Binarity: Follow the angular momentum!

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Dictionary translation of my name from Hebrew to English (real!):

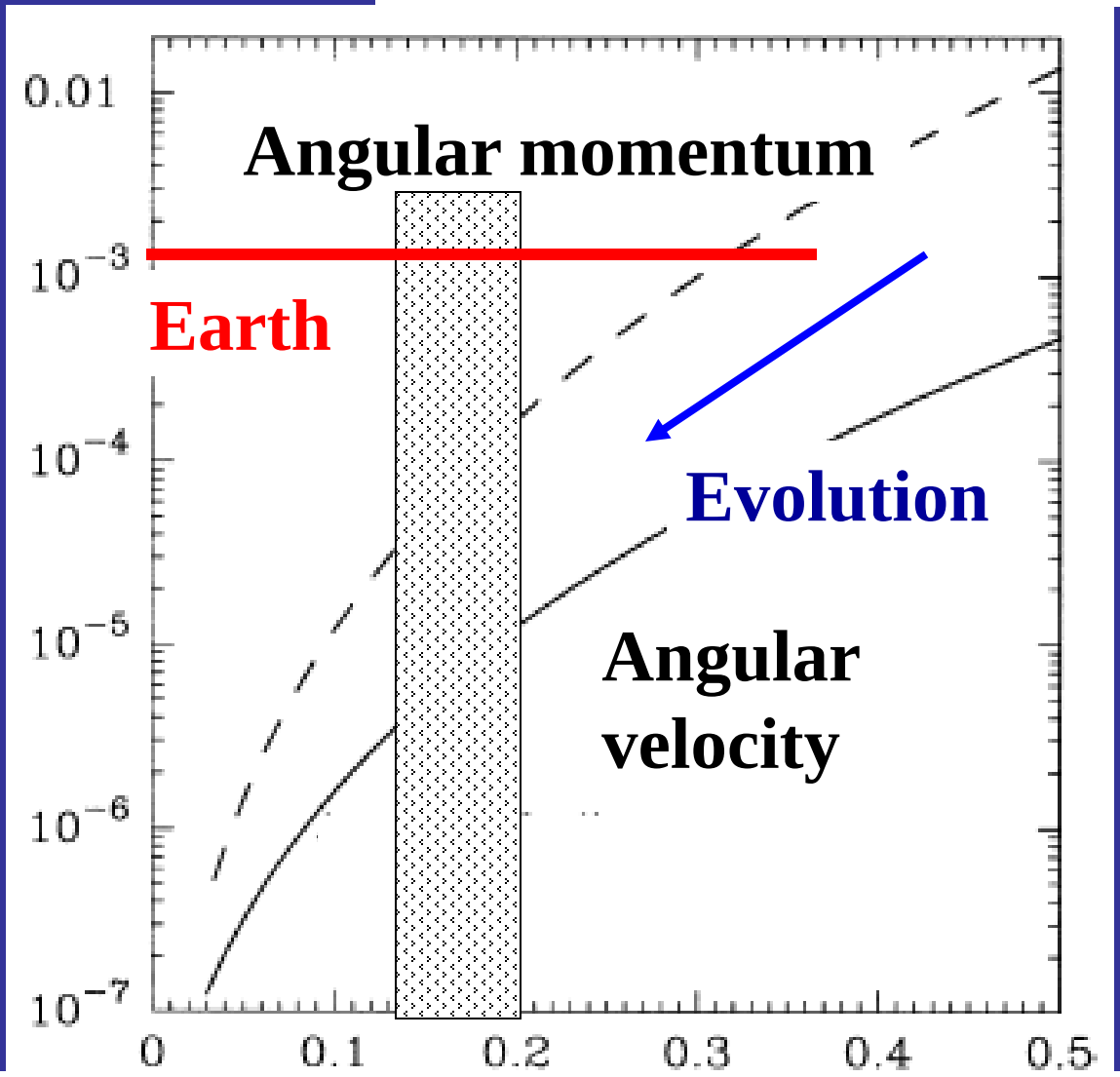
Pleasantness Review

The main open questions in stellar evolution are related to angular momentum (AM) evolution

Peculiar PNe ≡ Really spherical PNe

Even planets can do the job

(angular momentum, not energy)



IC 418: Elliptical planetary nebula

Envelope mass of the sun as it becomes giant (Mo)

Comments on magnetic (B)-fields:

(1) The Sun has a global dipole field, yet there are magnetic cloud ejected by the Sun.
These are locally-high-B clouds.

(2) B-fields work in launching jets. But I term this jet-shaping, not B-shaping.
B-shaping is for B in the AGB envelope.

Points to note:

(1) Binary shaping is not an alternative to magnetic field shaping, or shaping by jets. The stellar companion is *required* to allow such mechanisms to work.

(tomorrow I will present my view on jets)

Points to note:

(2) The common envelope (CE) might end with the companion merging/colliding with the AGB core (rapid rotation of CCSP—Poster 13).

➔ What effect does this have on the shaping?

➔ No one of you will find the companion!

- The importance of Companion-Core merge is in dispute. I tend to think it is frequent enough to study it in detail (e.g., when the companion is a WD, progenitors of some SN Ia).

Points to note:

(3) Energy and angular momentum

Companion outside the AGB envelope:

Energy from accretion onto the companion

➔ jets launched by the companion.

Angular momentum: (a) Tidal spin-up of AGB ➔ magnetic activity in AGB envelope.

(b) Mass loss from L2 ➔ equatorial mass loss

Common envelope: Spiraling-in ➔ envelope ejection mostly equatorial mass loss

Merger ➔ Huge amount of energy ➔ **?**

List of points to note:

(1) Binary shaping is not an alternative to magnetic field shaping, or shaping by jets. The companion is *required for these*.

(2) Merger might occur at the end of the CE.

(3) Companion outside AGB envelop: Jets and/or mass loss from L2 and/or tidal spin-up. Common envelope ejection mostly from equator.
Jets might be launched prior to the CE phase.

For gravitational energy to play a role in shaping,

the accretion of mass Δm on a star of mass M_* requires

Accretion energy ≈ Energy of nebula

$$\frac{G\Delta m\, M_*}{R_*} \approx \frac{1}{2} M_{neb} v^2 \approx M_{neb} \frac{G\, M_{AGB}}{R_{AGB}}.$$

If half the accreted energy goes to shape the nebula, then

$$\frac{\Delta m}{M_{neb}} \approx 0.05 \left(\frac{M_{AGB}}{5 M_*} \right) \left(\frac{R_*}{1 R_\odot} \right) \left(\frac{R_{AGB}}{1 AU} \right)^{-1}.$$

$\Rightarrow$ Less than 10% of nebular mass is needed to be accreted.

$\Rightarrow$ To have accretion + ejection $\Rightarrow$ Non-spherical flow $\Rightarrow$

accreion disk + jets.

Angular momentum sources

Large enough specific angular momentum of accreted mass is required for the formation of an accretion disk.

- **Mass transfer in a binary system.**

- **Fall back onto the post-AGB star. This can work much better in a post-CE evolution.**

➔ Maybe born-again PN have fall back material on their central star ?!?!

Asymmetry during the post-AGB phase:

- Most of the interactions listed above will also terminate the AGB, ➔➔ correlation between high mass loss rate at the end of the AGB and asymmetry.

- Many of the interaction lead to departure from axisymmetry.

Triple systems:

In many areas (from planets to WD-WD collision), people discussing the Kozai-Lidov mechanism, where a tertiary star orbit a close binary system and perturbs the inner binary system and drives it to collision (merger).

I encourage young people (younger than 55.17 yr) to start discussing such systems to explain some interesting PNe.

The universal bright end of the planetary nebulae luminosity function (**PNLF—Poster 30)**) is a big puzzle.

Binarity seems might be the solution . .somehow. . ., unless . . . .

there are star-formation episodes in elliptical galaxies later than what traditional methods teach us.