

LIGHT ECHOES OF TYPE IA SUPERNOVAE

DR. CHARLOTTE M. WOOD



UNIVERSITY OF
NOTRE DAME

IOWA STATE
UNIVERSITY



NORTH CAROLINA
AGRICULTURAL AND TECHNICAL
STATE UNIVERSITY

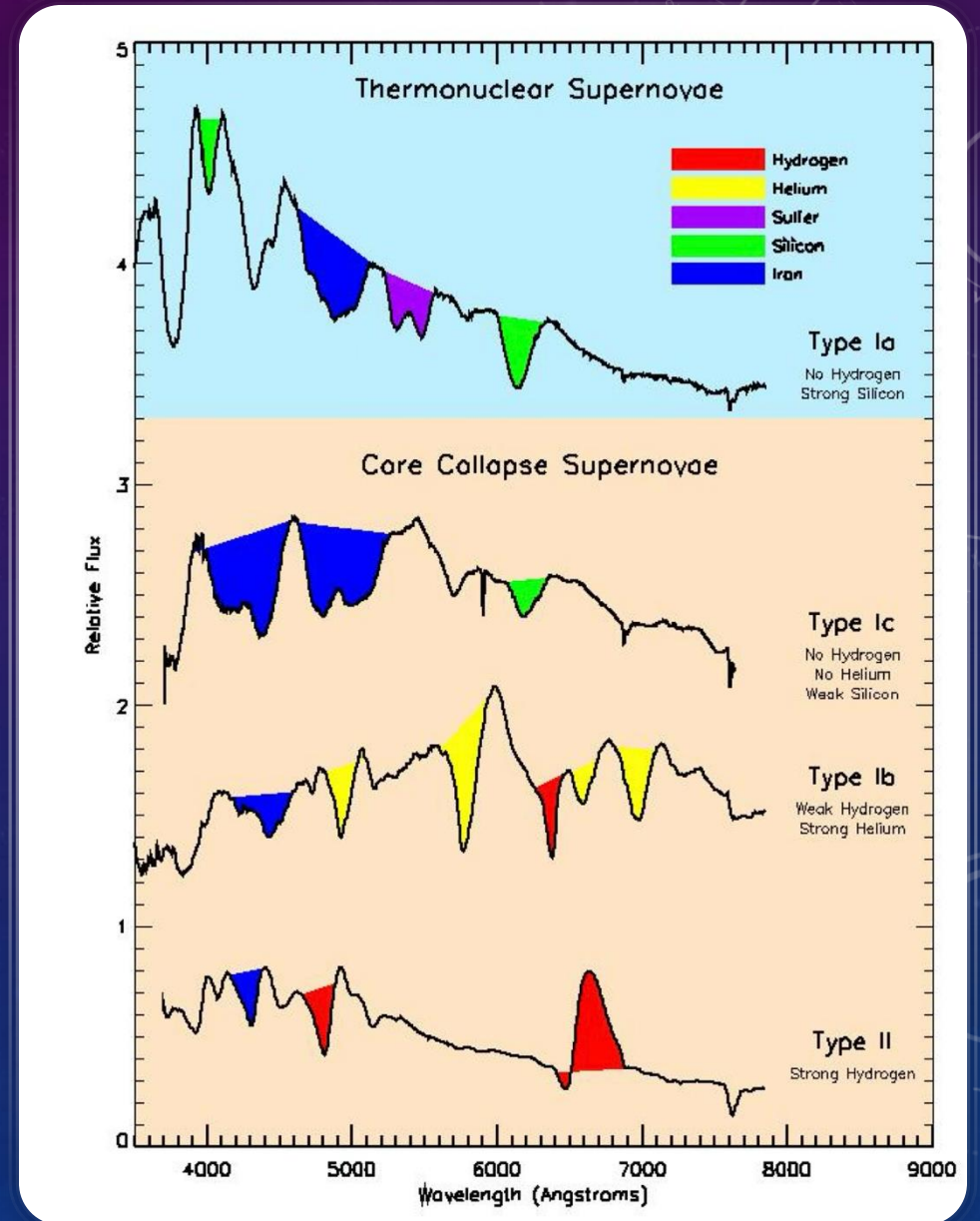
INTRODUCTION!



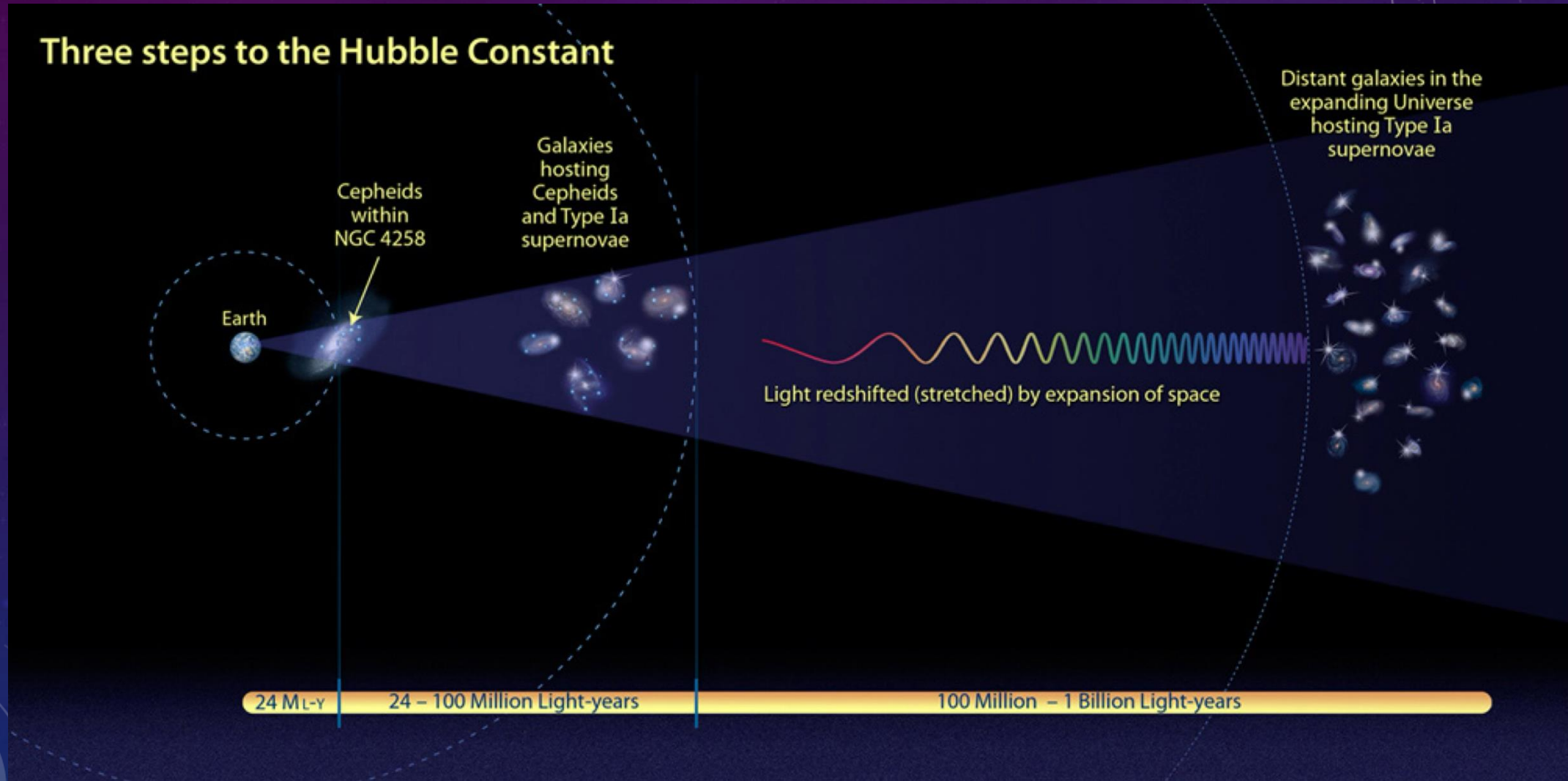
WHAT ARE TYPE IA SUPERNOVAE?

- A **supernova** is a bright explosion of a star that happens at the end stages of stellar evolution
- A **type Ia supernova** (SN Ia) is an explosion resulting from a runaway nuclear fusion event on a white dwarf star

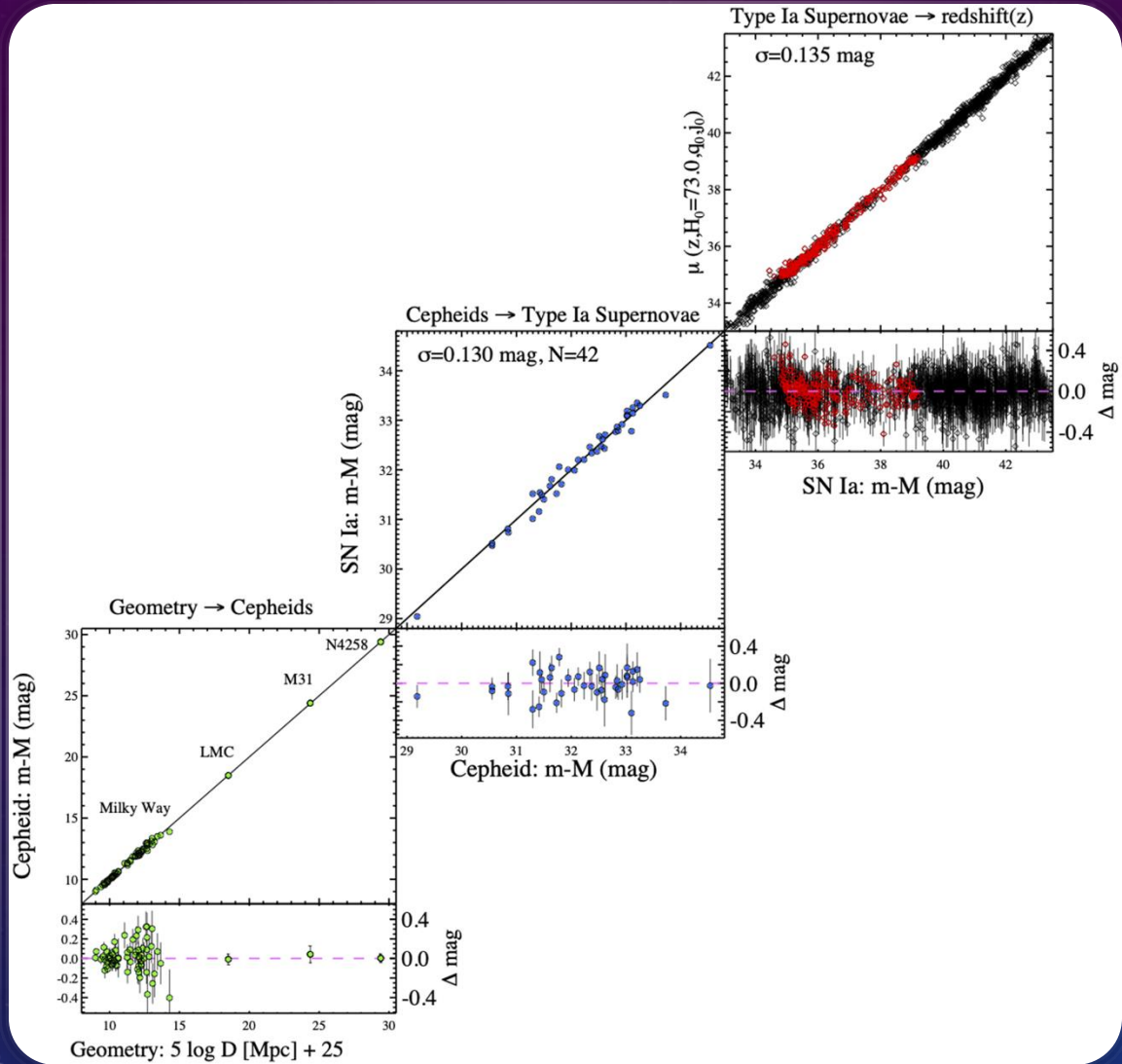
SNe Ia have *extreme* and *predictable* luminosities, so they can be used as “standard candles.”



THE COSMIC DISTANCE LADDER

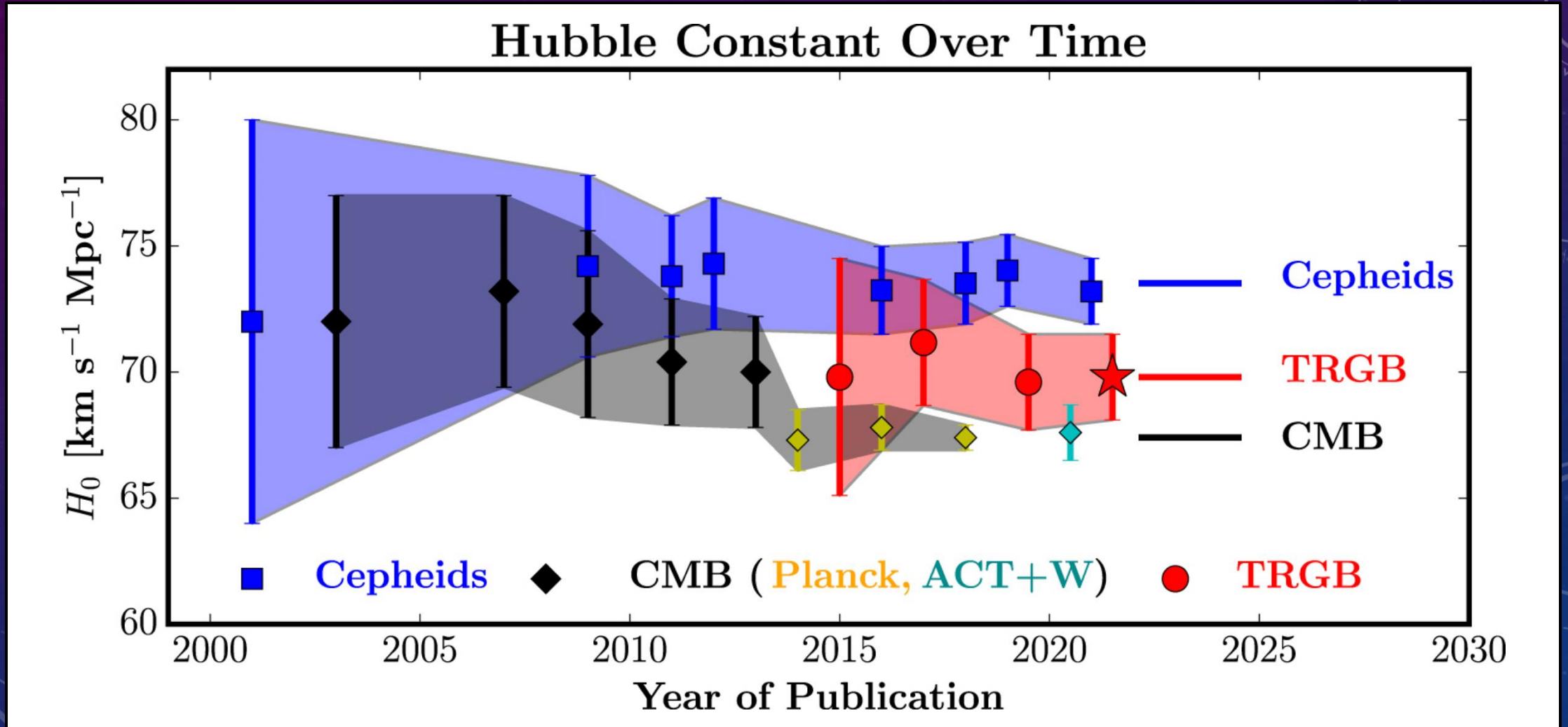


PRECISION COSMOLOGY



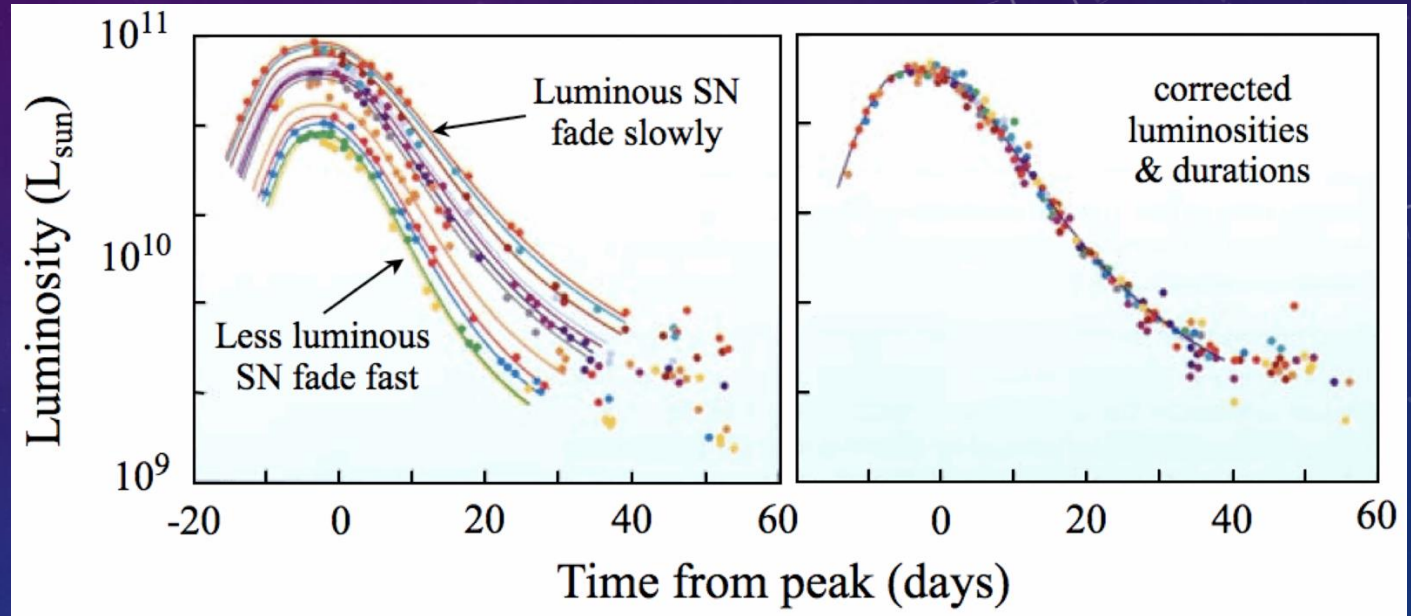
- **Cosmology**: the branch of astronomy concerned with understanding the history and structure of the Universe
- **Precision Cosmology**: measuring cosmological parameters as precisely as possible
- **Parameters of interest**
 - H_0 : the Hubble constant, a measure of the current expansion rate of the universe
 - w : the equation of state of dark energy, assumed to be -1.0 for a flat universe

MOUNTING TENSION: THE HUBBLE CONSTANT



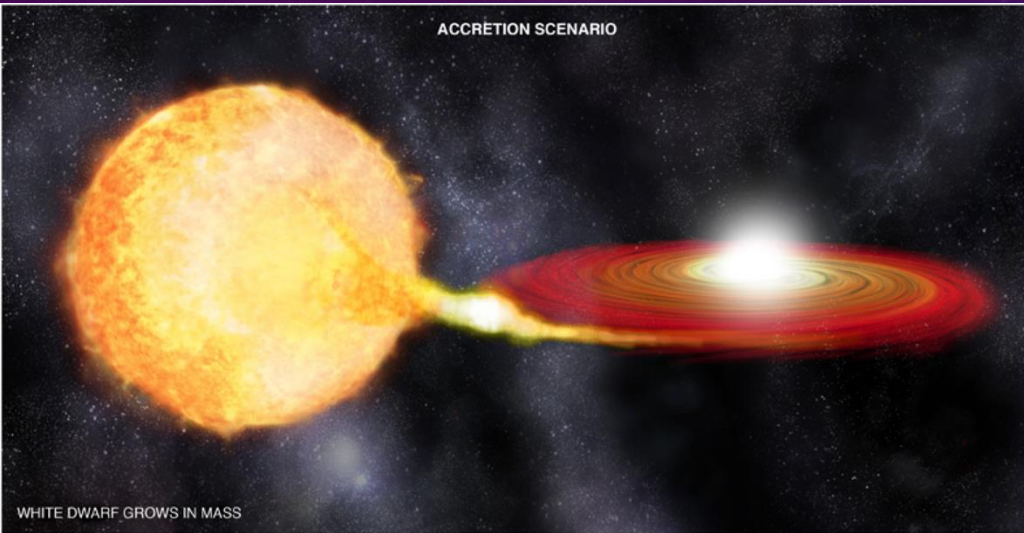
STANDARD VS. STANDARDIZABLE CANDLE

- SNe Ia are not perfectly standard – they vary between individual events
- Phillips Relation: correlation between SN Ia peak luminosity and decline rate
- SN Ia color at peak also correlates with peak luminosity
- There are also correlations between SN properties and host galaxy properties (type, mass, star formation history, etc.)

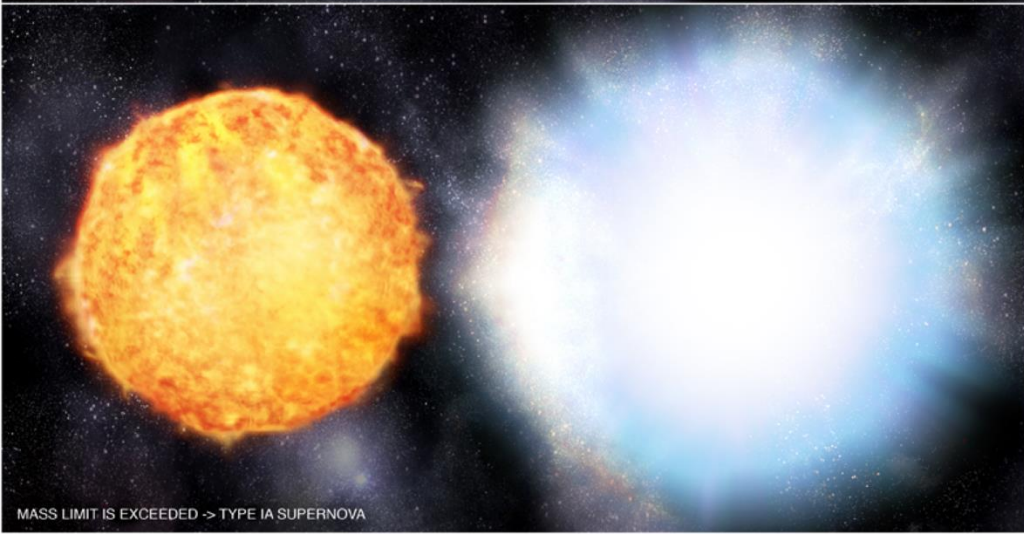


Correlations are most simply interpreted as resulting from different progenitor *masses*, but can also indicate different progenitor *types*.

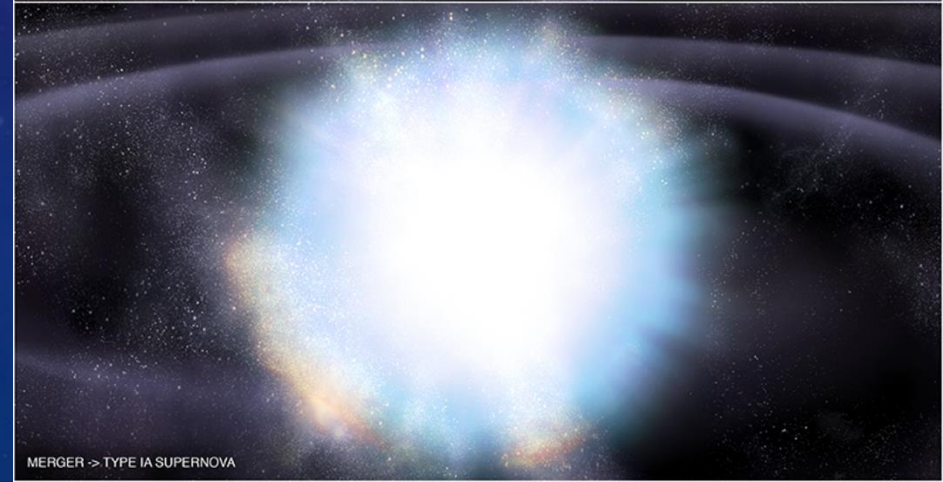
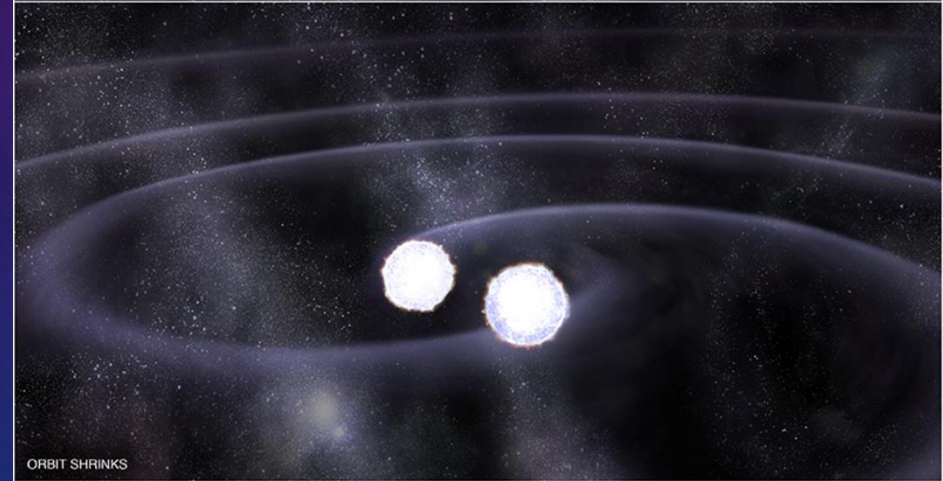
TYPE IA SUPERNOVA PROGENITORS



Single-Degenerate System:
one WD, one main-
sequence/giant companion



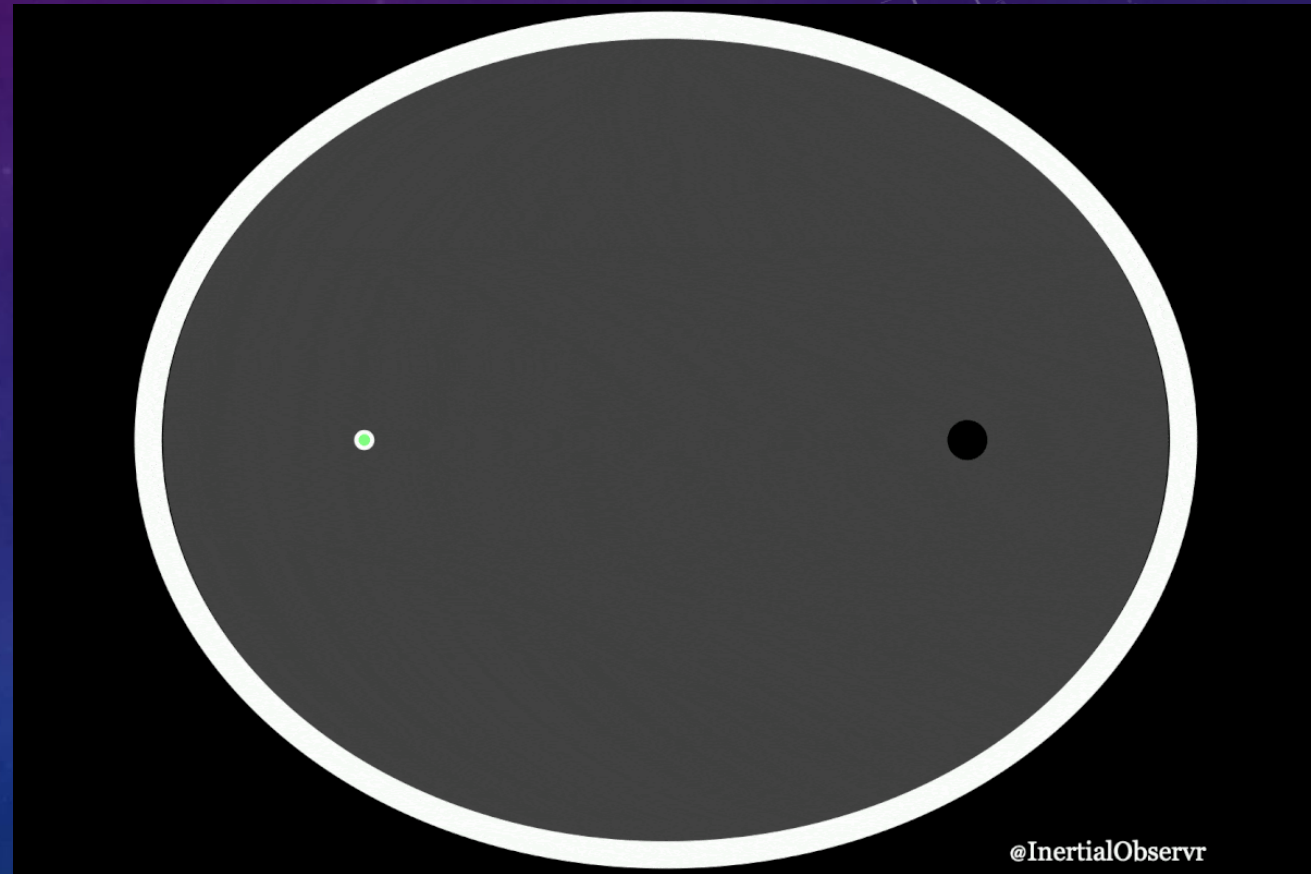
Double-Degenerate System:
two WDs



WHAT ARE LIGHT ECHOES?

- A **light echo** is a transient reflection nebula caused by dust scattering light from any bright, variable/transient source into our line of sight
- Only light that hits dust intersecting the non-physical “**equal-time-delay surface**” will be scattered towards us

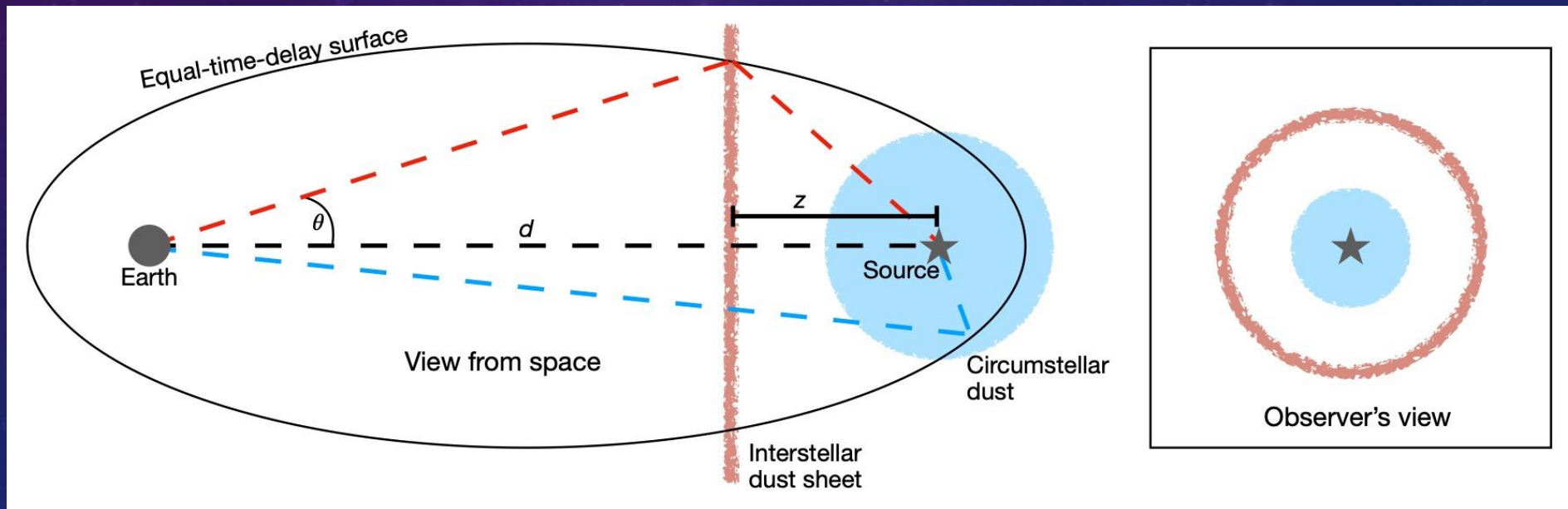
$$z = \frac{\theta^2 D^2}{2ct} - \frac{ct}{2}$$



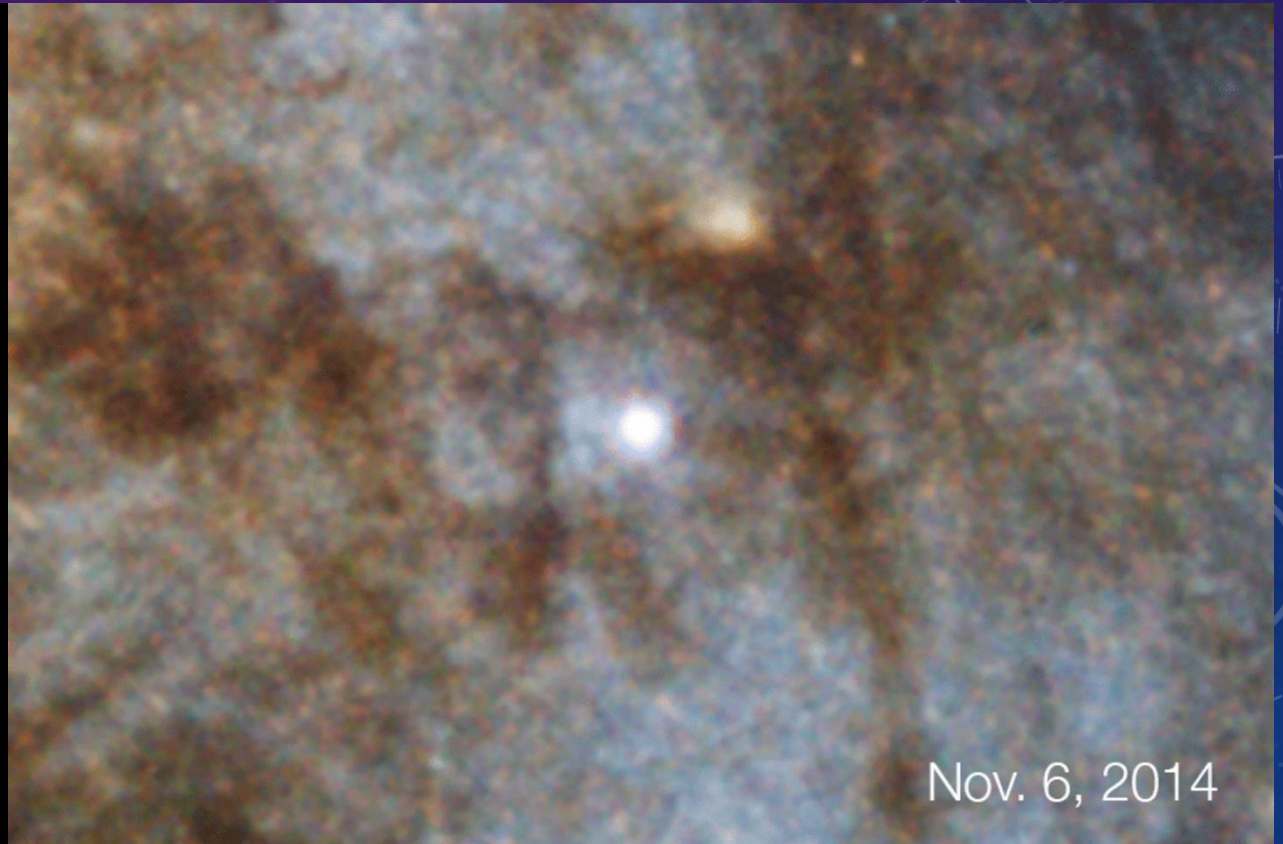
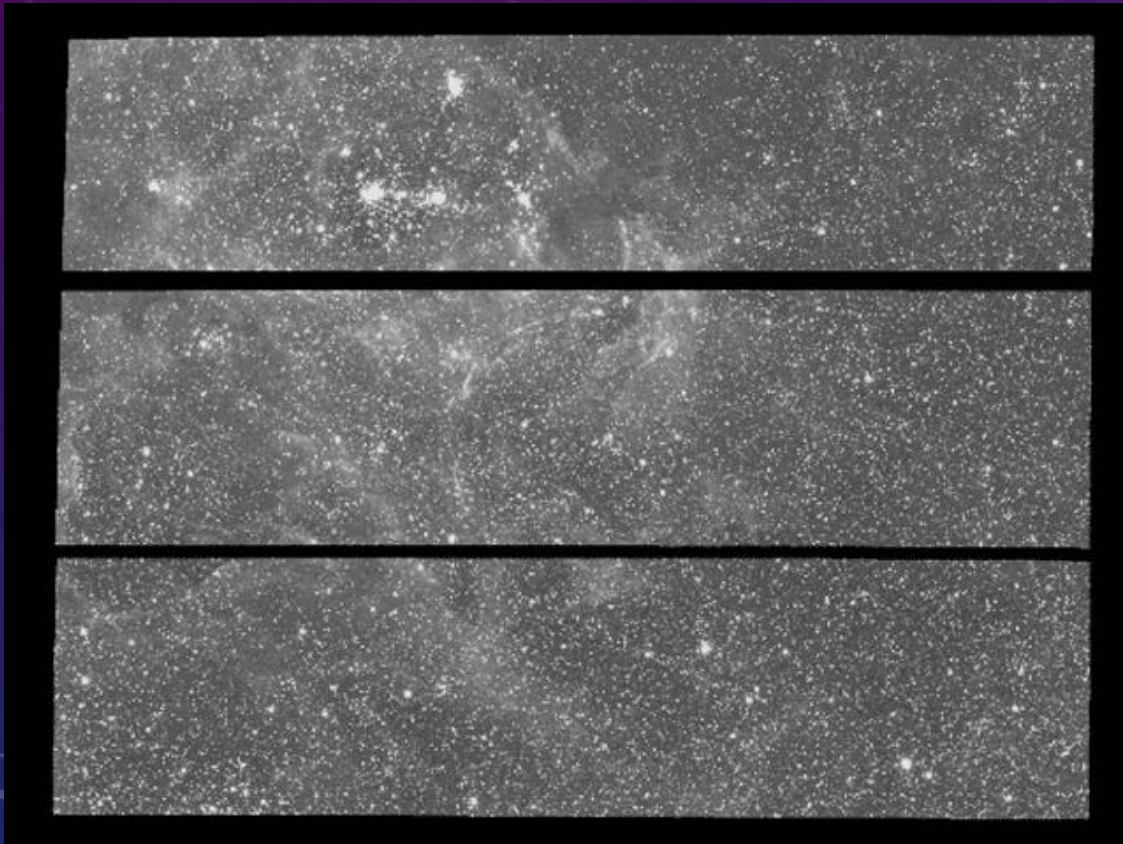
REVISITING SHOES: A SEARCH FOR LIGHT ECHOES INTERSTELLAR VS. CIRCUMSTELLAR DUST

Large, rapidly expanding rings/arcs are caused by *interstellar* dust

Compact, slowly fading disks are caused by *circumstellar* dust

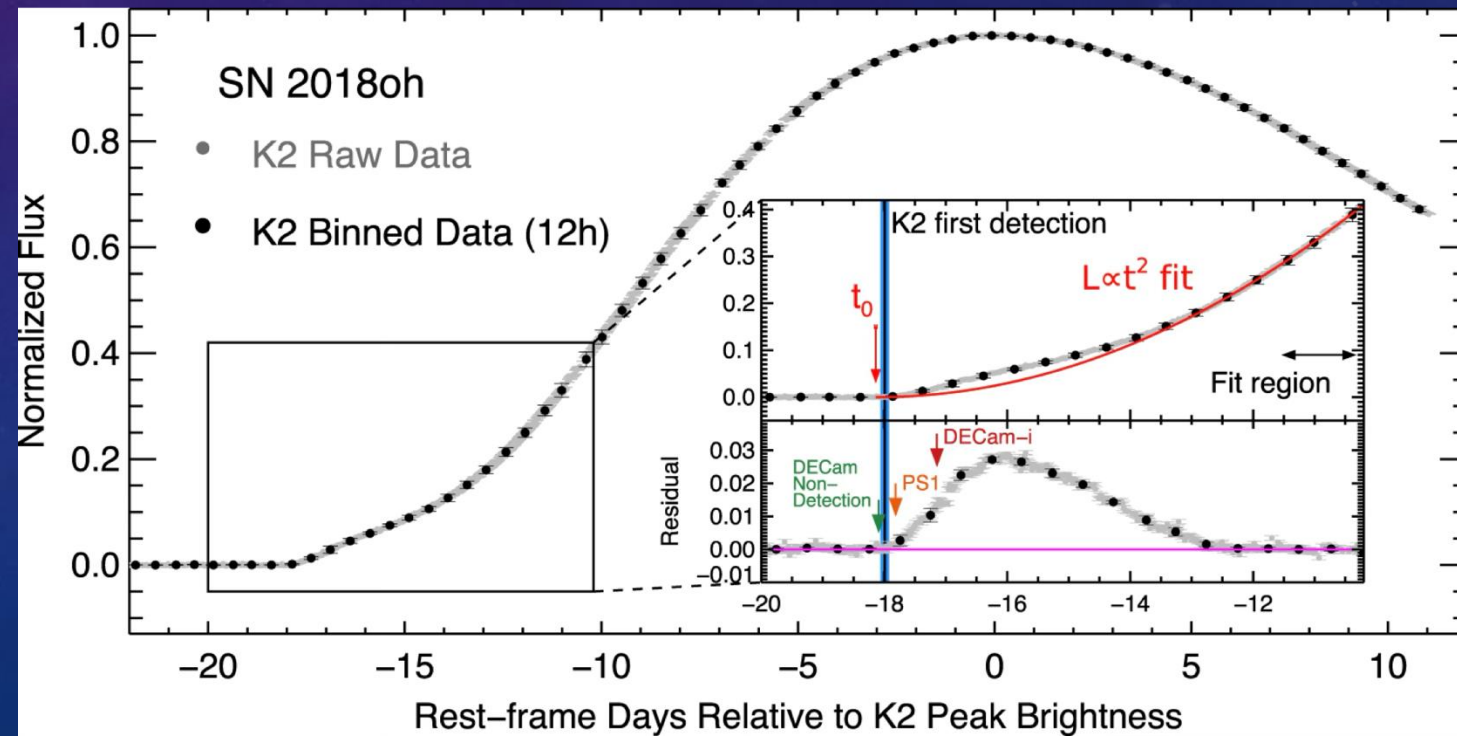
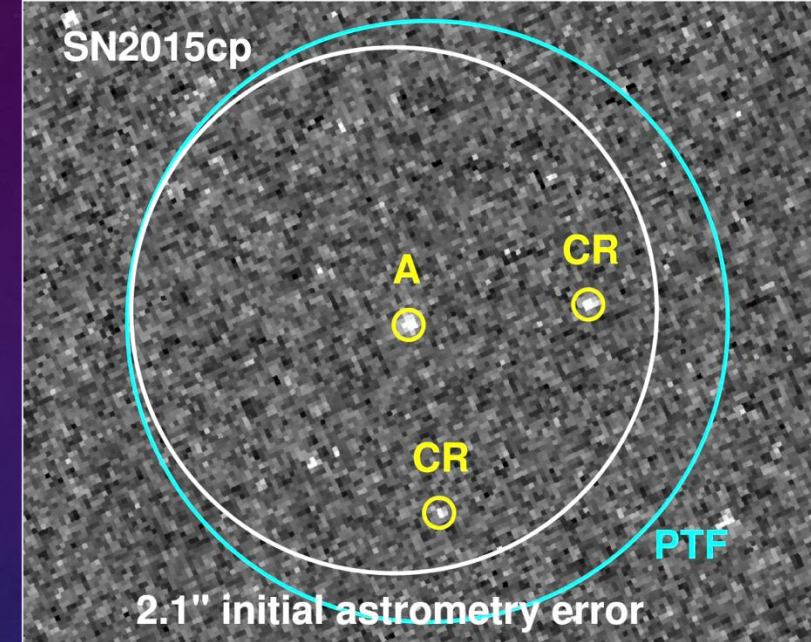


EXAMPLE: LIGHT ECHOES AROUND SN 1987A AND SN 2014J

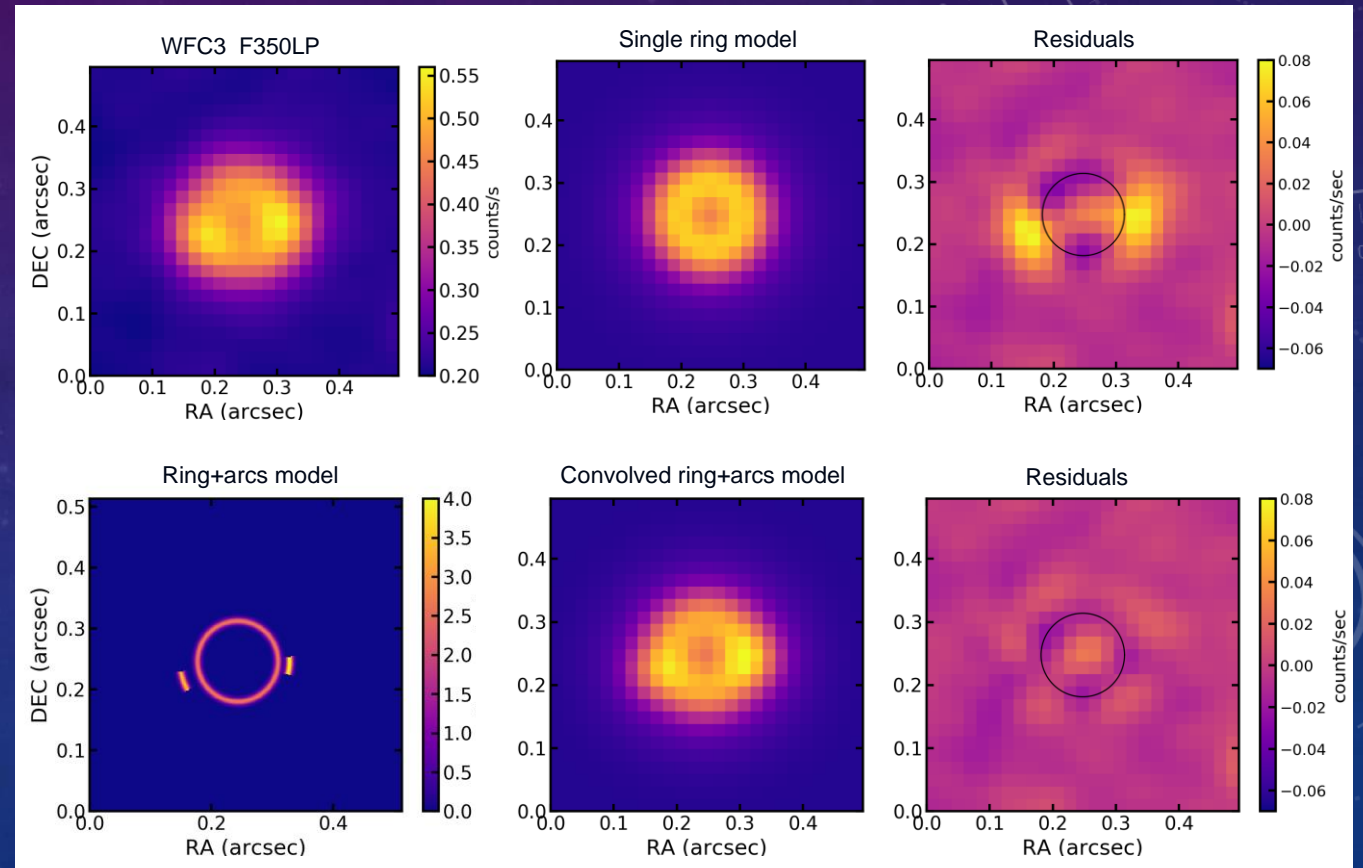
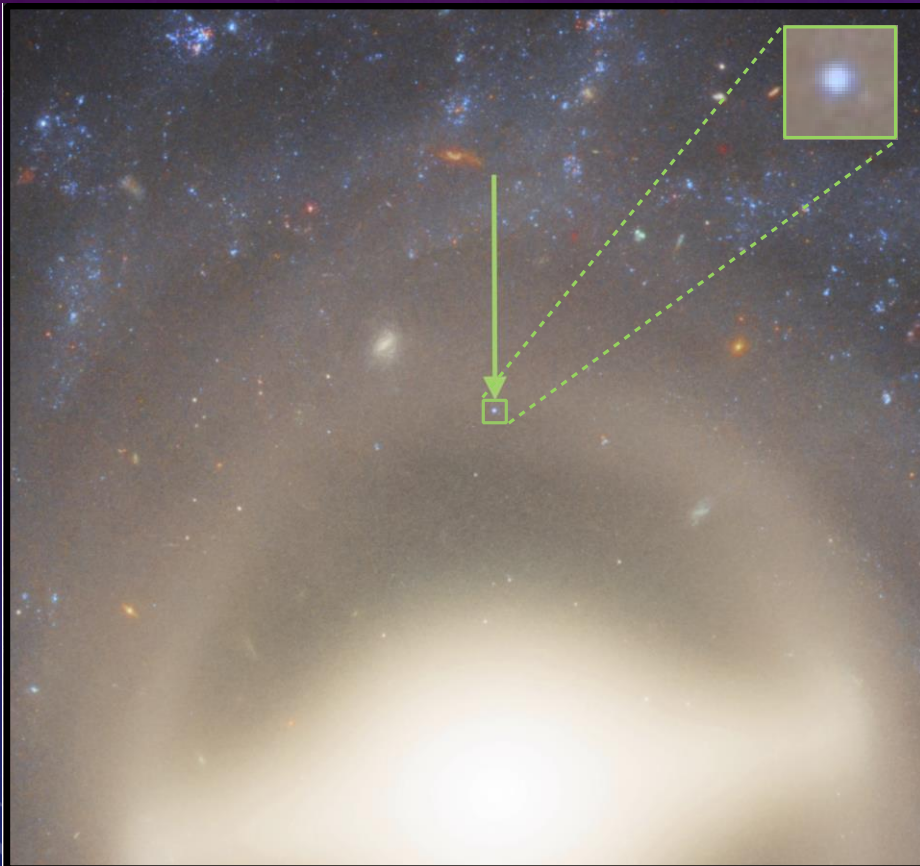


WHY USE LIGHT ECHOES?

- White dwarf stars are very faint – we cannot observe the progenitors of SNe Ia directly
- Methods for confirming single-degenerate scenarios involve looking for evidence of interactions between the dust in the accretion disk and the SN ejecta
- Caveats to other methods:
 - Interactions occur rarely and happen quickly
 - Even more rare to get high-quality data to prove the interaction occurred
- Benefits of light echoes:
 - Are visible immediately after the SN fades and stay visible for decades
 - Easy to get high-quality imaging



BUILDING THE SAMPLE – A SEARCH FOR LIGHT ECHOES IN THE SHOES DATASET



HOW CAN YOU BE INVOLVED?

- The SHOES dataset consists of 42 SNe Ia, which all need the same initial data analysis completed
 - Potential project: Help automate the initial data reduction pipeline
- Any new light echoes found will need a more in-depth analysis
 - Potential project: Repeat the analysis done on SN 2009ig for other SNe
- New SNe are occurring often and may occur in previously observed SHOES galaxies or galaxies of similar type and distance
 - Potential project: Find recent SNe that would be good candidates for hosting a light echo and check if there is already sufficient data