CONGRESO COLOMBIANO DE ASTRONOMÍA Y ASTROFÍSICA 2024

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Bachelor's Degree in Astronomy
University of Antioquia

THE RELATIONSHIP BETWEEN ROTATION AND MAGNETIC ACTIVITY IN COLD DWARFS, AS SEEN IN H-ALPHA EMISSION OF STARS IN OPEN CLUSTER GROUP-X

Supervisor:

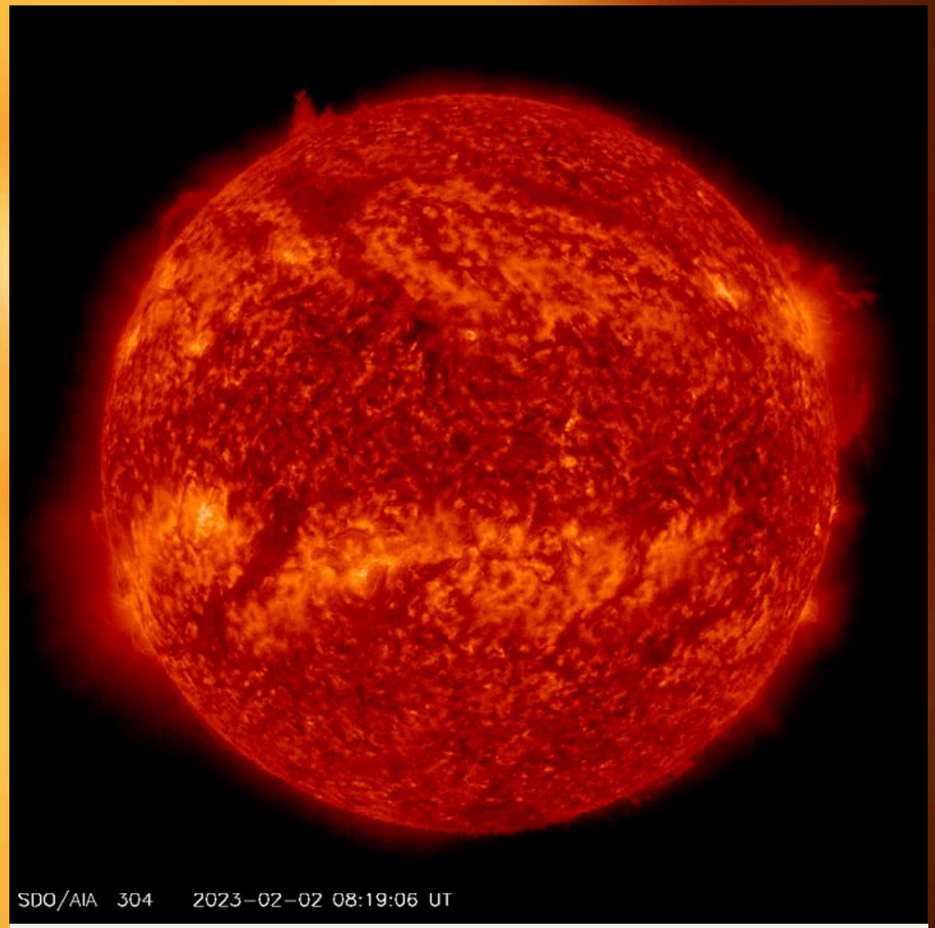
Dr. Alejandro Núñez

Columbia University

SOLAR DYNAMICS OBSERVATORY

INSTRUMENT: AIA
BAND: 307 Å
PRIMARY ROLE: HE II
REGION: CHROMOSPHERE, TRANSITION REGION

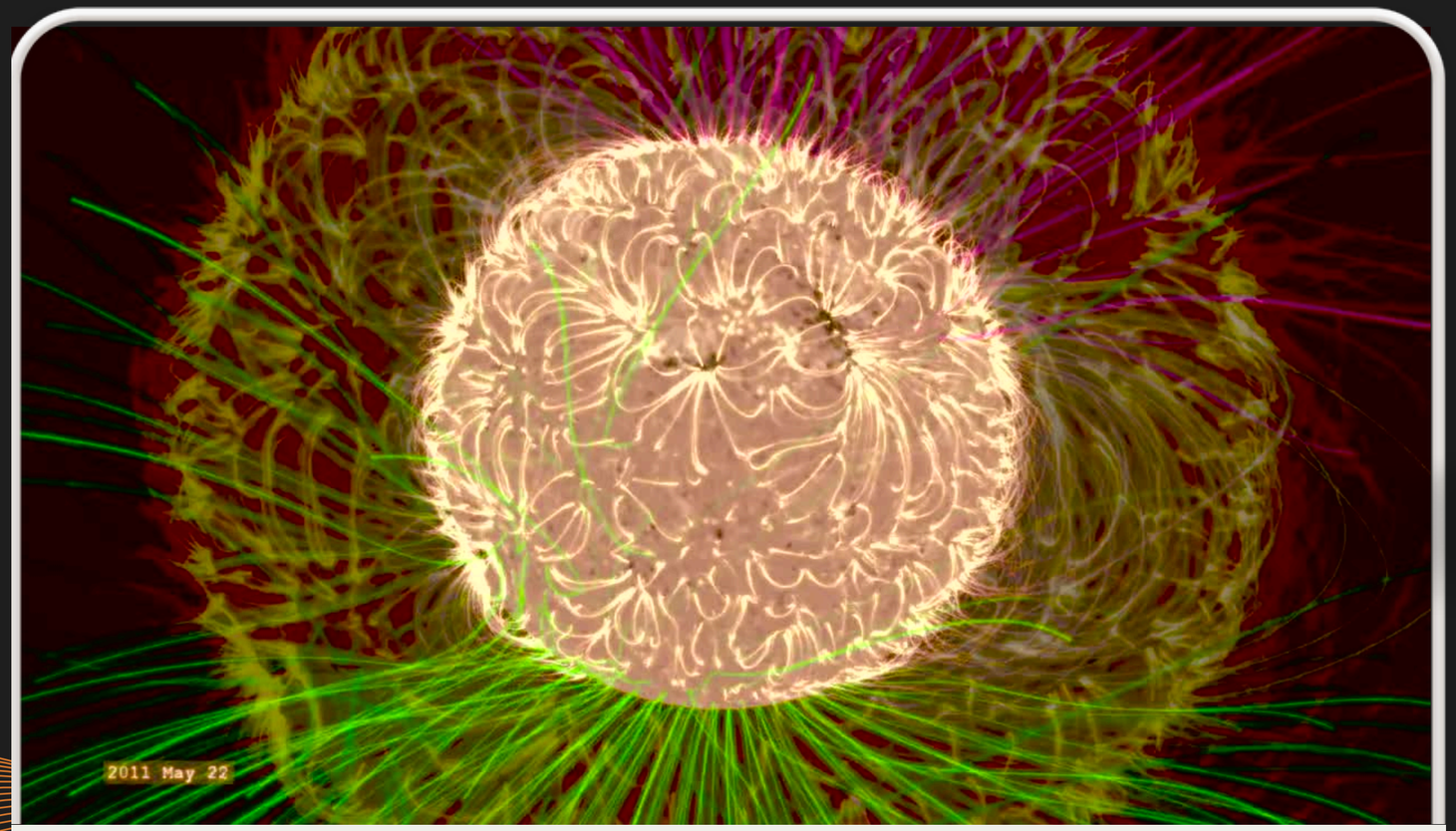
Media of a polar vortex at the north Sun's north pole, captured by SDO on February 2, 2023.



POLAR VORTEX ON THE SUN

COURTESY OF NASA/SDO AND THE AIA, EVE, AND HMI SCIENCE TEAMS

BACKGROUND IMAGE: ESA



CREDIT: NASA

VISUALIZATION OF THE SLOW CHANGES IN THE SUN'S MAGNETIC FIELD OVER THE COURSE OF FOUR YEARS

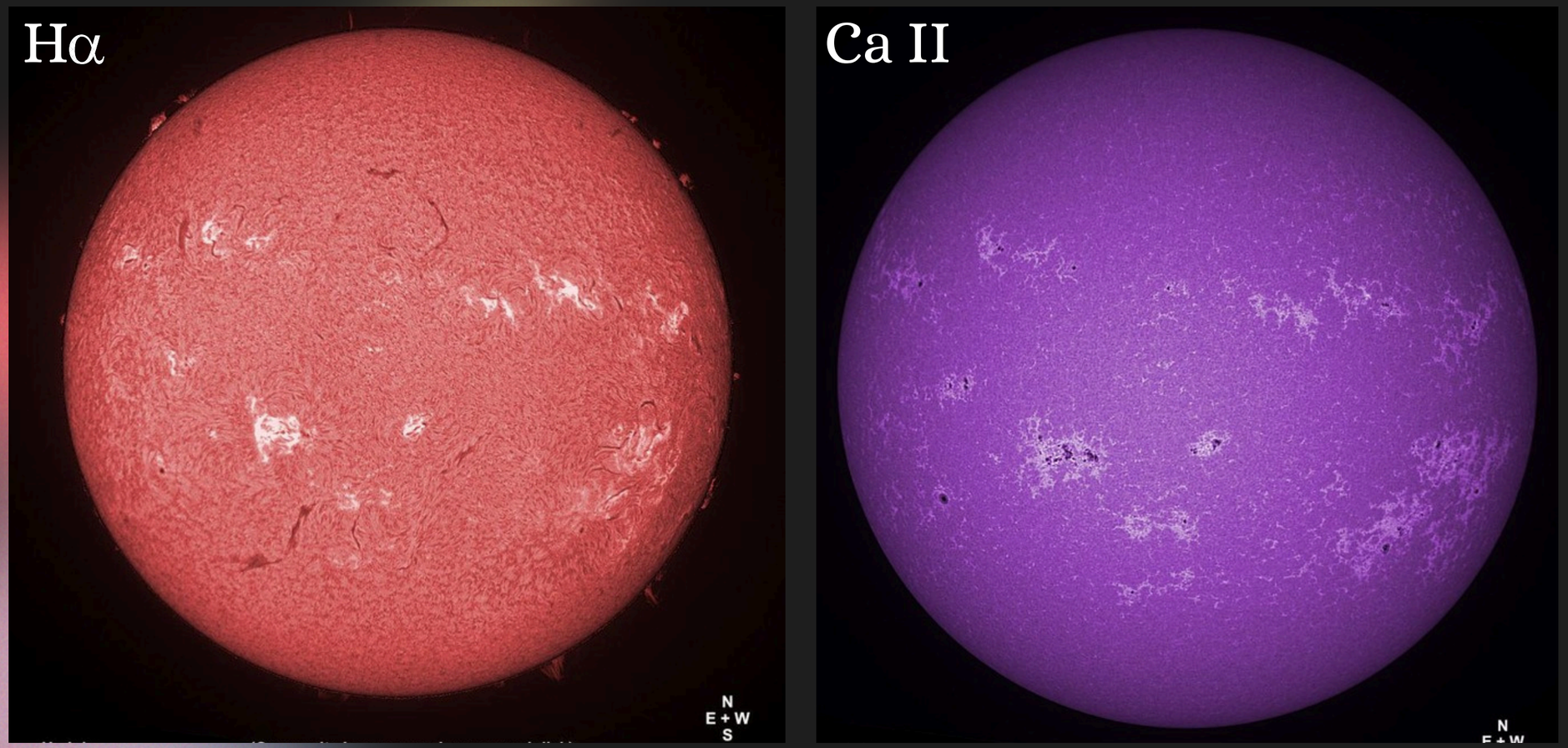
NASA ID: GSFC_20160129_Dynamic_m12104_Magnetic

How can we explain the behavior of stars' magnetic fields?

TWO OPTIONS...

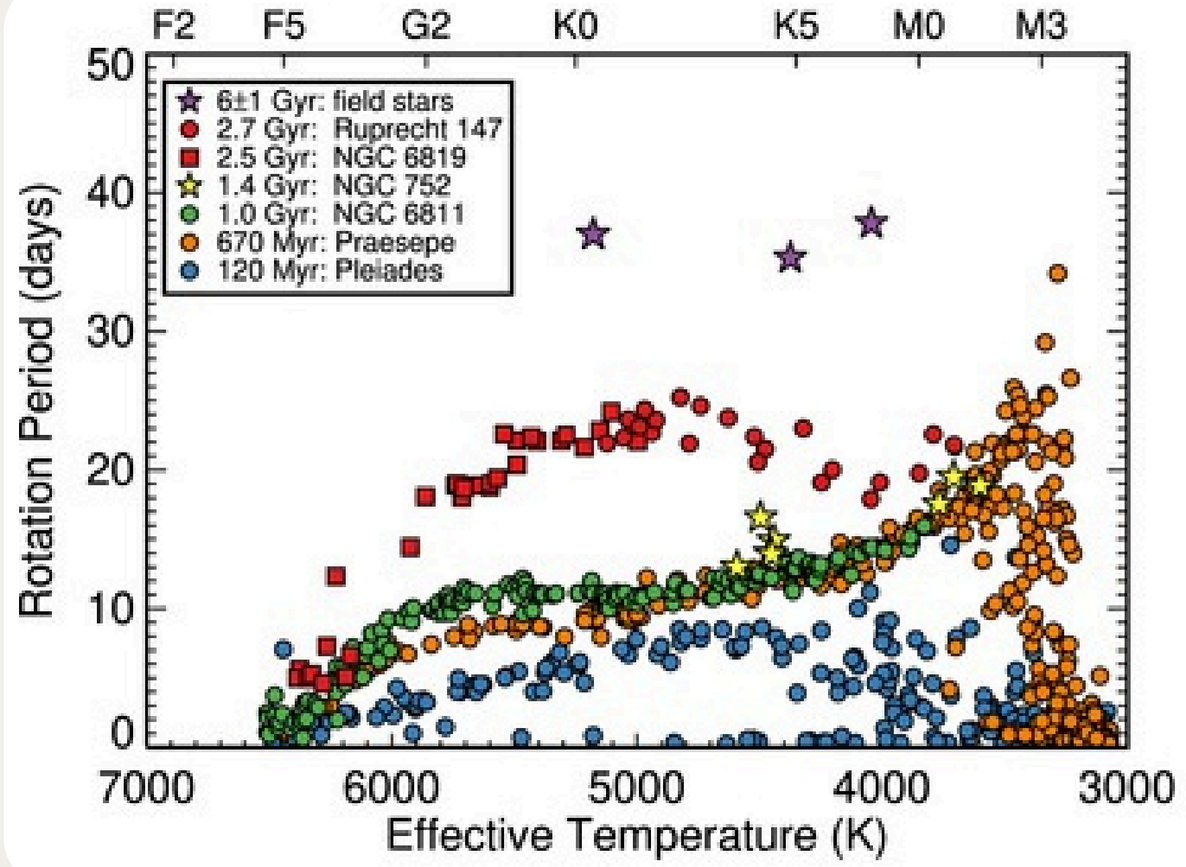
1. SIMULATIONS
2. CHARACTERIZATION

CRHOMOSPHERE



SUN IMAGES IN H-ALPHA (LEFT) AND CA-K (RIGHT) FILTERS TAKEN ON JULY 28, 2024

CREDIT: HOWARD E. **IN** HTTPS://COMMUNITY.SPACEWEATHERLIVE.COM/GALLERY/IMAGE/4737-2024-07-18-1326-HWESK-CAKJPG/



TAKEN FROM: CURTIS ET AL. (2020)

ROTATION PERIOD AS A FUNCTION OF THE STAR'S TEMPERATURE FOR DIFFERENT CLUSTERS OF VARYING AGES.

NASA ID: GSFC_20160129_Dynamic_m12104_Magnetic

Stelar Age & Rotation Period

1. **Rotation is the basis of the magnetic activity**
2. **The rotation period is dependent on spectral type and age.**
3. **Stars rotate more slowly as they age.**
4. **“When do stalled stars resume spinning down?”**

Group-X

NAME: COMA BERENICE

OBJECT: OPEN CLUSTER

AGE: ~700-800 Myr (Tang et al., 2019)

DISTANCE: ~85 pc

Second closest open cluster

PHOTO CREDIT: ALBERTO PISABARRO

TAKEN FROM: HTTPS://EN.LOSCOLORESINVISIBLES.COM/GALERIA-1?PGID=JZE4I6MP-D2E78F05-E090-4EDC-8A92-D8D8B4BE4AA9

BACKGROUND IMAGE: DSS2

NAME: GROUP-X

OBJECT: OPEN CLUSTER

AGE: ~400 Myr

DISTANCE: ~65 pc

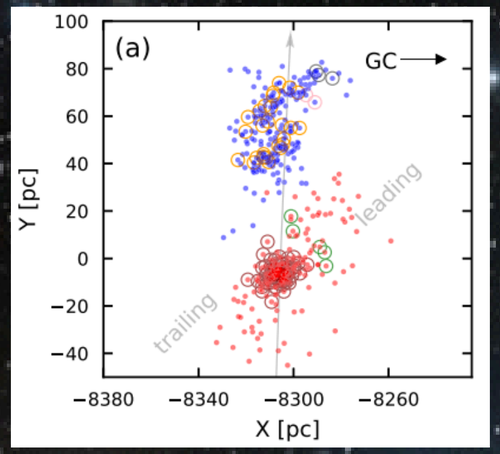
MEMBERS: 218

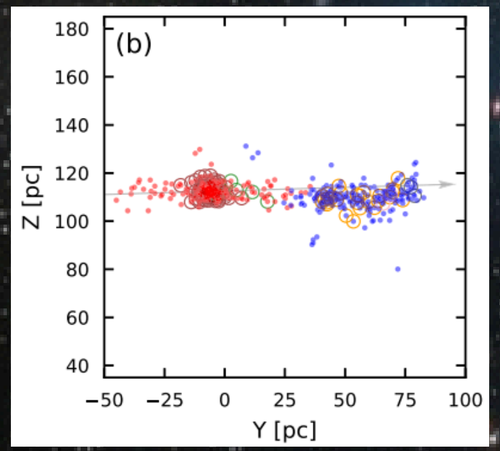
Tang et al. (2019)

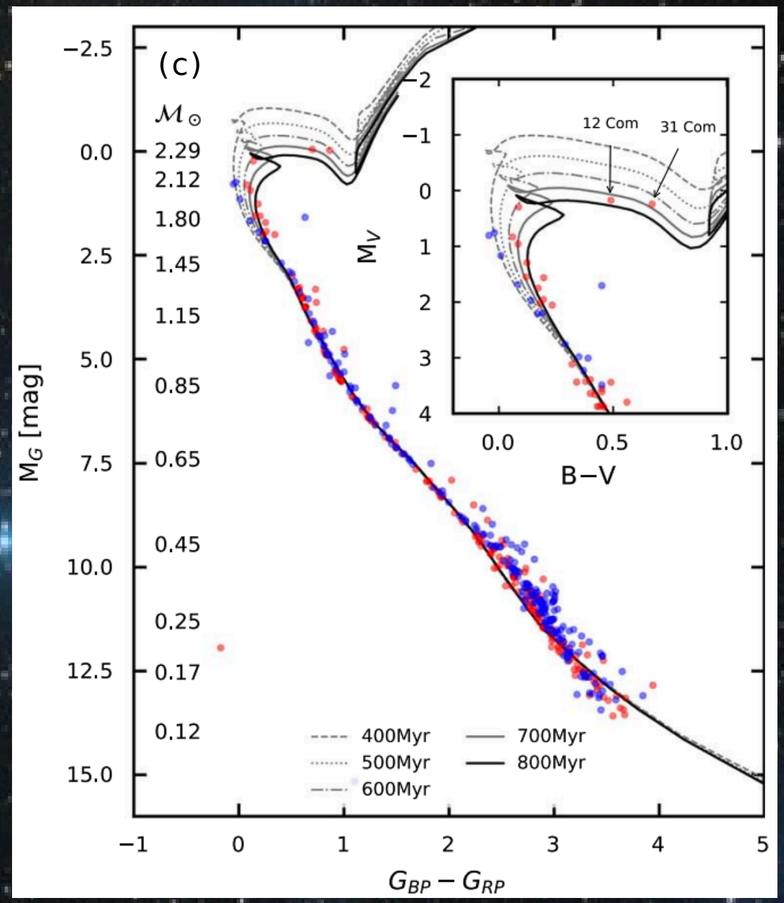
(A) Spatial distribution of member candidates on xy plane in Galactocentric cartesians coordinates. Blue dots represents Group-X stars, red dots represents Coma Ber stars.

(B) Spatial distribution of member candidates on yz plane in Galactocentric cartesians coordinates.

(C) Color-Magnitude Diagram of the Absolute Magnitude MG. Gaia parallax and color is used, PARSEC isochrones are overploted.







TAKEN FROM: TANG ET AL. (2019)

GROUP-X IS COMPOSED OF TWO STRUCTURES

LATYSHEV 2:

OBJECT: OPEN CLUSTER

AGE: ~400 Myr

DISTANCE: ~95 pc

MEMBERS: 186

MECAYOTL 1:

AGE: 400-600 Myr

DISTANCE: ~104 pc

MEMBERS: 146

Olivares et al. (2023)

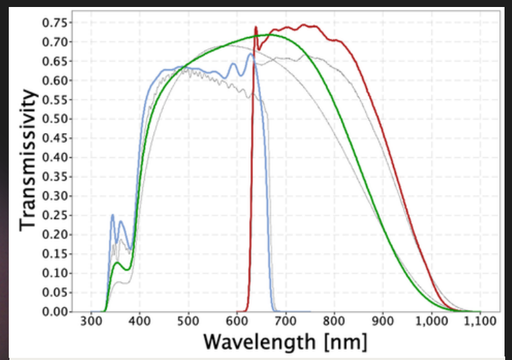
PHOTO CREDIT: ALBERTO PISABARRO

Gaia Data Release 3

CREDIT: ESA

GAIA MISSION VIDEO ANIMATION

ESA ID: 432267



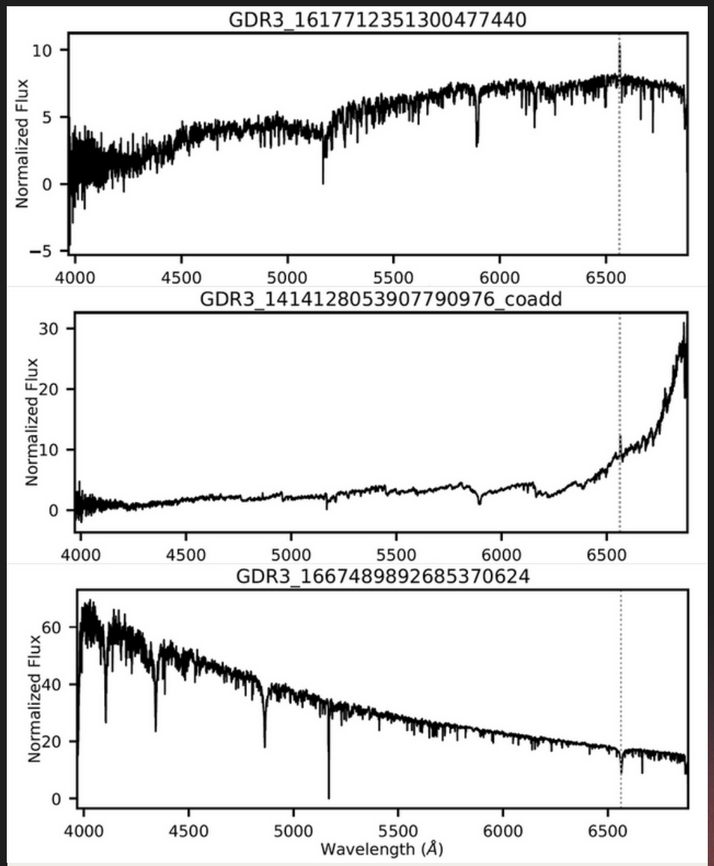
GAIA DR3 PASSBANDS:

G_BP: BLUE CURVE

G_RP: RED CURVE

G: GREEN CURVE

CREDITS: ESA/GAIA/DPAC, P. MONTEGRIFFO, F. DE ANGELI, M. BELLAZZINI, E. PANCINO, C. CACCIARI, D. W. EVANS, AND CU5/PHOTPIPE TEAM.



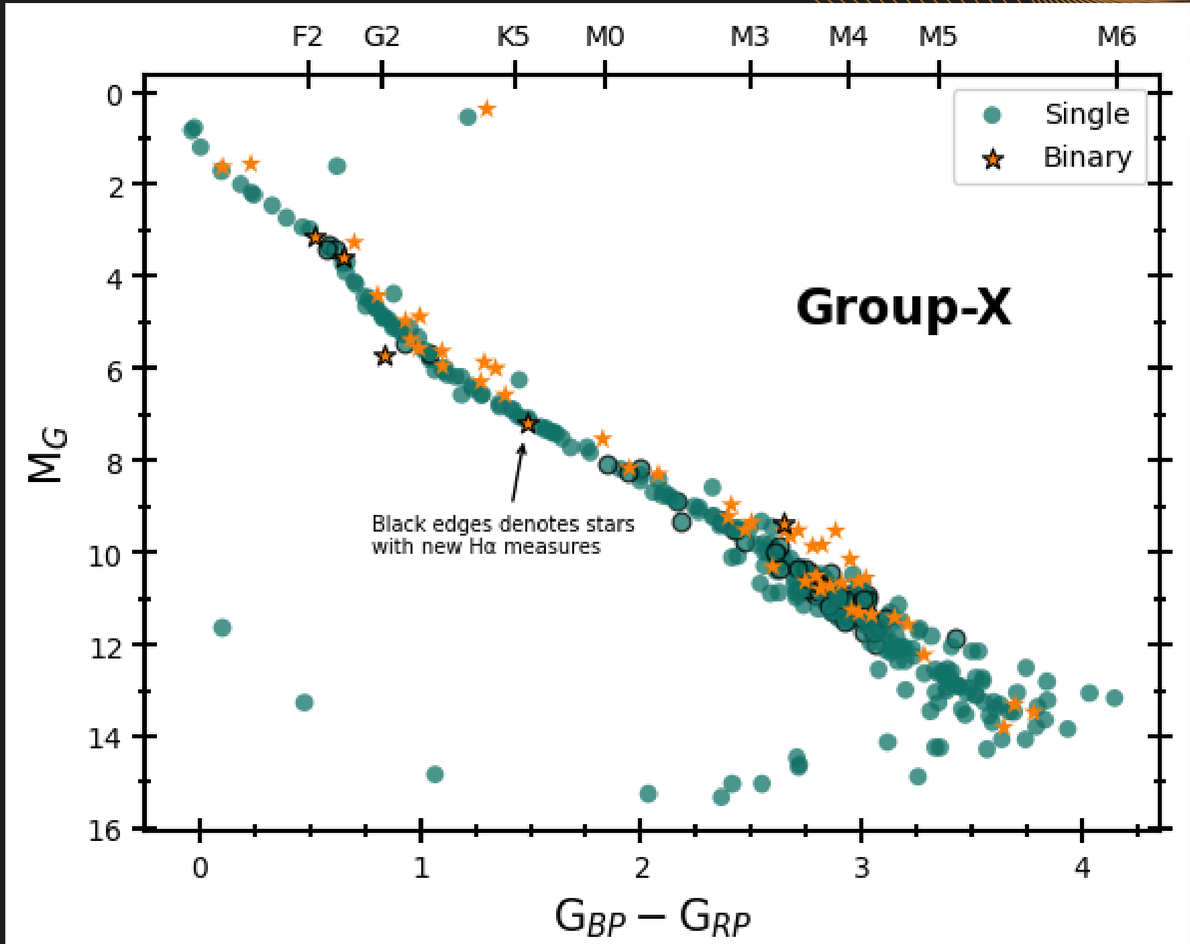
DATA FROM: MDM OBSERVATORY, OPERATED BY DARTMOUTH COLLEGE, COLUMBIA UNIVERSITY, OHIO STATE UNIVERSITY, OHIO UNIVERSITY, AND THE UNIVERSITY OF MICHIGAN

SDSS MDM LAMOST

328 TOTAL GROUP-X CANDIDATE STARS

NEW H-ALPHA EW MEASUREMENTS FOR 167 STARS

IF RUWE > 1.4 THE STAR IS BINARY

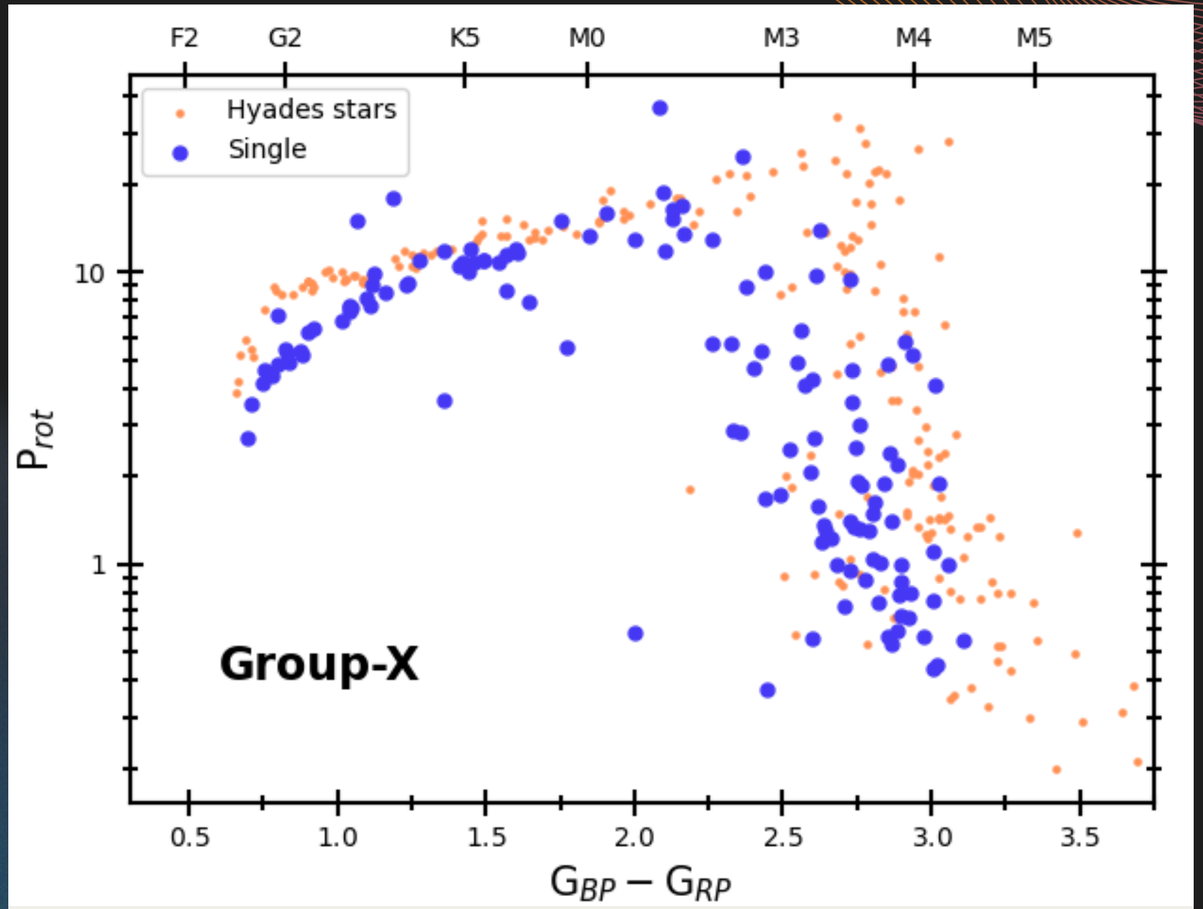


GAIA DR3 COLOR-MAGNITUDE DIAGRAM FOR GROUP-X. BLUE CIRCLES AND ORANGE STARS INDICATE SINGLE AND BINARY GROUP-X MEMBERS, RESPECTIVELY

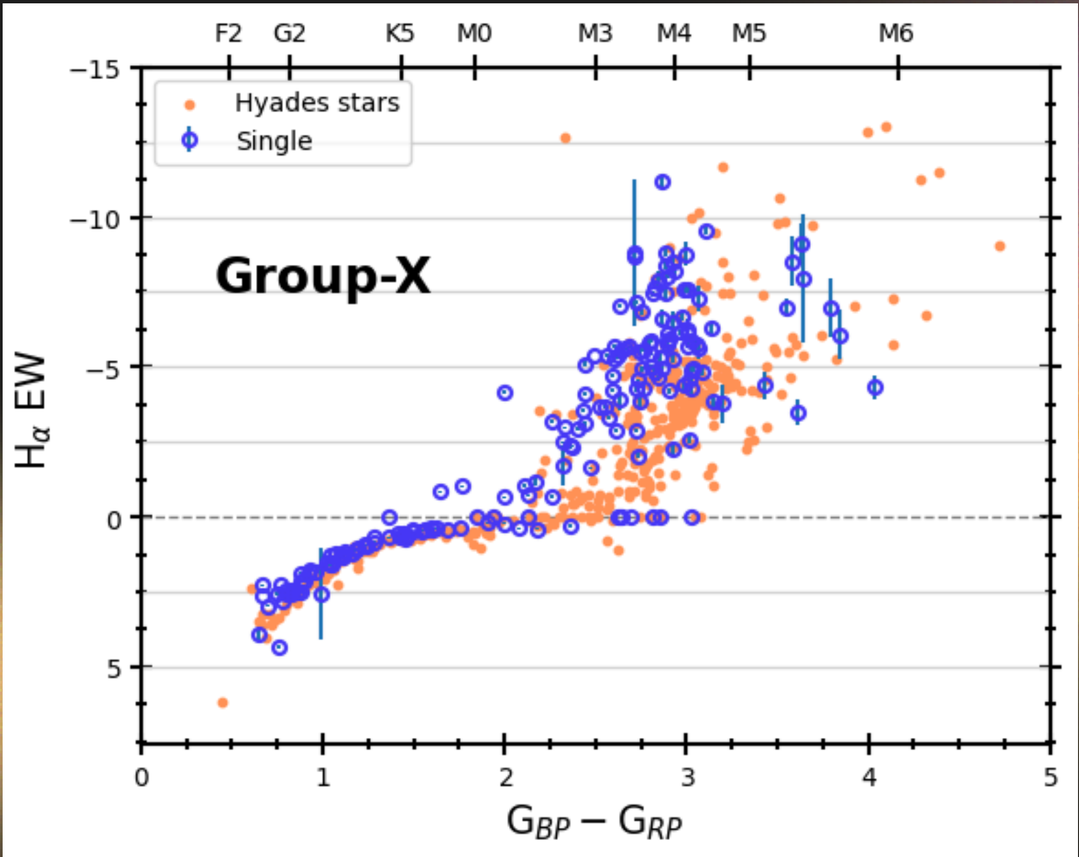
THE RELEVANT STARS FOR THIS STUDY HAVE SPECTRAL TYPES F5 OR LATER.

THE STELLAR ROTATIONAL DISTRIBUTION OF OPEN CLUSTERS EVOLVE WITH AGE

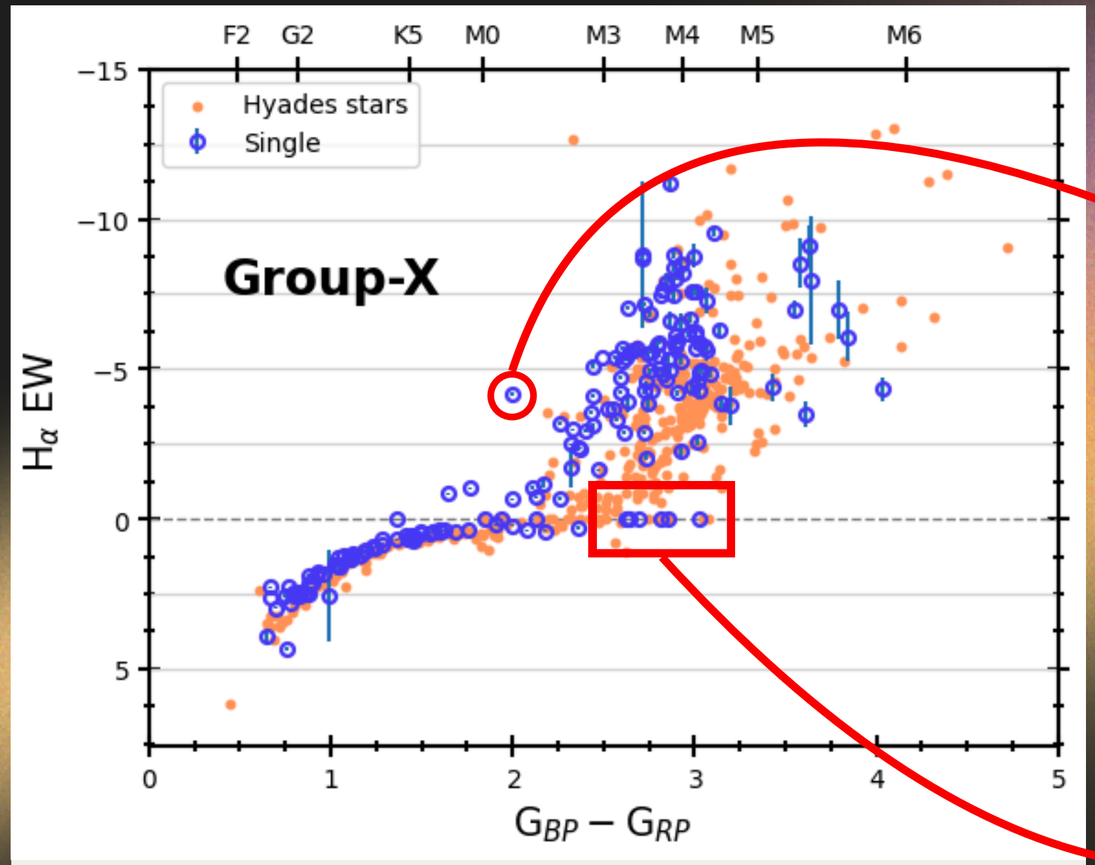
HYADES HAS A BETTER DATA COVERAGE FOR THE LATER TYPE DUE TO ITS PROXIMITY



ROTATION PERIOD VS GAIA COLOR FOR GROUP-X SINGLE STARS (BLUE CIRCLES) AND HYADES SINGLE STARS (ORANGE CIRCLES). **HYADES** IS **~700 MYR** OLD AND HAS A DISTANCE OF **~47 PC.**



MEASURED H-ALPHA EW FOR GROUP-X AND HYADES SINGLE STARS, ONLY GROUP-X H-ALPHA EW ERRORS ARE PLOTED. FOR THE NEW EW MEASUREMENTS, WE USE THE PHEW CODE, WHICH EMPLOYS PYSPECKIT FOR FITTING AND 1,000 MONTE CARLO SIMULATIONS FOR ERROR ESTIMATION.



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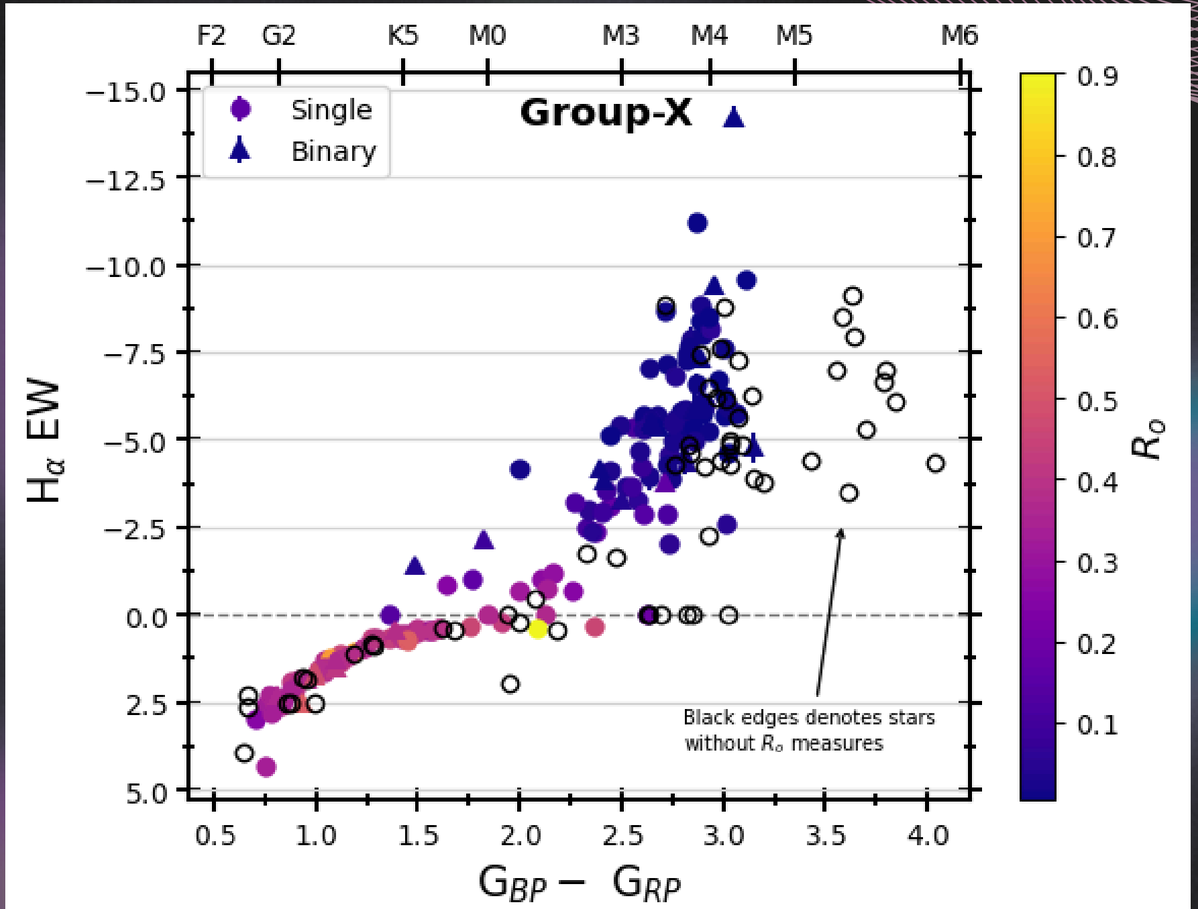
SOME STARS ARE FAR BEYOND WHAT IS EXPECTED OF THE DISTRIBUTION.

THIS COULD MEANS THAT THEY ARE FLARES OR FALSE MEMBERS.

THE ROSSBY NUMBER COMPARES THE ROTATION PERIOD TO THE CONVECTIVE OVERTURN TIMESCALE.

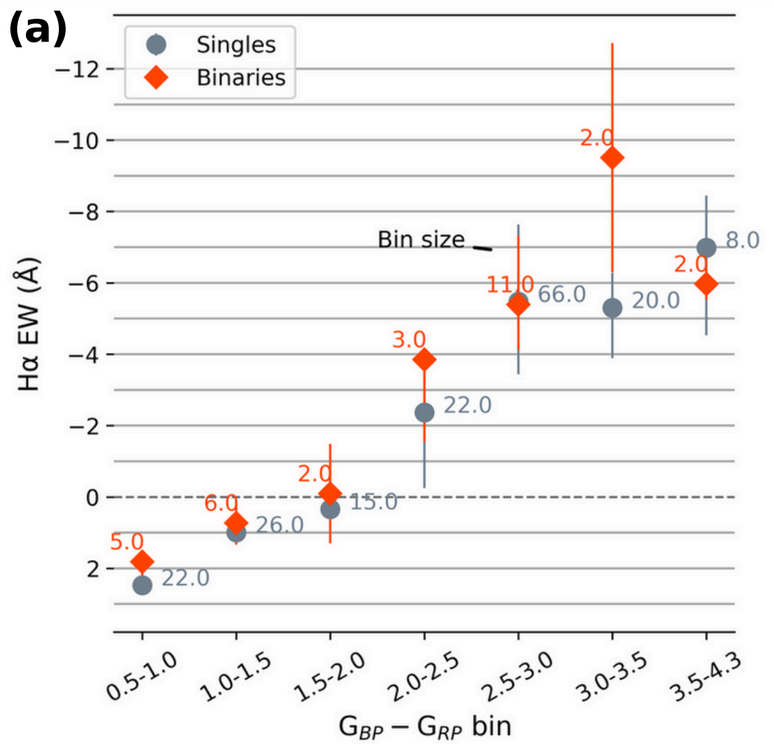
THERE IS A CLEAR RELATIONSHIP BEETWEEN EMISSION AND ROTATION.

ROSBY COLORMAP HELPS TO IDENTIFY POSSIBLE FALSE MEMBERS

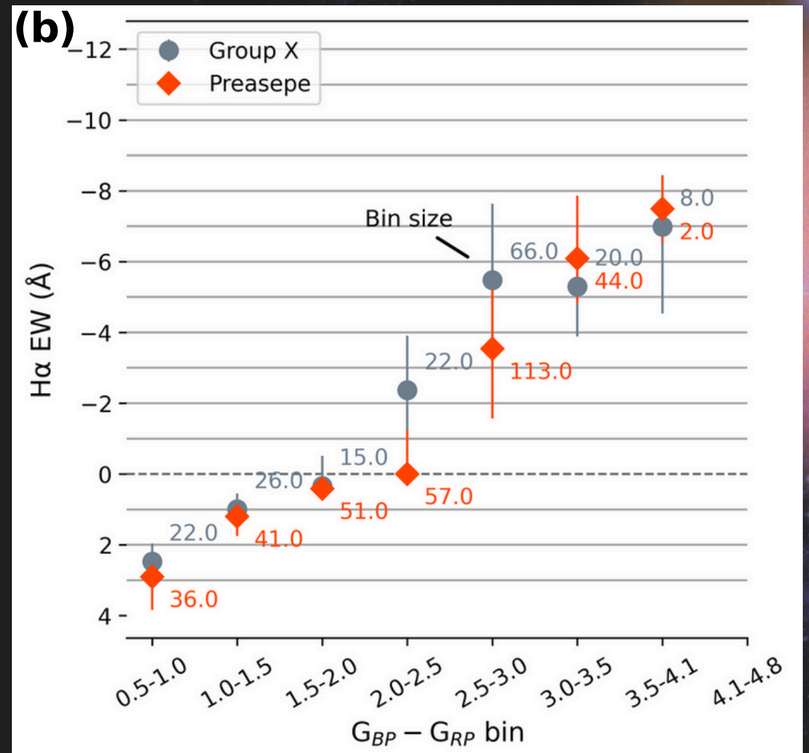


MEASURED H-ALPHA EW FOR SINGLES (CIRCLES) AND BINARY (TRIANGLES) GROUP-X STARS. A COLOR MAP OF THE ROSSBY NUMBER IS APPLIED, VERIFYING THE ROTATION-EMISSION RELATION.

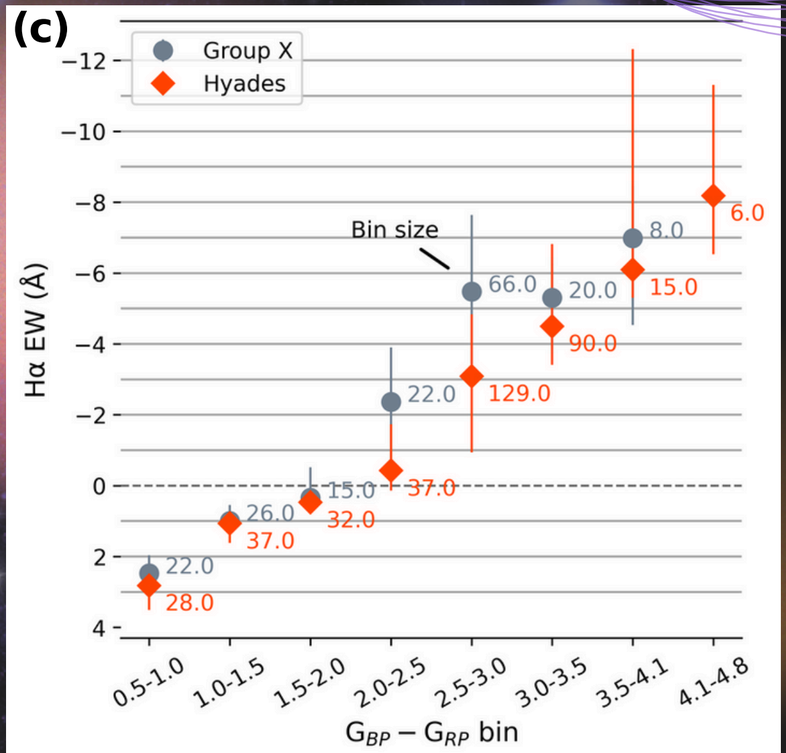
COLOR-BINNED MEDIAN MEASURED H-ALPHA EQUIVALENT WIDTHS



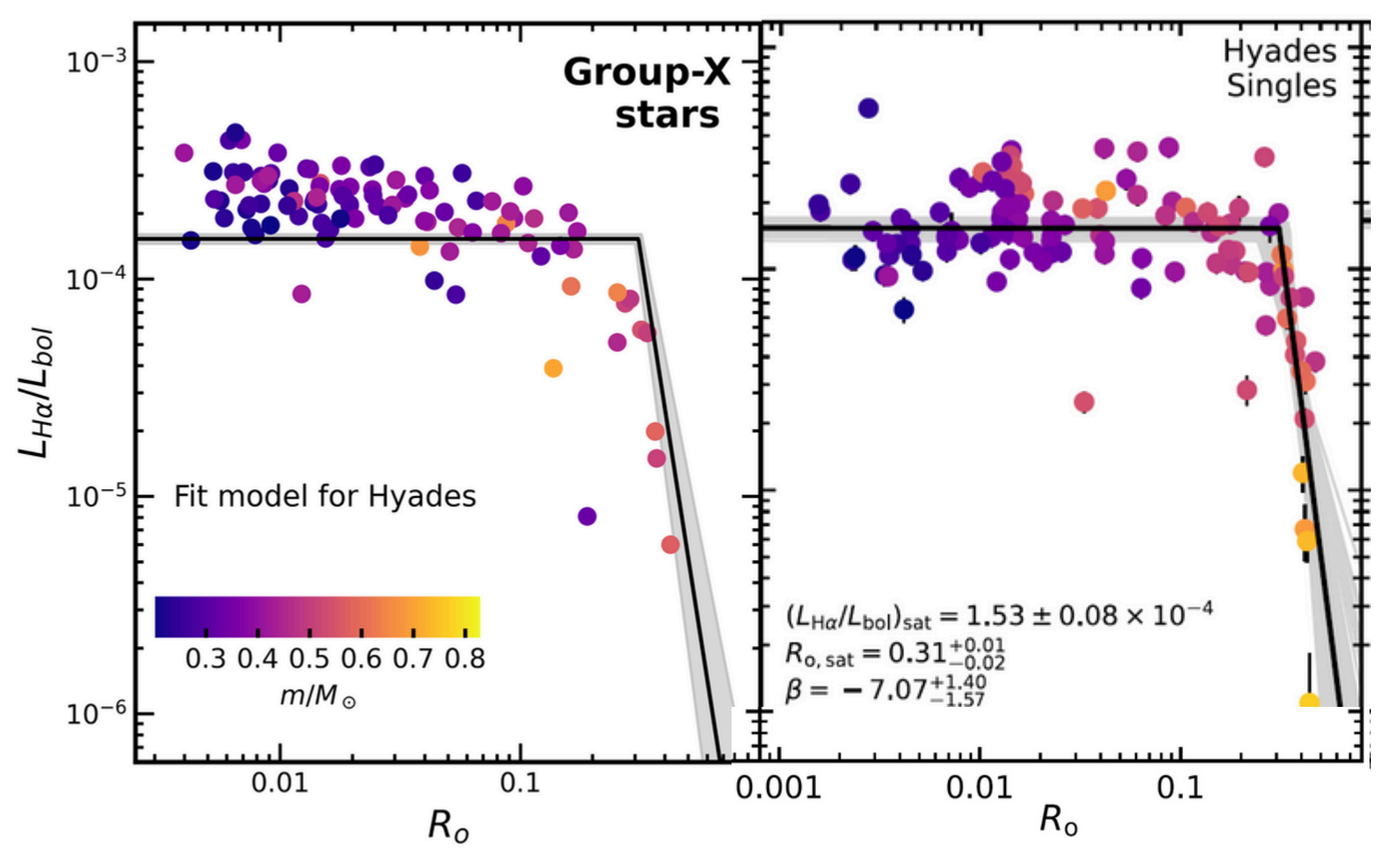
SINGLE STARS (GRAY CIRCLES) AND BINARY (ORANGE DIAMONDS) IN **GROUP-X,** WITH THE 16TH AND 84TH PERCENTILES REPRESENTED BY WHISKERS. NUMBERS NEXT TO SYMBOLS INDICATE THE NUMBER OF STARS IN EACH BIN.



SINGLE STARS OF **GROUP-X** (GRAY CIRCLES) AND SINGLES OF **PRAESEPE** (ORANGE DIAMONS) WITH THE 16TH AND 84TH PERCENTILES.



SINGLES STARS OF **GROUP-X** (GRAY CIRCLES) AND SINGLES OF **HYADES** (ORANGE DIAMONS) WITH THE 16TH AND 84TH PERCENTILES.



FRACTIONAL H-ALPHA LUMINOSITY VERSUS ROSSBY NUMBER IN PRAESEPE AND HYADES SINGLE STARS. LEFT PANEL TAKEN FROM NÚÑEZ ET AL. (2024).

MAGNETIC SATURATION

FOR HYADES, RAPID ROTATORS TEND TO HAVE HIGH ACTIVITY, HOWEVER, THEY REACH A SATURATION LEVEL AT APPROXIMATELY RO = 0.2

FOR GROUP-X THE REGIME OF FAST-ROTATING STARS (RO $\lesssim$ 0.3) EXHIBITS A

SHALLOW DECLINE CONSISTENT WITH A POWER-LAW!

Conclusions

- There is an enhancement of chromospheric activity in Group-X with respect to Hyades an Praesepe clusters.
- Fast-rotating stars exhibits a power-law shallow decline, contrary to the typical flat "saturated" relation found in the same studies.
- Group-X emerges as a crucial reference point for understanding the evolution of the rotation-activity relationship in low-mass stars.

What's next?!

- Determine the best-fit model parameters for the magnetic activity of Group-X.
- Compare the correlation between H-alpha and X-ray emission.
- Obtain additional spectral data of members to finalize the stellar census of Group-X, and possibly use the new Gaia DR4 data.
- Perform a detailed analysis of binary member identification.

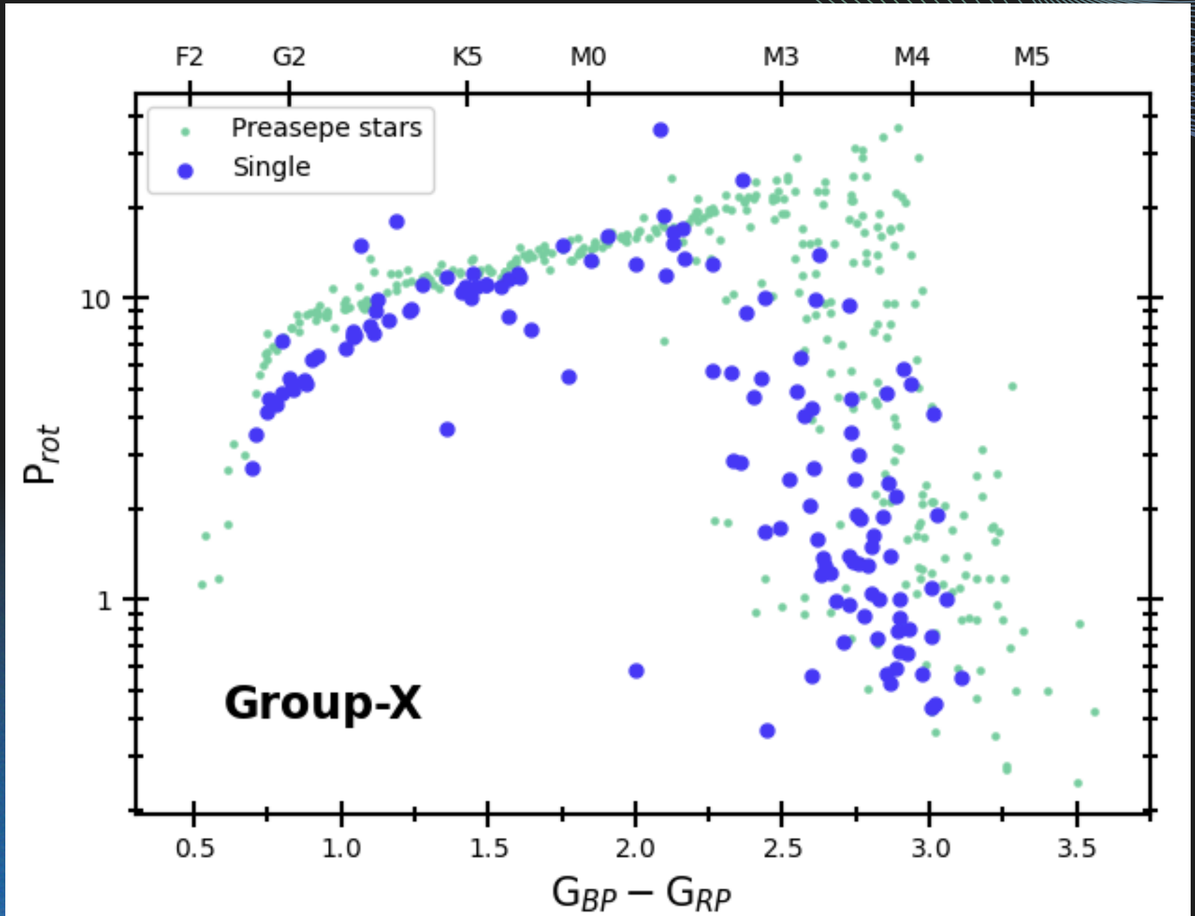
Thank you

Backup Slides

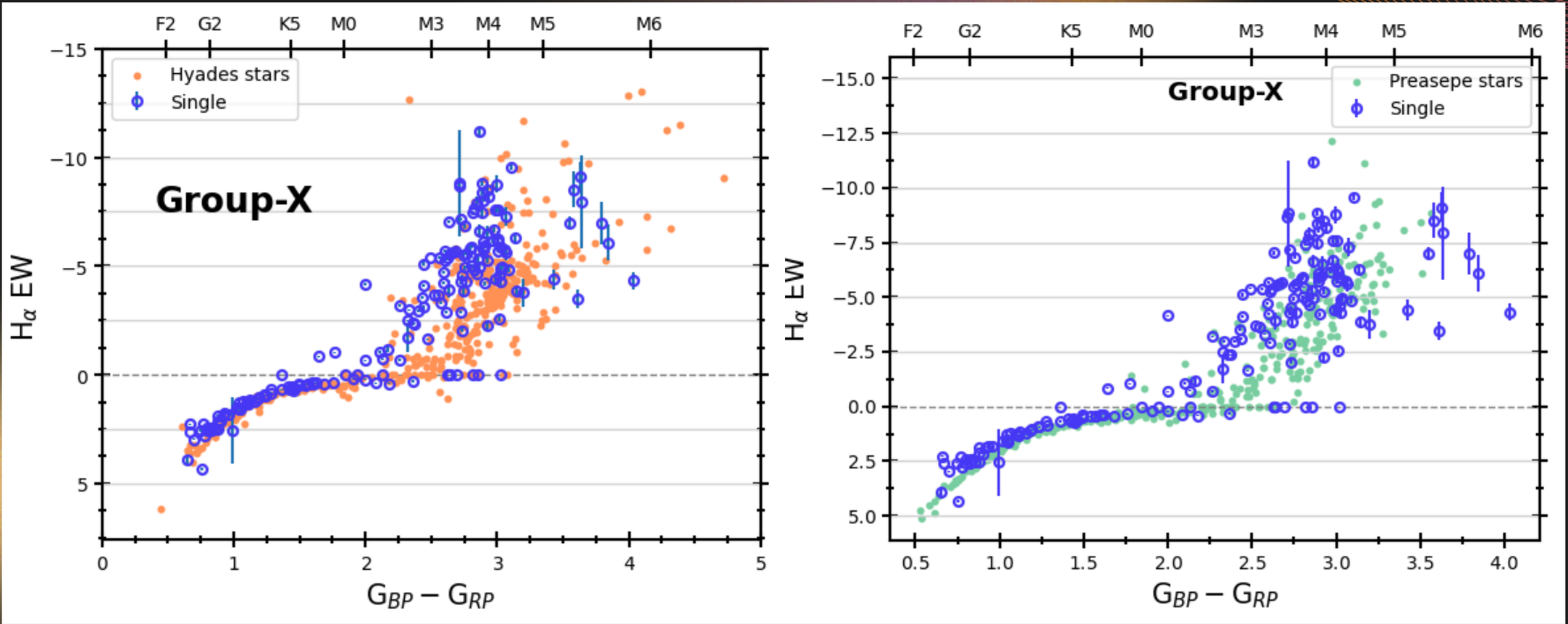
THE RELEVANT STARS FOR THIS STUDY HAVE SPECTRAL TYPES F5 OR LATER.

THE STELLAR ROTATIONAL DISTRIBUTION OF OPEN CLUSTERS EVOLVE WITH AGE

BUT WHAT HAPPENS IN THE RANGE BETWEEN G AND K?

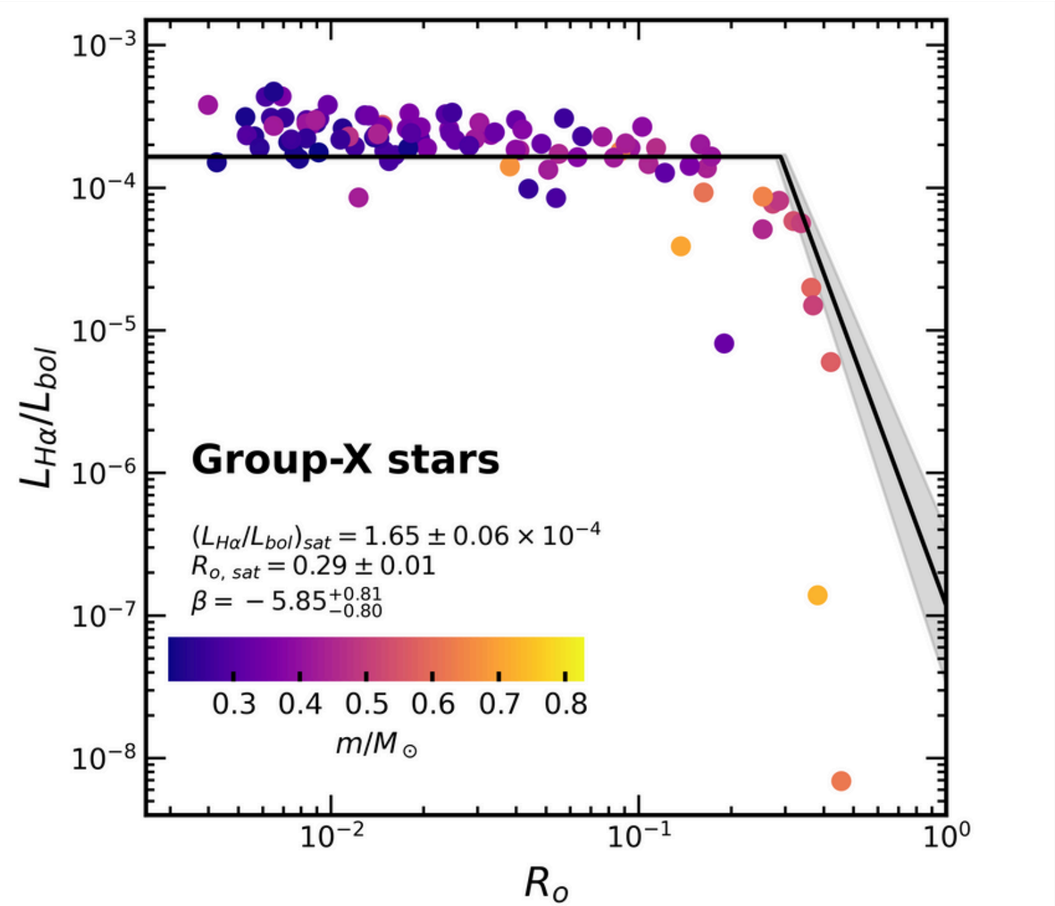


ROTATION PERIOD VS GAIA COLOR FOR GROUP-X SINGLE STARS (BLUE CIRCLES) AND PRAESEPE SINGLE STARS (GREEN CIRCLES). **PRAESEPE** IS **~700 MYR** OLD AND HAS A DISTANCE OF **~180 PC**.



MEASURED H-ALPHA EW FOR GROUP-X AND HYADES SINGLE STARS (LEFT PANEL), AND GROUP-X AND PRAESEPE SINGLE STARS (RIGHT PANEL). ONLY GROUP-X H-ALPHA EW ERRORS ARE PLOTED. FOR THE NEW EW MEASUREMENTS, WE USE THE PHEW CODE, WHICH EMPLOYS PYSPECKIT FOR FITTING AND 1,000 MONTE CARLO SIMULATIONS FOR ERROR ESTIMATION.

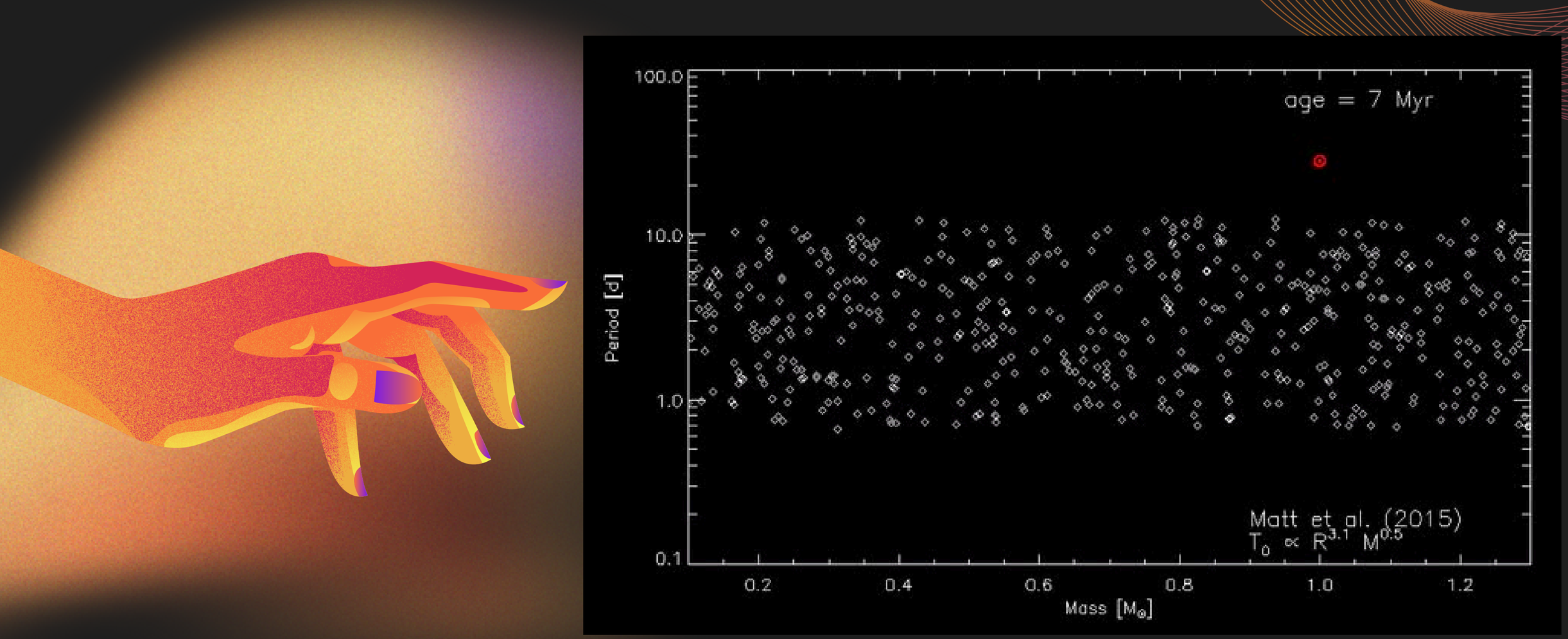
MAGNETIC SATURATION



RELATIVE AMOUNT OF STAR'S LUMINOSITY THAT IS OUTPUT AS H-ALPHA EMISSION VERSUS ROSSBY NUMBER IN GROUP-X MEMBERS.

THE RELATIONSHIP BETWEEN LHA/LBOL AND RO REVEALS A RAPID POWER-LAW DECAY FOR SLOW-ROTATING STARS (RO $\gtrsim$ 0.3).

THE REGIME OF FAST-ROTATING STARS (RO $\lesssim$ 0.3) EXHIBITS A **SHALLOW DECLINE CONSISTENT WITH A POWER-LAW!**


age = 7 Myr
Period [d]
100.0
10.0
1.0
0.1
0.2
0.4
0.6
0.8
1.0
1.2
Mass [M⊙]
Matt et al. (2015)
$T_0 \propto R^{3.1} M^{0.5}$