

ESS UNIT 1 LECTURE 3

CLASSIFICATION AND LIFE CYCLE OF STARS



NUCLEAR FUSION

THE MOST EFFICIENT WAY TO TRANSFORM ENERGY

WHAT IS NUCLEAR FUSION

- A NUCLEAR PROCESS WHEREBY SEVERAL SMALL NUCLEI ARE COMBINED TO MAKE A LARGER ONE WHOSE MASS IS SLIGHTLY SMALLER THAN THE SUM OF THE SMALL ONES.
- THE DIFFERENCE IN MASS IS CONVERTED TO ENERGY BY EINSTEIN'S EQUIVALENCE $E=mc^2$

WHAT FUELS A STAR?

- HYDROGEN MAKES UP ABOUT 75% OF OUR SUN
- HYDROGEN IS THE MOST ABUNDANT ELEMENT IN THE UNIVERSE AND IS THE SMALLEST, MOST BASIC ELEMENT IN THE UNIVERSE
- THE HYDROGEN NUCLEI TYPICALLY FUSE TO FORM HELIUM



LIFE CYCLE OF A STAR

FROM BIRTH TO DEATH

NEBULAR PHASE

- A LARGE GAS CLOUDS (MAINLY HYDROGEN)
- EXTREMELY COLD AND DENSE, 10 TO 20K ABOVE ABSOLUTE ZERO
- SINCE THESE REGIONS ARE DENSE, THEY ARE OPAQUE TO VISIBLE LIGHT AND ARE KNOWN AS DARK NEBULA
- WE HAVE TO USE IR AND RADIO TELESCOPES TO INVESTIGATE THEM

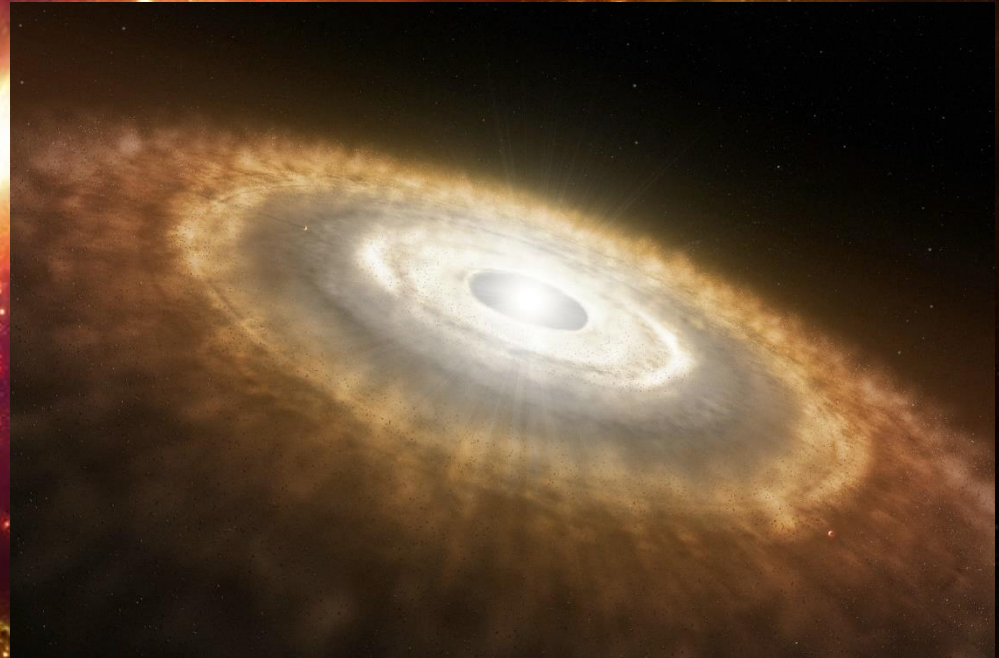


NEBULAR PHASE (CONT.)

- THE HYDROGEN ATOMS ARE DRAWN TOGETHER
- AS THE NEBULAR GAS IS PULLED IN, IT STARTS TO SPIN AND GET HOT
- EVENTUALLY THESE AREAS COLLAPSE UNDER THEIR OWN GRAVITY
- THE CORES ARE DENSER THAN THE OUTER CLOUD, SO THEY COLLAPSE FIRST
- AS THE CORES COLLAPSE THEY FRAGMENT IN TO CLUMPS ABOUT 0.1 PARSECS IN SIZE
- THESE CLUMPS BECOME PROTOSTARS

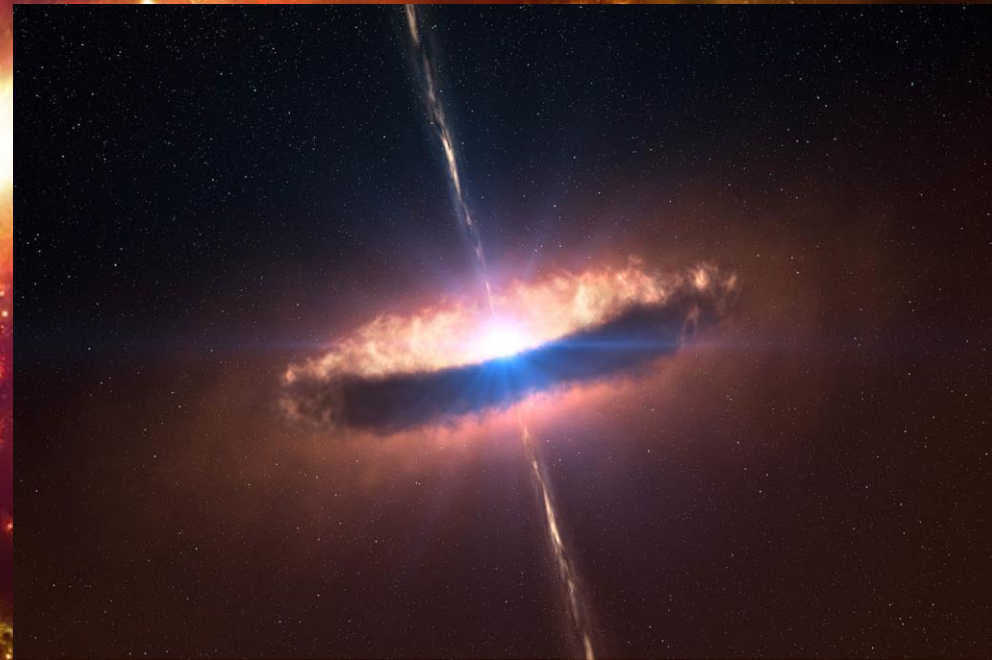
PROTOSTAR PHASE

- AS THESE CLUMPS BREAK OFF, THE ANGULAR MOMENTUM OF THE ROTATING GAS TURNS THE IRREGULAR CLOUD INTO A ROTATING DISK
- THE CENTRAL REGION OF THIS DISK BECOMES MORE DENSE AND FORMS THE PROTOSTAR
- THE DISK FORMS SLOWER AND WILL LATER BECOME THE PLANETARY RINGS



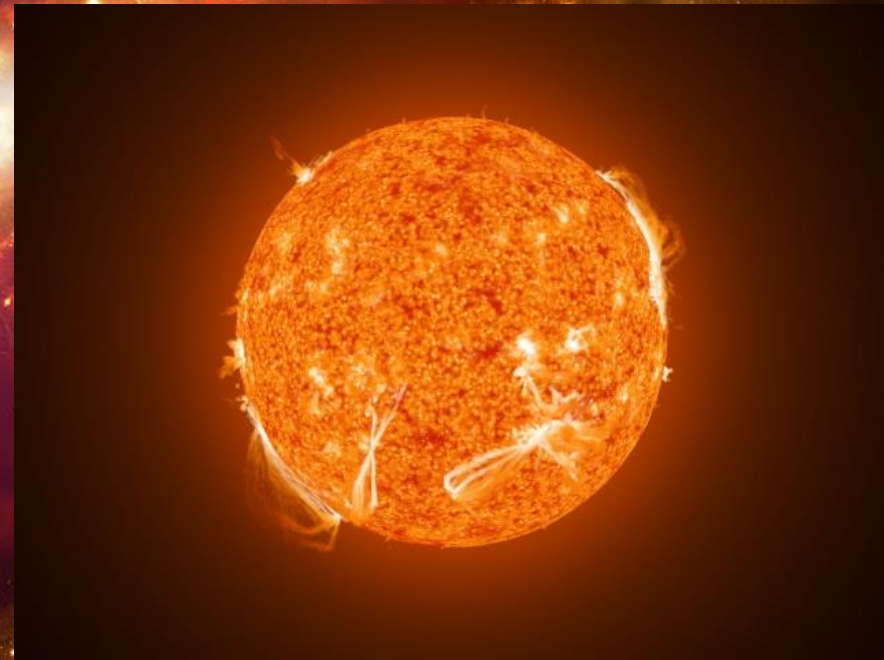
PROTOSTAR PHASE (CONT.)

- AS MATTER IS PULLED TO THE CENTER, CALLED INFALLING, THE SIZE OF THE PROTOSTAR INCREASE BY A FACTOR OF 100
- INFALL IS STOPPED WHEN THE PROTOSTAR BEGINS THERMONUCLEAR FUSION AND PRODUCES A STRONG STELLAR WIND



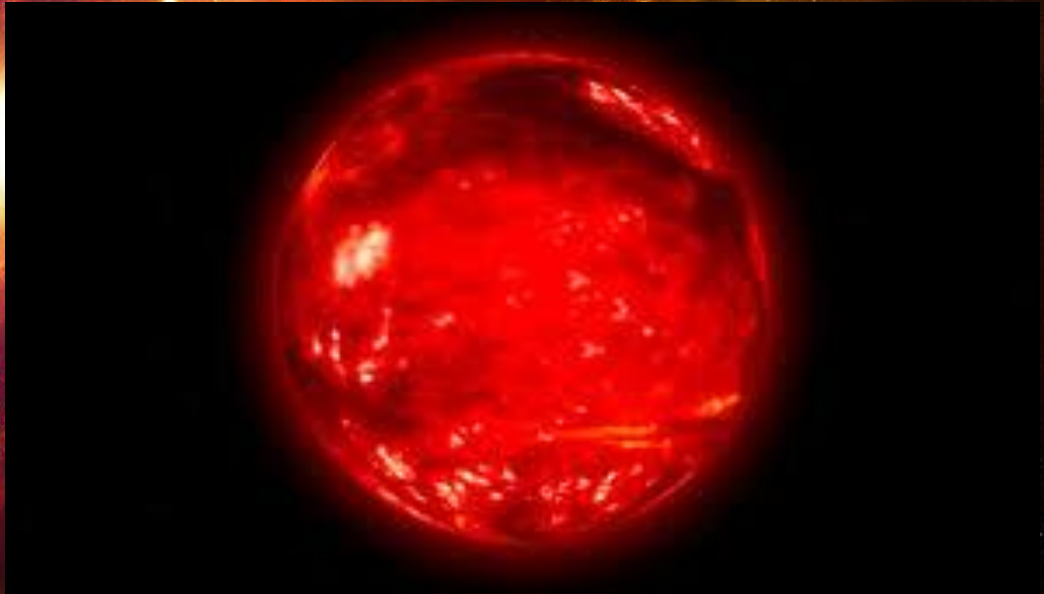
MAIN SEQUENCE PHASE

- A STAR SPENDS MOST OF ITS LIFE AS A MAIN SEQUENCE STAR
- ONCE STARS BEGIN THERMONUCLEAR FUSION, THEY BALANCE THE INWARD PULL OF GRAVITY WITH OUTWARD PUSH OF PRESSURE AND HEAT, THE BALANCING ACT CREATES STABILITY
- ONCE THE HYDROGEN IS EXHAUSTED, A STAR HAS TO BURN HELIUM IN ORDER TO SURVIVE, THIS IS THE BEGINNING OF THE END



RED GIANT PHASE

- ONCE THE STAR STARTS TO BURN HELIUM (WHICH HAPPENS AT A FASTER RATE THAN WITH HYDROGEN, THE OUTER SHELL OF THE STAR EXPANDS BECAUSE OF THE CHANGES IN THE FORCES ASSOCIATED WITH BURNING HELIUM
- BECAUSE OF THIS EXPANSION OF THE OUTER SHELL, OFTEN THE NEW STAR IS CALLED A RED GIANT





DEATH PHASE

THE BIGGER THEY ARE, THE FASTER THEY DIE

LOW-MASS STARS

- ONCE HELIUM IS EXHAUSTED, ALL THAT IS LEFT IS CARBON
- USUALLY ONCE HELIUM IS EXHAUSTED, THE CORE WILL COLLAPSE SENDING OUT A SHOCKWAVE THAT CASTS OFF ITS OUTER LAYER LEAVING BEHIND A WHITE DWARF.
- A WHITE DWARF IS ALMOST SOLELY IRON BUT IT IS WHITE HOT BECAUSE OF ALL THE LEFT OVER HEAT
- OVER TIME A WHITE DWARF WILL COOL TO THE SURROUNDING TEMPERATURE OF SPACE AND BECOME PITCH BLACK, NOW IS CALLED A BLACK DWARF.
- GENERALLY THE SIZE OF THE WHITE DWARF IS ABOUT THE SIZE OF THE EARTH



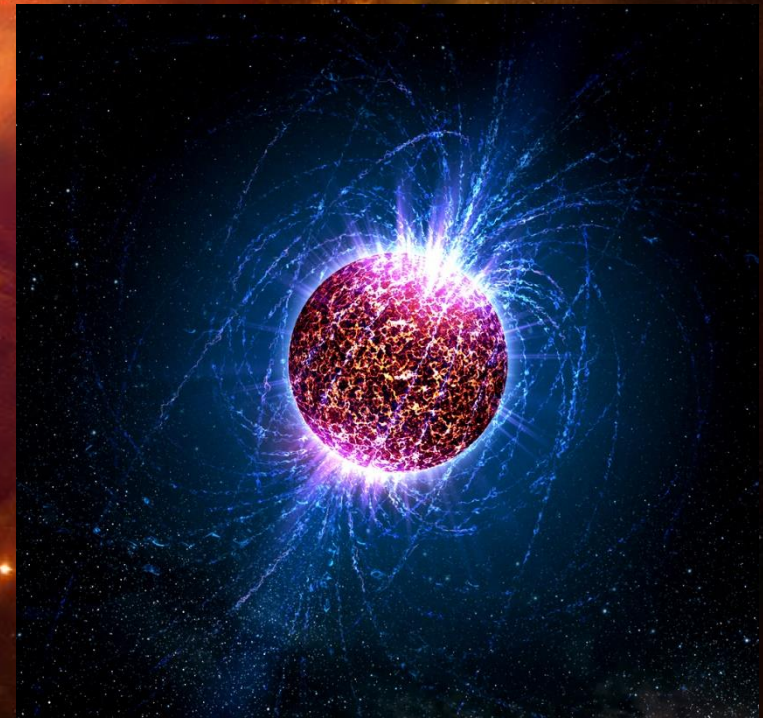
HIGH-MASS STARS

- HIGH MASS STARS BURN THROUGH THEIR FUEL FASTER THAN THAT OF SMALLER MASS STARS
- THE DIFFERENCE BETWEEN HIGH MASS STARS AND LOWER MASS STARS IS THAT THE PRESSURE IN THE CORE OF THE HIGH MASS STARS IS ENOUGH TO FUSE CARBON INTO IRON
- THIS PROCESS ACTUALLY TAKES ENERGY RATHER THAN GIVING IT, SO AS A STAR STARTS TO LOOSE ENERGY IT CAN NO LONGER HAVE BALANCE BETWEEN OUTWARD PRESSURE AND GRAVITY
- AS A RESULT GRAVITY WINS AND THE CORE COLLAPSES IN A VIOLENT EXPLOSION CALLED A SUPERNOVA



NEUTRON STAR

- A SOLAR MASS OF 1.4-9 WILL FORM A NEUTRON STAR
- A NEUTRON STAR IS WHERE THE PULL OF GRAVITY WAS SO GREAT DURING THE SUPERNOVA THAT THE ELECTRONS ENTERED INTO THE CORE OF THE ATOM COMBINING WITH PROTONS TO MAKE NEUTRONS
- THE RESULT IS THAT THE LEFT OVER NEUTRON CORES WILL NOW PACK SO TIGHT THAT THERE IS VIRTUALLY NO SPACE BETWEEN THEM
- USUALLY THE SIZE OF A NEUTRON STAR IS THAT OF A LARGE METROPOLITAN CITY LIKE MANHATTAN, NY



BLACK HOLE

- IF THE MASS OF A STAR IS GREATER THAN 9 SOLAR MASSES, THE LEFT OVER CORE WILL CONTINUE TO COLLAPSE TO WHERE NOT EVEN LIGHT CAN ESCAPE, WE CALL THESE MASS GRAVITY SINGULARITIES AS BLACK HOLES.

