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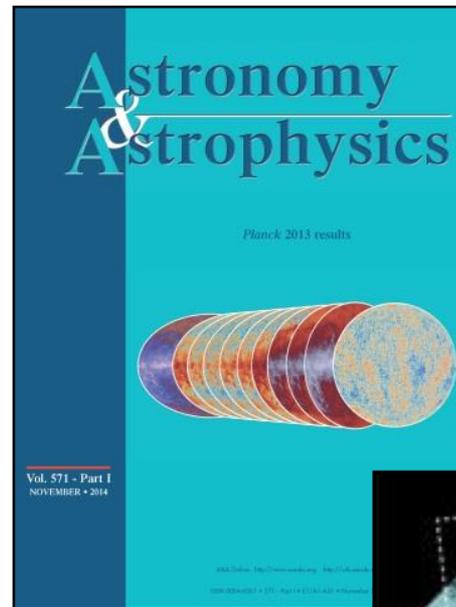
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Astronomy  
 Astrophysics  
 Special issue

Gaia Data Release 1

## Gaia Data Release 1

### Summary of the astrometric, photometric, and survey properties

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#### ABSTRACT

**Context.** At about 1000 days after the launch of Gaia we present the first Gaia data release, Gaia DR1, consisting of astrometry and photometry for over 1 billion sources brighter than magnitude 20.7. **Aims.** A summary of Gaia DR1 is presented along with illustrations of the scientific quality of the data, followed by a discussion of the limitations due to the preliminary nature of this release. **Methods.** The raw data collected by Gaia during the first 14 months of the mission have been processed by the Gaia Data Processing and Analysis Consortium (DPAC) and named into an astrometric and photometric catalogue. **Results.** Gaia DR1 consists of three components: a primary astrometric data set which contains the positions, parallaxes, and mean proper motions for about 2 million of the brightest stars in common with the HIPPARCOS and Tycho-2 catalogues – a realization of the Tycho-Gaia Astrometric Solution (TGAS) – and a secondary astrometric data set containing the positions for an additional 1 billion sources. The second component is the photometric data set, consisting of mean G-band magnitudes for all sources. The G-band light curves and the characteristics of ~3000 Cepheid and RR Lyrae stars, observed at high cadence around their mean ecliptic pole, form the third component. For the primary astrometric data set the typical uncertainty is about 0.3 mas for the positions and parallaxes, and about 1 mas yr<sup>-1</sup> for the proper motions. A systematic component of ~0.5 mas should be added to the parallax uncertainties. For the subset of ~94000 HIPPARCOS stars in the primary data set, the proper motions are much more precise at about 0.08 mas yr<sup>-1</sup>. For the secondary astrometric data set, the typical uncertainty of the positions is ~10 mas. The median uncertainties on the mean G-band magnitudes range from the ranging level to ~0.03 mag over the magnitude range 5 to 20.7. **Conclusions.** Gaia DR1 is an important milestone ahead of the next Gaia data releases, which will feature five-parameter astrometry for all sources. Iterative validation shows that Gaia DR1 represents a major advance in the mapping of the heavens and the availability of basic stellar data that underpin observational astrophysics. Nevertheless, the very preliminary nature of this first Gaia data release does lead to a number of important limitations to the data quality which should be carefully considered before drawing conclusions from the data.

**Key words catalogues – astrometry – parallaxes – proper motions – surveys**



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219 four clouds (Orion Molecular Cloud 1 -- 4, OMC) and \object{OMC1} holds the Kleinmann-Low
220 Nebula (KL), often referred to as \object{Orion-KL} (but
221 also numerous other name, as listed in
222 SIMBAD\footnote{http://simbad.u-strasbg.fr/simbad/sim-id?Ident=Orion-KL}). The
223 Orion-KL nebula is the nearest massive star forming region (distance equal to 414
pc\,$\approx$, 7), pc,
224 \citealt{2007ApJ...67..11615,2007A&A...474..515N}) and as such has attracted
225 considerable attention and is the subject of thousands of publications. The core is complex
with several remarkable sources, the Hot Core (HC), the
226 Compact Ridge (CR), the Extended Ridge (ER), the Plateau, numerous Methyl Formate (MF) peaks
\citep{Favre:2011ha}, and
227 other infrared/submillimeter peaks listed in many papers
\citep[e.g.][{Rieke1973,2005AJ...129..1534R,Friedel:2011kv}], including 3
228 runaway objects, BN, I and n \citep{2005ApJ...635..1166G,Rodriguez:2005fy}. Among the studies
aimed at identifying molecules
229 in Orion, which is the reference source along with \object{SgrB2} in which to search for new
species, many surveys have been conducted with
230 single dish telescopes from the ground (from some of the earliest works by
\citealt{1985ApJS...58...341S,1986ApJS...60...357B}) to
231 recent observations with the IRAM-30m,
\citealt{2010A&A...517A..96T,Tercero:2011ky,Cernicharo:2016fm}, etc. and with
232 Herschel in a dedicated 1.2 THz bandwidth survey, \citealt{Bergin2010,Crockett:2014er}). With the
sensitivity progress of the
233 spectroradiometers, these surveys have reached the confusion limit, \object{f132}
234 almost all the recorded channels containing
235 emission of some species, implying strong blending and %the
236 difficulty to determine the baseline level.
237 The confusion limit is partly due to the impossibility for single dish telescopes to spatially
separate the contribution of the different
238 sources in Orion which occur at different velocities, increasing therefore the overlap between
lines. Naturally, interferometers
239 have been used to separate the components, diminish the confusion, and help understand the
ongoing evolution of the chemical
240 and physical complex structure
\citep[e.g.][{Favre:2011ha,Feng:2012ei,Brouillet:2013hq,Feng:2015cl,Tercero:2015dl}].
241
242 During a dedicated Key Program of the Herschel Space Observatory aimed at finding O$_2$ in the
interstellar medium, after the
243 numerous negative results from SWAS \citep{Goldsmith:2000df} and Odin \citep{2003A&A...402L..77P}
spacecrafts,
244 counterbalanced by a single detection in $\rho$ Ophiuchi \citep{Larsson:2007dx} with Odin, we
detected O$_2$ towards
245 Orion \citep{2011ApJ...737...96G} and confirmed detection towards $\rho$ Ophiuchi,
\citep{Liseau:2012}. However the detection has an ill-defined direction that made the
246 interpretation of the observations insecure
\citep{2011ApJ...737...96G,Chen:2014ku} despite the
247 rare velocity value of 11.3 km/s (all velocities are expressed in the Local Standard of Rest,
LSR) which
248 should have limited the probable emission region to a few spots at the same LSR velocity as
traced by NH$_3$ (6,6) inversion
249 transition \citep{Goddard:2011gs}. In hope to better localize the emission region, we observed with
ALMA both the Orion-KL region and the H$_2$ vibrational peak further
250 north in coincidence with the Herschel pointings \citep{2011ApJ...737...96G,Chen:2014ku} to try

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spots at the same LSR velocity as traced by NH<sub>3</sub> (6,6) inversion transition (?). In hope to better localize the emission region, we observed with ALMA both the Orion-KL region and the H<sub>2</sub> vibrational peak further north in coincidence with the Herschel pointings (??) to try to detect the <sup>16</sup>O<sup>18</sup>O N<sub>2</sub> → O<sub>1</sub> transition at 233.946 GHz. This species has never been found before despite numerous attempts (e.g. ??). From the Herschel observations of the main isotopologue, the line was expected to be very weak (10 mJy/beam in a 5'' source) and only ALMA could reach the needed sensitivity (2 mJy/beam) in a reasonable amount of time (from Cycle 2 onwards, with at least 37 antennas used during the observations). From the 7 survey, the frequency region in the 234 GHz band seemed clear of any strong emission and the prospect of finding <sup>16</sup>O<sup>18</sup>O looked reasonable. To increase the interest of these deep observations, we took advantage of the possibility to divide the run in 5 independent observing blocks to move the backend windows as much as possible to cover the maximum bandwidth. The choice of the window positions was a compromise between the technical limitations and the inclusion of species somewhat related to O<sub>2</sub> in their formation process like SO and NO, or of species necessary for a diagnostic of the source where O<sub>2</sub> would have been detected compared to the other sources of the region in order to understand the reason for a limited emission region.

In this paper, we present the data resulting from this survey and the first results we obtain. Further analysis, and in particular the first detection of acetic acid and of the pGg' conformer of ethylene glycol will be reported in a series of forthcoming papers (Favre et al. in prep., Paganì et al. in prep.). These are presently the most sensitive interferometer observations towards Orion-KL.

The paper is organised as follow. In Sect. 2, we present the observations and the data reduction. In Sect. 3, we present the data analysis (new species or new vibrationally excited transitions, related species from previous tentative detections, non-detected species, velocity components, and source structure considerations). Conclusions are developed in Sect. 4.

### 2. Observations and data processing

The observations were performed on the 29th of December 2014 with 37 antennas for the first 4 scheduling blocks and on the 30th of December 2014 for the last block with 39 antennas. Two pointing directions were observed, the same as those used in the Herschel observations (??), namely ra<sub>J2000</sub>: 05°35'14.160", dec<sub>J2000</sub>: -05°22'31.504" and ra<sub>J2000</sub>: 05°35'13.477", dec<sub>J2000</sub>: -05°22'08.50". The resolution was set to 488 kHz to get ~0.6 km s<sup>-1</sup> resolution to spectrally resolve the expected <sup>16</sup>O<sup>18</sup>O linewidth of 1.5 – 2 km s<sup>-1</sup>. The resolution selection gives a bandwidth of 0.937 GHz per window. For each pointing, we split the observations into five observing blocks with different frequency setups, resulting in 16 different frequency bands (four windows per setup, one window always centered on <sup>16</sup>O<sup>18</sup>O at 234 GHz, the other three moved around), covering approximately 16 GHz of total bandwidth between 215.15 and 252.04 GHz. The details of the frequency coverage are given in Table 1. Compared to the Cycle 0 Science Verification survey of Orion (SVO), we cover half of the original frequency coverage, with an extension between 250 and 252 GHz not included in the SVO data, with the same frequency resolution, a beam slightly smaller

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estimated in the UV tables and subtracted, velocity correction to LSR scale was performed and data (UV tables) were subsequently exported and converted to Gildas format for final processing (cleaning) using the MAPPING application<sup>7</sup>. For each source, spectra were extracted in a CLASS<sup>8</sup> file, converted from Jy/beam to K (see Table 1) and corrected for primary beam coupling. The primary beam coupling runs from 99% for the source IRC7 to 71% for MF10.

### 3. Analysis

Because we presently lack the zero spacing data to recover the extended emission of many species, we will generally not attempt to derive column densities and excitation temperatures of the species we discuss here. This will be done in a future work once these data are obtained and included in the data processing. However, for all species, we tried to fit emission with the supposition of Local Thermodynamical Equilibrium (LTE), by adjusting their column density, excitation temperature, velocity and linewidth (except for methyl cyanide, CH<sub>3</sub>CN, see Sect. 3.7.2). The fit was adjusted by eye to reasonably fit most of the lines of each species but is not considered as a valid constraint on the species column density and excitation temperature but only on the line velocity and width. This allows to determine the number of velocity components necessary to fit the profiles. The LTE fit was performed using LINEDB and WEEDS sets of routines inside CLASS<sup>8</sup> (?). The line catalogues we have used are from the Cologne Database for Molecular Spectroscopy (CDMS, ??) and from the Jet Propulsion Laboratory (JPL) catalogue (?), with some complementary private catalogues provided by A. Bellocche from the ?, hereafter B13 work.

#### 3.1. Continuum map

Due to the density of lines, it is somewhat difficult to find enough channels free of emission to build a continuum map. We could find two reasonably clean frequency ranges in the 218 and 235 GHz bands, each constituted by a selection of channels across the 1 GHz bandpass, which gave similar results, confirming the non-pollution of the channels by line emission. On the same continuum map, we have marked the position of the ten sources we have been studying in detail in this work (Fig. 1). The continuum peak emission (at the HC position) has a peak value of ~1.2 Jy/beam after correcting for primary beam coupling, which corresponds to a brightness of ~2.9 × 10<sup>4</sup> MJy/sr.

#### 3.2. Line emission

We have extracted spectra for all ten sources labelled in Fig. 1, converted them to an antenna (main beam) temperature scale using the conversion factor listed in Table 1, corrected them for beam coupling by measuring the primary beam coupling at the source position (Fig. 1) and removed any residual continuum offset (typically 0.2 – 0.5 K, maximum 2 K). Hereafter, bands will be addressed by their window and block numbers such as spw3/sg1 for the 215150 to 216087 MHz band. Nine sources are infrared compact sources and sometimes methyl formate (MF) sources<sup>9</sup> (?). One source, not known as an infrared peak nor a MF

<sup>7</sup>http://www.iram.fr/IRAMFR/GILDAS/

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162 {We wish to improve our understanding of the Orion central star formation region (Orion KL), disentangle its
163 complexity, and search for the source of O\$_{2\$} emission detected with Herschel.}
164 % methods heading (mandatory)
165 {We collected data with ALMA during cycle 2 in 16 GHz of total bandwidth spread between 215.1 and 252.0 GHz with a
166 typical sensitivity of 5 mJy/beam (2.3 mJy/beam from 233.4 to 234.4 GHz) and a typical beam size of 1.7\''\times 1.0\'' (average pos. angle of 89\degr). We
167 produced a
168 continuum map and studied the emission lines in 9 remarkable infrared spots in the region including the Hot Core and the
169 Compact Ridge, plus the recently discovered Ethylene Glycol peak.} HEY LISA HOW ARE YOU?
170 % results heading (mandatory)
171 {We present the data, and report the detection of several species not previously seen in Orion, including n- and i-propyl cyanide AND I CAN OTHER PLENTY OTHERS
172 (C\$_{3\$}H\$_{7\$}CN), and tentative detection of a number of other species including glycol aldehyde (CH\$_{2\$}(OH)CHO). The first detection
173 of g\$_{6\$} ethylene glycol (g\$_{6\$} (CH\$_{2\$}OH)\$_{2\$}) and of acetic acid (CH\$_{3\$}COOH) in Orion are presented in a
174 companion paper.
175 We also report for the first time in Orion the detection of several vibrationally excited states of cyanoacetylene
176 (HC\$_{3\$}N), and of its
177 \textsuperscript{13}C isotopologues. We cannot detect \citet{aec}
178 \textsuperscript{16}O \textsuperscript{18}O because of a strong vibrationally excited ethyl cyanide line nearby.
179 We do not confirm the tentative detection of
180 hexatriynyl (C\$_{6\$}H) and cyanohexatriyne (HC\$_{5\$}N) reported previously, nor of the hydrogen peroxide (H\$_{2\$}O\$_{2\$}) emission.
181
182 We report a complex velocity structure only partially revealed before. Components as far as -7 and +19
183 \km\ps are detected inside the hot region. Thanks to
184 different opacities of various velocity components,
185

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... However the detection is expressed in the Local Standard of Rest, LSR) which few spots at the same LSR velocity as traced by NH<sub>3</sub> (6,6) inversion localize the emission region, we observed with ALMA both the Orion-KL region (2011ApJ...737...96G, Chen:2014kw) to try to detect the emission at 233.946 GHz. This species has never been found before despite (Lal1997, Liseau2010). From the Herschel \ci observations of the main

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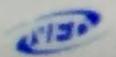
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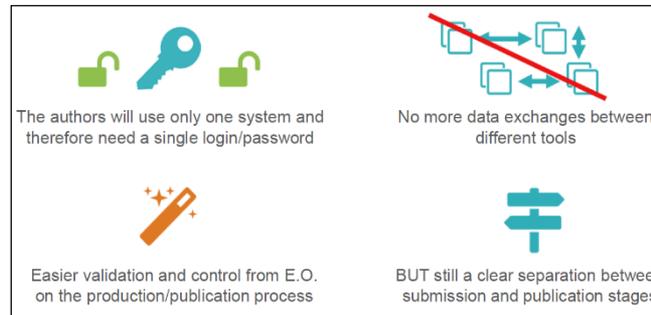
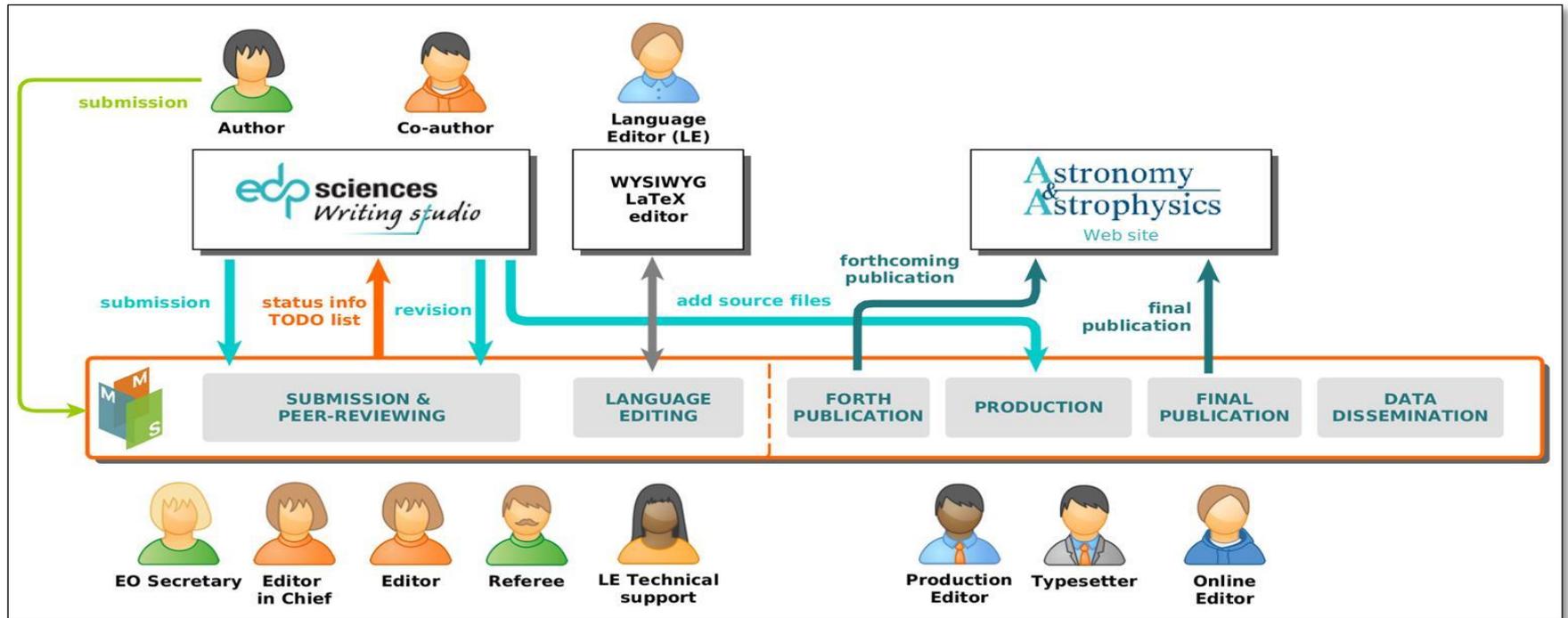
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