For source matching it is necessary to compute the celestial coordinates of a source without knowing its properties, including parallax and proper motion, or orbital motion for a solar system object. For most stars, the effects of parallax and proper motion over a few years are much less than an arcsec, which is probably adequate for matching. Gravitational deflection is at most 13 mas for GAIA and therefore also negligible in this context. Stellar aberration, on the other hand, has an amplitude of 20 arcsec but could be computed from the known satellite velocity. Thus it appears that the most relevant position for source matching corresponds to the "natural direction", which is the direction (unit vector) measured in a celestial frame at rest with respect to the solar system barycentre but with origin at the instantaneous position of the observer.

The natural direction to the source can be computed from an individual observation by the following procedure:

1. Compute the "observed" field angles (\(\eta, \zeta\)) by means of Eq. (14) in GAIA-LL-34.2 (the chromaticity term in \(\eta\) can be neglected).

2. Using the attitude quaternion \(q\) interpolated to the time of observations (see subroutine qint), transform the field angles to the observed proper direction \(u\).

3. Using the known barycentric velocity of the spacecraft (an approximate value is sufficient) remove stellar aberration by application of the inverse of Eq. (5) in GAIA-LL-34.3. It can be noted that the exact inverse of that equation is obtained by exchanging the vectors \(u\) (proper direction) and \(u_{nat}\) (natural direction), and reversing the sign of the velocity vector.

4. If required, the resulting natural direction \(u_{nat}\) can be converted to spherical coordinates (\(ra, dec\)) by subroutine vec2sph. But more likely the matching is made directly on the unit vector (this avoids the singularity at the poles and the \(2\pi\) ambiguity of the right ascension).

Steps 2 and 3 are implemented in the following subroutine f2natdir, which converts the field angles (\(f\)) to the natural direction \(u_{nat}\) using the attitude \(q\) and velocity \(vb\) as additional input arguments.

```
c***********************************************************************
SUBROUTINE f2natdir(f, q, vb, unat)
c***********************************************************************
c Computes the natural direction to a source in the celestial frame
from the (observed) field coordinates, attitude and velocity
If gravitational light deflection, parallax and proper motion
are neglected, then unat can be used for object matching. If
spherical celestial coordinates are needed, follow this routine by:
c     CALL vec2sph(unat, ra, dec)
c```
which returns (ra,dec) in [rad].

INPUT:
- f(1:2) = field angles (eta,zeta) in [rad]
- q(1:4) = attitude quaternion
- vb(1:3) = barycentric velocity of the satellite in [AU/day]

OUTPUT:
- unat(1:3) = natural direction to the source (satellitocentric direction without stellar aberration)

LL, Lund Observatory, 2001 May 29

IMPLICIT NONE
REAL*8 f(2), q(4), vb(3), unat(3)

INCLUDE 'const_math.h'
INCLUDE 'const_astr.h'

REAL*8 utel(3), amat(3,3), uprp(3), e, fe, caud, scalar
INTEGER i
PARAMETER (caud = clight/(au*sec))

Calculate source direction in telescope frame:
CALL sph2vec(f(1), f(2), utel)

Using attitude matrix amat, convert to celestial frame:
CALL qn_q2mat(q, amat)
CALL matxvec(amat, .TRUE., utel, uprp)

Remove stellar aberration to obtain the natural direction:

\[ e = \sqrt{caud^2 - \text{scalar}(vb,vb)} \]
\[ fe = \left(1 - \frac{\text{scalar}(uprp,vb)}{caud + e}\right)/e \]
DO i = 1, 3
  unat(i) = uprp(i) - vb(i)*fe
ENDDO
CALL vnorm(unat, unat)

RETURN
END