<u>1. Science aim/goal</u> : Hunting for hidden AGNs: Where are the most dust-enshrouded growing supermassive black holes (SMBHs) in the nearby Universe?

2. <u>(i) Scientific Importance:</u> Studying the accretion and growth of supermassive black holes (SMBHs) is essential for our understanding of how they evolve together with their host galaxies (Ho 2004). When SMBHs accrete matter they give rise to an Active Galactic Nucleus (AGN). AGN population synthesis models find an average ratio of obscured to unobscured AGN of about 3:1 in the local Universe and up to 50% of low luminosity AGNs may be so deeply embedded that they are obscured also in X-rays and the mid-IR (e.g. Alexander+11, Lusso+13). There is evidence that the most rapidly growing supermassive black holes (SMBHs) may be the most obscured. It is important that we search for and study the most heavily enshrouded AGNs or we *could be missing the majority of the small growing SMBHs in the local Universe.* Studying obscured AGNs can ultimately provide the best constraints on the AGN duty cycle; the complete picture of what type of environments drive the growth of SMB; help us determine the SMBH growth-efficiency parameter (i.e. SMBH mass density compared to AGN accretion) and a more complete understanding of the relation between host galaxy and SMBH growth (Alexander 2010).
The UV, and X-ray emission from the accretion disk of a deeply embedded AGN will be absorbed and re-emitted in the IR (Appendix B). Recent FIR and submm observations have revealed extremely compact and obscured nuclei with what could be the first candidates for deeply obscured ($N_H > 10^{24}$ cm^{-2}) accreting SMBHs (e.g. Sakamoto+08. Gonzalez-Alfonso+14, Aalto+16).(Appendix C)

<u>(ii) Measurements Required:</u> A survey for compact obscured nuclei could rely on a few diagnostic lines that indicate an extreme environment. Due to their heavy obscuration the activity in the enshrouded nuclei is best revealed at long wavelengths:
<u>Prio A: Far-IR lines:</u> Highly excited lines of H_2O (212 and 71 μm) and OH (65 μm) have proven efficient in identifying many compact obscured nuclei (e.g. Gonzalez-Alfonso+12,+14+15, Falstad+15,16). The line ratio of two water lines 7_{17}-6_{06}/4_{23}-3_{12} is a good test of the temperatures of the exciting FIR dust continuum. This effect becomes stronger for large columns (see Gonzalez-Alfonso+14, Falstad+15). Ro-vibrational lines of HCN and H_2O (20-500 μm) can be used to find buried high-surface brightness mid- and near-IR continuum. They require large H_2 columns ($>5\times10^{23}$ cm^{-2}) to be excited (e.g. Aalto+15b). The combination of these is also essential to separate photon- from non-photon driven processes. The ro-vibrational lines allow us to reconstruct the real IR SED buried behind the dust and gas. Adding simultaneous H_3O^+, H_2O^+, and OH^+ observations will provide ionization rates further addressing the nature of the enshrouded source.

<u>Prio B: mid-IR lines:</u> Important diagnostic lines are the 24.3-25.9 μm lines of [Ne V] and [O IV]. Emission will be heavily attenuated by the high obscuration and at column densities exceeding 10^{24} cm^{-2}, dust is optically thick at 26 μm and these lines are reliable tracers only at column densities below this. However, dust and gas are likely to be clumpy and line emission may emerge through cracks and/or be scattered. Deep observations will reveal the presence of these lines and an accreting SMBH. (Note that

the mid-IR line observations must be paired with the FIR-diagnostic lines to determine the level of attenuation to the mid-IR lines.)
Continuum: A dust SED could be dominated by extended star formation – masking a compact obscured nucleus and a vigorously growing SMBH. This could be sorted out by fitting multiple component to the SED, but if the mid-IR continuum from the AGN is absorbed by large columns of dust then the growing SMBH is missed. Hence continuum SEDs should be combined with the FIR-line diagnostics.

(iii) Uniqueness to 10 μm – FIR/submm wavelength facility:
These dust-enshrouded galaxy nuclei have their SED peak in the far-infrared – hence they are ideal targets for the FIR-surveyor**.** The Far-IR continuum and lines of H_2O and OH, cannot be observed by any other telescope than the FIR-surveyor. The selected lines allow us to directly reveal the presence of hidden, extreme surface-brightness regions heated by a buried source.

JWST: The mid-IR lines of [Ne V] and [O IV] could be observed in targeted observations by the JWST out to a redshift of z=0.07 and it would miss these diagnostic lines entirely for the more distant galaxies in the near-Universe. The JWST could not observe the longer wavelength IR lines necessary for the most extremely obscured nuclei.

ALMA: The diagnostically important highly excited lines of H_2O (212 and 71 μm) and OH (65 μm) are not accessible with ALMA or the JWST. ALMA could observe ro-vibrationally excited lines of HCN and H_2O with similar energy levels as those at FIR wavelengths, but they would be significantly fainter and difficult to survey.

4. Table:

Parameter	Unit	Required value	Desired Value	Comments
Wavelength/band	μm	20-500	10-500	See Footnote 1. In Appendix A
Number of targets		500	1500	See Footnote 2. In Appendix A
Survey area	$deg.^2$	-	-	The survey would be sensitivity driven – not so much by resolution.
Angular resolution	arcsec	-	-	See Footnote 3. In Appendix A
Spectral resolution	$\delta\lambda/\lambda$	100 km/s	20-30 km/s	See Footnote 4. In Appendix A
Continuum Sensitivity	mJy	3	0.03	See Footnote 5. In Appendix A
Spectral line sensitivity	mJy /100 km/s	Abs:1 Em: 3	Abs:0.01 Em: 0.03	See Footnote 6. In Appendix A