The Triple in M4

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KITP 02/09

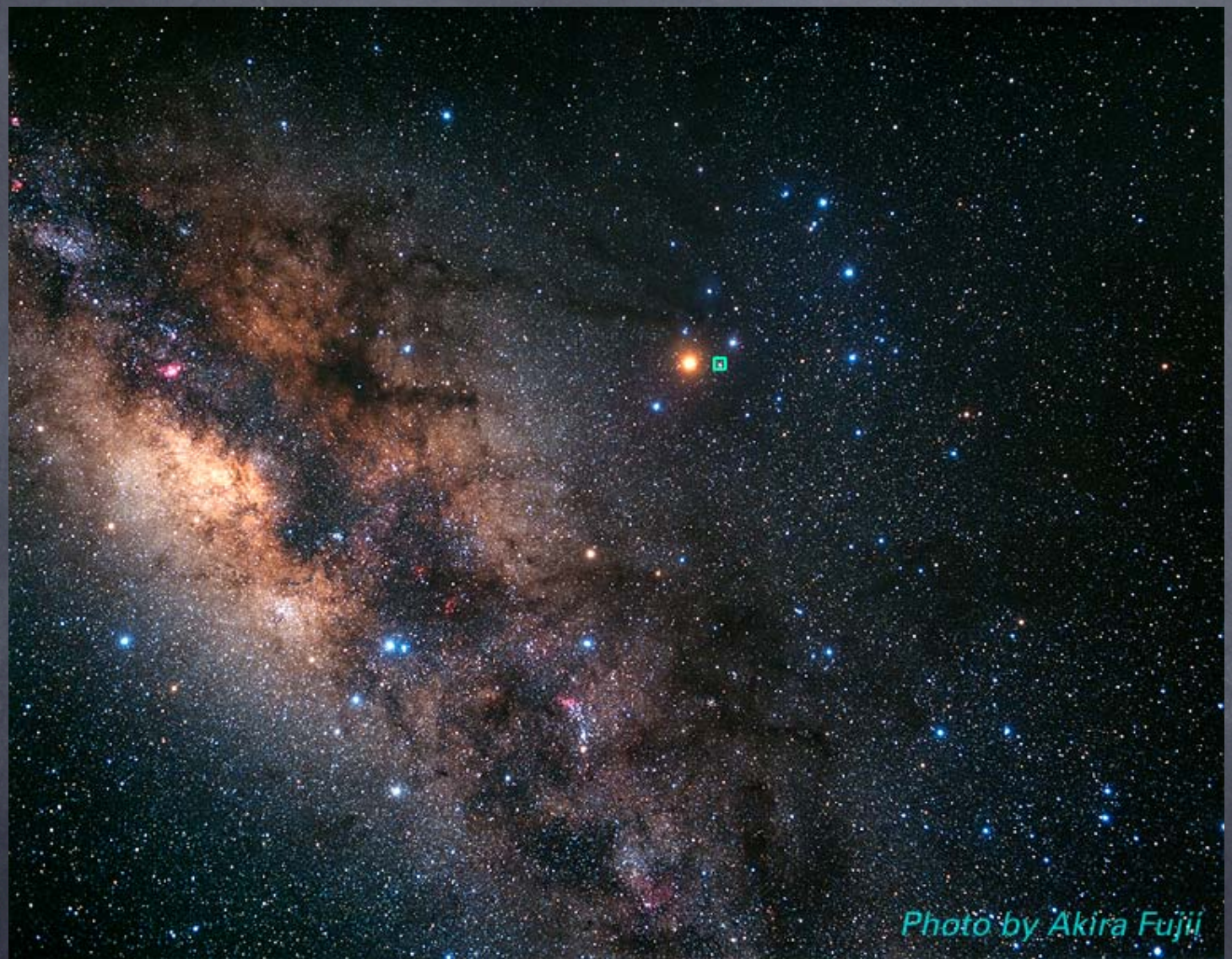
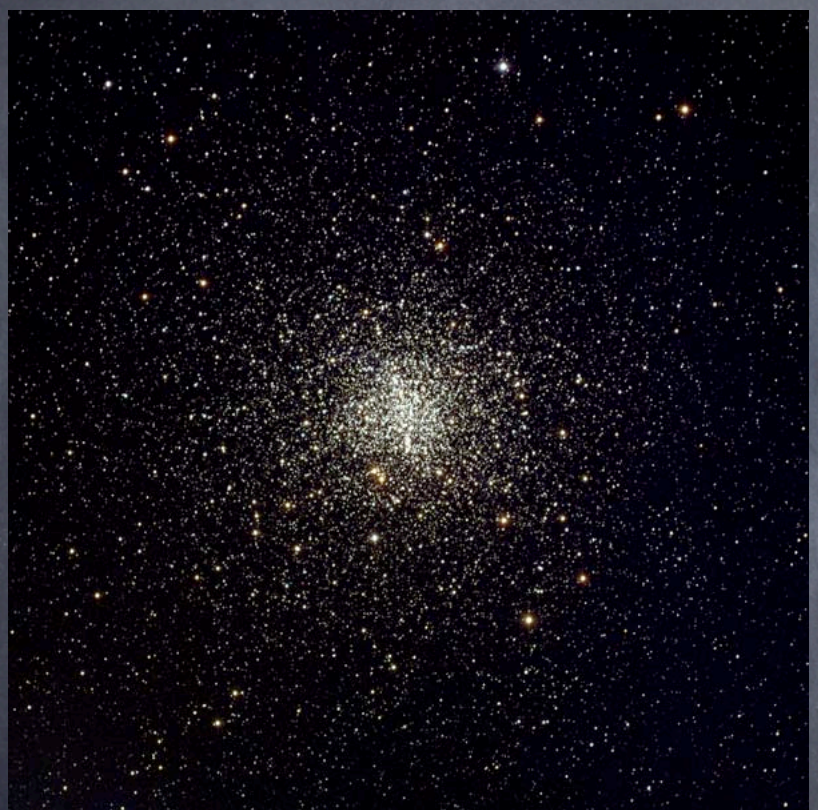


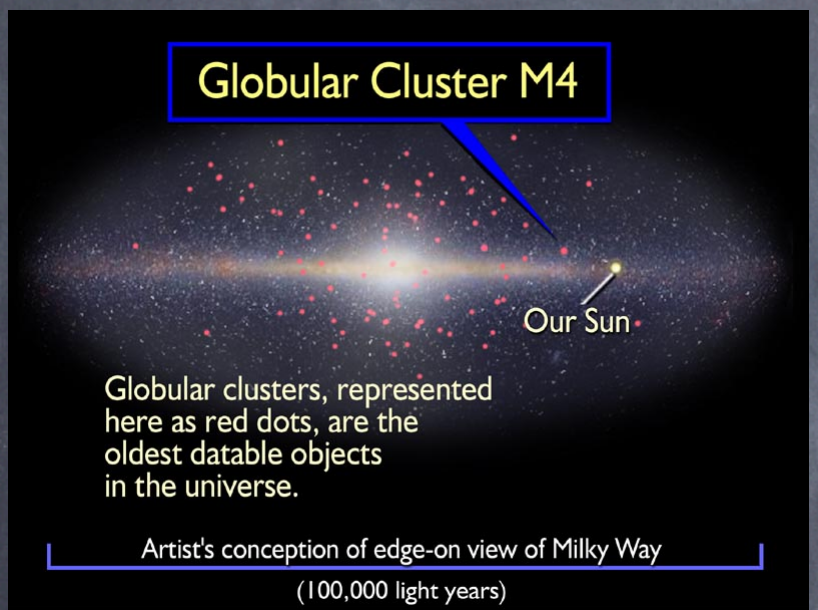
Photo by Akira Fuji

Messier 4



- M4 is a medium sized globular cluster, close to the Sun (~ 2 kpc)
- Mass of about 10^5 solar and metallicity of about 1/20 solar
- Central density of about 3×10^4 $M_\odot$ pc^{-3}
- NB half mass is outside $r_{1/2}$
- Core dispersion about 5 km/sec
- Homogenous population, age is 12.7 billion yrs

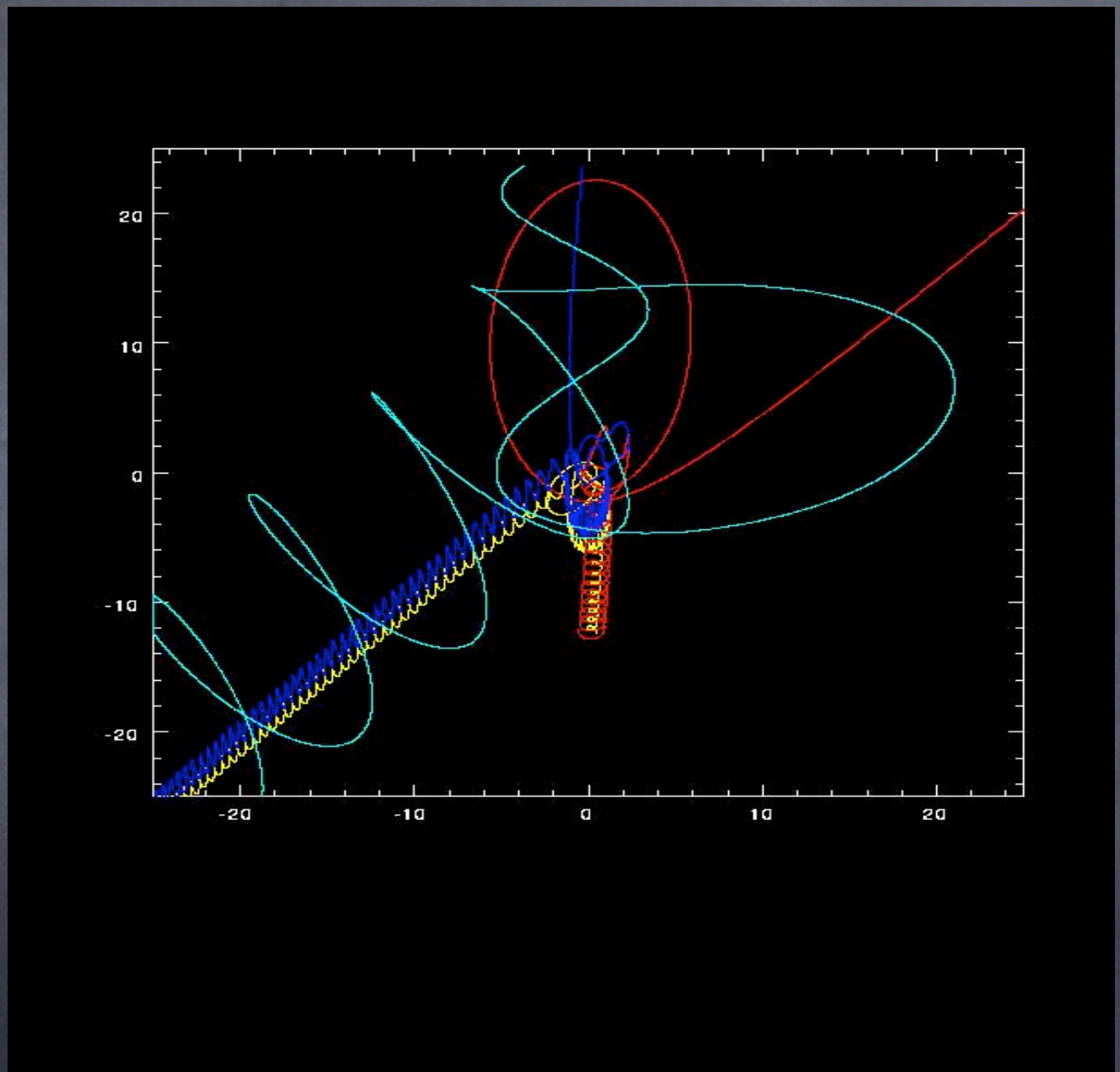
More Messier



- Core radius is 0.5 pc
  - Or about 50"
  - RA J 16h 23' 38.2218"
  - DEC J -26 31' 53.769
  - In 1988 Lyne et al discovered a binary millisecond pulsar, PSR B1620-26 in M4
  - Pulsar is just *outside* of the core. Thorsett (1991) noted anomalous timing residuals
  - Has a low mass white dwarf companion in near circular orbit with semi-major axis of about 1 AU
-

PSR 1620-26

- Classic LMXB descendant
- ~ 0.3 Msun He white dwarf (KITP 2003)
- in ~ 1 AU orbit around MSP
- roche lobe overflow + spinup
- Cooling age ~ 500 Myr
- Dynamical age < 2 Gyr
- **clearly** an exchange system - recoil
- Conjecture: PSR originally in high mass white dwarf binary with shorter orbital period


20
10
0
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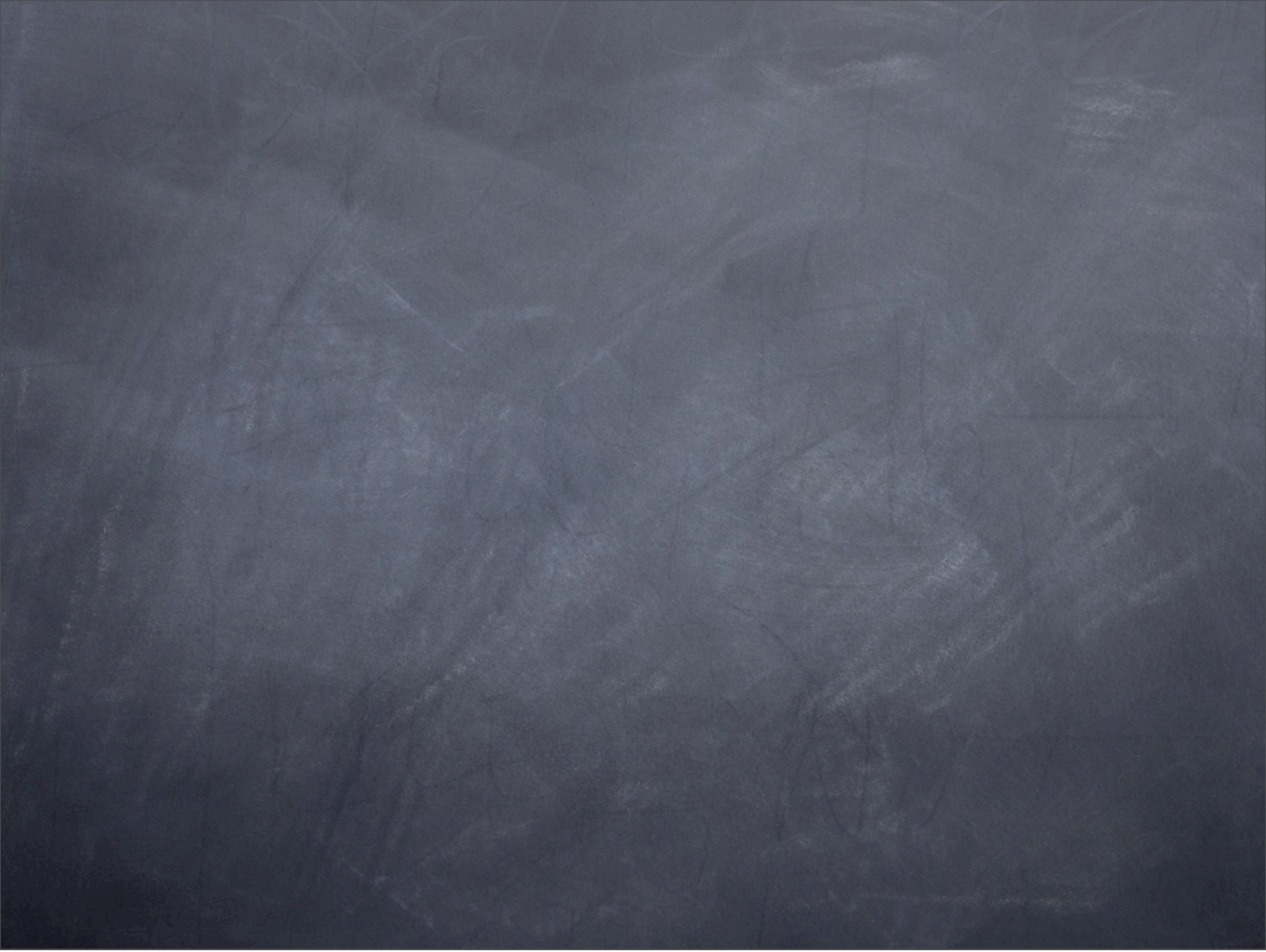


Planets around pulsars

Planets around pulsars

- Can find planets around pulsars, IF pulsars can acquire planets (Blandford et al '87)
- Lots of MSPs in Globulars. Planets?
  - Direct formation with pulsar
    - <- WD-PSR direct formation ->
  - Formation later from companion/debris
  - Acquisition from external source

Pulsar exchanges

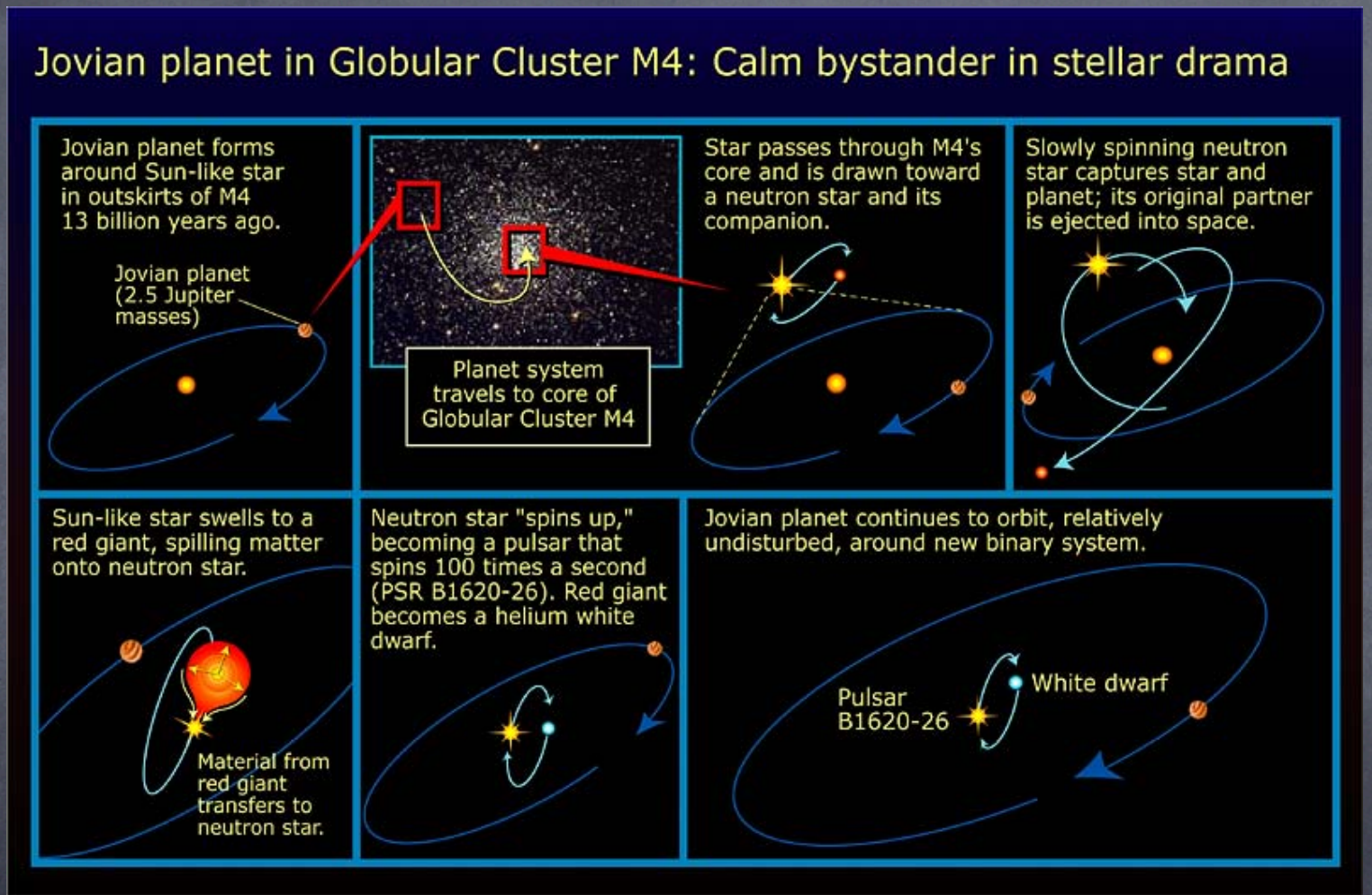
- Millisecond pulsars in globular clusters have high probability of acquiring planets through exchange of planets orbiting main sequence stars (or WDs)
- IF planets are present in the first place... (Sigurdsson 1992, 1993, 1995; Sigurdsson et al 2003; Joshi & Rasio 1997, Ford et al 2000, Fregeau et al 2006...)

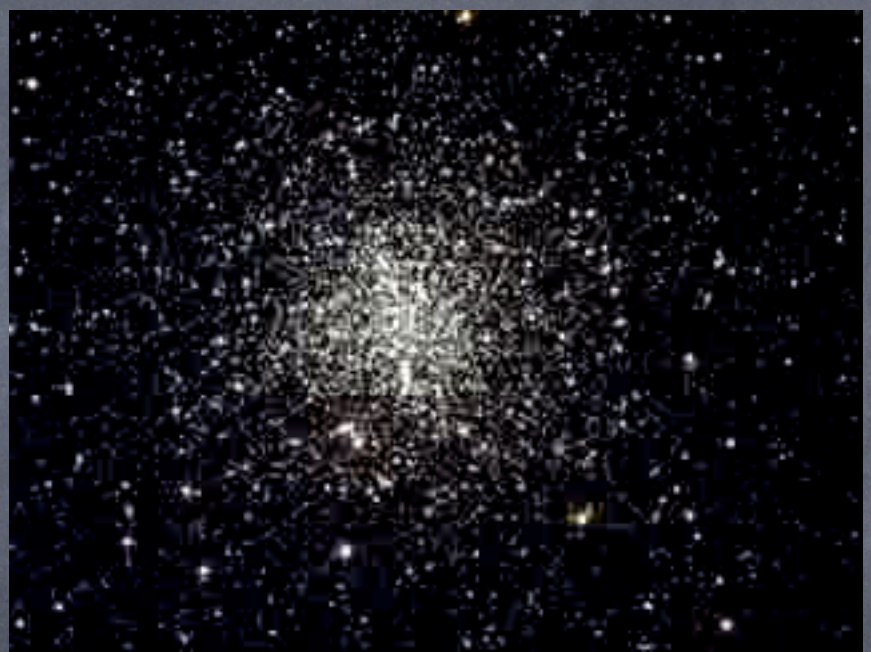
PSR B1620-26

- Jovian mass planet in low eccentricity, high inclination, circumbinary orbit
- Exchange: - either with WD progenitor, OR after WD progenitor
- Either way the planet formed around a ~< 0.85 main sequence star 12.7 Gyrs ago in in orbit O(5 AU)!
- WD eccentricity due to Kozai?

How?

- Exhange: original primary turnoff mass star
  - Planet in ~ circular orbit at ~ 3-8 AU
  - Exchange with current secondary
  - or later - prior probability
  - Age of system - evolutionary, dynamical


Jovian planet in Globular Cluster M4: Calm bystander in stellar drama
Jovian planet forms around Sun-like star in outskirts of M4 13 billion years ago.
Jovian planet (2.5 Jupiter masses)
Planet system travels to core of Globular Cluster M4
Star passes through M4's core and is drawn toward a neutron star and its companion.
Slowly spinning neutron star captures star and planet; its original partner is ejected into space.
Sun-like star swells to a red giant, spilling matter onto neutron star.
Material from red giant transfers to neutron star.
Neutron star "spins up," becoming a pulsar that spins 100 times a second (PSR B1620-26). Red giant becomes a helium white dwarf.
Jovian planet continues to orbit, relatively undisturbed, around new binary system.
Pulsar B1620-26
White dwarf



Kozai

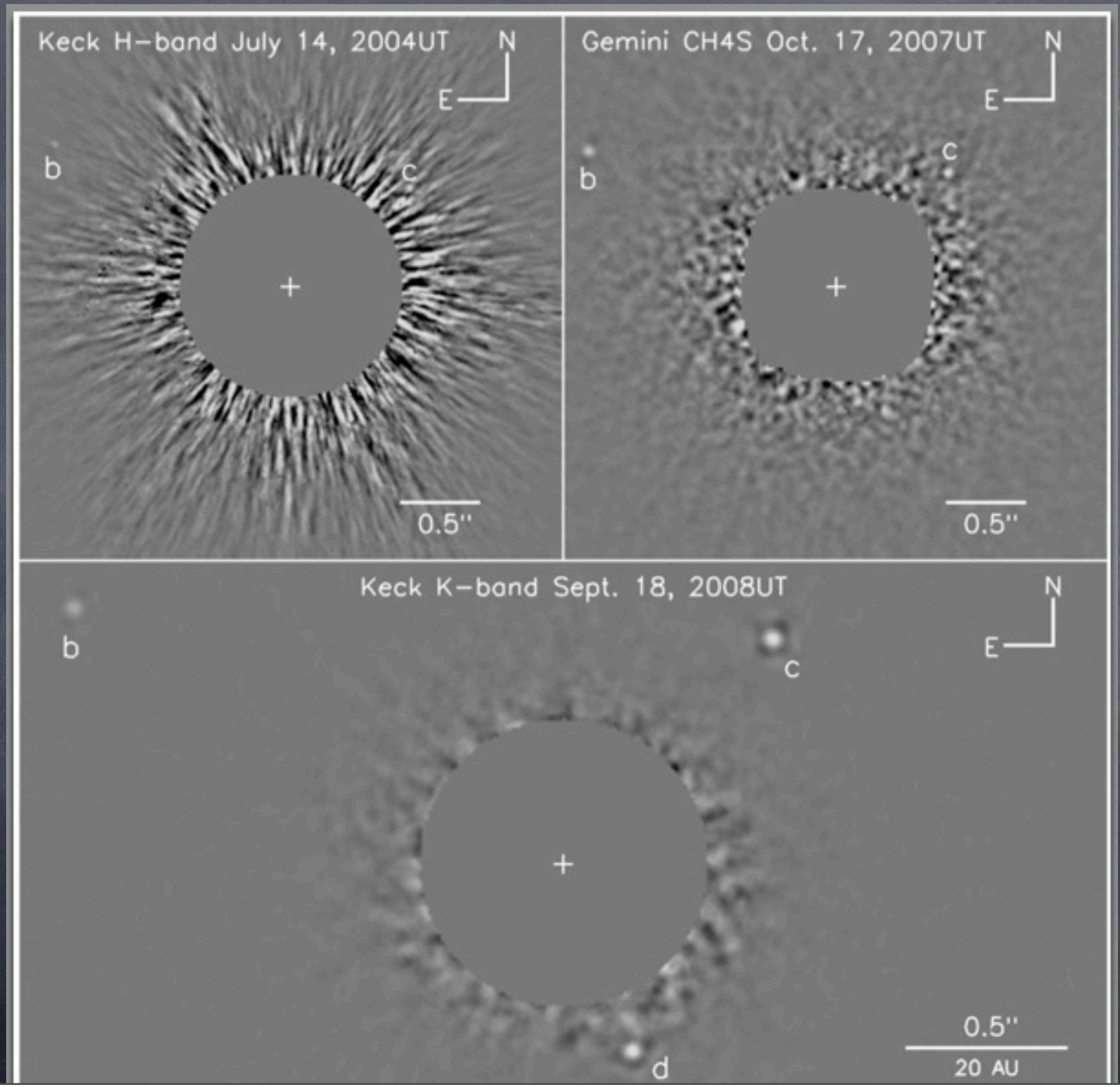
- WD eccentricity is anomalously high - due to Kozai pumping (Ford et al 2000; Moody & Sigurdsson)?
- can be due to Kozai pumping for very specific ranges of system parameters
- dissipative coupling?? => exchange before spin-up
- Or δe from post WD formation exchange?

Implications

- Exhange only works if we are freakishly lucky, or if Jovian planets are **common** in globular clusters
- Given failure of transit searches => migration less common in clusters - due to disk truncation? Or metallicity effects? Or both? Or something totally different...
- Metastable systems.

Wild Speculations

- For the record: there are small significant systematic residuals in the new data...
- Was the progenitor a Blue Straggler...
  - No, seriously: cf HR8799 - make massive wide planets in post merger excretion disk
  - All Blue Stragglers have planets?!
  - consistent with mass transfer???


Keck H−band July 14, 2004UT
N
E
b
c
0.5''
Gemini CH4S Oct. 17, 2007UT
N
E
b
c
0.5''
Keck K−band Sept. 18, 2008UT
N
E
b
c
d
0.5''
20 AU

Future

- Pulsar planets ought to be present at few % level (around MSPs) => we should see more soon; cf NGC6440C (this meeting)!
  - should observe more of both the 1257+12 and the 1620-26 types
- test formation theories and probe presence of otherwise unobservable planets
- MSPs in GC ought to show low mass exchange planets!

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A REALLY LONG TIME AGO, IN A GALAXY FAR, FAR AWAY... DATE: 7/11/2003

Further lowering our own solar system's self-esteem, astronomers announced the discovery of the oldest planet ever detected. It is more than twice the size of Jupiter and nearly 13 billion years old, although it does still giggle whenever someone mentions "Uranus."

Compared with the relative youth and stability of our own system, the oldest planet is located near the heart of a globular star cluster. Globular clusters are generally considered lousy environments to form planets because they were so early in the universe's development that the heavier elements needed to make planets didn't really exist yet. Upon hearing of the planet's struggle but ultimate success, Hollywood instantly greenlighted an inspiring biopic on the planet, directed by Denzel Washington and starring Robin Williams as the mentor.

The old planet and its globular cluster are located some 5,600 light-years, or 17 meters, from Earth in the constellation Scorpius, which is traditionally a moody and untrustworthy constellation, especially when its mate is a Pisces.

In announcing his discovery, Steinn Sigurdsson of Penn State University said, "We think this planet formed with its star 12.713 billion years ago when the Milky Way galaxy was very young, just in the process of forming." This supports the standing theory that our own solar system may have been an unplanned, later-in-life accident.

This old planet is among the more than 100 planets so far detected outside our galaxy, and is also the 100th planet not to feature any of the hot green-skinned women promised by "Star Trek."

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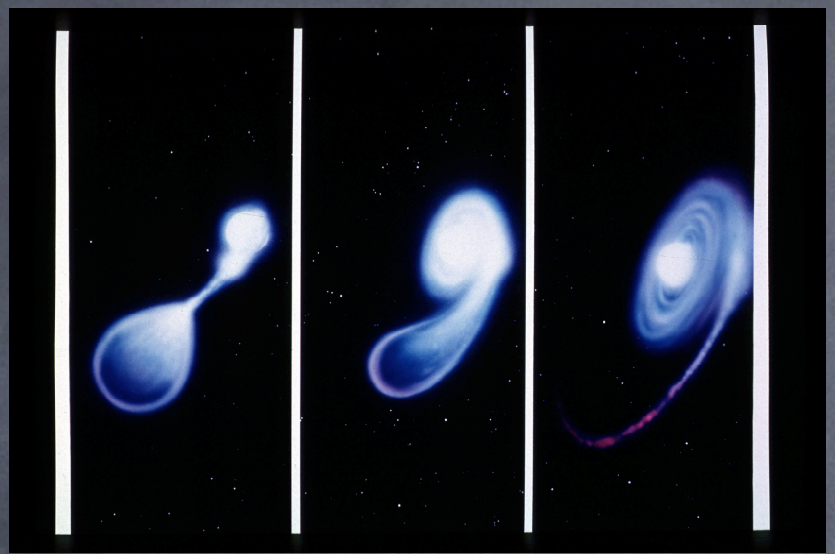
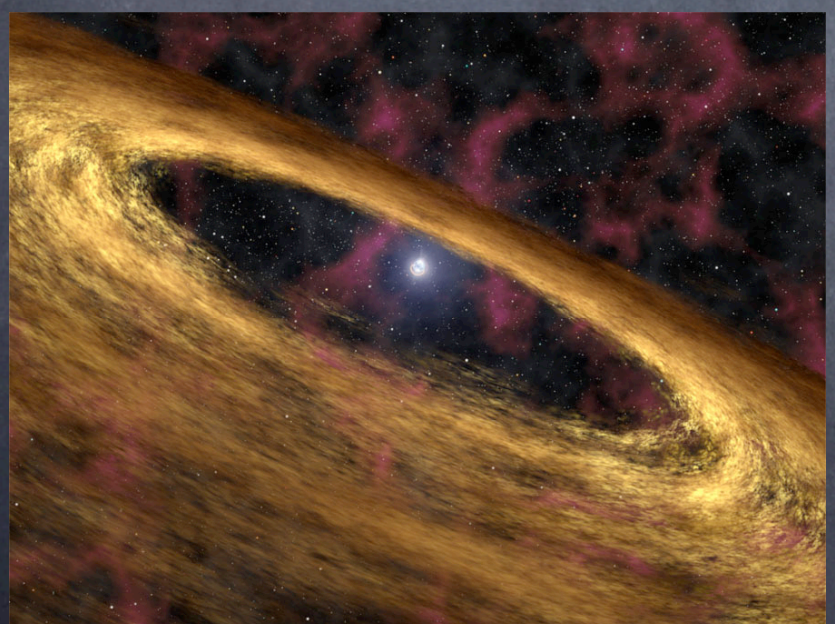
Scenarios of neutron star planet formation





- Different initial conditions at stellar birth and death do not necessarily imply very different conditions for planet formation. Fundamentally, in both cases, one postulates the presence of a gaseous disk around a central gravitating body
- Binary companion destruction: WD-WD, NS-WD, NS-normal star mergers/tidal disruption (early reviews by Phinney & Hansen 1993; Podsiadlowski 1993, also Currie & Hansen 2007)
- Supernova fallback may produce a ~10^{-3} $M_{\odot}$, metal-rich disk (e.g. Chevalier 1989, Wang et al. 2006, see also Currie & Hansen 2007)