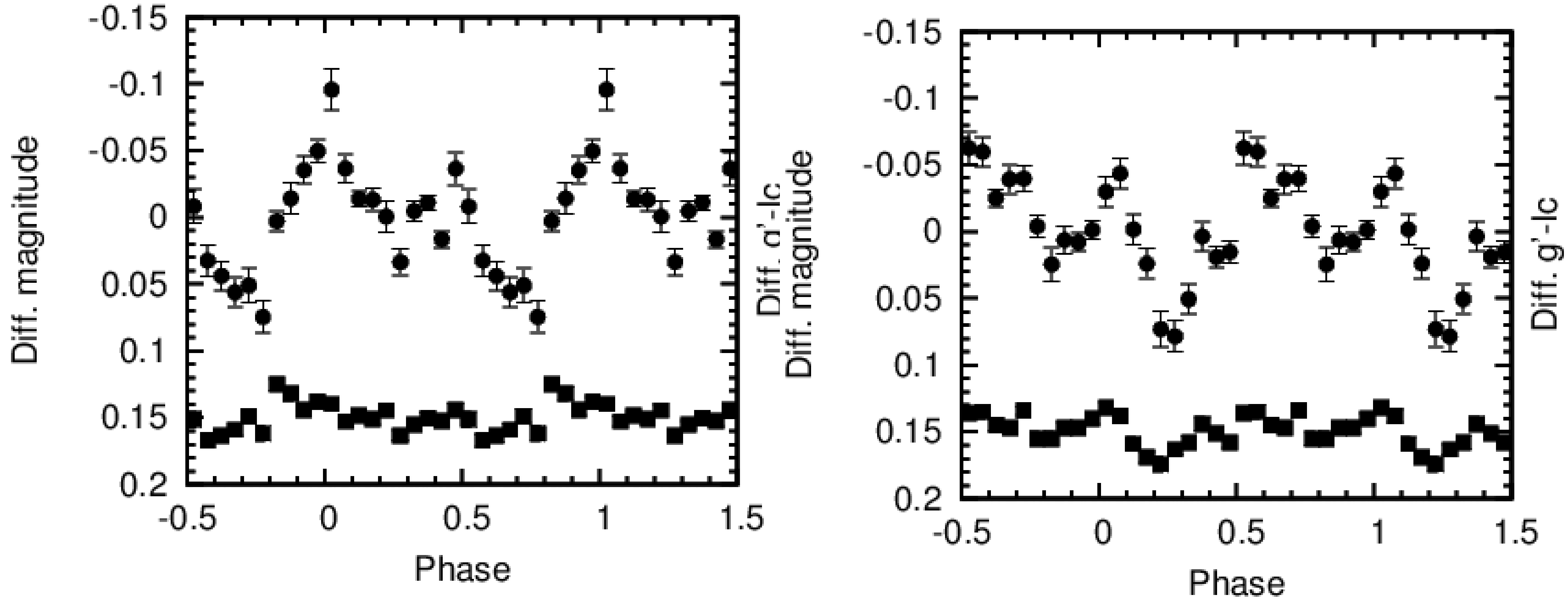
（このあと業界騒然の驚きの結果！）

Rc band light curve



- 静穏時中も緩やかに減光
- **「明るい静穏時」の存在**
- Failed outburstの検出

Normal outburst中にsuperhumpを発見



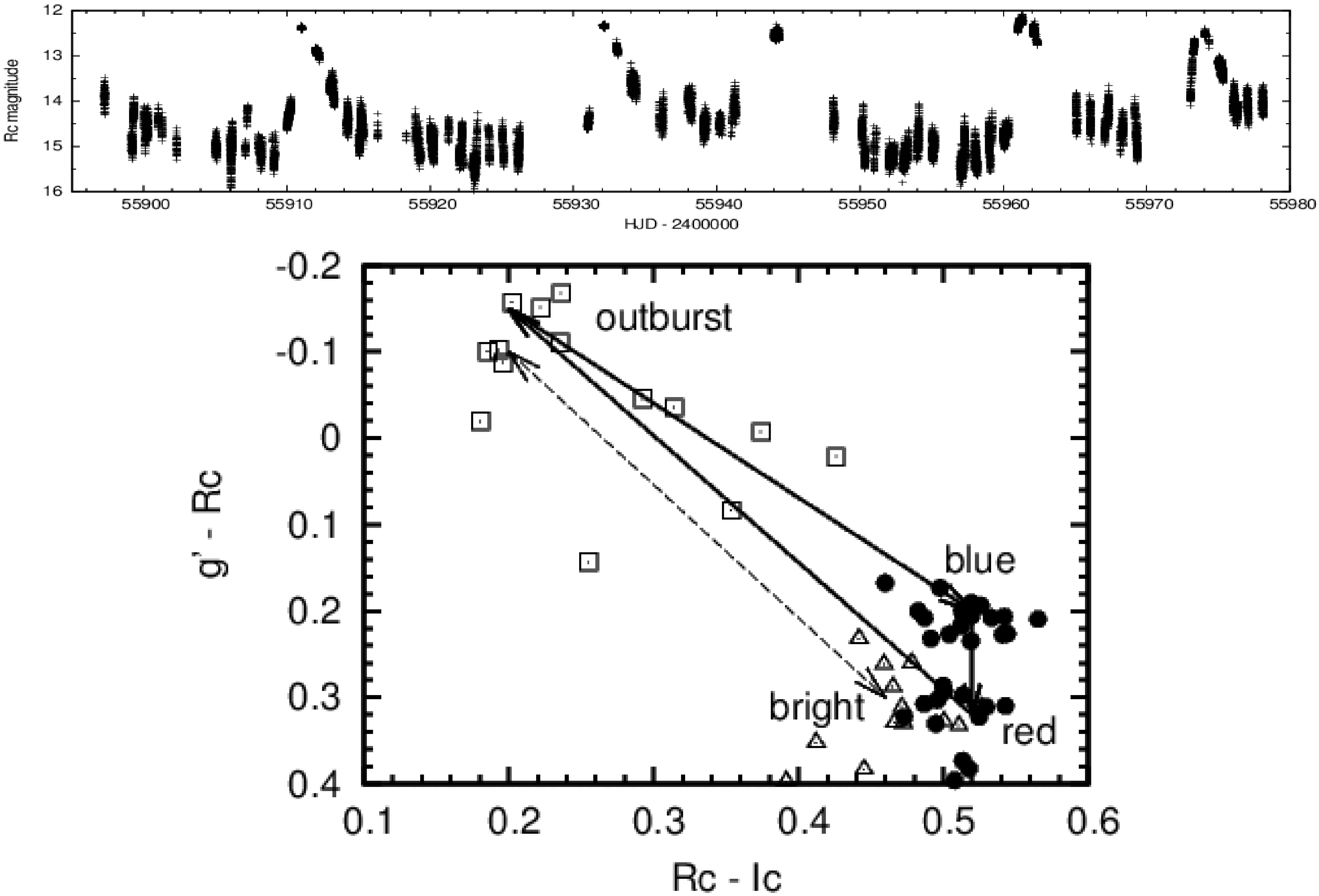
●単独のnormal outburst中に観測されたのは史上初

●色-等級変化が過去の観測例と同じ(e.g., Matsui et al. 2009)

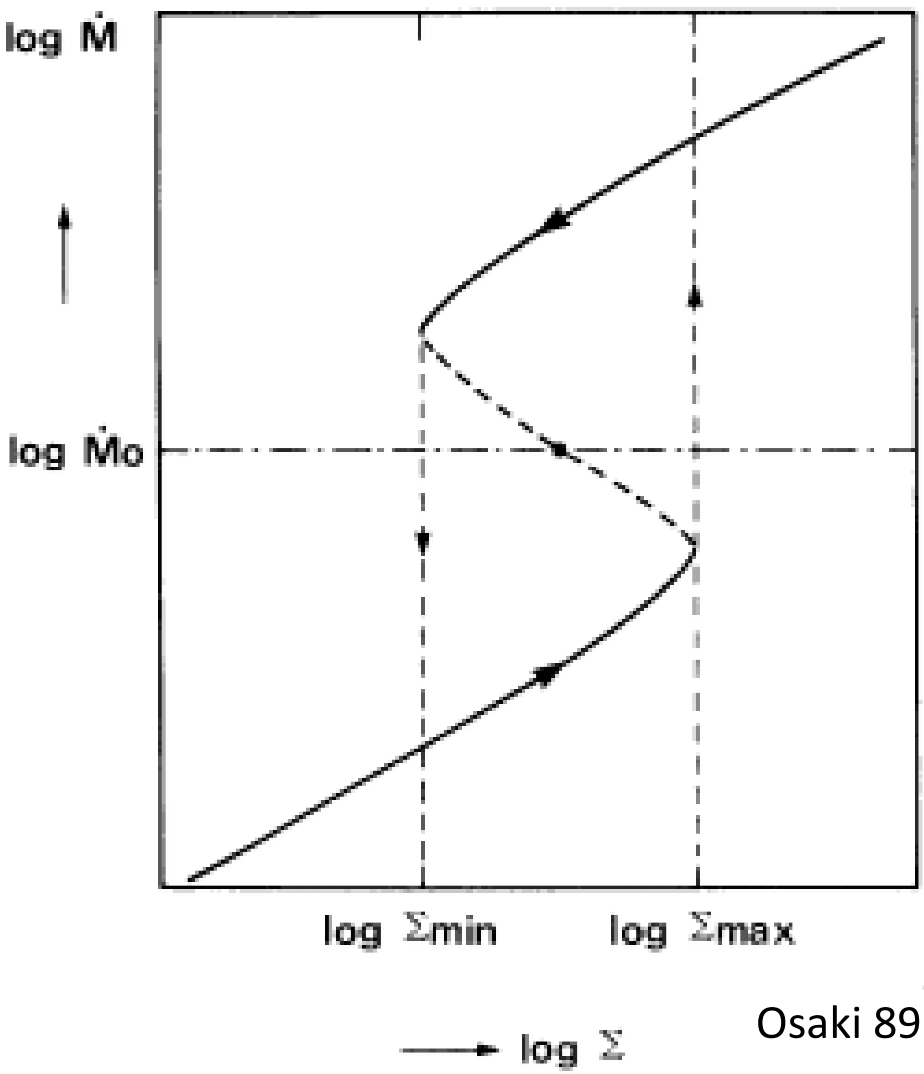
→ superhumpと断定

→ TTI modelのreformを要請

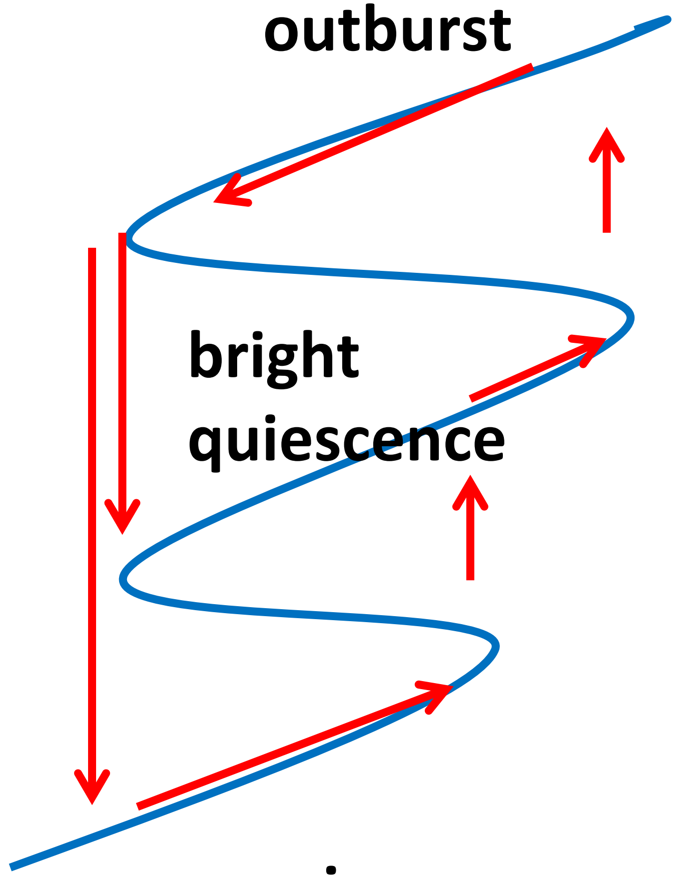
color-color diagramでoutburstを「予知」



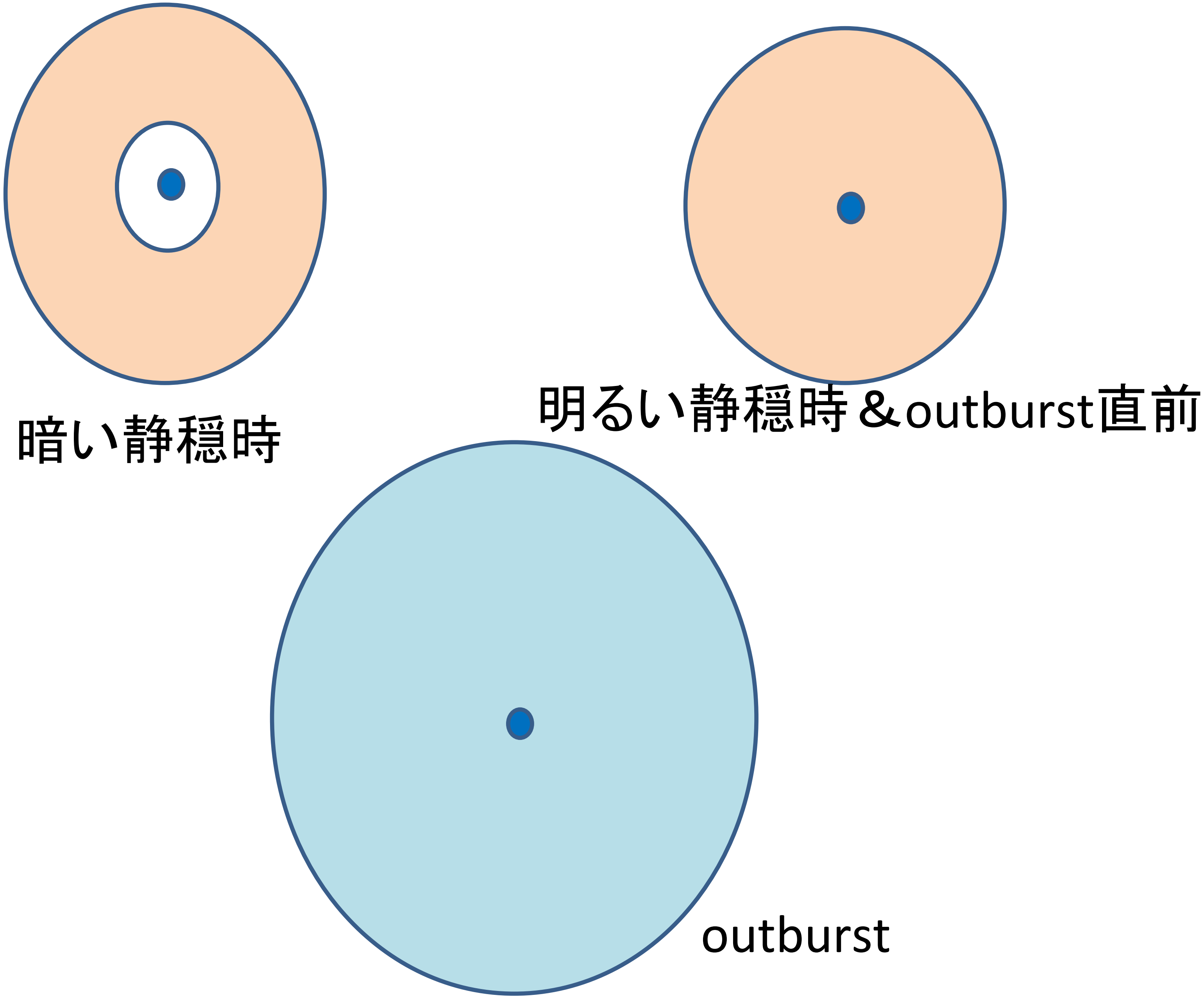
Thermal limit cycleを思い出すと解釈に苦しむが



Osaki 89



何故g’ bandだけ？？



まとめ

- MITSuMEで矮新星を観測
- Normal outburst時にsuperhumpを検出
- Outburst直前の「予兆」を検出

- MITSuMEでの矮新星観測は今後も独自性を発揮して様々な成果が期待できる。

(今あるデータだけでも4-5本/yearの論文生産可)