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DO THE TIDES CONTROL ELEMENTAL ABUNDANCES IN STELLAR ATMOSPHERES OF A-TYPE STARS?

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✦From the textbooks – energy transport?

Hot stars (spectral types O, B & A) – radiative transfer, convective cores;

Cool stars (spectral types F, G, K, …) – convective transfer, outer convective zone, cooler is the temperature, deeper is the zone

✦From the textbooks – particle transport?

Hot stars (O & B) radial flows, stellar winds;

Cool stars (late-F, G, K…) – convection;

BUT - A and early-F – no mass loss, no convection

What happens in stable stellar atmospheres?

Metallic line (Am) stars – a summary

+Most numerous sub-group among all peculiar stars

+Sp(Ca) < Sp(H) < Sp(met) –
Ca,Sc: deficient, Fe-peak, heavy: overabundant

+Neither spectral, nor photometric variations –
homogenous surface structure, non-magnetic

+Slow rotation - statistically all non-magnetic
A-type stars with vsini < 80 km/s are metallic
line stars

+Almost all of them can be found in binary systems

Microscopic diffusion

+Radiation pressure vies with gravity

+Relative drift and separation of elements in
STABLE atmospheres

+Some species sink, some species levitate, as a result –
metal-rich atmosphere

+Slow rotation is probably a *conditio sine qua non*
to have radiatively driven diffusion successfully
working in the stellar atmospheres

+Not in the textbooks – "Stars are non-uniform
multi-component gases" – S.Vauclair

Microscopic diffusion and…

Rotation plays a key role

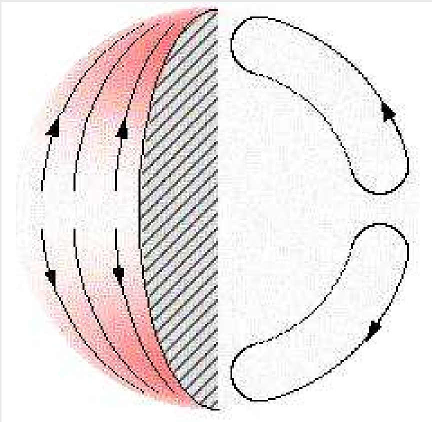
+Growing amount of publications in support

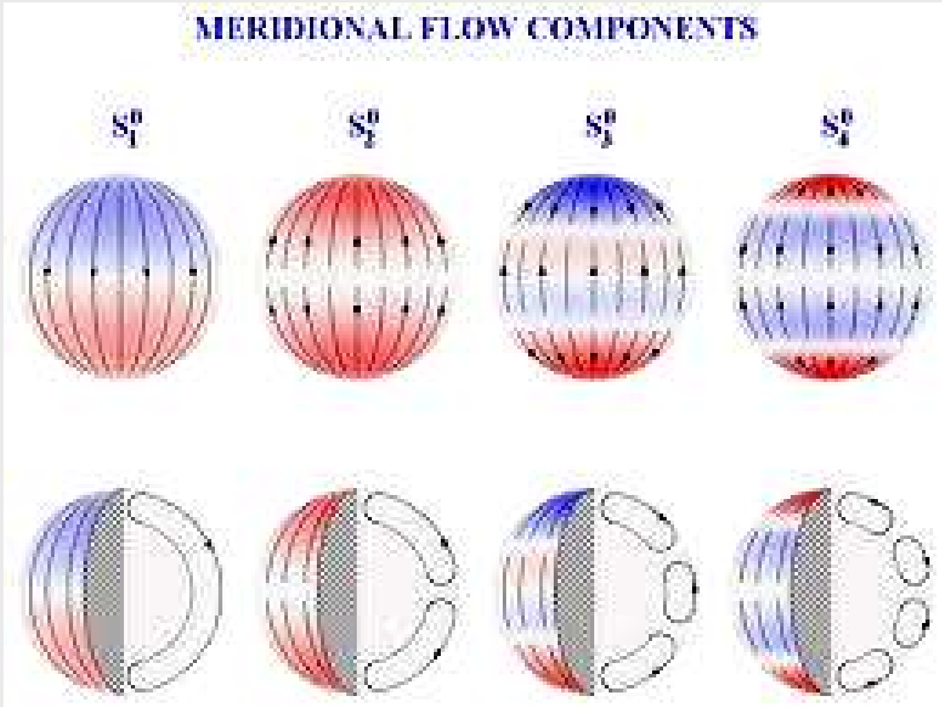
+An extreme conclusion – 'rotation alone can explain the appearance of an A-star as peculiar or normal'

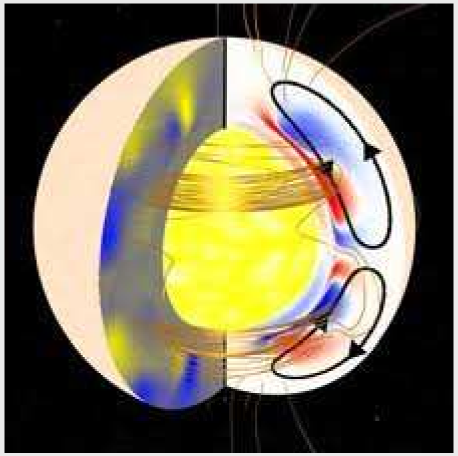
Why?
Meridional mixing is induced by the rotation.

+Not in the textbooks – "Stars are non-uniform multi-component gases" – S.Vauclair

Meridional circulation due to rotation







Deep meridional flows set up
the solar activity cycle

Microscopic diffusion and…

Binarity - the new dimension

- Large scale motions (flows, oscillations) are induced by the companion star
- Additional mixing factor => tidal mixing
- Tidal mixing interferes with the rotational mixing => stabilization factor
- An analogy too far – some tidally-locked late-type binaries exhibit overabundances of Lithium

Microscopic diffusion and…

Binarity - the new dimension

+'Tidal mixing + stabilization' hypothesis:

Abundance peculiarities in binary systems with Porb < 180 days may depend on the orbital elements.

They have to be more pronounced in binary systems with larger eccentricities, and possibly with longer periods.

Binarity – a new dimension

Two semi-competing, and semi-converging theoretical models

Dynamic tide theory (Zahn)

A variety of gravity modes are induced, esp. if eccentric orbits are assumed.

Radiative damping retards the dynamical tides in stars with radiative envelopes which results in synchronization and circularization.

Tidal bulge is caused to lag (or to lead) the secondary star.

Binarity – a new dimension

Two semi-competing, and semi-converging theoretical models

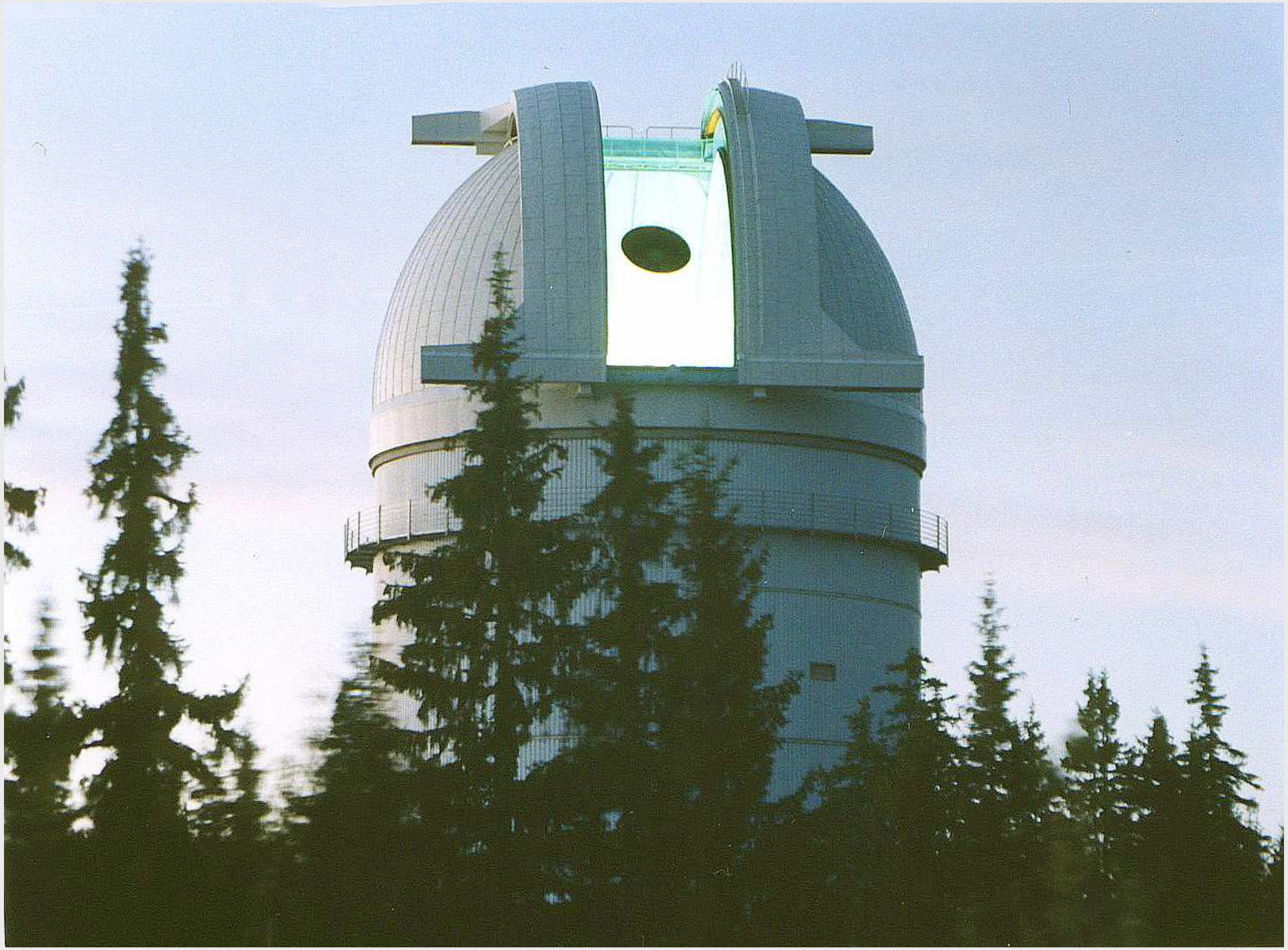
<u>Hydrodynamical mechanism (Tassoul^2)</u>

The lack of axial symmetry in a non-synchronously rotating tidally distorted star produces large-scale meridional currents. These currents exchange mass and angular momentum. Effective up to Porb = 100 days. Their geometry is similar to the geometry of rotationally induced meridional flows.

If Prot < Porb ---> rise at the equator & sink at the poles;

if Prot > Porb ---> sink at the equator & rise at the poles.

The Telescope



2-m Ritchey-Chretiene-Coude

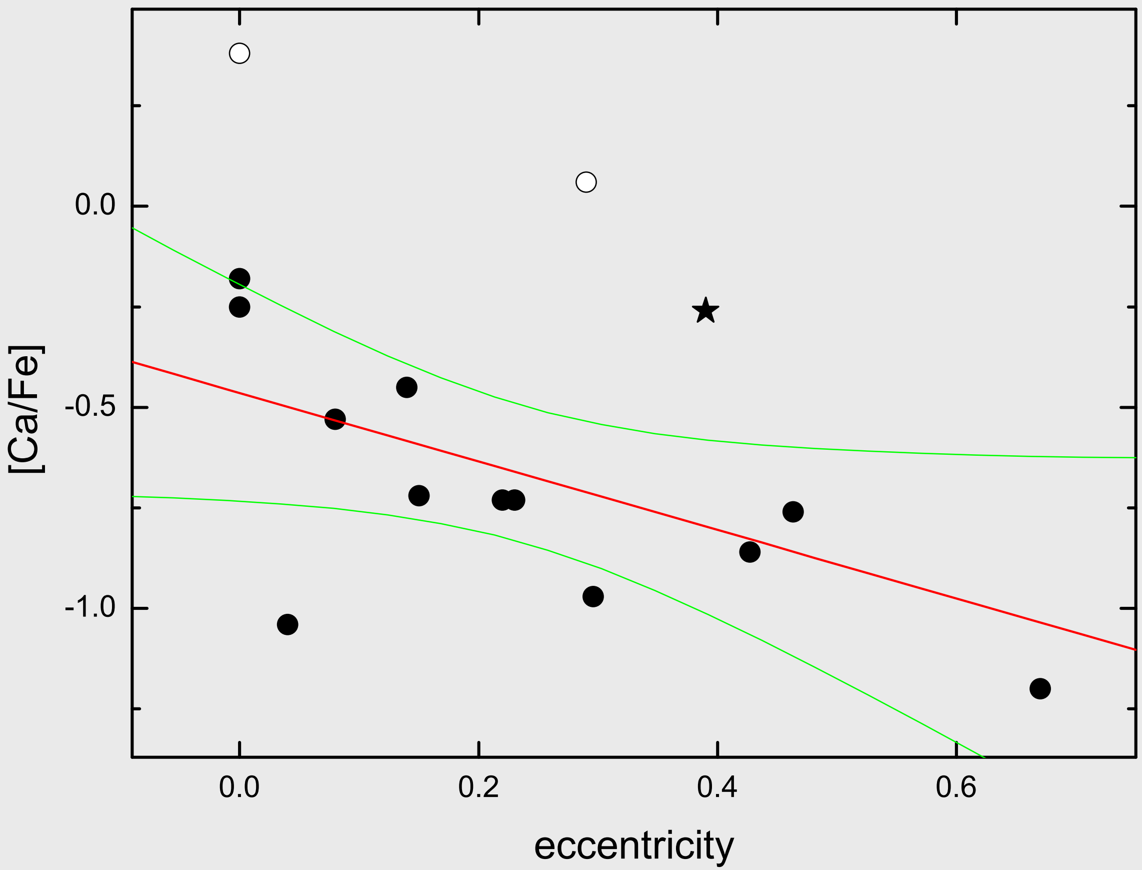
Focal ratios
1:8 RC & 1:36 Coude

High resolution spectroscopic observations carried out with the 2-m RCC telescope of Rozhen NAO in a region around 6439 A, S/N ratio of about 300, R ~ 30,000, standard IRAF procedures.

Fifteen binary systems from an extended sample list have been observed so far. Synthetic spectrum computations to determine elemental abundances.

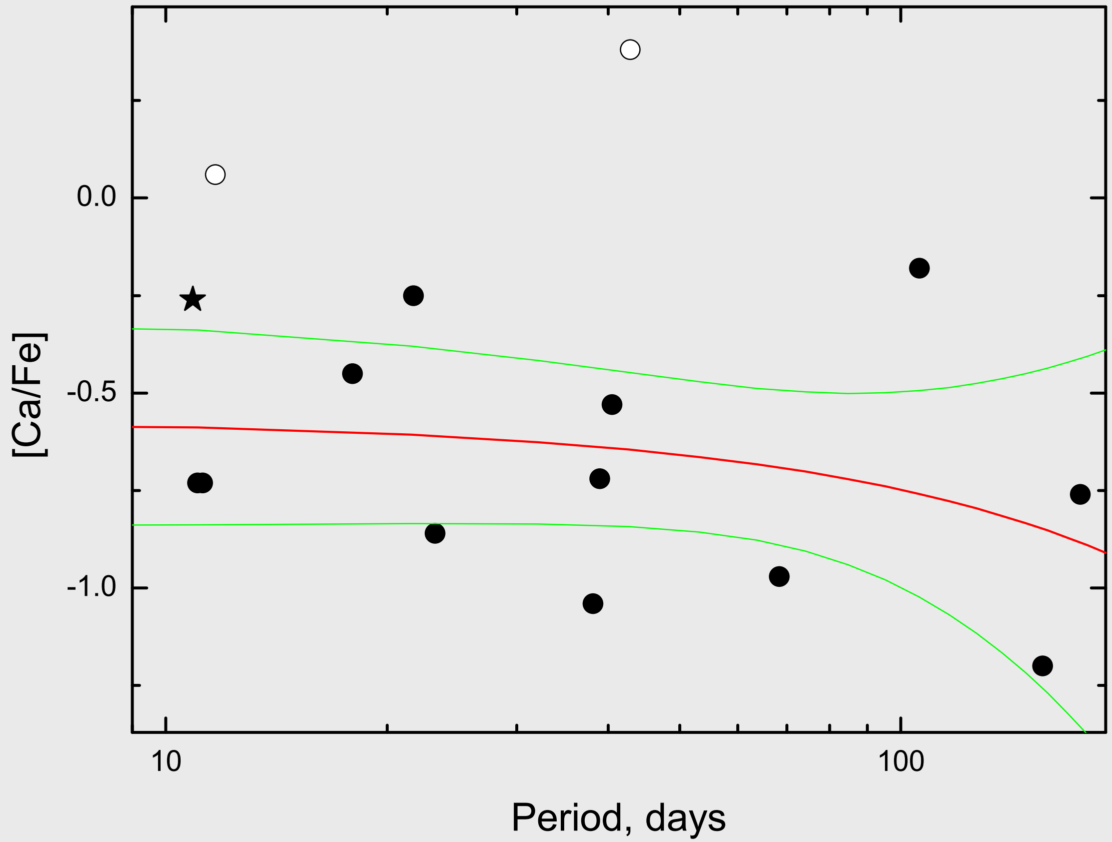
[Ca/Fe] ratio has been chosen to measure the abundance anomalies.

<u>We have</u> ---> Ca is in deficit, Fe is overabundant.
<u>We expect</u> ---> anomalies to be <u>more pronounced</u> in binary systems with <u>larger eccentricities</u>, and (possibly) with <u>longer periods</u>.



[Ca/Fe] vs. period

[Ca/Fe] = 0.0 means
no anomalies



[Ca/Fe] vs. period

[Ca/Fe] = 0.0 means
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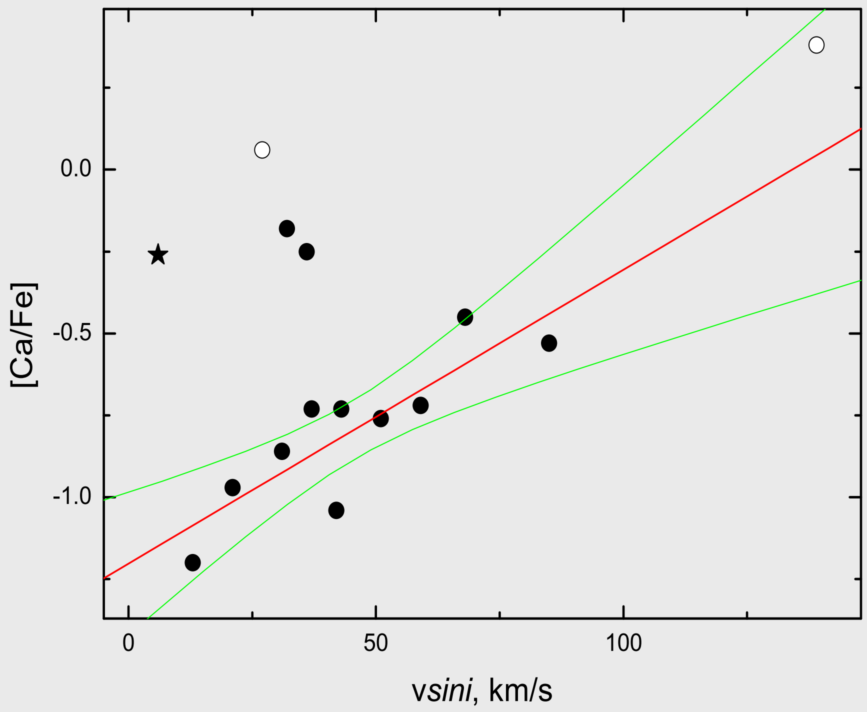
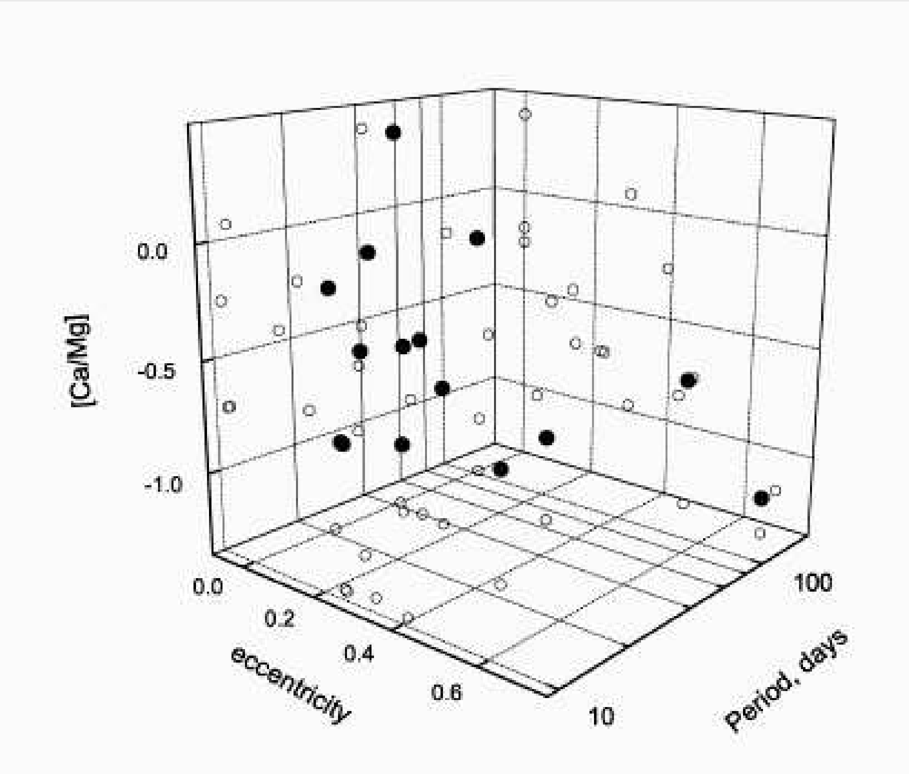


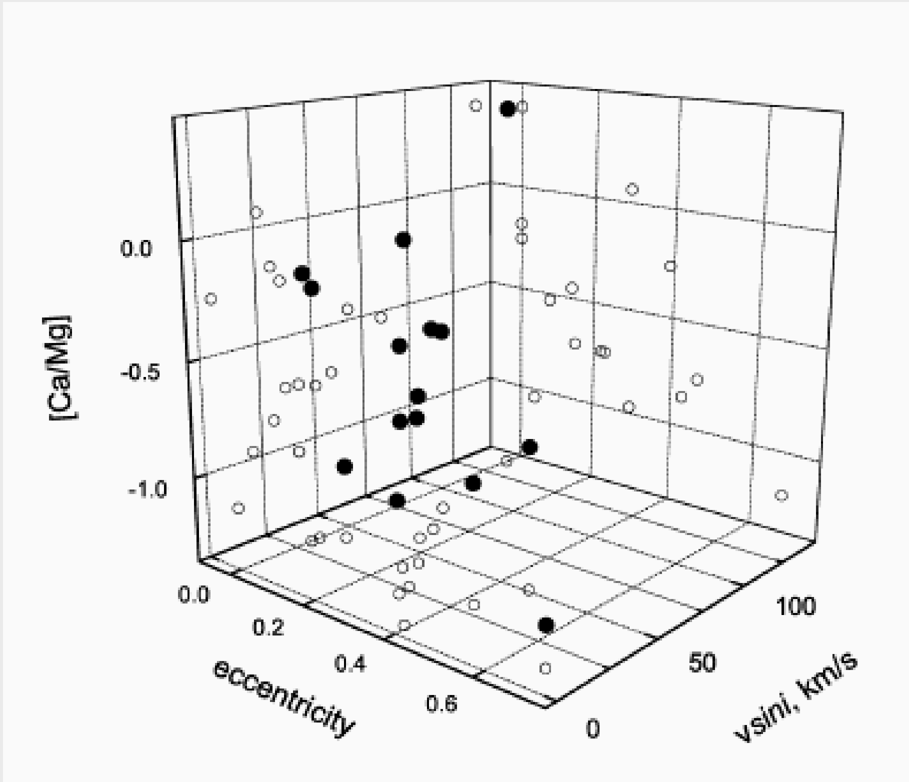
[Ca/Fe] vs. rotation

[Ca/Fe] = 0.0 means
no anomalies

3D



[Ca/Mg]
0.0
-0.5
-1.0
0.0
0.2
0.4
0.6
eccentricity
10
100
Period, days



[Ca/Mg]
0.0
-0.5
-1.0
0.0
0.2
0.4
0.6
eccentricity
0
50
100
vsini, km/s

Пуно вам хвала на пажњи!

The End