

ALTERNATIVE PLANET FORMATION SCENARIOS

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SUMMARY

When extra-solar giant planets were first discovered, I did not believe that they were planets formed in the circumstellar disk, but that they were formed somehow from excess infall ejected from the protostar equator. They orbited near the star because they were formed near the star. That mechanism does not conserve angular momentum.

I have worked out a process that conserves angular momentum by projecting protostellar-, instead of infall-, material outward at the equator to balance infall during an FU Orionis event. Excess infall blocks convective downflow but not convective upflow. Stellar material inside the dipole torus that connects the star to the disk flows outward carrying angular momentum to make an oblate envelope that extends to 10 or 15 stellar radii and looks like a supergiant. When the infall drops back to normal levels, the oblate envelope is slowly evaporated by strong UV and X radiation from the protostar. Some matter flows or blows into the inner wall of the disk.

Humans like slow evolution in all realms, uniformitarianism, but Nature prefers catastrophes, catastrophism. Events happen in the (cosmic) blink of an eye.

(more)

SUMMARY continued

Magnetically-driven planet formation:

If the dipole field pulls out of the disk during an FU Ori event, the field wraps and tangles around the extended envelope. Reconnections compress the trapped plasma into an unstable magnetic torus orbiting the star (a tokamak). The torus reconnects into self gravitating magnetic spheroids (spheromaks) that become planetary cores. The reconnection radiation and winds heat and compress the disk causing agglomeration out to the snow line. The cores grow by collecting material infalling toward the star. They are in unstable orbits that can change radically or they can be ejected from the system. A core in a highly eccentric orbit that goes far into the disk can become very massive because it sweeps up material over a wide range of radii.

Radiatively-driven planet formation:

If the dipole field pulls out of the disk when the protostar is not in an FU Ori phase, the field wraps and tangles but there is no large reservoir of plasma to compress. The reconnections fill 75% of the surface of the star. The reconnection radiation and winds heat and compress the disk causing agglomeration out to the snow line. The agglomerated material rapidly forms planetesimals and inner planets.

Classical planet formation:

Outer disks form planets by slow uniformitarian processes.

FORMATION FACTOIDS

CONSERVATION OF ANGULAR MOMENTUM

CONVECTION

UNIFORMITARIANISM

FU ORIONIS EVENTS

MAGNETICALLY-DRIVEN PLANET FORMATION

RADIATIONALLY-DRIVEN PLANET FORMATION

CLASSICAL PLANET FORMATION

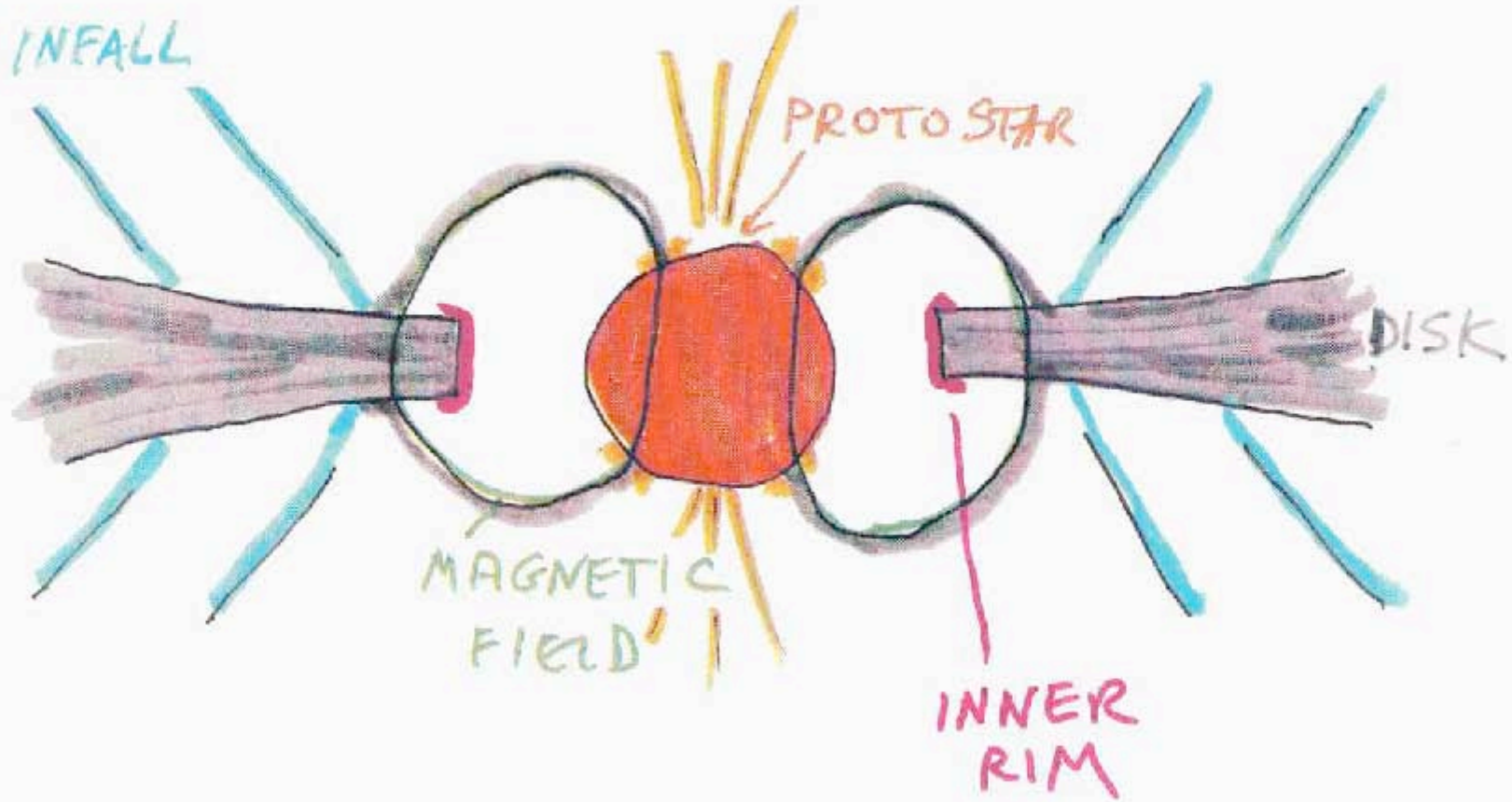
STAR FORMATION AND PLANET FORMATION FACTOIDS

**LYNNE HILLENBRAND COMMENTED AT
“STROMFEST 2008” THAT AS A CHILD SHE SAW A
CARTOON OF PLANET FORMATION IN A DISK AND
SINCE THEN SHE HAS BEEN TRYING TO MAKE IT
COME TRUE.**

**STEVE STROM REVIEWED WHOLE PICTURE
LUNCH TALK 19 APRIL 2010**

**SEAN ANDREWS REVIEWED WHOLE PICTURE
COLLOQUIUM 20 MAY 2010**

**BOTH EMPHASIZED FORMING PLANETS IN THE DISK
AND MINIMIZED THE ROLE OF THE DIPOLE FIELD
EXCEPT AS A CONVEYOR BELT TO SLOWLY
CHANNEL INFALL TO THE PROTOSTAR. HERE
IS MY VERSION OF LEE HARTMANN'S STANDARD
CARTOON.**



**A PROTOSTAR EXPERIENCES 10 TO 20 PREPARTUM
FU ORIONIS EVENTS IN WHICH INFALL INCREASES
AND OVERWHELMS THE DISK FLOW PATTERN.**

**THE SYSTEM BRIGHTENS BY 4 TO 7 MAG IN 1 TO 10
YEARS AND LOOKS LIKE A SUPERGIANT.
IT DECAYS OVER MANY DECADES,
PERHAPS CENTURIES.**

DEFINE THE BIRTH OF A LATE-TYPE STAR AS THE PULLOUT OF THE DIPOLE FIELD FROM THE DISK. THE PROTOSTAR AND THE DISK DECOUPLE.

WHAT HAPPENS TO THE DIPOLE FIELD?

THE BIRTHRATE FOR FGK STARS IN OUR GALAXY IS BETWEEN 1/DECADE AND 1/CENTURY.

**IT IS A ONCE IN A LIFETIME EXPERIENCE.
IT HAS, PROBABLY, NEVER BEEN OBSERVED.**

**THE FORMATION OF A STAR WITH WITH
EXTRA-SOLAR GIANT PLANETS HAPPENS ONCE
IN A MILLENNIUM.**

CONSERVATION OF ANGULAR MOMENTUM

SHU (1982)

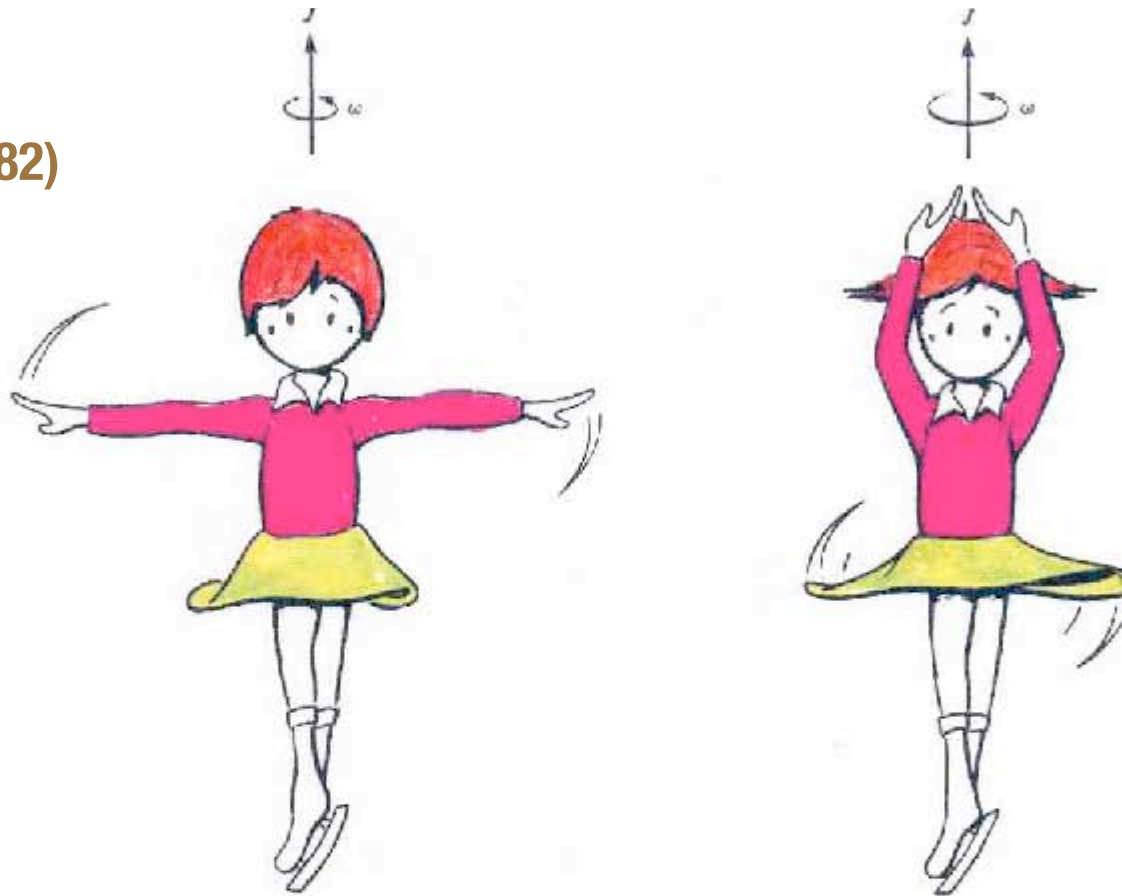


Figure 3.23. The spin-up of an ice-skater. When the twirling skater has her arms out, her moment of inertia I is large and her rate of spin ω is small for a given angular momentum $J = I\omega$. When she pulls her arms in, her moment of inertia I decreases, and the conservation of angular momentum implies that her rate of spin ω increases.

**HOWEVER, THIS CAPTION DOES NOT EXPLAIN
THE FIGURE.**

MASSES:

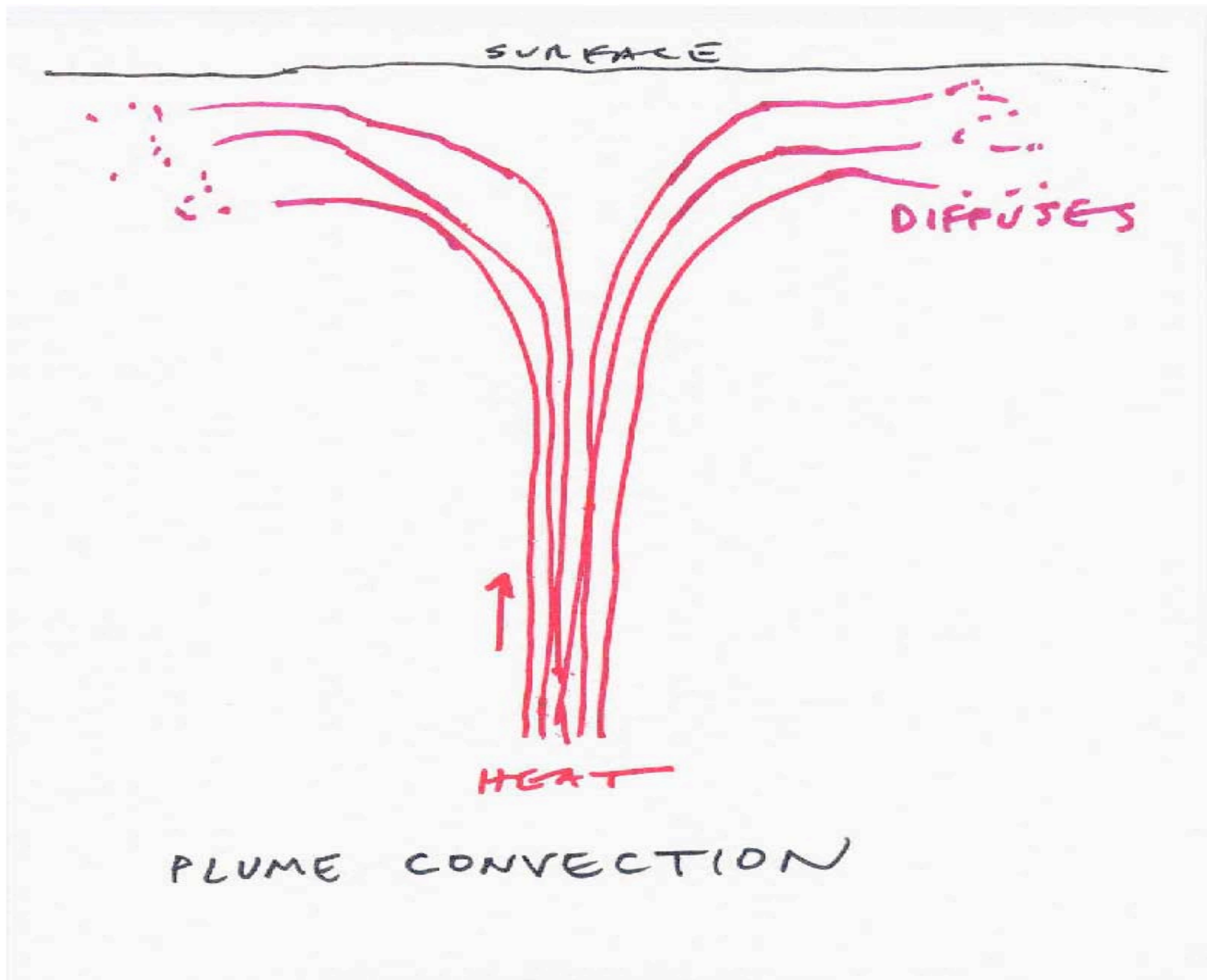
SKATER 50 KG, HAIR 50G, SKIRT 500G

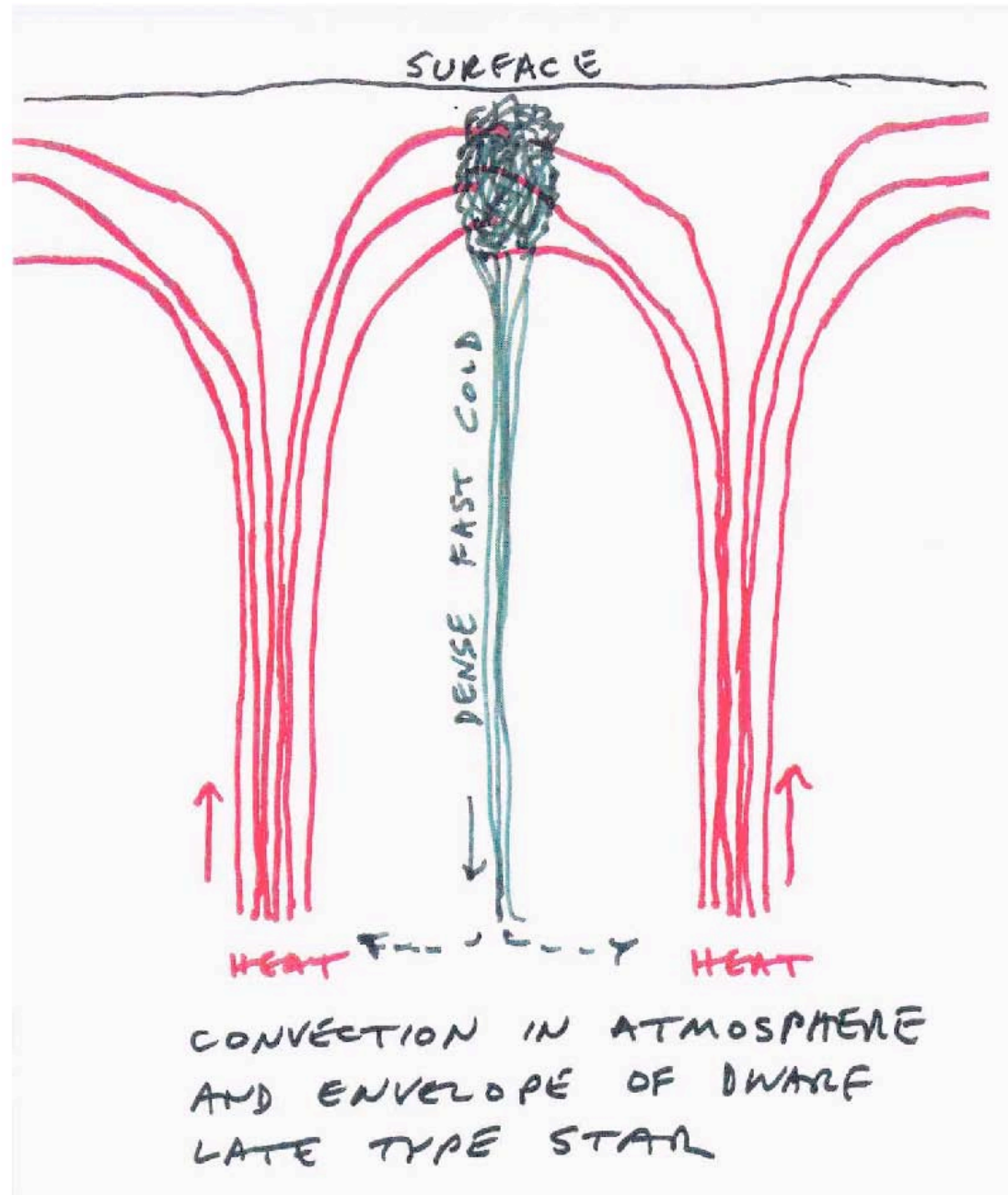
**WHILE THE ARMS ARE MOVING INWARD
1/1000 OF MASS MOVES OUTWARD IN HAIR
1/100 OF THE MASS MOVES OUTWARD IN SKIRT**

ADD TO CAPTION:

**A FLEXIBLE ROTATING BODY TRIES TO
MINIMIZE ITS SPINUP BY MAXIMIZING ITS
MOMENT OF INERTIA.**

CONVECTION



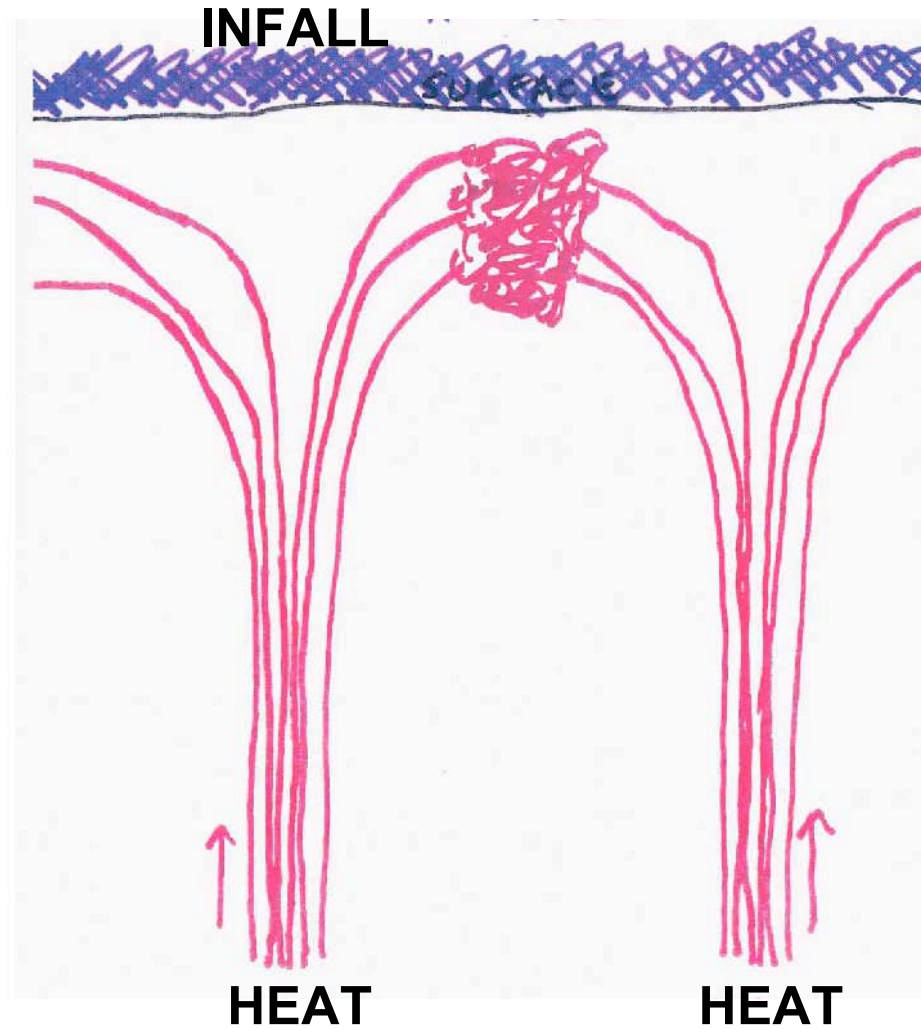


**EXCESS INFALL
BLOCKS CONVECTION.**

**RISING HOT MATERIAL
CANNOT RADIATE AT THE
SURFACE TO COOL.**

**THERE IS NO FALLING
COOL MATERIAL.**

THE STAR PUFFS UP.



UNIFORMITARIANISM IN GEOLOGY

100 YEARS AGO GEOLOGISTS WERE UNIFORMITARIANS. THERE WERE SLOW UPLIFTS, SLOW EROSION, SLOW LAYERING, AND THEN THE DEPOSITS WERE UPLIFTED AND THE CYCLE WAS REPEATED.

ALL IMPORTANT CONSTRUCTION TOOK A LONG TIME AT MM/YEAR.

IN 1915 WEGENER PROPOSED CONTINENTAL DRIFT THAT REQUIRED MOTIONS OF CM/YEAR AND UNKNOWN PHYSICS.

THE UNIFORMITARIANS RIDICULED THE THEORY, SUPPRESSED RESEARCH ON IT, AND PREVENTED PROGRESS FOR MORE THAN A GENERATION.

**THE UNIFORMITARIANS ALSO SUPPRESSED
CATASTROPHIC EXPLANATIONS FOR EVENTS,
EVEN VIOLATING COMMON SENSE AND
EVERYDAY EXPERIENCE.**

UNIFORMITARIANISM IN BIOLOGY

BIOLOGISTS USED TO THINK THAT EVOLUTION OCCURRED AT THE MUTATION RATE, RANDOMLY, SLOWLY, AND UNIFORMLY.

BUT, ACTUALLY, 90% OF EVOLUTION TAKES PLACE IN 10% OF THE TIME, “PUNCTUATED EVOLUTION”.

EVOLUTION IS DRIVEN BY CATASTROPHES THAT PRODUCE LIFE OR DEATH SITUATIONS. SPECIES MUST EVOLVE OR DIE OUT WHEN THEIR ECOLOGICAL NICHE CHANGES OR DISAPPEARS.

UNIFORMITARIANISM IN ASTRONOMY

**CURRENT THEORIES OF PLANET FORMATION AND
MIGRATION ARE UNIFORMITARIAN.**

**HUMANS HAVE BEEN MAKING SOPHISTICATED
OBSERVATIONS FOR LESS THAN A LIFETIME.**

**THEY GENERALIZE OBSERVED “CALM” PERIODS
INTO THE PAST AND INTO THE FUTURE.**

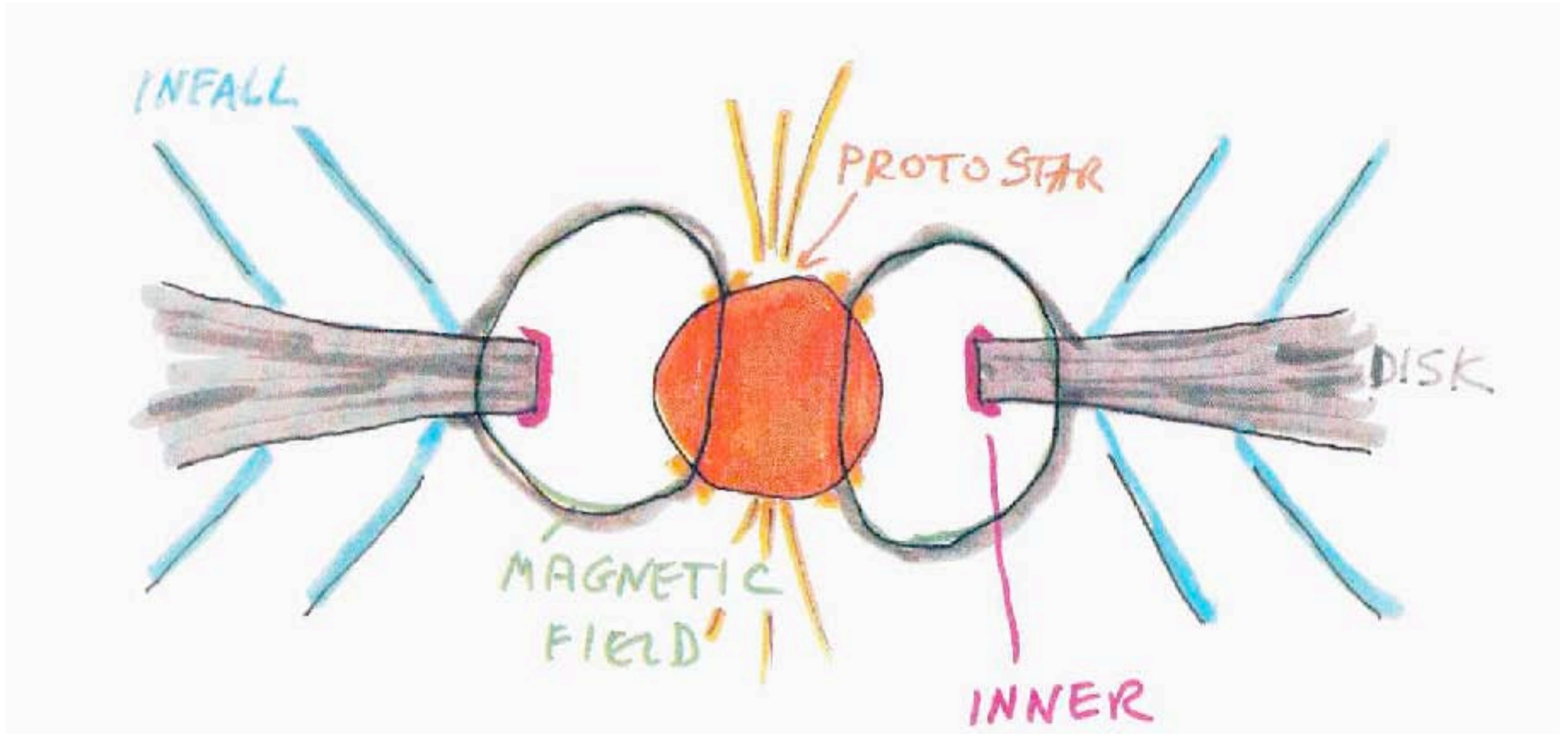
NATURE DOES NOT BELIEVE IN SLOW EVOLUTION.

CATASTROPHES ARE BUILT INTO SLOWLY EVOLVING SYSTEMS OR COME FROM OUTSIDE.

LONG BORING INTERVALS ARE ALWAYS PUNCTUATED BY EXCITING CATASTROPHES.

FOR EXAMPLE, WE DO NOT UNDERSTAND THE MAGNETIC FIELD IN THE SUN. AT ANY TIME THERE COULD BE A FLARE 1000 TIMES STRONGER THAN HAS EVER BEEN OBSERVED.

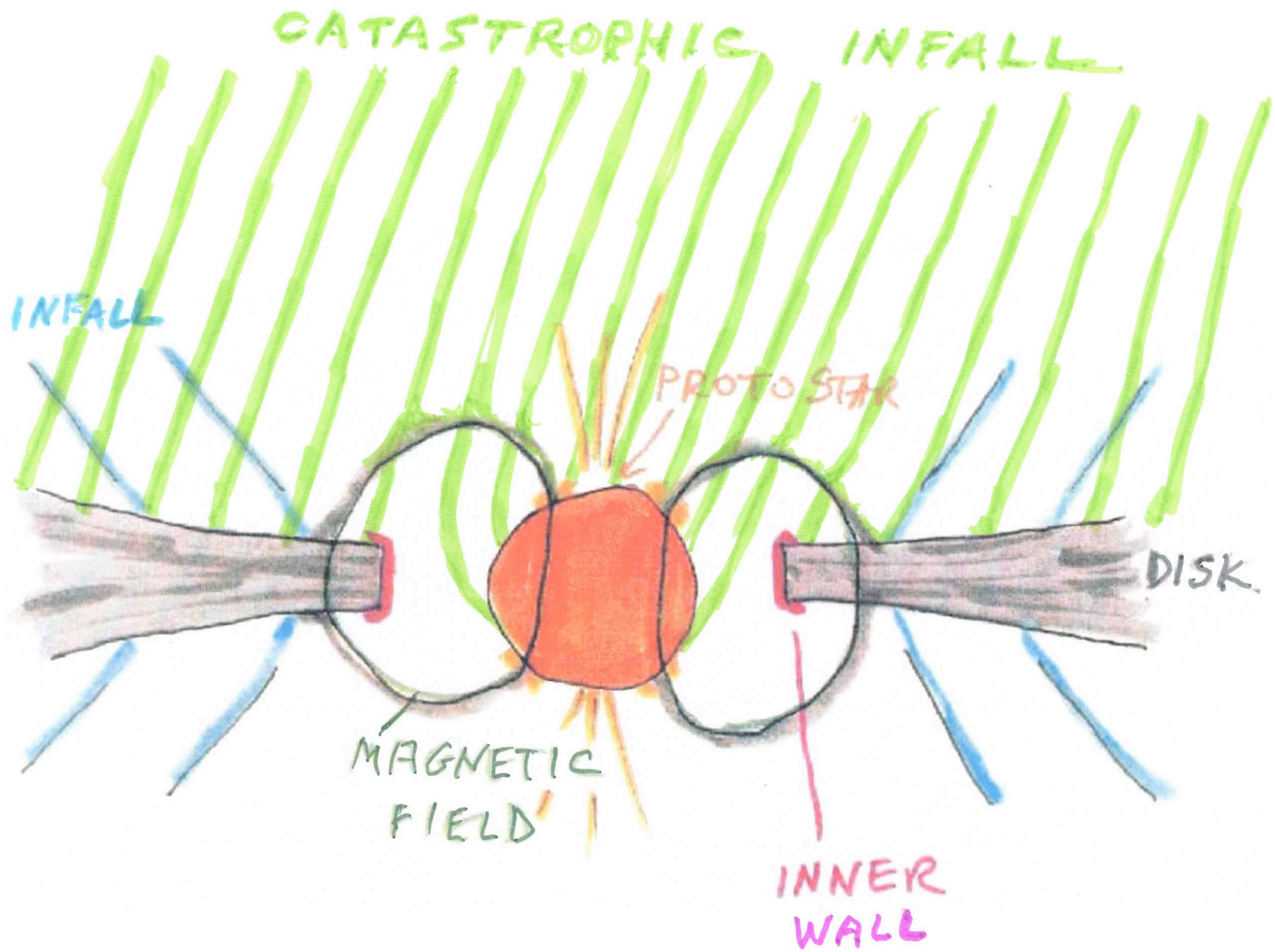
FU ORIONIS EVENTS



START WITH THE STANDARD PROTOSTAR ASSEMBLY MACHINERY ASSUMING ISOLATED EVOLUTION.

BUT STARS ARE FORMED IN CLUSTERS.

**IF THERE IS A COLLISION WITH A DENSE CLOUD,
OR WITH A STAR, OR IF AN OB STAR FORMS NEARBY,
OR IF THERE IS A SUPERNOVA, THERE CAN BE A
PULSE OF ENHANCED DENSITY.**



THE COMPLEX MACHINERY IS OVERWHELMED BY THE EXCESS INFALL. THE DISK BECOMES TURBULENT AND PUFFS UP (HARTMANN-KENYON). IT HEATS TO ABOUT 3000K.

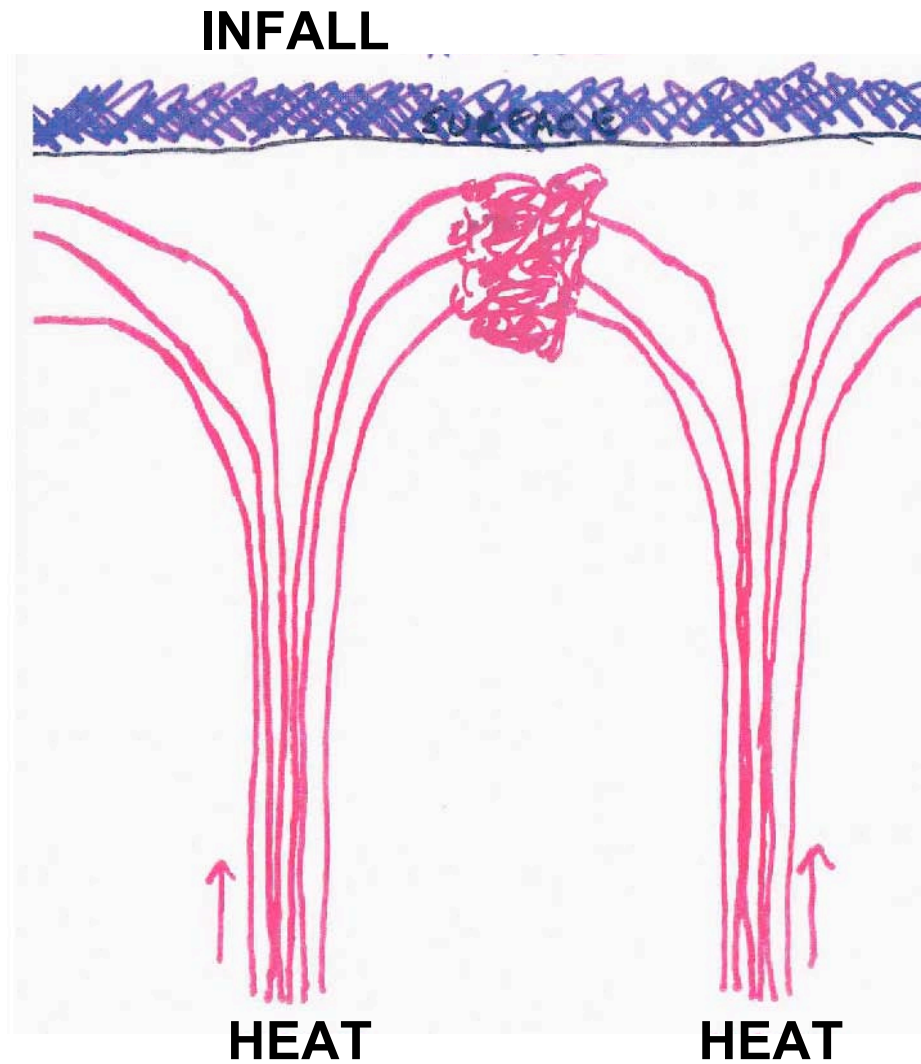
THE DIPOLE FIELD CANNOT CONTROL THE INFALL TO THE STAR. INFALL BOMBARDS THE STAR AND SPREADS OVER THE SURFACE.

**EXCESS INFALL
BLOCKS CONVECTION.**

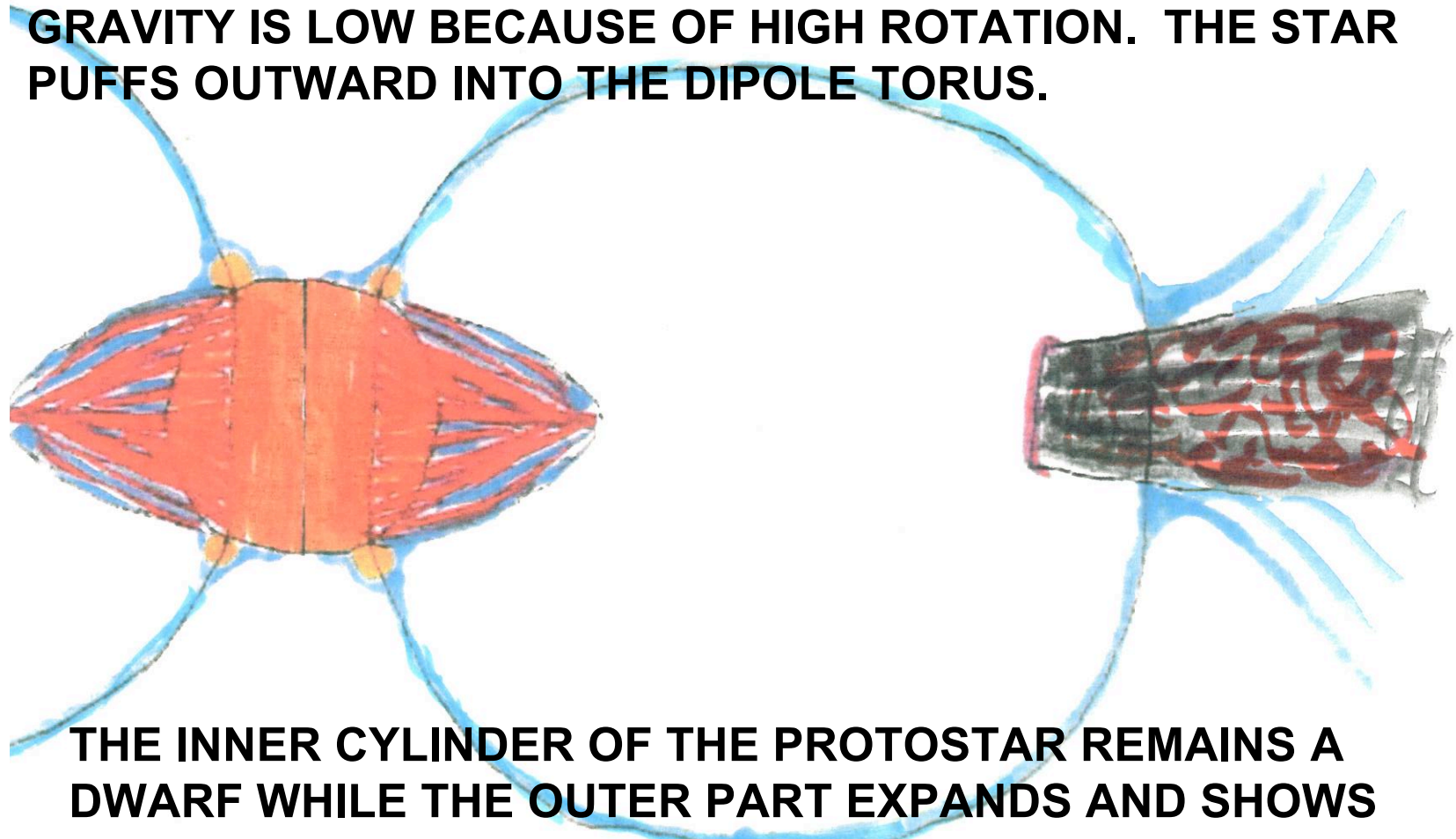
**RISING HOT MATERIAL
CANNOT RADIATE AT THE
SURFACE TO COOL.**

**THERE IS NO FALLING
COOL MATERIAL.**

THE STAR PUFFS UP.

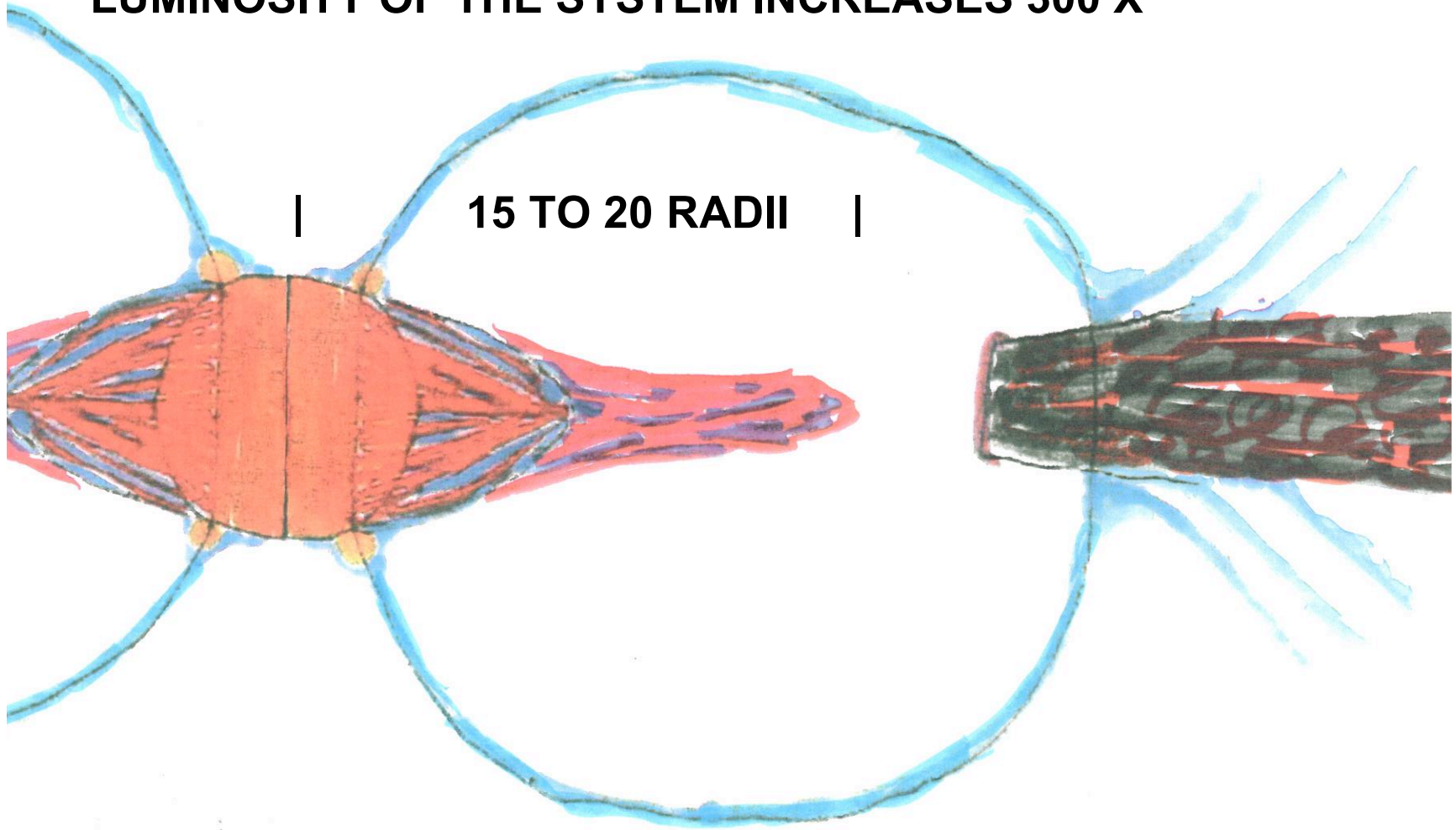


ENVELOPE AND ATMOSPHERE MATERIAL FLOW OUTWARD. SOME INFALL IS DRAGGED ALONG. AT EQUATOR EFFECTIVE GRAVITY IS LOW BECAUSE OF HIGH ROTATION. THE STAR PUFFS OUTWARD INTO THE DIPOLE TORUS.



THE INNER CYLINDER OF THE PROTOSTAR REMAINS A DWARF WHILE THE OUTER PART EXPANDS AND SHOWS A G0 SUPERGIANT SPECTRUM (HERBIG, PETROV, AND DUEMMLER 2003).

LUMINOSITY OF THE SYSTEM INCREASES 300 X



AFTER 1 TO 10 YEARS THE INFALL SURGE PASSES.

THE EXTENDED ATMOSPHERE IS EVAPORATED BY THE STRONG UV AND X RADIATION PRODUCED AT HIGH LATITUDES BY THE NORMAL INFALL. SOME FLOWS OR BLOWS TOWARD THE INNER WALL OF THE DISK.

EVENTUALLY EVERYTHING RETURNS TO UNIFORMITARIAN NORMALCY AS IF NOTHING HAD HAPPENED.

MAGNETICALLY-DRIVEN PLANET FORMATION

FREDERICK PONT LUNCH TALK 20 NOV 2006

PONT SAID, IN JEST, THAT EXOPLANETS SEEM TO BE DIFFERENT FROM OUR PLANETS AND THAT OUR PLANETS WOULD TURN OUT TO BE WEIRD.

THAT IS WHY I DECIDED TO GIVE THIS TALK.

EXOPLANETS (AS OF 2006)

THE ONLY CONNECTION BETWEEN PLANETS AND EXOPLANETS IS THAT THEY BOTH ORBIT STARS.

IN GENERAL:

EXOPLANETS ORBIT CLOSE TO THE STAR

EXOPLANETS HAVE MORE ECCENTRIC ORBITS

EXOPLANETS ARE MORE MASSIVE

EXOPLANETS ARE LESS DENSE

NOT A SINGLE EXOPLANET CAN BE MATCHED TO A PLANET.

ANYONE WITH COMMON SENSE WOULD THINK THAT THEY ARE TWO SEPARATE CLASSES OF OBJECT.

"I think we're missing something fundamental about the interior structure or atmospheres of hot Jupiters."

--- Josh Winn

WHAT ARE THESE NEW OBJECTS?

PLANETS ARE WASTE DUMPS FROM THE DISK.

**MAYBE THEY ARE WASTE DUMPS, BUT NOT
FROM THE DISK.**

WASTE INFALL?

WASTE PROTOSTELLAR MATERIAL?

WASTE ANGULAR MOMENTUM?

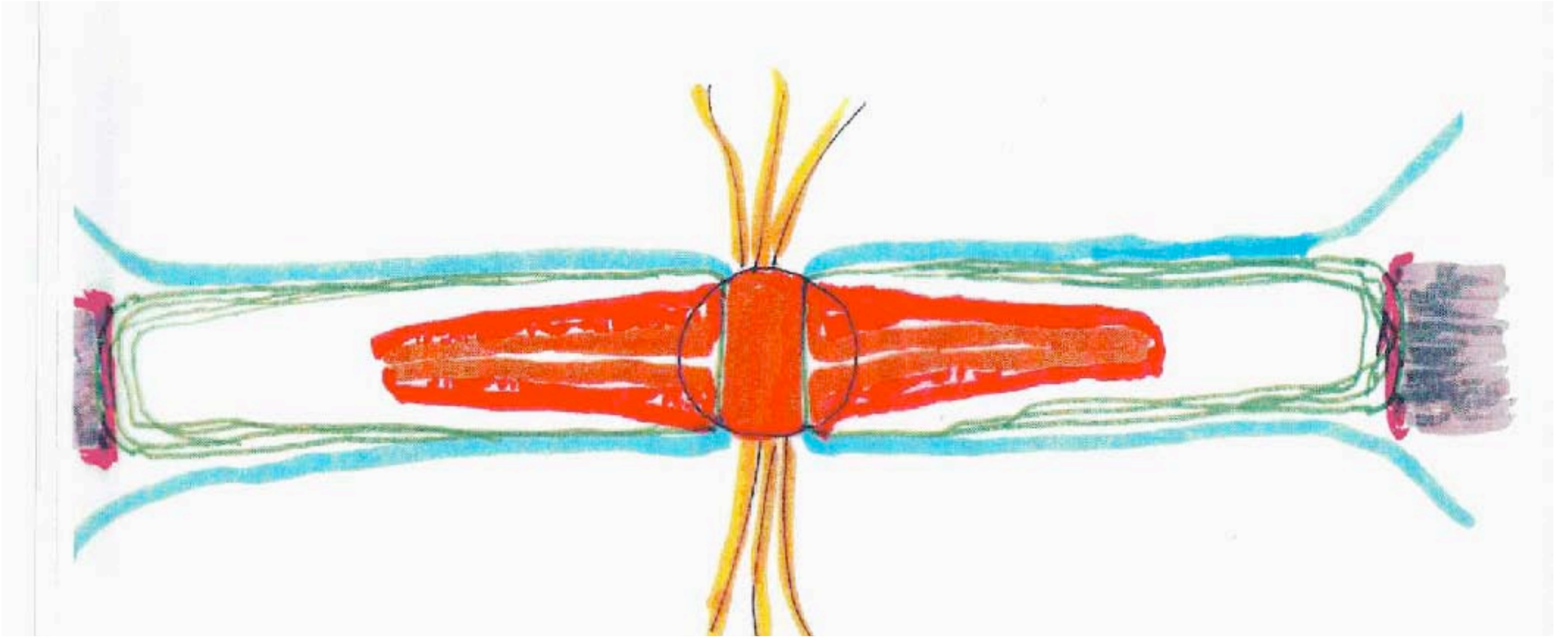
WASTE MAGNETIC FIELD?

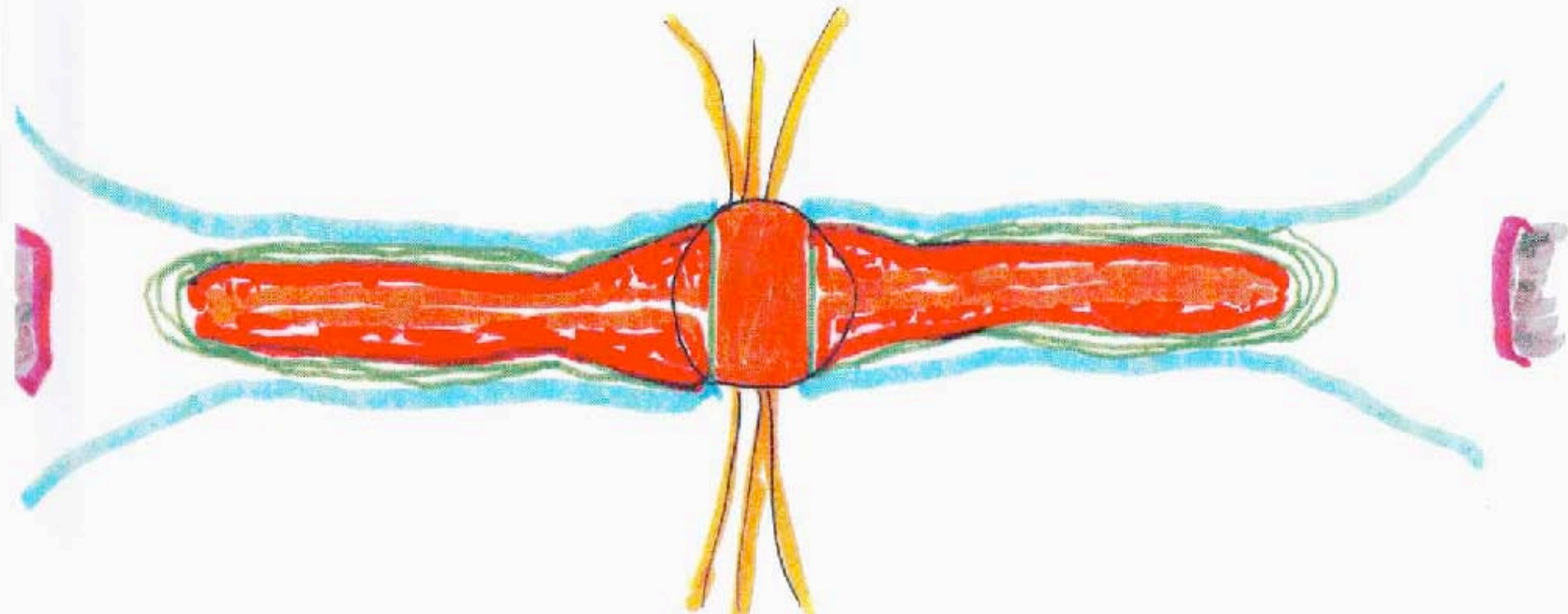
**SINCE THE OBJECTS ARE CLOSE TO THE
STAR, THEY ARE PROBABLY ALL FOUR AND
FORM BEFORE PLANETS.**

DURING AN FU ORIONIS EVENT THE MAGNETIC COUPLING BETWEEN THE PROTOSTAR AND THE DISK IS STRESSED.

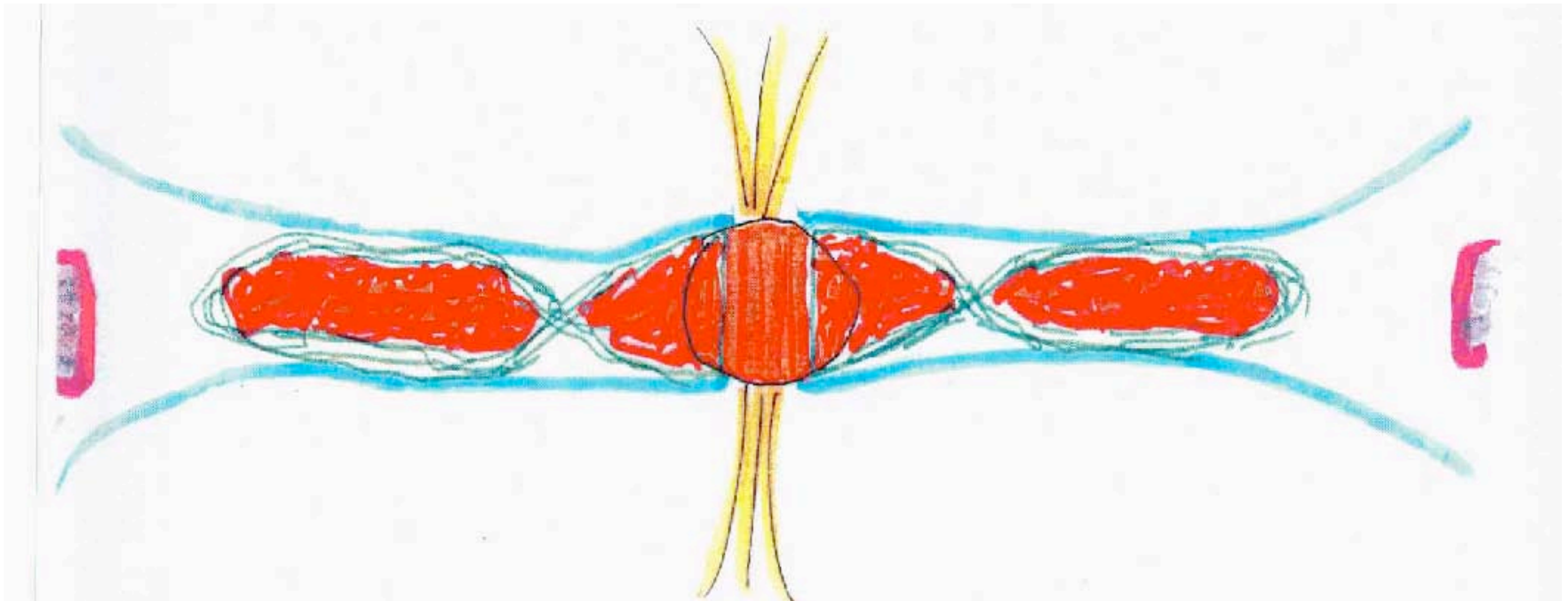
IF THE COUPLING BECOMES UNSTABLE THE FIELD LINES WRAP AND PULL OUT OF THE DISK.

THIS IS A RANDOM EVENT INFLUENCED BY THE AMOUNT OF INFALL. IF IT DOES NOT HAPPEN DURING ONE OF THE FU ORI EVENTS, THE STAR EVENTUALLY PRODUCES NORMAL PLANETS IN THE DISK.





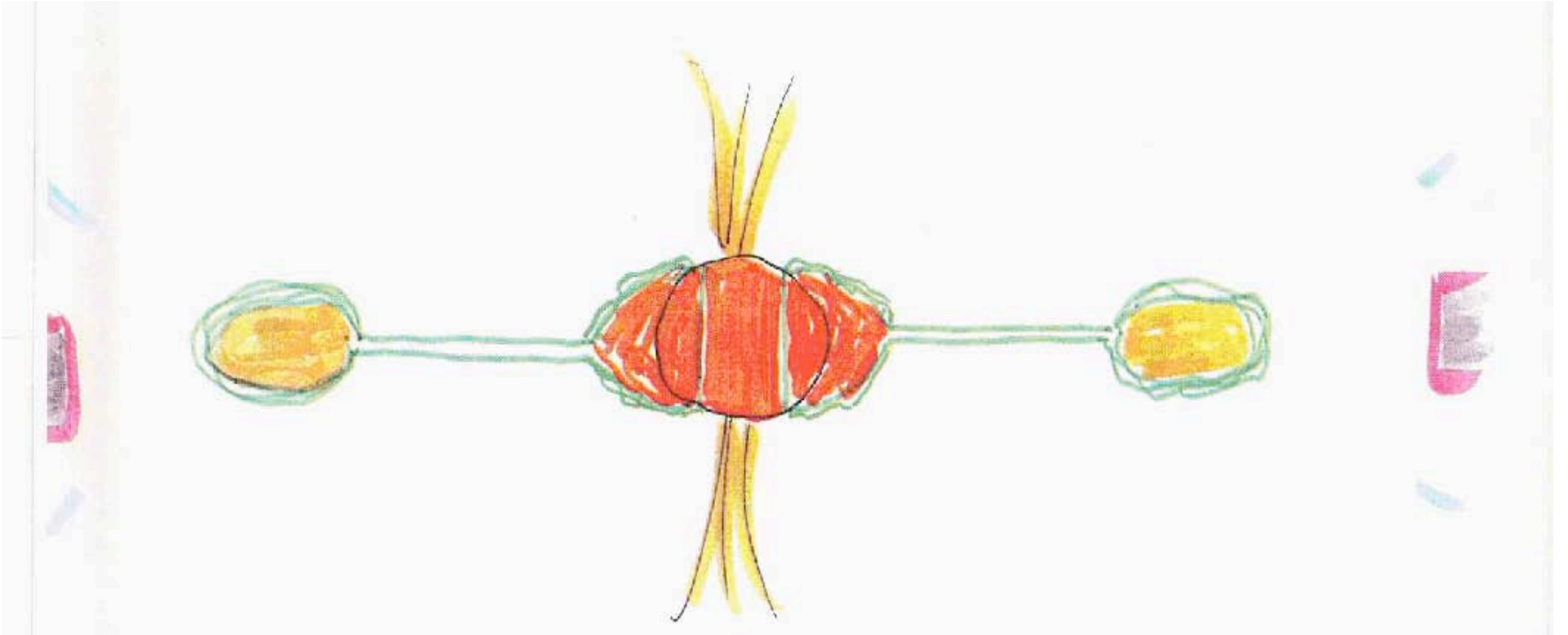
THE FIELD LINES PULL OUT OF THE DISK AND FORM AN UNSTABLE TORUS FILLED WITH DENSE GAS.

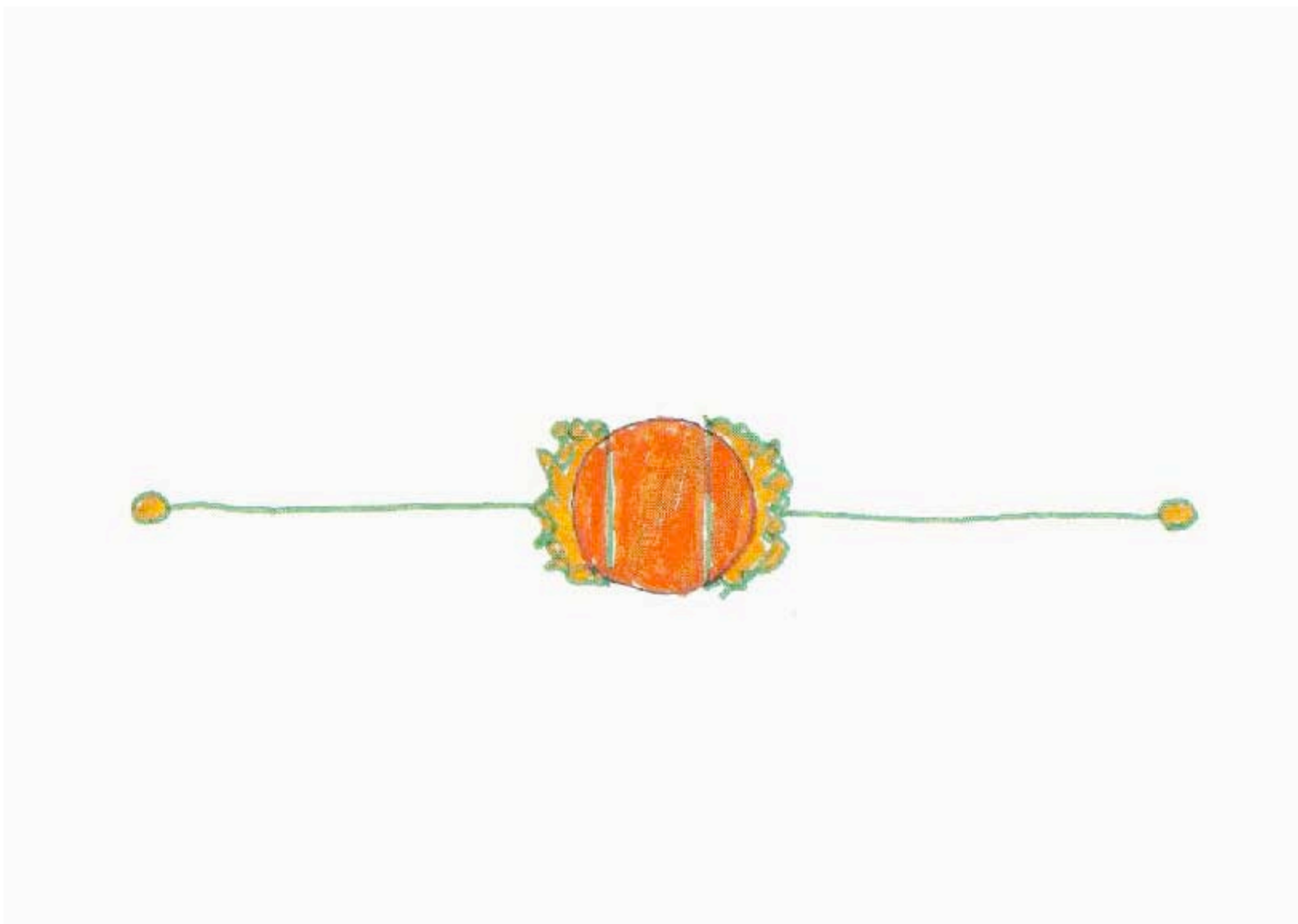


WHEN A THIN SPOT FORMS FROM OSCILLATIONS OR WHATEVER, THE MAGNETIC FIELD LINES CAN RECONNECT.

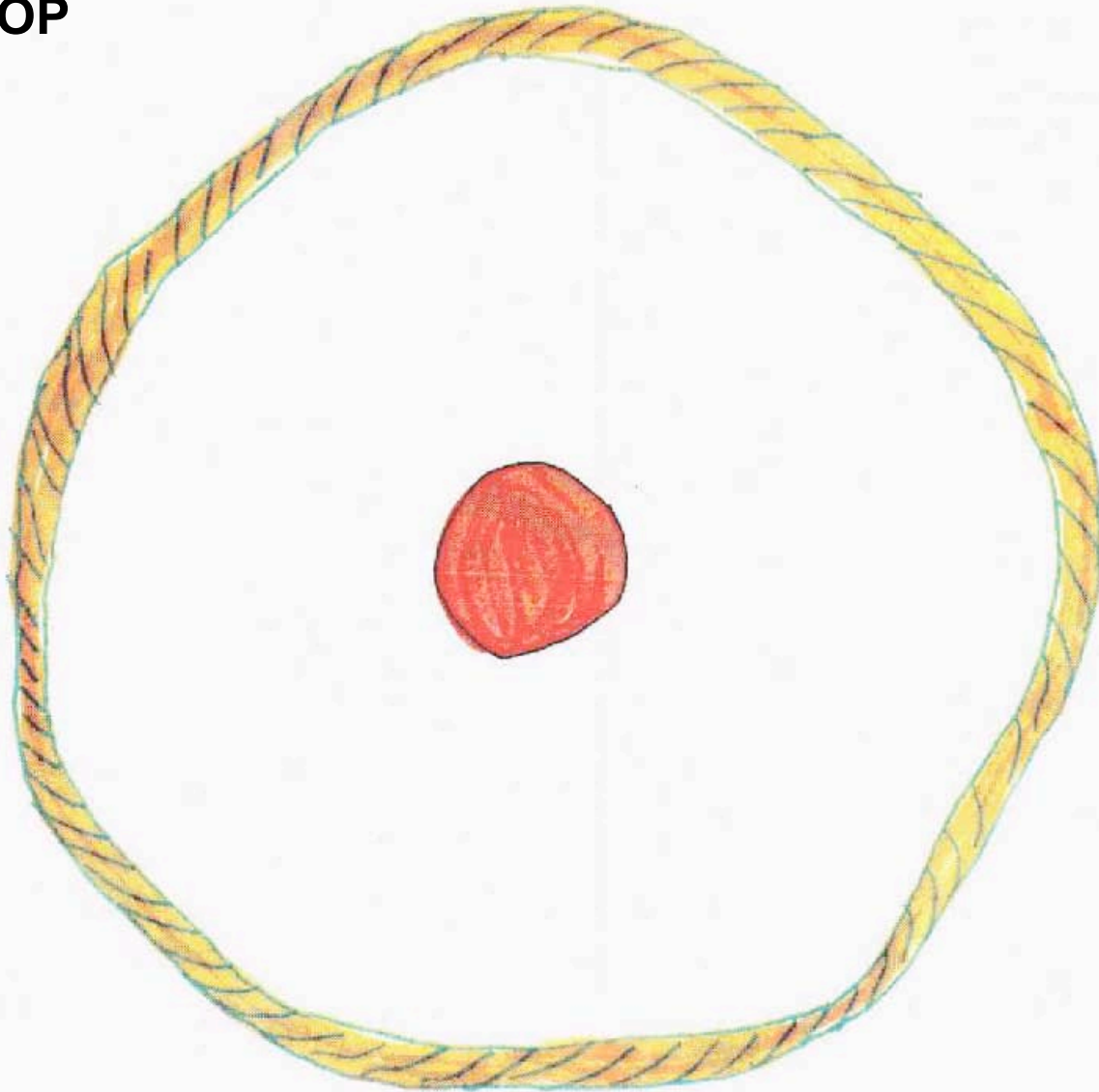
PART OF THE FIELD FALLS BACK TOWARD THE STAR TO MAKE A SUPER-CME.

PART FORMS A TOROIDAL RING, A TOKAMAK.





TOP



THE RING IS HOT AND DENSE AND HAS A LARGE SURFACE AREA.

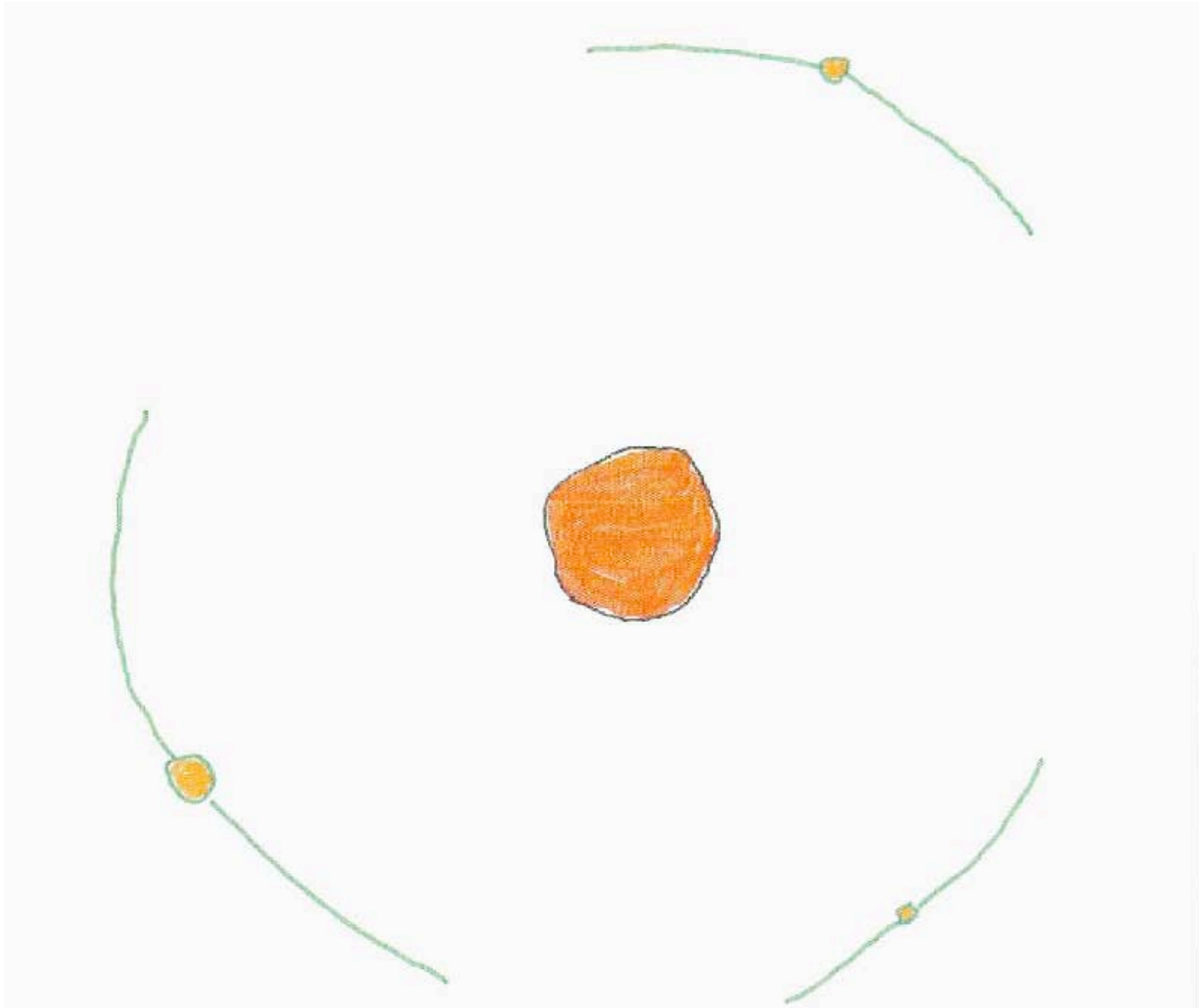
THE RING AND SUPER-CME ARE VERY LUMINOUS. THE SUPER-CME PRODUCES STRONG PARTICLE OUTBURSTS.

RADIATION AND WIND BLOW AWAY ALL INFALL OUT TO ~ SNOW LINE AND PUSH INWARD ON BOTH SURFACES OF THE DISK, VAPORIZING THE SURFACE, HEATING THE DUST, DRIVING IT INWARD, AND AGGLOMERATING IT.

RADIATION FROM THE RING PUSHES OUT THE INNER DISK AS WELL.

**THE RING IS
UNSTABLE AND
RECONNECTS IN SECTIONS**



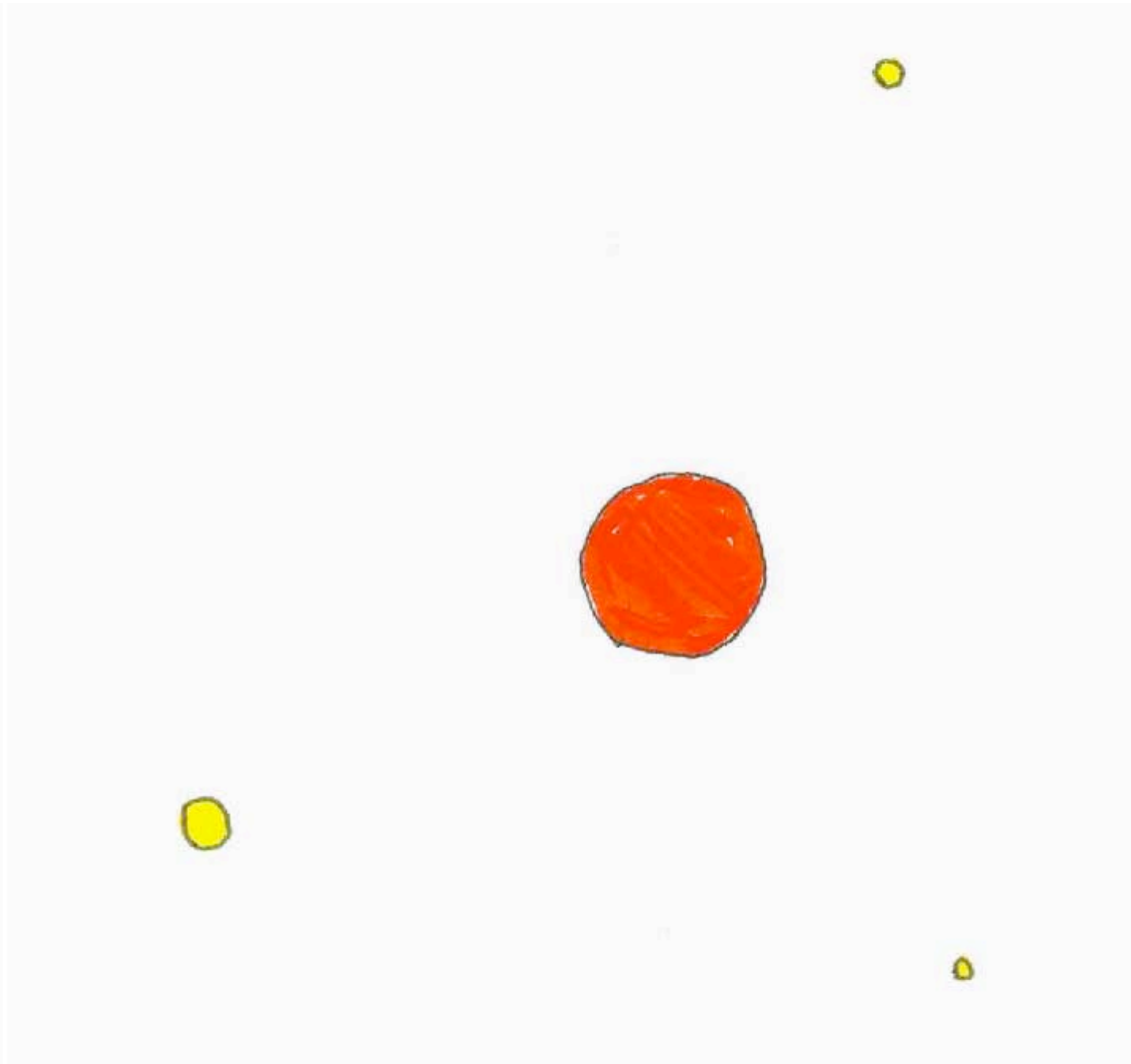


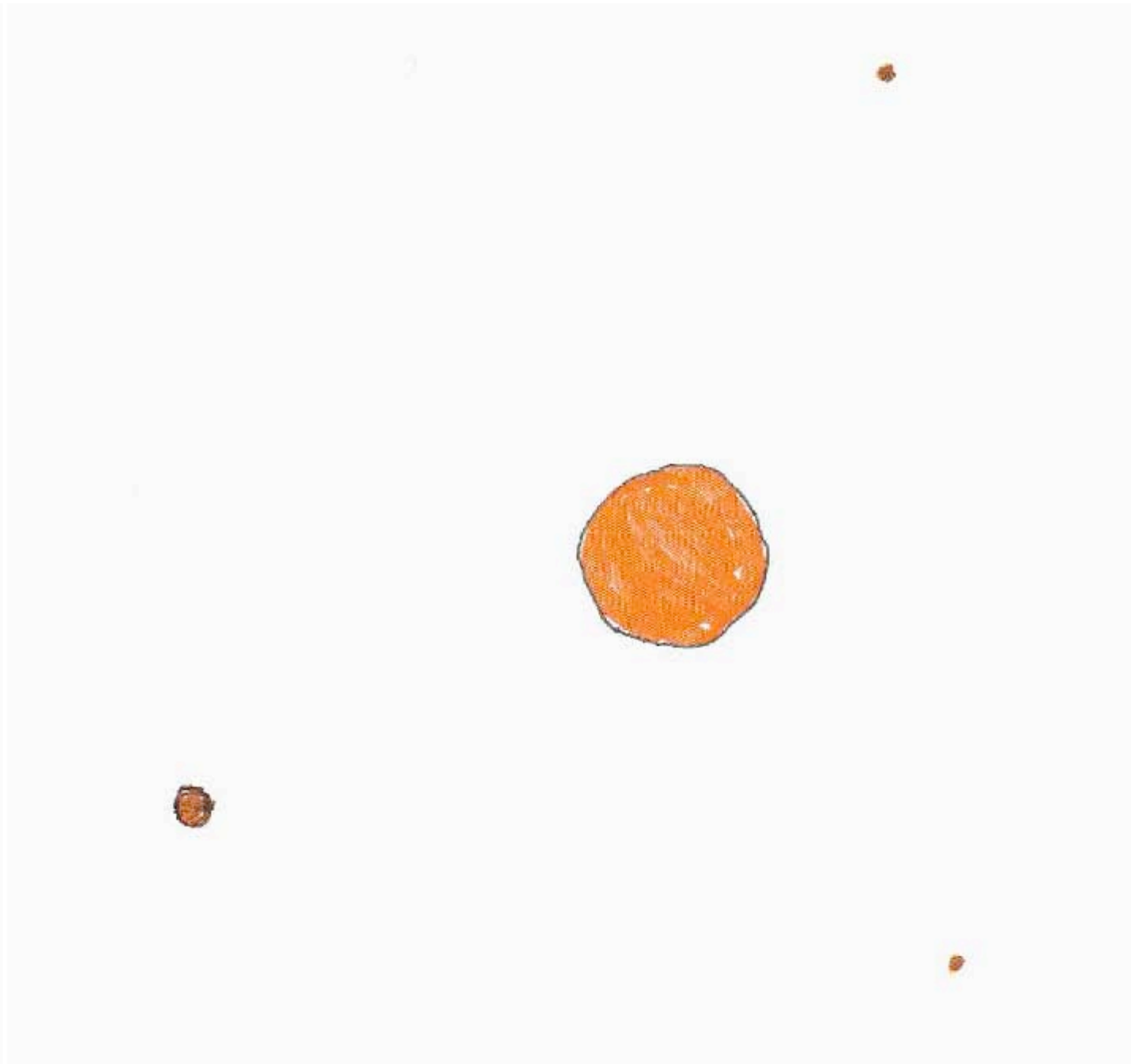
HOT DENSE PLASMA BLOBS ARE ENCAPSULATED IN SPHERICAL MAGNETIC BOTTLES, SPHEROMAKS. IONS CANNOT ESCAPE BUT RADIATION CAN.

MAGNETIC BOTTLES SHIELD THE CORES FROM ABLATION BY THE STELLAR WIND AND EVAPORATION BY RADIATION.

THE NUMBER OF SPHEROMAKS IS RANDOM.

THE BLOBS ARE LARGE ENOUGH AND DENSE ENOUGH TO BE GRAVITATIONALLY BOUND WHEN THEY COOL, PLANETARY CORES. THE CORES GROW BY ACCRETING MATERIAL INFALLING TOWARD THE PROTOSTAR.





**SOME OF THE SPHEROMAK CORES ARE EJECTED
FROM THE SYSTEM,
OR INTO ECCENTRIC ECLIPTIC ORBITS,
OR INTO OUT-OF-ECLIPTIC ORBITS,
OR FALL INTO THE STAR,
OR EVAPORATE,
OR MERGE,
OR CONTINUE TO ORBIT NEAR THE STAR.**

THE NUMBER THAT SURVIVE IS RANDOM.

PLANETS WITH SPHEROMAK CORES ARE A GENERAL PHENOMENON OF POP I UNARY LATE-TYPE STAR FORMATION.

OCCURENCE IS MORE THAN 10 %.

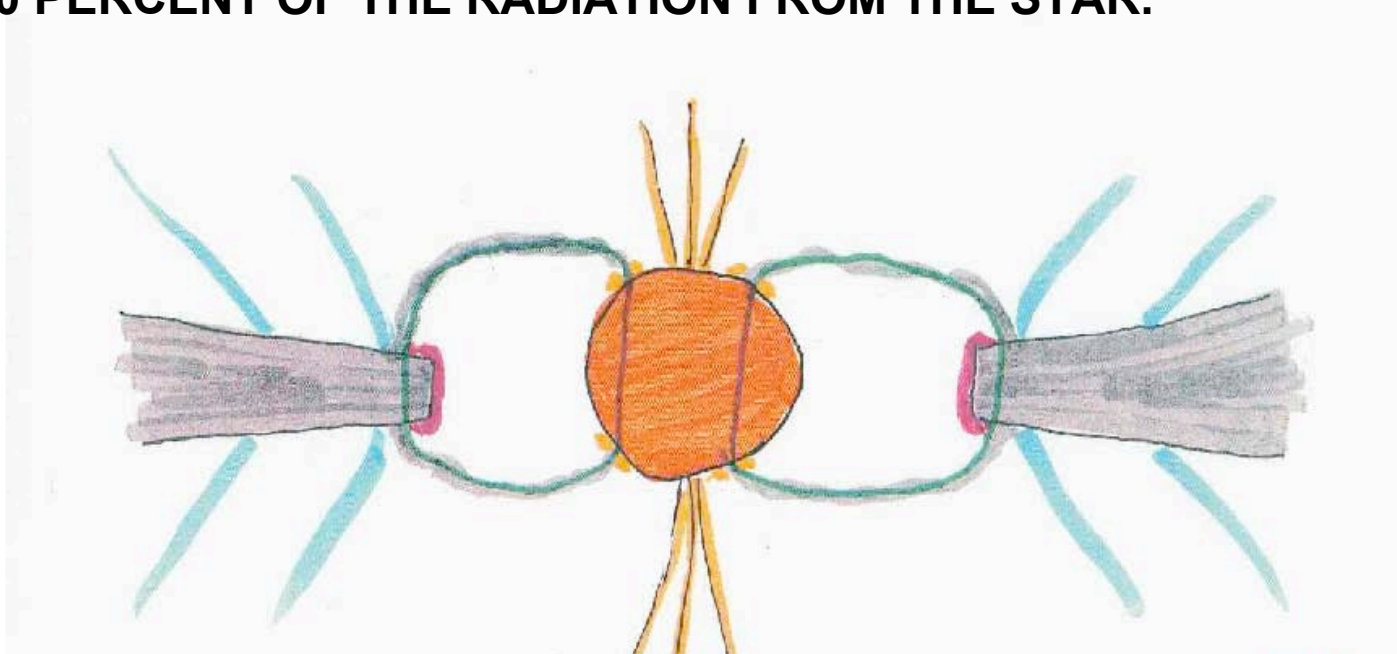
THEY GROW BY INTERCEPTING INFALL HEADED TOWARD THE STAR: GAS, PLANETESIMALS, COMETS, ASTEROIDS.

IN ECCENTRIC ORBITS THEY COLLECT GAS, DUST, ICE, EVEN PLANETS, AS THEY PASS THROUGH THE DISK. THEY CAN GROW QUITE LARGE.

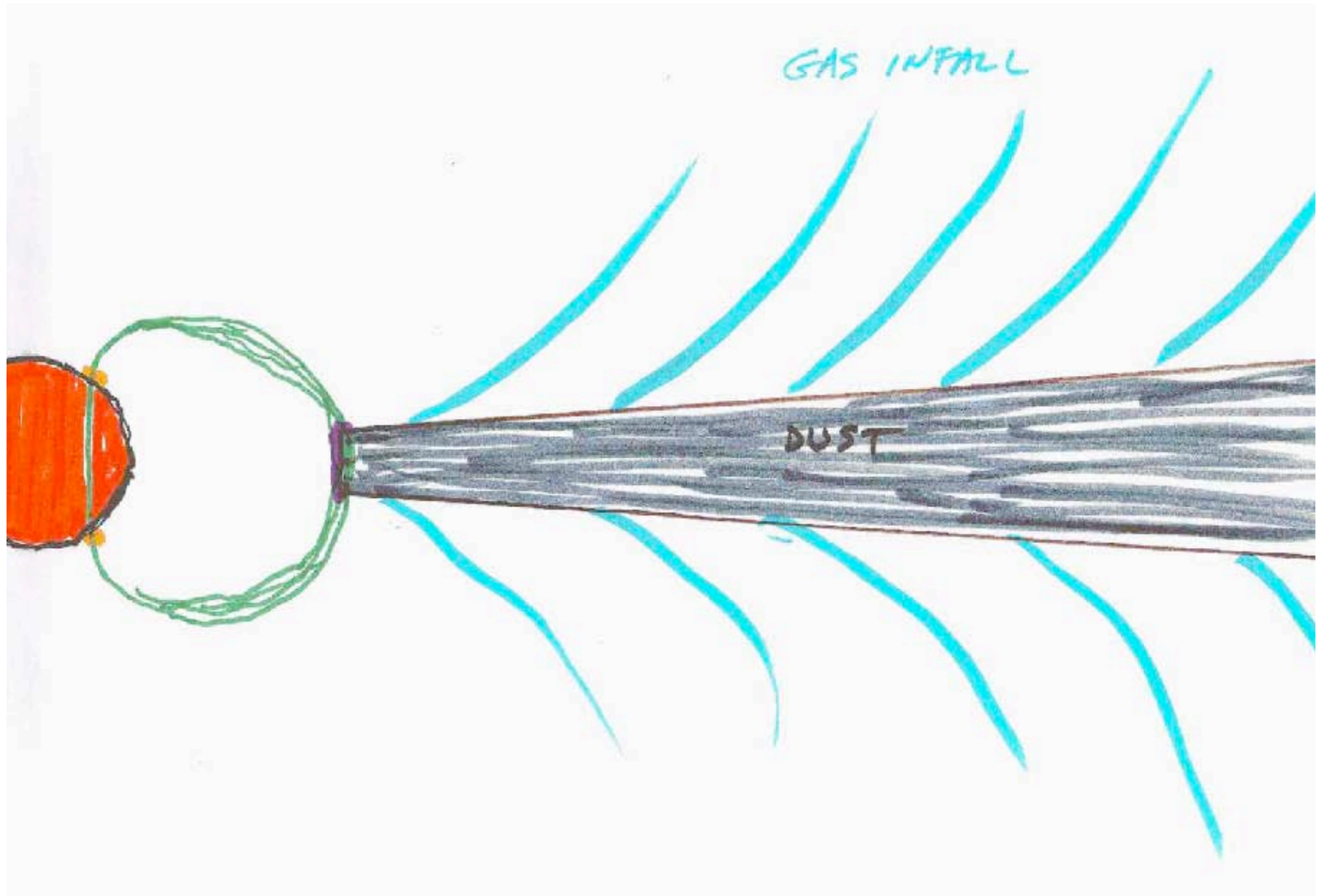
MASS CAN VARY FROM TINY TO BROWN DWARF.

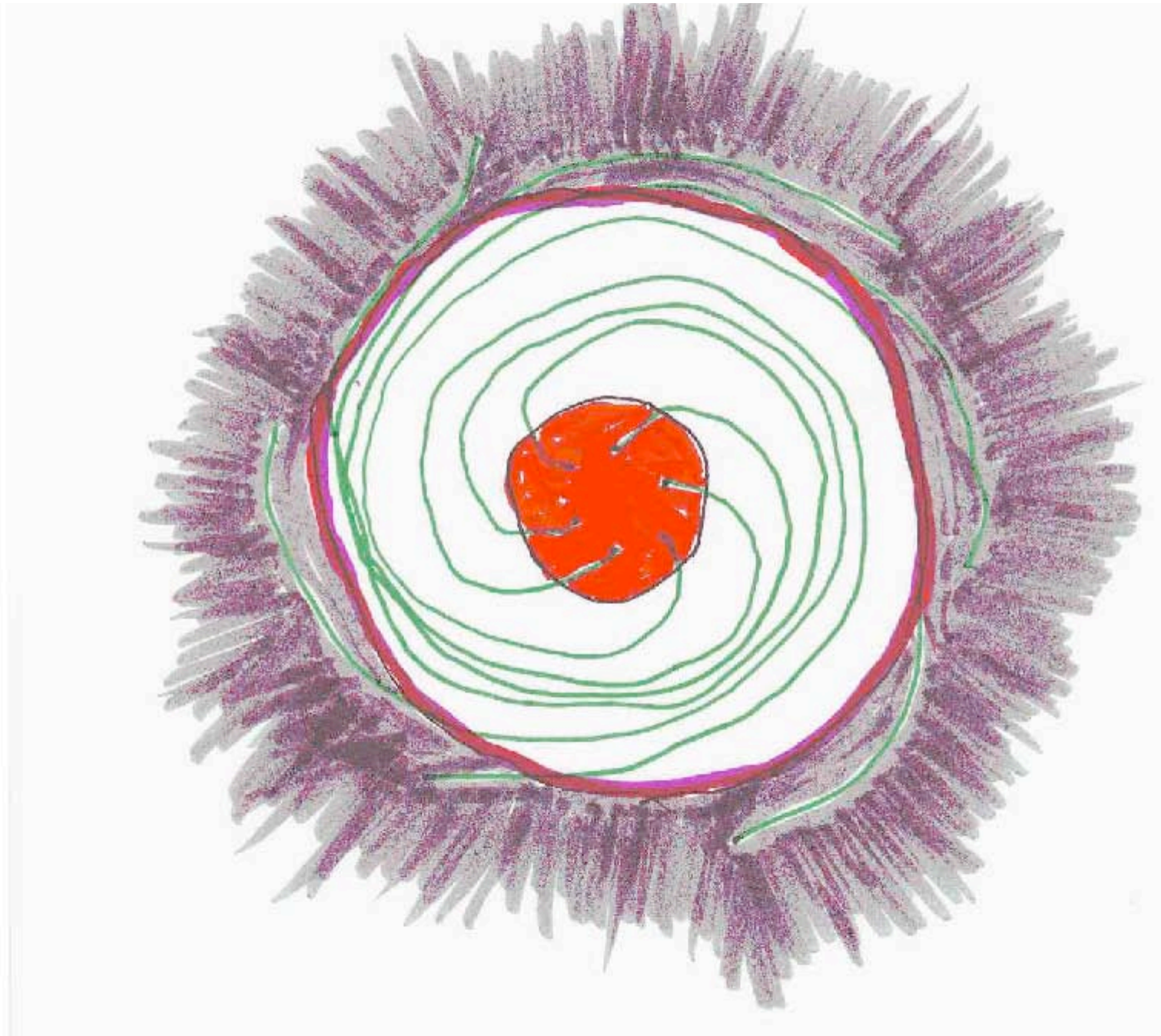
RADIATIVELY-DRIVEN PLANET FORMATION

RADIATION PRESSURE PUSHES DISK MATERIAL AND FORMS A WALL OF DENSE, WARM GAS AND DUST THAT ABSORBS 10 PERCENT OF THE RADIATION FROM THE STAR.



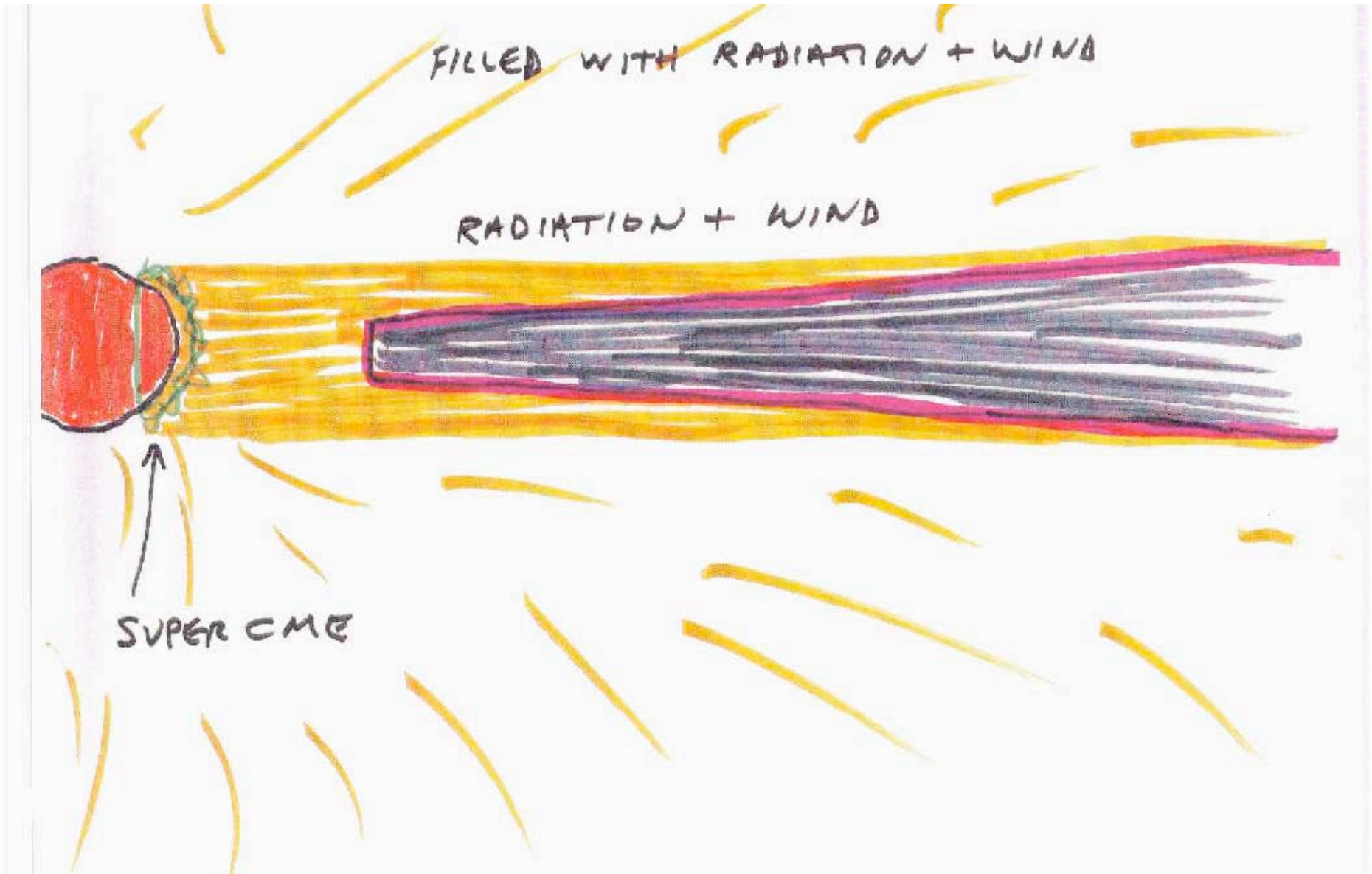
MAGNETIC FIELD IS STRETCHED OUTWARD WITH THE DISK SINCE IT IS PINNED TO THE DISK. AS THE COUPLING WEAKENS THE FIELD LINES WRAP.





**THE DIPOLE FIELD PULLS OUT OF THE DISK,
TANGLES,
AND STARTS RECONNECTING.**

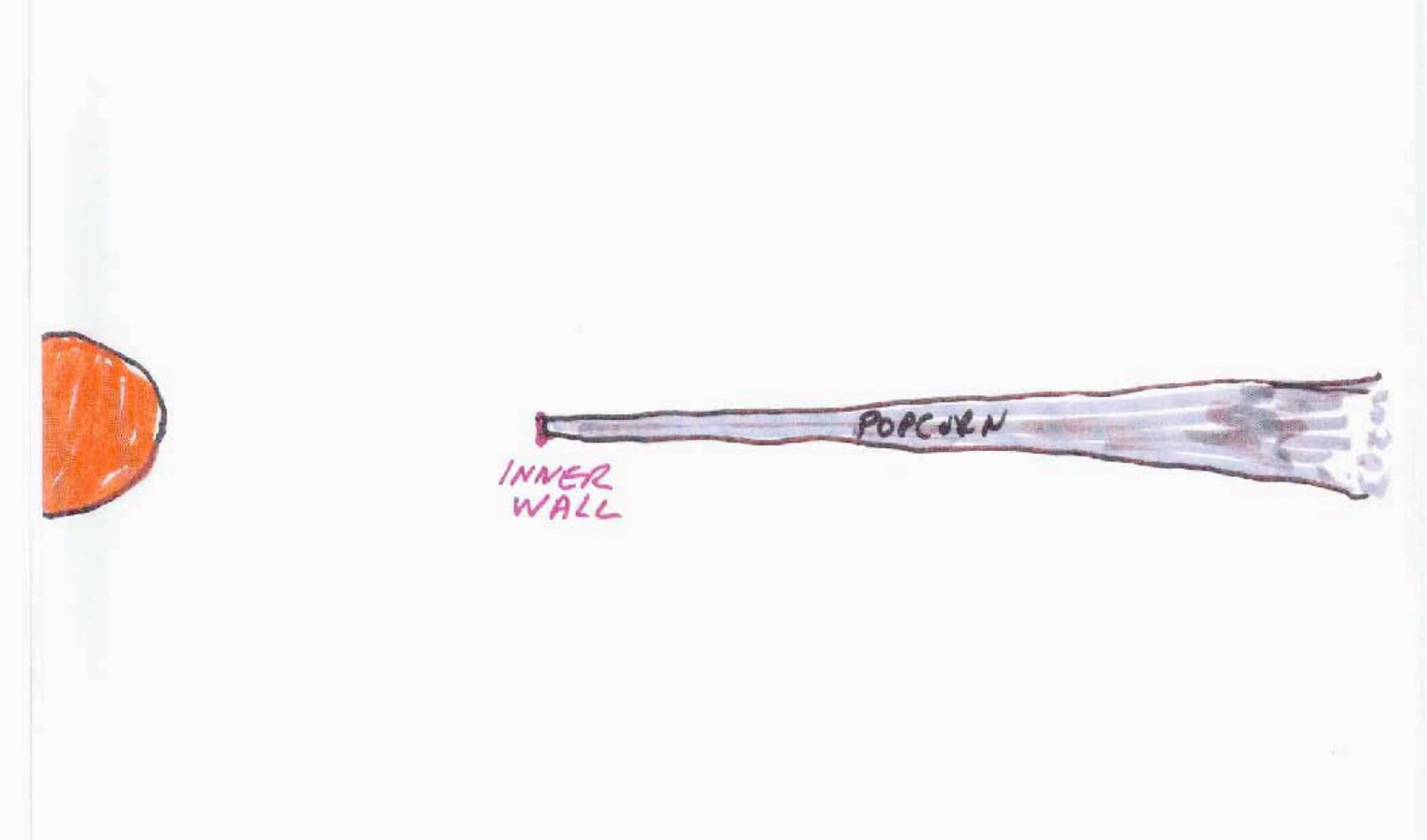
**THE FIELD FORMS A SUPER-CME THAT FILLS THE
SURFACE OF THE STAR FROM +70 TO -70 DEG LAT**



THE SUPER-CME ILLUMINATES BOTH SIDES OF THE DISK AS WELL AS THE INNER WALL.

RADIATION AND WIND BLOW AWAY ALL INFALL OUT TO ~ THE SNOW LINE AND VAPORIZE THE SURFACES OF THE DISK, HEATING THE DUST, DRIVING IT INWARD, AND AGGLOMERATING IT IN A THINNER WARM DISK.

I CALL THE AGGLOMERATED DUST POPCORN.



DISK MATERIAL IS

RADIOACTIVE, SELF-HEATING

MAGNETIC, FE ~SI

CARBONACEOUS

**DAMAGED BY RADIOACTIVITY, RADIATION,
AND PARTICLES,**

**FREE RADICALS, BROKEN MOLECULES,
POSITIVE AND NEGATIVE CHARGES**

CARCINOGENIC

GENERALLY STICKY

NEAR STAR, HOT

FAR FROM STAR, ICY.

POPCORN

STICKY

CRUSHABLE

INSULATING

RADIOACTIVELY SELF-HEATING

WARMED AND ANNEALED BY STAR

NOT LIKE PARTICLES IN MANY BODY CALCULATIONS



**LOW VELOCITY
COLLISION STICKS**

**MODERATE VELOCITY
COLLISION CRUSHES**



**COLLISION WITH SMALL DENSE FAST
PARTICLES PENETRATE**

POPCORN IS SELF-AGGLOMERATING AND WILL SLOWLY FORM PLANETS ON ITS OWN.

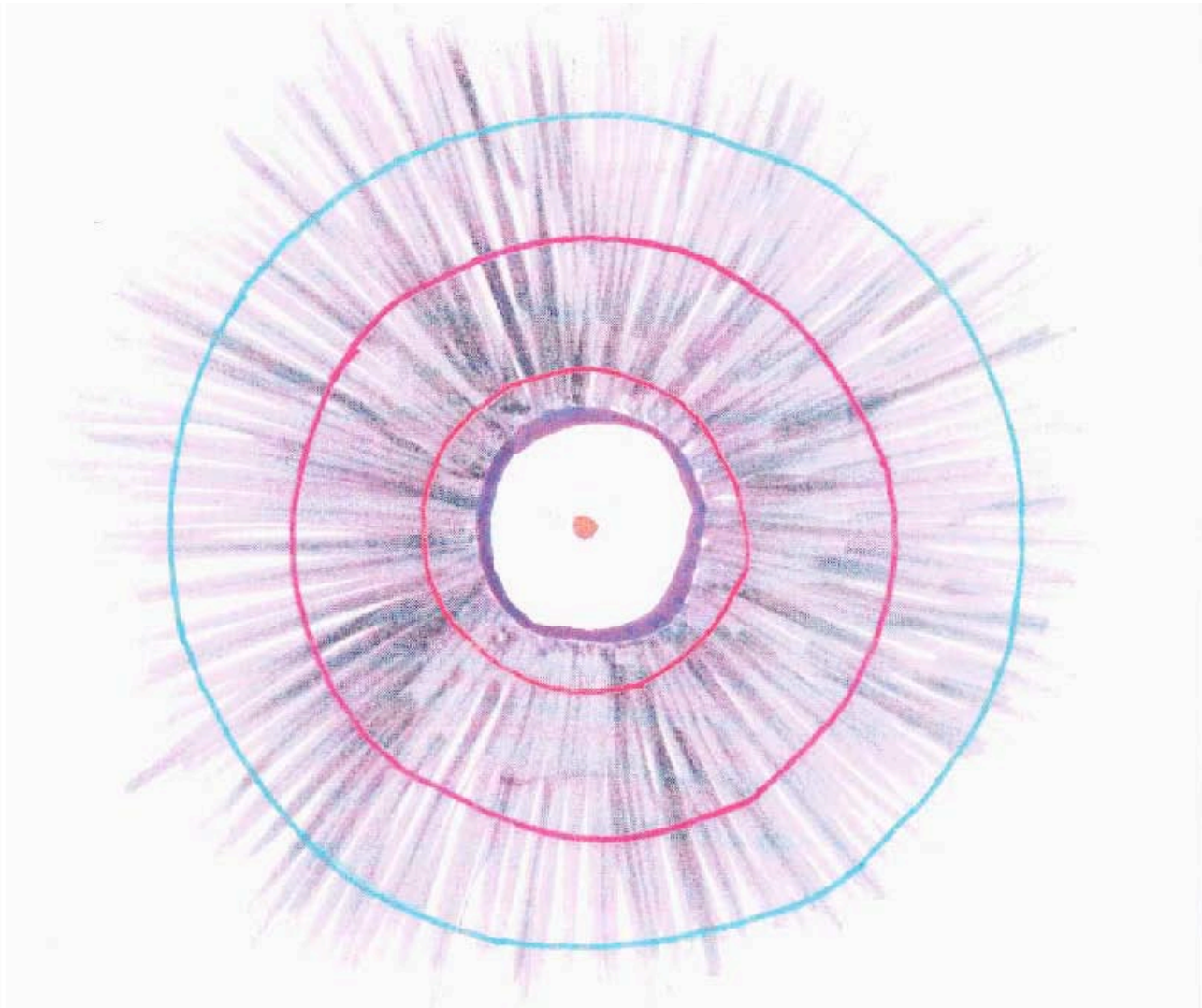
BUT RADIATION AND WIND FROM THE STAR HEAT POPCORN AND PUSH IT OUTWARD.

PLANETS FORM SEQUENTIALLY OUTWARD.

ORBITS MOVING OUTWARD CROSS STATIONARY ORBITS AND ORBITS MOVING INWARD AT A SHALLOW ANGLE SO COLLISIONS ARE SLOW.

WALL OF AGGLOMERATED POPCORN (= POPCORN BALLS) FORMS THAT ABSORBS 3-5% OF THE RADIATION FROM THE STAR.

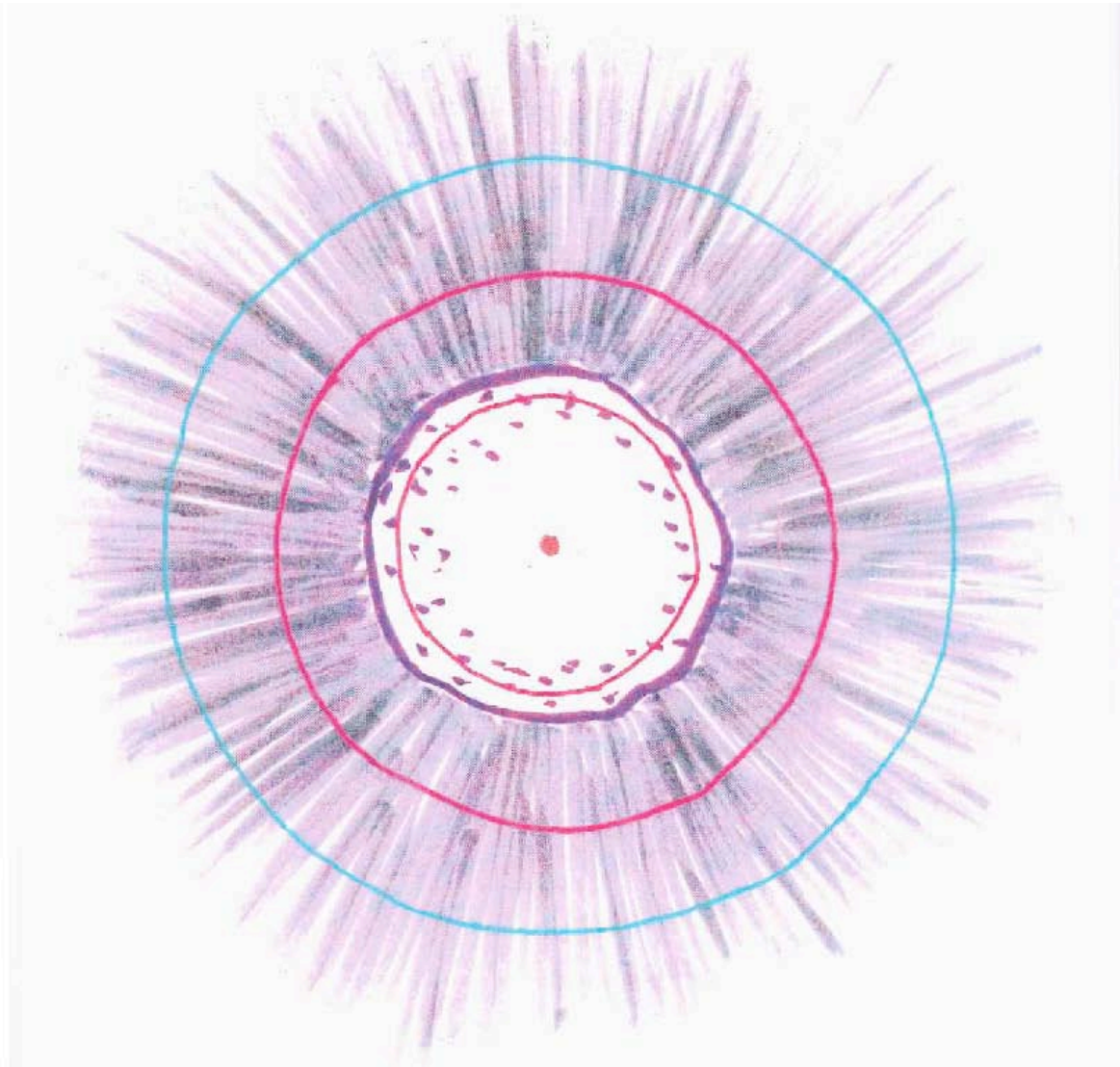
NEAR THE STAR VOLATILES ARE COOKED OUT.



**POPCORN AND POPCORN BALLS AGGLOMERATE
AND CONSOLIDATE INTO PLANETESIMALS
AND THE WALL BECOMES OPTICALLY THIN.**

**RADIATION FROM THE STAR CAN THEN REACH
MATERIAL FURTHER OUT THAT HAD BEEN
PROTECTED BY THE WALL.**

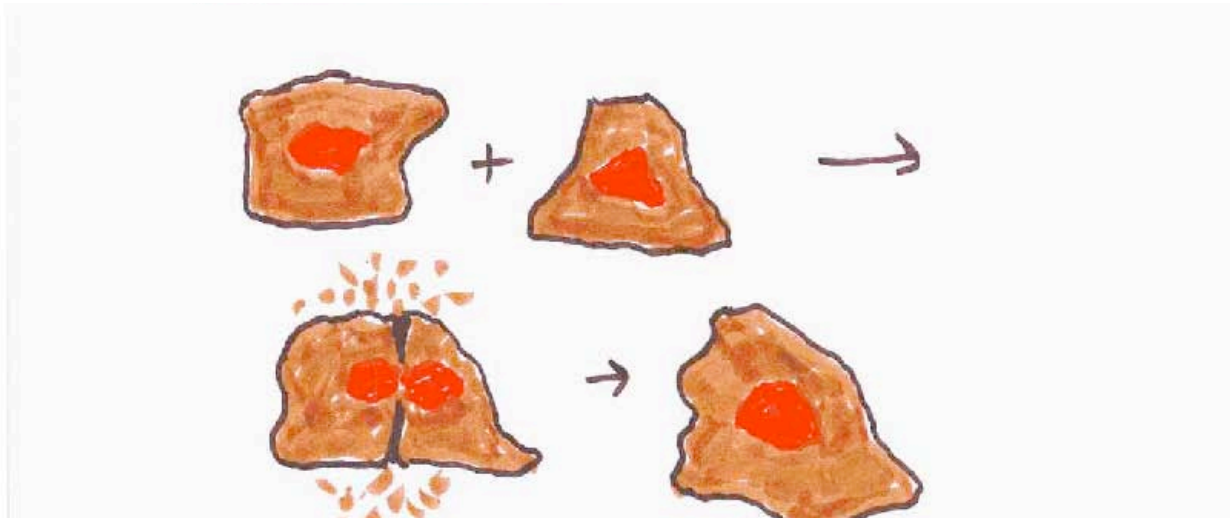
A NEW WALL FORMS AND THE PROCESS REPEATS.



WHEN A BODY GROWS LARGER, HEAT FROM RADIOACTIVITY IS TRAPPED IN THE CENTER AND DIFFERENTIATION BEGINS.

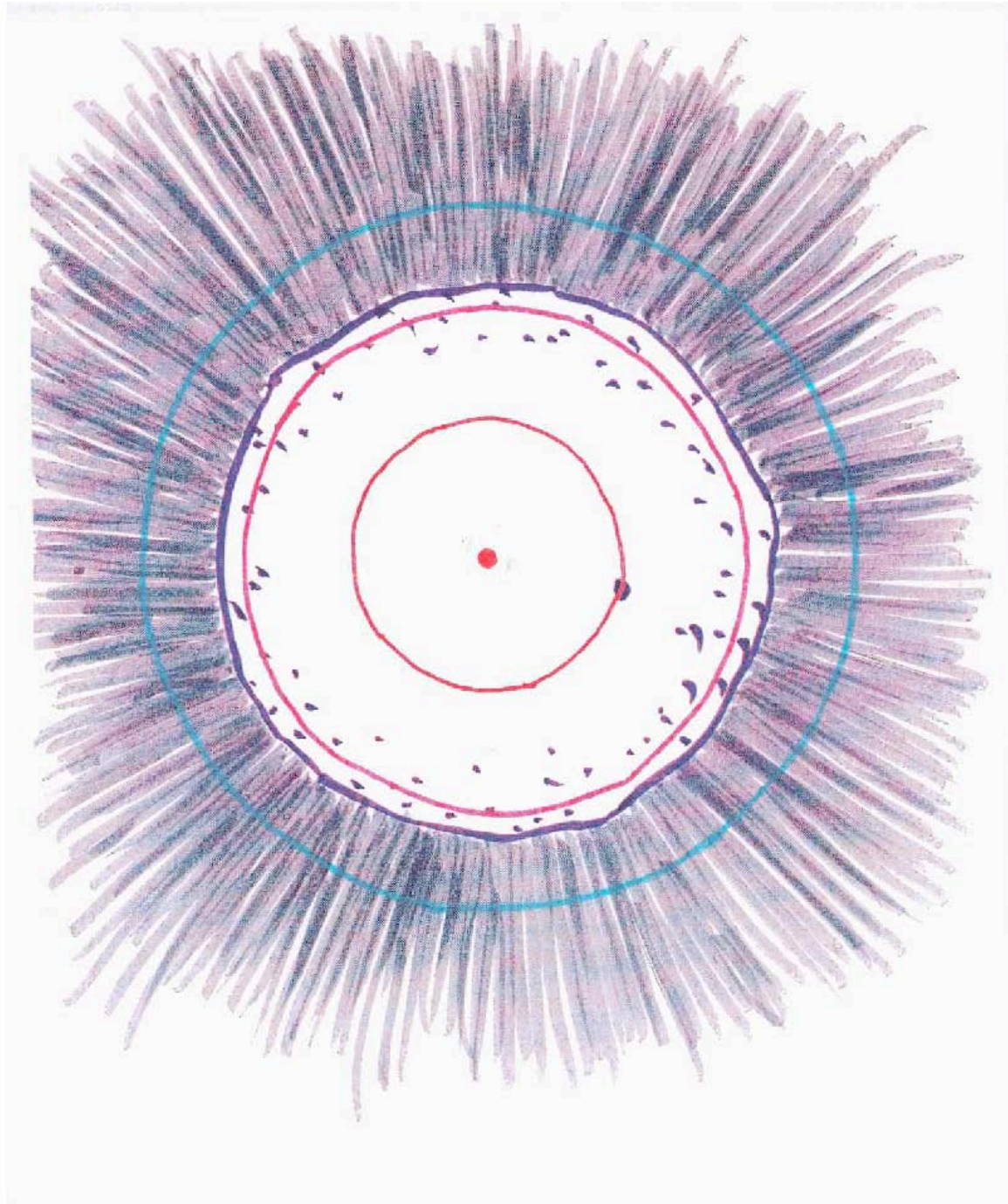
A SELF-GRAVITATING PLANETESIMAL CRUSHES UNDER ITS OWN WEIGHT. DIFFERENTIATION INCREASES. MELTING BEGINS.

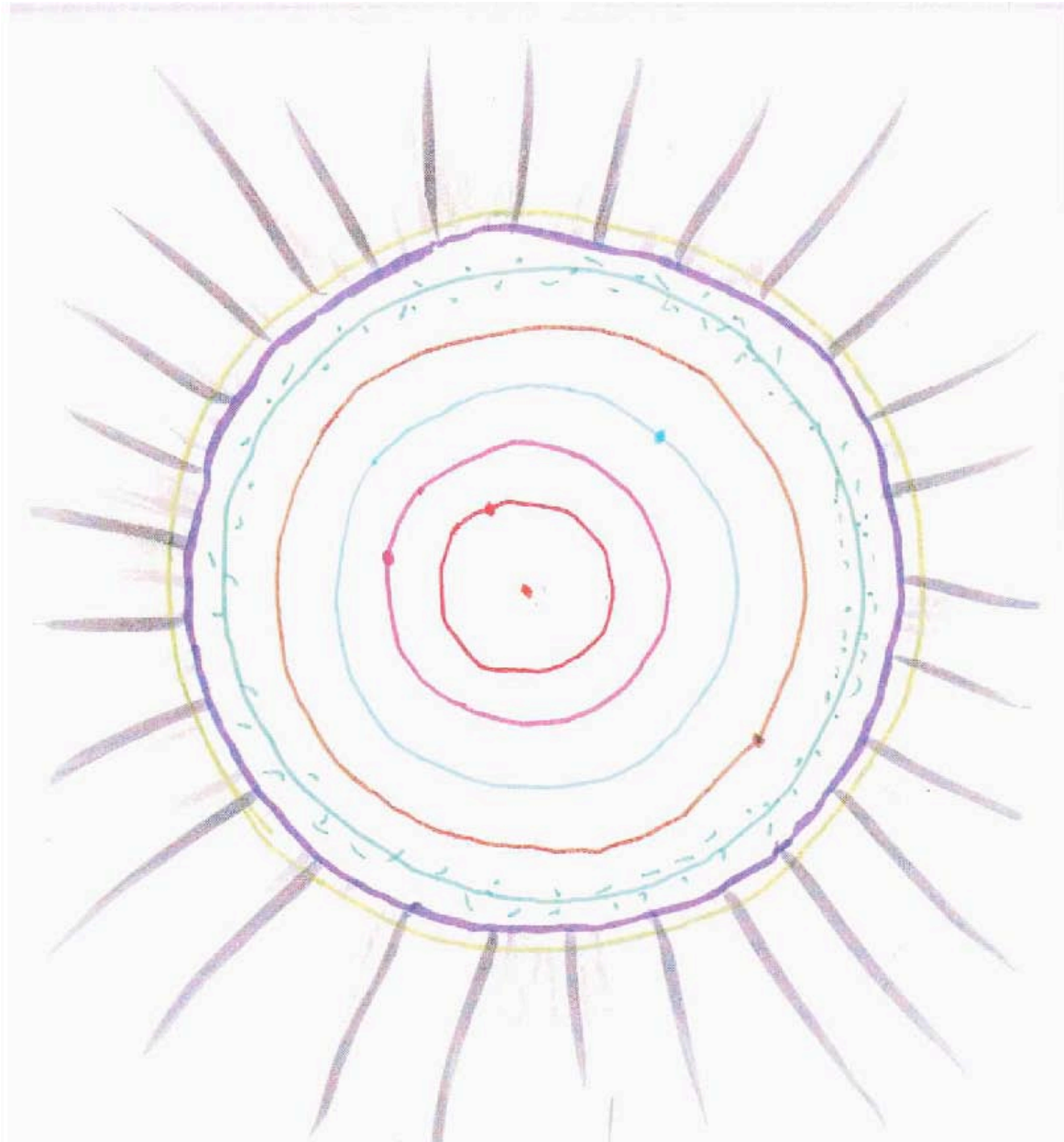
DIFFERENTIATION IS MAINTAINED WHEN PLANETESIMALS MERGE.



**THE DISPERSION OF THE DOTS IN THE CARTOONS
IS GREATLY EXAGGERATED.**

**PLANETESIMALS FORMED IN THE WALL ARE IN
NEARBY ORBITS. THEY RAPIDLY GRAVITATIONALLY
COLLAPSE INTO A PLANET.**

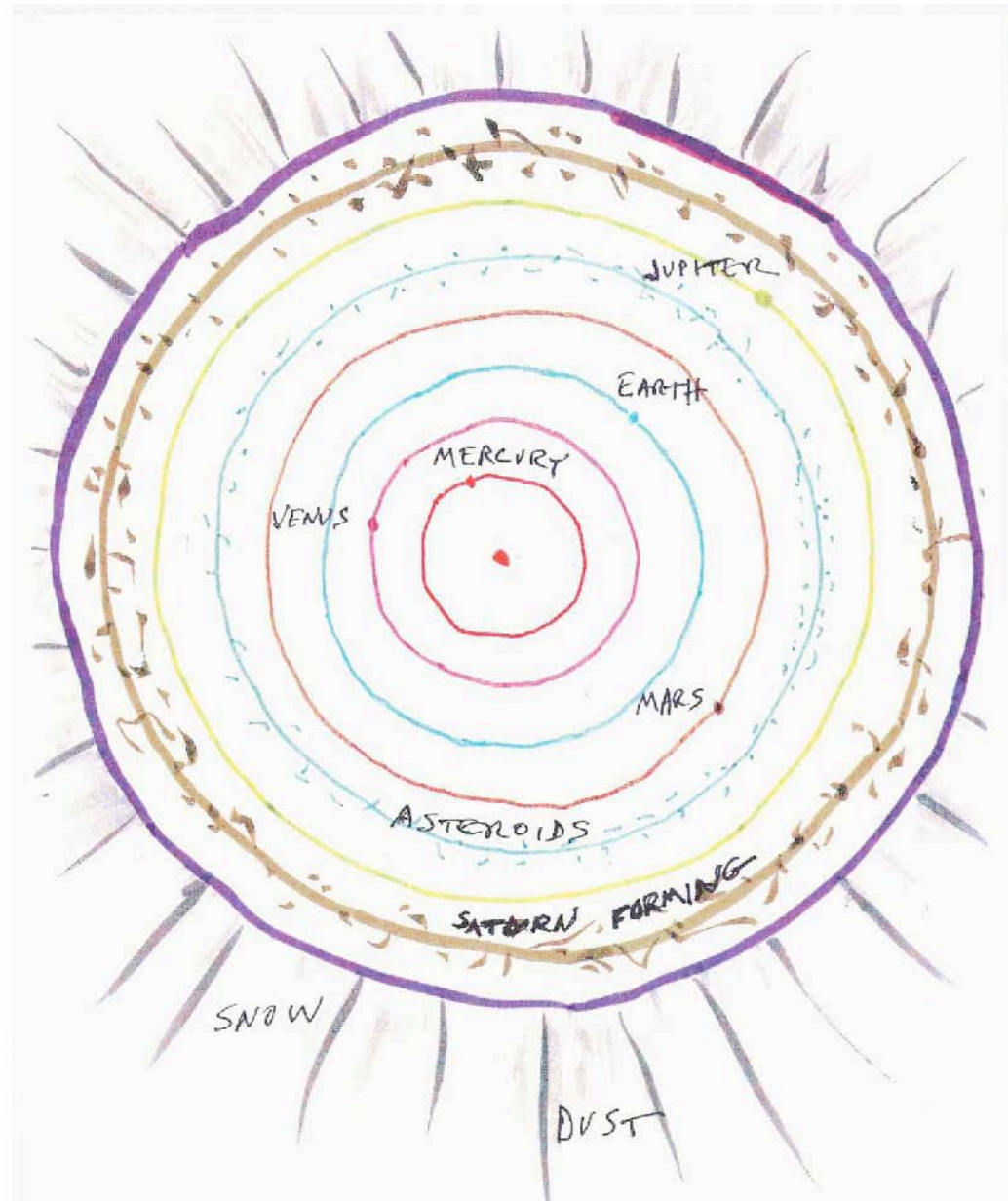




THERE IS NOT ENOUGH MASS IN THE “ASTEROID” WALL TO FORM A PLANET. IT REMAINS PLANETESIMALS.

NEXT COMES THE SNOW BELT.

ICE IS ADDED TO THE POPCORN AND DUST IN “JUPITER’S” WALL. A LARGE CORE FORMS THAT IS ABLE TO PULL IN GAS INFALLING TO THE DISK.



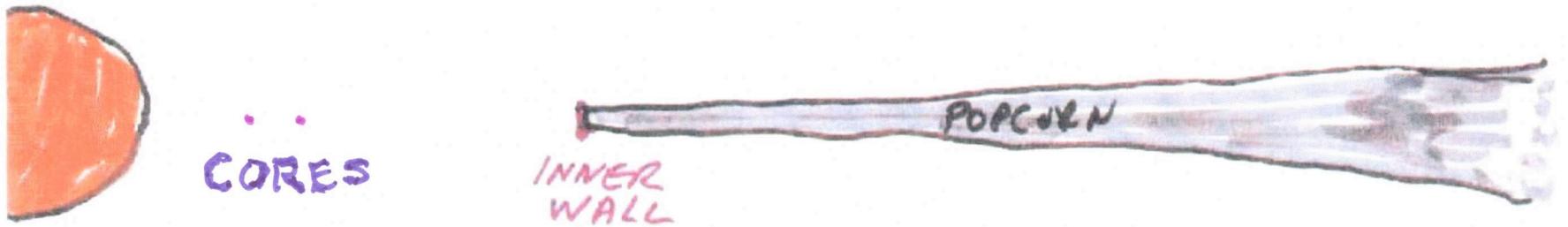
COLLOQUIUM 4 MAY 2006

DAVE WILLNER SHOWED IMAGES OF THE 20 CLOSEST “PROTOPLANETARY” DISKS THAT ARE VISIBLE THROUGH SURROUNDING GAS AND DUST.

THE DISKS HAD UNRESOLVED CENTRAL HOLES WITH DIAMETERS > 20 AU. SMALLER HOLES ARE NOT VISIBLE.

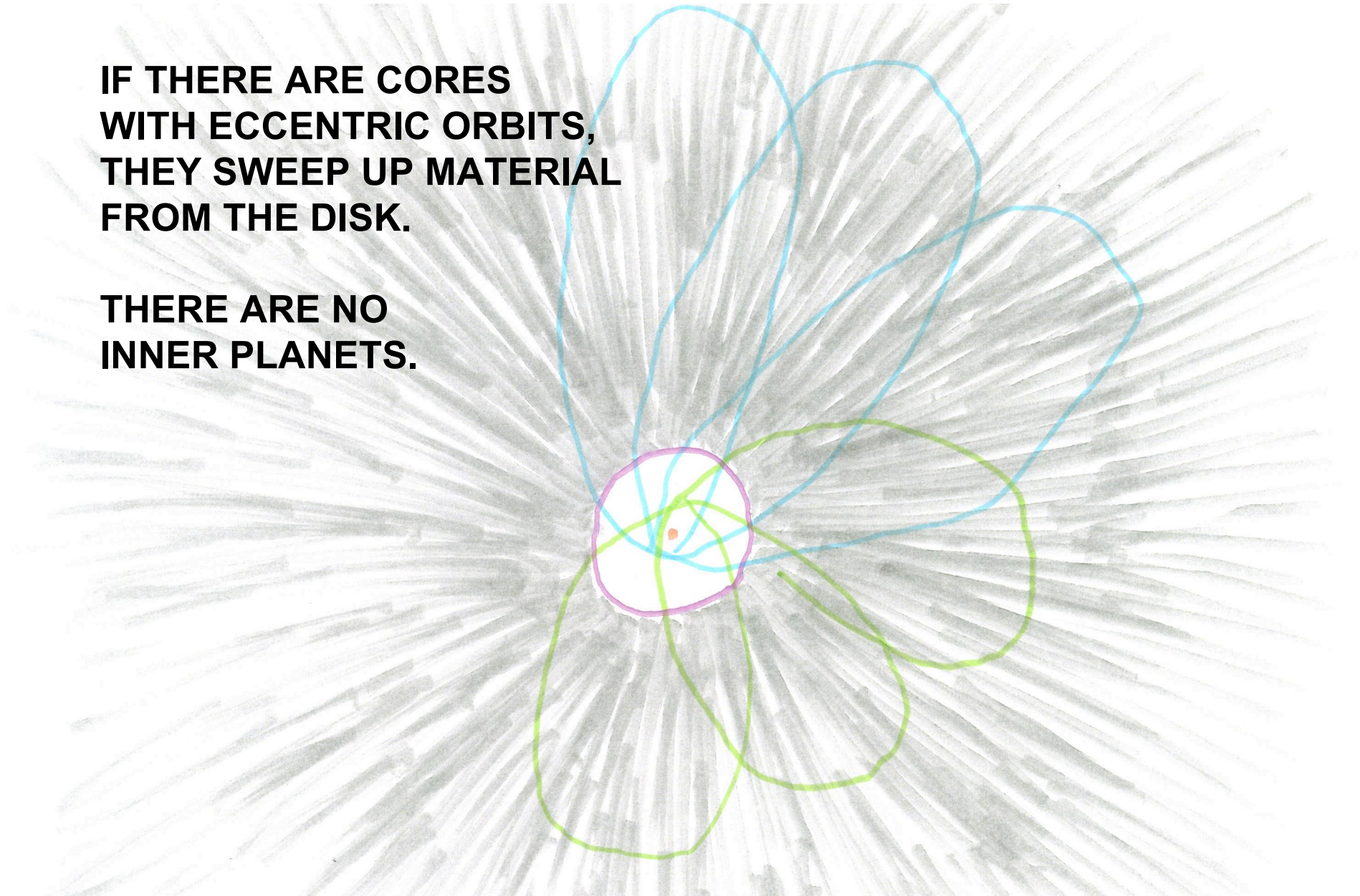
IN FACT, THESE ARE “POST-PLANETARY” DISKS. PLANETS HAVE ALREADY FORMED RAPIDLY OUT THROUGH “JUPITER”.

BACK TO THE MAGNETIC CASE



**IF THERE ARE CORES
WITH ECCENTRIC ORBITS,
THEY SWEEP UP MATERIAL
FROM THE DISK.**

**THERE ARE NO
INNER PLANETS.**



CLASSICAL PLANET FORMATION

**UNIFORMITARIANISM WORKS FOR FORMING
THE OUTER PLANETS.**

**SINCE RADIATION FROM THE STAR IS SO
WEAK AT THOSE DISTANCES, THEY ARE
ACCRETED SLOWLY BY UNASSISTED GRAVITY.
SEE SCOTT KENYON'S WORK ON DEBRIS DISKS.**

**RENU MALHOTRA COLLOQUIUM 15 SEPT 2005
FORMATION OF OUTER PLANETS.**

**MALHOTRA SHOWED THAT URANUS AND NEPTUNE
TOOK ~600 MILLION YEARS TO FORM AND MIGRATE
INTO PLACE.**

**THEIR FORMATION AND MIGRATION PRODUCED
RESONANCES IN THE ASTEROID BELT THAT EITHER
DROVE ASTEROIDS INWARD TO CRATER THE INNER
PLANETS, OR EJECTED THEM FROM THE SOLAR
SYSTEM.**

**X-RAY BURSTS FROM RECONNECTION MARK STARBIRTHS.
STARBIRTHS ARE RARE IN OUR GALAXY.
THERE ARE SEVERAL PER YEAR IN A STARBURST GALAXY.**

**IF THE RECONNECTION TAKES PLACE DURING AN FU ORI
EVENT, THE FIELD TRAPS PLASMA IN SPHEROMAKS THAT
ORBIT NEAR THE STAR. THEY SERVE AS PLANETARY
CORES THAT GROW BY ACCRETING DISK MATERIAL AND
INFALL. THERE ARE NO INNER PLANETS LIKE THOSE IN
OUR SOLAR SYSTEM (AND NO HABITABLE ZONES).**

**IF THE RECONNECTION IS NOT DURING AN FU ORI EVENT,
IT SIMPLY DESTROYS EXCESS DIPOLE FIELD. INNER
PLANETS FORM AS IN OUR SOLAR SYSTEM.**

**IN EITHER CASE OUTER PLANETS FORM SLOWLY IN DEBRIS
DISKS.**

