American Museum of Natural History

BDNYC

A Library of Light Curves

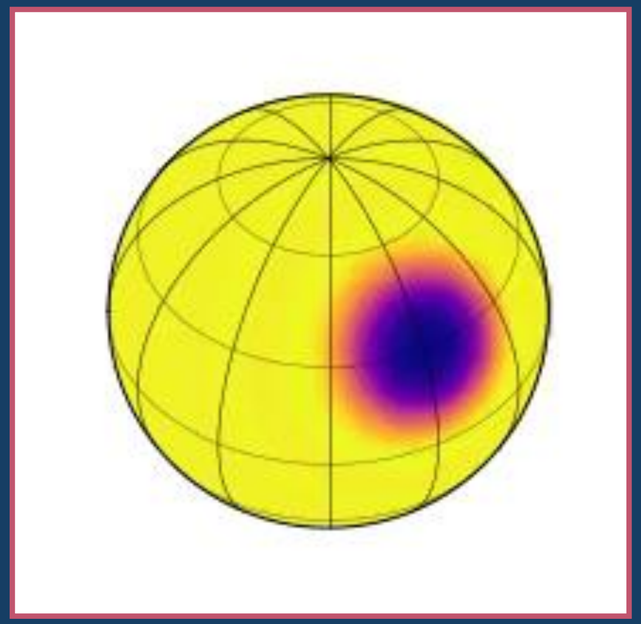
A Catalogue of All Known Complex Rotators through K2 and TESS

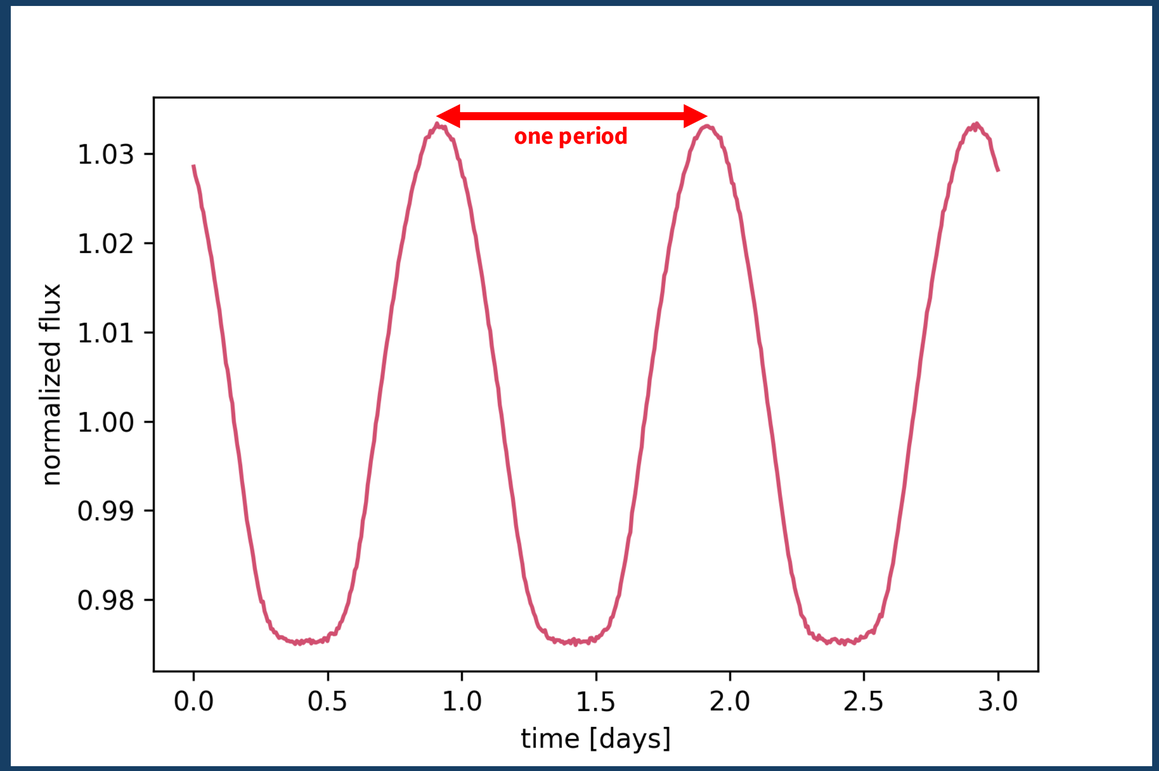
Sarah Draves, City Tech
Dr. Mark Popinchalk, AMNH

NEW YORK CITY COLLEGE OF TECHNOLOGY CUNY

AstroCom NYC

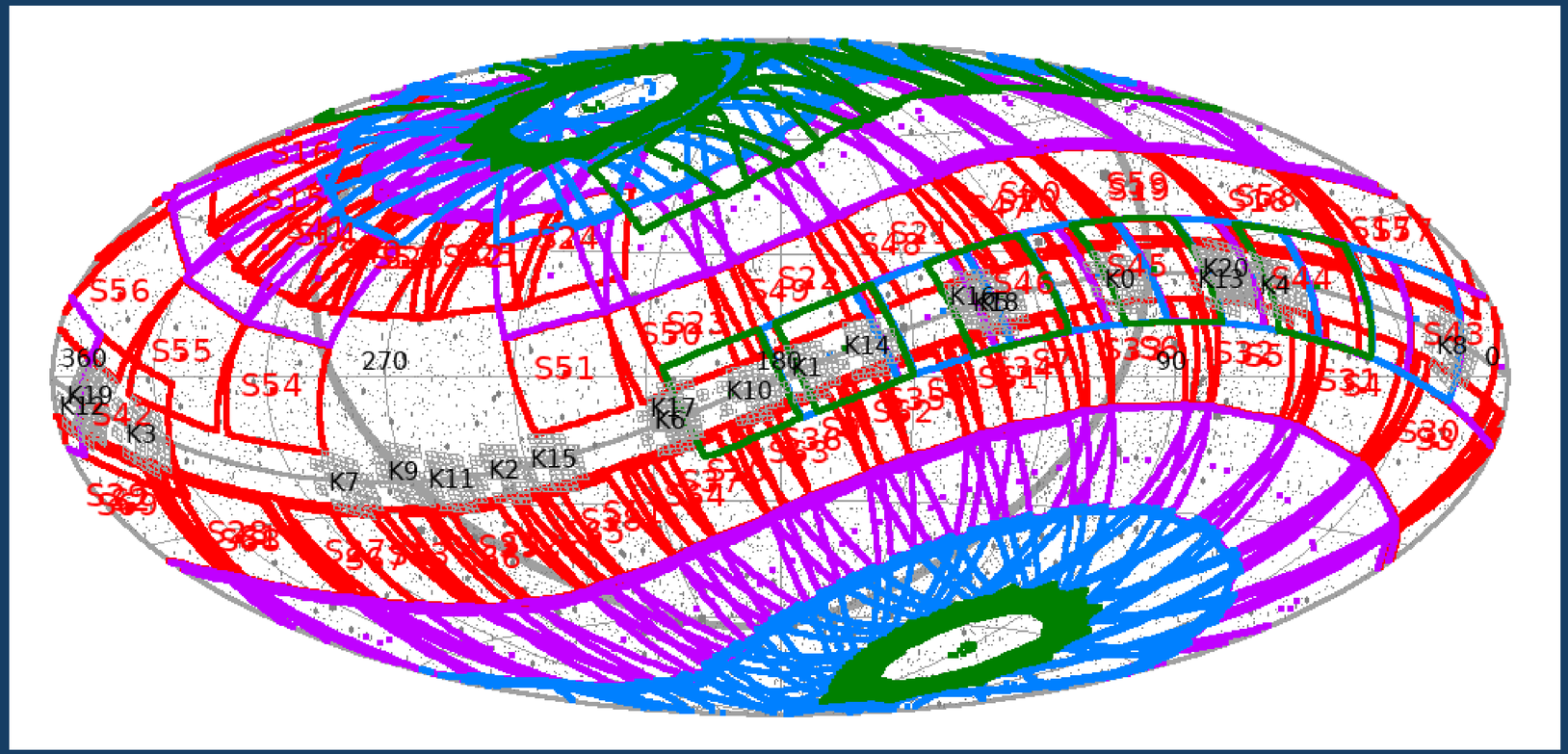
Light Curves



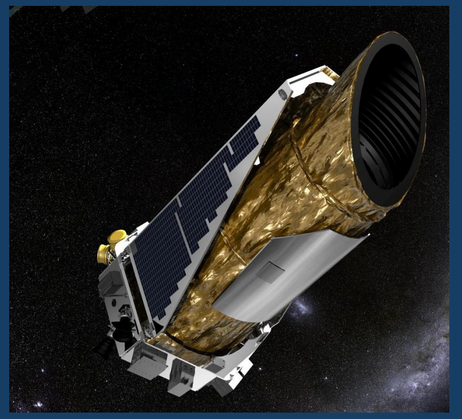


Credit: Mark Popinchalk

K2 and TESS Data



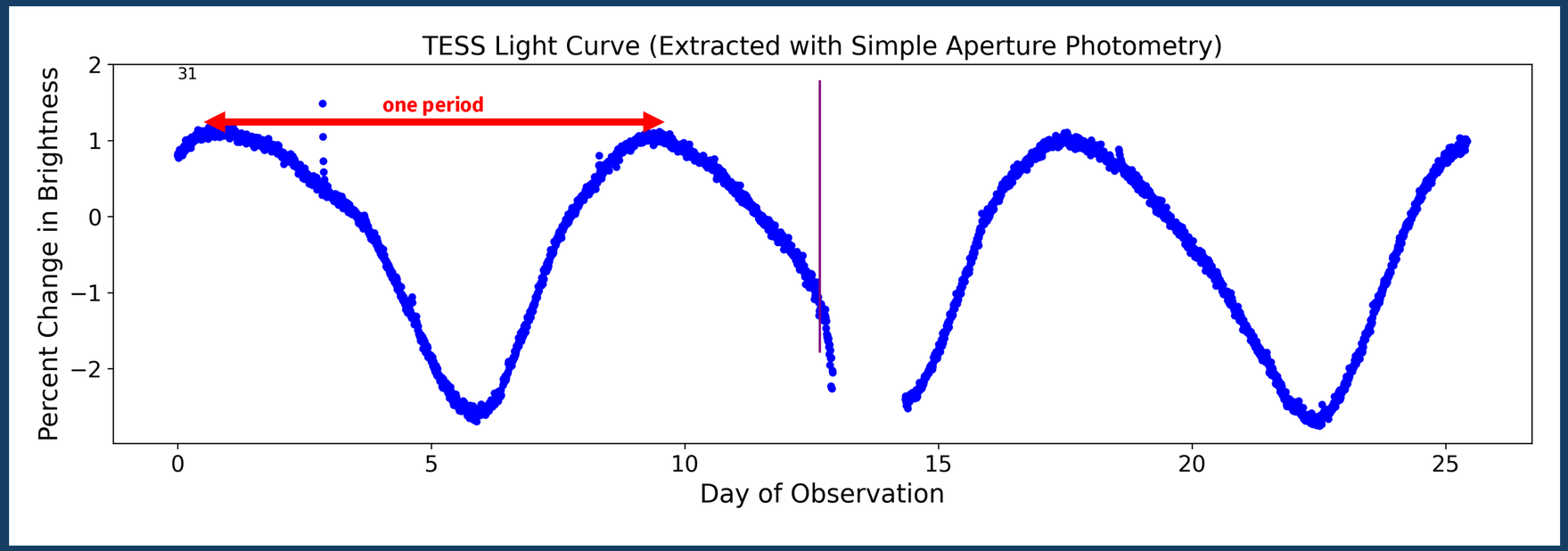
Credit: MIT/TESS



Credit: NASA/Kepler

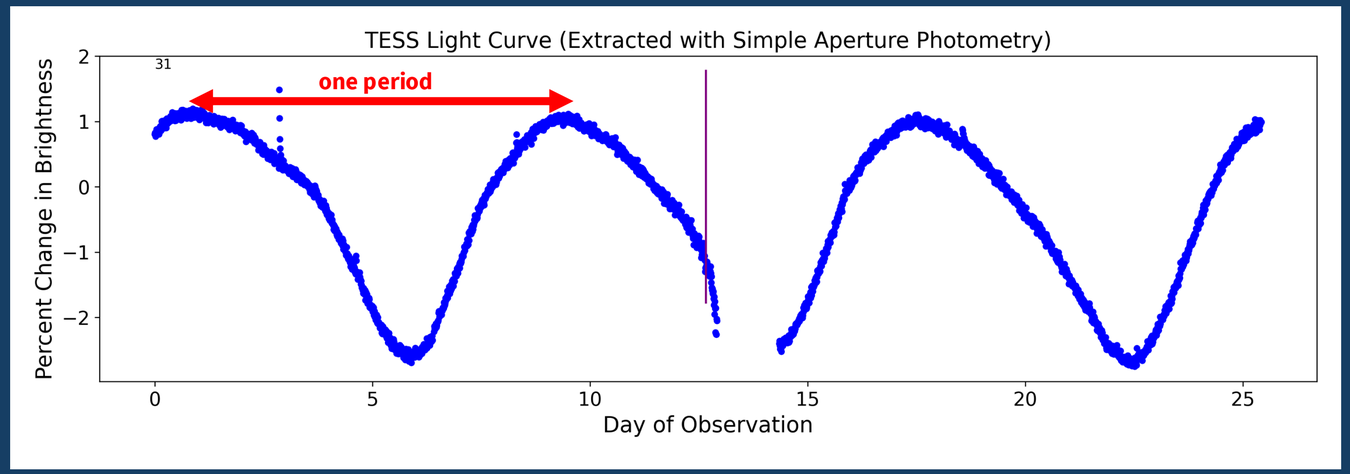
Credit: NASA/TESS

Light Curves from TESS

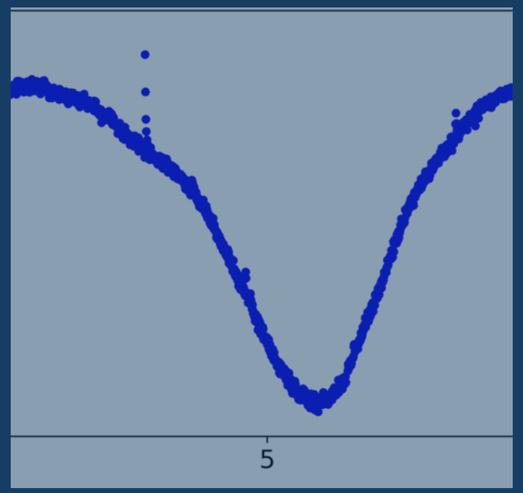


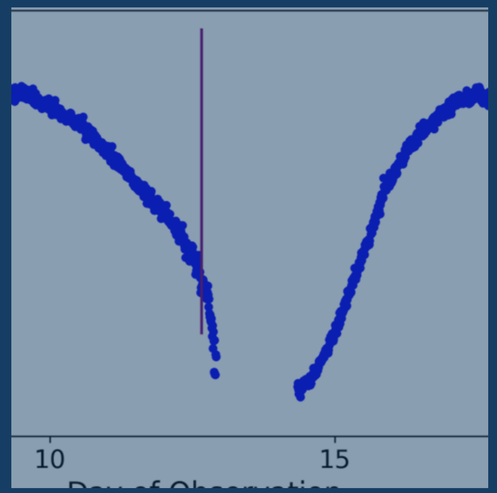
Credit: Mark Popinchalk

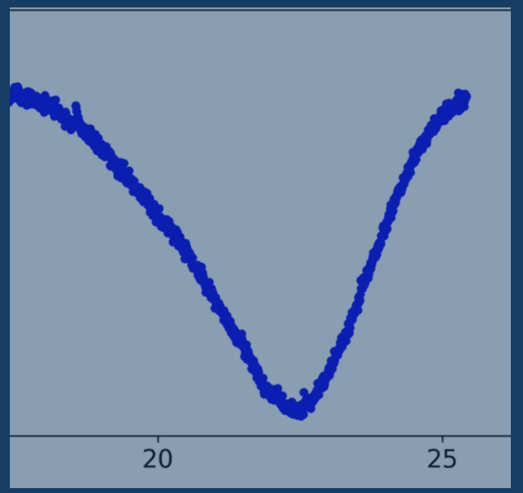
Light Curves from TESS



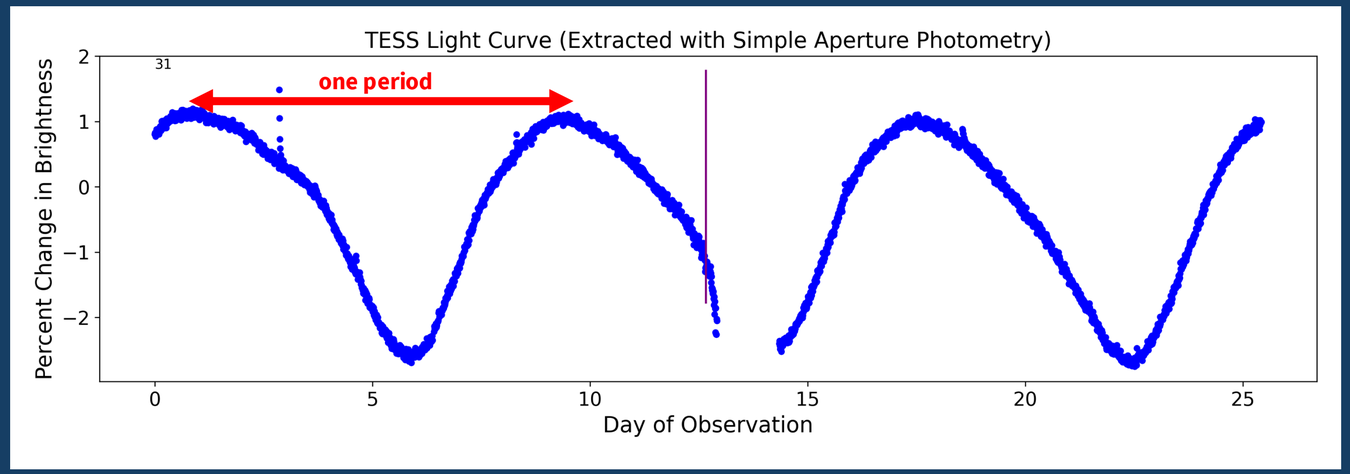
Credit: Mark Popinchalk



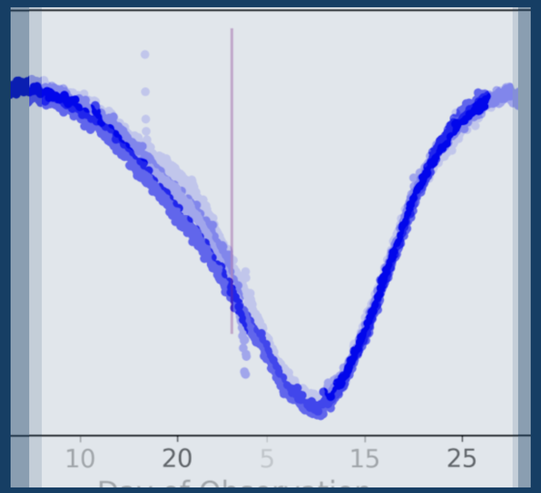




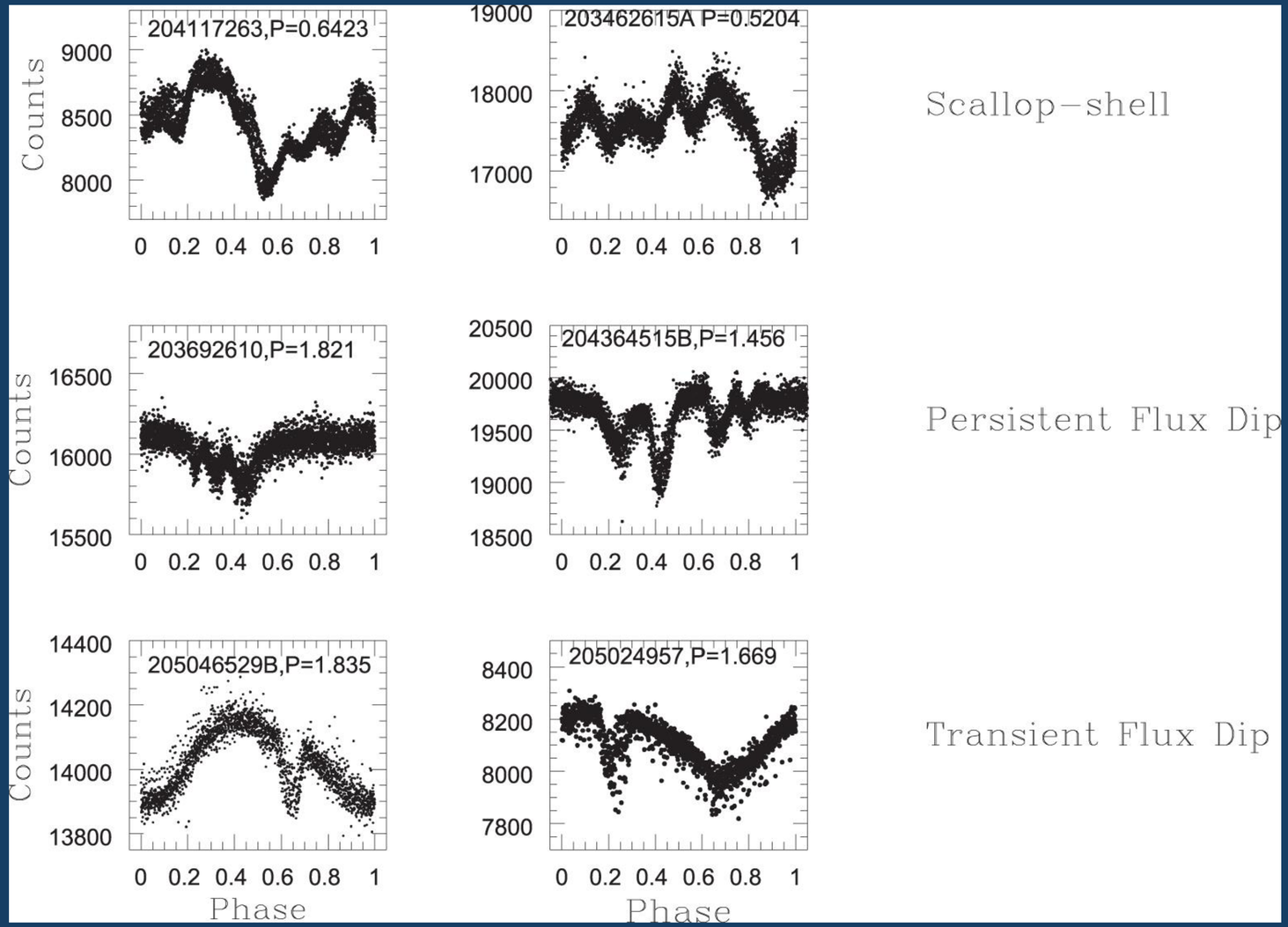
Light Curves from TESS



Credit: Mark Popinchalk

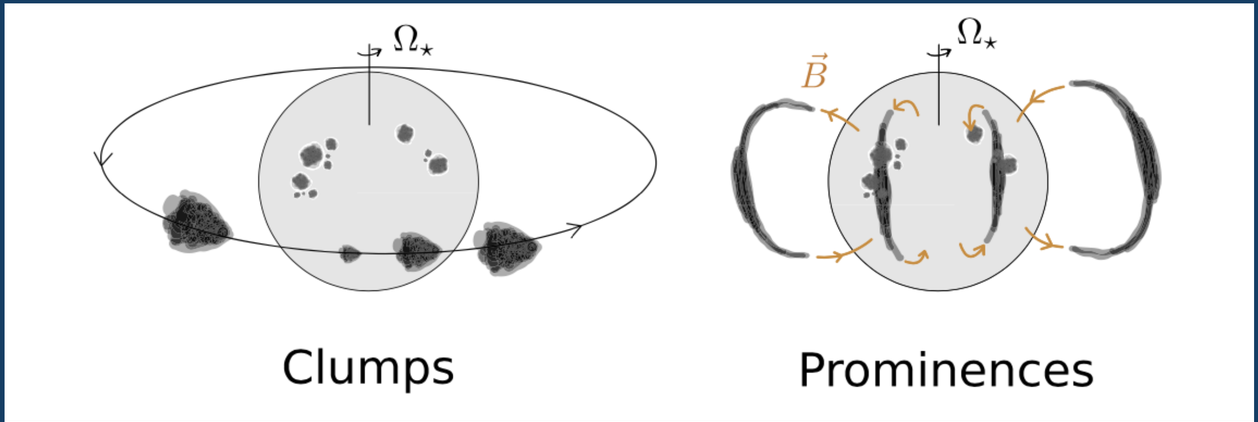


Initial Discovery of Complex Rotators



Credit: Stauffer+ 2017

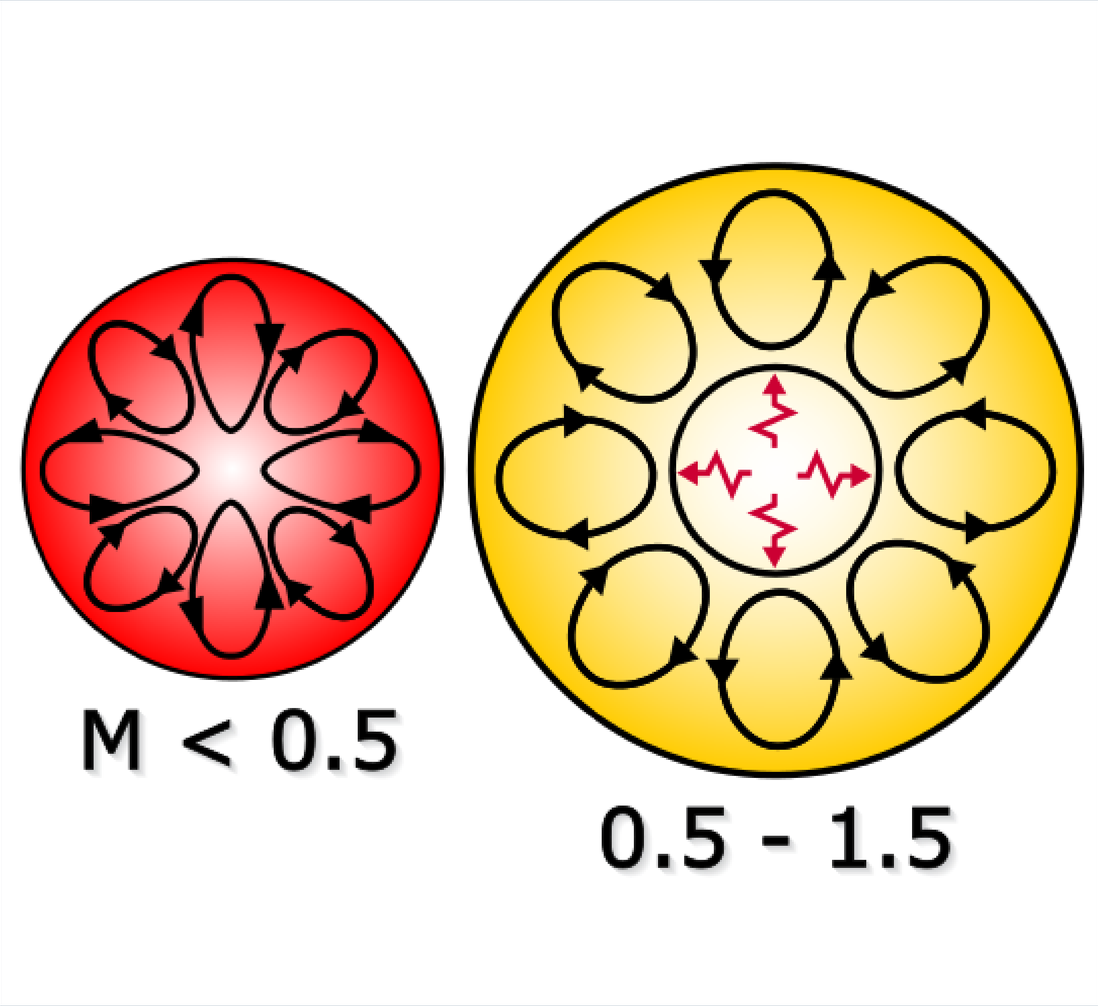
Potential Explanations



Credit: Bouma+ 2024

- Not favored:
  - Protoplanetary disk
  - Unusual star spot patterns
- Favored:
  - Material ejected by star and trapped at corotation radius by magnetic field
  - This explains why this behavior is only seen in young, rapidly rotating M dwarf stars

M Dwarf Magnetic Fields



- M dwarfs are lowest mass and most common type of main sequence star
- Relatively strong magnetic field because
  - Dominated by convective zone
  - Young M stars also spin faster

Project Goals

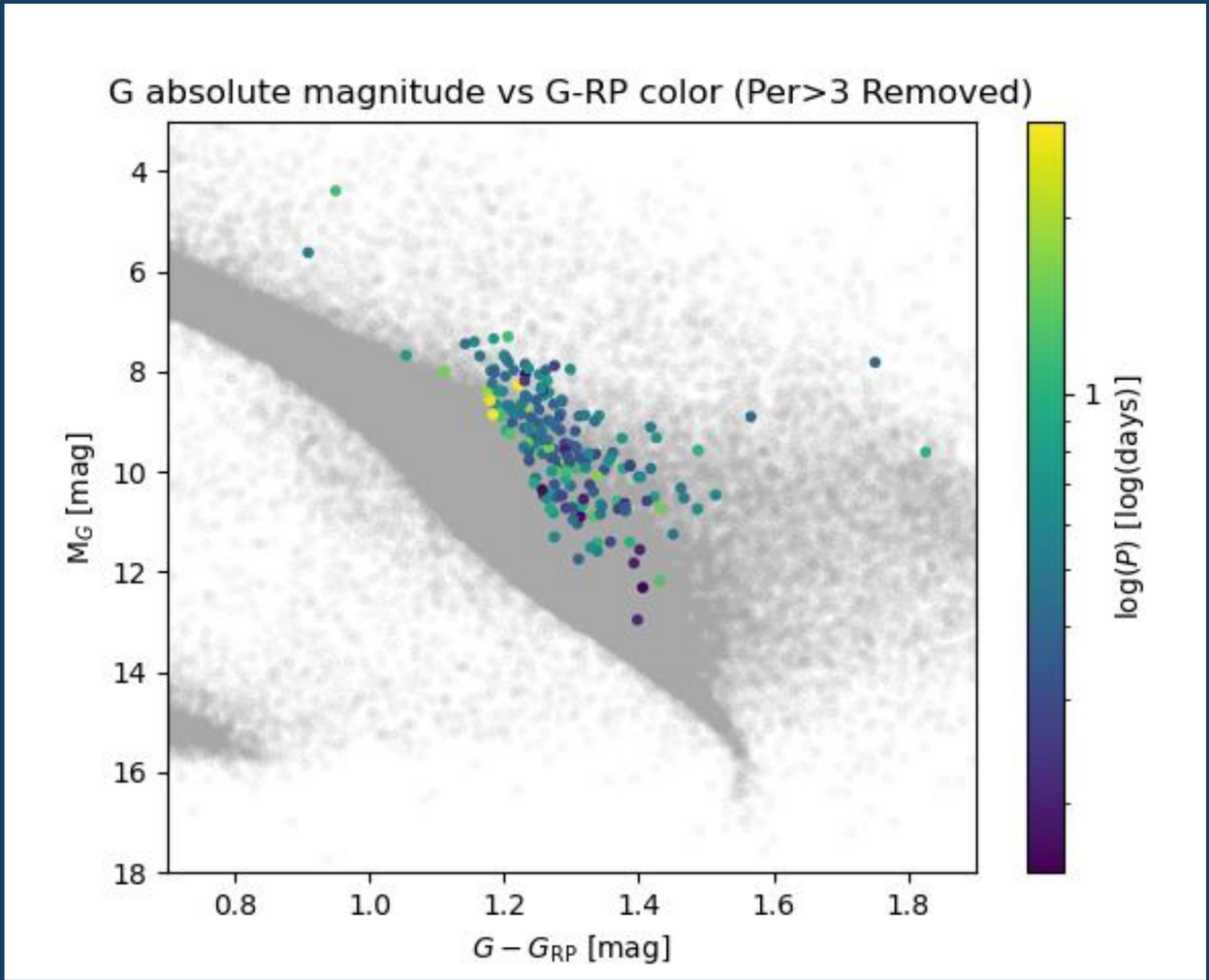
- Compile all known complex rotators from past discovery papers into one data set
- Look at all observations of each star in K2 and TESS, combining their powerful light curve repositories
- Analyze how complex behavior changes over time
- Look for behavior that does or does not fit with corotating material hypothesis

Compiled Data Set

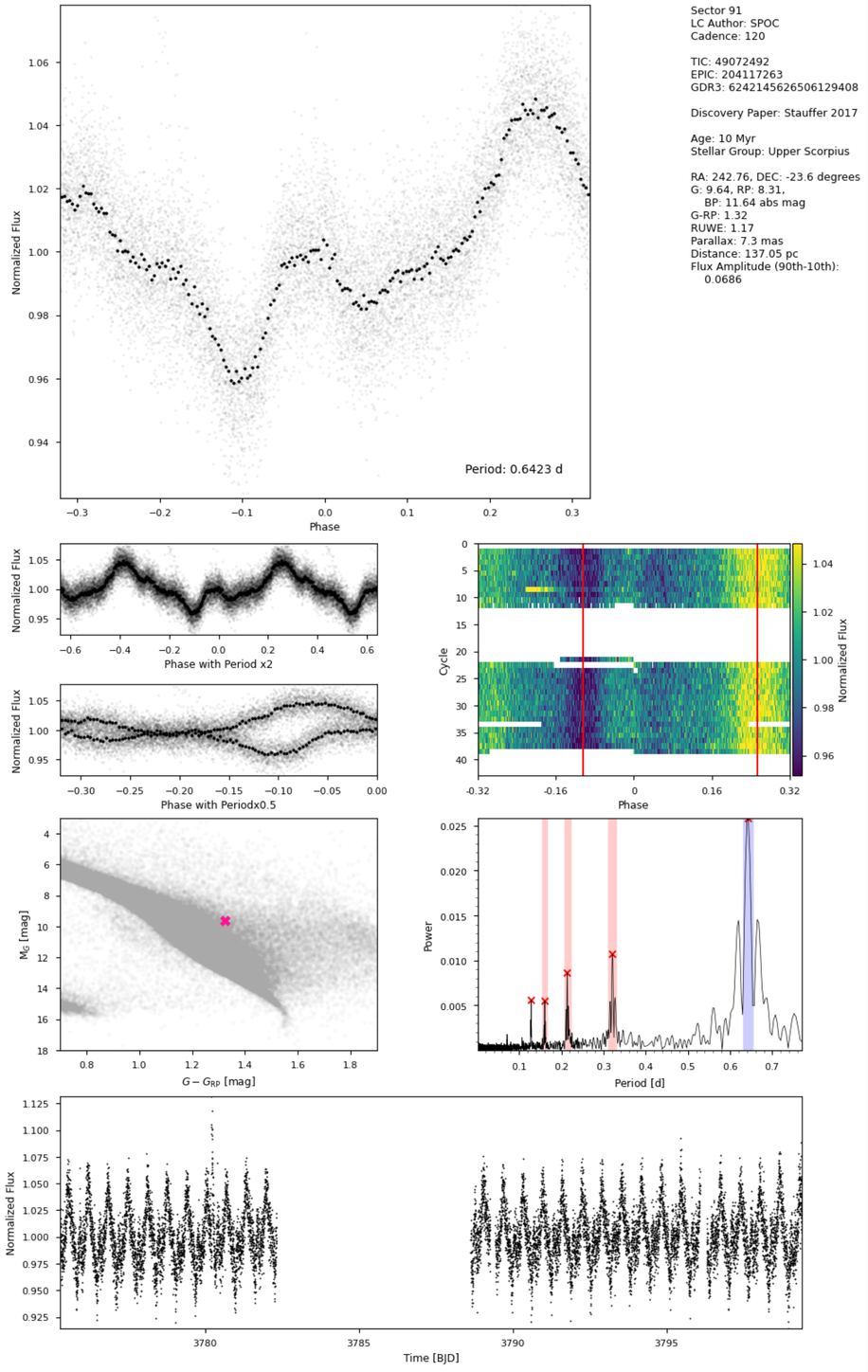
pop_id	TIC	gaiadr3_source_id	epic_id	per	per2	group	age_Myr	disco_paper	author	year
0	59129133	3392549449695395968	246676629	0.6253	0.6332	Taurus	2	Stauffer_2018	Stauffer	2018
1	59091144	3392553852037339776	246682490	0.4377	3.6324	Taurus	2	Stauffer_2018	Stauffer	2018
2	118769116	3411342134934571520	247343526	0.3568		Taurus	2	Stauffer_2018	Stauffer	2018
3	175594111	6045818685674325760	203354381	0.5993		Upper Scorpius	10	Stauffer_2018	Stauffer	2018
4	322928171	6048612514663537280	203636498	0.7794		Upper Scorpius	10	Stauffer_2018	Stauffer	2018
5	175743566	6049078741946841856	203821589	0.6677	0.9105	Rho Ophiuchi	1	Stauffer_2018	Stauffer	2018
6	98689067	6049136569386567296	203897692	0.6043	0.5011	Rho Ophiuchi	1	Stauffer_2018	Stauffer	2018
7	49072162	6049979104536677632	204060981	0.3996	0.3802	Upper Scorpius	10	Stauffer_2018	Stauffer	2018
8	203822419	6050952515921144192	204185983	1.0529		Rho Ophiuchi	1	Stauffer_2018	Stauffer	2018
9	48908525	6242105876588253056	204099739	0.7428	0.7158	Upper Scorpius	10	Stauffer_2018	Stauffer	2018
10	49815071	6246044017998844160	205267399	0.3344	0.3311	Upper Scorpius	10	Stauffer_2018	Stauffer	2018
11	204792541	6044751575283331840	203050730	0.4865	0.774	Upper Scorpius	10	Stauffer_2017	Stauffer	2017
12	205060766	6044838303564444544	203185083	0.44		Upper Scorpius	10	Stauffer_2017	Stauffer	2017
13	68502886	6048717277503393792	203534383	0.2784	0.3234	Upper Scorpius	10	Stauffer_2017	Stauffer	2017
14	66750314	6235428336315960576	203462615	0.5201	0.4421	Upper Scorpius	10	Stauffer_2017	Stauffer	2017
15	12659333	6237069013821425408	204066898	0.3956	0.5386	Upper Scorpius	10	Stauffer_2017	Stauffer	2017
16	49072492	6242145626506129664	204117263	0.6423		Upper Scorpius	10	Stauffer_2017	Stauffer	2017
17	49198167	6242649340270424704	204367193	0.4835		Upper Scorpius	10	Stauffer_2017	Stauffer	2017
18	49518818	6245595108015533824	205110559	0.4031		Upper Scorpius	10	Stauffer_2017	Stauffer	2017
19	220765024	6246944689821248128	204918279	0.4665	0.4594	Upper Scorpius	10	Stauffer_2017	Stauffer	2017
20	9669706	6247083125210430080	204897050	0.2639		Upper Scorpius	10	Stauffer_2017	Stauffer	2017
21	280945693	5234117008292638464		0.6363		Lower Centaurus	16	Stauffer_2021	Stauffer	2021
22	296790810	5236296171620605824		0.3713		UCL/LCC	16	Stauffer_2021	Stauffer	2021
23	290889135	5237270068366411392		0.4835		UCL/LCC	16	Rebull_2022	Rebull	2022
24	301432612	5341919587915807616		0.5044		UCL/LCC	16	Stauffer_2021	Stauffer	2021
25	93763678	5345273648130813696		0.9156		UCL/LCC	16	Rebull_2022	Rebull	2022

208 stars total!

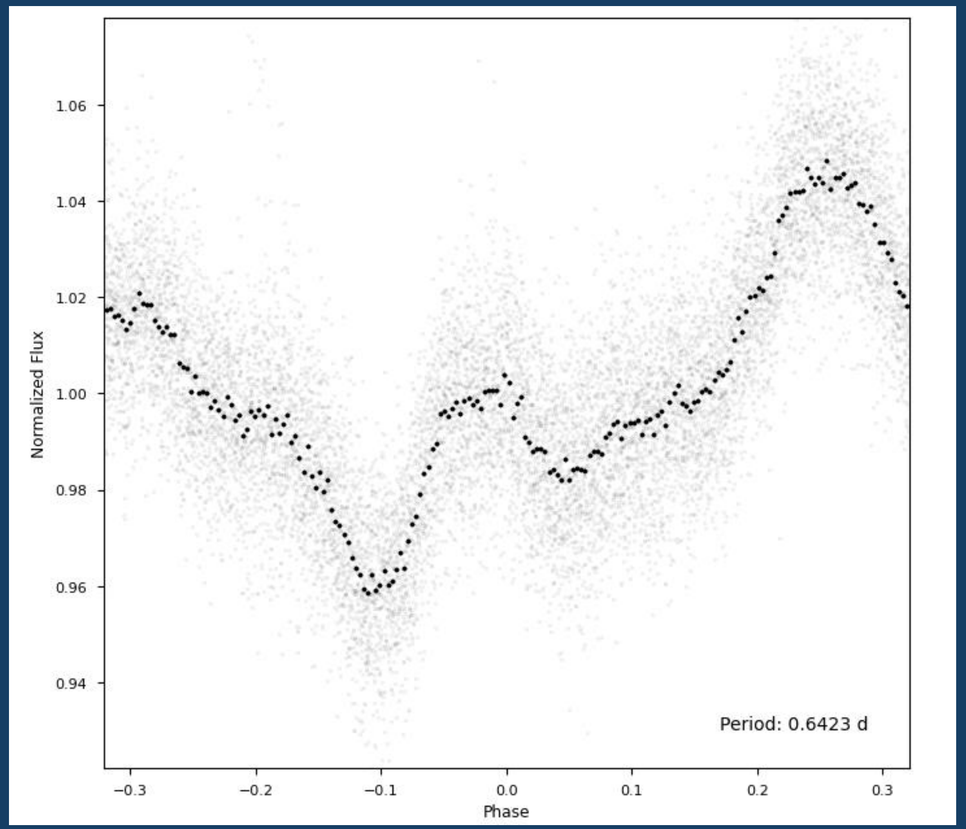
GAIA Data

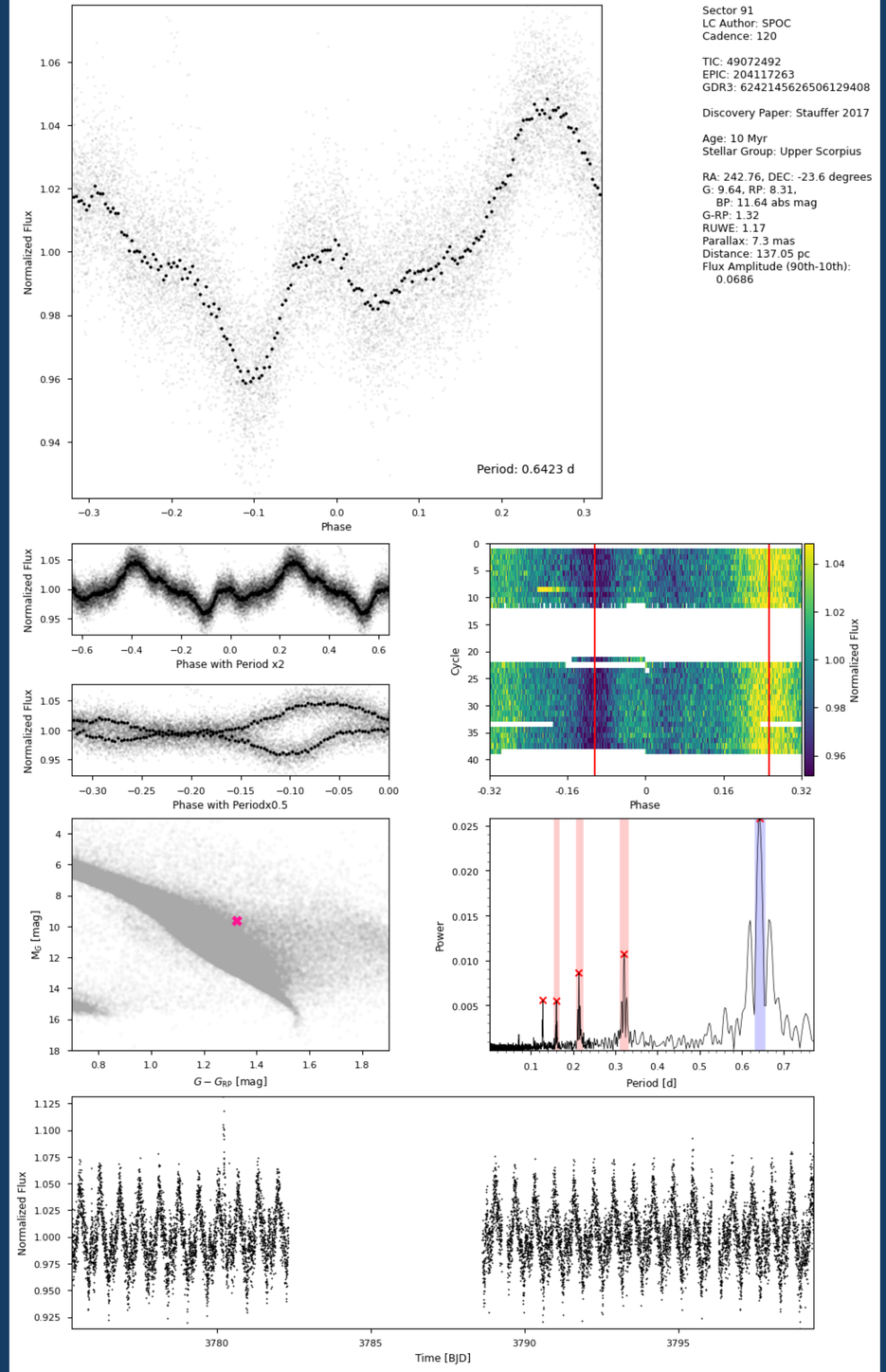

G absolute magnitude vs G-RP color (Per>3 Removed)
4
6
8
10
12
14
16
18
M_G [mag]
0.8
1.0
1.2
1.4
1.6
1.8
$G - G_{RP}$ [mag]
1
log(P) [log(days)]

Multiplots


Sector 91
LC Author: SPOC
Cadence: 120
TIC: 49072492
EPIC: 204117263
GDR3: 6242145626506129408
Discovery Paper: Stauffer 2017
Age: 10 Myr
Stellar Group: Upper Scorpius
RA: 242.76, DEC: -23.6 degrees
G: 9.64, RP: 8.31,
BP: 11.64 abs mag
G-RP: 1.32
RUWE: 1.17
Parallax: 7.3 mas
Distance: 137.05 pc
Flux Amplitude (90th-10th):
0.0686
Period: 0.6423 d
Normalized Flux
Phase
Phase with Period x2
Phase with Periodx0.5
Cycle
Power
Period [d]
M_G [mag]
$G - G_{Rp}$ [mag]
Time [BJD]

Multiplots


Normalized Flux
Phase
Period: 0.6423 d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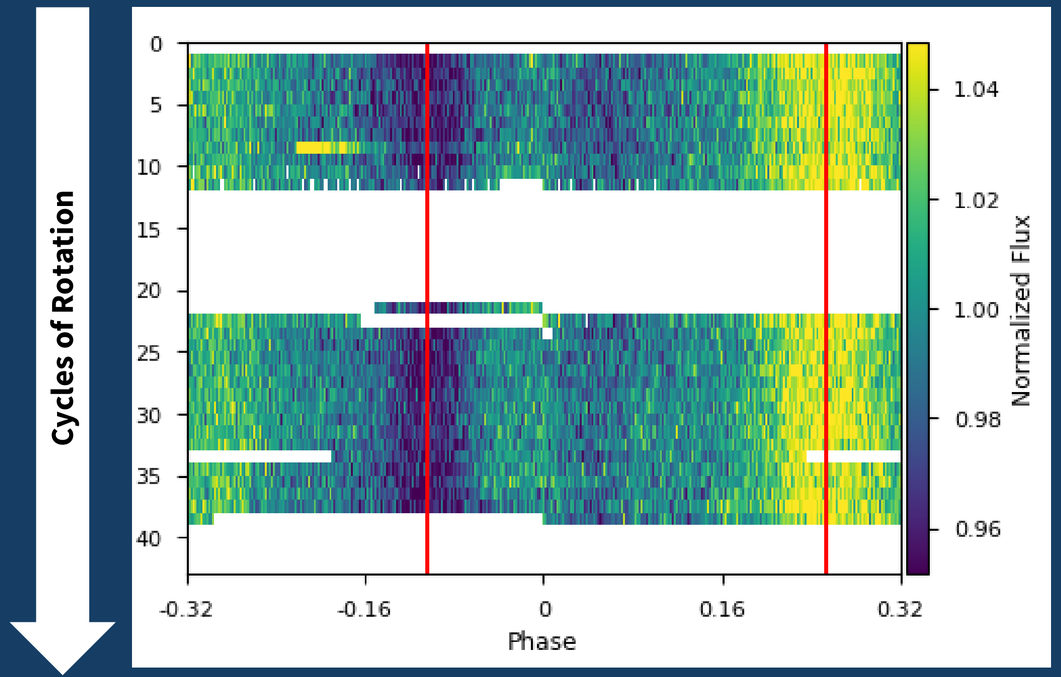
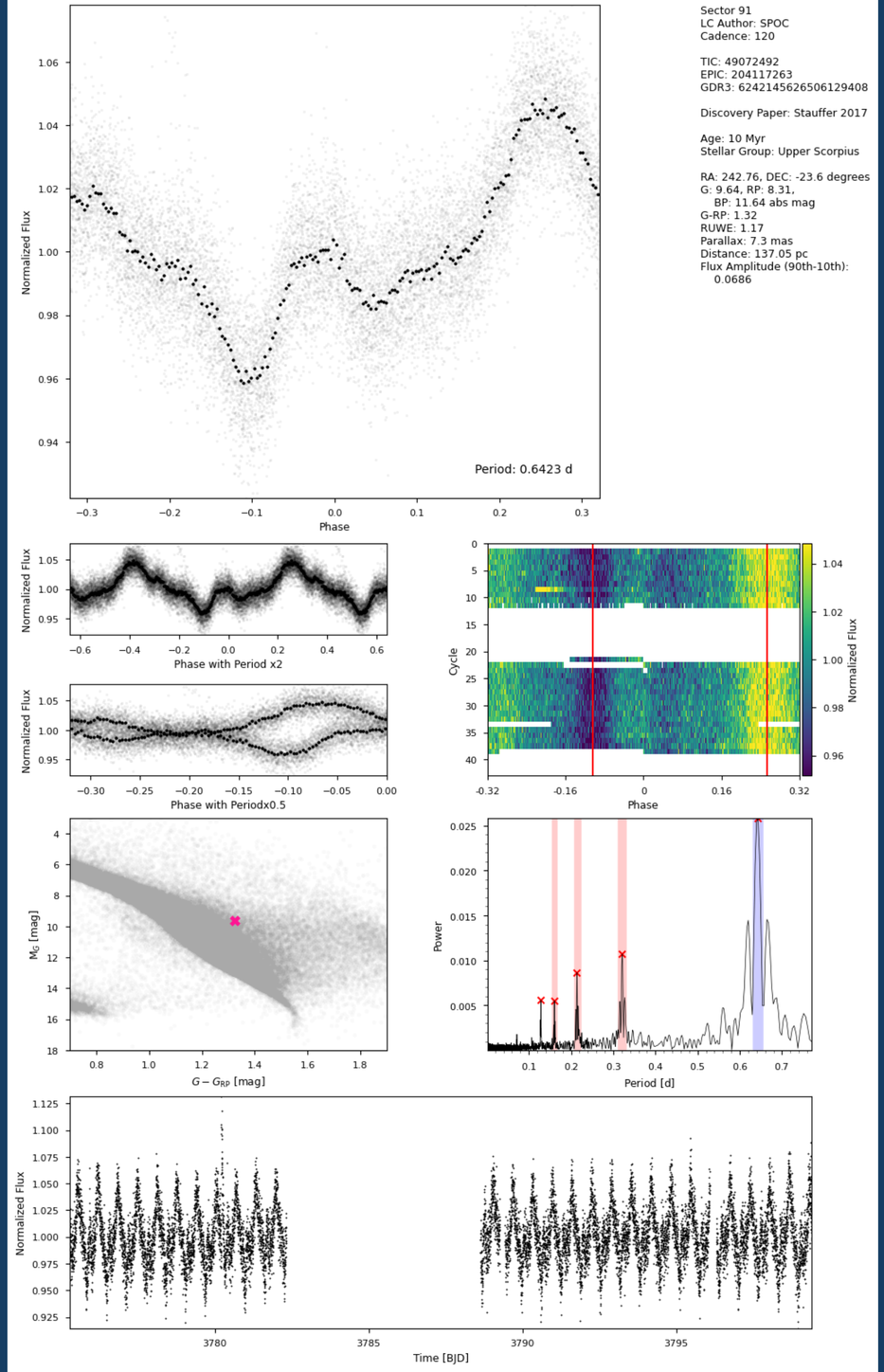
Phase with Periodx0.5
Cycle
M_G [mag]
$G - G_{RP}$ [mag]
Power
Period [d]
Time [BJD]

Multiplots


Cycles of Rotation
Phase
Normalized Flux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GDR3: 6242145626506129408
Discovery Paper: Stauffer 2017
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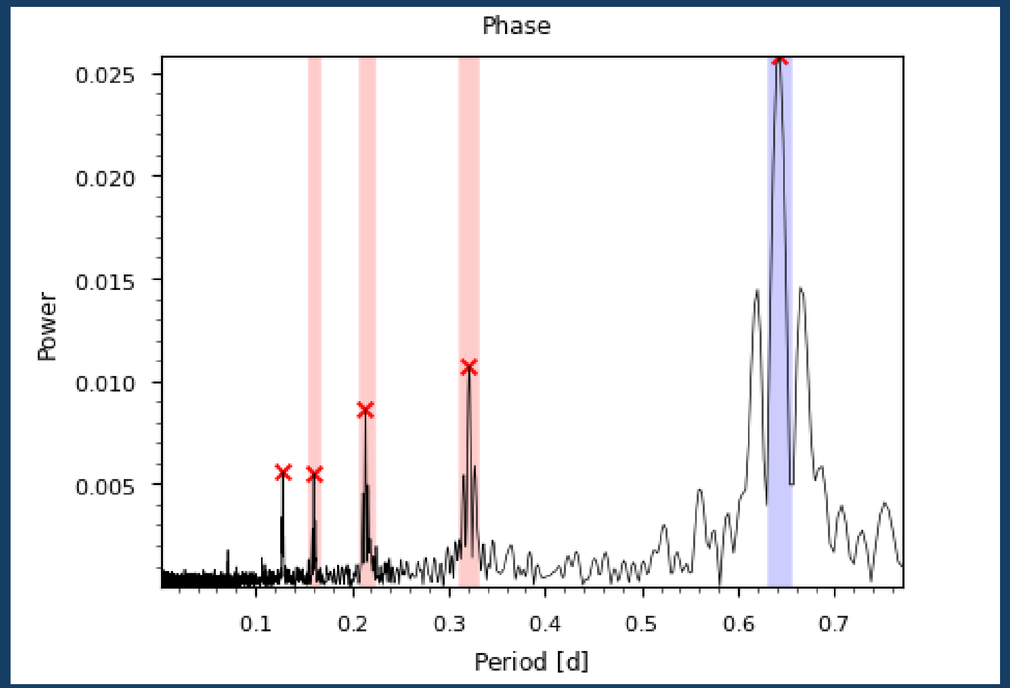
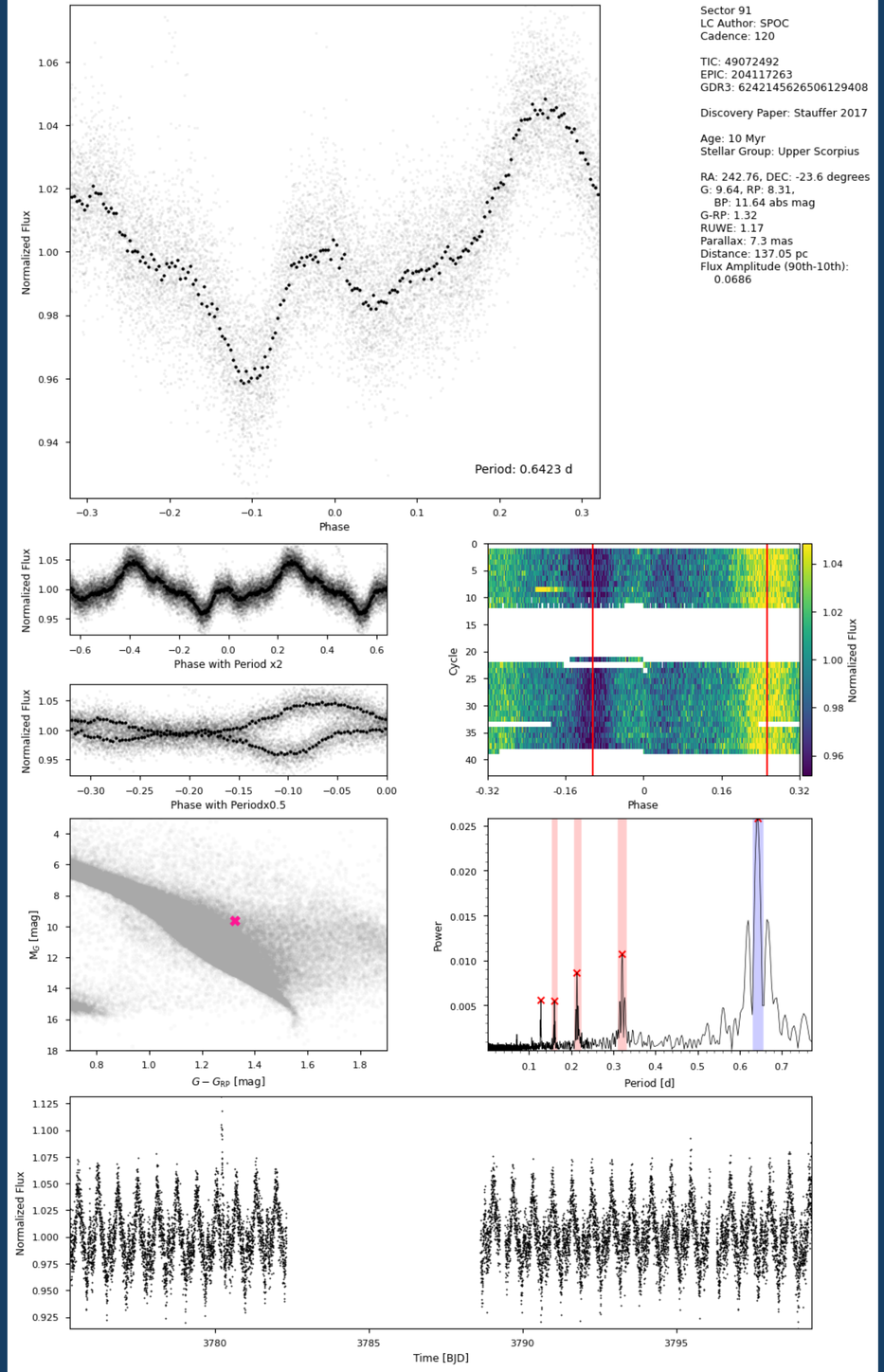
Cycle
M_G [mag]
$G - G_{RP}$ [mag]
Power
Period [d]
Time [BJD]

Multiplots


Phase
Power
Period [d]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Cadence: 120
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GDR3: 6242145626506129408
Discovery Paper: Stauffer 2017
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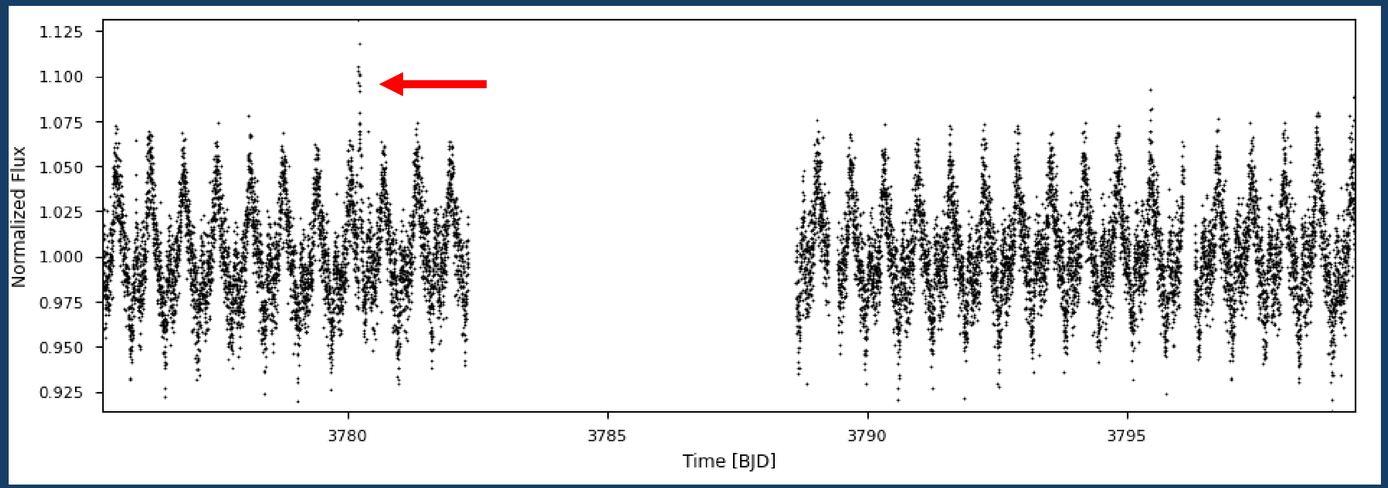
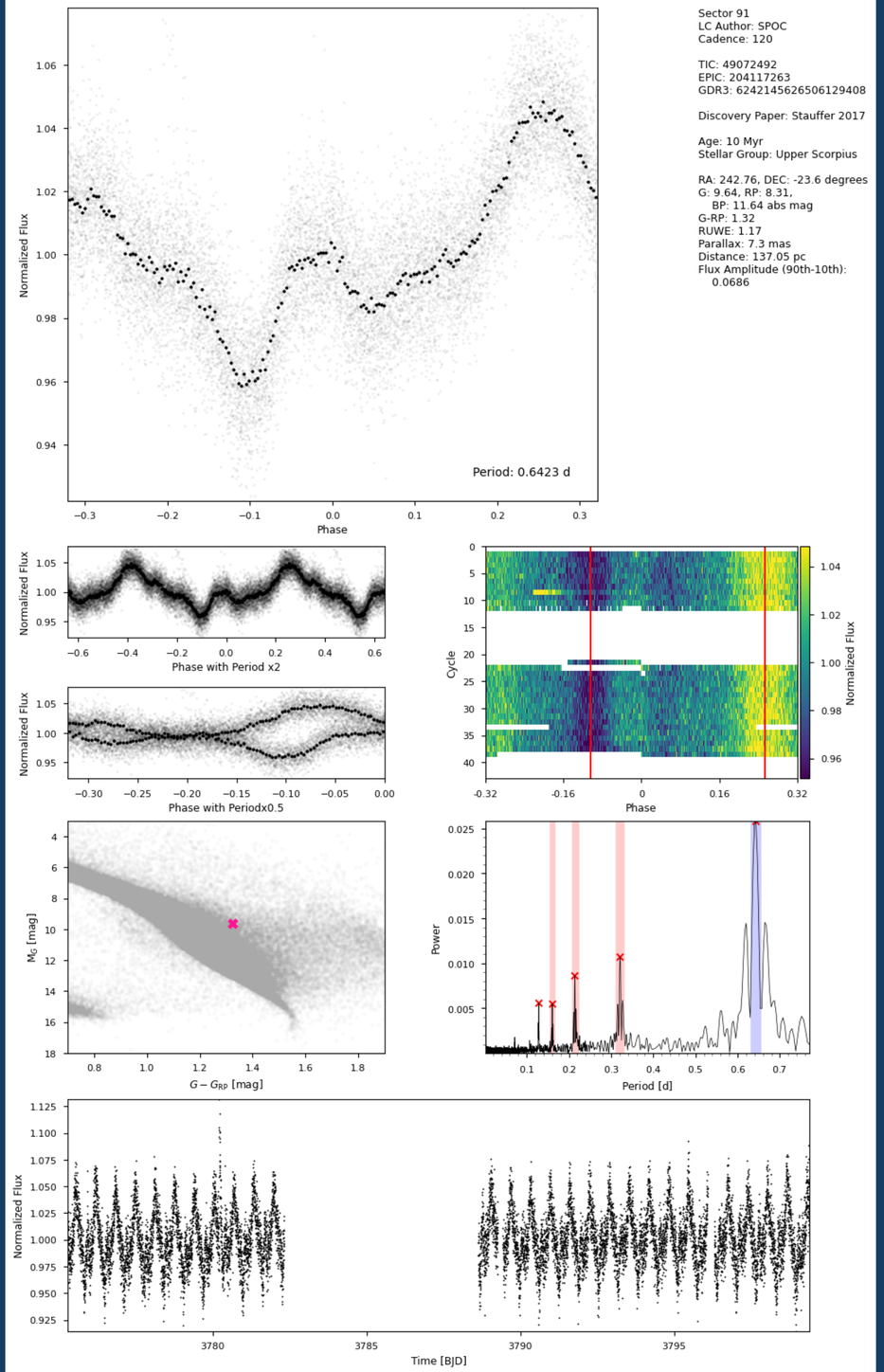
Cycle
M_G [mag]
$G - G_{RP}$ [mag]
Power
Period [d]
Time [BJD]

Multiplots


Normalized Flux
Time [BJD]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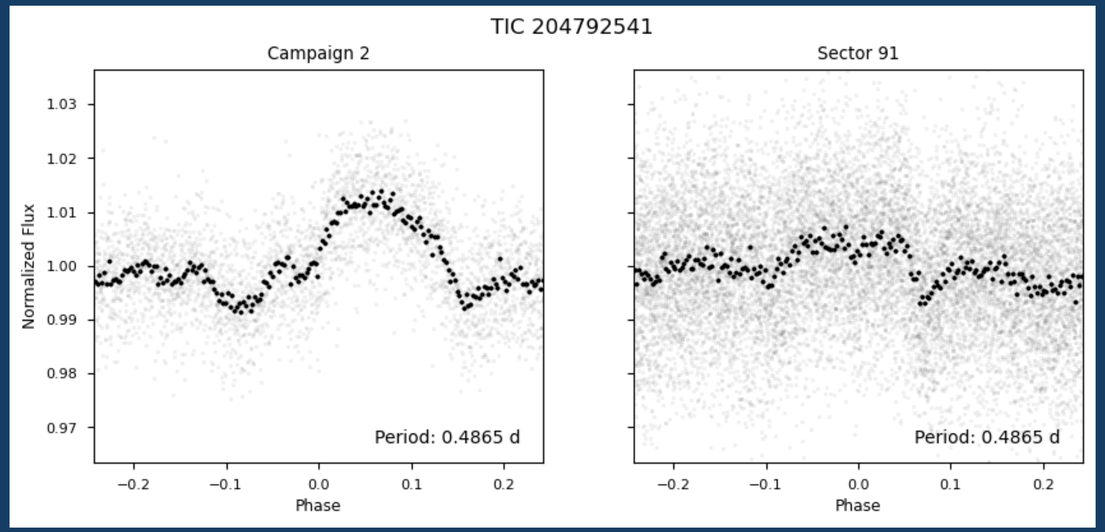
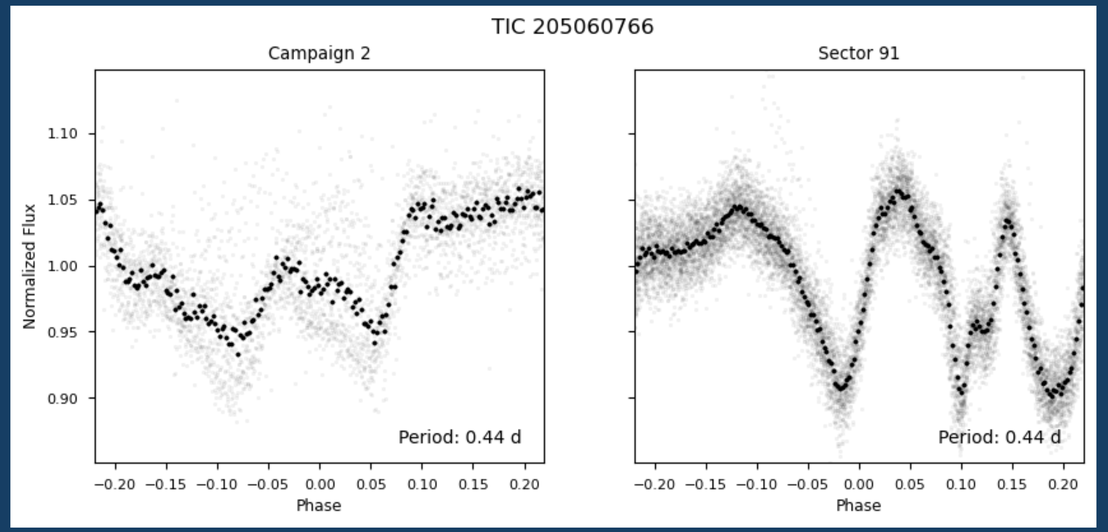
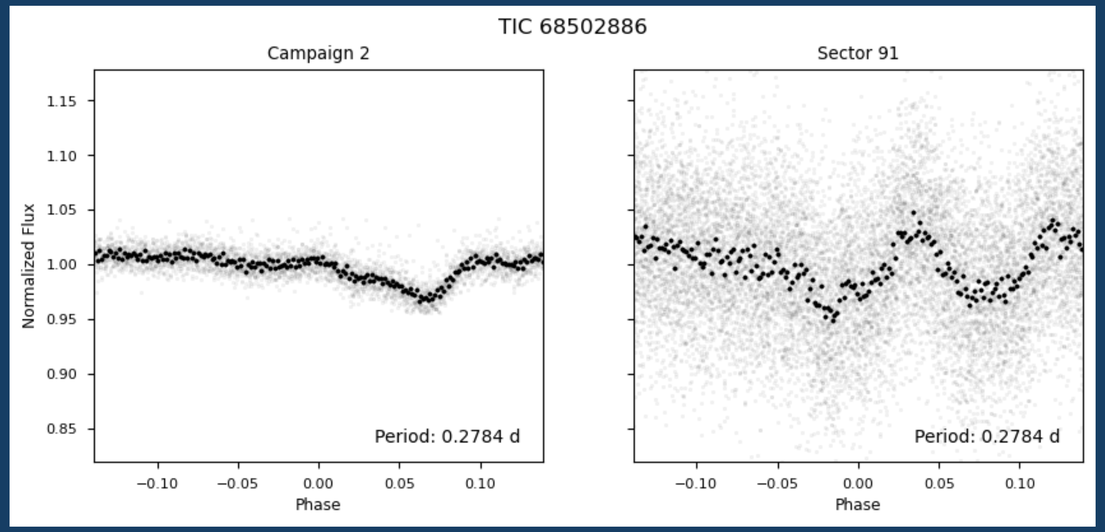
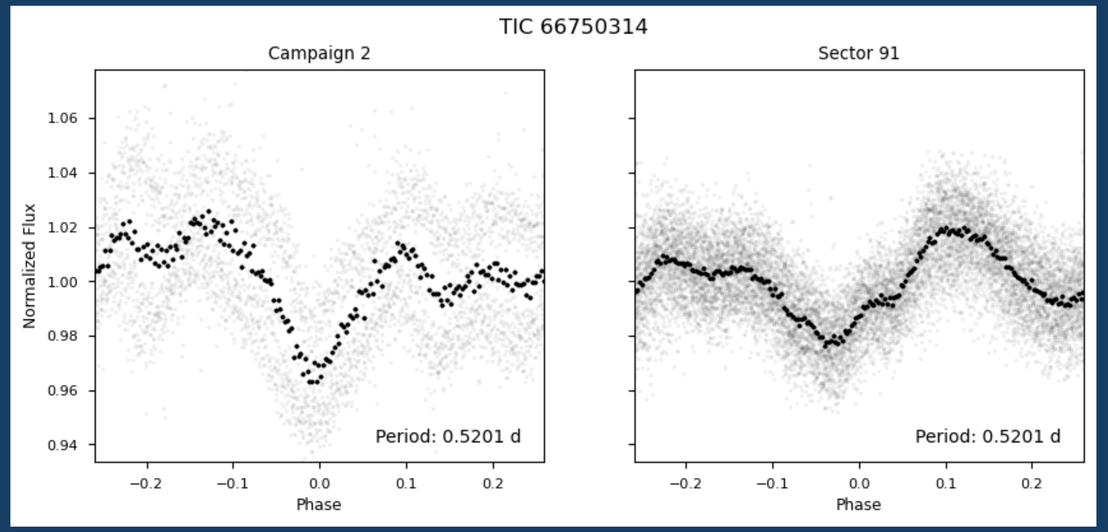
Phase with Periodx0.5
Cycle
M_G [mag]
$G - G_{RP}$ [mag]
Power
Period [d]
Time [BJD]

Stauffer Objects Revisited

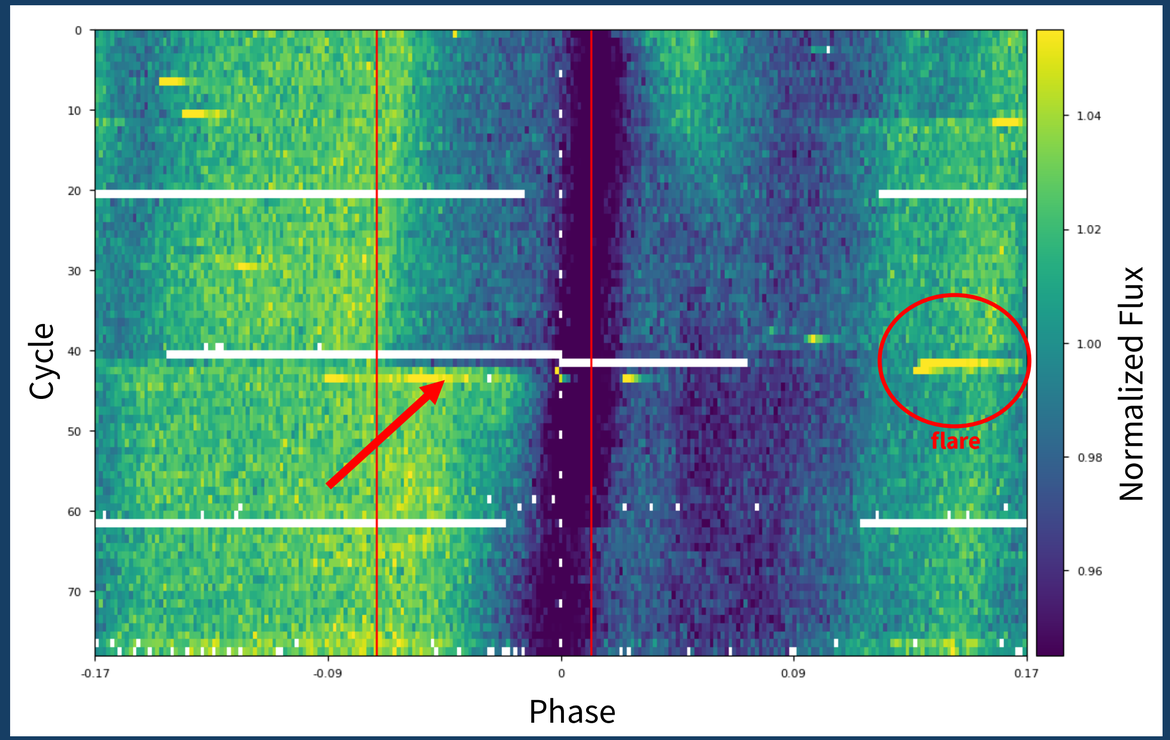


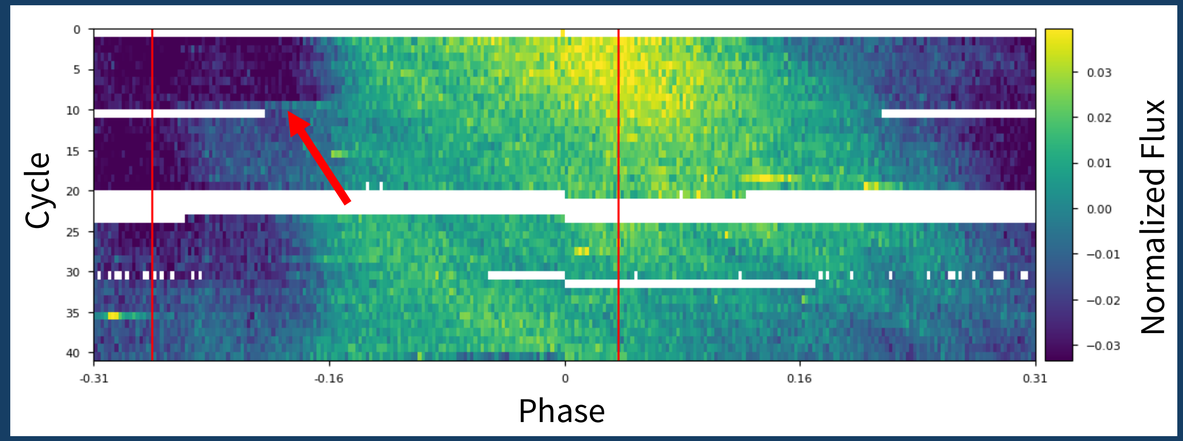






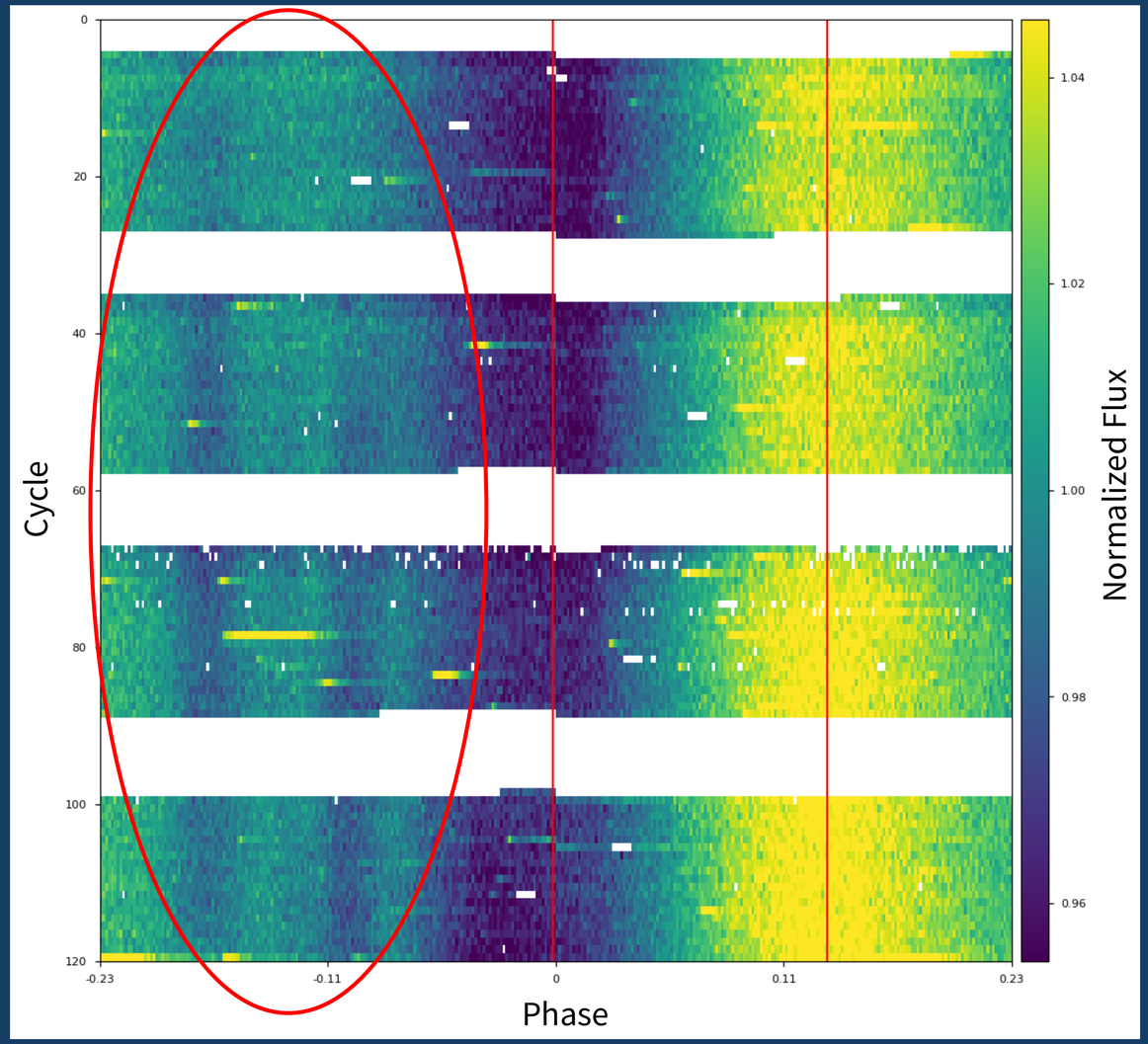
Sudden Brightness Increases





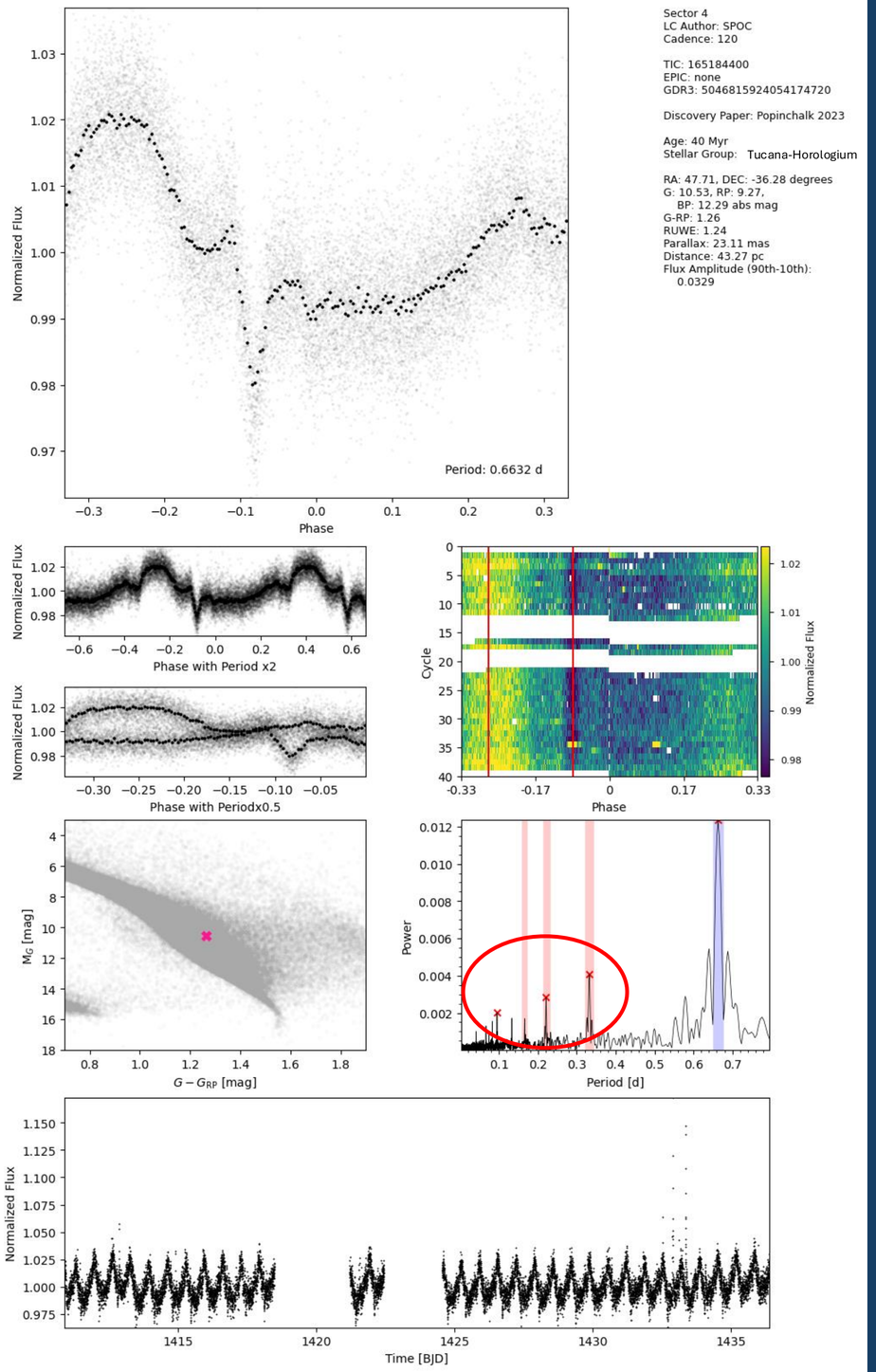
- Left: TIC 300651846, Sector 64
- Above: TIC 59129133, Sector 71
- Possibly material being blown away
- Sometimes follows a stellar flare

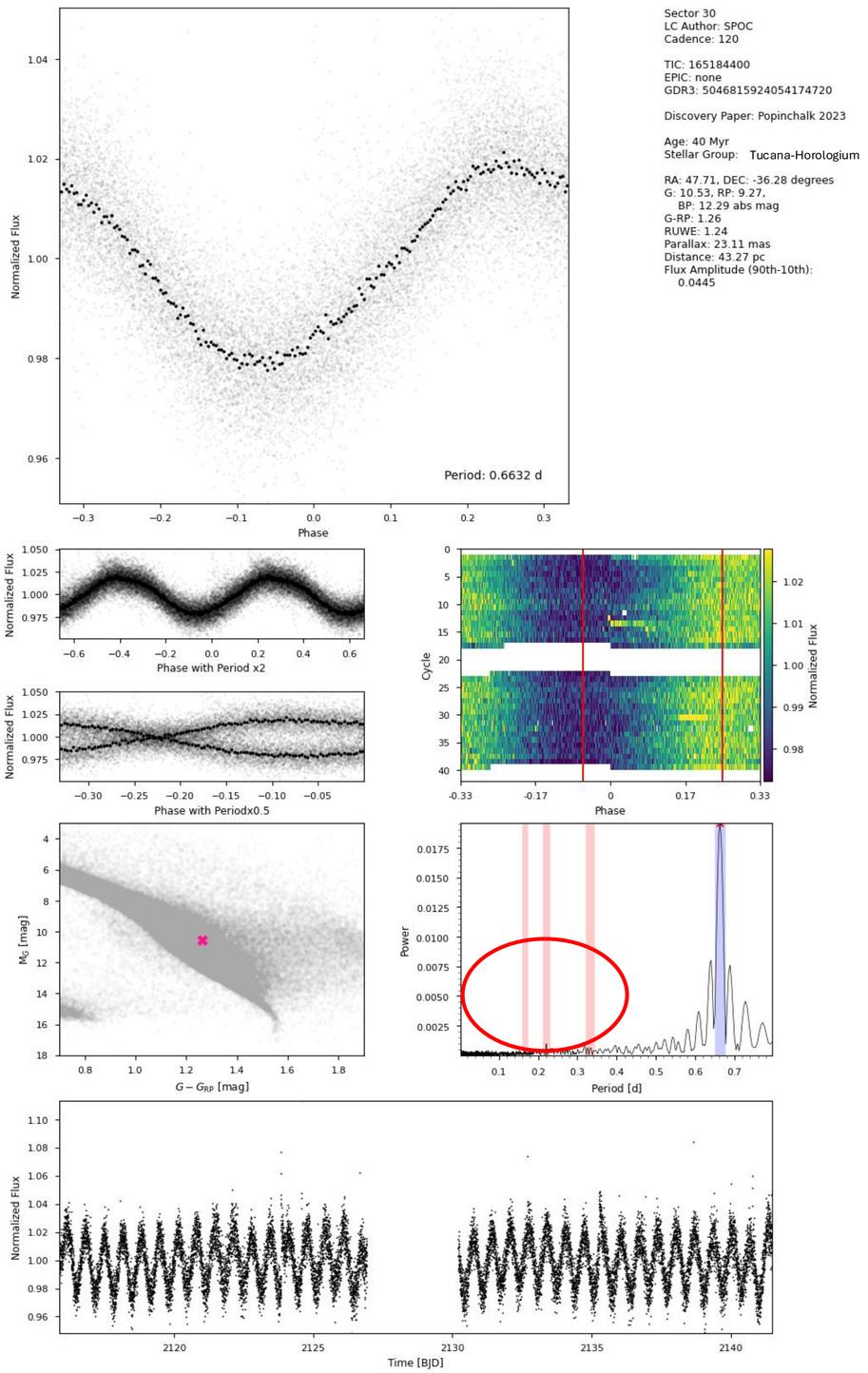
Gradual Brightness Decreases



- TIC 177309964
- Sectors 10 and 11
- Possibly material from star filling in clouds

Loss of Complexity





Conclusion

- Gathered over a decade of observations of 208 complex rotators
- Created over 900 multiplots of light curves
- Investigated changes in complexity
- Future goal: publish data set for use by other scientists

Thank you to Dr. Mark Popinchalk and the rest of the BDNYC group!