1 Title: VISIONS - VISTA Star Formation Atlas

PI: J. Alves, Austria
CoIs: S. Meingast, Austria; H. Bouy, Spain; M. Lombardi, Italy; J. Ascenso, Portugal; A. Bayo, Chile; E. Bertin, France; A. Brown, The Netherlands; Jos de Bruijne, ESA; J. Forbrich, Austria; A. Hacar, Austria; J. Kaufmann, Germany; R. Köhler, Austria; D. Mardones, Chile; A. Moitinho, Portugal; K. Peña, Chile; M. Petr-Gotzens, ESO; T. Prusti, ESA; L. Sarro, Spain; T. Robitaille, Germany; R. Ramlau, Austria; R. Schödel, Spain; P. Teixeira, Austria; W. Zeilinger, Austria

1.1 Abstract: (10 lines max)

We propose to construct a sub-arcsec near-infrared atlas of all nearby (d < 500 pc) star formation complexes accessible from the southern hemisphere. This atlas will become the community's reference star formation database, covering the mass spectrum down to a few Jupiter masses and spatial resolutions reaching 100-250 AU. The survey will use a new data reduction technique developed by our team to improve image quality by about 20% over the standard reduction, which will allow for sub-arcsec YSO morphometry, a critical missing step in YSO characterization. The novelty of the survey is that it will be carried out in a way optimizing precise proper motion measurements, allowing the community to derive for the first time the motions of complete ensembles of embedded objects, not accessible to ESA Gaia, as well as the revealed young population. Connecting Gaia and VISIONS will allow a robust 3D reconstruction of the local star forming ISM and tackle fundamental problems such as the origin of the IMF, the physics behind SFR, and the formation of clusters with unprecedented detail.

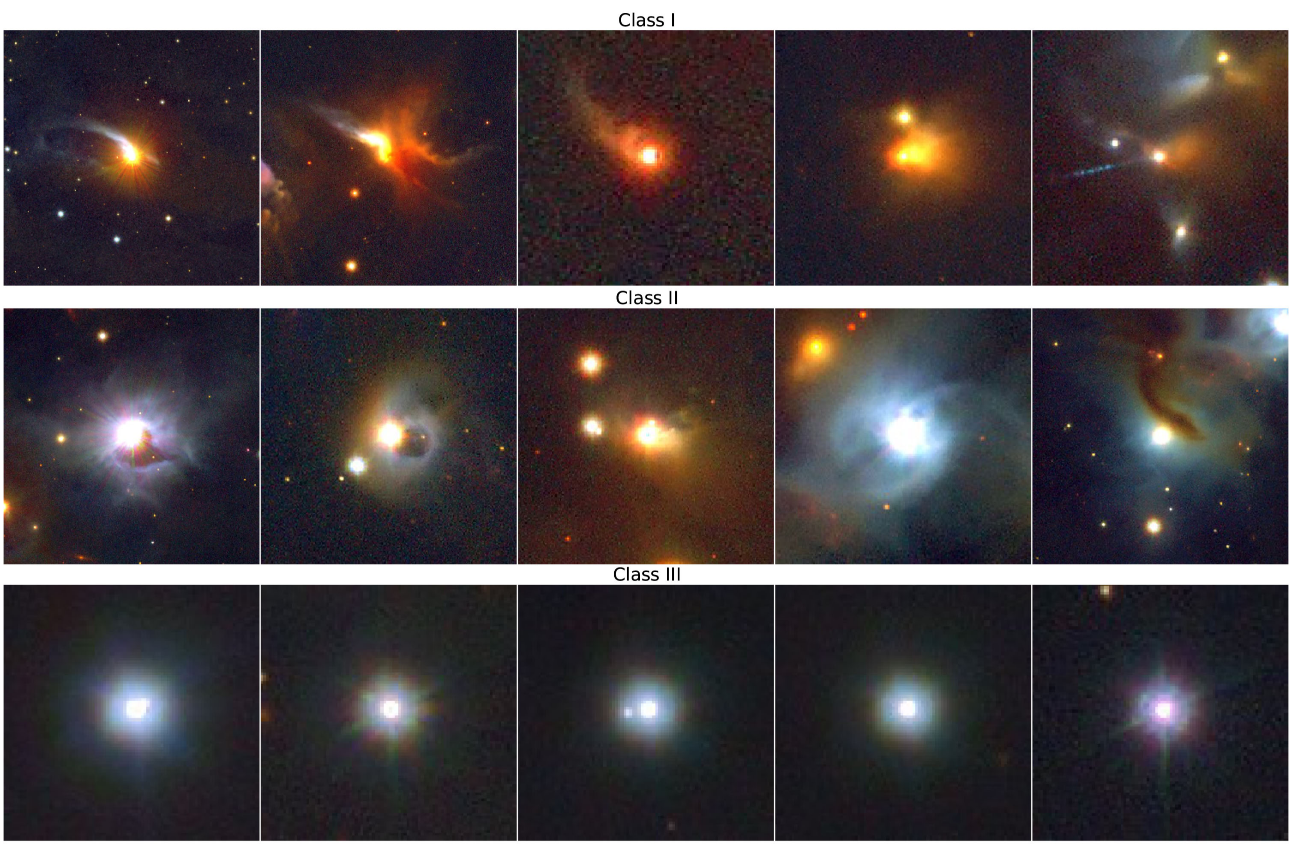

Figure 1: VISTA survey of Orion A, from Meingast et al. (2016)

2 Description of the survey: (Text: 3 pages, Figures: 2 pages)

2.1 Scientific rationale:

Star formation drives cosmic evolution and lies at the crossroads of cosmology, planet formation, and life. Over the last decades, studies of molecular clouds and young stars near the Sun have provided invaluable insights into this fundamental process and much of our physical understanding of this topic has been derived from such studies. We have found certain empirical rules on how the process operates, but we still lack a quantitative theory of star formation, a theory that, given a limited set of initial conditions, is able to predict the basic physical properties of stars, the rate at which these stars form, and how this rate varies in time. Arguably, the most critical unsolved problems confronting star formation research today are: understanding the origin of the stellar masses, determine the physical processes that control the star formation rate in molecular gas, understanding young stellar object (YSO) evolution and its implications for planet formation, and the origin and evolution of stellar clusters.

The last five years have brought a wealth of new data to the community, opening the infrared and submillimeter windows where the star formation process can be observed directly (e.g., VLT, ALMA, Spitzer, WISE, Herschel, Planck). An obvious miss in the 21st century star formation landscape is a deep wide-field NIR sub-arcsec, high image quality survey allowing for the characterization of YSOs at ~ 100 AU scales and improved spectral energy distribution (SED) modeling. Such a survey would allow, among others, for a robust calibration of the mostly unexplored submillimeter dust maps of ground- and space-based facilities, and, in particular, to open in a large and consistent manner the poorly explored window of YSO dynamics. VISIONS will connect the Gaia frame to the nearby embedded stellar populations opening a new window on YSO dynamics and dispersal into the Galactic field.

2.2 Immediate objective:

VISIONS, the VISTA star formation atlas, will allow the community to address in a complete and coherent way not only the fundamental star formation problems mentioned above, but a series of fundamental ISM and star formation topics. The VISIONS public survey, optimized for astrometry, aims to observe all molecular cloud complexes within 500 pc. We will observe 1) *wide* fields, covering the poorly known dispersed young population, 2) *deep* fields in the high-column density regions in these complexes ($A_V \gtrsim 5$ magnitudes), where sensitivity and resolution are key to recover the embedded population of protostars (e.g. Meingast et al., 2016), and 3) critical but often forgotten *control* fields. VISION will allow the community to explore the following scientific cases:

1. **A reliable look into the CMF/IMF relation**. The star formation atlas will allow the community to construct the Core Mass Function (CMF) for an estimated ~3000 dense cores for the clouds in the survey via a tracer (dust extinction) that is not affected by dust temperature and β variations, gas excitation conditions, or molecular depletion. Background WISE, and when available, Spitzer sources located behind high column density regions, where there will be a deficit of H and K-band background sources, can be used as extinction tracers. The community will be able to establish a close connection between dense cores and YSOs, compare starless and non-starless CMFs, as well as map the distribution of cores in the ensemble of clouds closer than 500 pc and correlate it to the distribution of YSOs. The resulting extinction maps, reaching resolutions of $10-15''$ towards the bulge and of $30-45''$ towards the Galactic anti-center, will be compared with the existing and similar resolution molecular line maps and archival dust emission maps to study the physical and chemical properties of the core population.

2. **Proper motions of embedded objects and young stars**. VISIONS will be carried out in a manner that optimizes proper motions measurements of the entire population of embedded objects and optically revealed young stars. This will be possible for the first time and will tie the embedded populations to the Gaia frame. The fields will be observed twice a year, for the three years of the duration of the survey,

providing six independent epochs. Together with at least the previous VISTA Hemisphere Survey (VHS) data (time baseline $\sim 8-10$ years), one can expect to reach proper motions of the order of $1-2$ mas at the end of the VISIONS survey (e.g Bouy et al., 2013), or the equivalent of transverse velocities of $0.1-0.3$ km/s, comparable with the precision of the ongoing near-infrared APOGEE radial velocity survey of embedded objects in the Orion star formation region (Hacar et al., 2016).

3. **3D map of the star forming ISM and the Gaia context**. Gaia will map the 3D distribution for the nearby young populations (distances to better than 1%) and those will be tied to the embedded/revealed populations in the nearby complexes. The VISIONS and Gaia complementarity will allow the construction of 3D maps of the young massive population providing new insights into how the ISM is shaped either by massive stars and global instabilities, so issues like triggered star formation and local spiral arm can hopefully be put on a more solid footing. The star formation history of the local Milkyway, a main Gaia delivery, will get its "zero-point" in VISIONS.

4. **The IMF down to the brown-dwarf/planet regime** reaching a few M_{Jup} for a 1 Myr object for all southern clouds within 500 pc. With the VISTA star formation atlas, and using YSO/young star PPM, the community will be able to securely identify the product of star formation in these cloud complexes across the entire stellar mass spectrum, down to planetary mass objects. Possible regional variations of the mass function, as well as an investigation of whether the formation of low mass stars is inhibited or enhanced by massive YSOs, and if there is a maximum stellar mass vs. cluster size relation, can be performed.

5. **Resolved Kennicutt-Schmidt "law" (down to the dense core size)**. VISTA extinction calibrated dust emission maps (mostly archival Herschel and Planck, that covered all the proposed targets; see e.g. Lombardi et al., 2014) will become the best representation of the distribution of mass in the clouds. Together with the essentially *complete* YSO catalog for the clouds (via VISIONS PPM, Spitzer when available, and WISE,), the community will be able to determine the star formation rate and efficiency, and map their possible variations across the different molecular cloud complexes. Apart from allowing for a fully resolved study of the Kennicutt-Schmidt relation (down to the dense core size) the community will also be able to confirm or reject the possible existence of a threshold for star formation and density threshold leading to the formation of clusters in the different clouds of the survey.

6. **YSO identification and characterization**. We have developed a new VISTA data reduction technique, geared towards Galactic observations, that improves VISTA image quality by about 20% over the standard CASU pipeline (see title page figure and description of technique in Meingast et al., 2016). This increase in spatial resolution is critical to characterize and inform on the nature of the YSOs (see Figure 1), not uniquely solved by available archival data. Scattered light nebula around protostars constitute powerful tools for confirming their protostellar nature and determining the inclination of the envelope cavity, critical in the modeling of the YSO systems. The higher resolution data allows also the study of YSOs in regions too embedded or confused in the available IR surveys, or altogether missed by Spitzer/Herschel (e.g., in bright nebula regions, or not covered, but accessible via either K-excesses or a combination with all-sky WISE).

7. **Combining the PPM of the embedded population with radio astrometry**. Where available, the community will be able to combine the astrometric information with precise radio astrometry. For regions that are accessible to the VLA and VLBA, this would mean that a fraction of the infrared sources, those with nonthermal radio counterparts, will have absolute astrometry with an accuracy down to 10 μas. For the Southern regions, millimeter VLBI observations with ALMA are now becoming possible. While the VLBI observations will not reach as many sources as the infrared observations, due to the lower radio detection fraction, the subsample that is detected in both bands will provide an important opportunity to calibrate the infrared astrometry against the absolute radio reference frame. Our large program to follow up hundreds of radio sources in the Orion Nebula Cluster with the VLBA is currently ongoing (Forbrich et al., 2016).

8. **Dust properties** The *Herschel* and *Planck* missions covered all the proposed targets. A combination of the extinction mapping with submillimeter dust emission data obtained by these missions will additionally provide with constraints on the ratio of the submillimeter dust opacity and the near-infrared extinction coefficient. This is a powerful tracer of regions where grain growth has occurred (e.g., Forbrich et al., 2015), and the community would thus be able to assess which fraction of the surface area of clouds shows detectable signs of grain growth. Where available, these studies could additionally include ground-based bolometer data to also assess the dust opacity spectral index β (ibd).

9. **Reddening law** The reddening law in the near-infrared (NIR, 1 to 2.5 μm) is assumed to be universal in the vast majority of observational studies. However, there is evidence that the NIR reddening law does change significantly from region to region (e.g., Indebetouw et al., 2005, Nishiyama et al., 2006), and assuming it is universal has important consequences in the parameters derived from NIR data, such as, for example, observational Cosmology (e.g., Nataf et al., 2015). The atlas spans a wide dynamic range in extinction and environments, providing the ideal data base for a study of the NIR reddening law produced by single dust clouds, without background confusion.

10. **Cluster formation and evolution.** The origin and fate of stellar clusters is determined during the earliest stages of evolution of these objects. As is normally assumed in the community, key parameters like the number of ejected objects and their masses, mass segregation processes, and the fraction of observed binaries, are determined by the mass fraction in stars and gas and the timescales for gas expulsion in young proto-clusters. The combination of VISIONS PPM of both the embedded population YSO and potentially runaway stars in the closest 30 embedded clusters to Earth will allow the observational community to constrain model predictions and parameters.

11. **Wide binaries.** Class II wide binaries (separations >> 100 au) are notoriously difficult to identify due to crowding from other sources that happen to lie along the same line of sight. The only reliable way to identify these binaries is via a proper motion study where the components are identified as co-moving pairs. Wider binaries have longer lived circumstellar disks around each component, compared to close binaries, and thus have, in principle, higher probability of forming planetary systems. VISIONS will allow for the first time to study very low mass wide binaries over complete star forming regions spanning several star formation environments.

12. **Jets and outflows.** Outflows and high velocity bipolar jets are characteristic of the early evolutionary stages of YSOs. With internal motions on the order of hundreds of km s^{-1}, the evolution of these ejections represents one of the few astronomical phenomena that can be measured within timescales of few years. The improved resolution and sensitivity of VISIONS will allow a better characterization of jets and outflows at IR wavelengths (see cover page figure). The study of their evolution over the 8$\sim$10 yr time baseline with VHS observations will also provide valuable inputs on the mechanisms responsible for these features.

13. **Other topics: Galaxy clusters, quasars, field ultracool dwarfs, solar system and serendipity.** Traditionally, the study of extragalactic sources is preferentially carried out far from the galactic plane, to avoid the heavy effects of extinction and the presence of bright stars. As a consequence, areas behind molecular clouds are virtually unexplored and offer a unique opportunity to do serendipitous discovery (cf. the discovery of Maffei's galaxies in the '70s). Indeed, in pure terms of "discovery volume", a VISTA survey of molecular clouds offers the largest impact: the combination of a wide field of view, together with NIR passbands (where extinction is one order of magnitude less effective) ensure that we can expect a large number of new background sources. Foreground nearby ultracool dwarfs, including the elusive T and and Y-dwarfs, have their peak of emission in the NIR and will be easily identified using the PPM. These ultracool objects, with effective temperature just above that of the human body, will be benchmark targets for the study of atmospheres and make the link between sub-stellar and planetary physics. Finally, our sruvey shall discover or detect several thousands of solar system bodies, which we will easily identify based on their fast proper motions. Their NIR photometry will help classify them and the precise astrometry will prove useful to derive accurate orbital parameters.

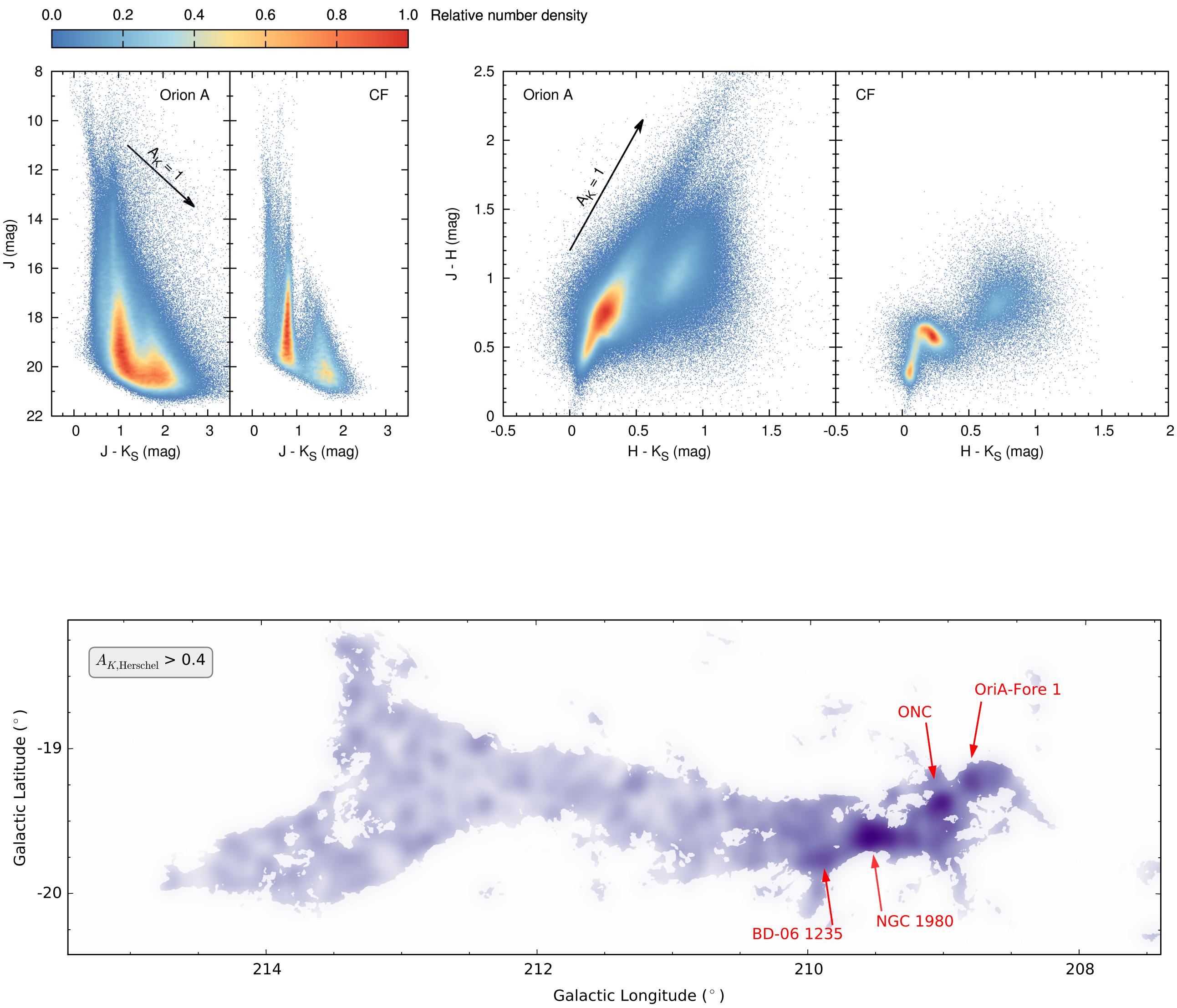

Figure 2: Top: Color-magnitude and color-color diagrams for both the VISTA Orion A and the control field data (from Meingast et al., 2016). While the Orion A data include ∼800 000 sources, we detected more than 90 000 for the single tile of the control field. The colors indicate normalized source density within a 0.1×0.1 mag box in the J vs. $J - K_S$ parameter space and 0.02×0.02 mag in $J - H$ vs. $H - K_S$. The black arrows indicate the effect of an extinction of 1 magnitude in K_S. The presence of heavy dust extinction in Orion A pushes many sources towards redder colors when compared to the control field, which itself has a clearly defined main-sequence and galaxy locus in both diagrams. The photometric quality of the VISTA data is stunning. A primary goal of VISIONS is to provide similar photometric (and images) data sets for all star forming cloud complexes within 500 pc and visible from Paranal (see Figure 3).
Bottom: Density maps of foreground stars projected on the Orion A cloud (darker indicates a higher density). The dust extinction in the cloud was used to effectively block background sources. The excess foreground population is clearly visible towards the Western regions of the cloud. This population is non uniformly distributed and was born from previous star formation episode that took place $\sim 5 - 10$ Myr ago. Gaia will be able to observe parallaxes (and PPM) for this population with errors of the order of 1%. VISIONS will provide PPM of both the embedded and foreground populations, allowing for the YSO populations to be tied to the Gaia frame.

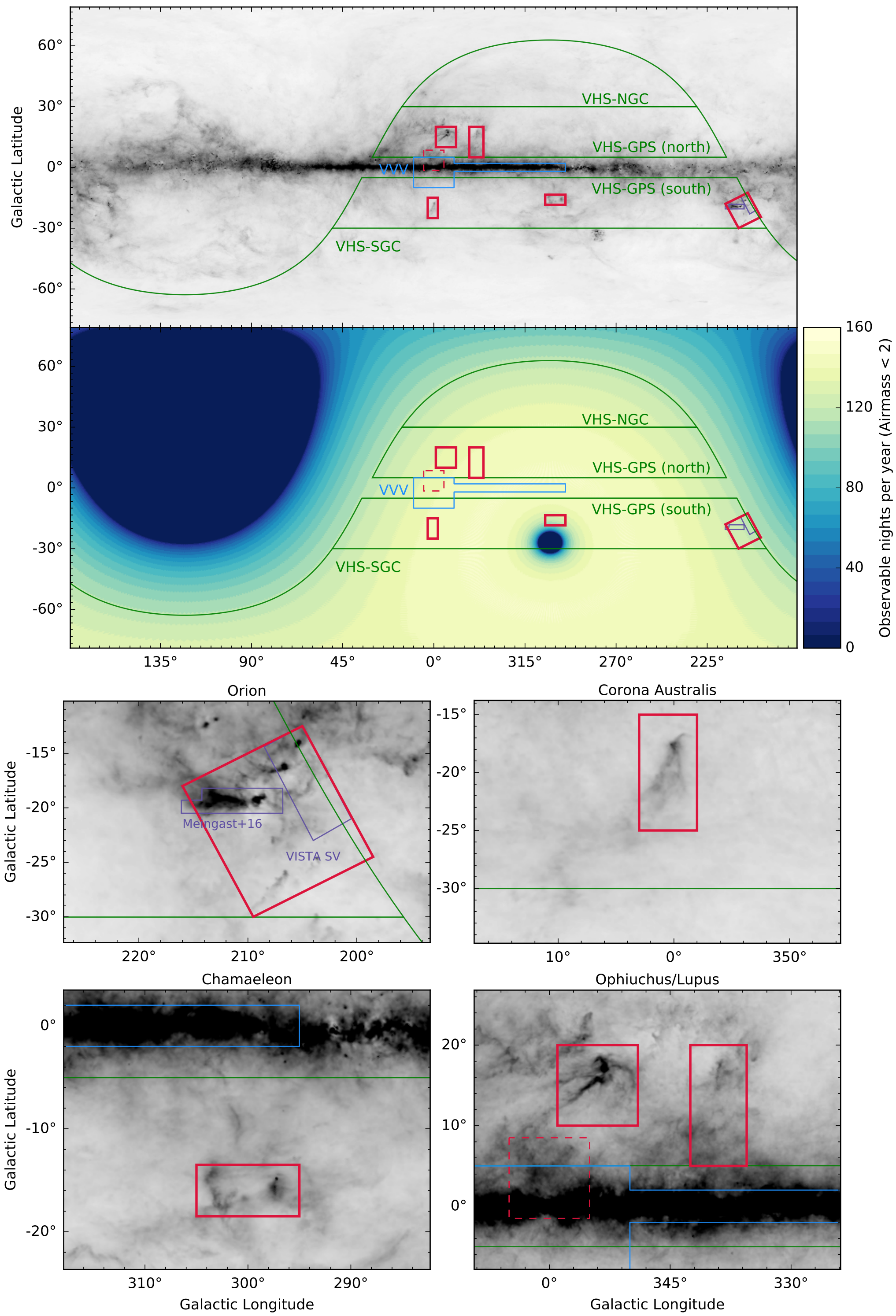

Figure 3: VISTA Star Formation Atlas coverage plan. The red boxes approximately mark the target fields for our *wide* astrometric survey. The background grayscale images are from the Schlegel et al. (1998) reddening maps.The dashed box represents the Pipe Nebula field now removed following a suggestion by the PSP (because it will be included in VVVX).

3 Are there similar ongoing or planned surveys? (1 page)

To our knowledge there are no similar surveys, ongoing or planned, aiming at complete surveys of nearby cloud complexes with high image quality and NIR astrometry. Still, part of what is planned in this survey could in principle be achieved with VVV because of its multi-epoch monitoring observations, even if not optimized for astrometry. However, VVV and its likely follow-up VVVX, focus on the plane and bulge of the Milky Way, which are far from ideal to tackle the star formation questions at the core of this Public Survey. This is because of the extreme crowding of clouds and stars along line-of-sights near the galactic plane, which makes essentially the science goals stated above unattainable.

Although not strictly similar, the APO Galactic Evolution Experiment Alam et al. (2015) (APOGEE and its follow-up APOGEE 2), covered, or will cover, some of the regions in the VISIONS target list. Orion A was already observed (Da Rio et al., 2016) and Ophiuchus and Lupus will be observed in APOGEE 2. The precision in the radial velocity measurements of APOGEE is about the same as the proposed VISIONS Public Survey. With VISIONS we expect to reach proper motions of the order of 1-2 mas, or the equivalent of transverse velocities of $0.1 - 0.3$ km/s, comparable with the precision of the APOGEE radial velocity survey of embedded objects in the Orion star formation region (Hacar et al., 2016). For these three regions the community will be able to re-construct the 3D space motion for the young stars associated with the clouds, and the clouds themselves, for the first time.

The Gaia-ESO survey (Gilmore et al., 2012), a ESO Public Spectroscopic Survey targeting about 10^5 stars, has a dedicated program to study the formation and evolution of open clusters that include two young clusters in the VISIONS sample, namely the Orion Nebula Cluster and the ρ Oph Cluster Rigliaco et al. (2016). The Gaia-ESO survey is an optical survey, so it will not be sensitive to the youngest sources still buried in the cloud, but for the visible and more evolved sources, it can be used in the same complementary way as APOGEE. Another similar survey to Gaia-ESO is HERMES-GALAH (De Silva et al., 2015). The primary HERMES-GALAH science project is Galactic Archaeology, which aims to reconstruct the history of our Galaxy's formation from precise multi-element abundances of 1 million stars derived from HERMES spectra, some of them observed at a spectral resolution similar to Gaia-ESO. Because of the wide-fields covered by VISIONS away from the Galactic plane, there will be a (small) fraction of sources in common between the two and observed at similar spectral resolutions as the Gaia-ESO survey, so allowing for space motions to be derived.

Activity and variability are ubiquitous among YSO and together with unresolved binaries, seriously affect radial velocity measurements and complicate greatly the interpretation and analysis of velocity distributions derived by surveys such as APOGEE and Gaia-ESO (e.g Cottaar et al., 2012). Proper motions, on the other hand, are much less sensitive to binaries, and almost not affected by activity and variability (Bouy et al., 2013), and allow more robust studies of the internal dynamics of young clusters.

UKIDSS (Lawrence et al., 2007) provided images comparable to VISTA for two clusters included in VISIONS, such as the Orion Nebula Cluster and the ρ Oph Cluster (under their Galactic Clusters Survey program). UKIDSS did not target complete molecular complexes, but for these two important clusters it will bring an extra epoch and a large time baseline, allowing for better proper motion measurements. In a similar manner, the NIR images produced by the SONYC survey (Muzic et al., 2014), that investigated the frequency and properties of sub-stellar objects over small areas in nearby star-forming regions, will be used to extent the time baseline for the regions in common, Lupus 3 and Chameleon I.

Finally, observatory archives, in particular the ESO archive, contains a multitude of NIR images from the embedded clusters and groups that will be targeted with VISIONS, covering a baseline of about 15 years. The available data covers usually relatively small fields centered on well known objects, but still worth combining with VISIONS. Overall, the VISIONS public survey will deliver sub-arcsec deep wide-field images of most major nearby clouds 10 to 15 years ahead of WFIRST.

4 Observing strategy: (1 page max)

The VISIONS survey includes three separate observing categories:

1. *Wide* multi-epoch observations of nearby star forming regions (Orion, Corona Australis, Chamaeleon, Ophiuchus, Lupus) to derive proper motions. Complementary to VHS.
2. *Deep* observations of the high column-density regions of nearby star forming regions.
3. *Control* field observations for statistical comparisons.

An overview of the approximate target regions is shown in Fig. 3 which also shows the coverage of previous public VISTA surveys. Our observing strategy for the *wide* fields was planned to efficiently cover all proposed targets in a multi-epoch survey spanning three years starting with Period 98 (October 2016). We plan to cover each star-forming region twice per year in a *wide* astrometric survey, where the two individual epochs should be carried out at the beginning and the end of the visibility period to provide large baselines for the proper motion measurements. We emphasize that the number of epochs (6 in this case) is almost as important as the time baseline itself to derive accurate and robust proper motions. As visible in the second panel of Fig. 3 most targets are well observable for more than 4 months per year, allowing us to efficiently distribute the observations. Targets and field sizes are listed in Table 1.

Chamaeleon, Ophiuchus, and Lupus are visible during parts of both observing semesters in a year. Orion is only observable during the Chilean Summer, Corona Australis mostly only during the Chilean Winter. For the *wide* survey we therefore propose the following schedule:

– P98/100/102 (Oct - March): 2/6 epochs Orion, 1/6 epoch for Chamaeleon, Ophiuchus, and Lupus
– P99/101/103 (April - September): 2/6 epochs CrA, 1/6 epoch for Chamaeleon, Ophiuchus, and Lupus

Since Chamaeleon, Ophiuchus, and Lupus are observable during both semesters, our survey schedule allows a certain degree of flexibility. Our targets overlap with the VISTA VHS Galactic Plane Survey which covers the region defined by $5 < |b| < 30$ deg, $\delta < 0$ deg in J and K_S band with 60s integrations. The observations of the *wide* fields are carried out in H-band also with 60s integrations, thus optimally complementing the VHS survey to provide a complete NIR (J, H, K_s) data-set. For an optimal position measurement of the detected sources and astrometric solutions, we require well sampled data. Therefore the observations should be carried out in observing conditions where the seeing is between 0.6 and 1 arcsec (pixel scale of VIRCAM is $\sim$0.34 arcsec/pix).

In addition to the *wide* astrometric survey we propose to carry out additional *deep* field observations. These *deep* fields cover the high-column density parts of the star-forming regions. The largest clouds (Orion A and B) have already been observed (Meingast et al., 2016 and VISTA science verification, thus the *deep* observations constitute a relatively small portion of the entire survey. An overview of the *deep* coverage for each region is listed in Tab. 1. Since all clouds should be observed with a consistent homogeneous strategy we adopt the Orion A *deep* observation strategy to cover the remaining *deep* fields (J, H, K_S with sky offsets). To provide the community with access to these catalogs as fast as possible we plan to include these observations at the beginning of the VISIONS survey (if necessary, the observations of the deep fields can be moved to later semesters). All targets for the *deep* observations are best observed during summer and are therefore included in Period 99.

For statistical comparisons (e.g. estimating intrinsic colors, discriminating stellar populations) we also include a set of control fields for each observed region (1 tile per region per band). These will be located in regions of low column-density at similar galactic latitudes to the science targets. The observing strategy for the *control* fields is the same as for the *deep* fields but without sky offsets.

All required calibration frames can be provided by the standard ESO VIRCAM calibration plan. No additional calibration frames are required.

5 Requested observing time:

VIRCAM covers an on-sky area of 1.017 deg $\times$ 1.475 deg = 1.501 deg^2 with the standard 6 pawprints. This area is exposed to at least two separate pixels. In addition an area of 0.092 deg $\times$ 1.475 deg adjacent to the edges of the short axis of the above mentioned field is covered once. For a full coverage of our survey fields, we include an overlap in both axes of the instrument towards adjacent fields. Thus, for our observing strategy we calculate tile sizes with a dimension of 1.0 deg $\times$ 1.45 deg = 1.45 deg^2. For the *wide* survey we will adapt the DIT/NDIT/NJITTER values based on the local stellar density and the presence of bright stars in the region. For 60s per pixel total exposure time we estimate on average a total duration of 15 minutes for one tile for the wide survey including all overheads (checked with P2PP). The total execution time per epoch for all star forming regions for the *wide* survey then amounts 79.5h (Orion: 27 h; Corona Australis: 8.75 h; Chamaeleon: 8.75 h; Ophiuchus: 17.5 h; Lupus: 17.5 h).

The exposure and execution times for the *deep* observations are based on our experience with the Orion A data (10 min exposure time for each tile per band; sky offsets due to extended emission). For the ten requested tiles we calculated a total duration of 56h (16h in J and 20h in both H and K_S). The control field observations follow the same strategy as the *deep* fields but without sky offsets. For these we calculate a total duration of 20h in all three bands.

Table 1 summarizes the target lists and covered areas, Tab. 2 lists the distribution of the observations over the planned three years. In total we request 553h for the the entire VISIONS survey.

Table 1: Overview of target fields for VISIONS

Region name	RA (hh:mm)	Dec (dd:mm)	Area (wide) (deg $\times$ deg)	Tiles (wide) (#)	Tiles (deep) (#)	Tiles (CF) (#)
Orion (*wide* only)	05:30	-05:30	12 $\times$ 13.05	12 $\times$ 9	-	3
Corona Austr.	19:10	-37:00	5 $\times$ 10.15	5 $\times$ 7	3	3
Chamaeleon	11:50	-78:00	10.15 $\times$ 5	7 $\times$ 5	6	3
Ophiuchus	16:30	-24:45	10.15 $\times$ 10	7 $\times$ 10	12	3
Pipe (*deep* only)	17:11	-27:20	-	-	3	3
Lupus	15:40	-36:40	7 $\times$ 14.5	7 $\times$ 10	6	3
Subtotal			461.1 deg^2	318 (1 epoch)	30	18
Subtotal time				79.5 h (1 epoch)	56 h	20 h
Total time (6 epochs *wide* + *deep* + *control* fields)						**553 h**

Table 2: Observing schedule for VISIONS

Period	Requested Time (h) (including overheads)	Exposure Time (h)	Mean RA (h)	Moon	Seeing	Filters	Transparency
P98	97.75 (*wide*)	6.52	5.5, 11.8, 16	none	$< 1.0, > 0.6$	H	clear
P99	61.25 (*wide*)	4.08	11.8, 16, 18	none	$< 1.0, > 0.6$	H	clear
P99	56 (*deep*)	5.0	11.3, 15.7, 18	none	< 1.0	JHK	clear
P99	20 (*control*)	3.0	11.3, 15.7, 18	none	< 1.0	JHK	clear
P100	97.75 (*wide*)	6.52	5.5, 11.8, 16	none	$< 1.0, > 0.6$	H	clear
P101	61.25 (*wide*)	4.08	11.8, 16, 18	none	$< 1.0, > 0.6$	H	clear
P102	97.75 (*wide*)	6.52	5.5, 11.8, 16	none	$< 1.0, > 0.6$	H	clear
P103	61.25 (*wide*)	4.08	11.8, 16, 18	none	$< 1.0, > 0.6$	H	clear

5.1 Time justification: (1 page max)

VISIONS aims to allow the measurements of PPM for complete samples of young stellar objects and young, optically revealed stars. For this, a two step approach is taken, namely a *wide* survey and a *deep* survey. The *wide* survey drives the PPM aspect of VISIONS, and the *deep* survey concentrates on the high column density regions to be able to address other star formation problems like dust mapping of dense cores, morphometry of YSO, and improved SED modeling. To allow the community to derive PPM, the large areas to be observed by the *wide* survey, done in H-band, will be compared with $\sim 8-10$ year old VHS (VISTA public survey) images in J and K. The *wide* survey areas will be observed twice per year, generating six epochs over the entire three years of the public survey. We estimate, based on our experience with VISTA (see Figure 4) that with this strategy, and using at least one epoch from the VHS survey, the community will be able to derive PPM reaching 1-2 mas (1-σ) or better, at the end of the VISIONS survey. This can be improved for the areas in the cloud complexes for which extensive NIR data exist in open archives such as ESO's.

There are six major star forming cloud complexes within 500 pc from the Sun and visible from Paranal, namely: Ophiuchus, Pipe Nebula, Lupus, Corona Australis, Chameleon, and Orion. The areas of the *deep* survey were chosen to include cloud material in these complexes above ~ 3 magnitudes of visual extinction and go as deep as in our study of Orion A (Meingast et al., 2016). The area of the *wide* survey was chosen to enable the observations of 10 Myr young stars, dispersing isotropically at a typical transverse velocity of 1 km/s from its parental cloud, typically a 10 degree sized box from the complexes seen towards the Galactic bulge. The Orion association, because of its well known population of 10-15 Myr objects, Blaauw's OB1a,b,c,d sub-groups, will be covered by slightly larger field than the other clouds in the sample, guided by the known location of Blaauw's sub-groups.

To avoid duplication of data, and following the Public Survey Panel recommendation, we removed the Pipe Nebula Wide field initially in our sample as it is one of the closest complexes to Earth, but also in the proposed extension of the VVV survey (VVVX), which will cover the bulge up to $b = +10°$. Following a suggestion from the Public Survey Panel to avoid data duplication, and after a clarification with the VVVX PIs about the observing strategy that will be followed by the VVVX team, we decided to remove the Pipe Nebula Wide field (leaving only the Deep field in B59, one VISTA tile) from our list of targets. See discussion in Section 8.

Finally, by observing H-band and matching to the VHS public survey's J- and K-band images (that will have to be re-reduced with our pipeline for image quality improvement), VISIONS will generate wide coverage of the clouds in JHK bands, about 4 magnitudes deeper than 2MASS.

The proposed survey is our last chance to map these very important clouds in the near-IR. They have been extensively observed in the mid and far infrared with space observatories such as WISE, Spitzer, Herschel and Planck, demonstrating the strong and broad interest of the community for these star forming regions. They host the most promising and exiting targets for present and future facilities such as the VLT, JWST, the E-ELT and ALMA. The proposed VISTA observations are therefore the last missing piece of the puzzle to complete a vast effort of the community to characterize their content and properties.

6 Data management plan: (3 pages max)

Critical parts of the data management plan include both the calibration of observed raw data into science-ready data product, as well as providing access to all data products to the community. While we plan to provide access to all data through ESO's phase 3 infrastructure, the data reduction will be carried out independently at local dedicated server environments and workstations at the University of Vienna.

Our team will be structured into two major groups: the Survey Management Team (SMT) and the Survey Support Team (SST). While the first is responsible for the successful execution of the survey, the latter team consists of multiple joint work groups which are specialized in specific tasks (see Sect. 6.2).

6.1 Team members:

Name	Function/task/expertise	Affiliation	Country	Team
J. Alves	PI	U Vienna	A	SMT
H. Bouy	Co-PI, Astrometry design	CSIC	E	SMT, SST
S. Meingast	Co-PI, Pipeline, observation preparation	U Vienna	A	SMT, SST
J. Ascenso	Young clusters, dust properties	FEUP	P	SST
A. Bayo	SED modeling and APOGEE	U Valparaiso	RCH	SST
E. Bertin	Pipeline and web interface	IAP	F	SST
A. Brown	Interface with Gaia	Leiden U	NL	SST
J. de Bruijne	Interface with Gaia	ESA	ESA	SST
J. Forbrich	Radio astrometry, dust properties	U Vienna	A	SST
A. Hacar	Cluster formation	U Vienna	A	SST
J. Kaufmann	Interface with SDSS stellar prop. and kin.	MPfR	D	SST
R. Köhler	Binaries, jets proper motions	U Vienna	A	SST
M. Lombardi	Extinction mapping	U Milan	I	SST
D. Mardones	Jets and outflows, obs. preparation	U Chile	RCH	SST
A. Moitinho	Young optical population	U Lisboa	P	SST
K. Peña	Interface with VVV, obs. preparation	U Valparaiso	RCH	SST
M. Petr-Gotzens	Observation preparation, binaries, IMF	ESO	D	SST
T. Prusti	Interface with Gaia	ESA	ESA	SST
R. Ramlau	PSF reconstruction, image quality	U Linz	A	SST
T. Robitaille	SED modeling, RadTran simulations	MPIA	D	SST
P. Teixeira	Observation preparation, binaries	U Vienna	A	SST
W. Zeilinger	Observation preparation, galaxy clusters	U Vienna	A	SST

6.2 Detailed responsibilities within the team:

The survey activities will be coordinated and overseen by the SMT (Alves, Bouy, Meingast). The SMT is responsible for the successful execution of the survey from the survey preparation (e.g. generating the OBs with the Survey Area Definition Tool and P2PP) to the timely delivery of phase3 data products. They will also manage and distribute tasks (e.g. quality control) to specific panels of the SST. Each panel will be chaired by a responsible, supported by other team members. From experience, many issues only become apparent when working directly with the generated data. Each member of our team has personal scientific interest in these data, which will guarantee quick real-life tests. The panels of the SST cover all major technical and scientific aspects of VISIONS: Survey execution and progress; Pipeline/Photometry/Astrometry; Data quality; Stellar clusters; Young Stellar Objects; Proper motions; dust properties. Each member is assigned to multiple support teams according to their specialization and scientific interests.

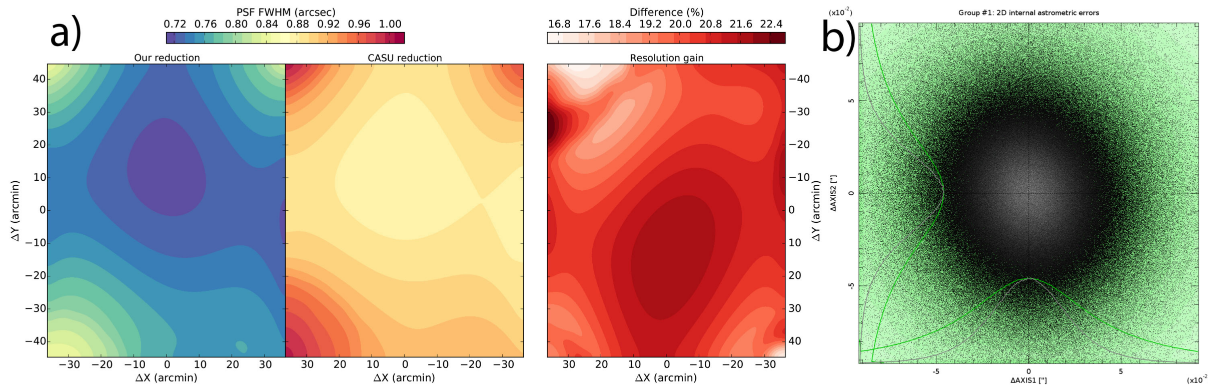

Figure 4: a) Example of a FWHM map for both our reduction and the standard CASU pipeline in H band (Meingast et al., 2016). Clearly a significant gain in image quality is achieved in our reduction. The typical improvement for all tiles in VISION is around 20% and mostly recovers the image quality on the pawprint level. **b)** 2D internal astrometric residuals obtained for a test-sample of 1600 K_S VHS VISTA images. The gray curve represents the integrated distribution for SNR> 100 sources, and the green curve the integrated distribution for SNR=10. They have a 1-σ dispersion of $\sim$ 20mas. Our observing strategy is designed with astrometric precision in mind and shall improve this result by 20-30%, reaching a final PPM precision between 1 and 2 mas/yr.

6.3 Data reduction plan:

Our team combines experts in observations and data processing, as demonstrated by our extensive use of VISTA data in the past, and we are ready to optimize the survey design and strategy, and process the data in a timely manner.

Meingast et al. (2016) carried out a VISTA survey of the Orion A molecular cloud and find that the data processing via the standard pipeline, operated by CASU, is not optimal for projects which aim for the highest image quality. Two major drawbacks in the CASU processing method make an independent data calibration absolutely necessary for the VISIONS project:

- To optimally co-add all reduced paw prints, each input image needs to be resampled onto a common reference frame. The CASU pipeline uses a radial distortion model together with fast bilinear interpolation to remap the images for the final tiling step. Bilinear interpolation, however, has several drawbacks. Apart from significant dispersions in the measured fluxes, it additionally "smudges" the images, leading to lower output resolution (see Bertin, 2010 for details and examples). It is especially critical to preserve image quality at all stages of the data reduction for astrometric measurements.
- For the zero-point calculation of each observed field the CASU pipeline applies a galactic extinction correction to all photometric measurements based on data from Schlegel et al. (1998) and Bonifacio et al. (2000). This will add systematic offsets with respect to photometric data for which no such correction was applied. For studies concerned with the intrinsic color of stars (e.g. extinction mapping), however, it is critical not to be biased in any way by such systematic offsets.

Meingast et al. (2016) implemented a completely independent data reduction environment which (a) uses higher-order resampling kernels and (b) directly calibrates the photometry towards the 2MASS system without biasing the results due to the galactic extinction corrections. Figure 4 shows a FWHM map for on observed tile of the Orion A survey in H band for both the CASU and the improved reduction, as well as the gain in resolution.

The optimized processing typically achieves 20% higher resolution compared to the standard CASU pipeline, i.e. a 20% smaller FWHM. In addition, one can observe a dependency of the resolution gain with observing conditions. While only a gain of 10-15% is reached for seeing conditions $>$ 1 arcsec, up to almost 30% can be gained for excellent conditions ($\sim$ 0.6 arcsec). Moreover, the improved reduction recovers the image quality of the pawprint level for the combined tiles which is not the case for the CASU reduction. In summary, the following capabilities have been implemented specifically for VIRCAM:

- Calculation of all required master calibration frames and parameters: bad pixel masks (BPM), dark frames, flat fields, and non-linearity coefficients.
- Basic image calibration: non-linearity correction, removal of the dark current, and first order gain harmonization with the master flat.
- Accurate weight map generation (confidence maps) for co-addition and source detection.
- Static and dynamic background modeling.
- Removal of cosmetic deficiencies (bad pixel masking, global background harmonization, etc.).
- Illumination correction (second order gain harmonization) using external standards.
- Source detection, astrometric calibration and co-addition via external packages.
- Robust aperture photometry using variable aperture corrections.
- Photometric calibration based on the 2MASS reference catalog.

All processed data and associated products will be made accessible through the ESO phase 3 web interfaces. This includes calibrated single pawprints, stacked pawprints, and combined tiles for the imaging science data, master calibration data (darks, flats, bad pixel masks, linearity tables), quality control data, and (merged) photometric catalogs.

The final mosaics and catalogues will be accessible online via the VisiOmatic web interface (Bertin et al., 2015), a new versatile and powerful web application designed for the visualization and scientific exploration of very wide field astronomical images. VisiOmatic is optimized for multi-wavelength surveys such as the one proposed here, leaving full control to the user and allowing for spectacular color combinations. It also allows the overlay of external catalogs (e.g using VO compliant services) as well as local catalogs, including those produced by the present survey. A sample illustrating some of the numerous capabilities can be seen on the following webpage: http://visiomatic.iap.fr/pleiades/

6.4 Expected data products:

- Instrumental corrected VISTA images (i.e. tiles, stacked pawprints, and individual pawprints), astrometrically calibrated, with ESO compliant headers including all reduction steps for reproducibility.
- Error and exposure maps for all image products.
- Calibration data (bad pixel masks, master-darks/flats, linearity tables).
- Photometric catalogs with multi-aperture, multi-epoch photometry, fitted parameters, errors, and source classification.
- Matched catalogs with multi-band photometry for VISIONS *deep* areas.
- Image atlas for all known YSOs.
- All data products (images and catalogs) will be available at CDS Strasbourg attached to the survey description paper.
- Interactive web interface to both images and catalogs.

6.5 General schedule of the project:

T_0 (= Period 98, October 2016): Start of VISIONS observations.

$T_0 + 1$yr: Release of *deep* survey data products.

$T_0 + 2$yr: Release of the data products for the first two epochs of the *wide* survey.

$T_0 + 3$yr: Release of the data products for the third and fourth epoch of the *wide* survey.

$T_0 + 4$yr (late 2020): Release of the data products for last two epochs of the *wide* survey.

7 Envisaged follow-up: (1 page max)

One of the main goals of a public survey is to provide the community with a rich target list of objects to be followed by the larger telescopes. VISIONS is not an exception here.

The following is ongoing or planned:

- Comparison of VISTA data extinction maps with millimeter line and dust emission data. Apart the available *Herschel* and *Planck* data, several molecular line data sets are available (e.g., COMPLETE CO survey), and others are planned for most Southern clouds (e.g., Hacar's IRAM 30m and ALMA survey of Orion A, ongoing).
- APOGEE data on Orion (existing), Ophiuchus, and Lupus. Adding APOGEE radial velocities to the YSO populations, and a cloud distance from Gaia, one will be able to derive the 6D space motion of the embedded and dispersing populations in these clouds.
- The SDSS consortium currently explores the potential and feasibility of follow-up NIR spectroscopy in the northern and southern hemisphere. We should learn soon how the SDSS consortium decides to proceed. Some of us have access to SDSS and will push for a VISIONS SDSS follow-up for the embedded populations.
- Many new proto-planetary disks will be resolved, or partially resolved in VISIONS. New samples of transitional disks, which are believe to host young planetary systems, will be discovered (about 10% of proto-planetary disks seem to be in a transitional state). All these will constitute an important target list for ALMA, SPHERE, and JWST.
- 4MOST on VISTA and MOONS on the VLT will be able to improve on the Gaia and APOGEE radial velocities, further improving the determination of the 6D space motions of the embedded and revealed young populations in the nearby clouds.
- The new samples will be prime targets for follow-up studies of the multiplicity with the present and future AO facilities at ESO and elsewhere, but also with the JWST and, in the long term, the E-ELT.
- YSO are prime targets for planet searches using high contrast and high resolution images, as young planets are brighter and easier to detect. The new sample will therefore include reference targets for follow-up studies with SPHERE and GPI, but also with ALMA.
- The proposed VISIONS observations will provide a census of the proper motions of stellar jets detected in the IR. The combination of these results with follow-up ALMA interferometric measurements of their corresponding molecular counterparts will allow the community to constrain the internal motions of jets.
- The high resolution of the new ALMA observations is now opening a new window on the study of disks at millimeter wavelengths. The characterization of the YSO properties derived from this survey (orientation, cavities, luminosity, etc...) will allow to constrain new samples of targets in future dedicated follow-ups.

8 Other remarks, if any: (1 page max)

One interesting cloud complex, the Pipe Nebula (dashed box in Figure 3), was initially in our sample as it is one of the closest complexes to Earth, but also in the proposed extension of the VVV survey (VVVX), which will cover the bulge up to $b = +10°$. Following a suggestion from the Public Survey Panel to avoid data duplication, and after a clarification with the VVVX PIs about the observing strategy that will be followed by the VVVX team, we decided to remove the Pipe Nebula *wide* field (leaving only the *deep* field in B59, one VISTA tile) from our list of targets. The monitoring nature of VVVX will mimic the VISIONS multi-epoch approach. We kept the *deep* field centered on B59 to be able to characterize the protostars associated with the dense star forming gas in B59, some of the closest protostars to Earth. We also removed the Galactic Center case from our original proposal as it was contained of the wide Pipe Nebula wide field. This reduces the total requested time to 553h. In case VVVX will not be approved we would request the inclusion of this cloud back on our list of targets.

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