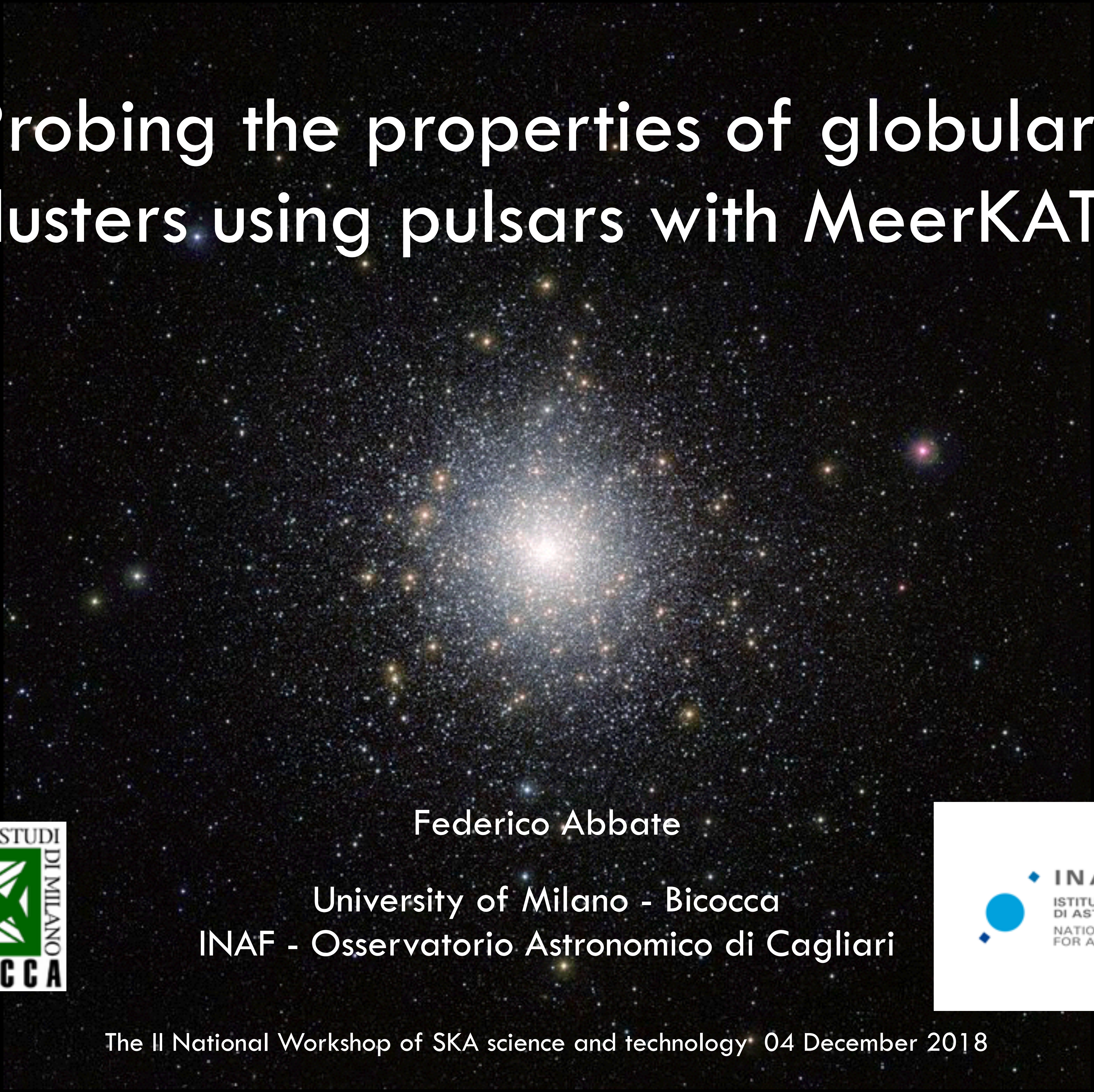

Probing the properties of globular clusters using pulsars with MeerKAT

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Globular cluster pulsars

Globular clusters are extremely dense

$$\sim 10^5 - 10^6\,\mathrm{M_\odot pc^{-3}}$$

Close encounters between stars are common

↓

Neutron stars acquire new companions and are recycled in millisecond pulsars efficiently

M15

Main research topics:

Exotic binaries

Black Widows
'Redbacks'
Eclipsing pulsars

Study of cluster properties

Pulsar timing

- Rotational period P

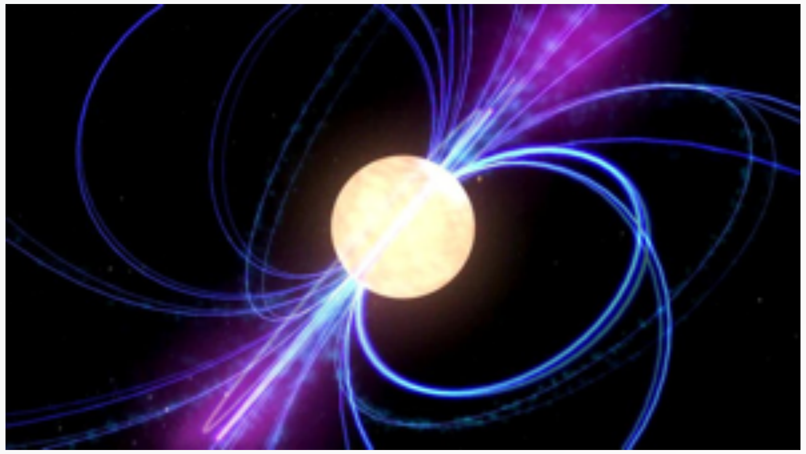
- First derivative of period $\dot{\mathrm{P}}$

$$\left(\frac{\dot{\mathrm{P}}}{\mathrm{P}}\right)_{\mathrm{meas}} = \left(\frac{\dot{\mathrm{P}}}{\mathrm{P}}\right)_{\mathrm{int}} + \frac{a_c}{c}$$

- Second derivative of period $\ddot{\mathrm{P}}$

$$\left(\frac{\ddot{\mathrm{P}}}{\mathrm{P}}\right)_{\mathrm{meas}} \propto \frac{\dot{a}}{c}$$

- Dispersion measure DM
- Faraday rotation measure RM



Cluster properties and IMBH

Estimate the three-dimensional position of the pulsars in the cluster

- **Probe the gravitational potential well of the host globular cluster**

Look for signatures of a central black hole in the accelerations and its derivatives

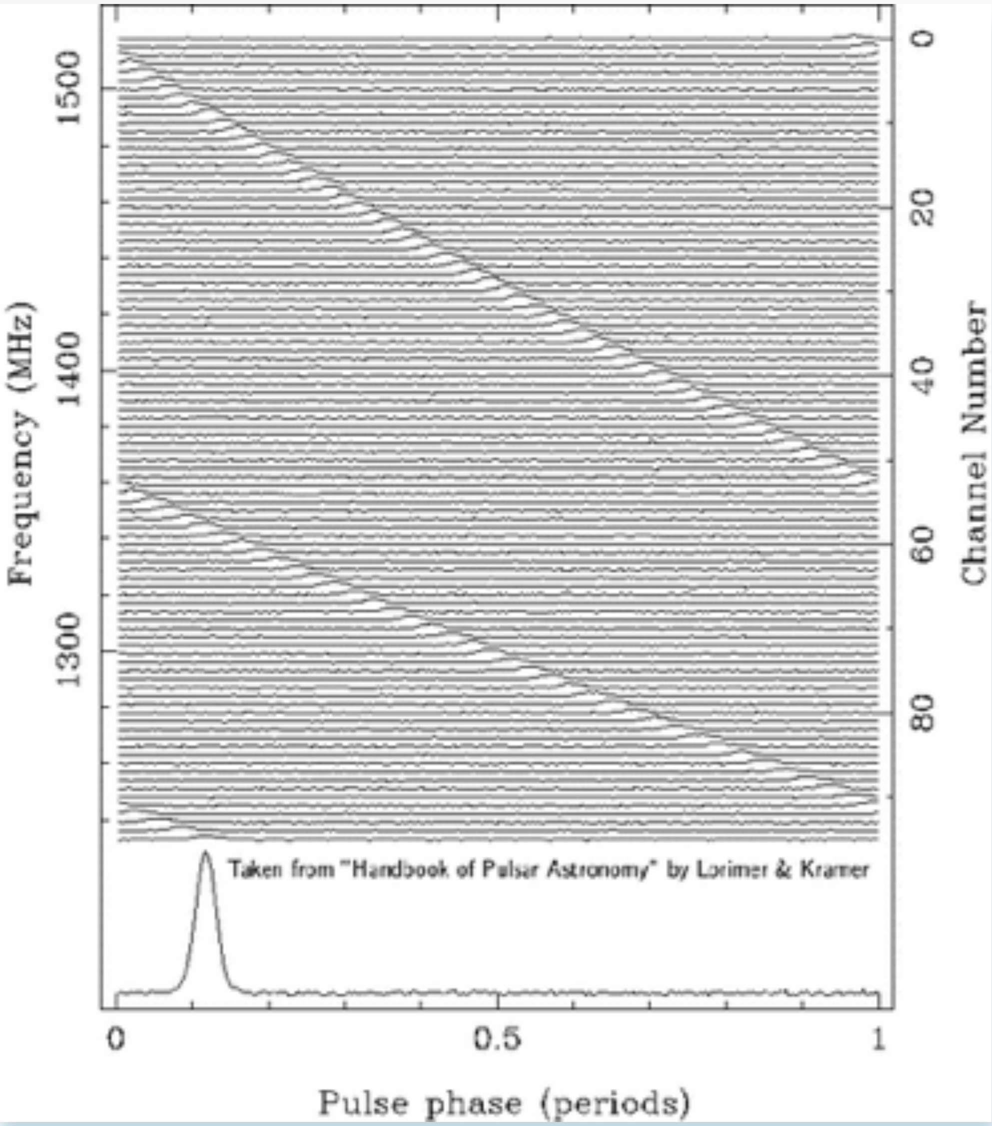
- **More stringent upper limits for masses of IMBHs or possible detections**

Dispersion measure

Ionized gas has refraction index that varies with frequency. At different frequencies the impulse is seen to lag behind. Measured by DM.

$$\Delta t_{DM} \simeq \left(\left(\frac{1200\mathrm{MHz}}{f_1}\right)^2 - \left(\frac{1500\mathrm{MHz}}{f_2}\right)^2\right) DM[\mathrm{ms}]$$

$$DM = \int_0^d \left(\frac{n_e}{\mathrm{cm}^{-3}}\right) dl\,[\mathrm{pc/cm}^3]$$

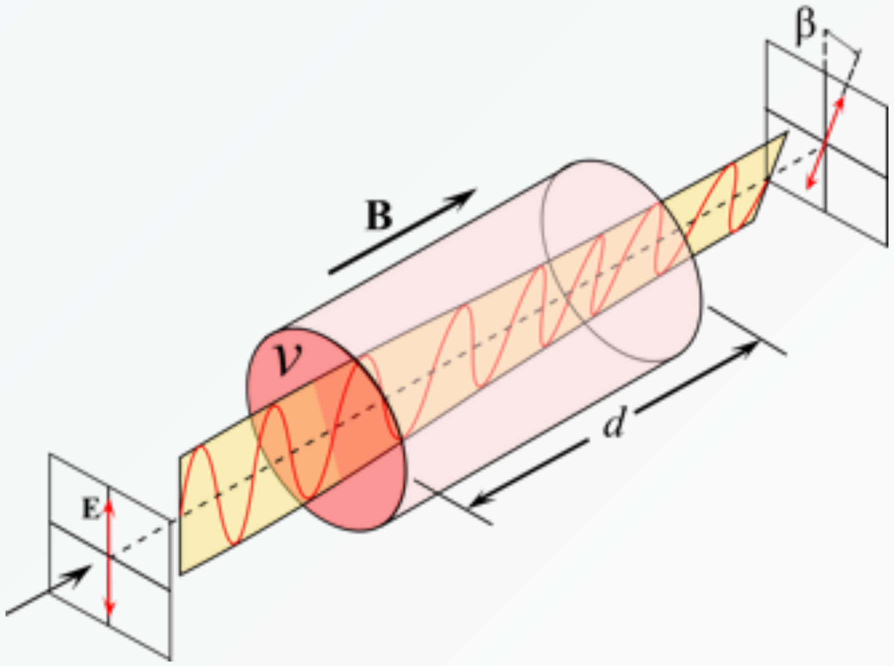


Freire et al. (2001)

Abbate et al. (2018)

Faraday rotation

In magnetised plasma the circular polarizations travel at different speeds at different frequencies causing a rotation in the axis of polarization.



The rotation of the polarization position angle is:

$$\beta = \frac{c^2}{\nu^2} \times RM$$ where:

$$RM = 0.81 \int_0^d \left(\frac{n_e}{\mathrm{cm}^{-3}}\right) \left(\frac{B_{\|}}{\mu G}\right) dl \, [\mathrm{rad/m}^2]$$ is the Faraday rotation measure

The average magnetic field along the line of sight can be estimated:

$$\langle B_{\|} \rangle \simeq 1.23 \mu G \left(\frac{RM}{\mathrm{rad/m}^2}\right) \left(\frac{DM}{\mathrm{pc/cm}^3}\right)^{-1}$$

Magnetic fields

Well known distance to the cluster

Very small angular scales (arcseconds to arcminutes)

- **Study the Galactic magnetic field on these scales**
- **Study the magnetic field in the Galactic halo**

If there is ionized gas inside the globular cluster:

- **Study the globular cluster magnetic field**

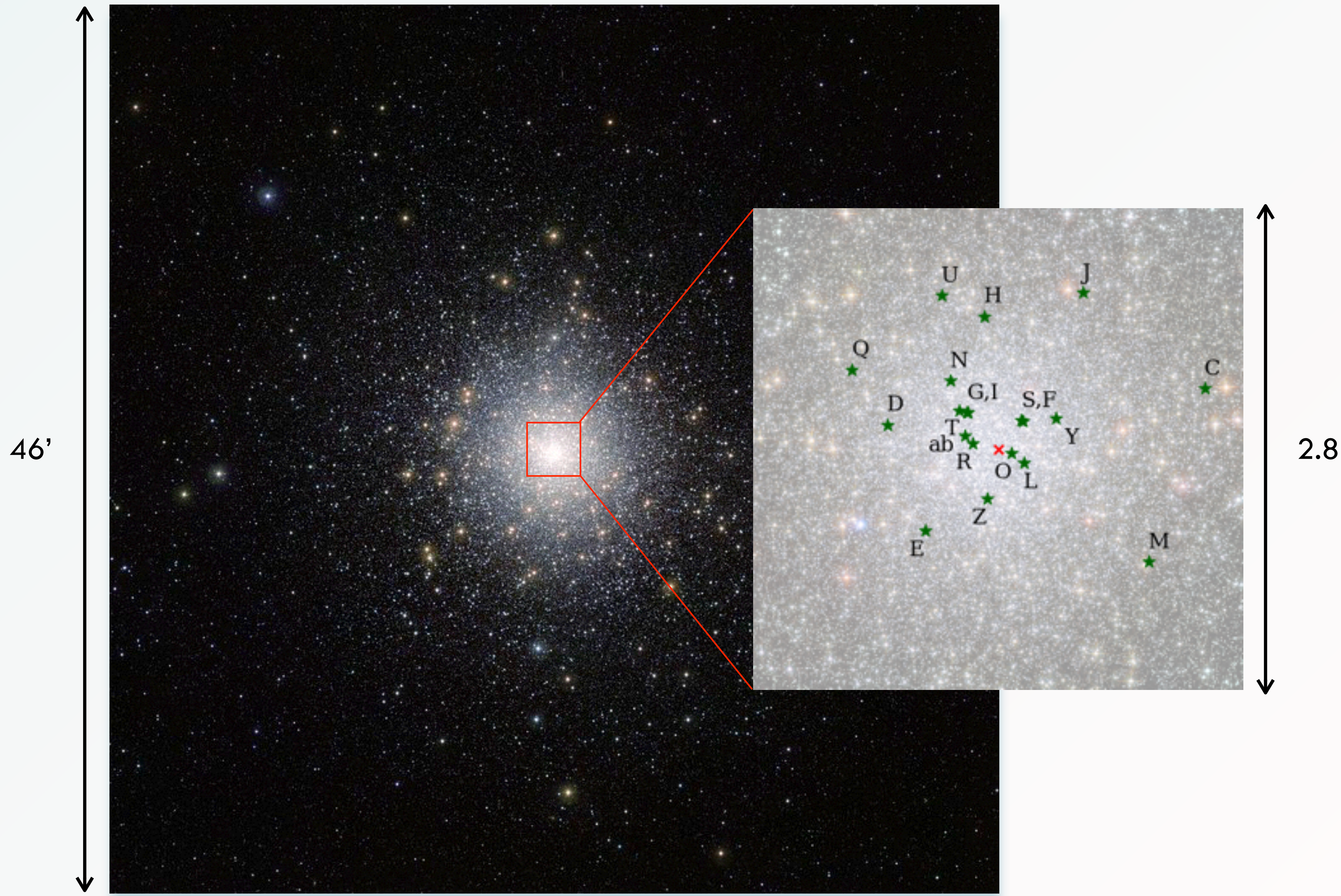
Abbate et al. in prep.

MeerKAT radio telescope

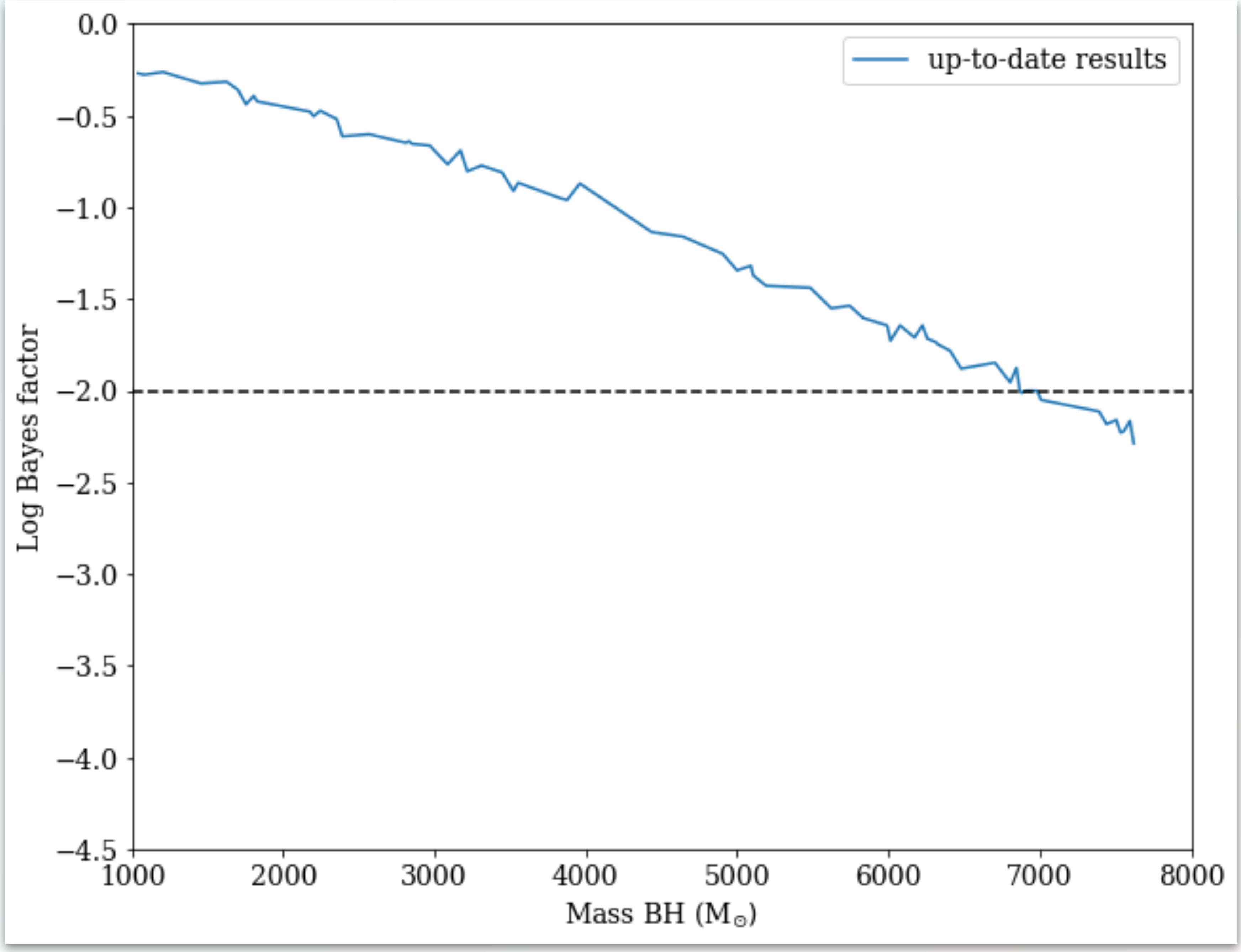
Thanks to its position it can observe all the globular clusters known to host pulsars.
More than twice the bandwidth than Parkes and three times the collecting area.

More pulsars detected in globular clusters
Better estimation of timing parameters

47 Tucanae

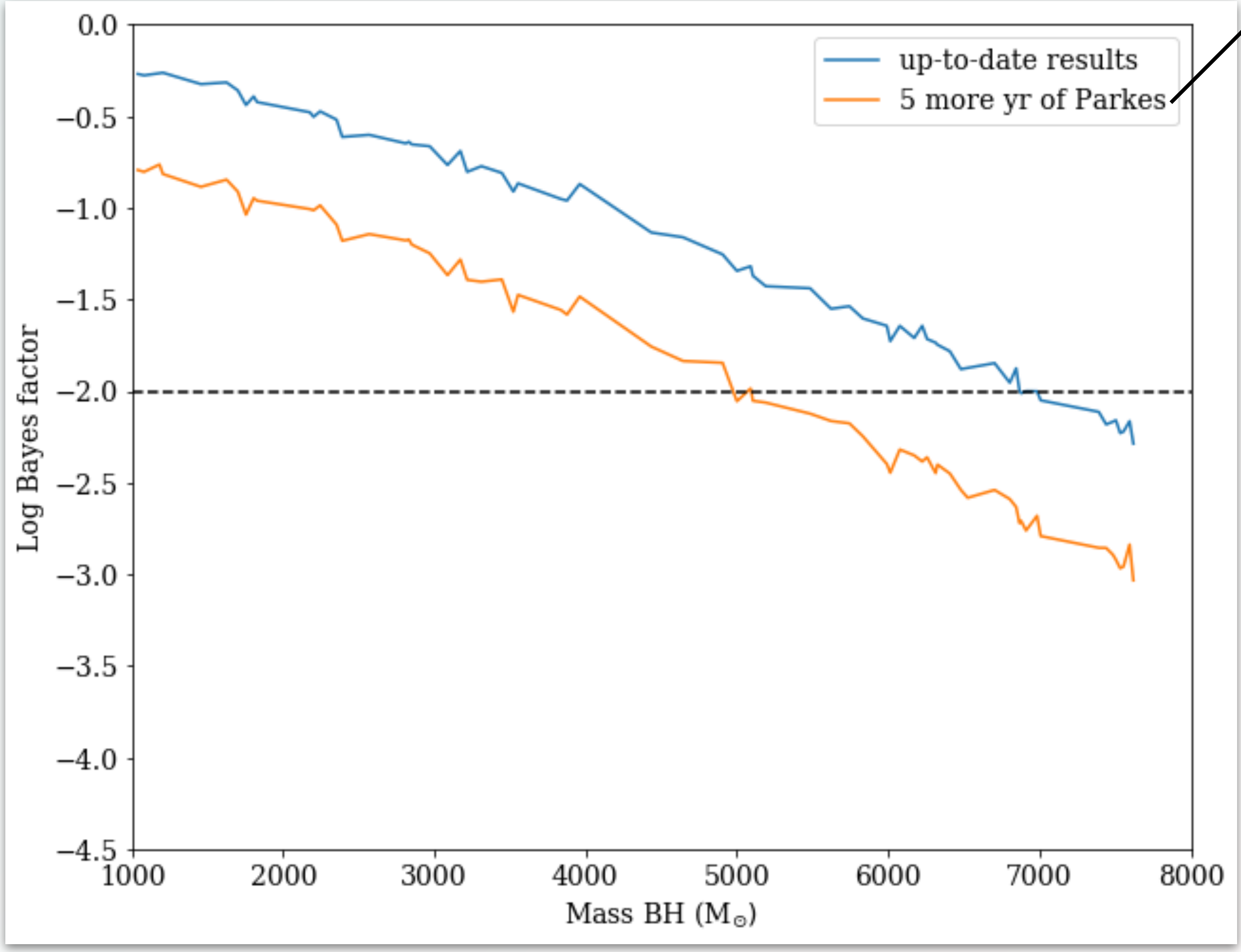


Increase with future observations



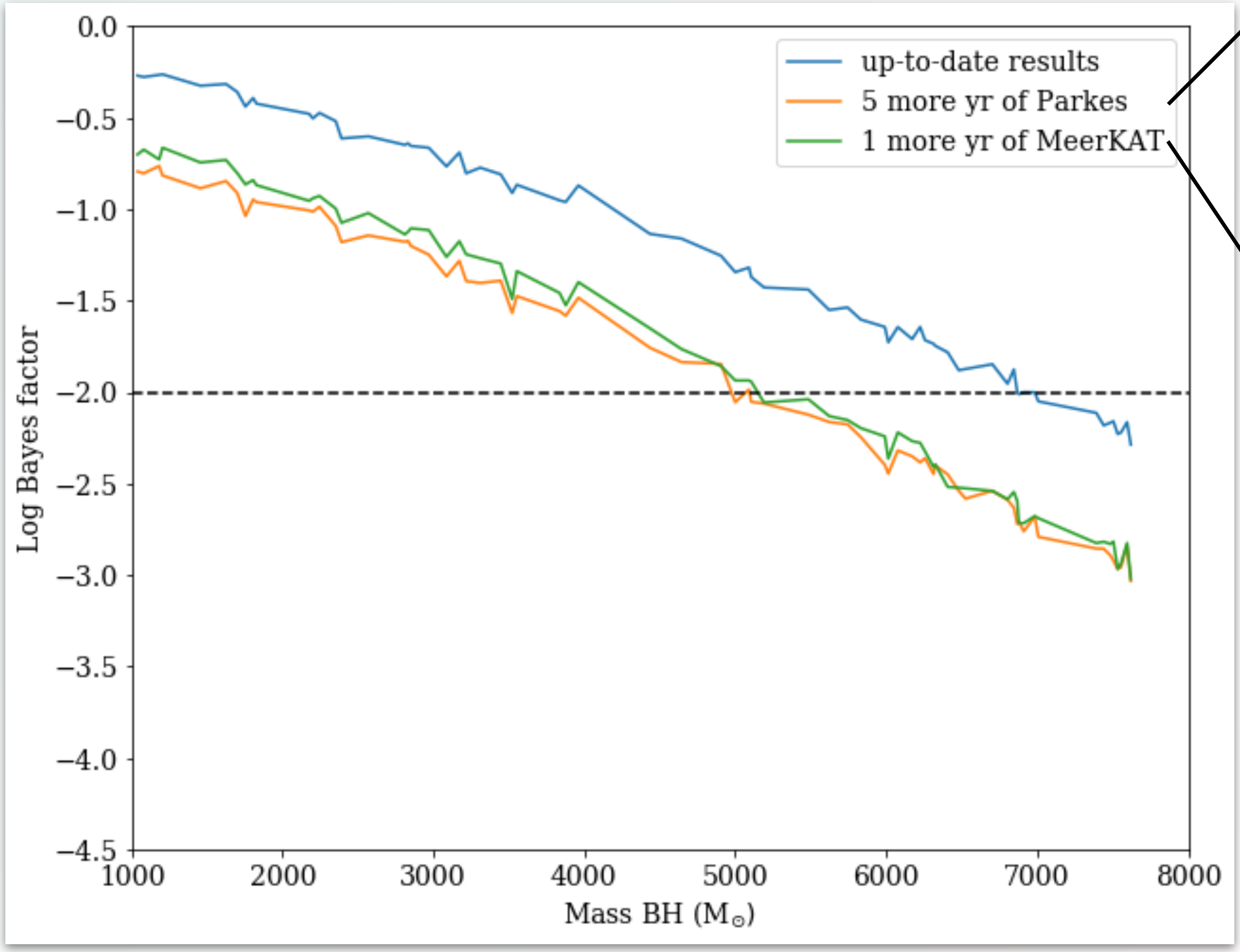
Abbate et al. in prep

Increase with future observations



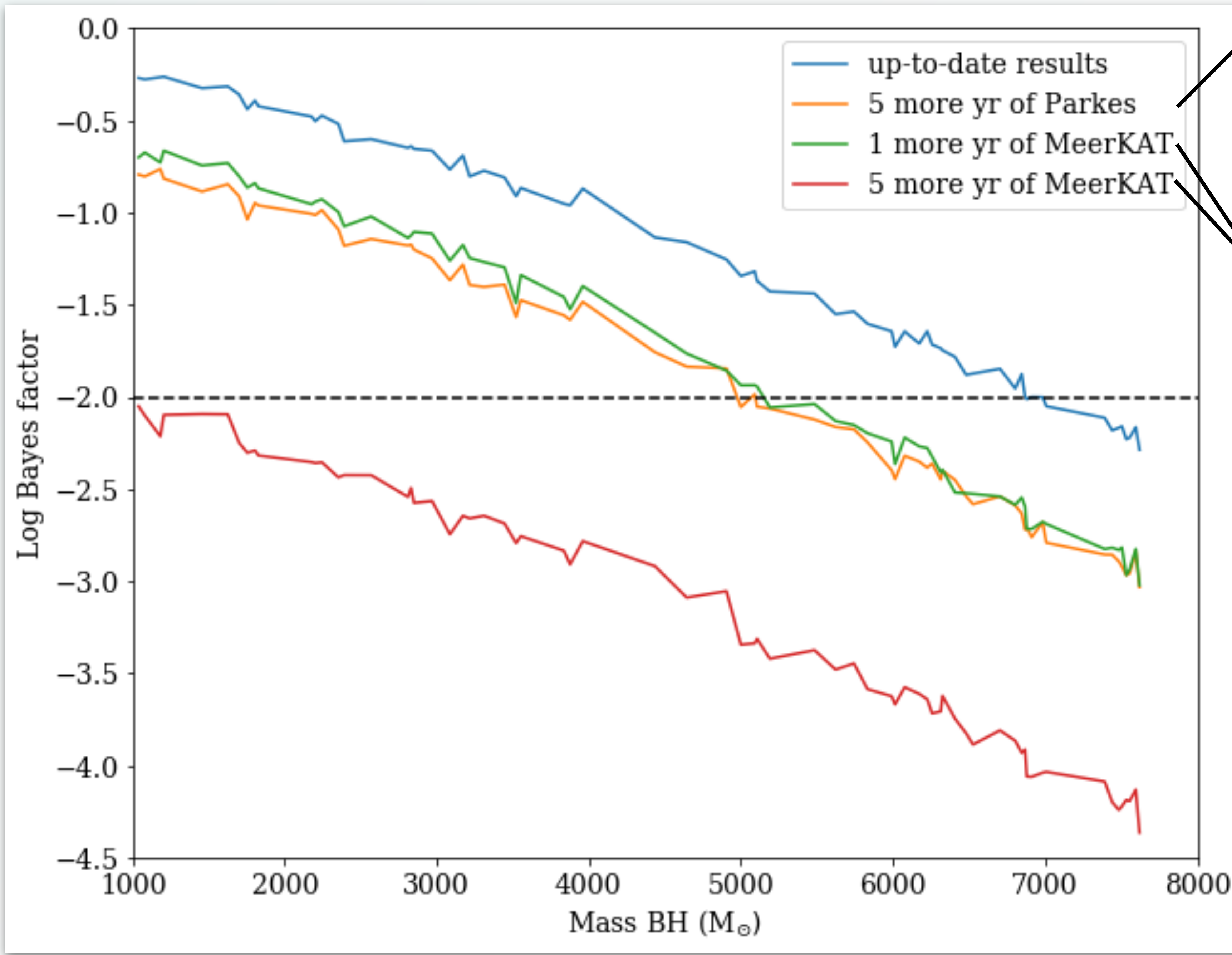
Abbate et al. in prep

Increase with future observations



Abbate et al. in prep

Increase with future observations



Abbate et al. in prep

Conclusions

- Globular cluster are unique environments where exotic pulsars can form
- Study the properties of globular clusters like the mass distribution and look for central black holes
- We can probe the Galactic magnetic field at very small scales and study the magnetic fields in the cluster and the halo
- The advent of MeerKAT will significantly push the science of globular cluster pulsars

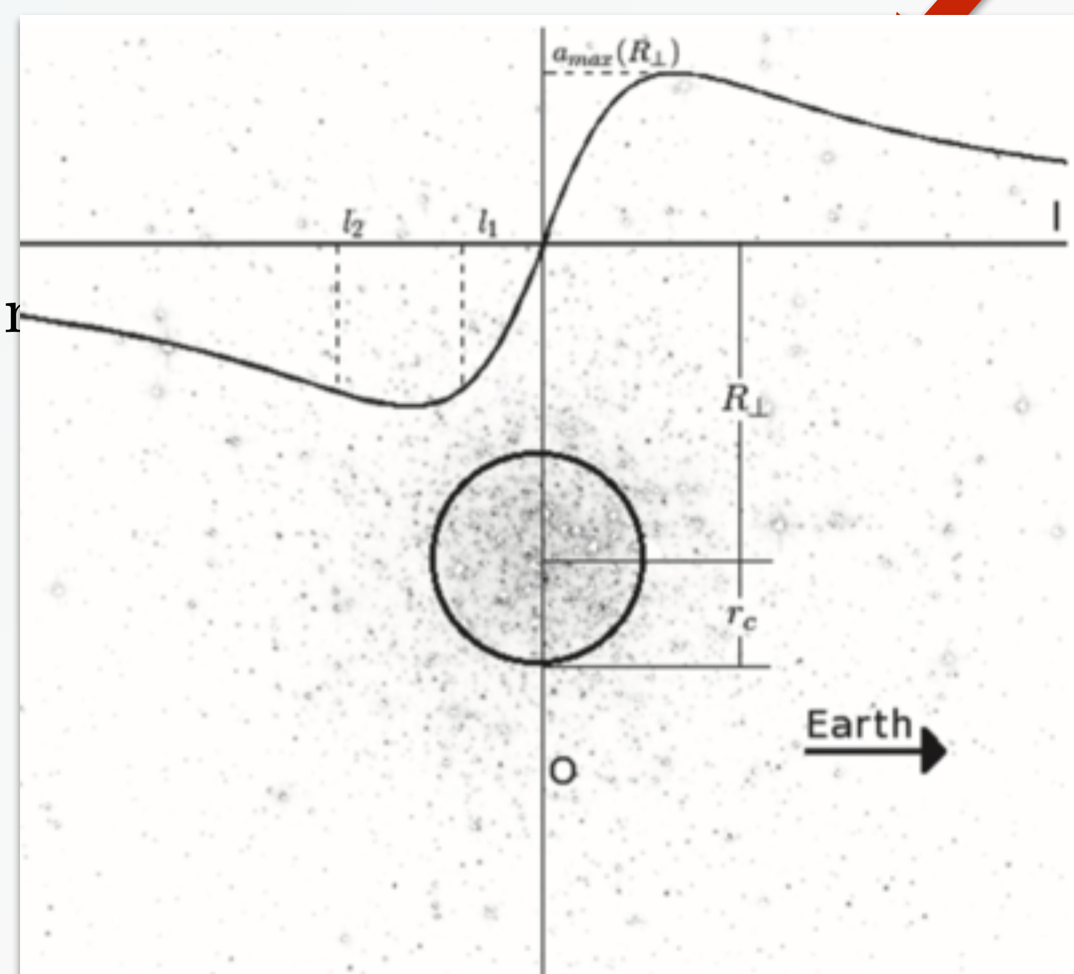
Thanks for your attention!

Pulsars in globular clusters

$$\left(\frac{\dot{\mathrm{P}}}{\mathrm{P}}\right)_{\mathrm{meas}} = \left(\frac{\dot{\mathrm{P}}}{\mathrm{P}}\right)_{\mathrm{int}} + \frac{a_c}{c} + \frac{a_g}{c} + \frac{a_s}{c}$$

$$\left(\frac{\dot{\mathrm{P}}_{\mathrm{b}}}{\mathrm{P}_{\mathrm{b}}}\right)$$

$$+ \frac{a_s}{c}$$



Measuring accelerations

$$\left(\frac{\dot{\mathrm{P}}}{\mathrm{P}}\right)_{\mathrm{meas}} = \left(\frac{\dot{\mathrm{P}}}{\mathrm{P}}\right)_{\mathrm{int}} + \frac{a_c}{c} + \frac{a_g}{c} + \frac{a_s}{c}$$

$$\left(\frac{\dot{\mathrm{P}}_{\mathrm{b}}}{\mathrm{P}_{\mathrm{b}}}\right)_{\mathrm{meas}} = \left(\frac{\dot{\mathrm{P}}_{\mathrm{b}}}{\mathrm{P}_{\mathrm{b}}}\right)_{\mathrm{int}} + \frac{a_c}{c} + \frac{a_g}{c} + \frac{a_s}{c}$$

$$\left(\frac{\ddot{\mathrm{P}}}{\mathrm{P}}\right)_{\mathrm{meas}} = \left(\frac{\ddot{\mathrm{P}}}{\mathrm{P}}\right)_{\mathrm{int}} + \dot{\mathbf{a}}_{\mathrm{mf}}\frac{\mathbf{n}}{c} + \dot{\mathbf{a}}_{\mathrm{nn}}\frac{\mathbf{n}}{c}$$