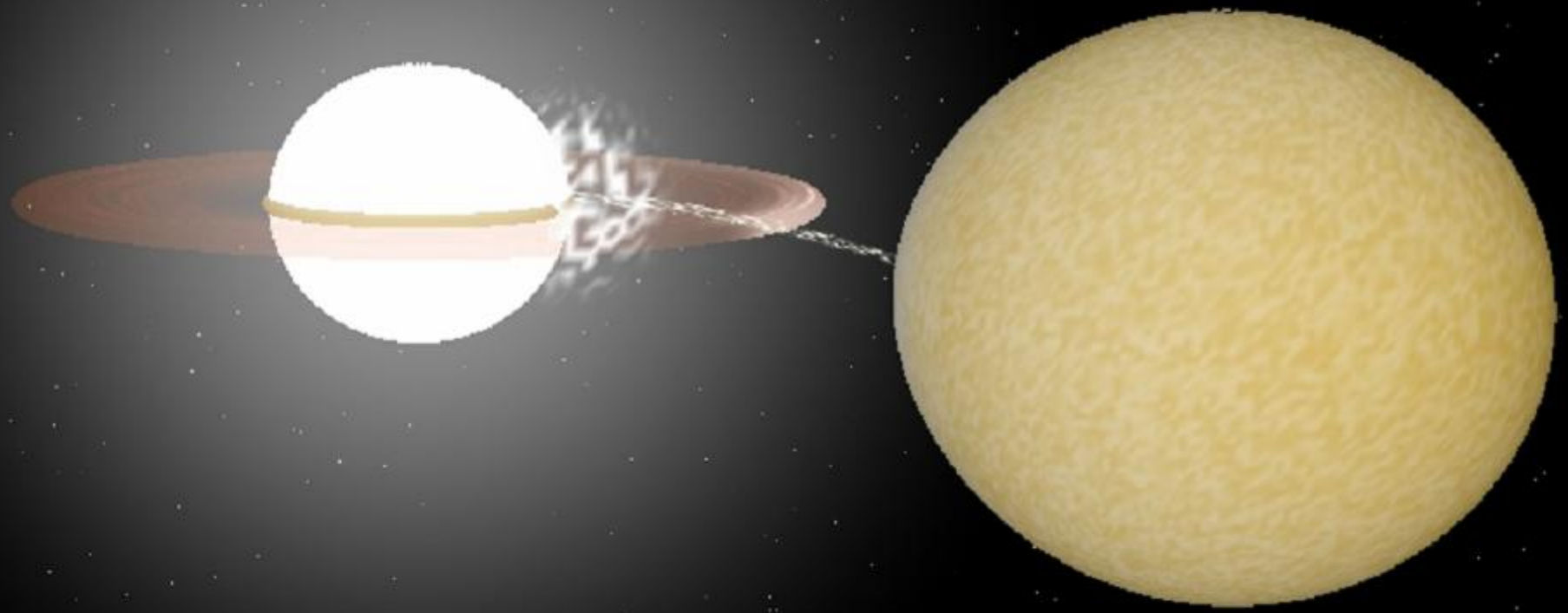
Ultracompact Binaries as GW sources



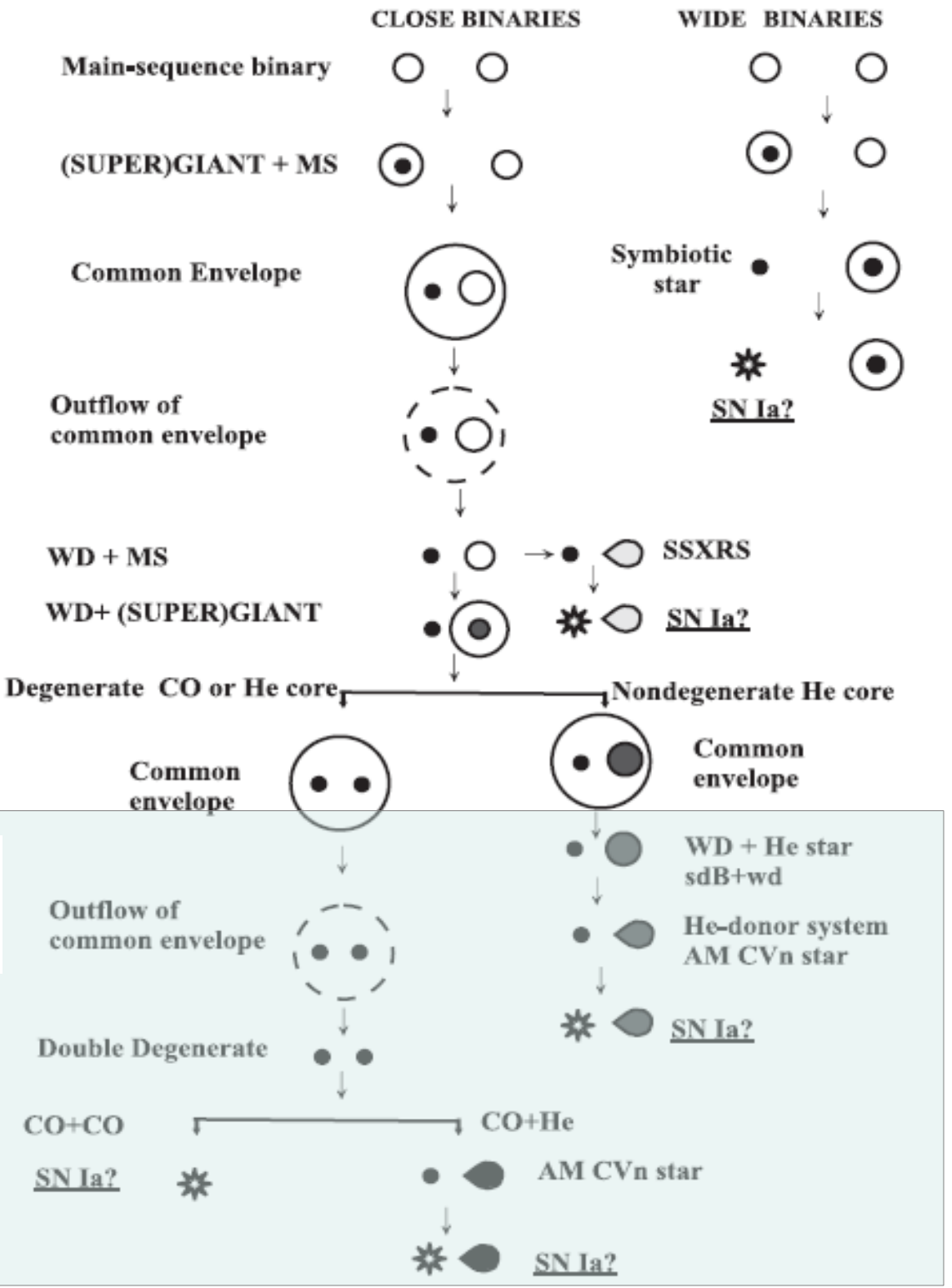
Paul Groot, Gijs Nelemans,
Radboud University Nijmegen

Binary evolution

Final evolution is completely set by gravitational wave emission!

$$\frac{\dot{J}}{J} = -\frac{32}{5}\frac{G^3}{c^5}\frac{M_1 M_2 (M_1 + M_2)}{a^4}$$

$$\frac{\dot{M}_2}{M_2} = \frac{\dot{J}}{J}\frac{2}{\zeta_2 + 5/3 - 2q},$$



Ultracompact Binaries

Stellar binaries with degenerate primary and secondary star

White dwarf

+ WD

10

- Detached
  Double degenerates
- Semi-detached:
  AM CVn stars

34

Neutron Star

+ WD

1

- Detached WD+NS systems:
  WD+pulsar
- Semi-detached:
  Ultracompact X-ray binary

9

+NS

- NS+NS system: **double pulsars**

3

Black Hole

+ WD ?

0

+ NS ?

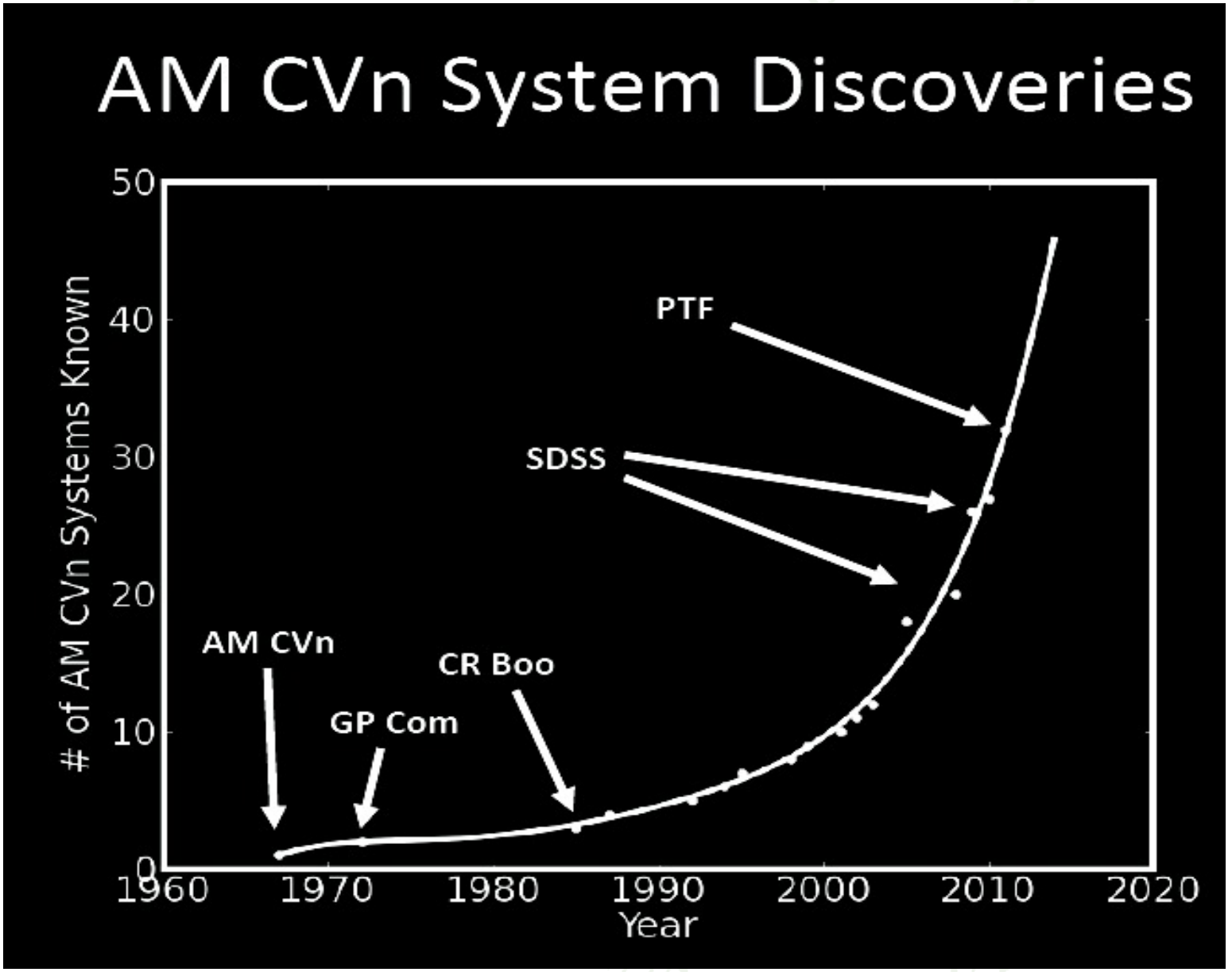
0

+ BH ?

0

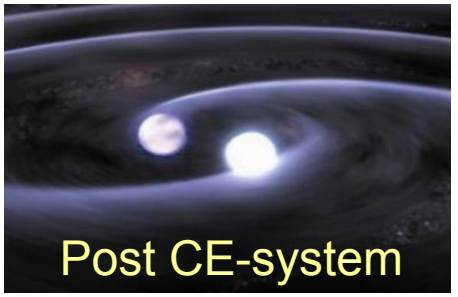
Short period systems: $P_{orbital}$ < few hrs
Intrinsically *rare!* Observationally rare!

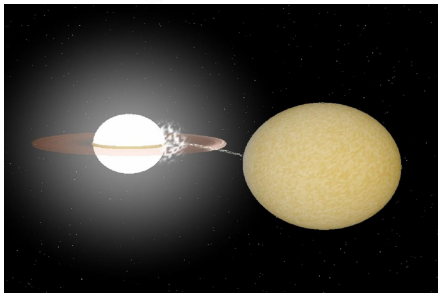
Number of AM CVn stars



Courtesy David Levitan

Gravitational wave evolution





Merger
SN Ia?

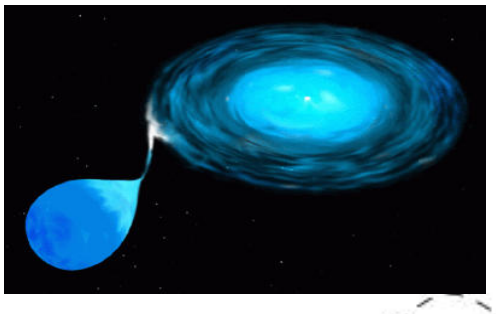
RLOF

Detached

LISA visible

LISA invisible

AM CVn



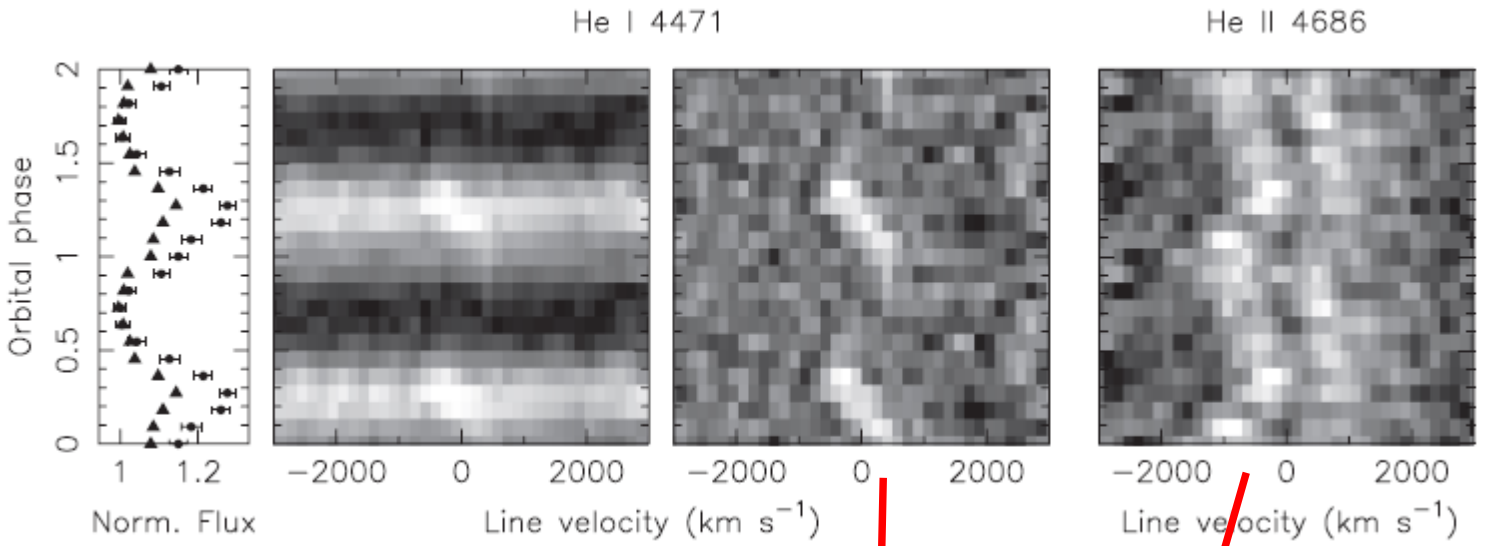
Gravitational wave strength

−20
−21
−22
−23

3.5
3
2.5
2
1.5

Orbital Period (log s)

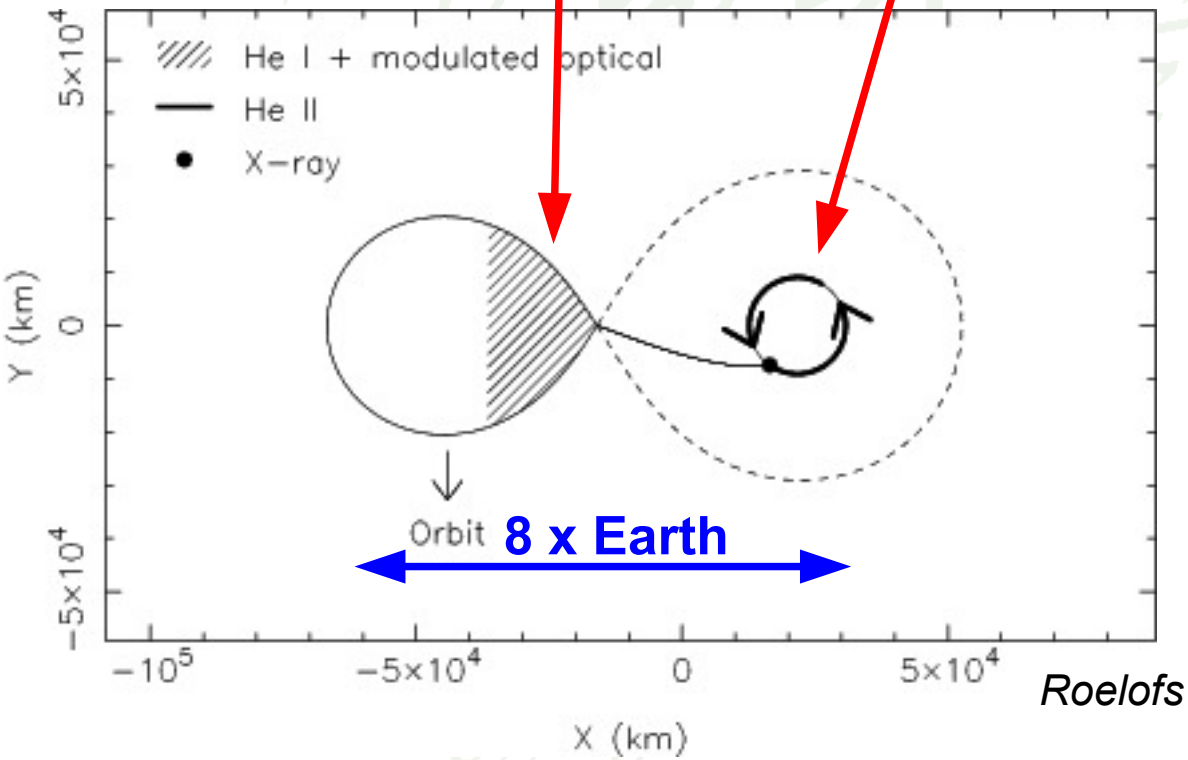
HM Cnc: P_{orb} = 5.4 min



System just started mass transfer:

Will most likely merge
(Roelofs & Deloye, 2010)

$M_1 = 0.55\ M_{sun}$
$M_2 = 0.27\ M_{sun}$



Roelofs et al., 2010

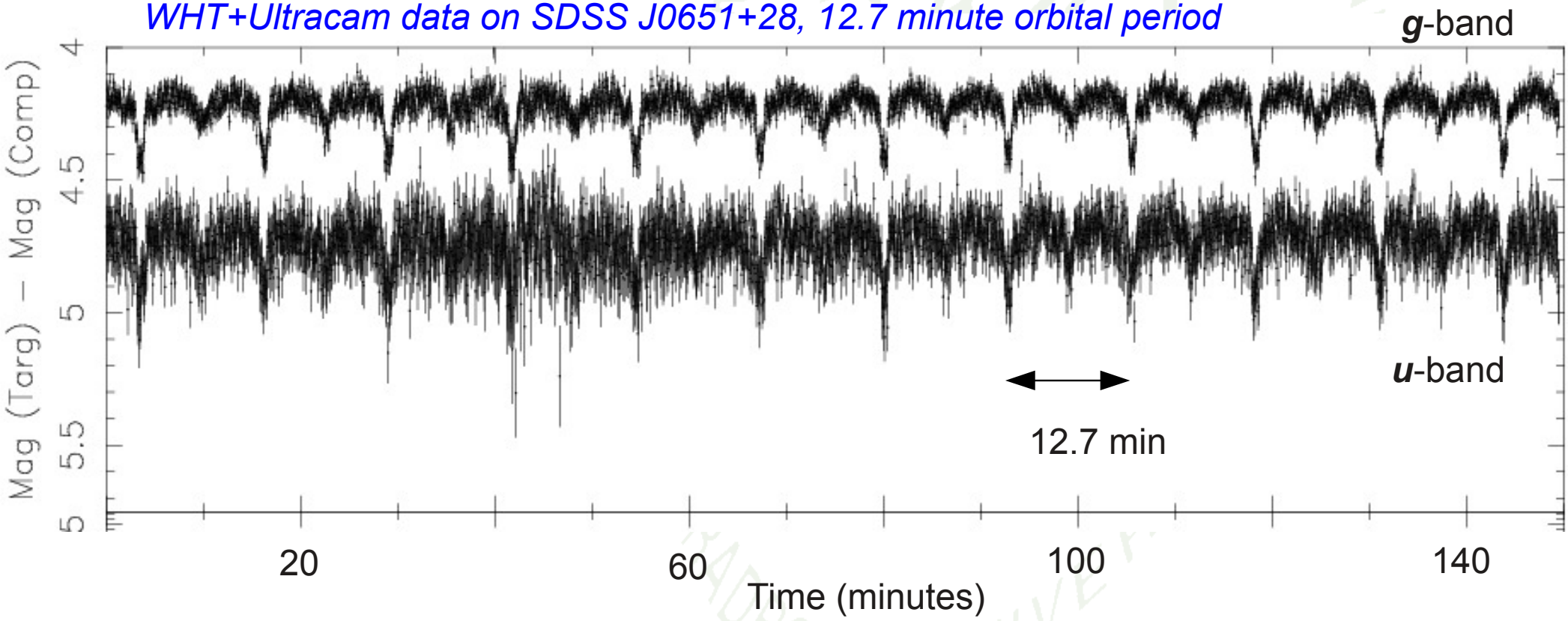
A detached eclipsing WD+WD binary

- SDSSJ0651+28; 12 minute orbital period!
- Merger time: 1 million years

(ELM survey; Kilic, Brown et al. 2011)

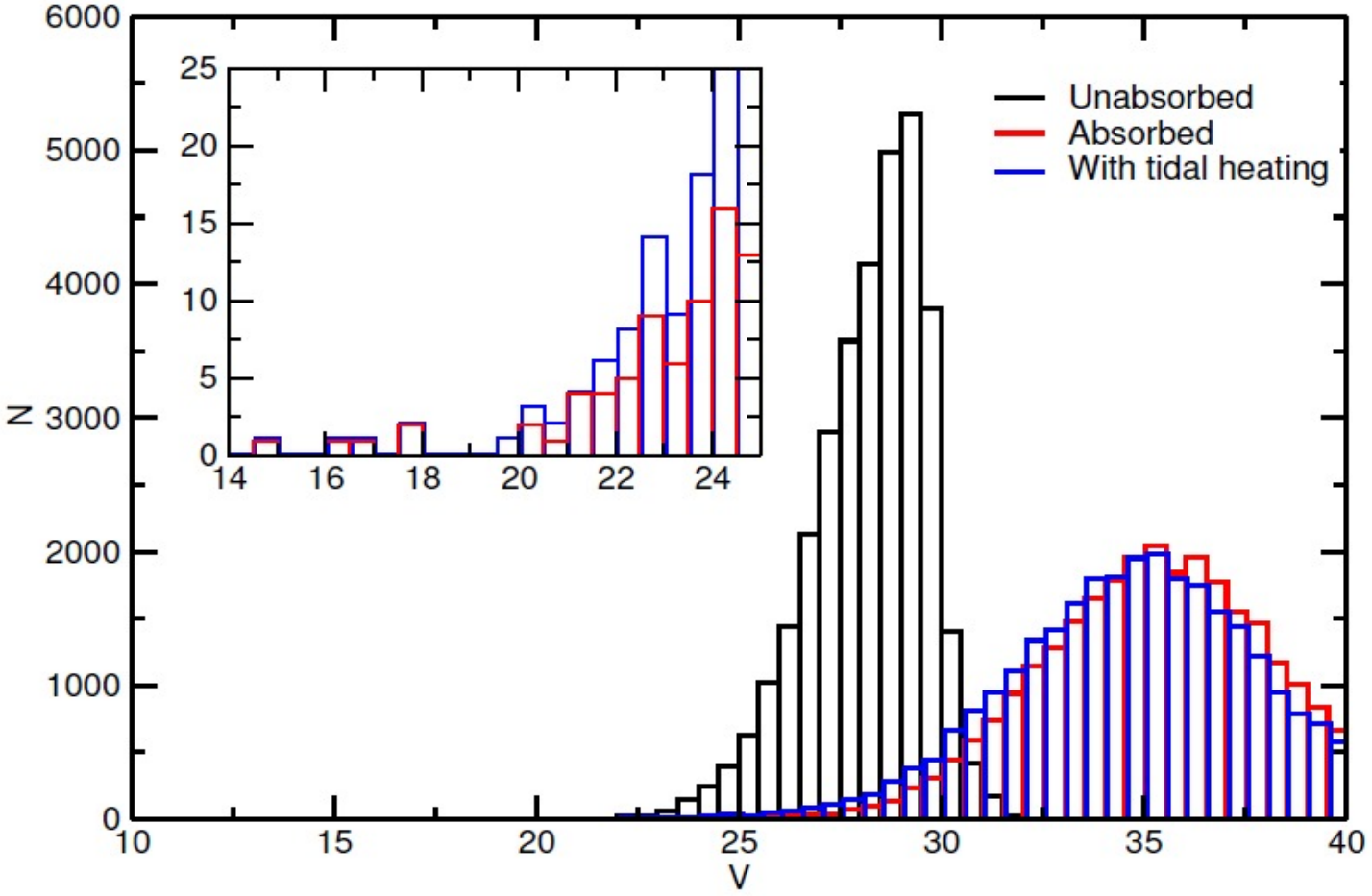
- Shift in time of arrival eclipses*:* 5s over 1 year
  if GR is only effect. If tidal locking: ToA > 5s

WHT+Ultracam data on SDSS J0651+28, 12.7 minute orbital period

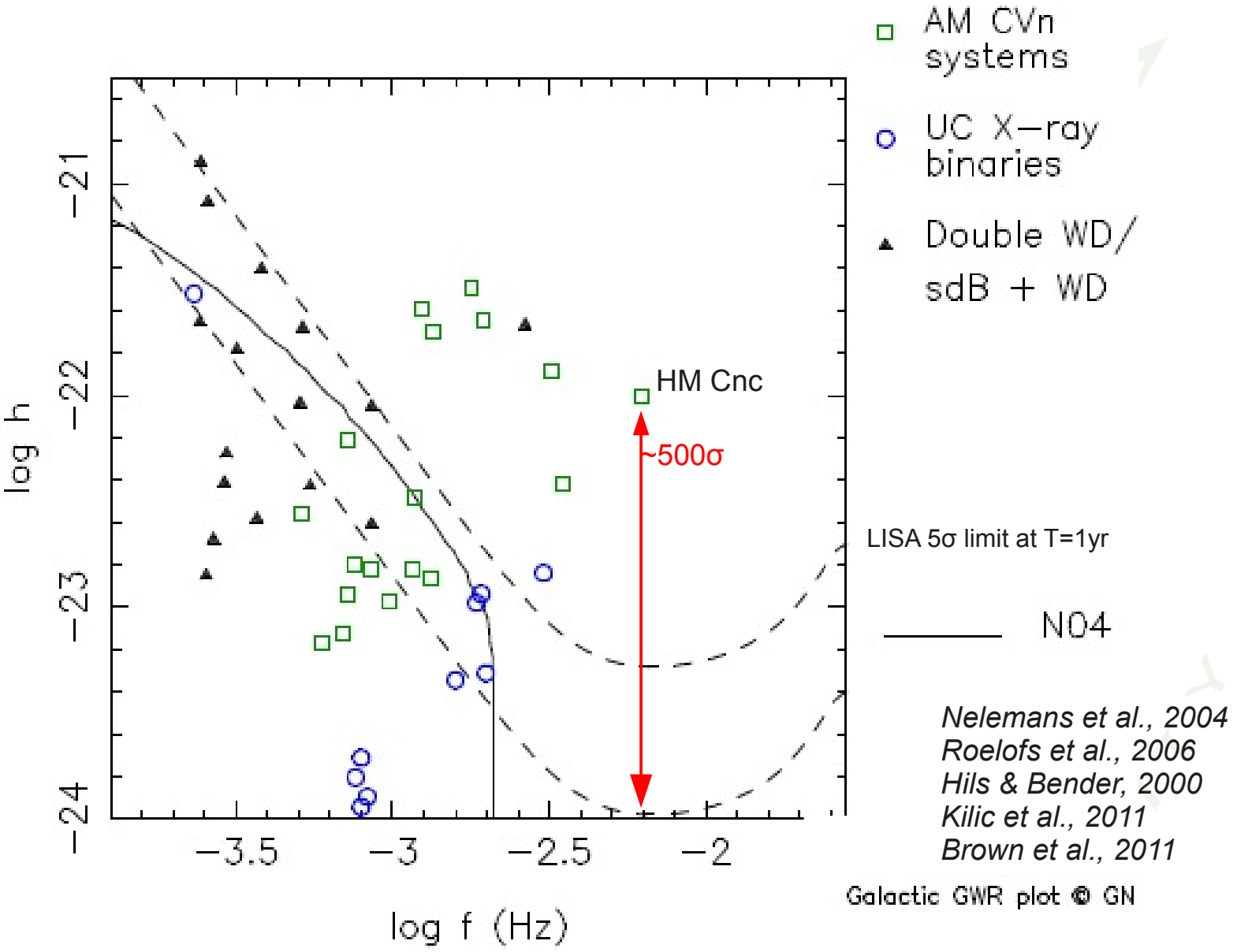


Population questions:

- How many in the Galaxy? Space densities
- How formed, which path, how often?
- Prior evolution: triple-point in evolution, survivors

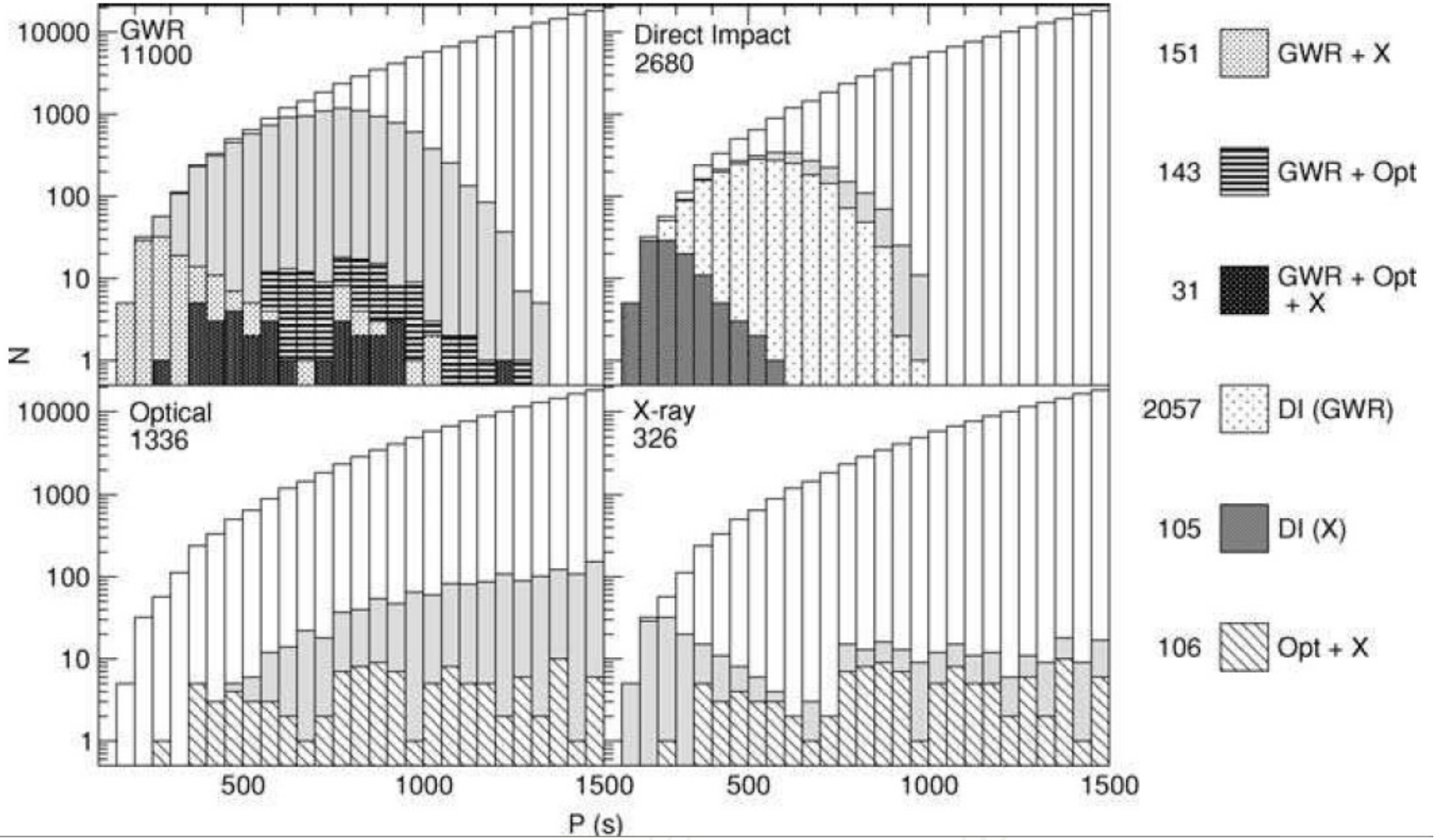


Gravitational wave population



Nelemans et al., 2004
Roelofs et al., 2006
Hils & Bender, 2000
Kilic et al., 2011
Brown et al., 2011

Galactic population of AM CVn systems



Nelemans, Yungelson & Portegies Zwart, 2004

Gravitational waves: future and issues

- GW are excellent ways of studying ultracompact binaries
- Ultracompact binaries are excellent test GR
- Ultracompact binaries are excellent verification eLISA
- First detections of NS+NS/NS+BH/BH-BH mergers with aLIGO/VIRGO

Issues:

- Crucial: Electromagnetic counterparts!

→ *See next talk Marica Branchesi*

- Use NL expertise in EM counterpart detections

→ *ERC Synergy grant Black Holes and Gravity (Nijmegen, Stockholm, Urbino)*

- Strategy: logical step: NL joins EGO,
  Combined FOM/NWO-EW program
  NL Astro work on EM detections

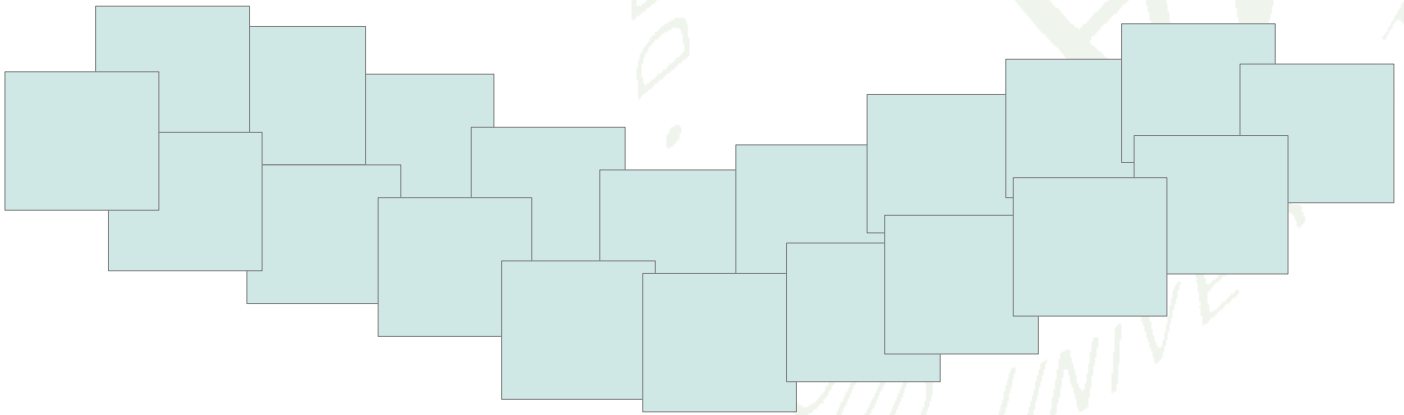
EM/Optical follow-up

- EM signals: γ/X-ray, radio, optical
- Optical has added value: redshift, hosts, environments
- *Needed:* position to ~100 sq.degr. @ T_0 + 10 min.

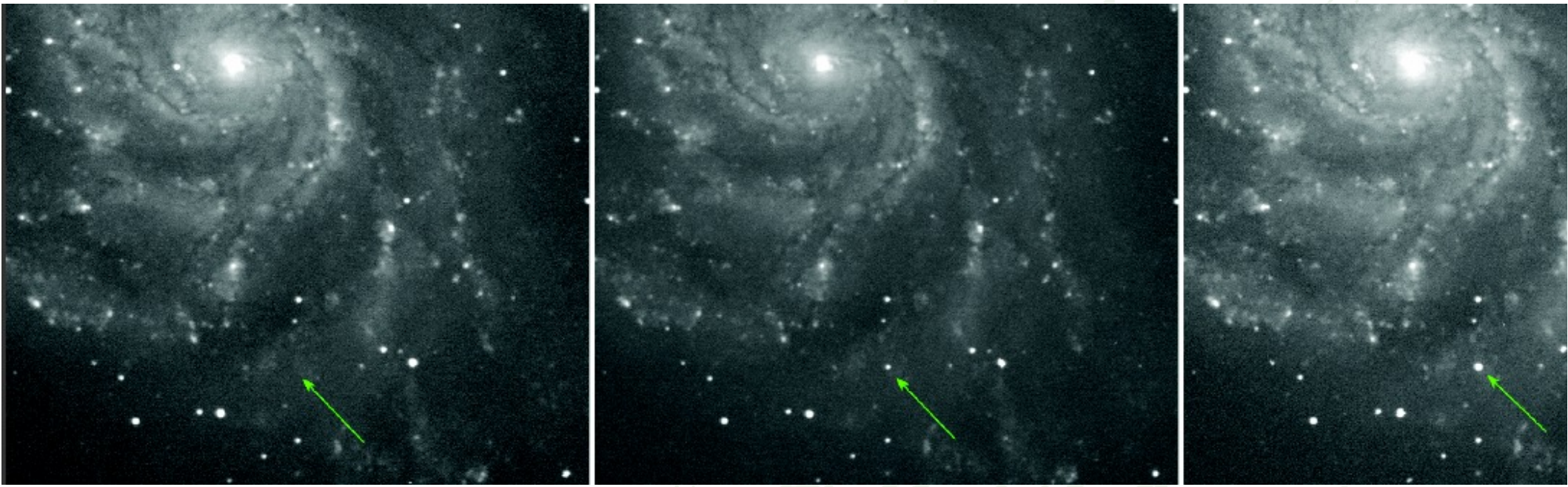
Don't wait for LSST to come around (2020+, 1G€). Act now

→ *North: Palomar Transient Factory 2: 45 sq.degr. imager 2014/2015 (10 M€)*

→ *South: 'Our' new proposed array of 20x50cm telescopes, each 0.75 sq.degr. => 15 sq.degr. in shape error box: 2015, 6 M€. Located at ESO La Silla, spec. follow-up with VLT/X-Shooter*



PTF/PTF2



SN Ia in M101, detected with PTF in August 2011 @ 7 Mpc