Table 3.1: Terrestrial missions that reported heavy molecular or metallic ions since 1980’s

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| mission/instrument (duration) @where | method | Specification (\*1) | what was actually observed | reference  (spec + obs m>26) |
| Cluster/CIS (2001-)  @magnetosphere (almost everywhere) | TOF (for > 28 eV)  RPA (for low-energy) | 0.7 eV/q – 40 keV/q  m/q: 1 - 16 (H+, He++, He+ O+) | 1 - ~40 amu/q (~50 lower statistics)  m/Δm ~ 5 – 7 | Rème et al., 2001.  Kistler et al., 2013. |
| Cluster/RAPID (2001-)  @magnetosphere (almost everywhere) | SSD TOF | > 400 keV  H, He, and O (C, N, O are not separated) | m>16 up to more than 60 | Wilken et al., 2001.  Haaland et al., 2020, Haaland et al., 2021. |
| e-POP/IRMS (2013-2021)  @325-1500 km altitude | TOF | < 70 eV/q  m/q: 1-64 | N+ and O+ are separated but not between N2+, NO+, and O2+. | Yau et al., 2015.  Yau et al., 2016. |
| Arase/LEPI (2017-present)  @Inner magnetosphere | TOF | 0.01-25 keV/q  m/q: 1 - 40 | H+, He++, He+, O++, O+, O2+(no separation between N and O)  m/Δm ~ 2-4 | Asamura et al., 2018.  Seki et al., 2019. (statistics) |
| Arase/MEPI (2017-present )  @Inner magnetosphere | SSD TOF | 7 - 87 keV/q  m/q: 1 - 48 | H+, He++, He+, O++, O+, O2+(no separation between N and O)  observed m/Δm ~ 3~5 | Yokota et al., 2017.  Seki et al., 2019. (statistics) |
| Kaguya/MAP-PACE/IMA (2008-2010)  @Moon | LEF-reflectron | 10 eV/q – 28 keV/q  m/q: 1 - ~ 60  m/Δm ~ 5 (m/Δm ~ 15 for reflected ions < 12 keVq) | Na+, Ca+, K+, C+, Si+, O+ are eparated.  no molecular ions (due to start foil breaks molecules) | Saito et al., 2010  Yokota et al., 2009. |
| Geotail/STICS (1992-2022)  @magnetosphere | SSD TOF | energy > 200 keV/q for m=30  m: <1 up to ~60-70 amu  m/q: <1 up to ~95 amu | 10^-2 Fe ions/ 3hr in -> at best once every 900 hr | Christon et al., 2017. |
| Wind/STICS (1994-)  @magnetotail | SSD TOF | 6 - 230 keV/q  otherwise, the same method as Geotail. | Separate O+ from Al+, Si+ | Mall et al., 1998. |
| Polar/TIDE (1996-2008)  @below 8 Re | TOF | 0.1-500 eV/q  1 - 40 amu/q  m/∆m = 4 | “Significant component of molecular ions in polar wind flux in response to CME” | Moore et al., 1995. |
| Polar/TIMAS (1996-2008)  @below 8 Re | Magnet (double focusing) | 15 eV/q – 33 keV/q  m: 1 - >32 amu/q  m/∆m = 2-5 | Separate O2+ from O+ (but not between N2+, NO+, and O2+ | Shelley et al., 1995.  Lennartson et al., 2000. |
| Akebono/SMS (1989-2002)  @up to 10000 km | RPA | < 50 eV/q  m/q: 1 - 40 | mostly <20 eV  Sometimes separate among N2+, NO+, and O2+ | Whalen et al. 1990.  Yau et al. ,1993.  Yau et al., 1998. |
| AMPTE/CHEM (1984-1989)  @Inner magnetosphere | TOF | 1-300 keV/q  m: <1 up to 90  m/q: <1, 74 | Can separate N2+, NO+, and O2+ | Gloeckler and Hamilton, 1987. |
| AMPTE/SULEICA (1984-1986)  @Inner magnetosphere | TOF |  | Detected metallic ions (SW charge state) | Stern, 1999.  Hilchenback, 2004. |
| DE-1/RIMS (1981-1984)  @568km x 4.6 RE | RPA | < 50 eV/q  m/q: 1 - more than 32 | Can separate N2+, NO+, and O2+ | Chappell et al., 1981.  Craven et al., 1985. |
| DE-1/EICS (1981-1991)  @568km x 4.6 RE | Magnet | 10 eV/q - 17 keV/q  m/q = 1 - 150  m/∆m ~10 | O2+, NO+, N2+ separated (in ‘drum mode’) | Shelley et al. 1981. |

(\*1) energy is with respect to spacecraft potential

Table 3.2: Planetary missions capable of separating metallic ions and molecular ions of < 100 keV

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| mission/instrument with Earth flyby data | metallic ions | molecular ions from atomic ions | Earth flyby? | reference |
| STEREO/PLASTIC | TOF | 0.2-80 keV  up to Fe | molecular @Tail 200-300 RE (2007) | Galvin et al., 2008  Kistler et al., 2010b |
| Cassini/MIMI-CHEMS | TOF | ~10 – 220 keV  m: 1 - 80 | only ring current ions @ring current (1999) | Christon et al., 2017 |
| JUICE/JDC  (Launched 2023) | TOF | 1 eV – 35 keV  m: 1 - 70  m/Δm=30 | Planned: 1 Moon (< 300 km) + 3 Earth (< 10000 km) flybys | Withmann, 2022 |
| JUICE/NIM  (Launched 2023) | LEF-reflection | < 10 eV (both neutrals + ions)  m: 1 - 1000  m/Δm=800 | same as above | Föhn et al., 2021 |

Table 3.3: Access method of relevant dataset and software with note on availability missions (everybody fill data type and software)

|  |  |  |  |
| --- | --- | --- | --- |
| mission /instrument | @where | database | notes on the software (basically request-basis) |
| Cluster/CIS | Magnetosphere | ESA Cluster Science Archive (ASCII) for routine product: https://csa.esac.esa.int/csa-web/  A separate telemetry product (“selected TOF events”) for TOF. | IFSI TOF software (IDL source code):  Reads level-1 binary files (selected TOF events). |
| Cluster/Rapid | Magnetosphere | ESA Cluster Science Archive (ASCII) for near-raw product: https://csa.esac.esa.int/csa-web/ | Direct event (TOF)  Reduced TOF |
| e-POP/IRM | 325-1500 km altitude | ePOP-data.phys.ucalgary.ca | (software for general-user access under development) |
| Arase/LEPI  Arase/MEPI | @ring current and inward | ERG science center (CDF file):  https://ergsc.isee.nagoya-u.ac.jp/data\_info/erg.shtml.en | (1) IDL SPEDAS for main data products, omcluding TOF histograms.  (2) IDL code for MEPI to look at raw PHA data |
| Kaguya/MAP-PACE IMA | Moon | SELENE data archive | (1) C code by Y. Saito (read binary data)  (2) IDL code Y. Harada |
| Wind/STICS | Magnetotail | NASA cdaweb (web interface) and spdf (CDF file)  https://spdf.gsfc.nasa.gov/pub/data/wind/sms/l2/ |  |
| Polar/TIDE | Magnetosphere below 8 RE | Level-Zero Telemetry Files hosted by the GSFC  https://spdf.gsfc.nasa.gov/pub/data/polar/  ftps://pwgdata.gsfc.nasa.gov/pub/compressed/po/tid/ |  |
| Polar/TIMAS | Magnetosphere below 8 RE | POLAR TIMAS H1 and H2 high resolution data: https://lasp.colorado.edu/timas/info/h12-data/h12-data.html Summary data: https://lasp.colorado.edu/timas/data/summary/ | https://lasp.colorado.edu/timas/info/h12-data/make\_h2.pro  https://lasp.colorado.edu/timas/info/h12-data/make\_h2\_cdf.pro |
| Geotail/STICS | Outer magnetosphere | summary plots available at  http://sd-www.jhuapl.edu/Geotail/Years\_dir.html | code developed by S. Nylund and S. Christon |
| Akebono/SMS | Magnetosphere below 10000 km | JAXA/ISAS Data Archives and Transmission System (DARTS): https://darts.isas.jaxa.jp/stp/akebono/SMS.html | under conversion to public database |
| AMPTE/CHEM | Inner magnetosphere | APL AMPTE site: http://sd-www.jhuapl.edu/AMPTE/chem/index.html  NASA spdf site: https://spdf.gsfc.nasa.gov/pub/data/ampte/cce/ | (1) Python code at UNH reading the CHEM FITS files  (2) PHAFLUX fortran code calculates fluxes from PHA events |
| AMPTE/SULEICA | Inner magnetosphere | data is not easy to access |  |
| DE-1/RIMS | Inner magnetosphere | NASA spdf site:  https://spdf.gsfc.nasa.gov/pub/data/de/de1/plasma\_rims/ | summary spectra  https://spdf.gsfc.nasa.gov/pub/data/de/de1/plasma\_rims/de1\_rims\_summary-spectrograms\_nasa-tm-19950009193.pdf |
| DE-1/EICS | Inner magnetosphere | NASA spdf site:  https://spdf.gsfc.nasa.gov/pub/data/de/de1/particles\_eics/ |  |
| MMS/HPCA | equatorial magnetosphere | NASA cdfweb and spdf site:  https://spdf.gsfc.nasa.gov/pub/data/mms/mms1/hpca/srvy/l2/tof-counts/  https://spdf.gsfc.nasa.gov/pub/data/mms/mms2/hpca/srvy/l2/tof-counts/  so on | TOF at NASA cdfweb https://cdaweb.gsfc.nasa.gov/cgi-bin/eval1.cgi |