Mass-transfer and starspot properties in eclipsing binary systems

Seminar at UCM on Nov. 29 2018

Shinjirou Kouzuma
(Chukyo University)

Self-introduction

- ✓Shinjirou Kouzuma（高妻 真次郎）
- ✓Chukyo University in Nagoya
- ✓One-year sabbatical (Apr. 2018-Mar. 2019) at UCM

Nagoya Station

Chukyo University

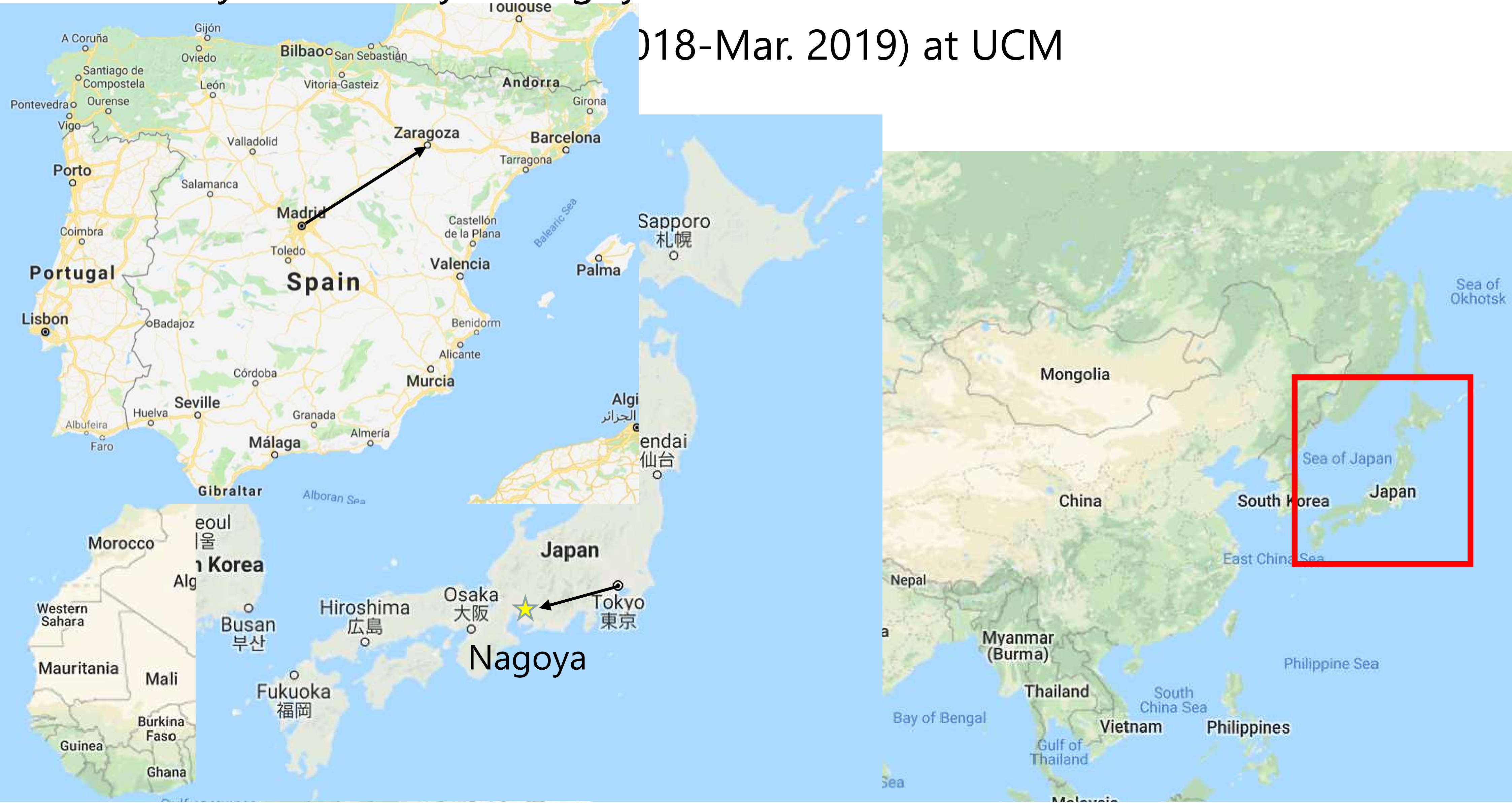
Nagoya castle

Self-introduction

✓Shinjirou Kouzuma（高妻 真次郎）

✓Chukyo University in Nagoya

18-Mar. 2019) at UCM



Today's topics

90-1

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Starspots in contact and semi-detached binary systems

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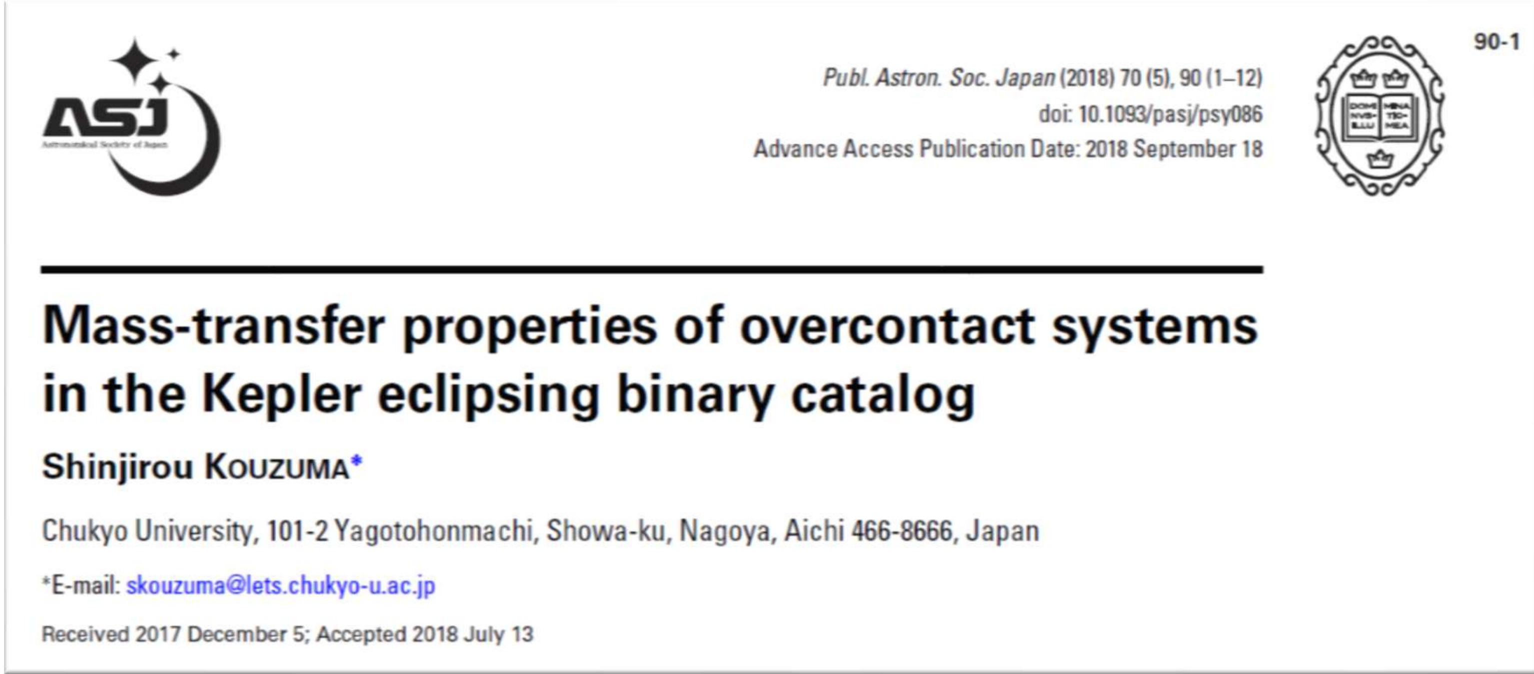
Main conclusions of first topic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Examine the dependence of mass-transfer rate on astrophysical quantities by using Kepler data

✓W- and A-types may have different properties

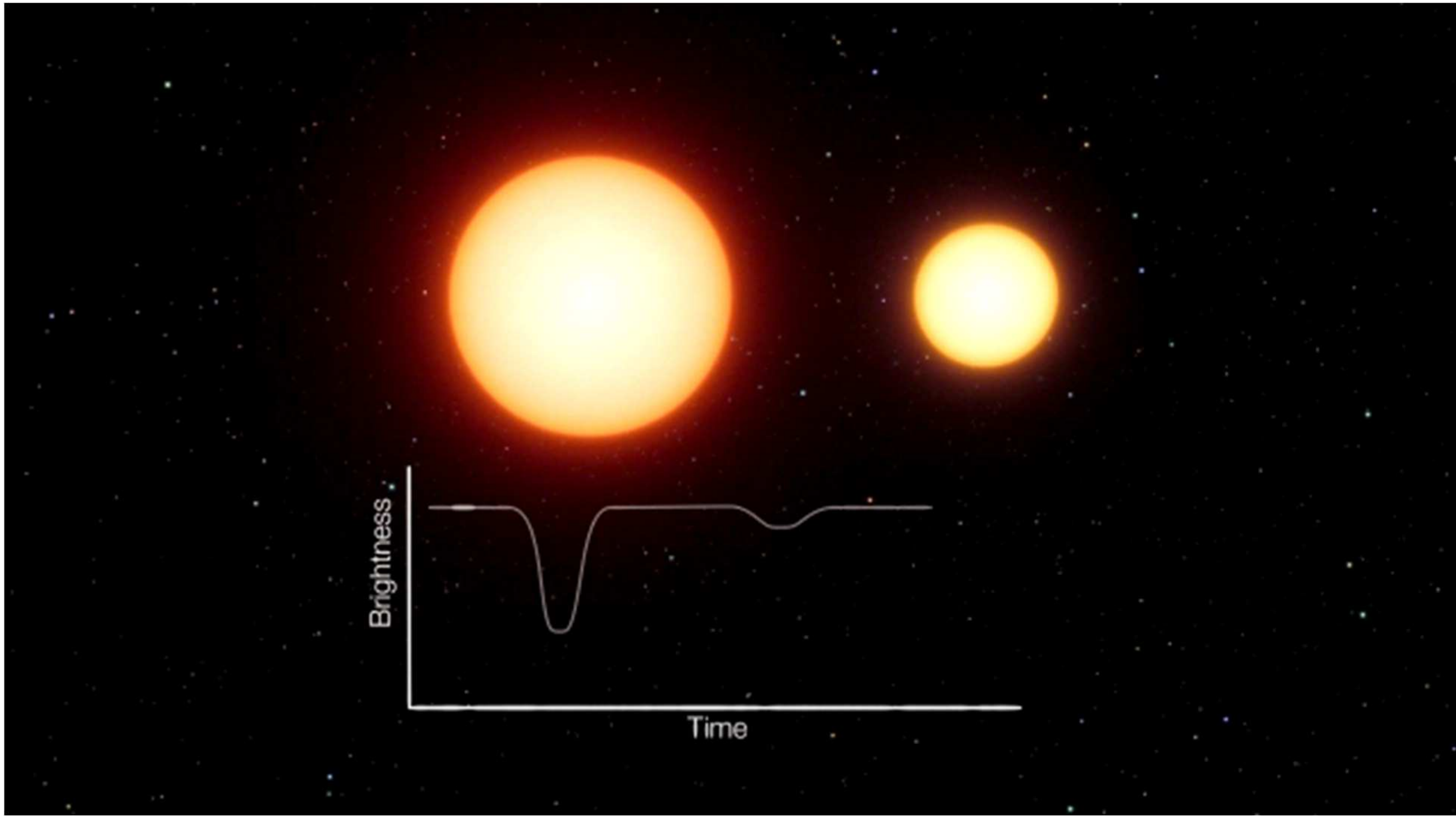
✓Mass exchange from more- to less-massive stars (less- to more-massive stars) generally becomes rapid (slow) as the mass exchange evolves.

Introduction: What are eclipsing binaries?

Binary stars ⇨ systems in which two stars are gravitationally bound

Eclipsing binary stars

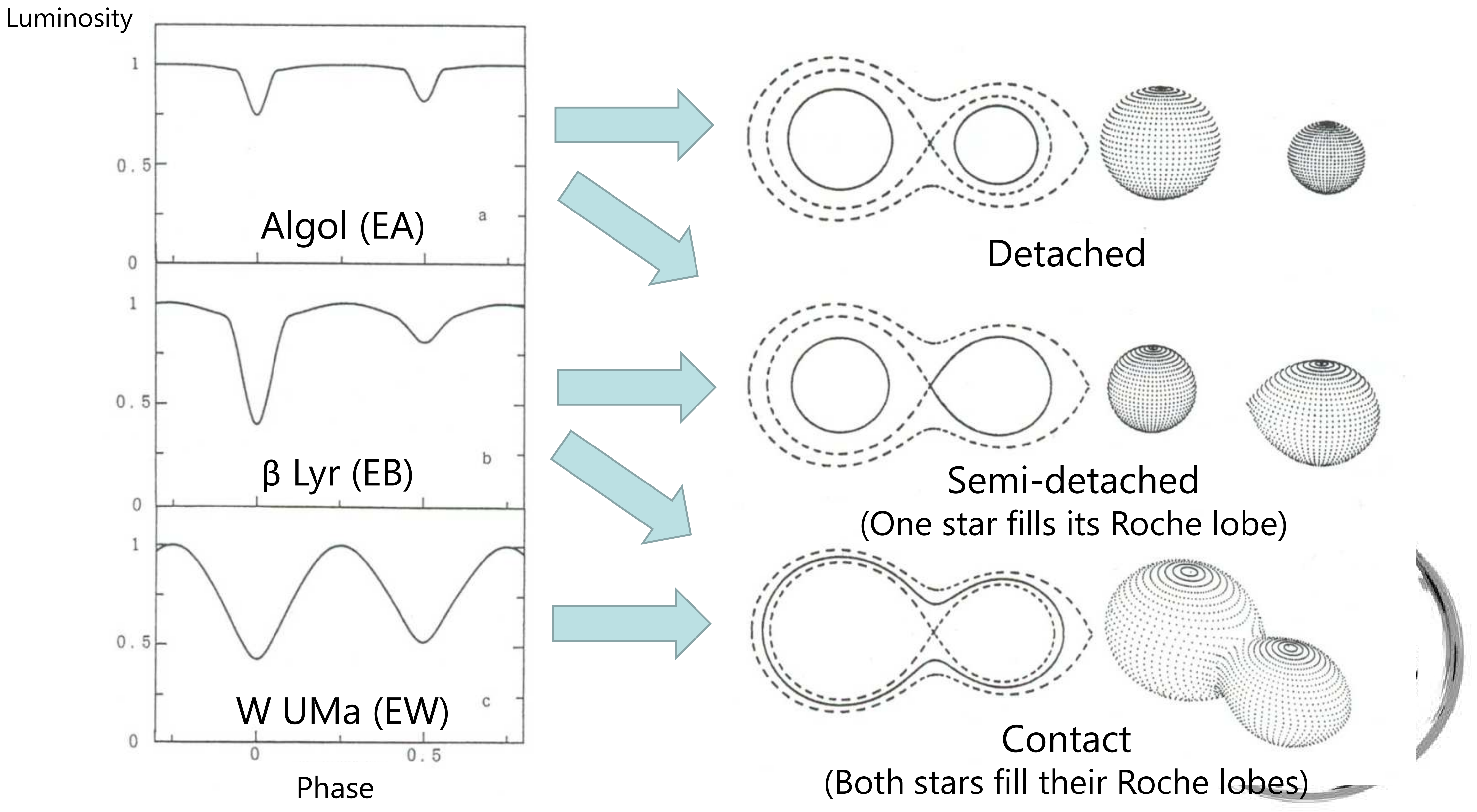
⇨ Binary stars which have periodic minima in their light curves



Types of close binaries: Kopal's classification

Typical light curves

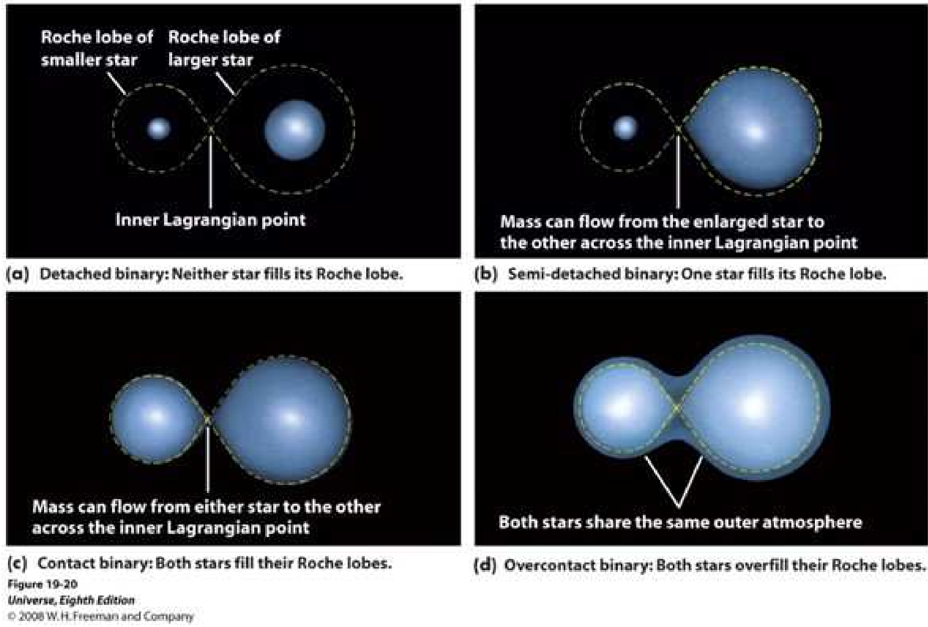
Kopal's classification (Kopal 1955)



Why is mass-transfer important?

Mass transfer is classified into two cases

- **Mass exchange** between component stars (ME)
- **Mass loss** (ML)

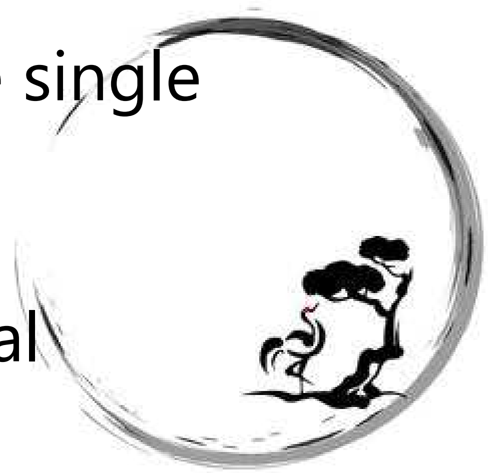


Mass transfer results in the changes of binary parameters

- **Orbital period** (orbital separation)
- The **masses** of component stars
- etc.....

The binary star evolution is more complicated than the single star evolution

Nevertheless, few studies have focused on the statistical properties of mass-transfer!



How to estimate mass-transfer rates?

Mass transfer results in the change of orbital period

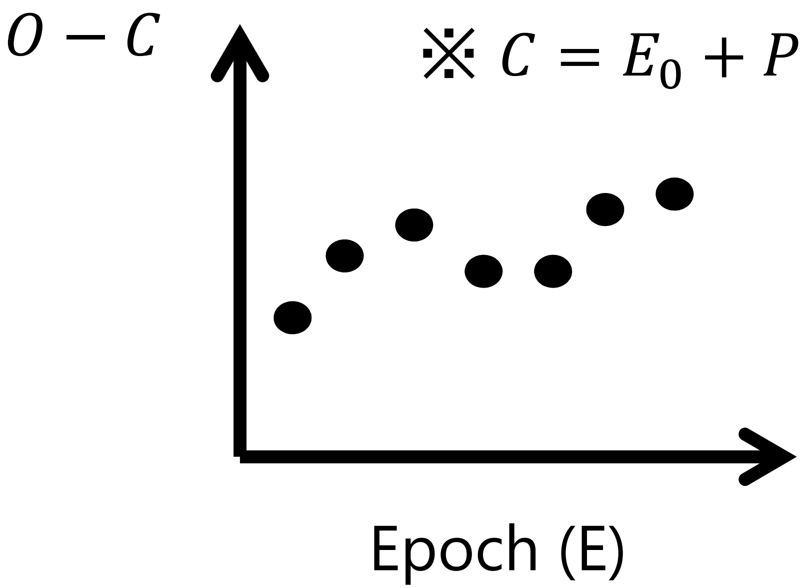
Mass exchange (ME) rate can be derived assuming the total mass and angular momentum are conserved (Hilditch 2001).

$$\frac{\dot{P}}{P} = \frac{3(m_1 - m_2)}{m_1 m_2}\dot{m}_1$$

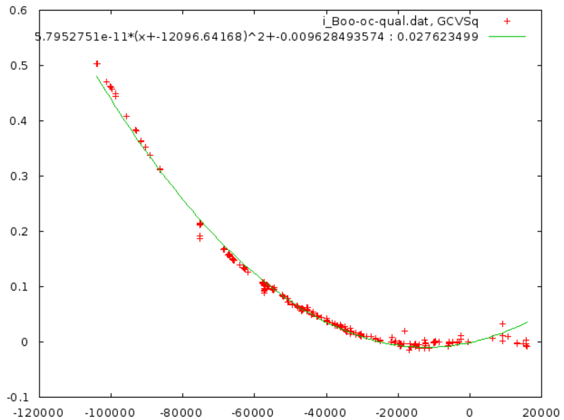
if $\dot{P} < 0 \rightarrow$ ME from more- to less-massive stars
if $\dot{P} > 0 \rightarrow$ ME from less- to more-massive stars

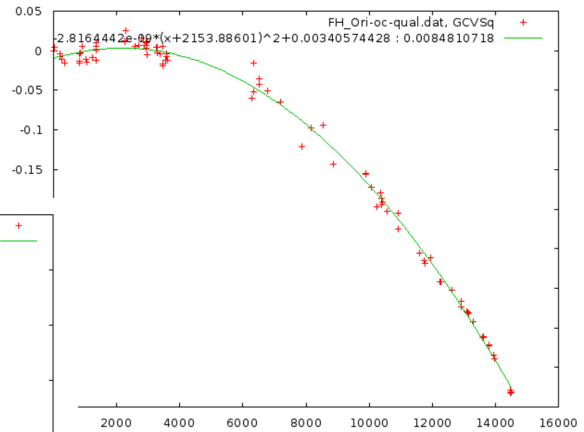
The period change rate can be estimated with O−C diagrams

※ $C = E_0 + P \cdot E$



$\dot{P} > 0$





$\dot{P} < 0$

Kepler space telescope

- Observation between 2009-2013 (primary mission)
- Telescope with a primary mirror of 1.4 m
- Wavelength range: 430-890 nm
- Monitored about 160 thousands objects
- A main purpose is to detect exoplanets

→ high time-resolution and extremely small uncertainty in brightness

↓

The Kepler data are also suitable to study eclipsing binaries

Kepler Eclipsing Binary Catalog

The catalog of eclipsing binaries observed by Kepler (Prsa et al. 2011)

The revised catalog used in this study contains 2,165 eclipsing binaries:

Systems	The number of objects
Detached	1,261
Semi-detached	152
Overcontact	469
Ellipsoidal variables	137
Uncertain or unclassified	147

The KEB catalog lists several physical parameters (mass ratio, temperature ratio, fill-out factor etc.)

Mass ratios, which are necessary for calculating the mass-transfer rate, are provided only for overcontact systems.

Method

1. Selected binaries which show parabolic-period variations by visual inspection

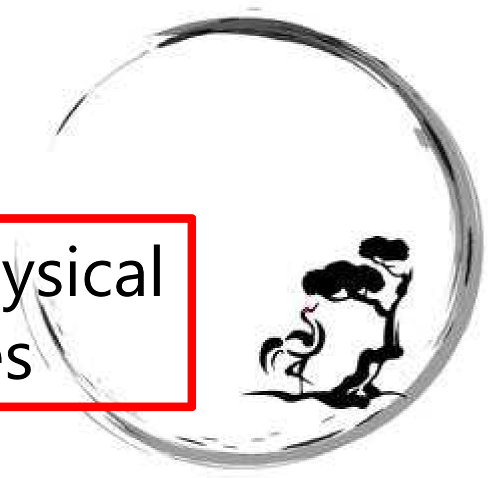
2. Calculated the orbital-period change rates of the selected binaries on the basis of the quadratic fitted O－C curves

3. The masses of component stars were computed from mass-temperature relation (Harmanec 1988) and mass ratio

4. Their mass-exchange rates were calculated by the following equation

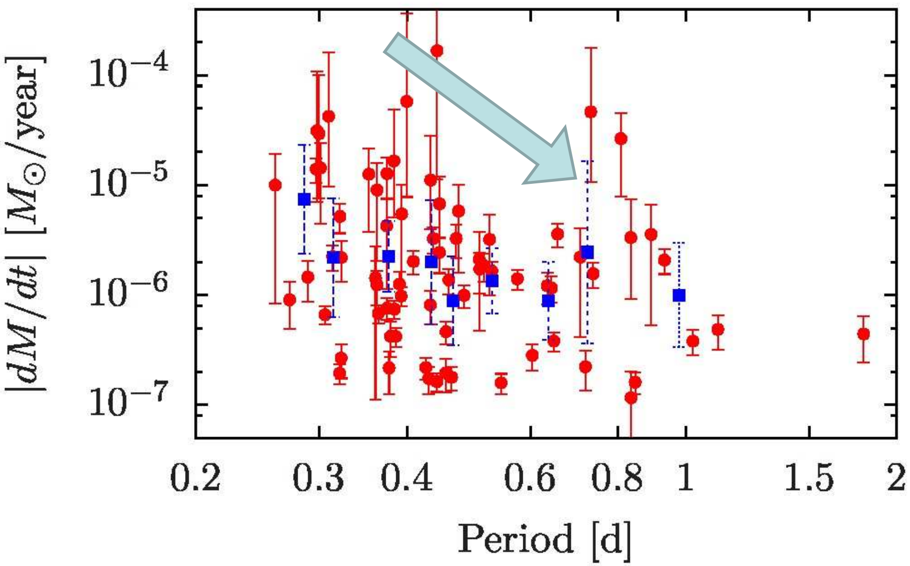
$$\frac{\dot{P}}{P} = \frac{3(m_1 - m_2)}{m_1 m_2}\dot{m}_1$$

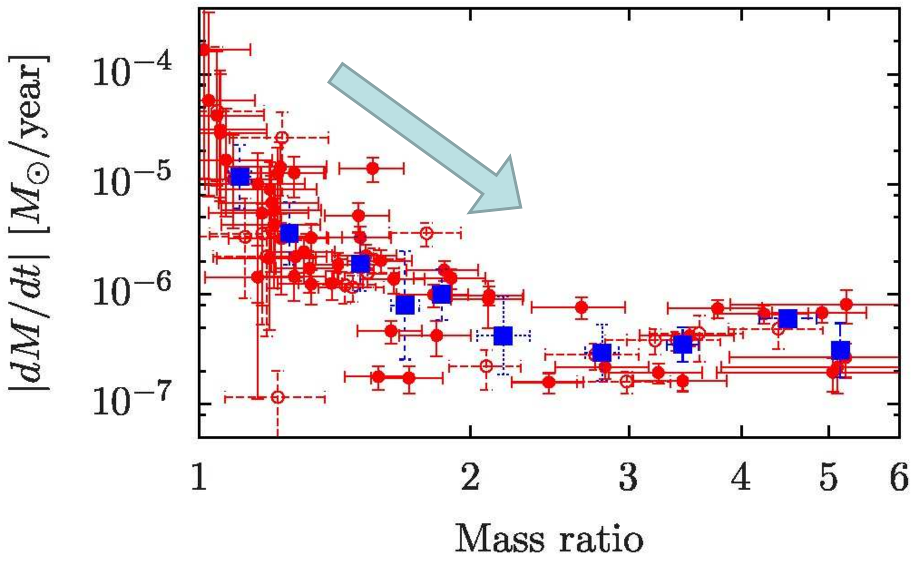
The dependence of mass-exchange rate on astrophysical parameters was investigated for 111 sample binaries

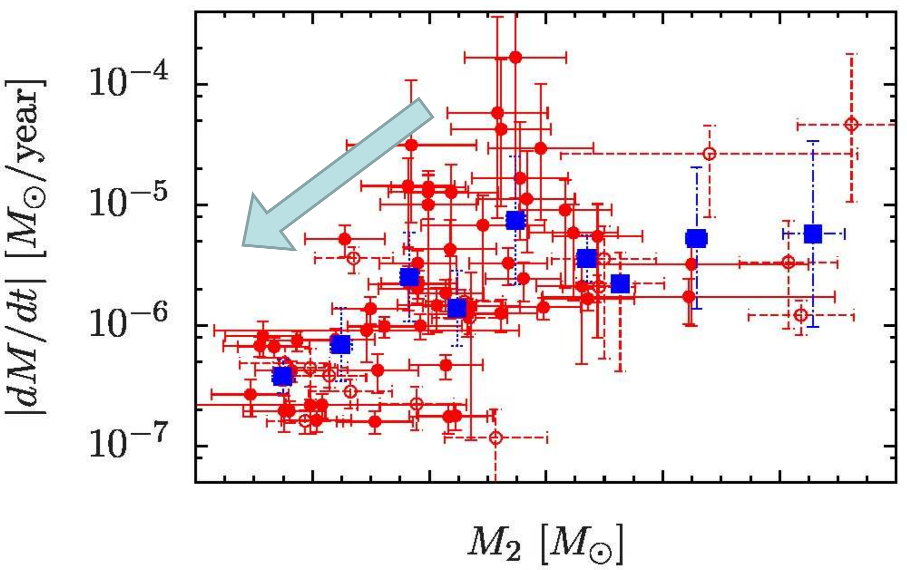


Result: ME from less- to more-massive stars

When the mass-exchange ($M_2 \rightarrow M_1$, $M_1 > M_2$) occurs,
P and mass ratio (M_1/M_2) increases and M_2 decreases



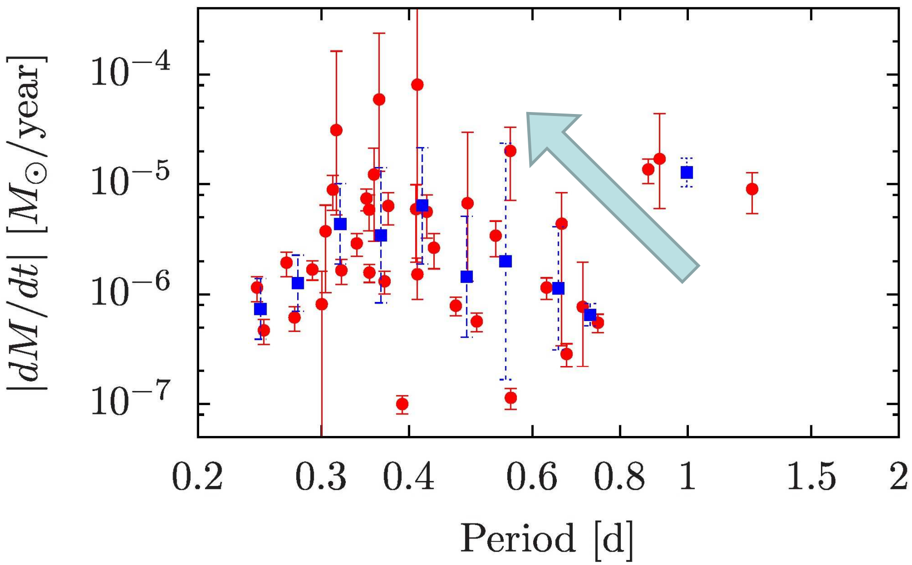


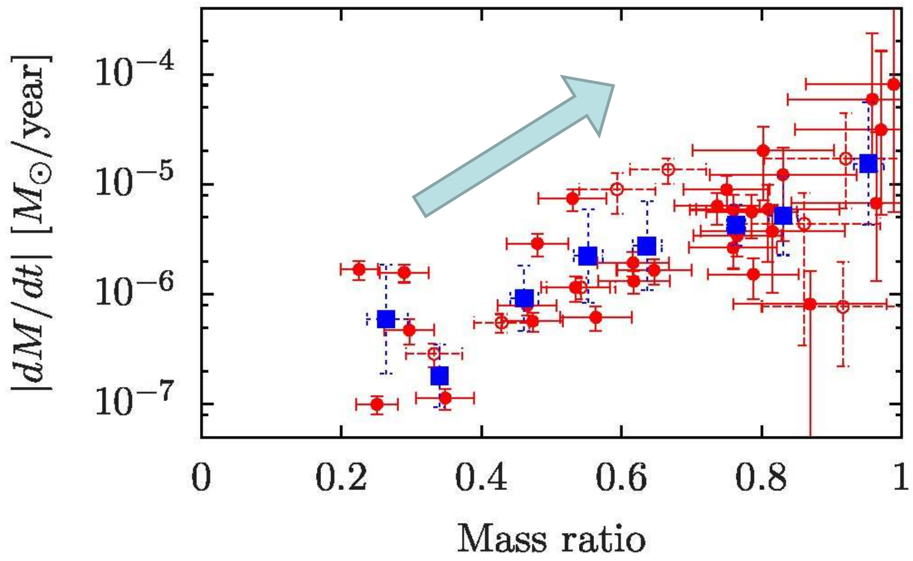


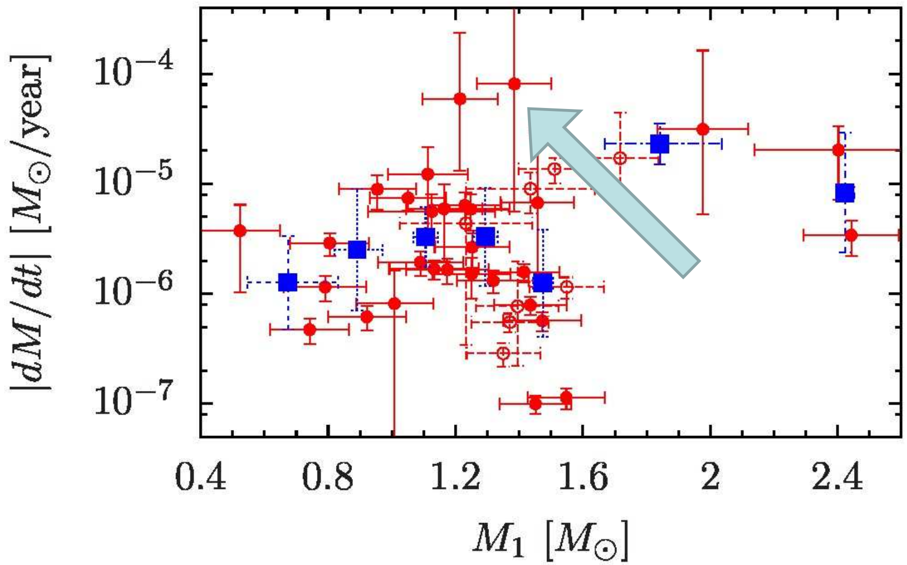
Mass-exchange becomes slow
as the mass exchange evolves!

Result: ME from more- to less-massive stars

When the mass-exchange ($M_1 \rightarrow M_2$, $M_1 > M_2$) occurs,
P and M_1 decrease and mass ratio (M_2/M_1) increases



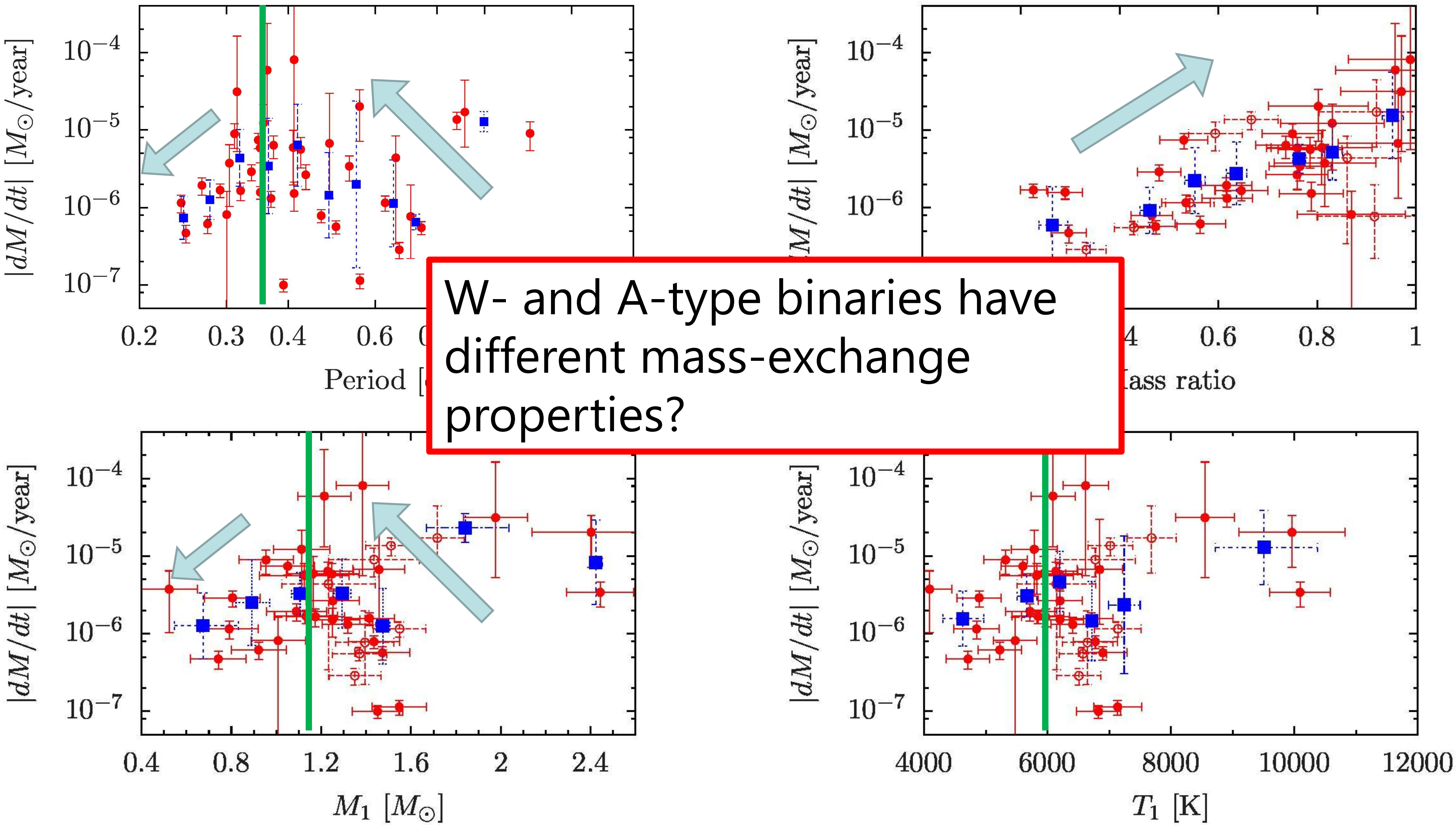




Mass-exchange becomes rapid
as the mass exchange evolves!

Result: ME from more- to less-massive stars

When the mass-exchange ($M_1 \rightarrow M_2$, $M_1 > M_2$) occurs,
P and M_1 decrease and mass ratio (M_2/M_1) increases



W- and A-type binaries have different mass-exchange properties?

Summary of mass-transfer study

Examined the dependence of mass-transfer rate on astrophysical quantities by using Kepler data

✓Mass exchange from more- to less-massive stars (less- to more-massive stars) generally becomes rapid (slow) as the mass exchange evolves.

✓W- and A-types may have different properties

Main conclusions of second topic

Starspots in contact and semi-detached binary systems

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⇨ Statistical analysis of starspots in close binary systems

⇩

✓The W-type systems show properties similar to those of sunspot

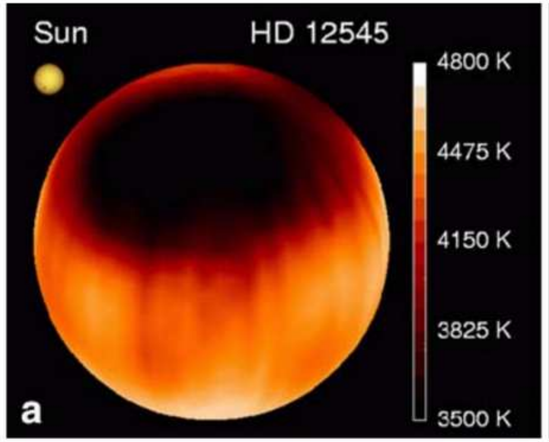
✓The spot properties of A-type systems differ from those of W-type systems

The importance of starspot activity

Starspot activity is closely associated with various stellar phenomena and the inner structure of stars.

⇨ magnetic activity, flare, superflare, and so on

Though investigating starspot properties solve problems associated with the binary star activity and evolution, few studies have examined their statistical properties.



The gigantic starspot of the K giant XX Tri (Strassmeier 2009)

<u>In addition,</u>

starspots in binaries sometimes show properties differing from sunspots

e.g.

Sunspot: a few percent of the surface; live for hours to months (Solanki 2003)

Starspot (mainly RS CVn): gigantic spot covering up to 20% (Strassmeier 1999); long-lived (~11 yr) polar spot (Vogt et al. 1999)

It is also important to examine whether such difference is also found in other types of binaries

Sample of spotted binary stars

The spot parameters were collected from literatures

These parameters were determined with light-curve modeling (light-curve synthesis)

	W-type	A-type	SD1	SD2	Total
Cool spot*	52 (27)	32 (21)	3 (2)	15 (4)	102 (54)
L/M†	13/39	13/19	1/2	11/4	34/60
C/H‡	39/13	21/11	1/2	11/4	72/30
Hot spot*	15 (7)	16 (12)	6 (0)	8 (2)	45 (21)
L/M†	5/10	8/8	6/0	1/7	20/25
C/H‡	10/5	8/8	6/0	1/7	2/20

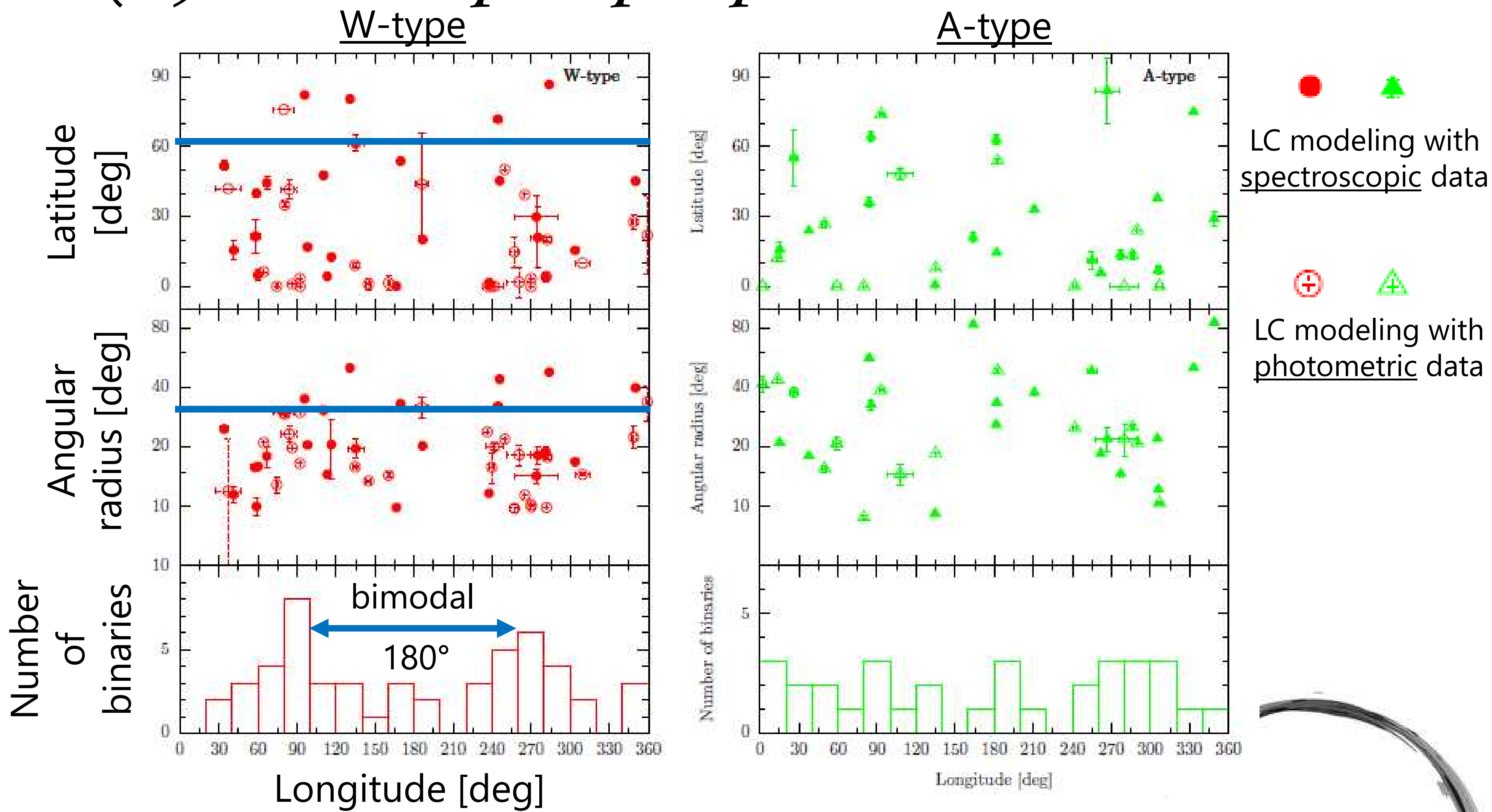
* **The numbers in parentheses represent the numbers of systems whose parameters were determined on the basis of spectroscopic mass-ratio.**

† The symbols L and M denote that the less-massive and more-massive component stars have a starspot respectively.

‡ The symbols C and H denote that the cooler and hotter component stars have a starspot respectively.

Examined correlations between starspot and binary parameters

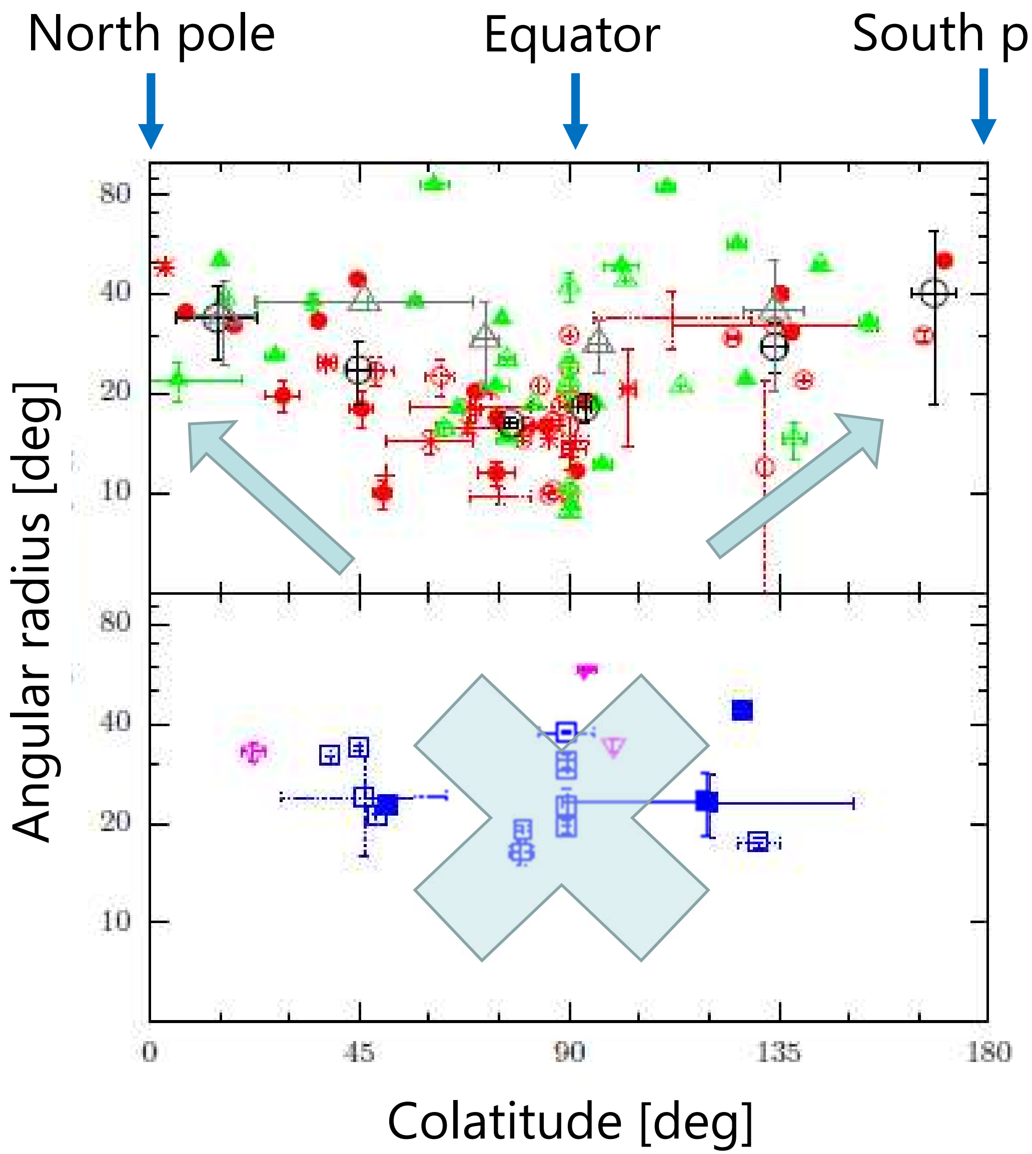
Results(I): Cool spot properties



Starspot activity in W-type tends to be active around l=90° and 270°

These properties are consistent with flip-flop phenomenon which can be explained by dynamo models

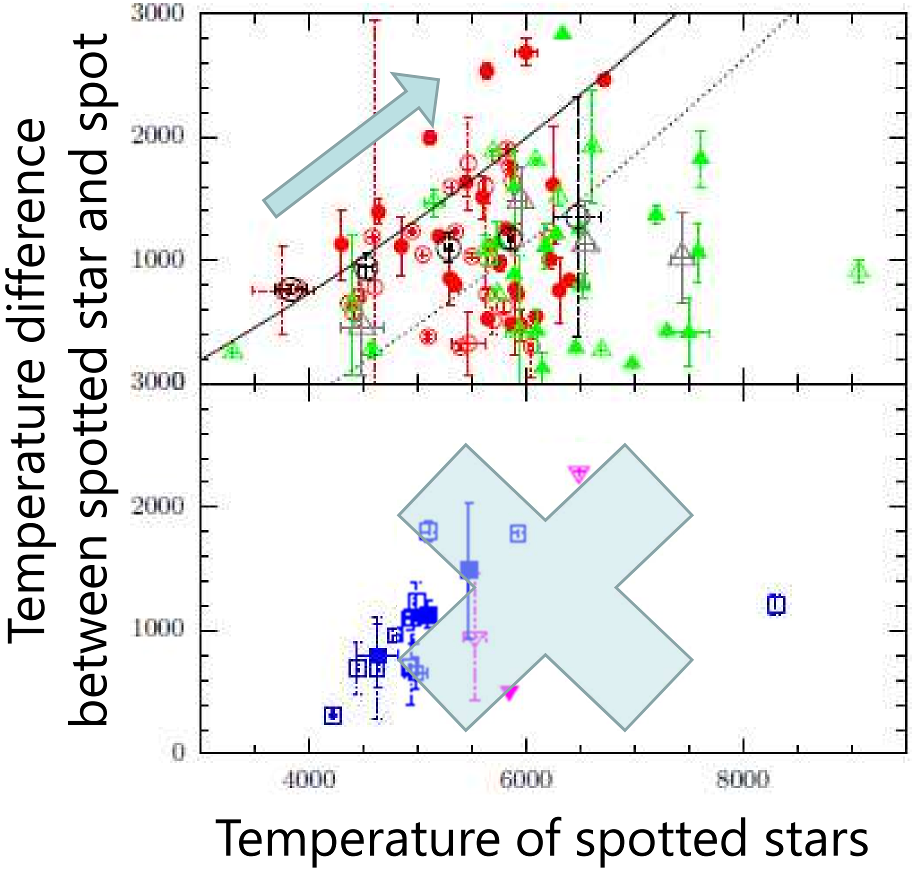
Results(2) : Cool spot properties

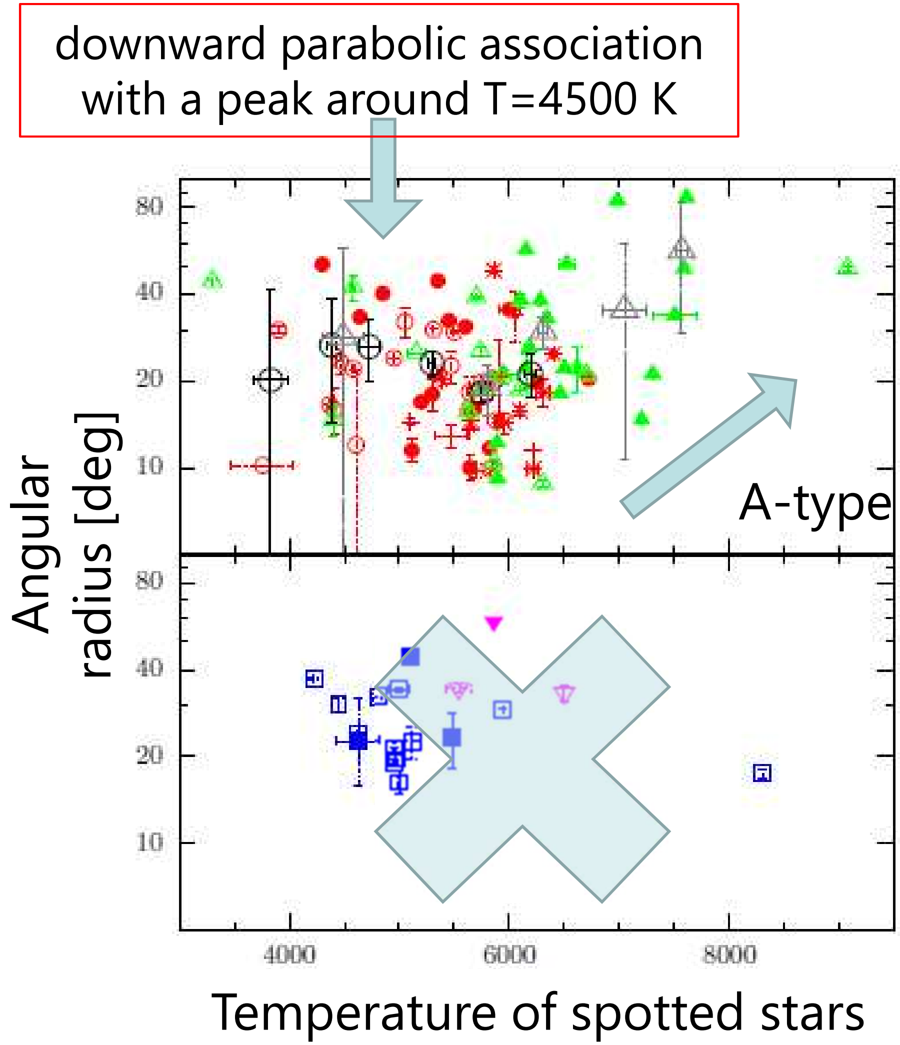


Starspots in W-type tend to be larger for spot positions close to the poles

Sunspots also show similar correlations (e.g. Li et al. 2003; Solanki et al. 2008)

Results(3)

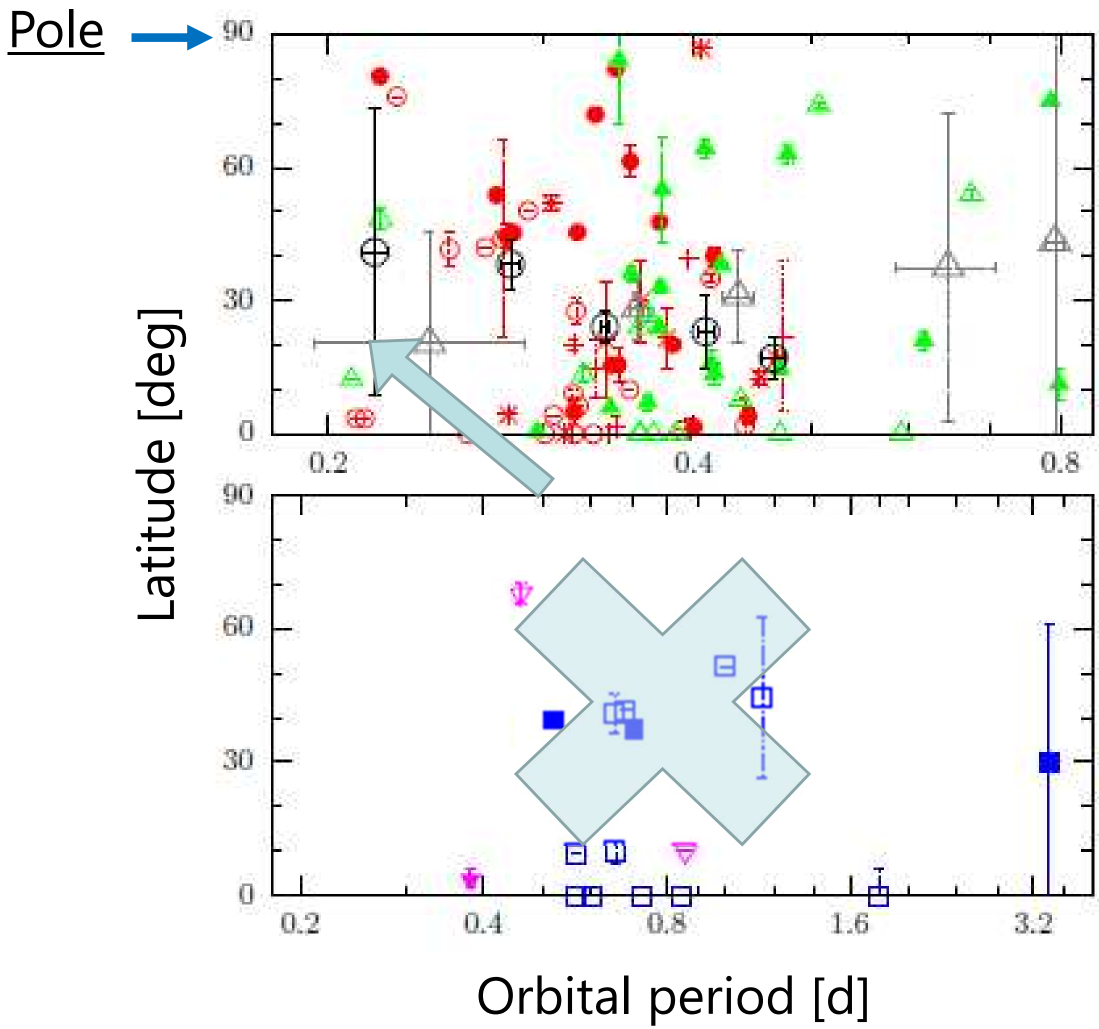




Both associations agree with the results from the starspot sample for star with T<6000 K of Berdyugina (2005)

→ Stars with T<6000 K generally have convective envelope and thus their internal dynamos can generate magnetic fields.

Results(4) : Cool spot properties



W-type binaries with short periods (i.e. rapidly rotating stars) tend to be present at higher latitude

Rapidly rotating stars exhibit active magnetic activity at higher latitude (Schussler & Solanki 1992; Schussler et al. 1996)

These authors explained the association by dynamo models

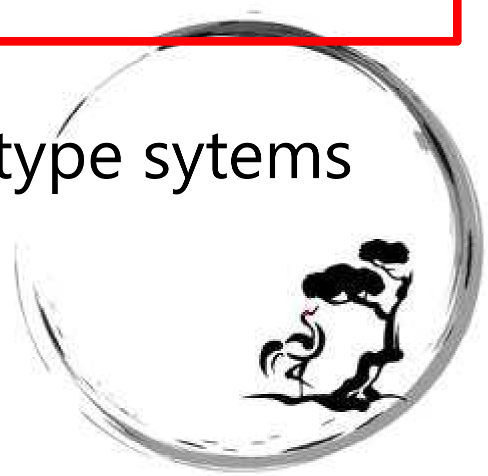
Summary of (cool) starspot study

Using the parameters collected from literatures, the correlations between starspot and binary parameters were examined.

✓The W-type systems show properties similar to those of sunspot

The cool spots in W-type systems can be explained by inner dynamo

✓A-type systems show properties differing from W-type sytems



Summary

Mass-transfer properties

Examine the dependence of mass-transfer rates on astrophysical parameters

✓ Mass-transfer properties seem to differ between W- and A-type.

✓mass exchange from more- to less-massive components (less- to more-massive components) generally becomes rapid (slow) as the mass exchange evolves.

Starspot properties

Examine the correlations between starspot and binary parameters

✓The W-type systems show properties similar to those of sunspot

✓A-type systems show properties differing from W-type sytems